CORRELATIONS BETWEEN BOTTOM FAUNA IN MURRAY'S AND BUTLER'S PONDS AND THE FOOD OF RAINBOW TROUT, SALMO GAIRDNERI RICHARDSON

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The Newfoundland Game Fish Protection Society

For your help and cooperation

June 30th, 1965

Leslie Downing.

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by

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A thesis
submitted in partial fulfillment of the
requirements for the degree of Master of
Science (Biology) at Memorial University
of Newfoundland

March, 1965

ABSTRACT

Limnological conditions were studied in two Newfoundland ponds having areas of 16 and 21 acres, and mean depths of 4.7 and 5.6 feet. The water was slightly acid in each and there was no dissolved oxygen deficiency; both are eutrophic and lie in an area of sedimentary rock. Rooted aquatic vegetation was not a major feature. The ponds are continuously stocked with rainbow trout and it is the most abundant of the three species of fish present. Numerically dominant bottom organisms were amphipods, dipteran larvae, sphaeriid clams, and amnicolid snails, while gravimetric analysis indicated the dominance of anisopteran nymphs. Seasonal variations in the bottom faunae were also studied. One pond has been fertilized experimentally and it revealed a standing crop of benthic organisms (46.0 kilograms per hectare) which tripled that of the control pond. Rainbow trout in one pond were feeding on a variety of bottom organisms while those in the other fed more intensely on a less varied diet of zooplankton. Seasonal differences in food consumption were studied along with the utilization of benthic organisms by the fish. Food preference was briefly discussed. Angler catch in one pond was shown to have a tendency to vary inversely with the amount of food available in the environment and that present in the stomachs of the rainbow trout.

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ACKNOWLEDGEMENTS

The author wishes to thank Dr. Cater W. Andrews for his encouragement and advice throughout the entire project; and also acknowledges the kind assistance of Messrs. Roy Dyke, Gerald Barbour, and Gerald Murphy, caretaker of the Murray's Pond Country Club; the suggestions and ideas of Mr. Paul Patey; and the typing of the final copy of this thesis by Miss Lillian Mercer.

Mr. James Dawson carried out a cursory investigation of the geology of the area and Dr. Donald H. Steele identified the amphipods.

Sincere thanks are offered to Dr. Steele and Dr. Thomas W. McKenney for their kind advise and suggestions following a critical review of the manuscript.

Appreciation is also extended to the executive and members of the Newfoundland Game Fish Protection Society for their co-operation in obtaining specimens and for the use of their facilities throughout the investigation.

The author acknowledges receipt of two twelve month Graduate Teaching Assistantships from Memorial University of Newfoundland.

In conclusion, to my wife, Daphne, for typing the first transcript of the manuscript, proof-reading and infinite patience and understanding, I offer my deepest gratitude and love.

I. INTRODUCTION

Very little work has been reported from Newfoundland on either the food of rainbow trout, Salmo gairdneri Richardson 1836 or the bottom fauna of the island's many lakes and ponds, and indeed it has been said that "Newfoundland and Labrador fresh waters have received little study" (Smith 1963:531). Nancy Frost (1940) provided a brief description of the food of four rainbow trout from Murray's Pond and included notes on the bottom fauna.

Only occasionally have organisms found in stomachs been related to their abundance in the same environment. Gerking (1962) quantitatively described the relationship between a bluegill population and its food supply in Indiana; while Allen (1951) in New Zealand, and Ball (1948) in Michigan have made similar investigations on other species of fish. There is often a disparity between the proportions of food organisms present in a body of water and those found in the stomachs of fish feeding in it. A few authors (Surber (1936) and Maciolek and Needham (1951)) have studied the food of rainbow trout in relation to that available in the environment.

On the other hand much has been written on the separate topics of benthos and on the food of rainbow trout. Forbes stated in his historic paper of 1880 that "It is, in fact, the objective point of the present investigation - to arrive at a knowledge of the correlations of structure and food habits sufficiently detailed and exact to make the tedious and difficult labour of examining the contents of stomachs unnecessary hereafter". However a review of the literature published since 1880 indicates that this objective has not been attained. Studies such as those of Juday (1907) in Colorado, Metzelaar (1928) in Michigan, Dimich and Mote (1934) in Oregon, Rayner (1941) in New York, Idyll (1941) and Crossman and Larkin (1959) in British Columbia, and Tebo and Hassler (1963) in North Carolina give an idea of the food of rainbow trout in other areas. Numerous studies on the food of other salmonid fishes include those on the brown trout (_Salmo trutta_) of the British Isles and others on the brook or speckled trout (_Salvelinus fontinalis_) of eastern Canada and the United States. These two species are of some interest in this study since they are the only other species of fish in the study area.

Deevey and Bishop (1942) state: "In evaluating the potential ability of a lake to produce fish, probably no single standard is so important as an estimate of the amount of bottom fauna". A large amount of data have been collected on bottom fauna by a legion of workers over the past 50 years. Among the workers of North America who are frequently cited are Baker (1918), for Oneida Lake, Juday (1920) for Lake Mendota, Adamstone (1924) for Lake Nipigon, Ricker (1952) for Cultus Lake and Rawson (1953) for Great Slave Lake.

The object of this paper is to analyse the quality and quantity of the bottom fauna and the food of the rainbow trout in two Newfoundland ponds. In addition, comments are made on two other aspects of the project: the difference between the bottom fauna production in a fertilized and an unfertilized pond and some factors influencing seasonal fluctuations in angler catch in one of these ponds.

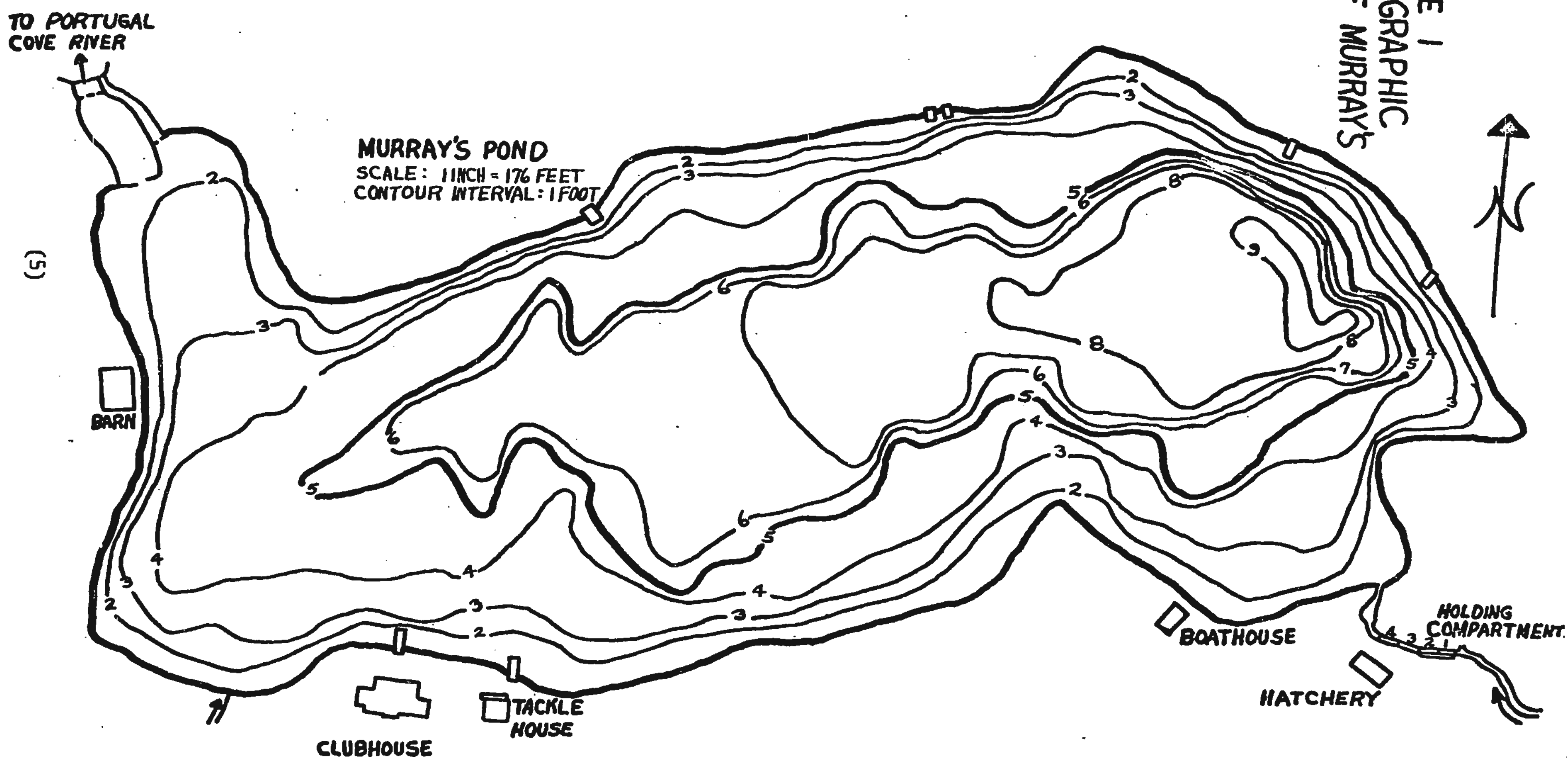
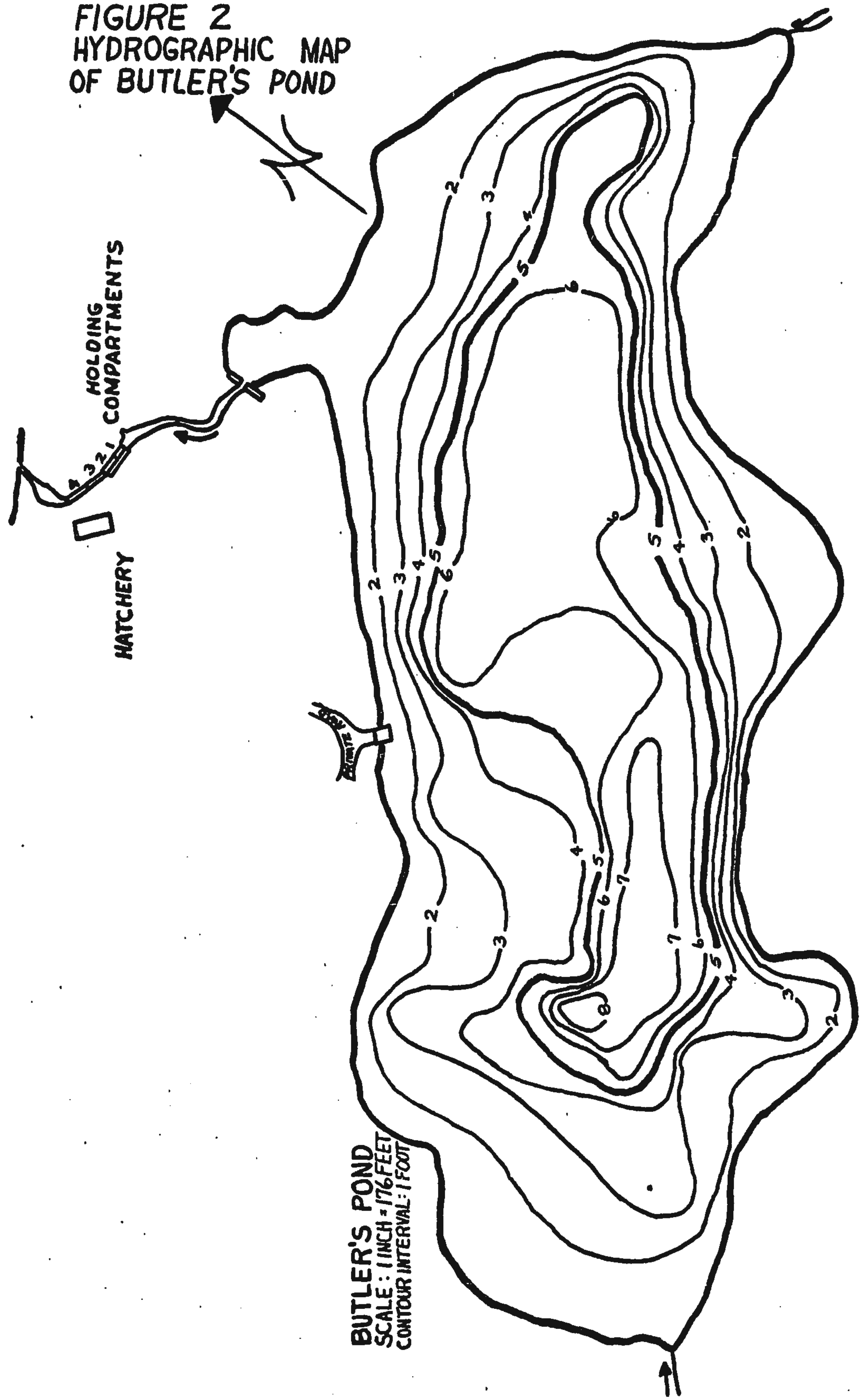


FIGURE 1 HYDROGRAPHIC MAP OF MURRAY'S POND

FIGURE 2
HYDROGRAPHIC MAP
OF BUTLER'S POND



(iii) Size and Shoreline

The area was surveyed by the author using the traverse method in 1962. Murray's Pond has an area of 21.0 acres while Butler's has an area of 16.0 acres. Both ponds are rectangular in shape and Murray's has a shoreline development of 1.43 and a volume development of 1.86 indicating that the shoreline is regular and the lake basin is close to the form of a cone whose height is the maximum depth and whose base is equal to the surface area of the lake. Butler's Pond has a shoreline development of 1.45 and a volume development of 1.74. Thus both ponds are similar in general shape and size. The watershed of both is covered principally by balsam fir forests. Both ponds were covered with ice from December 17, 1963 to April 23, 1964.

TABLE 1

MORPHOMETRIC DATA FOR MURRAY'S AND BUTLER'S PONDS

	MURRAY'S POND	BUTLER'S POND
Area	914,760 sq. ft.	696,959 sq. ft.
	21.0 acres/8.50 ha.	16.0 acres/6.48 ha.
Volume	5,095,213 cu. ft.	3,296,616 cu. ft.
Shoreline length	4,854 ft.	4,373 ft.
Shore Development	1.43	1.45
Slope	0.04%	0.03%
Maximum Depth	9 ft.	8 ft.
Mean Depth	5.6 ft.	4.7 ft.
Volume Development	1.86	1.74

(iv) Water Levels and Drainage

These ponds differ in seasonal fluctuations of the water level. In the summer of 1964, Murray's Pond rose a maximum of 5.2 inches, and Butler's Pond receded a maximum of 11.5 inches (Table 2). Three factors contribute to this difference: (1) There is no constant flow of water into Butler's Pond. The two sources seen on the map (Fig. 2) are bogland drainages and are eliminated during the warmer months when they dry up. (2) A small stream connects the two ponds and flows into Murray's Pond. (3) A series of dams at the outflow end of Murray's Pond retain the water during the warmer months.

TABLE 2

WATER LEVEL VARIATION FROM WHARF GAUGES

MURRAY'S AND BUTLER'S PONDS 1964

DATE	MURRAY'S POND	BUTLER'S POND
July 1	20.0 inches	20.0 inches
July 8	19.9 inches	18.0 inches
July 14	19.5 inches	16.4 inches
Aug. 10	24.3 inches	8.8 inches
Aug. 17	25.2 inches	8.5 inches
Aug. 31	22.0 inches	9.2 inches
Sept. 10	20.8 inches	16.8 inches
Sept. 25	22.2 inches	17.3 inches

2. Physical and Chemical Conditions

(i) Temperature

There is no thermal stratification in either of these shallow ponds and both may be regarded as consisting only of an epilimnion with uniform temperatures. Comparisons between surface and bottom temperatures indicate a maximum difference of 0.2°C.

In the spring of 1964, the lowest surface temperature recorded at Murray's Pond was 9.6°C on June 9th, while in Butler's Pond it was 8.8°C on May 22nd (Table 3). The highest surface temperature recorded at Murray's Pond for the same period was 23.1°C on July 8th, while the high at Butler's Pond was 22.3°C for the same day. Since these ponds are of almost identical size and they lie adjacent to one another, one would expect that a temperature reading on any given day would reveal closer readings in the two ponds. The discrepancy in the temperatures may be explained by the fact that Butler's Pond was checked at 10:00 AM and Murray's Pond at 2:30 PM after a longer period of warming.

TABLE 3

SURFACE WATER TEMPERATURES

MURRAY'S AND BUTLER'S PONDS SUMMER 1964

DATE	MURRAY'S POND	BUTLER'S POND
May 22	10.0°C	8.8°C
June 19	9.6°C	9.3°C
June 30	15.8°C	15.4°C
July 8	23.1°C	22.3°C

TABLE 3 - Continued

DATE	MURRAY'S POND	BUTLER'S POND
Aug. 10	22.5^{o}C	22.2^{o}C
Aug. 24	16.1^{o}C	17.5^{o}C
Sept. 8	15.0^{o}C	13.1^{o}C
Sept. 21	11.0^{o}C	10.0^{o}C

(ii) Dissolved Oxygen

During the summers of 1960, 1961 and 1962 the amount of dissolved oxygen in parts per million (p.p.m.) was determined for both ponds and no deficiency of this factor was recorded. It was therefore decided that it would be unnecessary to repeat these observations during 1964 since conditions had not been overtly altered in the interval. As Frost (1939) stated, "Since there is an abundant vegetation, a normal fauna, and a good head of trout and no pollution, it is assumed that there is no oxygen deficiency". It will be seen in the section of this paper on bottom fauna that there are large numbers of Amphipoda present in both these ponds and Pennak (1953:439) mentions that an abundance of dissolved oxygen appears to be an environmental necessity for these tiny aquatic organisms. Table 4 gives the dissolved oxygen for Murray's and Butler's ponds during the summer of 1962.

TABLE 4

DISSOLVED OXYGEN (P.P.M.) AT THE SURFACE OF

MURRAY'S AND BUTLER'S PONDS SUMMER 1962

(From Sturge, 1963)

DATE	MURRAY'S POND	BUTLER'S POND
May 23	11.7	11.5
June 10	8.7	8.5
June 29	8.5	8.7
July 8	8.4	8.5
Aug. 11	7.8	7.8
Aug. 15	8.1	8.0

(iii) Dissolved Carbon Dioxide

The amount of carbon dioxide dissolved in these waters is low and has been observed to change little throughout the summer months. This factor was therefore not checked during 1964 and the values for 1960 are given in Table 5.

TABLE 5

DISSOLVED CARBON DIOXIDE (P.P.M.) IN THE SURFACE WATERS OF

MURRAY'S AND BUTLER'S PONDS, SUMMER 1960

(From Sturge, 1963)

DATE	MURRAY'S POND	BUTLER'S POND
May 23	3.2	3.3
June 10	3.2	3.1
June 29	3.1	3.3
July 8	3.0	2.9
Aug. 11	2.6	2.7
Aug. 15	2.7	2.7

(iv) Hydrogen Ion Concentration

The pH of both ponds is a fairly constant factor except during the periods of heavy rainfall. The water of these ponds was slightly acid throughout the summer of 1964. Table 6 gives the results for that period.

TABLE 6

HYDROGEN ION CONCENTRATION OF THE SURFACE WATERS OF MURRAY'S AND BUTLER'S PONDS, SUMMER 1964

DATE	MURRAY'S POND	BUTLER'S POND
May 22	6.8	6.8
June 9	6.6	6.5
June 30	6.6	6.6
July 8	6.6	6.4
Aug. 10	6.6	6.7
Aug. 24	6.7	6.7
Sept. 8	6.2	6.2
Sept. 21	6.2	6.2

(v) Trace Ion Analysis

During the summer, 1962, the ions Na+, K^+ and PO_4^{---} were analysed in these two ponds. The results of this work are given in Table 7.

TABLE 7

TRACE ION ANALYSIS

MURRAY'S AND BUTLER'S PONDS, SUMMER 1962

(All values given in p.p.m.)

(From Sturge, 1963)

DATE	MURRAY'S POND			BUTLER'S POND		
	Na^+	K^+	PO_4^{---}	Na^+	K^+	PO_4^{---}
June 29	5.00	0.87		2.25	0.90	
July 24	2.86	0.95	Less	3.40	0.97	Less
July 27	3.20	0.97	than	3.20	1.14	than
July 31	4.51	1.50	0.05	4.51	1.38	0.05
Aug. 3	5.05	1.51		4.44	1.55	

3. Aquatic Plants and Bottom Types

The distribution, nature, and relative abundance of aquatic plants has a great bearing on the production of bottom animals which are important rainbow trout food. Although a systematic collecting program was not set up for the study of aquatic plants at Murray's and Butler's ponds, the following plants were taken by hand and while collecting bottom samples with an Ekman dredge: (i) *Sparganium sp.* (bur-weed) was taken in Murray's Pond only near the mouth of a stream entering it. (ii) *Potamogeton sp.* (pond weed) was taken only in Murray's Pond off the point of land near the boat house. (iii) *Nuphar variegatum* (yellow water lily) was found to cover approximately 6.3 per cent of the total surface of Murray's Pond and 8.5 per cent of Butler's Pond. These figures were determined from photographs, by direct observations, and drawings while at the ponds. (iv) Lobelia Dortmanna was a common submerged plant at both ponds. (v) Juncus sp. (possibly J. pelocarpus forma submersus) was also a common submerged plant in both ponds. (vi) Eriocaulon sp. (possibly E. septangulare) (pipe wort) was found near the head of the outlet stream of Murray's Pond and all around the edge of Butler's Pond. (vii) Utricularia sp. (bladder wort) was identified from the southwest corner of Murray's Pond where it was found around the base of Nuphar variegatum. (viii) A sedge or a different species of Potamogeton was dredged from a portion of the bottom of Murray's Pond east and always harboured a large quantity of bottom organisms.

Aquatic-plant beds were generally restricted to protected areas where organic matter was allowed to accumulate, but not below a depth of five feet. The most extensive beds of emergent plants were located along the western edge near the barn and in the north-central region of Murray's Pond. In Butler's Pond they were all along the northwestern shore and extended out past the centre of the pond in places.

The bottom type in both these ponds consists principally of a homogeneous organic brown muck (Roelofs 1944) which is semi-fluid in consistency, and often has the tubes of aquatic insect larvae in it. This type is found everywhere on the bottom of stretches of open water deeper than five feet. The shallow reaches of the bottom of both ponds is mainly of an inorganic nature having very little organic material in it. This type may be described as a thick brownish yellow clay (Roelofs 1944). Within two feet of the shoreline of these ponds, the bottom type is boulders, rubble, and gravel.

4. Fertilization

Fertilizer was first applied to Murray's Pond in 1944 when five tons of 4 - 12 - 6 (4 per cent nitrogen, 12 per cent phosphoric acid and 6 per cent soluble potash) along with three tons of ammonium nitrate were added. The program was continued in 1945, and although fertilization was continued from 1946 to 1952, the amounts were not recorded.

In 1962, 1963, and 1964 Murray's Pond was fertilized with 1,100, 2,400, and 1,280 pounds respectively of CIL (Canadian Industries Limited) 6 - 12 - 8.

Butler's Pond has not been fertilized and is used as the control in this experiment. No winterkill or excessive growths of filamentous green algae have ever been observed in either of these ponds.

III. TROUT POPULATIONS

1. Species present

Rainbow trout (*Salmo gairdneri* Richardson 1836), brown trout (*Salmo trutta* Linnaeus 1758), and brook or native trout (*Salvelinus fontinalis* Mitchill 1815) are the only three species of fish found in these two ponds.

Rainbow trout from California were introduced into Murray's Pond in 1890 by Mr. R. A. Brehm and the brown trout from Scotland at about the same time by Mr. John Martin. Brook trout is native to Murray's and Butler's ponds and is the most abundant trout in insular Newfoundland (Scott and Crossman 1964).

A small hatchery, which has been in operation since 1895, and four concrete-sided holding compartments (Fig. 1) are maintained at these ponds with the object of keeping the ponds stocked with rainbow trout. For the past three years the trout have been held in the compartments for their first two years and then released into Murray's and Butler's ponds. However, because of spring flooding, many of the trout have been lost from the holding compartments into Murray's Pond and therefore accurate figures on annual recruitment are not available.

Although accurate estimates of the trout populations in these ponds are not available, reliable figures can be given from the results of gill-netting during 1964 which provide a relative index. Murray's and Butler's ponds were fished at the beginning and at the end of the summer period with a gang of two gill nets, each 100 feet long, one having stretched mesh of one inch and the other being two inches.

The results (Table 8) show that rainbow trout is the most abundant species in Murray's Pond and the brown trout have a higher ratio in relation to the total fish population than do the native trout. However, while rainbow is dominant during June at Butler's Pond there appears to be some doubt regarding the validity of this dominance when the September netting results are examined.

TABLE 8

RESULTS OF GILL-NETTING AT

MURRAY'S AND BUTLER'S PONDS, SUMMER 1964

DATE	NAME OF POND	PERIOD OF FISHING	NUMBER PER HOUR RAINBOW	BROWN	NATIVE
May 26	Murray's	18 hours	8.6	0.3	0.1
Sept. 10	"	16 "	2.6	0.3	0.1
June 11	Butler's	18 "	0.9	-	0.4
June 12	"	24 "	0.8	-	-
June 13	"	13 "	1.5	0.2	-
Sept. 11	"	64 "	0.04	0.04	0.1
Sept. 12	"	24 "	0.1	-	0.1
Sept. 13	"	24 "	0.3	0.04	0.1

Statistics based on the total weights show that Butler's Pond has the largest rainbows (Table 9)

TABLE 9

ARITHMETIC MEAN AND STANDARD DEVIATION OF RAINBOW TROUT WEIGHTS (GRAMS)

MURRAY'S AND BUTLER'S PONDS SUMMER 1964

(Trout taken by both gill-netting and angling)

POND	ARITHMETIC MEAN	STANDARD DEVIATION	NO. IN SAMPLE
Murray's	140.59	± 27.36	292
Butler's	158.93	± 54.21	81

2. Angling Results

Table 10 gives the results of sport fishing at Murray's and Butler's ponds during the season June 1 to September 15, 1964. A total of 1,737 fish were taken from Murray's and 122 from Butler's; revealing an average weight of 0.4 pounds and 0.5 pounds respectively. More rainbow trout were caught in Murray's Pond, but Butler's Pond yielded the largest individuals. More rainbow trout were taken from both ponds in June and in Murray's Pond a definite downward trend is evidenced thereafter; September being the poorest month. A somewhat similar trend is revealed in Butler's Pond, although here it is interrupted by the results shown for August. Murray's Pond provided the greatest number of fish per rod over the summer.

TABLE 10

RAINBOW TROUT CATCH RECORDS IN MURRAY'S AND BUTLER'S PONDS, SUMMER, 1964

	No. Rods	No. Fish	No. Per Rod	Total Weights	Average Weight (Lb.)	Fish Caught Per Acre (Lb.)
Murray's						
June	162	703	4.34	205.1	0.3	9.8
July	211	771	3.65	253.2	0.3	12.1
August	116	247	2.13	112.5	0.5	5.4
September	11	16	1.45	6.0	0.4	0.3
TOTALS	500	1,737	11.57	576.8	0.4	27.6
Butler's						
June	8	23	2.87	8.7	0.4	0.5
July	15	26	1.73	10.4	0.4	0.6
August	31	69	2.23	34.2	0.5	2.1
September	4	4	1.00	1.8	0.5	0.1
TOTALS	58	122	7.83	55.1	0.5	3.3

IV. THE BOTTOM FAUNA

1. Sampling Program

A complete quantitative and qualitative appraisal of the bottom fauna of Murray's and Butler's ponds was conducted from May 22 to September 21, 1964. To do this, an adequate sampling program was developed which would sample the quantity and quality of the fauna and its expected variation due to depth and time. Randomly stratified samples are more efficient for quantitative estimates of abundance than samples selected at random when it is known that the population in an area is not homogeneous (Snedecor 1946). Northcote (1952) recommends this system for bottom fauna after a study of variability at different depths in some Canadian lakes.

Neyman (1934) has shown that the samples in a randomly stratified design should be taken in proportion to the area which the populations occupy and to the standard deviation to be expected in the samples in each area. The 1 - 5 and the 5+ feet zones were chosen to separate the total fauna into sampling units because these intervals distinguished the major ecological habitats of the lake; i.e., that covered by aquatic plants and that in which loose muck predominates.

Before the initial samples were taken, it was necessary to estimate the standard deviations to be expected at different depths.

Bottom fauna collections taken from Murray's and Butler's ponds in 1962 during a preliminary survey (unpublished) were used for the measurements. Variability was computed in terms of numbers of organisms rather than dry weights because information on weight was lacking for the 1962 data.

TABLE 11

THE COEFFICIENT OF VARIATION TO BE EXPECTED AT VARIOUS DEPTHS IN MURRAY'S AND BUTLER'S PONDS AS COMPUTED FROM THE PRELIMINARY STUDY, 1962

DEPTH ZONE (FEET)	STANDARD DEVIATION	ARITHMETIC MEAN	COEFFICIENT OF VARIATION
Murray's Pond			
1 - 5	14.09	22.78	61.85 %
5+	9.90	14.19	69.76 %
Butler's Pond			
1 - 5	8.82	14.28	61.76 %
5+	6.08	8.97	67.78 %

The bottom fauna in the deeper zones is more variable than that in the shallow zones (Table 11). As the table indicates, the coefficient of variation to be expected at the two depth zones in Murray's Pond on the basis of the preliminary study varies from 61.85 per cent in the 1 - 5 feet zone to 69.76 per cent in the 5+ feet zone, making it apparent that the relative variation in the bottom fauna is less for the shallow zone than for the deeper zone. The same is true for Butler's Pond. This differs from the results reported by Gerking (1962) in that he produced a coefficient of variation indicating the opposite effect at various depth zones.

Two hundred and forty samples were chosen on the basis of past experience as the number which could be handled conveniently and sorted carefully each summer. The total number was subdivided into eight equal series of 30 each, sixteen in Murray's Pond and fourteen in Butler's Pond in each series. One series was taken on each of the following days: May 22, June 9, June 30, July 8, August 10, August 24, September 8, and September 21. Replication by series was expected to provide a measure of seasonal change in abundance.

TABLE 12

VARIABILITY IN NUMBER OF BOTTOM ORGANISMS AND NUMBER OF SAMPLES REQUIRED AT VARIOUS DEPTHS AS COMPUTED FROM THE PRELIMINARY STUDY OF MURRAY'S AND BUTLER'S PONDS, 1962

DEPTH ZONE (FEET)	AREA (NO. OF HECTARES)		STANDARD DEVIATION (NO. OF ORGANISMS)		PRODUCT (AREA X STANDARD DEVIATION)		SAMPLE SIZE	
	MUR *	BUT **	MUR	BUT	MUR	BUT	MUR	BUT
1 - 5	5.20	4.63	14.09	8.82	73.27	40.84	11.1	11.0
5+	3.30	1.85	9.90	6.08	32.67	11.25	4.9	3.0
					105.94	52.09	16.0	14.0

* Murray's ** Butler's

The sample stratification for 1964 is computed from the 1962 series. This is determined as follows (Table 12): The area (hectares) of each contour is multiplied by the expected standard deviation; the products are summed, each product is multiplied by the ratio of the total number of samples in each series (sixteen in Murray's and fourteen in Butler's) to the sum of the products (Gerking 1962). The number of samples scheduled in both ponds in each of the two depth zones is 11 and 5 for Murray's and 11 and 3 for Butler's, arranged according to depth.

The samples were randomized by gridding the two depth zones, numbering each space of the grid in each zone, and selecting the space to be sampled from a table of random numbers. The stations were located on the ponds by using familiar landmarks and depth soundings.

2. Methods and Materials

All the bottom samples throughout this investigation were collected using a standard Ekman dredge (225 cm^2 or 36 in^2). This dredge was satisfactory on all bottom types sampled except those covered by a thick growth of the submerged aquatic plants of Murray's Pond identified either as a sedge or another species of *Potamogeton*. When this plant was present (12.5 per cent of the dredgings in Murray's Pond), the jaws of the dredge would not close properly because of the great mass of this prolific weed across the jaws. This was also mentioned by Rawson (1930). This plant occurred in only a small portion of the total area of Murray's Pond (less than 3 per cent of total area), and it was not avoided while sampling the bottom fauna. In an attempt to overcome this sampling difficulty, a sampler was constructed following the description given by Gerking (1957), but the equipment did not function properly. This method was designed for sampling the littoral phytomacrofauna or periphyton, but it is useless in depths over 2.5 feet and the main aquatic plant beds in both ponds are in the depth zone from 3 to 5 feet.

Field sampling at any station involved the removal of two dredgings of bottom material and placing them in a two-gallon enamel pail. This was taken ashore with samples from other stations and sifted through a large mesh wire screen (13 mm. mesh) to remove plants and large pieces of debris. Often large dragon fly larvae and leeches would be retained by the screen. These would be picked off and placed in the pail with the rest of the sample. After the sample had been thoroughly washed and the material retained by the screen was checked for the presence of living organisms, the bottom material in the pail was stirred vigourously, using the hand to insure complete mixing, and then two 32 oz. bottles were immersed in it, filled and removed. Before the aliquots were capped the following information was enclosed: (1) name of pond, (2) position of sample, (3) date, (4) time, (5) surface pH, (6) surface temperature, (7) condition of weather, (8) depth, and (9) bottom type. These bottom samples were then taken to the laboratory and refrigerated over night and sorting was carried out on the following day. Many workers use a series of graded sieves to sort bottom material in the field, but this method is time consuming when a large number of samples have to be taken in a day and has been shown to be inaccurate in many cases (Jonasson 1955 and 1958).

Visual examination and hand sorting was the method employed for laboratory analysis of the bottom samples. The problem of clouding by fine particles suspended in solution was overcome by designing a system using the following materials:

(1) An electric suction pump of one quarter horse power.

(2) Two number 5 Bruckner funnels which were eight inches in diameter and connected in parallel to the pump by use of rubber hose material.

(3) Bolting cloth of 38 meshes per inch (0.66 mm.) which was used as a filter for the Bruckner funnel.

The mud was poured out from the 32 ounce bottle aliquot onto the bolting cloth in the Bruckner funnel. A stream of tap water was directed at the mud. By doing this, the small particles of mud in suspension were subsequently removed by the suction pump. The residue in the bolting cloth consisted of benthic animal life and pieces of bottom material which were too large to pass through the bolting cloth.

This residue was then washed from the bolting cloth into a large white enamel tray (17 x 20 x 2 inches). The resultant cleared bottom material was then carefully picked over and all the animal life removed. The fauna from each sample was preserved in suitably labelled vials using a solution of 40 per cent ethanol and 4 per cent formalin.

Later the animals were identified, counted and weighed (dry). Identification was carried out to families and, in the case of insects, to order: except in the case of the amphipods which were identified to species (see Acknowledgements). It is recognized that in studies of this nature, species of organisms are of prime importance, but in this preliminary study, identification beyond the family level was not attempted.

Dry weights of organisms in similar taxonomic groups were taken instead of preserved weight, because considerable error results from estimating live weights from specimens preserved in alcohol or formalin as Borutsysky (1934) has shown. Dry weight was measured by evaporating the preservative from the organisms in an oven for 48 hours at 70°C and weighing them to within 0.1 mg. on an analytical balance, after they had all attained constant weight. Before weighing, caddis flies were removed from their cases and the shells of molluscs were dissolved by treatment with 10 per cent hydrochloric acid as Holme (1953) did in his studies of the English Channel bottom fauna and Hayes (1957) advised in his comprehensive paper on bottom fauna studies.

3. Sources of Error

At this juncture certain inadequacies in the methods used for this bottom fauna study are mentioned.

(1) Water less than one foot deep was not sampled because of the inability of the Ekman dredge to operate on rock substratum. However, this zone in each pond amounted to less than 9 per cent of the area and therefore a serious miscalculation is not introduced. Furthermore, it has been observed that the majority of the animals of this region dwell on the underside of the rocks and since the objective of this study is to correlate the bottom fauna with the food of rainbow trout, this sampling error does not enter into such a comparison. Well-concealed fauna is not an available source of trout food (Rawson 1927). Finally, since both ponds were treated in the same manner, the error is non-existent for a comparison of Murray's and Butler's ponds but it does apply when an attempt is made to compare these ponds with those of other studies.

(2) Beds of aquatic vegetation were poorly sampled. This difficulty was mentioned previously (Methods and Materials, Page 23), and an abortive attempt to use a new technique was described. It is known that the difference in the amounts and types of fauna between vegetated and barren areas is pronounced (Andrews and Hasler 1943, Wohlschlag 1950, Rosine 1951, and Gerking 1957). On the average vegetated areas have four times the fauna in terms of numbers and dry weight than the barren areas (Gerking 1962). It is further noted that the phytomacrofauna is considerably less abundant on the floating leaves and erect stems of the yellow water lily (Nuphar) than on plants with more dissected leaves (Gerking 1957). In both Murray's and Butler's ponds the dominant aquatic plant is Nuphar variegatum (Page 13) while plants with highly dissected leaves such as the sedge are very low in abundance and are found only in Murray's Pond. Therefore the error introduced by poor sampling techniques is not further compounded, in view of what is know about the fauna of aquatic plants.

(3) The dredge technique is felt by some to be unsuitable for a quantitative study of certain motile organisms such as (1) water boatmen (Corixidae), (2) Mayfly nymphs (Baetidae), (3) adult aquatic beetles (Coleoptera), and (4) Damselfly nymphs (Zygoptera). This error is, however, relatively constant since the techniques were not changed.

(4) The bolting cloth mesh size of 0.66 mm. employed in the laboratory as a filter appears to have been small enough to prevent any of the macroscopic bottom fauna from passing through. A survey of mesh size employed by various investigators from 1907 to 1949

shows that they have settled on a mesh size of 0.6 mm. (Jonasson 1955). Uniformity with respect to time and method of sampling make the present data within themselves valuable for comparison (Smith 1961b).

(5) A final error was introduced in the calculation of standing crops and relative abundance when the surface area was used instead of the area of the bottom of each pond. Since it appears from the writings of other workers that they too have overlooked this factor, the present study is therefore comparable both within itself and with other areas.

4. Qualitative Analysis of the Bottom Fauna With Notes on Distribution, Size and Abundance

General - Murray's Pond (Table 13 and Figure 3). Of the animals considered, the most important group in the bottom fauna of Murray's Pond with respect to number of individuals are the amphipods (41.0 per cent) which is followed by Diptera larvae (21.5 per cent), fingernail clams (Sphaeriidae) (20.7 per cent) and small snails (Amnicolidae) (12.0 per cent). The gravimetric analysis reveals that the large dragonfly nymphs (Anisoptera) are the dominant group since their weight is 39.2 per cent of the total. Leeches (Hirudinea) (14.3 per cent) is next and is followed by the amphipods (12.1 per cent), Diptera larvae (10.2 per cent) and Amnicolidae (8.8 per cent).

Butler's Pond (Table 13 and Figure 3) As in Murray's Pond, the most important group in numbers is the Amphipoda (32.9 per cent) while the Diptera larvae (31.7 per cent) are almost as abundant. The lesser groups, as in Murray's Pond, are the Sphaeriidae (13.1 per cent) and Amnicolidae (10.9 per cent). The gravimetric analysis again shows that the dominant group is the anisopteran nymphs (44.1 per cent) followed by the Amnicolidae (12.4 per cent) Amphipoda (9.7 per cent), Planorbidae (9.6 per cent), and Diptera larvae (8.7 per cent).

TABLE 13

BOTTOM FAUNA PER SQUARE FOOT BY NUMBERS, DRY WEIGHT (MILLIGRAMS) AND TAXONOMIC GROUP IN RELATION TO DISTRIBUTION IN MURRAY'S AND BUTLER'S PONDS, SUMMER 1964

BENTHIC GROUP		MURRAY'S POND 1' - 5'	5'+	Average	%	BUTLER'S POND 1' - 5'	5'+	Average	%
Planariidae	No.	0.2	-	0.1	-	-	-	--	-
	Dry Wt.	0.1	-	0.1	-	-	-	--	-
Nematoda	No.	0.2	0.4	0.3	0.1	0.1	-	0.1	-
	Dry Wt.	0.2	0.1	0.1	-	0.2	-	0.1	0.1
Oligochaeta	No.	2.7	2.8	2.7	0.6	3.2	0.3	1.8	1.4
	Dry Wt.	6.1	4.5	5.2	1.3	4.2	0.4	2.3	2.3
Hirudinea	No.	1.7	1.2	1.5	0.3	1.6	1.0	1.3	1.0
	Dry Wt.	49.6	69.2	59.4	14.3	1.4	0.2	0.7	0.8
Amphipoda	No.	237.4	127.8	182.6	41.0	67.7	18.4	43.1	32.9
	Dry Wt.	66.1	34.3	50.2	12.1	15.8	3.4	9.6	9.7
Hydracarina	No.	4.7	2.2	3.5	0.8	1.8	2.3	2.1	1.6
	Dry Wt.	0.6	0.2	0.4	0.1	0.2	0.3	0.3	0.2
Ephemeroptera	No.	1.0	0.6	0.8	0.2	5.4	1.3	3.4	2.6
nymphs	Dry Wt.	0.8	1.3	1.0	0.3	1.7	0.9	1.4	1.4
Anisoptera	No.	2.9	2.8	2.9	0.6	2.2	-	1.1	0.9
nymphs	Dry Wt.	211.0	116.0	163.5	39.2	86.9	-	43.5	44.1
Zygoptera	No.	0.5	-	0.3	-	0.6	-	0.3	0.2
nymphs	Dry Wt.	2.9	-	1.5	0.3	1.5	-	0.7	0.8

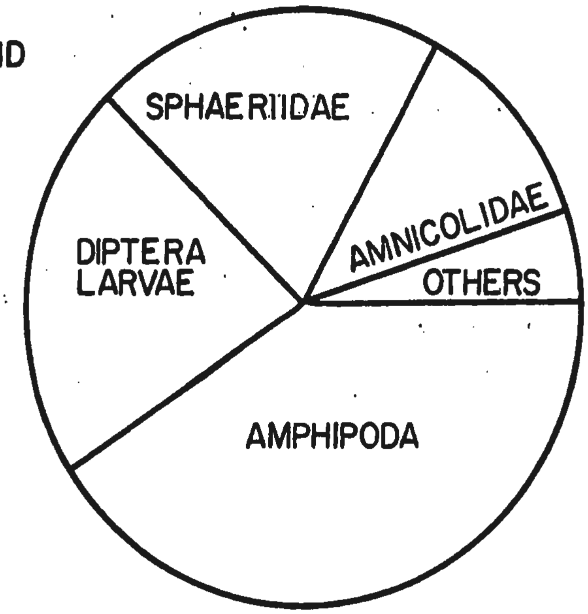
TABLE 13 - Continued

BENTHIC GROUP		MURRAY'S POND 1' - 5'	5'+	Average	%	BUTLER'S POND 1' - 5'	5'+	Average	%
Trichoptera	No.	1.3	0.8	1.0	0.2	1.1	0.4	0.8	0.5
larvae	Dry Wt.	25.8	4.8	15.3	3.7	6.3	0.6	3.4	3.5
Trichoptera	No.	0.2	-	0.1	-	0.2	-	0.1	0.1
pupae	Dry Wt.	4.9	-	2.5	0.6	4.9	-	2.5	2.5
Coleoptera	No.	3.7	1.4	2.5	0.6	2.0	2.0	2.0	1.5
larvae	Dry Wt.	3.4	3.4	3.4	0.8	1.0	1.7	1.4	1.4
Diptera	No.	70.7	120.6	95.6	21.5	41.3	41.7	41.6	31.7
larvae	Dry Wt.	28.0	57.1	42.5	10.2	8.3	8.9	8.5	8.7
Diptera	No.	1.9	2.0	2.0	0.4	0.4	-	0.2	0.2
pupae	Dry Wt.	1.1	1.0	1.0	0.2	0.3	-	0.1	0.2
Sphaeriidae	No.	83.7	100.2	91.9	20.7	24.4	10.0	17.2	13.1
	Dry Wt.	10.1	9.5	10.0	2.4	3.2	1.4	2.3	2.3
Amnicolidae	No.	58.1	49.0	53.5	12.0	18.3	10.3	14.3	10.9
	Dry Wt.	29.7	43.4	36.6	8.8	15.4	9.1	12.3	12.4
Planorbidae	No.	3.6	5.0	4.3	1.0	2.7	1.0	1.3	1.4
	Dry Wt.	25.9	22.1	24.0	5.7	14.8	4.2	9.5	0.6
Total	No.	474.5	416.8	445.6	100.0	173.0	88.7	130.8	100.0
	Dry Wt.	466.3	366.9	416.7	100.0	166.1	31.1	98.6	100.0
Number of Samples		88	40			88	24		
Area Sampled (Sq. Ft.)		11.0	5.0			11.0	3.0		

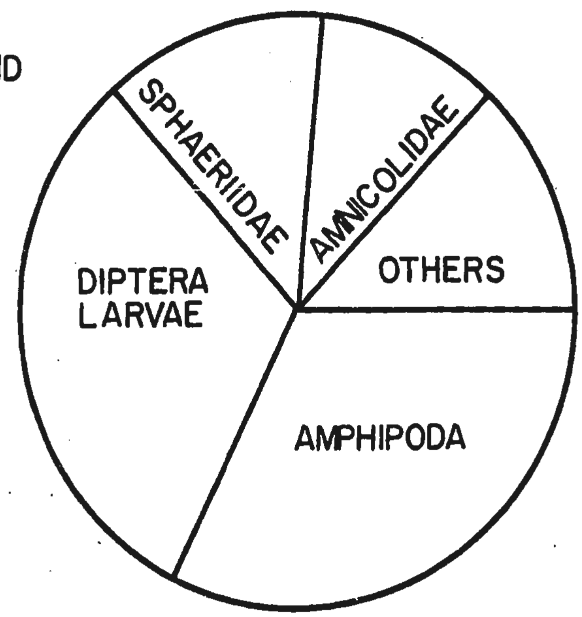
FIGURE 3

PIE DIAGRAMS OF THE NUMERICAL PERCENTAGE COMPOSITION OF BOTTOM FAUNA IN MURRAY'S AND BUTLER'S PONDS, SUMMER, 1964

MURRAY'S POND



BUTLER'S POND



For the remainder of the text in this section, refer to the Appendix, Tables A, B, C and D.

Planariidae - Murray's Pond Two were collected from the shallow zone among submerged aquatic vegetation.

- Butler's Pond No individuals from this family were taken.

Nematoda - Murray's Pond Members of this phylum, although few in numbers, were found in both depth zones.

- Butler's Pond One specimen was taken from a depth of three feet.

Annelida - Murray's Pond This phylum is represented by the classes Oligochaeta and Hirudinea. There was a slight tendency for the members of these classes to be found in the shallow areas, and although more oligochaetes were captured, the weight of the leeches was much greater. The heavier leeches were in depths greater than five feet.

- Butler's Pond The same two classes were present in this pond. As in Murray's Pond, they were taken more frequently from shallow water, and again more oligochaetes were captured. However, the total weight of oligochaetes in Butler's Pond was greater than the total weight of leeches in direct opposition to the data for Murray's Pond. This indicates that the individual leeches in Murray's Pond are larger than those in Butler's Pond by 34.9 milligrams (51 times larger) (calculated from average weights).

Amphipoda - Murray's Pond Two species of these small crustaceans were taken: (1) Hyalella azteca and (2) Crangonyx richmondensis. Only one specimen of the latter was taken and it came from a depth of about four feet. _C. richmondensis_ is noticably larger than _H. azteca_ and the one examined weighed 12.5 milligrams while the average weight of the latter was 0.3 milligrams. _H. azteca_ was present at all depths and was most often encountered in shallow water less than five feet deep, generally in areas of aquatic vegetation. The amphipods were the most abundant animals on the bottom of Murray's Pond.

- _Butler's Pond_ _H. azteca_ was the only species of the amphipoda found in Butler's Pond. It was encountered at all depths but more frequently in the shallow region around aquatic vegetation. As in Murray's Pond, the amphipods of Butler's Pond are the most numerous group of organisms of those considered.

Hydracarina - _Murray's Pond_ Members of this order were taken occasionally in all areas but were more frequent in the shallow zone. Since many of these animals are capable of clambering and swimming about with agility it is conceivable that the sampling technique employed did not catch all that were present in any given area.

- _Butler's Pond_ The water mites were less abundant in this pond and were found more often in the deeper waters of the pond, in opposition to the situation in Murray's Pond.

Ephemeroptera - _Murray's Pond_ Fourteen specimens of mayfly nymphs were taken from this pond and they occurred in all depth zones.

- _Butler's Pond_ More than four times as many mayfly nymphs were dredged from this pond as from Murray's Pond and the majority of them occurred in the shallow zone.

Anisoptera - Murray's Pond Both depth zones of this pond had approximately equal numbers of dragonfly nymphs but those in the shallow zone weigh almost twice as much as those in the deeper regions. The explanation may be that the nymphs crawl out of the water in order to metamorphose into adults. It is assumed that the smaller nymphs in the deeper zones are younger and have not begun to migrate towards the shore, while the shallow water has an abundance of large nymphs which are almost ready to change into adults and are approaching the shore. Gravimetrically, these organisms are the dominant group in the bottom fauna of Murray's Pond.

- Butler's Pond There were no predacious dragonfly nymphs encountered at depths greater than five feet. It is believed that the explanation above applies to the distribution of dragonfly nymphs in Butler's Pond. As in Murray's Pond, this group was by far the heaviest constituent of the bottom fauna.

Zygoptera - Murray's Pond Only five damselfly nymphs were taken from this pond and they all came from the shallow zone. They had very little influence on the total fauna.

- Butler's Pond Only six nymphs were taken in this pond and again they all came from the 1 to 5 feet zone.

Trichoptera - Murray's Pond This pond revealed only eighteen caddis fly nymphs and two pupae. The majority of the nymphs (14) and both the pupae came from the shallow water.

- Butler's Pond A similar situation existed in this pond in that thirteen nymphs and two pupae were taken.

A caddis fly nymph was the only member of this order which was found deeper than five feet.

Coleoptera - Murray's Pond The larvae of this insect order were abundant in shallow water (72 per cent of their numbers) but they exerted little overall influence on the total bottom fauna.

- Butler's Pond Fewer beetle larvae were found in this pond than in Murray's Pond but the distribution differs in that equal numbers were found in both deep and shallow water zones.

Diptera - Murray's Pond Many more dipteran larvae were found below five feet than above and they demonstrated a reasonable influence on both numerical and gravimetric totals. Dipteran pupae were equally abundant in both depth zones, but their numbers were small.

- Butler's Pond Dipteran larvae were evenly spread over the bottom of this pond and there were almost as many present as there were amphipods, the dominant group in Butler's Pond. No dipteran pupae were found below five feet and only five were taken.

Sphaeriidae - Murray's Pond Numerically, these small pelecypods were the third most abundant group in this pond. Most were from depths greater than five feet.

- Butler's Pond These were again the third most abundant group, but many more were found in shallow water than in the deeper areas.

Amnicolidae - Murray's Pond Similar numbers of these small snails were found on all types of bottom in this pond and they were fourth with respect to total abundance in the bottom fauna.

- Butler's Pond The relative numbers and the distribution of these gastropods here was similar to that described for Murray's Pond.

Planorbidae - Murray's Pond These large gastropods had very little influence on the total fauna of the pond and were less abundant towards the shallow regions. However, approximately six per cent of the total dry weight of the bottom fauna is planorbid snails, making them the fifth heaviest group.

- Butler's Pond Few were present on the bottom, but, as opposed to Murray's Pond, the Planorbidae here were more numerous in the shallower regions of the pond. They ranked fourth among the total fauna with a dry weight of almost 10 per cent of the total.

5. Quantitative Analysis of the Bottom Fauna Including Comparison with Other Areas And Remarks on the Effects of Fertilization

Throughout all phases of this investigation, efforts have been made to eliminate error and derive a reasonably accurate estimate of the standing crops of the bottom faunae in these ponds. The sampling procedure, field and laboratory methods, and the equipment used were therefore chosen with great care, since these things are requisite for achieving the desired result.

The amount and dry weight of the bottom fauna per square foot was calculated for both ponds and is shown in Table 13. The actual numbers and corresponding dry weights of the organisms collected are given in the Appendix, Tables A, B, C and D for each sampling day, but these figures are not comparable except within similar depth zones because they are not given per unit area and the number of samples taken varied between depth zones. The figures are given per square foot in Table 13, using the following information: Each sample was taken from an area of one half square foot (two dredge hauls) and the two bottles of material taken from the complete sample constituted an aliquot which was one quarter of the original sample. Therefore each aliquot represented one eight of a square foot. This fraction (one eighth) was then multiplied by the number of samples in a particular zone and the resultant figure divided into the number of organisms and their respective dry weights in order to get their amounts and weights per square foot.

TABLE 14

COMPARISON OF THE DRY WEIGHT OF THE BOTTOM FAUNAE IN MURRAY'S AND BUTLER'S PONDS WITH OTHER AREAS IN NORTH AMERICA

POND	TOTAL AREA (Acres)	MEAN DEPTH (Feet)	AVERAGE BOTTOM FAUNA (Kg/ha)
Murray's Pond	21.0	5.6	46.0
Butler's Pond	16.0	4.7	13.7
Wyland Lake, Indiana (Gerking 1962)	8.3	4.0 approx.	8.3

TABLE 14 - Continued

POND	TOTAL AREA (Acres)	MEAN DEPTH (Feet)	AVERAGE BOTTOM FAUNA (kg/ha)
Boar's Back Lake, Nova Scotia (Smith 1961a)	55.8	8.5	1.2
Crecy Lake, New Brunswick (Smith 1952)	50.4	7.9	6.1
Linsley Pond, Connecticut (Deevey 1941)	23.5	6.7	348
Moriarity's Lake, Connecticut (Deevey 1941)	19.5	4.0	38.8
Great Slave Lake, North West Territories (Rawson 1953)	6,720,000	206.0	96.8 (0-16 ft. zone)

The data indicate that both ponds have a relatively high standing crop of bottom organisms, with Murray's Pond being very rich indeed. (Table 14) Such results are not surprising since it has been recorded as a general observation by Welch (1952:325) and Rawson (1953) that shallow lakes are often very productive. Welch also notes that the quantities produced at the various depths in a shallow lake are not necessarily the same, but the differences are of a much smaller magnitude than in the lakes of greater depths. It can be seen from Table 15 that this is indeed true for the bottom fauna of Murray's Pond in that the standing crop of bottom fauna for the shallow zone (1 - 5 feet) is 50.2 kilograms per hectare, while in the deeper zone (5+ feet) it is 39.5 kilograms per hectare, demonstrating that the difference between the two zones is not great. A greater significance of these figures may be realized when a large lake such as Great Slave Lake (Rawson 1953b) is used for comparison. Here the shallow zone (0 - 16 feet) had 96.8 kilograms per hectare while the deep zone (1639 - 1967 feet) had 3.4 kilograms per hectare. Deevey (1941) has demonstrated that small lakes show no orderly relationship between mean depth and bottom population.

To facilitate comparison with the quantity of the bottom populations in some lakes of North America, Table 14 has been prepared by drawing together, from the sources acknowledged in the table, data on the weight of the bottom fauna in seven small lakes; and Great Slave Lake which has been included as an example of a large lake. In order to give some idea of what a "good" or a "bad" standing crop of bottom organisms would be, it is noted here that Rawson (1948:330) described the bottom fauna of Clear Lake, Manitoba (22.6 kilograms per hectare) as a "fairly dense population"; while Smith (1961a) stated that the summer standing crop of bottom macroorganisms in Boar's Back Lake, Nova Scotia (1.2 kilograms per hectare) was quantitatively poor. Using the work of these two limnologists, along with the others cited in Table 14, as a frame of reference, we can examine the results of the present investigation.

It is realized that Murray's Pond has a rich summer standing crop of bottom organisms (46.0 kilograms per hectare) and this weight is rarely surpassed by other lakes in the temperate region. The standing crop of Butler's Pond (13.7 kilograms per hectare)

TABLE 15

STANDING CROPS OF BOTTOM FAUNAE AND THE DATA REQUIRED FOR THE CALCULATIONS, MURRAY'S AND BUTLER'S PONDS, SUMMER 1964

	MURRAY'S POND			BUTLER'S POND		
	1' - 5'	5'+	Total	1' - 5'	5'+	Total
Area (hectares)	5.20	3.30	8.50	4.63	1.85	6.48
Number of Samples	88	40	128	88	24	112
Area (Sq. Feet)	559,746	355,014	914,760	498,326	198,633	696,959
Area Sampled (Sq. Feet)	11	5	16	11	3	14
Total Standing Crop (Numbers)	26.58×10^7	14.80×10^7	41.38×10^7	8.62×10^7	1.76×10^7	10.38×10^7
Bottom Fauna (Nos. per sq. foot)	474.9	416.8		173.0	88.7	
Standing Crop (kg./ha.)	50.2	39.5	46.0	17.9	3.3	13.7
Standing Crop (gm per square meter)	5.0	4.0	4.6	1.8	0.3	1.4

is less than one third of that in Murray's Pond although the two bodies of water are adjacent and have similar physical characteristics and morphometry. The outstanding difference between them as previously indicated (Page 15) is that Murray's Pond has been fertilized and Butler's Pond has not. The effect of the application of fertilizer to fresh water lakes has been observed in other areas by studying the bottom fauna, both qualitatively and quantitatively and noting any changes which occur after fertilization (Ball, 1949; Smith, 1961b, etc.). Unfortunately, the bottom fauna of the two ponds in question was not studied previous to fertilization, but in 1962, the same year that the fertilization program was reinstated after a ten-year lapse, the bottoms of the ponds were dredged during a preliminary study. The quantitative results of this study are given below in order to indicate the changes which have occurred after three years of fertilization. The effects of the renewed fertilizing of Murray's Pond should not be expected to appear until about two or three years after the fertilizer has been added (Smith 1961b), and therefore the comparison given in Table 16 is valuable as an indication of the trends.

TABLE 16

NUMBER OF BOTTOM ORGANISMS PRESENT PER SQUARE FOOT IN MURRAY'S AND BUTLER'S PONDS IN THE SUMMERS OF 1962 AND 1964

YEAR	MURRAY'S	BUTLER'S
1962	141.5	93.0
1964	445.8	130.8

Numbers of organisms have been given instead of dry weights because the latter were not available for 1962. The materials used during that year were the same as those used in 1964, but the sampling procedure was changed. During 1962, the total area of both ponds was gridded and the sampling stations were selected randomly, while the other techniques and methods were not changed from those described for 1964. This factor was considered for the calculations involved in Table 16.

This table shows that the bottom fauna increased more than threefold over the three year period in Murray's Pond while, the increase in Butler's Pond was less than twofold. Furthermore, the number of bottom organisms in Murray's Pond for both years was greater than in Butler's Pond. It is important to note that the difference between the two ponds in 1962 in organisms per square foot was 48.5 while in 1964, this difference is over six times as great at 315.0. The difference observed in 1962 is not surprising since it has been noted many times (Patriarche, 1948) that no two bodies of water are exactly alike. However, the increase in the amount of bottom fauna present in Murray's Pond, 1964, is real since this fertilized pond has 3.4 times more benthos than the unfertilized pond. This difference is similar to that reported by Howell (1941) for two Alabama ponds (3.5 times). Ball (1949), during a study of 21 ponds at three Michigan fish hatcheries, found that populations of bottom invertebrates were considerably larger in fertilized ponds, while Smith (1961b:724) in a brief report on Crecy Lake, New Brunswick, stated that "for the bottom fauna as a whole the effects of fertilization were definitely positive in providing quantities of organisms".

With respect to the quantity of benthic organisms, it would appear that the fertilization in Murray's Pond has been successful in that the productive capacity has been increased substantially. No deleterious effects such as winterkill or excessive production of filamentous green algae have been observed. However there is strong evidence (Murray 1956) that the rainbow trout population in this experimental pond is stunted and information drawn from lake fertilization trials elsewhere indicates that artificial enrichment of the water only aggravates the situation rather than improves it (Maciolek, 1954).

6. Seasonal Change in Abundance of Bottom Organisms

Murray's Pond - Table 17 contains the number and percentage of bottom organisms per square foot on each sampling day throughout the summer months. There is clearly an upward trend caused by increased numbers of bottom organisms as the summer progressed and this trend is graphically illustrated in Figure 4. The total bottom fauna was at an intermediate level in May, June, July and early August, after which it rose to summer heights in late August and September. Dipteran larvae were the most abundant insect group and their emergence from the water began in late June and continued through July to early August, a fact which is substantiated by personal field observation. It does not appear, however, that this emergence had any large affect on the overall trend in bottom fauna abundance. The species which governed the seasonal fluctuations of the benthic fauna was the tiny amphipod, *Hyalella azteca*. Whenever the numbers of this species varied, the total fauna was affected

TABLE 17

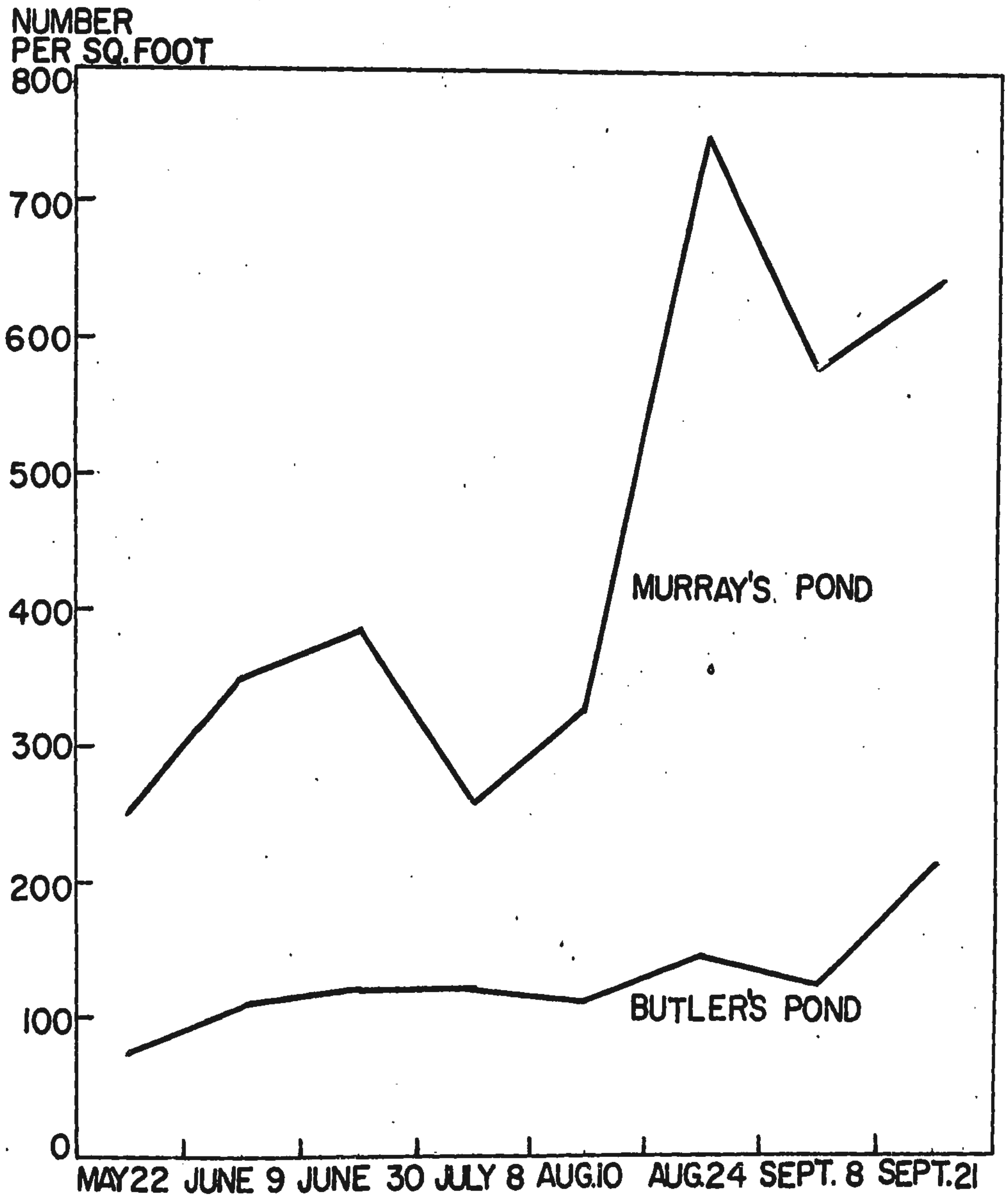
NUMBER AND PERCENTAGE OF BOTTOM ORGANISMS PER SQUARE FOOT IN MURRAY'S POND BY SAMPLING DAYS, SUMMER 1964

Benthic Group		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21	Average
Planariidae	No.	0	0	0.4	0	0	0	0	0.4	0.4
	Per Cent	-	-	0.1	-	-	-	-	0.1	0.1
Nematoda	No.	0	0	0	0.4	0.8	0.4	0	1.2	0.7
	Per Cent	-	-	-	0.1	0.2	0.1	-	0.2	0.2
Oligochaeta	No.	4.9	1.9	2.4	2.6	3.1	4.7	0.7	1.8	2.7
	Per Cent	1.9	0.6	0.6	1.0	0.9	0.6	0.1	0.3	0.6
Hirudinea	No.	2.3	0.4	0.4	1.5	2.5	1.1	1.2	2.3	1.4
	Per Cent	0.9	0.1	0.1	0.6	0.8	0.1	0.2	0.3	0.3
Amphipoda	No.	36.1	69.4	96.7	46.6	138.9	436.1	262.8	374.1	182.6
	Per Cent	14.3	19.8	24.9	17.6	42.1	58.3	45.3	57.1	40.7
Hydracarina	No.	6.5	6.0	1.1	2.9	4.5	2.2	1.5	5.2	3.7
	Per Cent	2.6	1.7	0.3	1.1	1.4	0.3	0.3	0.8	0.8
Ephemeroptera	No.	1.5	1.6	0.7	1.1	0.4	0	0	1.1	1.1
nymphs	Per Cent	0.6	0.5	0.2	0.4	0.1	-	-	0.2	0.3
Anisoptera	No.	0.7	2.8	2.2	1.9	2.6	6.7	2.6	3.3	2.8
nymphs	Per Cent	0.3	0.8	0.6	0.7	0.8	0.9	0.4	0.5	0.6
Zygoptera	No.	0	0	0	0	0	0	0.7	1.1	0.9
nymphs	Per Cent	-	-	-	-	-	-	0.1	0.2	0.2
Trichoptera	No.	1.2	0.7	0.4	1.1	0	0	1.6	3.3	1.4
larvae	Per Cent	0.5	0.2	0.1	0.4	-	-	0.3	0.5	0.3

TABLE 17 - Continued

Benthic Group		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21	Average
Trichoptera pupae	No.	0	0	0.4	0	0	0.4	0	0	0.4
	Per Cent	-	-	0.1	-	-	0.1	-	-	0.1
Coleoptera larvae	No.	1.8	5.0	3.8	0	0.7	1.1	1.8	6.3	2.9
	Per Cent	0.7	1.4	1.0	-	0.2	0.1	0.3	0.9	0.6
Diptera larvae	No.	112.1	115.1	107.7	90.6	57.1	95.7	91.4	95.1	95.6
	Per Cent	44.3	32.9	27.8	34.2	17.3	12.8	15.8	14.5	21.3
Diptera pupae	No.	2.2	1.2	3.9	3.3	2.3	2.3	0.4	0	2.2
	Per Cent	0.9	0.3	1.0	1.3	0.7	0.3	0.1	-	0.5
Sphaeriidae	No.	55.0	91.3	97.0	79.6	81.5	105.6	136.8	88.9	91.9
	Per Cent	21.7	26.1	25.0	30.1	24.7	14.1	23.6	13.6	20.5
Amnicolidae	No.	26.2	52.4	65.5	32.0	31.6	82.2	71.3	67.0	53.5
	Per Cent	10.4	15.0	16.9	12.1	9.6	11.0	12.3	10.2	11.9
Planorbidae	No.	2.3	1.9	5.0	1.1	3.8	9.6	7.0	3.8	4.3
	Per Cent	0.9	0.6	1.3	0.4	1.2	1.3	1.2	0.6	1.0
TCTALS	No.	252.8	349.7	387.6	264.7	329.8	748.1	579.8	654.9	448.5
	Per Cent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
No. of Samples		16	16	16	16	16	16	16	16	128
Area Sampled (Sq. Feet)		2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	16.0

FIGURE 4
SEASONAL VARIATION IN NUMBERS OF BOTTOM ORGANISMS AT MURRAY'S AND BUTLER'S PONDS, 1964



accordingly and it was the dominant organism in Murray's Pond during August and September (Table 17). It is during these months that H. azteca breeds and the young are hatched in Murray's Pond accounting for the increased numbers. During the first three months of May, June and July, the dominant organisms were dipteran larvae and their influence decreased thereafter following emergence. Two other groups of the bottom fauna which influenced the total numbers were the Sphaeriidae and the Amnicolidae.

Butler's Pond - The data on the number and percentage of bottom organisms per square foot on each sampling day in this pond is contained in Table 18 and illustrated graphically in Figure 4. In this figure the same scale is used to plot the data of both ponds which shows that Butler's Pond has a low standing crop of benthic organisms compared with its neighbour. In spite of the low numbers, however, the overall seasonal trend shows an increase from May through September.

As in Murray's Pond, the total bottom fauna in Butler's Pond was at an intermediate level in May through early August after which it rose to summer peaks in late August and September. A single dominant benthic group is not clearly defined in Butler's Pond since, although the amphipods show the greatest numbers (43.0 per sq. ft.), the dipteran larvae are nearly as numerous (41.5 per square ft.). Furthermore it appears that for each collecting day shown on Table 18 except the last three, the group governing the seasonal fluctuations in bottom fauna abundance are the dipteran larvae, but on the final three sampling days the tiny amphipods double their

TABLE 18

NUMBER AND PERCENTAGE OF BOTTOM ORGANISMS PER SQUARE FOOT IN BUTLER'S POND, BY SAMPLING DAY, SUMMER 1964

BENTHIC GROUP		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21	Average
Planariidae	No.	0	0	0	0	0	0	0	0	0
	Per Cent	-	-	-	-	-	-	-	-	-
Nematoda	No.	0	0	0	0	0	0.3	0	0	0.3
	Per Cent	-	-	-	-	-	0.2	-	-	0.2
Oligochaeta	No.	1.5	2.9	1.8	0.3	1.8	1.5	2.2	2.4	1.8
	Per Cent	2.0	2.6	1.4	0.2	1.7	1.0	1.7	1.1	1.4
Hirudinea	No.	0	1.8	0.7	1.4	2.5	0	0.7	3.5	1.8
	Per Cent	-	1.6	0.5	1.1	2.3	-	0.5	1.6	1.3
Amphipoda	No.	15.8	17.5	13.4	16.5	29.9	59.3	57.6	133.8	43.0
	Per Cent	21.4	15.6	10.7	13.3	27.8	40.1	43.3	61.4	32.2
Hydracarina	No.	3.0	2.2	0	1.2	0.7	1.1	6.1	1.3	2.2
	Per Cent	4.1	2.0	-	1.0	0.7	0.7	4.6	0.6	1.7
Ephemeroptera	No.	1.5	4.4	6.7	5.8	0.7	0.7	0.7	6.2	3.3
nymphs	Per Cent	2.0	3.9	5.4	4.6	0.6	0.5	0.5	2.9	2.5
Anisoptera	No.	2.2	0.7	0.7	0.7	0.7	2.2	0.3	0.7	1.0
nymphs	Per Cent	2.9	0.6	0.6	0.6	0.7	1.5	0.2	0.3	0.8
Zygoptera	No.	0.3	0	0	0	0.7	1.1	0	0	0.7
Nymphs	Per Cent	0.4	-	-	-	0.6	0.7	-	-	0.5

TABLE 18 - Continued

BENTHIC GROUP		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21	Average
Trichoptera	No.	0	0.3	1.1	0	0	0	1.2	2.5	1.3
larvae	Per Cent	-	0.3	0.9	-	-	-	0.9	1.1	1.0
Trichoptera	No.	0	0.7	0	0	0	0	0	0	0.7
pupae	Per Cent	-	0.6	-	-	-	-	-	-	0.5
Coleoptera	No.	0	1.2	1.9	0.3	2.6	1.5	3.5	3.8	2.1
larvae	Per Cent	-	1.0	1.5	0.2	2.4	1.0	2.6	1.8	1.6
Diptera	No.	29.7	50.6	57.6	56.1	33.2	52.6	29.7	22.8	41.5
larvae	Per Cent	40.1	45.1	46.2	45.1	30.8	35.7	22.3	10.5	31.1
Diptera	No.	0.3	0	0.7	0	0.3	0	0.3	0	0.4
pupae	Per Cent	0.4	-	0.6	-	0.3	-	0.2	-	0.3
Sphaeriidae	No.	7.6	6.7	19.3	25.6	20.6	16.2	21.6	19.9	17.2
	Per Cent	10.3	6.0	15.5	20.6	19.1	11.0	16.2	9.1	12.9
Amnicolidae	No.	11.4	20.8	18.4	13.5	11.8	10.2	7.8	19.5	14.2
	Per Cent	15.4	18.5	14.7	10.9	11.0	6.9	5.9	8.9	10.6
Planorbidae	No.	0.7	2.5	2.5	3.0	2.2	1.1	1.5	1.5	1.9
	Per Cent	1.0	2.2	2.0	2.4	2.0	0.7	1.1	0.7	1.4
TOTALS	No.	74.0	112.3	124.8	124.4	107.7	147.8	133.2	217.9	133.4
	Per Cent	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
No. of Samples		14	14	14	14	14	14	14	14	112
Area Sampled (Sq. Feet)		1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	14.0

normal abundance and produced the peak in total faunal amounts during the late summer. This pond is similar to Murray's in this respect, except that the amphipod influence was felt for a longer period of time in the latter. As in Murray's Pond, the two other groups most influencing the total numbers in Butler's Pond were the Sphaeriidae and the Amnicolidae.

Examination of the difference between the lowest and highest numbers of organisms in each pond reveals that in both ponds the greatest abundance is exactly 2.9 times as great as the lowest. Such an occurrence indicates that the bottom fauna of these two ponds has similar fluctuations throughout the summer, although of varying magnitude, and the upward trend is not coincidental. This general pattern of invertebrate abundance is similar to those reported from lakes in Michigan (Ball 1948), Minnesota (Lux and Smith 1960), Iowa (Tebo 1952) and Lake Erie (Lancaster 1931). Northcote (1952) reported from British Columbia that the main fluctuating groups of his study were observed in nematodes, oligochaetes, pelecypods, hirudinians and gastropods. Such is also the case in these two Newfoundland ponds. Finally, Rosine (1951) reported that _Hyalella azteca_ is also the dominant organism of a Colorado lake but here the amphipod population showed three peaks: early May, early July and early October.

V. THE FOOD OF RAINBOW TROUT

There is a reasonable background of information about the food habits of the rainbow trout as mentioned above (Page 2) and it is generally agreed that small crustaceans, both pelagic and benthic, along with all stages of insects comprise the bulk of the diet. Each population, however, has its own feeding habits which are related to food preference or to the relative abundance of different organisms in the lake. Therefore it has been necessary to repeat the observations in Murray's and Butler's ponds.

1. Methods and Materials

The trout used for stomach analysis were all captured by angling or gill netting and the numbers and lengths of the trout from both ponds obtained by these two methods are given in Table 19. The fish in the samples did not vary greatly in size; the majority were from 20.0 to 25.9 cm in each pond. Such fish may be classed as relatively small when compared with rainbows in other areas such as Paul Lake, British Columbia (Crossman and Larkin, 1959). There were only two fish which weighed over one pound whereas Paul Lake rainbows averaged 1.2 pounds in 1957 (ibid).

The angled fish were all caught using an artificial fly by the members of the Newfoundland Game Fish Protection Society during the summer of 1964. The use of angling as a method of capturing fish for dietary studies has been criticized on the grounds that it may

TABLE 19

SIZE IN CENTIMETERS OF RAINBOW TROUT EXAMINED FROM MURRAY'S AND BUTLER'S PONDS, SUMMER 1964

MURRAY'S POND

LENGTH	NETTED FISH		ANGLED FISH	
Class (cms)	Number	Per Cent	Number	Per Cent
16.0 - 17.9	-	-	-	-
18.0 - 19.9	2	1.0	1	1.6
20.0 - 21.9	43	21.8	12	18.7
22.0 - 23.9	98	49.8	27	42.2
24.0 - 25.9	50	25.4	20	31.2
26.0 - 27.9	3	1.5	3	4.7
28.0 - 29.9	-	-	1	1.6
30.0 - 31.9	-	-	-	-
32.0 - 33.9	1	0.5	-	-
TOTALS	197	100.0	64	100.0

BUTLER'S POND

LENGTH	NETTED FISH		ANGLED FISH	
Class (cms)	Number	Per Cent	Number	Per Cent
16.0 - 17.9	-	-	-	-
18.0 - 19.9	2	2.9	-	-
20.0 - 21.9	16	23.5	-	-
22.0 - 23.9	28	41.2	5	26.3
24.0 - 25.9	11	16.2	8	42.1
26.0 - 27.9	7	10.3	3	15.8
28.0 - 29.9	3	4.4	2	10.5
30.0 - 31.9	1	1.5	-	-
46.0 - 47.9	-	-	1	5.3
TOTALS	68	100.0	19	100.0

be selective (Pentelow 1932) and that the captured fish might regurgitate their food (Phillips 1929). These criticisms have been discounted by Dimich and Mote (1934), Frost (1939) and Neill (1938). In their work on the food of Oregon trout, Dimich and Mote could detect no distinction in the amount or nature of the food between those netted and those caught in various ways by hook. Frost (1939) suggests regurgitation of food probably applies to any type of capture. It is because of this last point that all the trout in the present study were examined for stomach contents as soon as possible after capture.

The majority of the fish were captured using a gang of two 100 feet long gill nets tied together and having stretched mesh sizes of one inch and two inches. The smaller sized net was invariably tied to the shore while the large one usually rested in about five feet of water. It is noted that throughout the project very few rainbow trout were taken from the large net, although there are no precise data available on this topic. This observation may be explained as follows: (1) There are not very many large fish in these small ponds which could be trapped in the larger mesh. (Small fish could escape through this mesh.) (2) The fish tended to be more abundant in the shallow portions of the ponds. It is believed that both these factors acting together caused the discrepancy in the catch of the two nets. Perhaps a more adequate sample would have been obtained using a single net with variable mesh size throughout. Data on the results of gill netting during the entire study is contained in Table 8 (Page 17). It can be seen from this table that gill nets were employed at the beginning and at the end of the fishing season (June 1 to September 15). This was in compliance with a request from the executive of the Society in charge of the ponds. As a consequence, a complete sample was not obtained from Butler's Pond during July. During May, the gill nets, which were borrowed from another project, were available for only a short time and for this reason the trout of Butler's Pond were not sampled during that month either. Therefore a thorough appraisal of the summer food of rainbow trout and its correlation with the bottom fauna can be given for Murray's Pond only.

A total of 261 stomachs were examined from Murray's Pond and 26 were empty, while 87 with 16 empty were taken from Butler's. The following data were recorded for each fish: (1) fork length, (2) whole weight, (3) sex and maturity where possible, and (4) scale sample. The stomachs of the netted fish were removed on the day of capture and the contents preserved in a solution of 40 per cent alcohol and 4 per cent formalin. The angled fish were gutted at the pond immediately after capture and the entire stomach from the lower esophagus to the pyloric sphincter was preserved in 10 per cent formalin and placed in separate containers with appropriate labels. The contents of these were removed at a later date. Examination of the food was made with the aid of a dissecting microscope and was confined to the region described above. Identification was carried out to taxonomic levels similar to those used in the benthic study. Analysis of the food was undertaken by (1) the occurrence method, (2) the number method and (3) the weight method as described by Hynes (1950). The number method is based on a count of organisms present, with each food element evaluated as a per cent of the total number of all elements. In the occurrence method each food element is expressed as a percentage computed by dividing the number of stomachs containing the food, regardless of amount, by the total number of stomachs examined. Finally, the weight method is based on percentage dry weight. With respect to the last method, the weight of the food eaten was calculated from the known average weight of each food item as obtained from the results of the benthic study and in cases where the faunae differed, the actual weighings of large samples of the non-benthic food items. Such a modification of the weight method was carried out by Neill (1938) and Ricker (1937) among others. In using this method it must be assumed that feeding was not selective with respect to the size of the food items. The only comment on the number method which should be mentioned is that the numbers of certain small organisms of the zooplankton and dipteran pupae sometimes had to be estimated when large amounts were found in the stomachs. This estimation was carried out by placing the glass petri dish containing the organisms over a piece of paper on which was drawn a circle divided into quarters. After the organisms were spread out evenly over the bottom of the dish, one quarter of them were taken and counted. This method was used consistently throughout the analysis for such cases. A combination of the three methods described assess the relative importance of the food items.

The adult aquatic members of the Order Coleoptera were tentatively identified to genus using Leech and Chandler (1956) and Wallis (1933), while Moore (1963) identified the species of Daphnia present in the zooplankton at Murray's and Butler's ponds. Families of the Order Hymenoptera were determined using Jaques (1947). All other organisms were identified by referring to the following: Chu (1949), Needham and Needham (1962), Pennak (1953), and Ward and Whipple (1959).

2. Sources of Error

Although the weight of the food organisms has been reported here, this has been denounced by many (eg. Gerking 1962) on the grounds that it may give a false impression of accuracy for the following reasons (these reasons apply to all three methods of analysis in varying degrees):

(1) Hess and Rainwater (1939) have indicated a marked difference between the rate of digestion of the soft-bodied and that of the heavily chitinized forms such as dragonfly and mayfly nymphs. Some authors (eg. Ball, 1948) have not reported a single oligochaete from fish stomachs although they were very common in the lake.

(2) Gerking (1962) suggests that the head capsules of midges may tend to accumulate in the stomach, thereby exaggerating the contribution of midges and other similar organisms.

(3) The same author also says that sometimes ostracods may not serve as food although they are common in the stomachs. He explains as follows: "In some cases the bivalve carapace was not open and in several instances the animal tissue inside appeared to

be intact. Ostracods were found in the same condition in the lower intestine as in the stomach" (Gerking 1962:51).

(4) Neill (1938) says that the occurrence method of food analysis affords insufficient information on the relative status of different groups in the diet unless large numbers of fish are obtained for a particular period of time. This problem was encountered during June in Murray's Pond and during August and September in Butler's Pond; although in the latter pond it is felt that sufficient effort was made to obtain more fish, but to no avail. (Ref: Table 8, Page 17). Leonard and Leonard (1946), on the other hand, feel that volumetric or gravimetric data may be misleading, especially if unaccompanied by information on numbers and frequency of occurrence of organisms as well, and when based on small numbers of stomachs. In view of the comments of these and other writers, the present analysis is based on the three methods in an effort to give a reasonable indication of the relative importance of each type of food organism. It may be said that regardless of the method of analysis used, there are many uncontrollable variables inherent in food studies which detract from the precision of the results. One may safely conclude, however, that those food items that rank large in numbers, large in weight, and high in frequency of occurrence are important foods for the time and in the area sampled.

3. Qualitative Analysis of the Food

The major items of the rainbow trout food in both ponds changed with respect to season and abundance, and these variations will be discussed under separate topics. Under the present heading brief mention will be made of the general quality of the food eaten in both ponds.

Idyll (1941) has indicated that the rainbows of the Cowichan River system, British Columbia, are wholly carnivorous while other workers (Metzelaar 1928, Leonard and Leonard 1946, and Crossman and Larkin 1959) have reported findings of plants and plant remains in the stomachs, along with some debris. Although these items are not mentioned in the tables containing the quantitative results, pieces of vegetation were found in seven trout from Murray's Pond and inorganic debris was noted in six other fish, while two fish appeared to have eaten fish eggs. On the other hand only one fish with vegetation and two containing pieces of debris were recorded from Butler's Pond. It is possible that much, if not all, of the debris (gravel, sand, sticks, etc.) was derived from the houses of caddis worms which disintegrated in the stomachs, rather than resulting from inefficient feeding on the part of the rainbows. The plant material may have been taken incidentally during feeding activity. Two fish stomachs from Butler's Pond contained large amounts (170 and 37) of what appeared to be plant seeds probably of the Genus Potamogeton.

No fish or fish remains were taken from the stomachs of any of the fish examined and while this is not in accord with finding in other areas, it must be remembered that practically all the fish used in this study were less than 12 inches long. It has been noted, incidentally, that fish 12 inches in length usually serve as the arbitrary dividing line between large and small trout in studies where a feeding difference is being investigated with respect to size of the fish (Scott and Crossman, 1964:32). The food of the two fish more than 12 inches long is listed below. One 33.0 centimeters (13.2 inches) long contained seven amphipods, 11 fingernail clams, six small snails, one small beetle larvae and the bulk was made up of five large dragonfly larvae. The other, 47 centimeters (18.8 inches) long and weighing three pounds, contained 267 large planorbid snails.

It would appear from these observations that the larger trout in these ponds simply eat more of the larger food items Than?! which are eaten by smaller fish.

As a final point under the discussion of piscivorous rainbows in Murray's and Butler's ponds, mention is made of a certain large rainbow which was accidentally placed in the compartment holding yearling hatchery-reared rainbows during 1962. When it was discovered and removed, it regurgitated the semi-digested remains of a young rainbow.

Of the groups identified from the benthic fauna, Oligochaeta and Planorbidae were not found at all in the stomachs while nematodes and Coleoptera larvae were eaten only in Murray's Pond. On the other hand, many groups which were not found on the bottom of these ponds had been ingested and are as follows: (1) zooplankton, (2) adult aquatic beetles, (3) several orders of adult aerial insects, (4) some hymenopterans, (5) one Collombola and (6) one hemipteran. The last two are included in the "Miscellaneous" class in the tables. One other group which is benthic in nature, but which was not found in the benthic samples, has been removed from the stomachs; namely, ostracods (both ponds).

In the Order Amphipoda, the same two species which have been previously mentioned as belonging to the bottom fauna were identified; namely, _Hyalella azteca_ and the larger _Crangonyx richmondensis_. It is noted that Murray's Pond trout had eaten 69 of the latter species while the rainbows of Butler's had only two in their stomachs. Two of the adult aquatic members of the Order Coleoptera were tentatively identified as being of the genera _Haliplus_ and _Helichus_. The dominant member of the zooplankton eaten by the trout in both ponds was either _Daphnia catawba_ or _D. pulex_. Finally, there were two families of Hymenoptera found in the stomachs: (1) Formicidae and (2) Cephidae.

4. Seasonal Changes

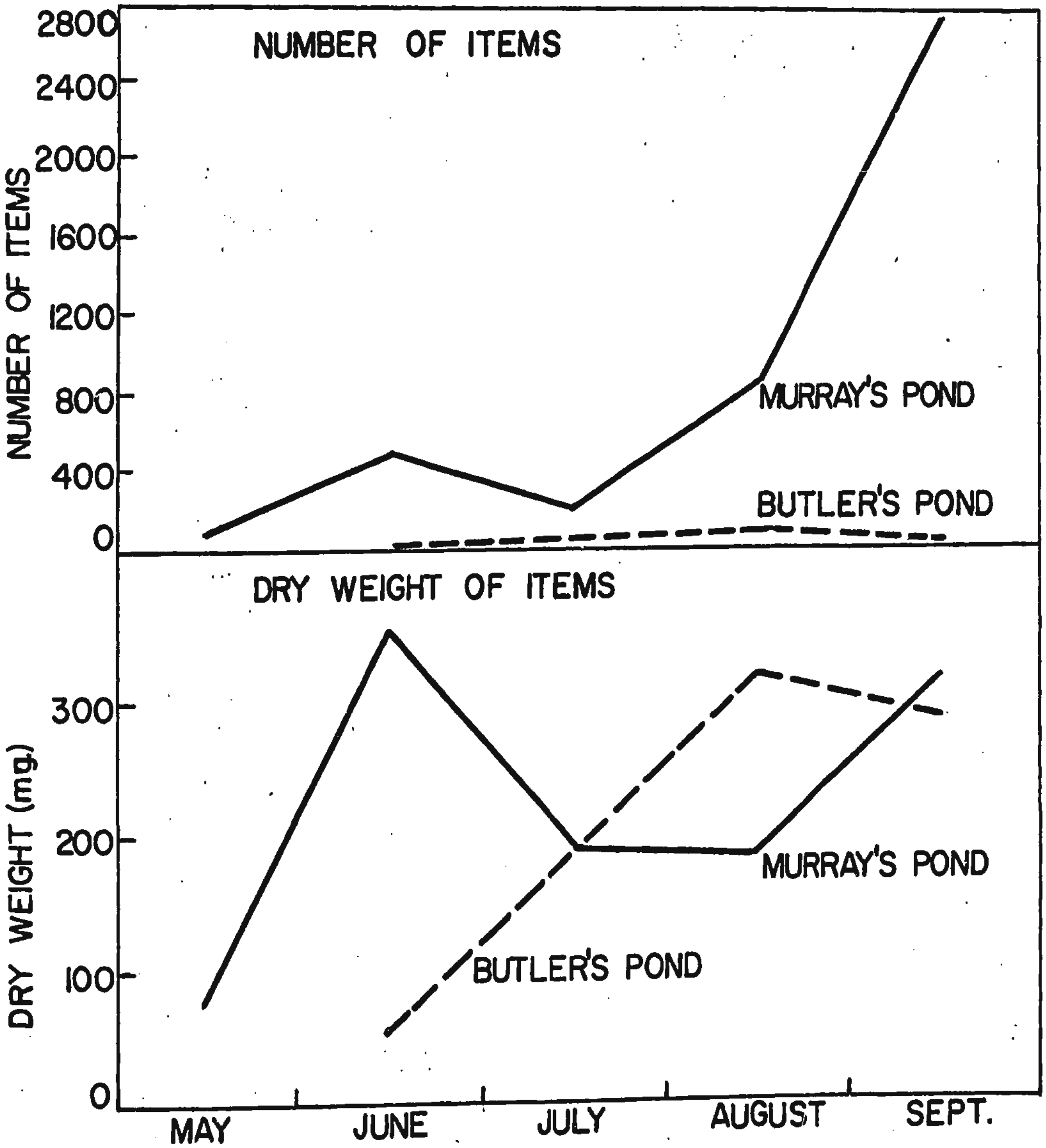
(i) Seasonal Changes in Average Amounts of Food Consumed

The Appendix, Tables E and F, contains the average dry weight of food consumed by individual fish in both ponds per month and the data is illustrated graphically in Figure 5. Peak consumption of food by the trout, in dry weight of organisms, was apparent at different times in each pond. It appeared during June in Murray's Pond but this peak is based on one small sample of ten fish and may not be too reliable. A second peak of a slightly smaller magnitude occurred in September. The data from Butler's Pond must also be regarded with caution since only three months are included. The summer peak appears during August in this pond. The summer peaks for both ponds occurred during late summer which is not unusual when compared with other studies (Lux and Smith 1960).

When examined numerically the highest peak in Murray's Pond occurs in September, while the month of June is lowered to a tertiary position (Figure 5). The curve for the Murray's Pond

FIGURE 5

SEASONAL VARIATION IN AVERAGE NUMBER AND DRY WEIGHT OF FOOD ITEMS EATEN BY RAINBOW TROUT AT MURRAY'S AND BUTLER'S POND, 1964



numerical data is more regular in appearance than the one plotted using dry weights, and it conforms to the results of the reference cited above. The curve produced for Butler's Pond this time is similar to the one described above for dry weight data.

(ii) Seasonal Changes in the Amounts of Different Food Items Eaten

The information necessary for the discussion in this section is contained in the Appendix, Tables E and F, in which the average number and dry weight of items per trout in Murray's and Butler's ponds are tabulated. Only those groups which have displayed some importance in the diets of the fish will be considered.

<u>Numerical data</u>

Amphipoda were high in June and September while only token amounts were eaten during the other three months in Murray's Pond. Butler's Pond trout took very few of these tiny crustaceans and highest amounts were observed during June which was slightly higher than the other two months studied.

Ephemeroptera nymphs were very abundant only during July in Murray's Pond while in the other smaller pond, June has the highest figure.

Anisoptera nymphs did not have any great numerical abundance in either pond except during September in Butler's, and their real value will be realized when dry weights are considered. The same thing applies for Trichoptera larvae which were noticeably abundant only during July in Murray's Pond.

Diptera larvae produced peaks in July and August in Murray's Pond while they were high during June in Butler's.

During August, in Murray's Pond only, the greatest amounts of Amnicolidae were eaten, while the large planorbid snails were high in both ponds during the same month.

Zooplankton was taken by rainbow trout in Murray's Pond only during July, August and September; there being higher amounts as the summer progressed. Butler's Pond trout ate them in high numbers only during August.

High numbers of Diptera pupae were taken during May and June in Murray's Pond, with a maximum forming in June. Smaller amounts were counted in the remaining three months. A negligible number of these emergent pupae appeared in Butler's Pond trout.

Adult Anisoptera were eaten in both ponds only during August and a similar occurrence was observed for adult Trichoptera, except that they were also taken during July in Murray's Pond. It will be remembered, however, that there are no data available on the food of rainbows for July in Butler's Pond.

Adult Diptera occurred during each month of study in Murray's Pond with a high recorded for July and a smaller though significant number in June. Only traces of them were found during June in Butler's Pond rainbow trout.

Gravimetric Data

The following lists of groups of organisms are presented as a brief description of the seasonal changes of foods as determined gravimetrically. The groups are listed in their order of magnitude, and the last group in each column for Murray's Pond occurs in the stomachs at an average of at least 5.0 milligrams per trout. The corresponding figure for Butler's Pond is 3.0 milligrams.

MURRAY'S POND

MAY	JUNE	JULY
Diptera pupae	Diptera pupae	Ephemeroptera nymphs
Anisoptera nymphs	Anisoptera nymphs	Trichoptera larvae
Hirudinea	Amphipoda	Zooplankton
Amphipoda	Ephemeroptera nymphs	Anisoptera nymphs
	Adult Coleoptera	Adult Diptera
	Trichoptera larvae	Trichoptera pupae

AUGUST	SEPTEMBER
Zooplankton	Zooplankton
Anisoptera nymphs	Anisoptera nymphs
Adult Anisoptera	Amphipoda
Planorbidae	Trichoptera larvae
Diptera larvae	
Diptera pupae	

BUTLER'S POND

JUNE	AUGUST	SEPTEMBER
Anisoptera nymphs	Adult Trichoptera	Anisoptera nymphs
Diptera larvae	Planorbidae	Planorbidae
Ephemeroptera nymphs	Anisoptera nymphs	Ostracoda
	Adult Anisoptera	Adult Coleoptera
	Zooplankton	
	Hymenoptera	

5. Benthic, Pelagic and Surface Feeding

The final two columns of Tables E and F in the Appendix tabulate the average amount and dry weight of food items eaten by rainbow trout in each pond throughout the summer months. In order to facilitate discussion under the present heading the groups of organisms have been divided into their ecological zones or niches in these two tables.

Murray's Pond (Appendix, Table E) A numerical appraisal of the results reveals that the trout in this pond are taking the vast majority of their food from the pelagic zone where zooplankton and Diptera pupae were the principal sources of food. Organisms from the benthic region were taken as a poor second, with amphipoda having the highest average. Gravimetrically, the overall results remained unchanged, although the gap between pelagic and benthic items was narrowed considerably. On the whole benthic organisms occur frequently in the stomachs but their numbers do not seem to be utilized effectively by the rainbow trout in Murray's Pond. These results are graphically illustrated in Figures 6 and 7.

Butler's Pond (Appendix, Table F) The totals for this pond indicate that greater amounts of benthic organisms were taken while pelagic animals were the second highest. Upon gravimetric consideration, however, the order of the groupings changed. The benthic items remained highest but the terrestrial group now appears in second place. It is believed that the gravimetric data provide a more acceptable result here since 1.5 adult Trichoptera would certainly have a greater benefit to the fish with respect to the

FIGURE 6
NUMERICAL PERCENTAGE COMPOSITION OF ORGANISMS IN THE BOTTOM FAUNA AND RAINBOW TROUT STOMACHS AT MURRAY'S POND, SUMMER, 1964

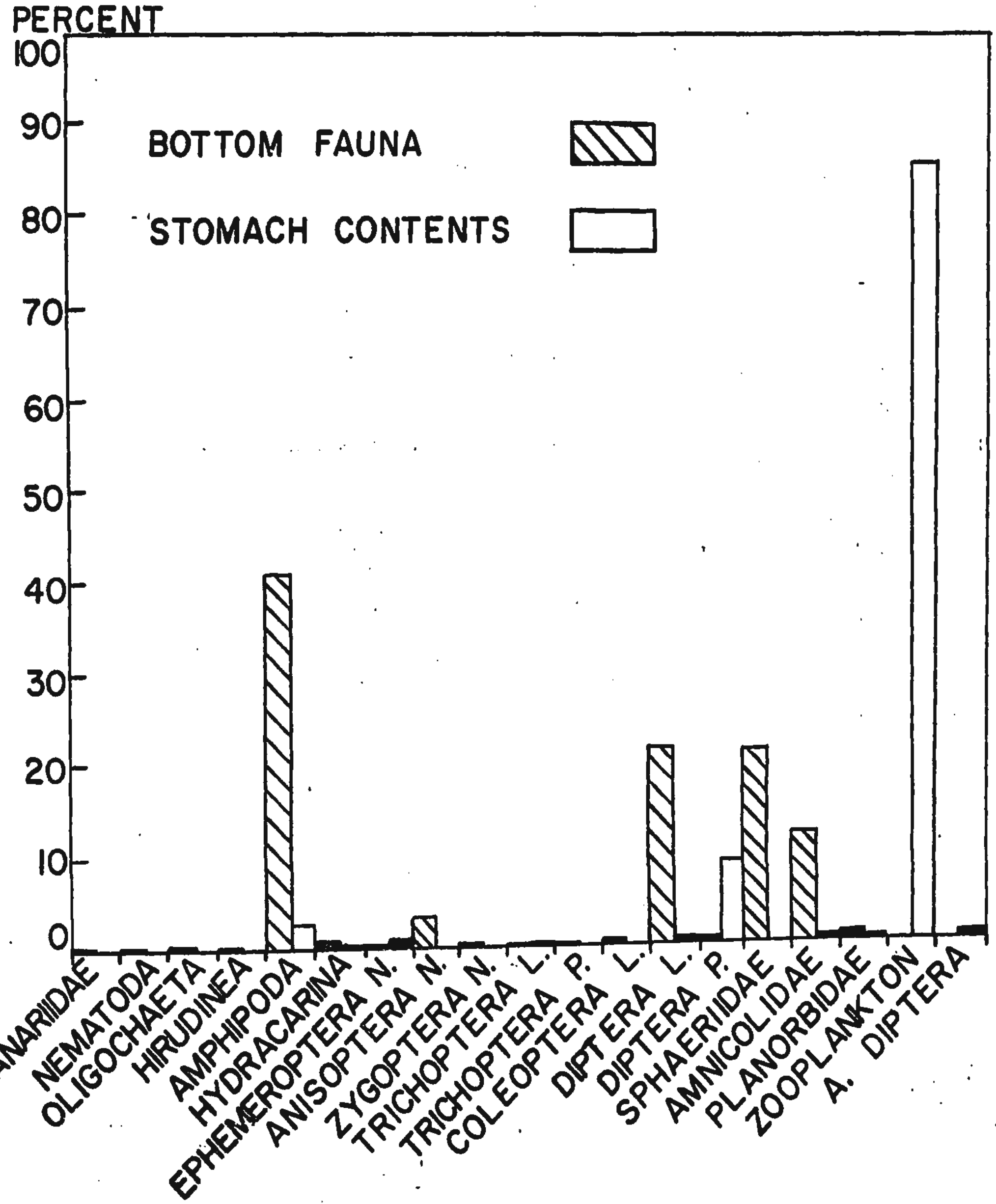
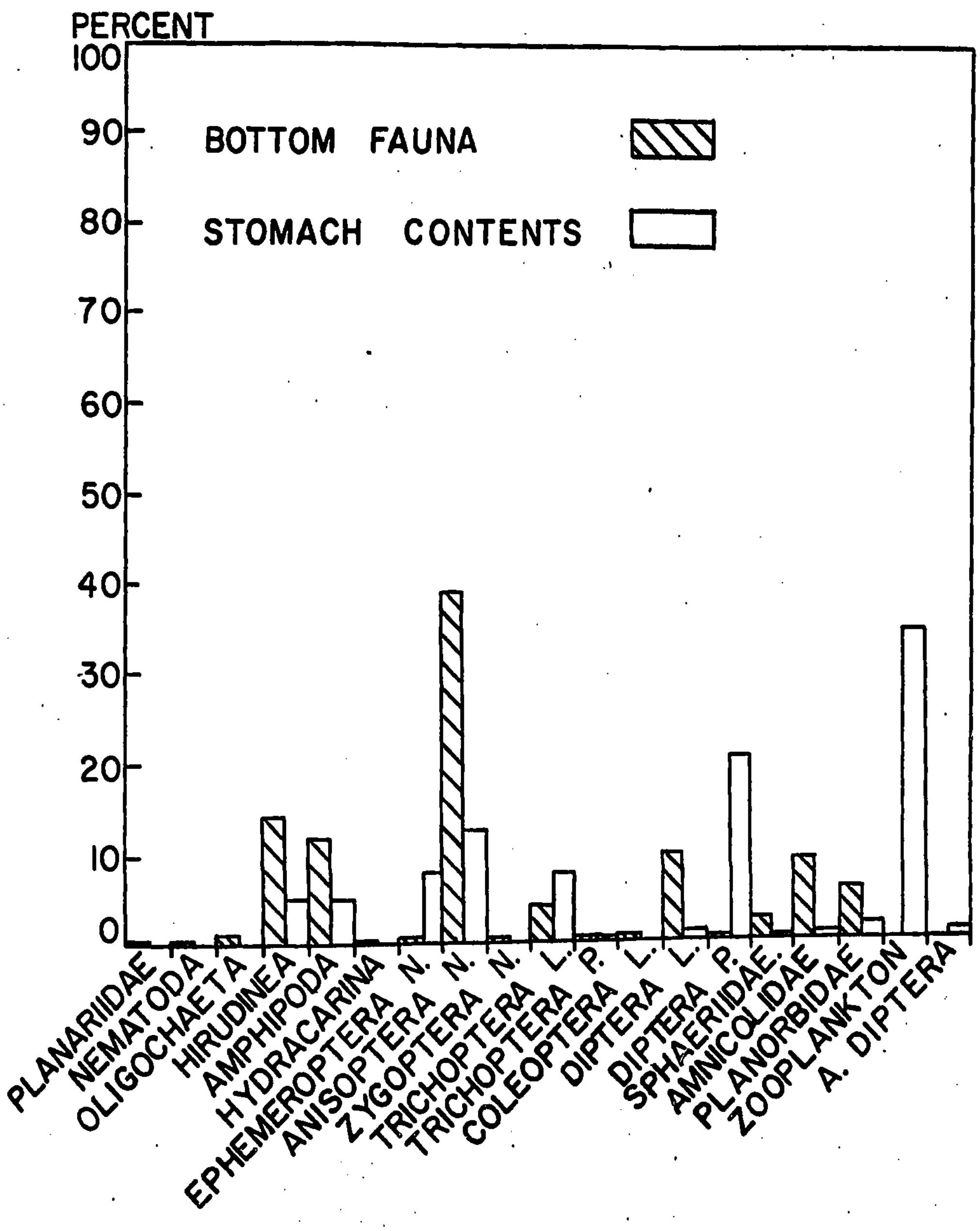


FIGURE 7

GRAVIMETRICAL PERCENTAGE COMPOSITION OF ORGANISMS IN THE BOTTOM FAUNA AND RAINBOW TROUT STOMACHS AT MURRAY'S POND, SUMMER, 1964



mass of food in its stomach than would 11.7 zooplankters. These results are graphically illustrated in Figures 8 and 9.

6. Quantitative Analysis of the Food

(i) Results from the three methods used - Relative percentages

(a) Occurrence method

Tables 20 and 21 give the results of stomach analysis by this method for both ponds by indicating the total numbers of stomachs in which an organism occurred throughout the summer months and their corresponding percentages. The following discussion is based on the percentage occurrence.

In Murray's Pond (Table 20) Diptera pupae (52.9 per cent) occurred more often than any other food item in the stomachs of rainbow trout. These organisms are classed as being pelagic since it is felt that they were taken while ascending to the surface during emergence throughout the summer. As bottom organisms these pupae are small and immobile and therefore would not be ready prey for a fish. Diptera larvae and Amphipoda occurred in the stomachs with similar frequencies while adult aerial Diptera, amnicolid snails, leeches, dragonfly nymphs and pelagic zooplankton appeared in decreasing frequencies. It is noted that, except where indicated, the food items were benthic in origin.

In Butler's Pond, (Table 21) the tiny clambering adult aquatic Coleoptera were found to have the largest percentage occurrence and these are classed as being pelagic in distribution. Next came Diptera larvae, as in Murray's Pond, and these were followed closely by the large dragonfly nymphs and mayfly nymphs.

FIGURE 8

NUMERICAL PERCENTAGE COMPOSITION OF ORGANISMS IN THE BOTTOM FAUNA AND RAINBOW TROUT STOMACHS AT BUTLER'S POND, SUMMER, 1964

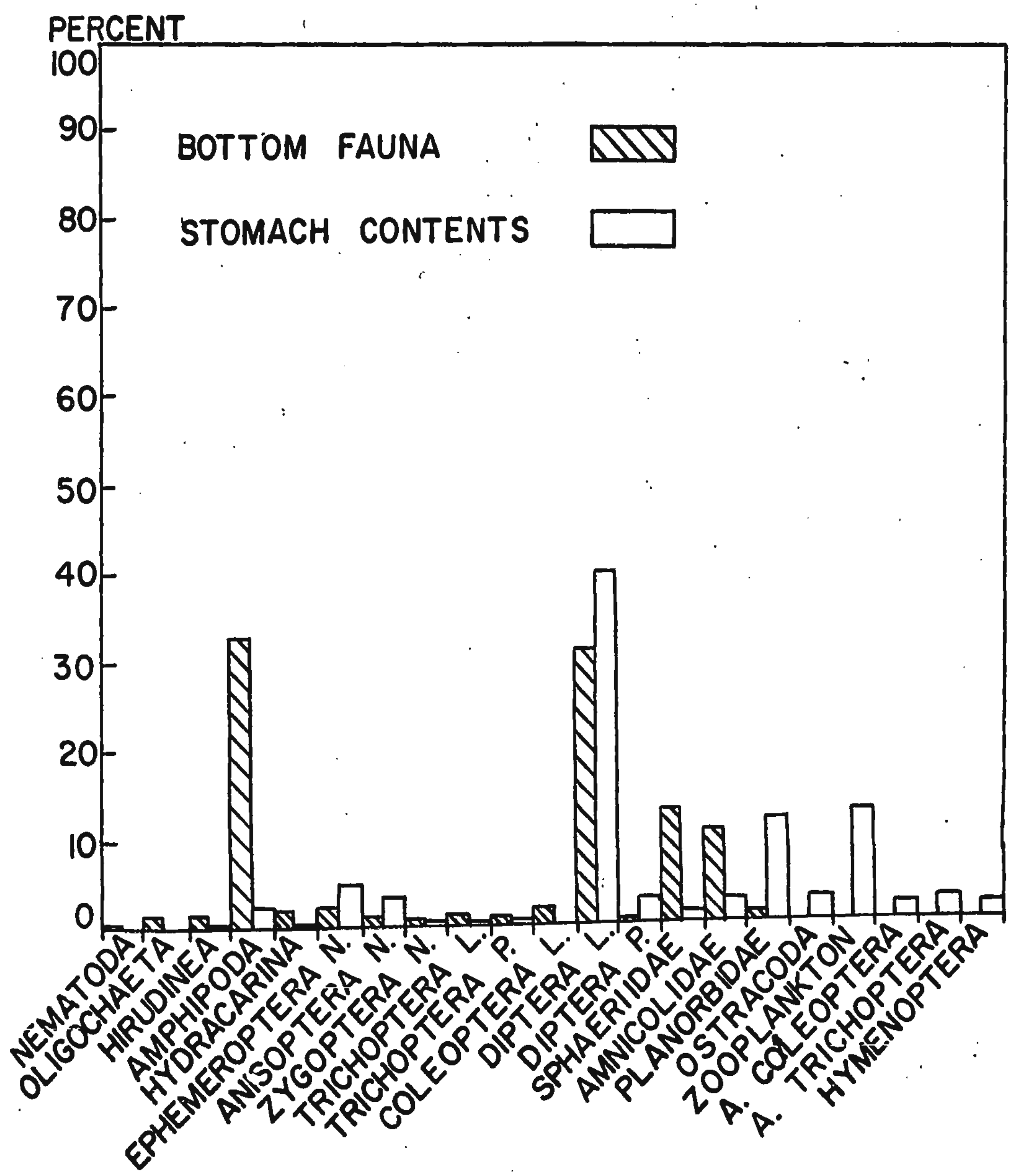


FIGURE 9

GRAVIMETRICAL PERCENTAGE COMPOSITION OF ORGANISMS IN THE BOTTOM FAUNA AND RAINBOW TROUT STOMACHS AT BUTLER'S POND, SUMMER, 1964

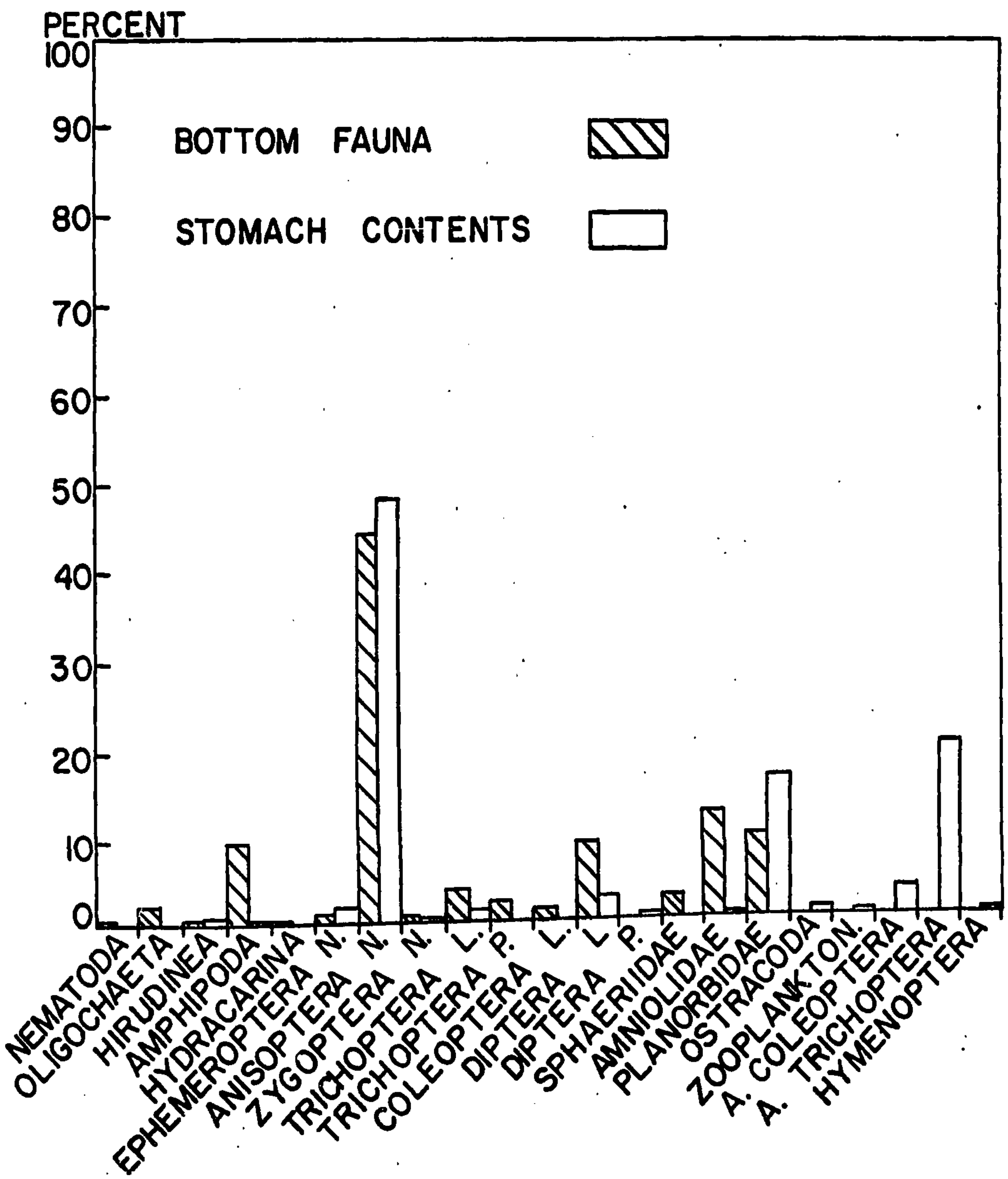


TABLE 20

THE FOOD OF RAINBOW TROUT EXPRESSED AS PERCENTAGES OF OCCURRENCE COMPOSITION AND DRY WEIGHT IN MURRAY'S POND THROUGHOUT FIVE SUMMER MONTHS COMBINED, 1964

	No. of Stomach.	% Occur.	No. of Indiv.	% Comp.	Dry Wt. Mgs.	Dry Wt. %
Benthic						
Nematoda	5	1.9	6	T	3.7	T
Hirudinea	43	16.5	54	T	1922.4	5.0
Ostracoda	11	4.2	64	T	109.9	0.3
Amphipoda	73	28.0	3817	2.5	1857.7	4.8
Hydracarina	14	5.4	190	0.2	19.0	0.1
Ephemeroptera nymphs	26	10.0	1445	0.9	3002.6	7.8
Anisoptera nymphs	42	16.1	67	T	4221.6	10.9
Trichoptera larvae	30	11.5	163	0.1	2787.3	7.2
Trichoptera pupae	26	10.0	130	0.1	210.2	0.5
Coleoptera larvae	7	2.7	13	T	14.4	T
Diptera larvae	85	32.6	980	0.6	402.8	1.0
Sphaeriidae	29	11.1	62	T	6.0	T
Amnicolidae	45	17.2	308	0.2	189.1	0.5
Planorbidae	11	4.2	120	0.1	697.0	1.8
Total		172.2	1421	4.7	15463.9	40.0
Pelagic						
Zooplankton	40	15.3	135451	85.5	13274.0	34.4
Adult Coleoptera	37	14.2	85	0.1	231.5	0.6
Diptera pupae	138	52.9	14283	9.0	7922.2	20.5
Total		82.4	149819	94.6	21427.7	55.5
Terrestrial						
Isopoda	9	3.4	39	T	698.1	1.8
Adult Anisoptera	2	0.8	5	T	528.0	1.4
Adult Zygoptera	1	0.4	1	T	16.8	T
Adult Trichoptera	2	0.8	2	T	64.6	0.2
Adult Diptera	53	20.3	1117	0.7	389.2	1.0
Hymenoptera	6	2.3	8	T	24.0	0.1
Miscellaneous	1	0.4	1	T	0.6	T
Total		28.4	1173	0.7	1721.3	4.5
Grand Totals		283.0	158413	100.0	38612.9	100.0

TABLE 21

THE FOOD OF RAINBOW TROUT EXPRESSED AS PERCENTAGES OF OCCURRENCE, COMPOSITION AND DRY WEIGHT IN BUTLER'S POND THROUGHOUT THREE SUMMER MONTHS COMBINED, 1964

	No. of Stomach	% Occur.	No. of Indiv.	% Comp.	Dry Wt. Mgs.	% Dry Wt.
Benthic						
Hirudinea	3	3.5	3	0.1	106.8	1.0
Ostracoda	4	4.7	77	3.0	130.9	1.2
Amphipoda	15	17.4	56	2.2	41.0	0.4
Hydracarina	2	0.8	3	0.1	0.3	T*
Ephemeroptera nymphs	20	23.3	110	4.3	220.0	2.0
Anisoptera nymphs	21	24.4	83	3.2	5229.0	48.2
Zygoptera nymphs	11	12.8	17	0.7	57.8	0.5
Trichoptera larvae	6	7.0	8	0.3	136.8	1.3
Trichoptera pupae	3	3.5	16	0.6	25.6	0.2
Diptera larvae	22	25.6	1022	40.0	289.3	2.7
Sphaeriidae	11	12.8	33	1.3	3.3	T
Amnicolidae	14	16.3	57	2.2	34.6	0.3
Planorbidae	11	12.8	307	12.0	1780.6	16.4
Total		164.9	1792	70.0	8056.0	74.2
Pelagic						
Zooplankton	4	4.7	524	20.4	60.1	0.5
Adult Coleoptera	29	33.7	49	1.9	320.0	3.0
Diptera pupae	6	7.0	85	3.3	47.6	0.4
Total		45.4	658	25.6	427.7	3.9
Terrestrial						
Adult Anisoptera	2	0.8	2	0.1	211.2	2.0
Adult Trichoptera	9	10.5	66	2.6	2131.8	19.7
Adult Diptera	2	0.8	2	0.1	0.8	T
Hymenoptera	10	11.6	42	1.6	22.4	0.2
Miscellaneous	1	1.2	1	T	3.0	T
Total		24.9	113	4.4	2369.2	21.9
Grand Totals		235.2	2563	100.0	10852.9	100.0

* Trace

Relatively low occurrences were found for Amphipoda and Amnicolidae.

The sums of the percentages (Tables 20 and 21) of trout feeding on each group of organisms are considered to constitute a measure of the number of trout which take a variety of foods. It is evident that in Butler's with a total of 235.2 the largest number of trout fed upon a variety of foods, while in Murray's Pond at 169.8 the opposite was the case. A corollary of this datum is that the feeding of an individual trout in Murray's Pond tended to be more intense on a less varied diet. It will be noted that the figure for Murray's Pond has been adjusted to a three month basis.

(b) Numerical Method (Tables 20 and 21, Pages 72 and 73)

In Murray's Pond (Table 20) the most abundant group of organisms found in the stomachs over the five month period were the small plankters (85.5 per cent), while a very low relative abundance was reached for Diptera pupae and Amphipoda. All other food items had a percentage composition of less than 1.0 per cent. It will be seen later during the discussion of seasonal changes in the stomach contents that the zooplankton appeared only during the last three months of the summer (July, August and September).

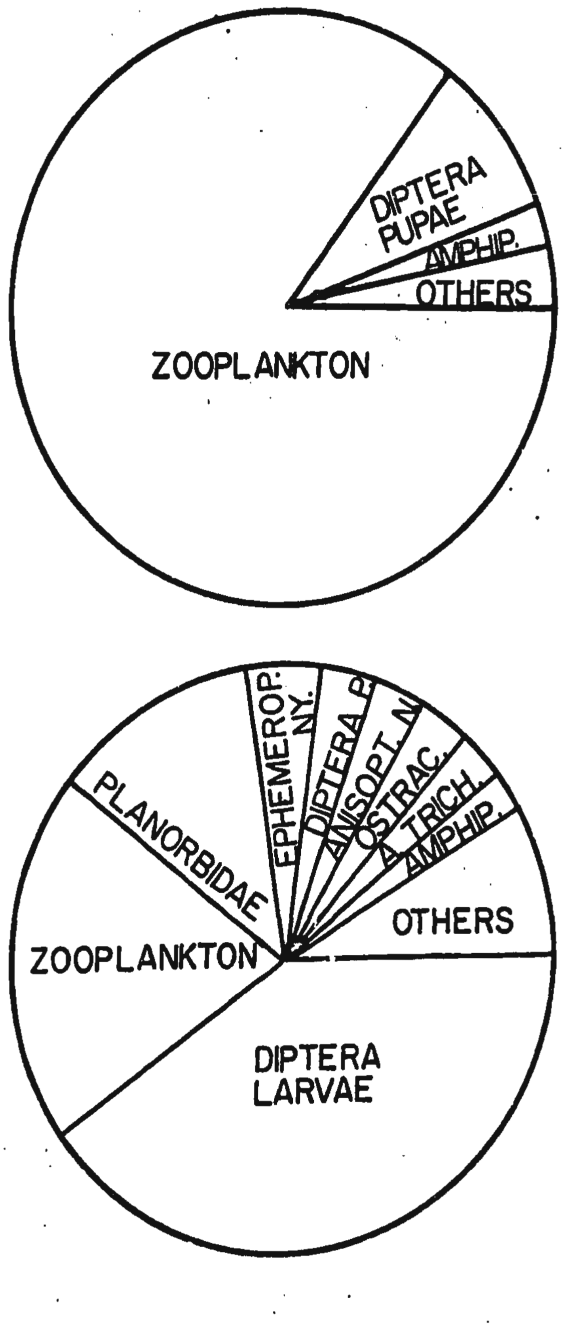
In Butler's Pond (Table 21) on the other hand, Diptera larvae appeared in greatest amounts in the stomachs while zooplankton and planorbid snails followed. It must be remembered throughout this discussion of the dominant organisms eaten that since the figures calculated in each method are percentages, the comparison between the ponds is therefore relative. An absolute comparison, employing the average numbers and weights of food eaten in these ponds, will be given later. The results for both ponds are illustrated

FIGURE 10

PIE DIAGRAMS OF THE NUMERICAL PERCENTAGE COMPOSITION OF THE FOOD ITEMS OF RAINBOW TROUT IN MURRAY'S AND BUTLER'S PONDS, SUMMER, 1964

MURRAY'S POND

BUTLER'S POND



graphically in Figure 10.

(c) Gravimetric Method (Tables 20 and 21, Pages 72 and 73)

In Murray's Pond (Table 20) the heaviest group of organisms recorded from dry weights was the zooplankton (34.4 per cent). This was followed by Diptera pupae and Anisoptera nymphs. All other groups fell below 10 per cent of the total calculated dry weight.

In Butler's Pond (Table 21) this method of analysis revealed a surprising change in the dominant food items in that Anisoptera nymphs, (48.2 per cent) were the heaviest group and adult aerial caddis flies (Trichoptera) were next. Planorbid snails followed the latter closely in this category. As will be seen later, adults of the Order Trichoptera were present in the stomachs of Butler's Pond rainbows only during one month (August), while the other two items mentioned appeared in all three months. This indicates that food abundance is an important aspect of the feeding behavior of these fish since general field observations revealed that there were more aerial adult caddis flies present around Butler's Pond during August.

(ii) Discussion and Conclusions

Murray's Pond - Two of the three methods of analysis indicate that zooplankton forms make up the most important part of the diet of these fish. The occurrence method was the only one that produced any doubt as to their dominance since they occurred in only 15.3 per cent of the total stomachs examined. This is not surprising when it is realized that a bloom of these animals does not appear until late summer in this pond when they become very abundant (Moore 1963). Diptera pupae followed as the next most important food item in that they occurred in the most stomachs and rated second for the other two methods. It is very difficult to choose a single item which ranks third without relying on the individual methods rather than a combination of them. It would appear that the following groups share this position: (1) Amphipoda, (2) Anisoptera nymphs, and (3) Diptera larvae. Of the three, amphipods had the greatest numbers, nymphal dragonflies produced the greatest dry weight while Diptera larvae occurred in the most stomachs. The Anisoptera nymphs are more important in regard to their weight, but these organisms are heavily chitinized and therefore the rate of digestion would be considerably slower than smaller organisms (Hess and Rainwater 1939). For this reason they remain in the stomachs for a longer period in a relatively undigested state. The dragonfly nymphs are probably of greatest value to the fish with respect to nutrition, since work by Geng (1925), as reproduced in Gerking (1962), shows that the damselfly, a close relative of the dragonfly, has 70.11 per cent protein per unit dry weight as compared with 58.04 per cent for Daphnia pulex.

Butler's Pond - Since the dominant food items were not clearly demonstrated in the stomachs here, it is necessary to arithmetically combine the percentages from the three methods of analysis in order to ascertain the most important items. This combination method, which serves as a simplified and useful index, was devised by Welsh (1949), in which each kind of food was evaluated by a percentage rating which was "an average of the per cent of the total bulk of the individual food used (indicating food value), the total numbers of individual food-animals used (indicating abundance), and the total number of stomachs in which the individual foods were found (indicating availability)". A modification of this method was employed for evaluating the dominant food items in Butler's Pond. This revealed that the large Anisoptera nymphs rated highest since they had the largest percentage dry weight (43.6) and a high occurrence in the stomachs (24.4 per cent). They were followed by the Diptera larvae, while adult Coleoptera and large planorbid snails were the next most important items.

Similar results were not produced by these three methods of food evaluation with respect to important items and therefore no one of them can alone be considered adequate. Obviously, a food occurring in a large number of trout stomachs does not necessarily correctly indicate its importance, since that organism may occur at a rate of only one per trout, or its volume may be too small to form any sizeable part of the total fish food. Thus the importance of the dipteran larvae was exaggerated by its occurrence in a large percentage of the trout population. Conversely, a food with a large percentage occurrence in trout stomachs may be present in great numbers in only a very limited number of fish, and though the volume of the food item under such conditions may be quite large, its importance as a food to the fish population as a whole is limited. An example of this situation occurred in Butler's Pond in August when one trout stomach contained 267 planorbid snails. Likewise a food item such as adult trichoptera though forming a large part of the gravimetric food total in Butler's Pond was numerically rare in its occurrence and was of importance to a relatively small number of fish. Therefore, a food item, to be important to a fish population in general, must be important in its rating by all three methods of evaluation.

(iii) Absolute results of food analysis

Tables E and F in the Appendix present the average number and dry weight of organisms found in rainbow trout stomachs, from Murray's and Butler's ponds. These data were compiled in order to give a set of absolute or concrete figures on which to base a short discussion on the food of rainbow trout in these ponds and it will also supplement the data which has already been presented on the relative importance of the food items as derived from percentage occurrence, numbers and dry weight.

Murray's Pond - (Appendix, Table E) It is again readily seen that the zooplankton with an average of 721.9 organisms weighing 70.7 milligrams in each stomach is by far the most important group in the summer diet of Murray's Pond rainbows (c.f. page 76). Dipteran pupae having comparative figures of 98.9 organisms and 56.1 milligrams also maintain the second position. There was an overall average of 876.6 animals weighing 224.7 milligrams in each trout stomach in this pond.

Butler's Pond - (Appendix, Table F) A large number of organisms were numerically and gravimetrically important in Butler's Pond. The most important were: Anisoptera nymphs, adult Trichoptera and Planorbidae. There was an overall average of only 35.0 organisms per stomach which is considerably lower than the figure for Murray's Pond. However, the large amounts of small zooplankters created a very great influence on the numerical food analysis for the latter pond. The average weight of food in the stomachs of Butler's Pond trout was 218.6 which is slightly less than the figure for Murray's Pond. The rainbow trout in Butler's Pond, then, are obtaining a high total weight of food per fish from a comparatively small amount of organisms. Having reviewed a portion of the work by Geng (1925), it is believed, although Geng did not specifically state it, that such large organisms are more nutritious than smaller ones because their protein content is higher.

VI. UTILIZATION OF THE BOTTOM FAUNA

The extent to which a group of organisms is eaten by a trout population has been termed the "utilization" of that group. Allen (1941) states that a method of measuring the relative extent to which an animal is eaten is given by the ratio between its percentage occurrence in the stomach contents, and its percentage occurrence in the benthos, at the same time and in the same place.

1. Sources of Error

The accuracy of this or any other method for determining utilization depends upon: (1) the accuracy of measurement of the numbers of organisms in the benthic groups; and (2) the accuracy of the determination of the numbers of organisms eaten by the fish.

(1) To determine benthic populations accurately, the uneven distribution of certain groups at different depths and on different bottom types must be considered. In addition, certain groups of benthic organisms are agile to varying degrees, and are thus able to escape capture by the dredge. By dividing each pond into two depth zones in which certain bottom types predominated, and by calculating benthic populations in each of these zones separately, it is hoped that sufficient consideration has been given to the uneven distribution of benthic organisms. No steps were taken to obtain more accurate counts of motile forms than were made possible by the dredge sampling. Since these organisms escaped the dredge to some extent, total population estimates must be regarded as minimal.

Counts of water bugs might be made possible by marking off a known area in shallow water and counting the organisms when they resume natural activity. This method would be much more difficult to apply to motile forms such as Coleoptera larvae and adults, which make vegetation their microhabitats.

(2) In determining the number of organisms eaten by the trout, the chief obstruction to accuracy is the difference between the rates of digestion of the various organisms in the trout stomachs. This selective digestion tends to make the more rapidly digested organisms appear among the stomach contents less frequently and to make persisting slowly digested forms appear more frequently. Only by determining the rates of digestion of the various organisms can this difficulty be completely overcome. Recognition of this source of error was important because considerable quantities of soft-bodied, rapidly digested organisms such as Diptera larvae and pupae, and many hard shelled, slowly digested organisms such as adult coleopterans and molluscs, are eaten by the trout. In addition, there is also a difference in the rate of digestion at various temperatures; food passing through the body more quickly at higher temperatures (Hess and Rainwater 1939).

It is recognized that, since the lengths of time required by the trout for the digestion of the different organisms, and since the numbers of various organisms eaten in a unit of time were not determined, it is not possible, from the data presented, to estimate the actual extent to which a population of trout will utilize a food supply over any period of time.

2. Method

Methods of determining availabilities of food organisms by utilization studies have been proposed by Allen (1941), Hess and Rainwater (1939), Hess and Swartz (1941), and Smith (1946). A discussion of the method employed in the present study follows:

The Allen Method - Allen (1941:50) stated that a measure of the relative extent to which an organism is eaten is given by the ratio of its percentage occurrence in the stomach contents to its percentage occurrence in the bottom. The resultant ratio or fraction is termed the "availability factor" for that organism. Thus, if organism "A" occurs in the benthos to the extent of 20 per cent of the total population, and forms 40 per cent of the stomach contents, the "availability factor" of the organism will be 2.0. An organism eaten by the fish in proportion commensurate with its abundance in the supply would have an availability factor of 1.0. Since these "availability factors" are established on a percentage basis, their values are relative to those of other organisms present.

Two difficulties were encountered in using Allen's method for determining the utilization of the various groups in the benthos.

(1) In those cases where organisms are eaten by the trout, but are not captured by the dredge the availability factors are infinity (designated by "+" in the tables); e.g., ostracods in Murray's Pond during July, August and September. If several such cases occur within one series of samples, each with infinite utilizations, arrangement of these highly utilized foods in order of their utilization is difficult. Thus, the purpose of the method

is defeated by inadequate sampling of these organisms. Since the dredge was designed to sample the population of organisms in a measured volume of bottom materials, it does not adequately sample certain of the motile benthic organisms. By taking further measures to sample these motile populations, the difficulty of arrangement of these highly utilized food items in their respective orders would be overcome.

(2) Since Allen's method involves relative values, it assigns on each sampling date the same total benthic population and the same total number of organisms in the trout stomachs; one hundred per cent. For this reason, comparison of the average utilization for all foods in different sampling series is impossible; nor does it permit comparisons of the total utilizations by trout in different populations.

Allen's method is used to compare the utilizations of the various organisms in the ponds, since, being based on percentages, it allows comparison of data from one pond with data from the other.

Utilization data, as determined by Allen's method are presented in Tables 22 and 23. Figures 6 and 8 compare the numerical percentages which each group of organisms constitutes, of the total populations sampled, and of the total numbers of food organisms consumed by the trout. Figures 7 and 9 compare these data gravimetrically. These histograms illustrate the extents of utilization of the various foods by the trout.

3. Intensity of Utilization

Murray's Pond - The Ostracoda were the most intensely and efficiently utilized organisms from the bottom fauna, since, although

TABLE 22

UTILIZATION (ALLEN'S METHOD)

"AVAILABILITY FACTORS" OF EACH FOOD ITEM
INDICATING THE RELATIVE EXTENTS OF UTILIZATION
OF THE VARIOUS ORGANISMS IN MURRAY'S POND, SUMMER, 1964

BENTHIC GROUP	MAY	JUNE	JULY	AUG.	SEPT.	AVERAGE
Nematoda	-*	-	0.5	0.2	-	0.1
Oligochaeta	0*	0	0	0	0	0
Hirudinea	0.5	0.2	0	0	0.04	0.2
Ostracoda	-	-	+*	+	+	
Amphipoda	0.6	0.7	0.1	0.006	0.03	0.3
Hydracarina	0.01	-	0.4	0.01	0.3	0.2
Ephemeroptera nymphs	0.7	2.3	38.0	+	+	8.2
Anisoptera nymphs	0.5	0.4	0.1	0.2	0.02	0.2
Zygoptera nymphs	-	-	+	-	0.004	0.001
Trichoptera larvae	0.3	0.3	3.4	0	0.1	0.8
Trhichoptera pupae	+	-	+	1.0	+	0.2
Coleoptera larvae	0.03	0	+	0	0.004	0.007
Diptera larvae	0.04	0.02	0.09	0.3	0.001	0.09
Sphaeriidae	0.005	0.003	0.01	0.0004	0.0008	0.004
Amnicolidae	0.1	0.006	0.03	0.07	0.002	0.04
Planorbidae	0.1	0	0.03	0.4	0.02	0.11

* Legend: -, organism present in neither stomachs or bottom fauna

0, organism present in bottom fauna only

+, represents infinity, ie. organism present in stomachs only.

TABLE 23

UTILIZATION (ALLEN'S METHOD)

"AVAILABILITY FACTORS" OF EACH FOOD ITEM
INDICATING THE RELATIVE EXTENTS OF UTILIZATION
OF THE VARIOUS ORGANISMS IN BUTLER'S POND, SUMMER, 1964

BENTHIC GROUP	JUNE	AUGUST	SEPT.	AVERAGE
Nematoda	-*	0*	-	0
Oligochaeta	0	0	0	0
Hirudinea	0.4	-	0	0.1
Ostracoda	+*	-	+	
Amphipoda	0.5	0.006	0.07	0.2
Hydracarina	0.1	0.3	0	0.1
Ephemeroptera nymphs	5.6	0.9	0	3.2
Anisoptera nymphs	5.7	0.7	63.3	23.2
Zygoptera nymphs	+	0	+	
Trichoptera larvae	2.0	-	1.6	1.2
Trichoptera pupae	0	+	-	
Coleoptera larvae	0	0	0	0
Diptera larvae	0.2	0.1	0.2	0.2
Diptera pupae				
Sphaeriidae	2.5	0	0.03	0.8
Amnicolidae	0.6	0.06	0.08	0.2
Planorbidae	0.2	1.4	7.4	3.0

* Legend: -, organism present in neither stomach or bottom fauna

0, organism present in bottom fauna only

+, represents infinity ie. organisms present in stomachs only.

they were not eaten in prodigious numbers by the trout, the dredge failed to capture them and this resulted in availability factors of infinity in July, August, and September. Trichoptera pupae, Ephemeroptera nymphs, Coleoptera larvae and Zygoptera nymphs followed behind the ostracoda since they had two factors of infinity during some months. Trichoptera larvae, Anisoptera nymphs, Hydracarina and Planorbidae were poorly utilized members of the bottom fauna, while those groups remaining may be classed as being very poorly utilized. It is recalled at this point that the bottom fauna of Murray's Pond has previously been shown (Page 66) to constitute a very small portion of the total diet of rainbow trout when it is compared with pelagic organisms.

Butler's Pond - Ostracods were again shown to be the most intensely utilized organisms in this pond and again this is explained as it was for Murray's Pond (ie., values of infinity for two months). Zygoptera nymphs followed very closely behind the ostracods and they were followed by Trichoptera pupae, Anisoptera nymphs, Ephemeroptera nymphs and Planorbidae. Trichoptera larvae and Sphaeriidae were poorly utilized while the remaining groups were very poorly utilized.

4. Seasonal Changes in Utilization Intensity

Seasonal variations in the extent of utilization of the various food organisms were also evident.

Murray's Pond - The relative utilization of the various food supplies in this pond appeared to be greatest during July and reasonably high again in September. During the peak month, such food items as Ostracoda, Zygoptera nymphs, Trichoptera pupae, Coleoptera larvae and Ephemeroptera nymphs were more extensively cropped than at other times. Extensive inroads on the supplies of all the items just mentioned, except Zygoptera nymphs and Coleoptera larvae, were also made during early September. Utilization of the available food supply was least extensive in the early summer months.

<u>Butler's Pond</u> - In Butler's Pond cropping by the trout appeared to be heaviest in September. At this time Ostracoda, Anisoptera nymphs, Zygoptera nymphs and Planorbidae were intensely utilized. The month of June appeared to have the next greatest inroad on the food supply when all the organisms just mentioned were again heavily utilized except Planorbidae, which was replaced by Ephemeroptera nymphs. The food supply was cropped least in August.

<u>General Conclusion</u> - Since peak utilization of the benthic food supply occurred at different times during the summer in these two ponds, it would seem that the vigor and intensity of feeding was not determined by the season, but rather by some factor or factors affecting each pond or each trout population at different times.

<u>5. General Utilization of Benthic Organisms</u>

<u>Intensely utilized organisms</u> - Ostracoda, Trichoptera pupae and Zygoptera nymphs were intensely cropped in both ponds throughout the summer months. Besides these, Anisoptera nymphs were cropped extensively in Butler's Pond, while Ephemeroptera nymphs were similarly utilized in Murray's Pond.

<u>Moderately utilized organisms</u> - Trichoptera larvae appear to have been moderately utilized in both ponds, but the figure is higher for Butler's Pond. Planorbidae snails fell into this category of

utilization in Butler's Pond only. The majority of benthic food items were at least moderately utilized in the latter pond.

<u>Poorly utilized organisms</u> - The Hirudinea, Amphipoda, Hydracarina, Diptera larvae and Amnicolidae, were poorly utilized in both bodies of water. The Nematoda, Sphaeriidae, Planorbidae and Coleoptera larvae were poorly cropped in Murray's Pond.

<u>Non-utilized organisms</u> - Oligochaetes were not utilized at all in either of the ponds and such an occurrence is not unusual (Ball 1948). In many other ponds, these organisms have been reported to form a large part of the total bottom fauna, but this is not the case in these small ponds and therefore, there was not a large supply of potential food which was not utilized. However, the Amphipoda almost present such a situation since they were poorly utilized in both ponds while their numbers formed the major proportions of the total benthic organisms in the ponds. The Nematoda and Coleoptera larvae of Butler's Pond fell into the category of non-utilized organisms also.

VII. AVAILABILITY OF ORGANISMS

Certain groups of organisms were more readily captured by, or were more readily available to, the trout than others. This may be due to any one or more of several factors. The organisms may be too large to be devoured by the trout, or certain characteristics of the organisms themselves may be such that the animals are able to escape capture. Thus, certain organisms may be camouflaged by color or by their cases, and may escape detection by predatory trout. Furthermore, the niche of individual organisms may not be readily accessible to the trout. Such habitats could conceivably occur in a deep zone, not frequented by the trout, or the organism might occur at a depth below the surface of the pond bottom, which is not usually explored by the trout in search of food.

In all sampling of the benthos, no organism was captured which could be considered too large for most of the trout to devour. Although limited association with the water depth was indicated among certain benthic organisms, it was apparent that this factor did not affect the availability of the organism to the trout. Reasonably large numbers of both shallow water organisms, such as the Amphipoda, and of the deep water forms, such as certain Diptera larvae, were taken apparently with more or less equal ease. It is evident, therefore, that the differences in availabilities are, in these ponds, mainly due to the various microhabitats of the organisms and to certain other characteristics of the animals themselves.

Thus, the Oligochaeta were never captured by the trout. Certainly these organisms are not agile enough to escape capture by the same trout which may catch many agile insects. Moreover, it seems doubtful that the trout ignore them through some aversion to their flavour, while they accept with such apparent relish their terrestrial cousins. It seems logical, therefore, that the reason for the failure of the trout to utilize oligochaetes is that they are not available to the trout. The fact that oligochaetes live well below the surface of a lumpy clay bottom type, where trout apparently do not forage for food, lends support to this deduction.

Similarly, the difference between the low utilization of Diptera larvae and the contrasting high utilization of Diptera pupae may be attributed to a difference between their availabilities to the trout. The larval stages, living on the bottom, are largely camouflaged, in some instances, by the cases in which they live and may be able to escape detection and possible capture by the trout. In their pupal stages these insects emerge by freely floating from the bottom to the surface, and are unprotected by cover or fleetness and are vunerable to capture by the trout.

Sphaeriids and amnicolids were found to have similar distributions in depth. Amnicolids may be more exposed to trout capture than sphaeriids, since they climb about on aquatic vegetation whereas sphaeriids remain on the bottom; both were unable to escape detection and capture by trout. It appears that these two organisms are nearly equal in their absolute availabilities to the trout, and that if a difference between their availabilities does exist, the amnicolids may be only slightly more available to the trout.

Ephemeroptera nymphs and adult aquatic beetles may also be considered equally available to the trout. Both organisms are typically found among aquatic vegetation and they are both able to move fairly quickly.

The availabilities of other benthic food organisms are more difficult to compare because of differences in the factors influencing their respective vulnerabilities to capture.

VIII. PREFERENCE

Certain organisms, though apparently equally available to the trout, did not appear in the trout stomachs in numbers commensurate with their occurrence in the benthos. This seems to indicate that trout select certain organisms in preference to others.

It should be recalled that Hess and Rainwater (1939:154) proposed a method for determining the food preferences shown by trout. The theory of this method is, in effect, that, if two equally available organisms are present in the benthos in one ratio, and appear in the trout stomachs in the same ratio then no preference between these organisms is shown by the trout. A difference between these two ratios is brought about when the trout select one organism in preference to another.

To use this method for determining whether a preference for certain organisms exists, the availabilities must be known. Since utilization values do not distinguish between availability and preference, they are inadequate as a basis to establish preferences. Thus it was necessary, before the method of Hess and Rainwater (1939) could be applied, to arbitrarily evaluate the availabilities of the benthic organisms on an ecological basis.

At the end of the last section on availabilities two pairs of organisms were selected which were considered to have equal availabilities, and an attempt is made here to determine preference between one of these pairs; namely the molluscs rather than mayfly nymphs and adult aquatic beetles. The reason for selecting only one pair is that the quantities of adult aquatic beetles in the environment are not known for these ponds.

Murray's Pond - In the benthos of this pond, these two organisms occurred in a ratio of 2:1 (two sphaeriids to one amnicolid). In the stomach contents, they were present in a ratio of 1:5 (one sphaeriid to five amnicolids). These ratios indicate that the trout in Murray's Pond selected amnicolid snails in preference to the more abundant spheriids.

This observation supports that reported above (Page 66) when it was stated that the trout in Murray's Pond were taking the majority of their food from the pelagic zone. Therefore, it appears that these trout prefer to eat off the bottom.

Butler's Pond - Sphaeriids and amnicolids were present in the benthos of Butler's Pond in a ratio of 1:1 and were also found in the stomachs in a ratio of 1:1. These data indicate that rainbow trout in Butler's Pond do not have any preference with respect to these two molluscs.

Data such as these give slight indication that different populations of trout may prefer different food items. Such a conclusion is a reminder that studies of this kind should be carried out to the species level, since each genus within a family and each species within a genus, occupying slightly different microhabitats, have different availabilities to the trout.

IX.. THE FOOD SUPPLY AS A POSSIBLE INFLUENCE ON THE ANGLER CATCH IN MURRAY'S POND

The fact that angler success at Murray's Pond is high in the early summer months and drops steadily during the season to a low in September has been a constant source of bewilderment to the fishermen there. This section is an attempt to bring to light one of the possible explanations of such a phenomenon which occurs not only in Murray's Pond but in many other sport fishing areas that have been reported in the literature. It has been suggested that such a decline in the amount of fish caught is associated with an increase in the available food which makes game fish less likely to be caught, since they are not hungry; and it is this postulation that is dealt with here. The information required to carry out such an investigation is given as follows: (a) Relationship between the angler success and available food. (b) Relationship between the angler success and the total food intake. (c) Relationship between the foods selected by fish to the availability of such food in the environment.

Estimates of the bottom fauna as available food have been given previously along with food selection by rainbow trout in Murray's Pond. In our discussion of the food of rainbow trout in this pond, it was clearly indicated that the bulk of the food was derived not from the benthic fauna, but from the pelagic organisms, especially the zooplankton. Unfortunately, this latter element of the total fauna was not studied during 1964 and therefore, in order to facilitate the present discussion, zooplankton data from 1960 and 1961 in Murray's Pond have been extracted from the work of Moore

(1963), and it is included in the Appendix (Table G) for ready reference.

Table 10 (Page 19), which was included in the section on trout populations, gives data on the number of fish caught per fisherman during each summer month. This information was taken from the catch records of the Newfoundland Game Fish Protection Society. The one obvious flaw of such a tabulation is that, since fishermen fish for a longer time in the early summer when the period of evening light is greater and the weather is warmer, as opposed to the late summer when conditions are less favourable, it is better to use "number of fish per rod-hour" rather than "number of fish per rod". However such information was not recorded by the members of the Society.

Regardless of this inadequacy, it is felt that the results contained in Table 10 are too definite to be disputed and a definite seasonal increase from June to September in angler catch is present. Similar trends are reported by Smith (1952) for Gibson Lake, New Brunswick; Fry (1939) for Lake Openogo, Ontario; and Lux and Smith (1960) for Linwood Lake, Minnesota.

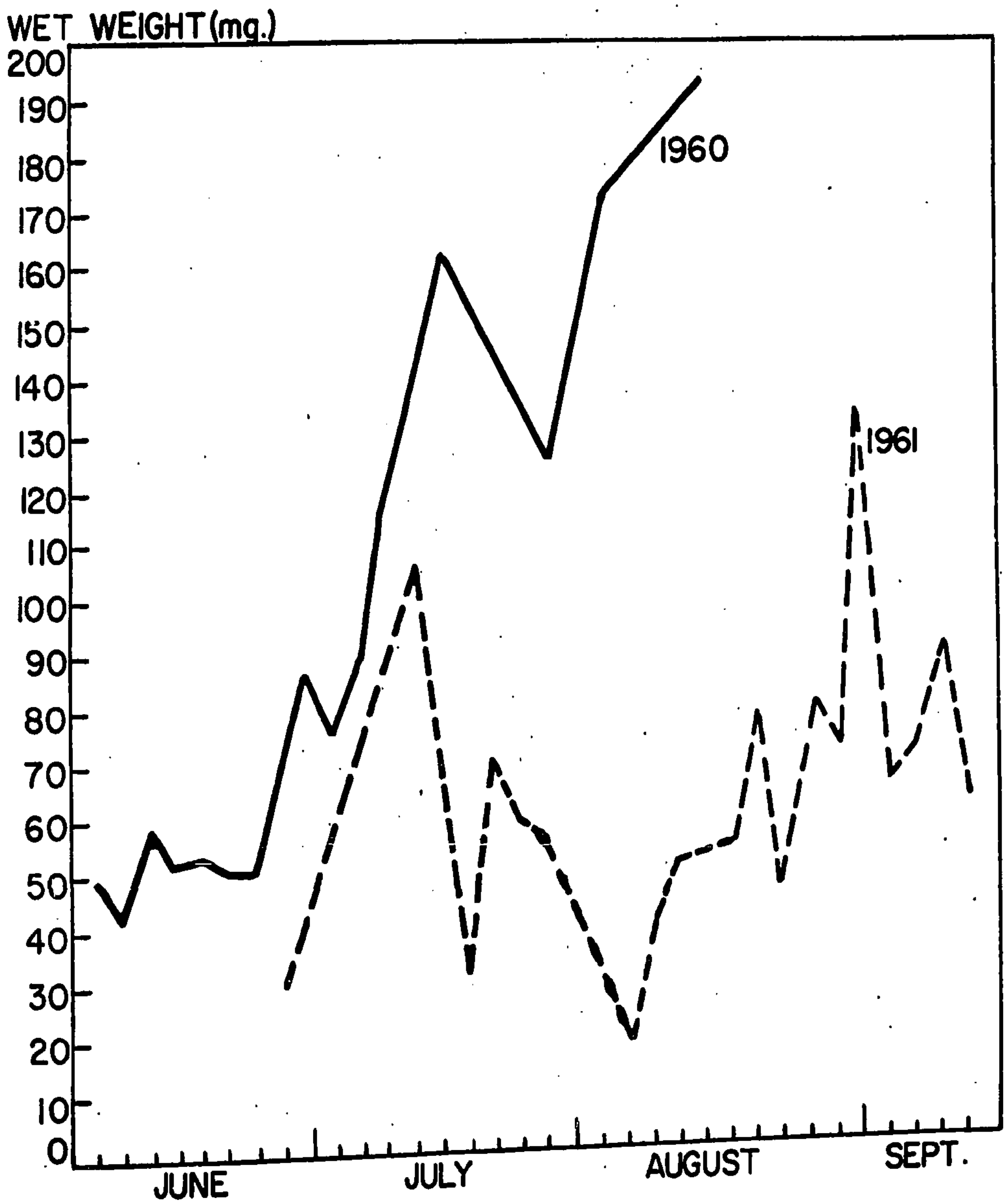
With respect to available food, bottom organisms and zooplankton are the only two groups which can be considered since the terrestrial and surface animals have not been sampled quantitatively at Murray's Pond. Table 17, Page 45 contains the number of bottom organisms per square foot on each sampling day throughout the summer months. Figure 4 (Page 47) graphically illustrates that there is an upward trend as the summer progresses in Murray's Pond which is caused by increased numbers of bottom organisms. As has been previously indicated, the total bottom fauna was at intermediate levels in May, June, July and early August after which it rose to summer heights in late August and September.

The results of zooplankton collections in 1960 and 1961 are contained in the Appendix, Table G and they are illustrated in Figure 11. Both years demonstrated a definite upward trend through the summer caused by an increase in the wet weight of the plankton; 1960 being more obvious than the next year 1961.

The food of rainbow trout has been presented in the Appendix, Table E, which gives the numerical data of this study, while Figure 5 (Page 62) graphically illustrates these results. These data show that rainbow trout consumed a greater quantity of food during the late summer months than in the months of late May, June, July and early August. Briefly stated, the overall trend of food consumption is up, with a sharp rise in September, when the least number of fish-per-rod were taken.

Angler success for rainbow trout in Murray's Pond was best when the number of organisms in the stomachs was at its lowest level; namely, early summer (June to early August). Generally as the food intake increased, the angler catch decreased until September, when the number of organisms in the stomachs rose to its summer high, the angler catch was at its correspondingly lowest level. These results are graphically presented in Figure 12. The situation reported here for Murray's Pond is very similar to that found by Lux and Smith (1960:79) in a Minnesota lake and the same authors state that "changing food supply is therefore believed to bear a reciprocal relationship to changes in rate of catch and to be the principal

FIGURE 11
SEASONAL VARIATION IN WET WEIGHT OF ZOOPLANKTON AT MURRAY'S POND, 1960 AND 1961

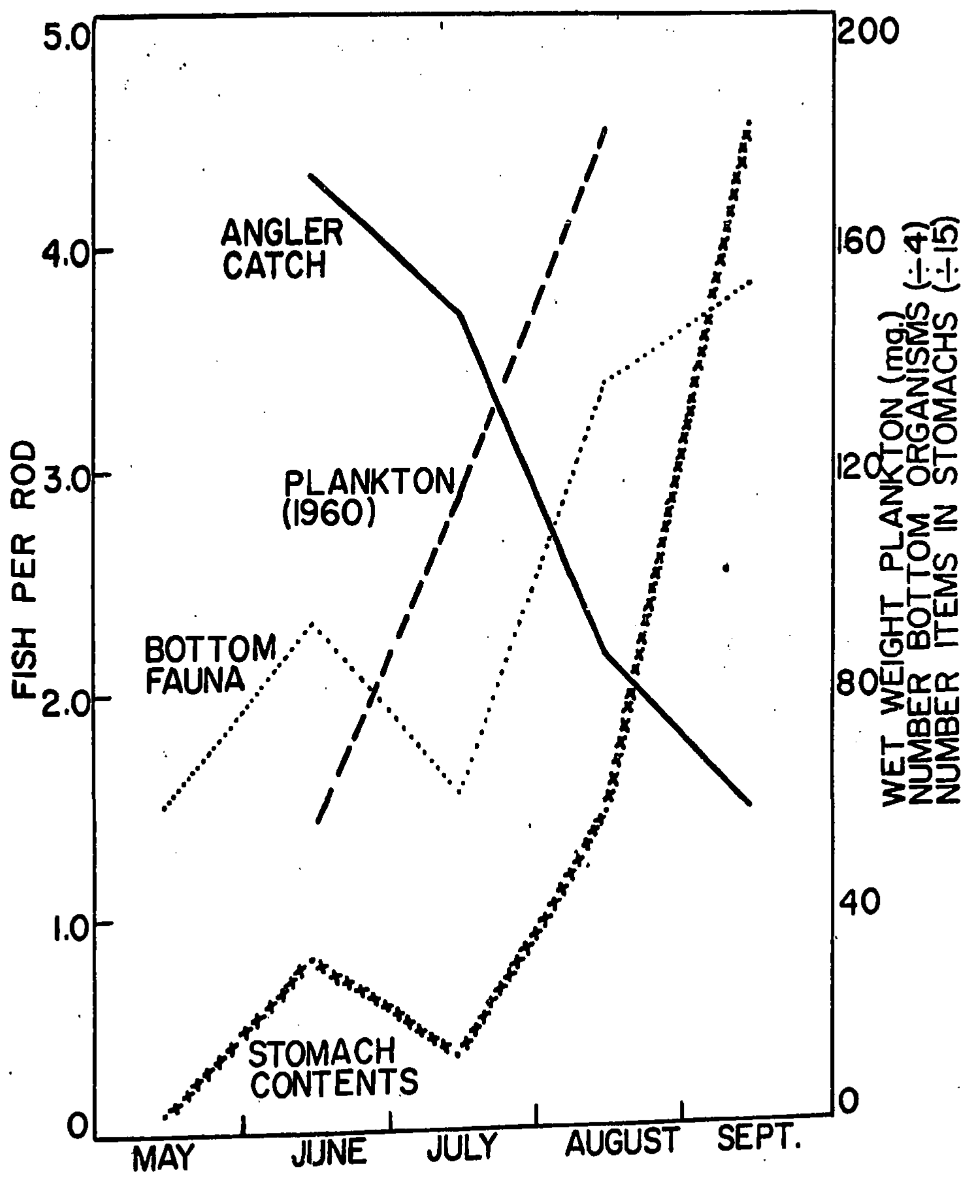


factor causing seasonal fluctuation in angler success".

The results of benthic and stomach analyses along with those of angler success in Butler's Pond, although not presented under the present heading, appear to be consistent with the relationship described above for Murray's Pond.

FIGURE 12

ANGLER SUCCESS, AVAILABLE FOOD AND FOOD INTAKE OF RAINBOW TROUT IN MURRAY'S POND, 1964 (PLANKTON SAMPLES TAKEN IN 1960)



X. SUMMARY AND CONCLUSIONS

Murray's and Butler's ponds are two small, eutrophic ponds lying in an area of sedimentary rocks and having mean depths of 5.6 and 4.7 feet with respective areas of 21 and 16 acres. The maximum temperatures (July 8, 1964) were recorded at 23.1°C in Murray's and 22.3°C in Butler's; the water is slightly acid in each pond and there is no dissolved oxygen deficiency. The yellow water lily is the dominant emergent aquatic plant and the bottom type covering most of the bottom in each pond is described as homogeneous organic loose muck.

An experiment involving artificial fertilization is in progress in Murray's Pond which has been treated with fertilizer in the summers of 1944-52 and again in 1962-64 while Butler's Pond has remained as the control pond. Another feature of limnological management obvious at these ponds is the presence of a rainbow trout hatchery and four holding compartments, all of which are employed to keep the ponds stocked with these game fish.

Rainbow, brown and brook trout are the only fish species present and the former are by far the most abundant. Murray's Pond has the largest population while the largest individual rainbow trout are found in Butler's Pond.

The bottom fauna was sampled eight times from May 22 to September 21, 1964. The areas which the benthic populations occupied and the standard deviations to be expected in samples from each area were employed to calculate the number of samples to be taken in the various depth zones of the ponds. The samples were collected with a small Ekman dredge and the analysis was carried out by direct counts and dry weights of the organisms. It is felt that a sufficient number of samples was taken to insure an accurate description and appraisal of the bottom fauna.

Numerically, the largest group of organisms in Murray's Pond were members of the Order Amphipoda while Anisoptera nymphs had the greatest dry weight. Butler's Pond is similar with respect to the dominant groups by both methods of analysis except that Diptera larvae exert almost as great an effect as the amphipods on the total numbers.

Both ponds have high standing crops of bottom organisms when they are compared with other areas of the temperate zone. Murray's Pond is quite high (46.0 kilograms per hectare) while Butler's Pond has about one-third as much (13.7 kilograms per hectare). The quantity of benthic organisms has increased in both ponds since the year fertilization was resumed (1962); the increase in Murray's being far greater than that recorded for the other pond. Part of the explanation for this significant rise is believed to be due to the addition of artificial fertilizer to Murray's Pond.

Seasonally there was a greater amount of bottom organisms found during late August through September in both ponds. Since the ratio between the highest and lowest level of abundance in both ponds is the same, the upward trend in amounts as the season progresses is believed to be real and not coincidental.

Rainbow trout were captured for stomach analysis by gill-nets and angling. Two hundred and sixty-one were examined from Murray's

Pond and 87 were taken from Butler's Pond. No fish were taken during May and July in Butler's Pond. The size difference within or between the samples was not great enough to permit a study of change in the diet with increasing size of the fish. The food was examined and appraised using three methods: (1) direct counts, (2) dry weights and (3) occurrence. The rainbows in Butler's Pond were found to be feeding on a variety of foods while those in Murray's fed more intensely on a less varied diet of zooplankton. Some plant material and debris was found in the stomachs from both ponds, but there were no fish remains present.

The most important food item in the rainbows of Murray's Pond was the pelagic zooplankton, followed by Diptera pupae. In Butler's Pond, benthic Anisoptera nymphs formed the most important part of the diet while Diptera larvae were next. Peak consumption of food by the trout was apparent at different months in each pond, but it appears that the summer peaks for both ponds occurred during late summer.

The benthos of Murray's was poorly utilized by rainbows and pelagic organisms formed the most important part of the diet. However, greater amounts of benthic organisms were taken by the trout in Butler's Pond.

The utilization of the various food organisms by the trout was determined using Allen's method, which is described. Ostracods were the most intensely utilized items from the bottom fauna in Murray's and Butler's pond and they were followed in Murray's by Trichoptera pupae and Ephemeroptera nymphs.. In Butler's Pond, Trichoptera pupae and Anisoptera nymphs were cropped most intensely apart from the ostracods. Peak seasonal utilization occurred in July and again in September in Murray's Pond, while in Butler's Pond the peak appeared to be in September. It would seem, then, that the intensity of feeding was not determined by season, but rather by some factor or factors affecting each pond or each trout population at different times. The dominant group in the bottom fauna of both ponds, the Amphipoda, were poorly utilized as a food supply; and the Oligochaeta were not utilized at all.

Trout apparently select certain food organisms in preference to others. It was shown that trout in Murray's Pond selected Amnicolidae in preference to Sphaeriidae, whereas no preference was demonstrated in Butler's Pond between the same two groups.

Finally, angler catch in Murray's Pond was shown to have a tendency to vary inversely with respect to the amount of food available in the environment and that present in the stomachs of the trout. Data are presented which indicate that during the late summer months fishing success was poor while the greatest quantities of food were available in the environment and there was a corresponding greater intake of food by rainbow trout.

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APPENDIX

TABLE A

THE BOTTOM FAUNA BY TOTAL NUMBERS, DRY WEIGHT (MILLIGRAMS) AND TAXONOMIC GROUP IN RELATION TO DISTRIBUTION AND DATE COLLECTED IN MURRAY'S POND, 1964

Note: Data are from 1 - 5 feet zone

BENTHIC GROUP		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21
Planariidae	No.	0	0	1	0	0	0	0	1
	Dry Wt.	-	-	0.7	-	-	-	-	0.4
Nematoda	No.	0	0	0	1	0	1	0	1
	Dry Wt.	-	-	-	1.3	-	0.7	-	0.6
Oligochaeta	No.	7	3	0	7	4	2	2	5
	Dry Wt.	24.1	6.6	-	15.8	9.0	3.4	2.0	5.4
Hirudinea	No.	2	1	1	2	7	3	1	2
	Dry Wt.	31.1	90.8	32.0	21.3	55.1	109.2	127.0	78.6
Amphipoda	No.	86	94	147	93	239	735	505	712
	Dry Wt.	34.8	55.9	96.6	50.0	69.7	176.9	86.9	156.7
Hydracarina	No.	9	12	3	8	8	6	2	10
	Dry Wt.	0.9	0.8	0.3	0.9	1.1	0.7	0.3	1.1
Ephemeroptera	No.	2	0	2	3	1	0	0	3
nymphs	Dry Wt.	5.7	-	0.3	2.1	0.3	-	-	0.4
Anisoptera	No.	2	1	6	3	5	3	5	7
nymphs	Dry Wt.	168.6	7.4	428.9	77.5	562.2	345.7	271.4	458.9
Zygoptera	No.	0	0	0	0	0	0	2	3
nymphs	Dry Wt.	-	-	-	-	-	-	12.7	19.8

TABLE A - Continued

BENTHIC GROUP		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21
Trichoptera larvae	No.	1	2	1	3	0	0	0	7
	Dry Wt.	36.3	87.3	30.3	112.1	-	-	-	17.6
Trichoptera pupae	No.	0	0	1	0	0	1	0	0
	Dry Wt.	-	-	32.3	-	-	21.9	-	-
Coleoptera larvae	No.	5	5	6	0	2	3	5	15
	Dry Wt.	8.2	12.8	8.6	-	2.4	1.0	0.9	3.9
Diptera larvae	No.	128	134	85	137	58	63	82	90
	Dry Wt.	90.5	63.2	33.5	33.5	21.7	15.5	25.3	24.2
Diptera pupae	No.	6	1	2	7	2	2	1	0
	Dry Wt.	2.3	0.1	0.7	2.0	6.2	0.4	0.1	-
Sphaeriidae	No.	61	214	60	89	81	121	176	119
	Dry Wt.	6.6	31.2	9.3	8.9	7.2	7.8	25.8	15.1
Amnicolidae	No.	39	98	114	55	32	105	84	112
	Dry Wt.	32.4	52.5	37.4	33.2	24.8	41.6	53.4	51.9
Planorbidae	No.	4	1	5	3	6	11	6	4
	Dry Wt.	99.5	0.9	56.8	37.9	36.8	30.4	20.5	6.2
TOTALS	No.	352	564	434	411	445	1,056	871	1,091
	Dry Wt.	537.0	409.5	767.7	396.5	796.5	755.2	626.3	840.8
No. of Samples		11	11	11	11	11	11	11	11
Area Sampled (Sq. Feet)		1.375	1.375	1.375	1.375	1.375	1.375	1.375	1.375

TABLE B

THE BOTTOM FAUNA BY TOTAL NUMBERS, DRY WEIGHT (MILLIGRAMS) AND TAXONOMIC GROUP IN RELATION TO DISTRIBUTION AND DATE COLLECTED IN MURRAY'S POND, 1964
NOTE: Data are from 5+ feet zone

BENTHIC GROUP		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21
Planariidae	No.	0	0	0	0	0	0	0	0
	Dry Wt.	-	-	-	-	-	-	-	-
Nematoda	No.	0	0	0	0	1	0	0	1
	Dry Wt.	-	-	-	-	0.4	-	-	0.2
Oligochaeta	No.	3	1	3	0	2	5	0	0
	Dry Wt.	1.9	2.3	7.7	-	4.8	5.9	-	-
Hirudinea	No.	2	0	0	1	0	0	1	2
	Dry Wt.	220.5	-	-	110.6	-	-	1.5	13.5
Amphipoda	No.	6	44	54	16	65	211	99	144
	Dry Wt.	1.0	39.2	32.3	7.5	17.1	29.6	11.8	33.1
Hydracarina	No.	4	2	0	0	2	0	1	2
	Dry Wt.	0.4	0.2	-	-	0.3	-	0.1	0.3
Ephemeroptera	No.	1	2	0	0	0	0	0	0
nymphs	Dry Wt.	0.4	6.2	-	-	-	-	-	-
Anisoptera	No.	0	3	0	1	1	7	1	1
nymphs	Dry Wt.	-	174.5	-	17.6	1.8	269.6	88.9	27.5
Zygoptera	No.	0	0	0	0	0	0	0	0
nymphs	Dry Wt.	-	-	-	-	-	-	-	-

TABLE B - Continued

BENTHIC GROUP		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21
Trichoptera	No.	1	0	0	0	0	0	2	1
larvae	Dry. Wt.	16.1	-	-	-	-	-	3.5	4.5
Trichoptera	No.	0	0	0	0	0	0	0	0
pupae	Dry Wt.	-	-	-	-	-	-	-	-
Coleoptera	No.	0	4	2	0	0	0	0	1
larvae	Dry Wt.	-	9.8	6.1	-	-	-	-	0.5
Diptera	No.	82	83	96	51	45	91	77	78
larvae	Dry Wt.	16.6	47.0	51.2	32.2	30.2	28.4	19.2	60.6
Diptera	No.	0	1	4	1	2	2	0	0
pupae	Dry Wt.	-	0.1	1.3	1.6	1.4	0.4	-	-
Sphaeriidae	No.	41	17	94	59	65	77	91	57
	Dry Wt.	3.3	3.1	12.2	7.3	3.4	4.4	8.3	5.8
Amnicolidae	No.	15	21	30	15	25	55	51	33
	Dry Wt.	16.6	31.8	24.2	20.5	23.5	35.7	25.8	38.9
Planorbidae	No.	1	2	4	0	2	7	6	3
	Dry Wt.	10.2	18.3	17.3	-	22.3	22.1	7.7	12.5
TOTALS	No.	156	180	287	144	210	455	329	323
	Dry Wt.	287.0	332.5	152.3	197.3	105.2	396.1	166.8	197.4
No. of Samples		5	5	5	5	5	5	5	5
Area Sampled (Sq. Feet)		0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625

TABLE C

THE BOTTOM FAUNA BY TOTAL NUMBERS, DRY WEIGHT (MILLIGRAMS) AND TAXONOMIC GROUP IN RELATION TO DISTRIBUTION AND DATE COLLECTED IN BUTLER'S POND, 1964
NOTE: Data are from 1 - 5 ft. zone

BENTHIC GROUP		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21
Nematoda	No.	0	0	0	0	0	1	0	0
	Dry Wt.	-	-	-	-	-	2.6	-	-
Oligochaeta	No.	4	8	5	1	5	4	6	3
	Dry Wt.	0.9	9.9	5.8	3.2	11.1	5.0	6.3	3.4
Hirudinea	No.	0	5	2	0	3	0	2	6
	Dry Wt.	-	4.6	0.8	-	2.1	-	4.7	2.5
Amphipoda	No.	36	46	37	38	75	130	114	269
	Dry Wt.	5.6	13.5	21.7	10.8	16.5	25.3	20.3	60.3
Hydracarina	No.	6	6	0	1	2	3	2	0
	Dry Wt.	0.6	1.0	-	0.3	0.2	0.3	0.2	-
Ephemeroptera	No.	4	10	11	12	2	2	2	17
nymphs	Dry Wt.	0.7	1.8	7.4	5.7	0.2	0.3	0.3	2.9
Anisoptera	No.	6	2	2	2	2	6	1	2
nymphs	Dry Wt.	326.7	104.5	121.9	46.3	119.0	179.2	44.7	14.2
Zygoptera	No.	1	0	0	0	2	3	0	0
nymphs	Dry Wt.	7.0	-	-	-	3.6	5.3	-	-
Trichoptera	No.	0	1	3	0	0	0	1	7
larvae	Dry Wt.	-	4.8	59.2	-	-	-	1.3	3.5
Trichoptera	No.	0	2	0	0	0	0	0	0
pupae	Dry Wt.	-	54.8	-	-	-	-	-	-

TABLE C - Continued

BENTHIC GROUP		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21
Coleoptera larvae	No.	0	1	3	1	0	4	6	7
	Dry Wt.	-	1.5	5.9	1.0	-	0.6	0.7	1.3
Diptera larvae	No.	34	68	74	103	51	53	34	37
	Dry Wt.	6.7	13.8	12.8	18.2	12.7	8.8	9.7	8.3
Diptera pupae	No.	1	0	2	0	1	0	1	0
	Dry Wt.	0.2	-	1.7	-	0.5	-	0.2	-
Sphaeriidae	No.	21	11	31	41	42	30	41	51
	Dry Wt.	2.5	3.0	6.0	7.6	5.6	3.7	3.5	3.9
Amnicolidae	No.	27	39	25	26	25	17	14	28
	Dry Wt.	22.2	30.0	25.3	16.1	23	14.8	1372.6	24.3
Planorbidae	No.	2	7	3	1	6	3	4	4
	Dry Wt.	10.4	55.6	6.4	3.9	33.4	15.7	23.2	13.5
Totals	No.	142	206	198	226	216	256	228	431
	Dry Wt.	383.5	298.9	274.9	113.1	227.9	261.6	128.8	138.1
No. of Samples		11	11	11	11	11	11	11	11
Area Sampled (Sq. Feet)		1.375	1.375	1.375	1.375	1.375	1.375	1.375	1.375

TABLE D

THE BOTTOM FAUNA BY TOTAL NUMBERS, DRY WEIGHT (MILLIGRAMS)
AND TAXONOMIC GROUP IN RELATION TO DISTRIBUTION AND DATE
COLLECTED IN BUTLER'S POND, 1964
Note: Data are from the 5+ feet zone

BENTHIC GROUPS		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21
Nematoda	No.	0	0	0	0	0	0	0	0
	Dry Wt.	-	-	-	-	-	-	-	-
Oligochaeta	No.	0	0	0	0	0	0	0	1
	Dry Wt.	-	-	-	-	-	-	-	1.2
Hirudinea	No.	0	0	0	1	1	0	0	1
	Dry Wt.	-	-	-	0.3	0.1	-	-	0.2
Amphipoda	No.	2	1	0	2	2	9	12	27
	Dry Wt.	0.3	0.2	-	0.7	0.2	2.0	1.9	4.8
Hydracarina	No.	1	0	0	1	0	0	4	1
	Dry Wt.	0.1	-	-	0.1	-	-	0.4	0.1
Ephemeroptera	No.	0	1	2	1	0	0	0	0
nymphs	Dry Wt.	-	0.1	0.9	1.8	-	-	-	-
Anisoptera	No.	0	0	0	0	0	0	0	0
nymphs	Dry Wt.	-	-	-	-	-	-	-	-
Zygoptera	No.	0	0	0	0	0	0	0	0
nymphs	Dry Wt.	-	-	-	-	-	-	-	-
Trichoptera	No.	0	0	0	0	0	0	1	0
larvae	Dry Wt.	-	-	-	-	-	-	1.9	-

TABLE D - Continued

BENTHIC GROUPS		May 22	June 9	June 30	July 8	Aug. 10	Aug. 24	Sept. 8	Sept. 21
Trichoptera pupae	No.	0	0	0	0	0	0	0	0
	Dry Wt.	-	-	-	-	-	-	-	-
Coleoptera larvae	No.	0	1	1	0	2	0	1	1
	Dry Wt.	-	0.8	2.9	-	1.1	-	0.1	0.2
Diptera larvae	No.	13	19	23	14	11	25	13	7
	Dry Wt.	1.9	4.8	2.7	2.1	5.4	6.1	2.4	1.4
Diptera pupae	No.	0	0	0	0	0	0	0	0
	Dry Wt.	-	-	-	-	-	-	-	-
Sphaeriidae	No.	0	2	6	8	4	4	5	1
	Dry Wt.	-	0.9	0.9	1.2	0.4	0.3	0.3	0.1
Amnicolidae	No.	2	5	7	3	2	3	2	7
	Dry Wt.	0.5	6.8	4.5	1.8	1.7	2.6	2.3	7.1
Planorbidae	No.	0	0	1	2	0	0	0	0
	Dry Wt.	-	-	7.4	5.2	-	-	-	-
Totals	No.	18	29	40	32	22	41	38	46
	Dry Wt.	2.8	13.6	19.3	13.2	8.9	11.0	9.3	15.1
No. of Samples		3	3	3	3	3	3	3	3
Area Sampled (Sq. Feet)		0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375

TABLE E

AVERAGE NUMBER AND DRY WEIGHT OF ORGANISMS PER TROUT STOMACH BY MONTH IN MURRAY'S POND, SUMMER 1964

FOOD ITEM	May (154)* No.	May Dry Wt.	June (10) No.	June Dry Wt.	July (34) No.	July Dry Wt.	Aug. (20) No.	Aug. Dry Wt.	Sept. (43) No.	Sept. Dry Wt.	Averages No.	Averages Dry Wt.
Benthic												
Nematoda	-	-	-	-	0.1	0.1	0.1	0.1	-	-	T *	T
Hirudinea	0.3	11.1	0.1	3.6	-	-	-	-	0.1	4.1	0.1	3.8
Ostracoda	-	-	-	-	1.7	2.9	0.3	0.4	T	T	0.4	0.7
Amphipoda	7.5	7.2	64.0	21.0	5.5	1.5	3.6	1.0	41.1	11.1	24.3	8.4
Hydracarina	T	T	-	-	1.3	0.1	T	T	3.3	0.3	0.9	0.1
Ephemeroptera nymphs	0.3	0.6	3.4	7.1	40.0	83.1	0.2	0.4	T	0.1	8.8	18.3
Anisoptera nymphs	0.2	11.9	1.0	63.0	0.1	9.3	0.5	31.5	0.3	19.1	0.4	26.9
Zygoptera nymphs	-	-	-	-	T	0.5	-	-	T	0.1	T	0.1
Trichoptera larvae	0.1	1.1	0.3	5.1	3.6	62.4	0.1	1.7	0.6	9.5	0.9	16.0
Trichoptera pupae	T	T	-	-	3.1	5.0	0.5	0.7	0.3	0.5	0.8	1.2
Coleoptera larvae	T	T	-	-	0.2	0.3	-	-	T	T	T	0.1
Diptera larvae	1.2	0.5	3.3	1.0	6.1	1.9	26.7	12.0	0.5	0.2	7.6	3.1
Sphaeriidae	0.1	T	0.5	0.1	0.6	0.1	T	T	0.5	T	0.3	T
Amnicolidae	0.9	0.5	0.3	0.2	0.9	0.6	5.8	3.6	0.5	0.3	1.7	1.0
Planorbidae	T	0.2	-	-	T	0.2	4.3	25.3	0.6	3.5	1.0	5.8
Total Averages	10.6	33.1	72.9	101.1	63.2	168.0	42.1	76.7	47.8	48.8	47.2	85.5

* Trace

TABLE E - Continued

FOOD ITEM	May (154)* No.	Dry Wt.	June (10) No.	Dry Wt.	July (34) No.	Dry Wt.	Aug. (20) No.	Dry Wt.	Sept. (43) No.	Dry Wt.	Averages No.	Dry Wt.
Pelagic												
Zooplankton	-	-	-	-	115.6	11.3	813.5	79.7	2680.3	262.7	721.9	70.7
Adult Coleoptera	0.3	1.4	1.4	7.0	0.5	2.4	0.4	1.8	0.1	0.6	0.5	2.6
Diptera pupae	62.8	34.4	414.5	236.3	8.1	4.6	8.7	5.0	0.3	0.2	98.9	56.1
Total Averages	63.1	35.8	415.9	243.3	124.2	18.3	822.6	86.5	2680.6	263.5	821.3	129.4
Terrestrial												
Isopoda	0.3	4.5	-	-	-	-	-	-	-	-	0.1	0.9
Adult Anisoptera	-	-	-	-	-	-	0.3	26.4	-	-	0.1	5.3
Adult Zygoptera	-	-	-	-	-	-	T	0.8	-	-	T	0.2
Adult Trichoptera	-	-	-	-	T	0.9	T	1.6	-	-	T	0.5
Adult Diptera	0.1	T**	10.2	3.5	23.1	8.1	2.1	0.7	3.9	1.4	7.9	2.7
Hymenoptera	T	0.1	-	-	-	-	0.2	0.6	-	-	T	0.1
Miscellaneous	-	-	-	-	-	-	-	-	T	T	T	T
Total Averages	0.4	4.6	10.2	3.5	23.1	9.0	2.6	30.1	3.9	1.4	8.1	9.7
Grand Total Averages	74.1	73.5	499.0	347.9	210.5	195.3	867.3	193.3	2732.3	313.7	876.6	224.7

* Numbers in brackets refer to stomachs analysed.

** Trace

TABLE F

AVERAGE NUMBER AND DRY WEIGHT OF ORGANISMS PER TROUT STOMACH BY MONTH IN BUTLER'S POND, SUMMER 1964

FOOD ITEM	June (59) * No.	Dry Wt. mg.	Aug. (15) No.	Dry Wt. mg.	Sept. (12) No.	Dry Wt. mg.	Averages No.	Dry Wt. mg.
<u>Benthic</u>								
Hirudinea	T**	1.8	-	-	-	-	T	0.6
Ostracoda	0.2	0.3	-	-	5.7	9.6	2.0	3.3
Amphipoda	0.8	0.7	0.1	T	0.5	0.1	0.5	0.3
Hydracarina	T	T	0.1	T	-	-	T	T
Ephemeroptera nymphs	1.8	3.6	0.2	0.5	-	-	0.7	1.4
Anisoptera nymphs	0.4	26.7	0.7	42.0	4.0	252.0	1.7	106.9
Zygoptera nymphs	0.2	0.5	-	-	0.7	2.3	0.3	0.9
Trichoptera larvae	0.1	1.7	-	-	0.2	2.9	0.1	1.5
Trichoptera pupae	-	-	1.1	1.7	-	-	0.4	0.6
Diptera larvae	16.8	4.7	1.3	0.6	0.7	0.2	6.2	1.8
Sphaeriidae	0.5	0.1	-	-	0.1	T	0.2	T
Amnicolidae	0.9	0.5	0.2	0.1	0.1	T	0.4	0.2
Planorbidae	0.2	0.9	18.5	107.1	1.8	10.1	6.8	39.4
Total Averages	21.9	41.5	22.2	152.0	13.8	277.2	19.3	156.9
<u>Pelagic</u>								
Zooplankton	-	-	34.3	3.4	0.8	0.8	11.7	1.4
Adult Coleoptera	0.3	1.4	2.0	10.0	1.4	7.1	1.2	6.2
Diptera pupae	1.2	0.7	0.8	0.4	-	-	0.7	0.4
Total Averages	1.5	2.1	37.1	13.8	2.2	7.9	13.6	8.0

**Trace

TABLE F - Continued

FOOD ITEM	June (59) * No.	Dry Wt. mg.	Aug. (15) No.	Dry Wt. mg.	Sept. (12) No.	Dry Wt. mg.	Averages No.	Dry Wt. mg.
Terrestrial								
Adult Anisoptera	-	-	0.1	14.1	-	-	T**	4.7
Adult Zygoptera	-	-	-	-	-	-	-	-
Adult Trichoptera	-	-	4.4	142.1	-	-	1.5	47.4
Adult Diptera	T	T	-	-	-	-	T	T
Hymenoptera	0.4	1.2	1.2	3.4	-	-	0.6	1.5
Miscellaneous	-	-	0.1	0.2	-	-	T	0.1
Total Averages	0.4	1.2	5.8	159.8	-	-	2.1	53.7
Grand Total Averages	23.8	45.8	65.1	325.6	16.0	285.1	35.0	218.6

* Numbers in brackets refer to number of stomachs analysed.

** Trace

TABLE G

TOTAL ZOOPLANKTON WEIGHT FROM CONSISTENT PLANKTON TOWS IN MURRAY'S POND, 1960 AND 1961

(DATA TAKEN FROM MOORE (1963))

DATE (1960)	TOTAL WET WT. (mg.)	DATE (1961)	TOTAL WET WT. (mg.)
June 2	48	June 29	73.0
8	41		
10	58	July 13	105.7
15	52	17	28.4
17	53	20	69.8
22	50	24	57.0
24	50	27	46.7
30	87	31	41.0
July 4	75	Aug. 4	18.8
6	90	7	40.3
8	118	10	51.0
15	162	14	54.9
27	126	17	79.0
		21	46.7
Aug. 1	172	24	80.5
12	192	28	71.1
		31	132.8
		Sept. 5	63.0
		7	71.7
		11	91.7
		14	62.3