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A LIFE HISTORY STUDY OF THE AQUATIC SOWBUG, ASELLUS INTERMEDIUS FORBES, IN HOUGHTON CREEK, OGEMAW COUNTY, MICHIGAN[1]

By Robert J. Ellis

Although the North American fresh-water isopods of the family Asellidae are widely distributed, their life histories are little known. Most of the published work on this group has been on taxonomy, morphology, or physiological responses. In *Asellus* the information which has been reported usually cannot be ascribed to a species because authors have confused three of the common species (Van Name, 1942 and Pennak, 1953).

Studies of the bottom fauna of Houghton Creek, Ogemaw County, Michigan, from 1950 to 1952 revealed a large and somewhat localized population of *Asellus intermedius*. Subsequent investigations of the relationships between the bottom fauna and the growth patterns of brown trout in Houghton Creek (Ellis and Gowing, 1957) indicated that *Asellus* was especially important in the diet of trout because of its abundance during the summer months. Intensive study of the life history of *A. intermedius* began in 1953 and continued through May, 1956. The study methods included sampling of the animals in Houghton Creek and rearing of specimens in the laboratory.

The objectives of this investigation were to study: (1) reproduction and growth of *Asellus* in the stream and in the laboratory; (2) seasonal changes

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[1] A contribution from the Institute for Fisheries Research, Michigan Department of Conservation. On February 21, 1958, the author joined the staff of the Oregon Fish Commission.

in length frequency distribution in the stream; and (3) the distribution and seasonal abundance in the stream.

Allee studied aggregations (1927) and rheotactic responses (1912, 1914) of *Asellus communis*. Hatchett (1947) correlated size of brood with size of female, for a single collection of *A. communis* from a northern Michigan lake. Markus (1930) studied the life history of *Mancasellus macrourus* from a stream in Illinois. He determined the number of instars, rate of growth, and seasonal changes in reproduction and in size distribution of the species. Wesenberg-Lund (1939) summarized the biology of the common European aquatic sowbug, *A. aquaticus*. Berg (1948) reported on seasonal abundance and distribution, and size of brood of *A. aquaticus* in a Danish river system.

Acknowledgments

This work was done while the author was employed on a research fellowship with the Institute for Fisheries Research, Michigan Department of Conservation. The investigation was suggested by Drs. J. S. Rogers and J. W. Leonard. Most of the work was done under the supervision and guidance of Dr. F. F. Hooper. Dr. D. W. Hayne gave valuable guidance in the statistical tests employed. My wife, Rosemary, ably assisted in field work and made most of the length measurements and sex determinations. Identification of *Asellus intermedius* Forbes and *A. militaris* Hay was confirmed by Dr. J. G. Mackin of Texas A. and M. Research Foundation.

Study area

Houghton Creek is a trout stream with a yearly temperature range of 0° C. to 20° C. (32° F. to 68° F.), a pH of about 8.4, and a methyl orange alkalinity of about 175 ppm. In the main study area (Fig. 1) the base flow of the stream is about 16 c.f.s.[2] Further details concerning general aspects of the stream are given by Ellis and Gowing (1957).

[2] From discharge data for October 20, 1951 and October 25, 1952 supplied by the Grayling, Michigan office of the U. S. Dept. of the Inter. Geol. Surv.

Figure 1.--Map of Houghton Creek showing sampling sites and reference points.

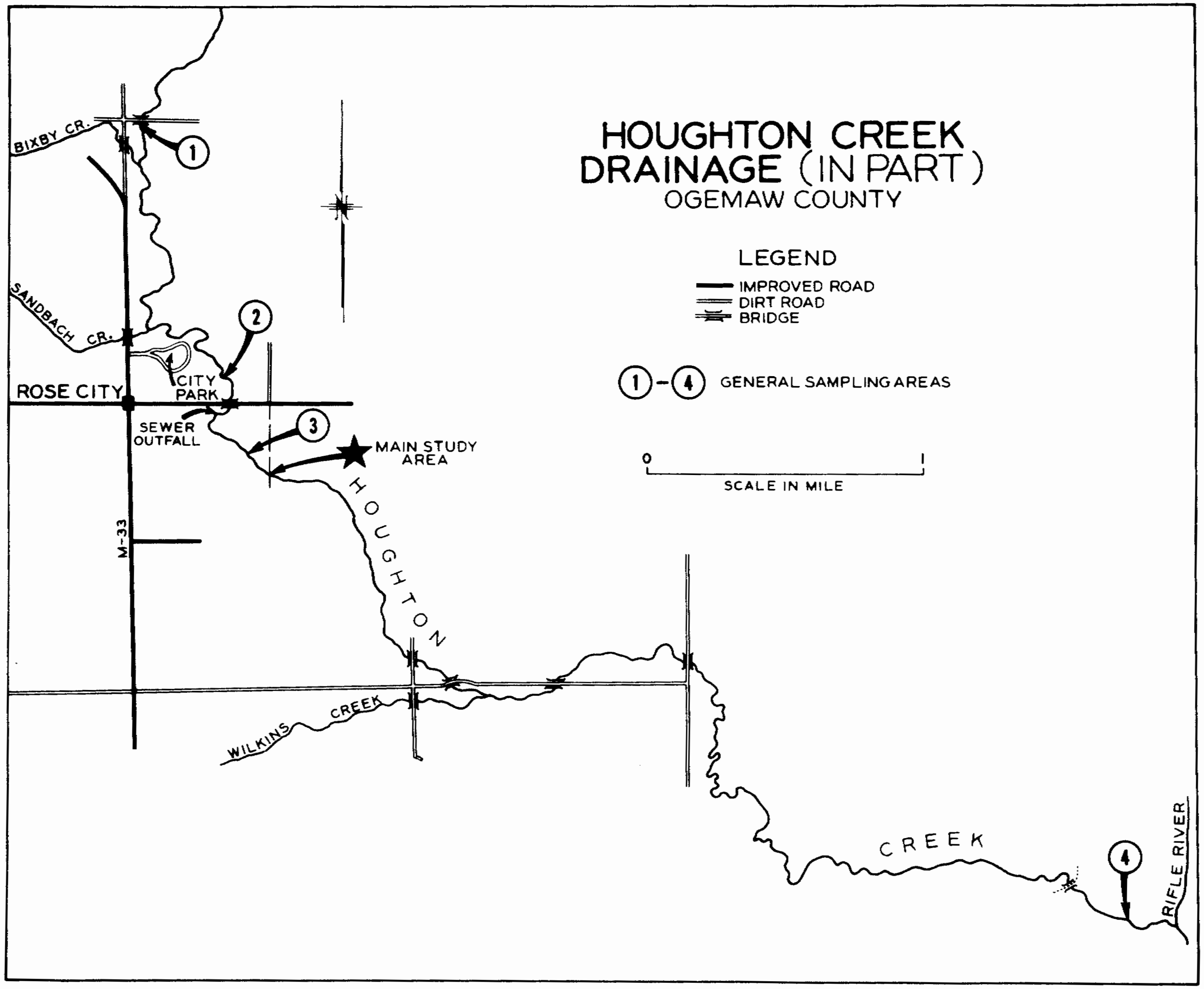
HOUGHTON CREEK
DRAINAGE (IN PART)
OGEMAW COUNTY
LEGEND
IMPROVED ROAD
DIRT ROAD
BRIDGE
1 - 4 GENERAL SAMPLING AREAS
0
1
SCALE IN MILE
BIXBY CR.
SANDBACH CR.
ROSE CITY
CITY PARK
SEWER OUTFALL
MAIN STUDY AREA
M-33
HOUGHTON
CREEK
WILKINS CREEK
RIFLE RIVER
1
2
3
4

Figure 1

The greatest concentration of Asellus in Houghton Creek was found within a one-mile stretch of stream extending downstream from about 100 yards below the outfall of the sewer from Rose City (Fig. 1). This area was known as Study Area Two in the previous study (Ellis and Gowing, 1957). Most of the Asellus used in this study came from the main study area mid-way in this one-mile stretch below the sewer outfall. This area contained a shallow gravelly riffle, and an area of deeper water with gravel bottom and slower current. Along the edges of the stream and in the slower current, the bottom was soft silt, dark grey in color, and there were many sticks and pieces of rotting logs.

Methods

Quantitative samples of Asellus were collected in three different ways: (1) riffle areas were sampled with a Surber stream bottom sampler, (2) areas of still water and vegetation were sampled with a section of 7-inch diameter stove pipe, (3) samples were removed from large stones covered with growth of Fontinalis by scraping measured areas with a knife blade. Qualitative samples were collected with a wire mesh dip net and by hand picking and washing from stones, logs and vegetation. The volumes of organisms in quantitative samples were determined by measuring the water they displaced in a 15-ml. centrifuge tube. The lengths of individual sowbugs were measured under a dissecting microscope on a miniature measuring board ruled in millimeters. The animals were straightened, but not stretched, ventral side up and measured from the anterior end of the head to the posterior margin of the telson. The anterior flagella and posterior uropods were not included in measurements.

The lengths of females used in brood counts and of animals whose growth was being followed were estimated to the nearest tenth of a millimeter. All other lengths were recorded to the nearest millimeter.

Since it was difficult to determine the sex of small isopods and small individuals escaped from collecting nets, only animals 4.0 mm. and larger are included in the population data.

Animals were maintained in the laboratory in open enameled trays (45 cm. x 30 cm. x 9 cm.), in finger bowls (12 cm. x 6 cm.), in shell vials (25 mm. x 88 mm.) and in watch glasses (6.5 cm. x 1.5 cm.). Open enameled trays were used to hatch and follow the growth of an entire brood of Asellus; the finger bowls and shell vials were used when observing the incubation period and for observations of breeding and molting habits; watch glasses were used when observing the growth and molting of individual animals.

The Asellus maintained in the laboratory were supplied with filamentous algae (Pithophora) and dried elm and poplar leaves. They were observed to scrape the aufwuchs from the filamentous algae and would eat all of a poplar or elm leaf except the larger veins. The Asellus would occasionally eat their dead kin but were never observed to attack one another. Young animals (through the ninth instar) commonly ate their exuviae, however this act was only occasionally observed in the older animals.

Reproduction

In structure of external reproductive organs and in observed mating behavior, Asellus intermedius is very similar to A. aquaticus (Unwin, 1920) and Mancasellus macrourus (Markûs, 1930). The female carries the eggs and young in a marsupium or brood pouch formed by broad, plate-like oostegites which arise from the base of each of the anterior 5 pairs of legs. Oostegites are first visible as small projections when the animals reach a length of about 3 to 4 millimeters. These oostegites become progressively larger with each molt until maturity. At the time of the pre-mating molt they are narrow and finger-like and contain the tightly folded lamellae which, at the molt which accompanies mating, are released to form the marsupium. As in A. aquaticus (Unwin, 1920), the oostegites of A. intermedius return to their pre-mating condition at the first molt following the departure of the young from the marsupium. Following this molt the female may mate again.

The male Asellus seizes the mature female when she is ready for breeding and carries her under him with her ventral side down. This relationship is maintained until the posterior half of her exoskeleton is molted at which time he inseminates and releases her. Within a few hours the female molts the anterior half of her exoskeleton and the eggs are secreted into the marsupium formed by the newly released lamellar oostegites. The male is usually larger than the female he seizes. In one case in which a male was given a larger mature female, the male seized her immediately but had difficulty in subduing the female. Several minutes of struggling took place before she was brought into carrying position and then the pair had difficulty in walking.

Allee (1912) noted that the breeding season of Asellus communis was from spring to mid-summer and Berg (1948) observed that A. aquaticus bred in spring, summer and occasionally at other times. In Mancasellus macrourus, Markus (1930) found the peak of reproduction to be in March and April after which a much lower level was maintained for the remainder of the year.

The main breeding season of Asellus intermedius was found to be from May to September when 40 percent or more of the females were pregnant in one or the other of the sampled habitats. Gravid females were found during every month of the year either in samples collected for this study or in extensive preliminary samples, but the reproductive rate was apparently low in winter (Table 5).

Incubation

The brood pouch

Water in the brood pouch is constantly renewed by the bellows-like, alternate contraction and expansion of the walls of the pouch (Unwin, 1920; Markus, 1930). Unwin presented a drawing of the broad, feather-lobed, plate-like maxilliped of Asellus aquaticus. He believed that the lobe functions to move water through the pouch while the pouch is inactive. Gravid A. intermedius also were observed here to possess a feather-lobed maxilliped which differs from that of A. aquaticus only in minor details. Males of A. intermedius and females which lacked a brood pouch did not possess this lobe.

Stages in development

The embryonic development of Asellus aquaticus has been illustrated and summarized by Faxon, 1882. The gross features of the development of A. intermedius were nearly identical to those of A. aquaticus and correspond to the four developmental stages recognized by Naylor (1956) for the European marine isopod, Idotea emarginata. The inner and outer egg membranes of A. intermedius are present when the egg is first deposited in the brood pouch. As the embryo develops, and before the abdominal appendages are bi-lobed, the outer membrane splits and is shed. The embryo is then within the inner egg membrane and the larval membrane which is now evident. The dorsal organ is now present and is fully extended. As development continues, the larva sheds the inner egg membrane and then the larval membrane. The young animal is then able to fully flex its appendages and body. Before leaving the brood pouch, the animal molts and eats its exuviae. The animal is now without the two dorsal organs which were part of the larval exoskeleton. Food can be seen in the gut of A. intermedius which have molted the larval exoskeleton but have not left the marsupium. Markus (1930) noted that Mancasellus macrourus has a digestive tract which is dark and can be seen from the exterior when they leave the brood pouch. Unwin (1920) noted that A. aquaticus eats debris in the brood pouch before leaving. Hatchett (1947) however stated that the terrestrial isopods he studied did not eat until after the first molt following departure from the brood pouch.

Brood size

The number of young in the marsupium increases with greater size of the female (Fig. 2). A similar relationship has been noted by Berg (1948) for Asellus aquaticus, and by Hatchett (1947) for A. communis and the terrestrial isopod Cylisticus convexus; their data for A. aquaticus and A. communis are compared with my data for A. intermedius in Figure 3. Apparently A. intermedius, on the average, carries more offspring than do A. aquaticus and A. communis of comparable size (not tested statistically). Hatchett showed that the terrestrial isopod, C. convexus, produces smaller broods than the three aquatic species considered above. Females of C. convexus, from 10 to 17 mm. in length, carried 19 to 63 young, while A. intermedius 10 mm. long averaged about 130 young.

Berg (1948) noted a non-linear regression of number of young upon size of female in Asellus aquaticus. The slope of the regression line increased for larger females (Fig. 3). Hatchett's (1947) data for A. communis do not seem to show this departure from linearity. In the present study, data for

Figure 2.--Correlation of brood size and length of female for 119 *Asellus intermedius* from Houghton Creek. The regression line shown was calculated using logarithms.

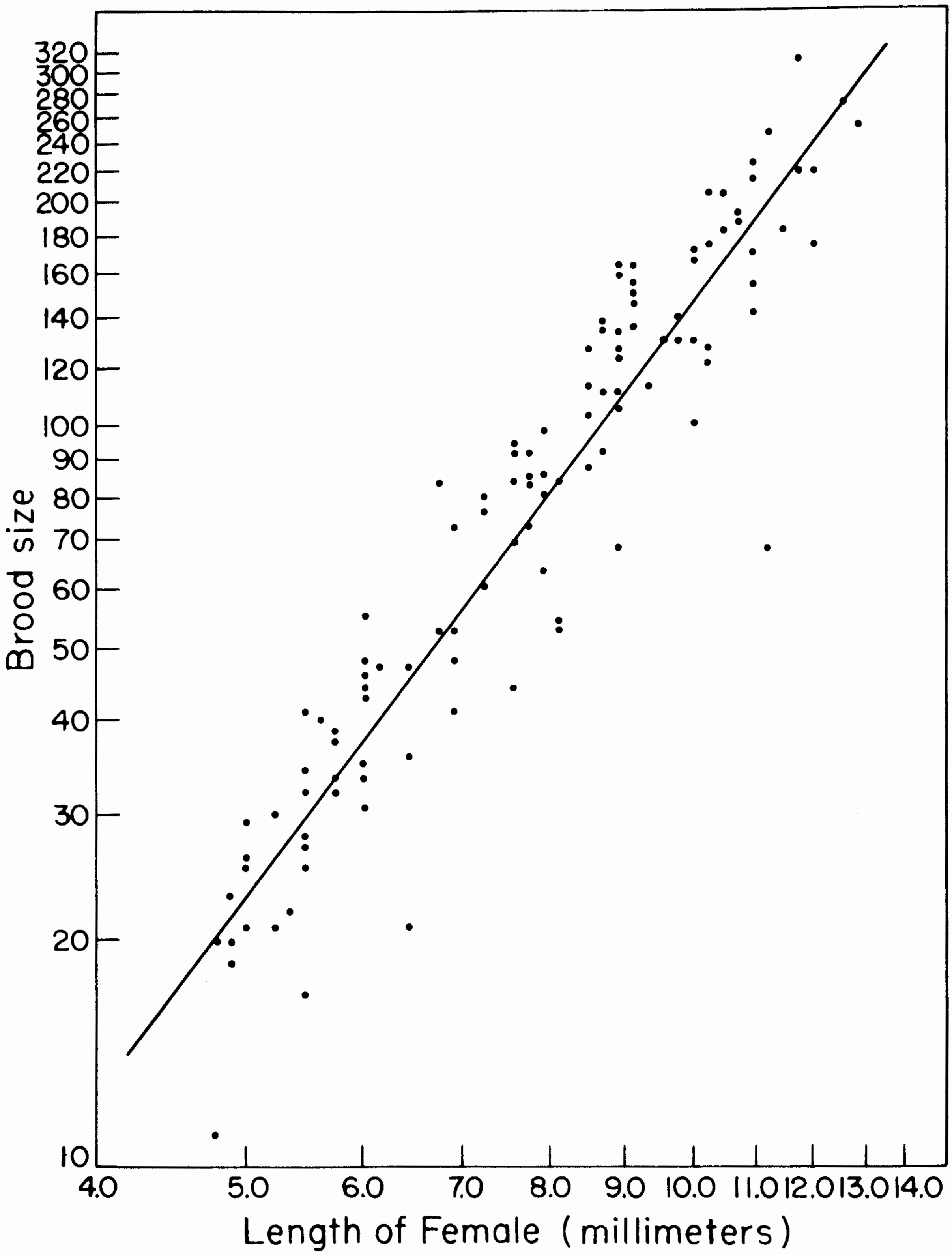
320
300
280
260
240
220
200
180
160
140
120
100
90
80
70
60
50
40
30
20
10
Brood size
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
Length of Female (millimeters)

Figure 2

Figure 3.--Comparison of length of female *Asellus* and average number of individuals in marsupia. Averages are for 0.5 millimeter size classes. Data for *A. aquaticus* is from Berg (1948), *A. communis* is from Hatchett (1947) and *A. intermedius* is from the present study.

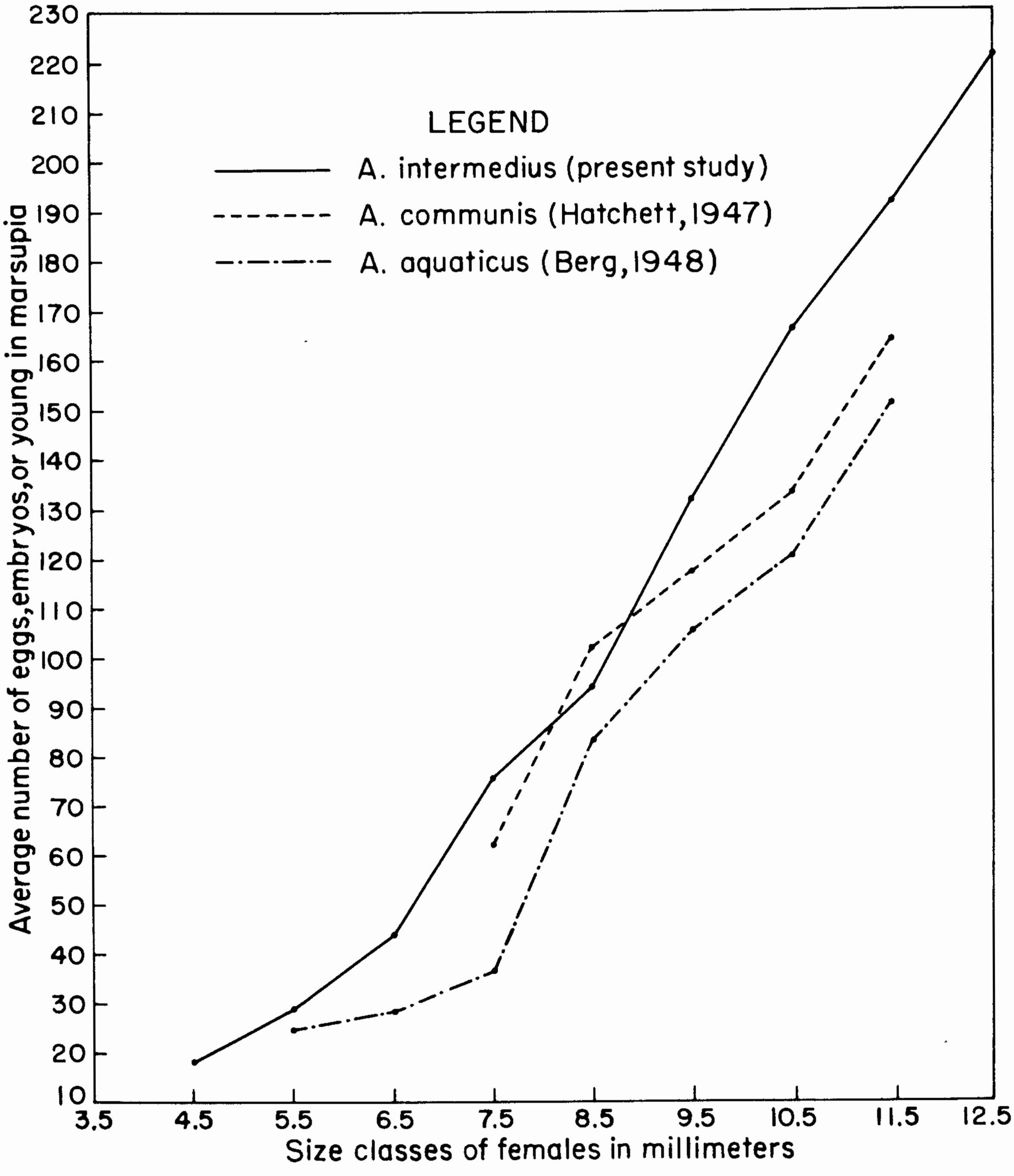
LEGEND
A. intermedius (present study)
A. communis (Hatchett, 1947)
A. aquaticus (Berg, 1948)
Average number of eggs, embryos, or young in marsupia
Size classes of females in millimeters
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
3.5
4.5
5.5
6.5
7.5
8.5
9.5
10.5
11.5
12.5

Figure 3

A. intermedius show the trend noted by Berg when plotted on a linear scale (Fig. 3), but when plotted on a log-log scale, the relationship seems to be reasonably linear (Fig. 2). The regression line for these data, fitted by least squares, indicates that size of brood is proportional to the 2.68 power of body length of the female. Since brood size is proportional to approximately the cube of body length in A. intermedius, it may be some function of body volume.

The mean number of eggs and embryos in Asellus intermedius was compared with the number of larvae and young for each size class from 4 mm. to 11 mm. Among 72 females the number of eggs and embryos was about 17 percent greater than the number of larvae and young ready to leave the pouch. Hatchett (1948) noted a similar difference in Cylisticus convexus and believed it to be due in part to the failure of eggs to develop. In the present study few undeveloped eggs were noted; this suggests that mortality may have been from some other source. Brood pouches which appeared to be intact may have lost some fully developed young through early departure, although in the laboratory the entire brood was usually shed within a few hours. Jancke (1924) observed a gradual reduction in the brood size as development progressed, amounting to about 45 percent in A. aquaticus. He attributed this loss to ejection from the brood pouch due to crowding as the young increased in size. This observation would also be explained if less numerous broods tended to develop longer within the brood pouch.

Incubation period

The incubation period (from deposition of eggs in the marsupium to evacuation of fully developed young) was determined for 15 broods of Asellus intermedius at 6 temperatures and, for comparison, for 5 broods of *A. militaris* at a single average temperatures (Table 1). The young of *A. intermedius* grew more rapidly at high mean temperatures than at low, requiring 12 days at 25° C. as against 24 days at 13° C. However, raising the mean temperature to 27° C. did not further shorten the development period, suggesting that the temperature for maximum growth may have been passed. The broods of *A. militaris* emerged in about 25 percent less time than those of *A. intermedius* raised at the same temperatures. The shorter development period perhaps better fits *A. militaris* for its life in temporary ponds.

Markus (1930) observed an inverse relationship between incubation period and temperature, with *Mancasellus macrourus*. He found that with gravid females, kept at about 18° C., the time for eggs to hatch and all young to leave the pouch varied from 20 to 30 days. He attributed this variation to some young remaining in the pouch after others had departed.

Hatchett (1947) found by rearing in the laboratory many broods of four species of terrestrial isopods, that the average incubation period ranged from 39 to 52 days, with considerable variation within a species. Although he did not record the temperature, it seems likely that in the present study either *Asellus intermedius* or *A. militaris* developed more rapidly (10 to 15 days at room temperature) than did his terrestrial isopods.

Growth rates

Nine broods of *Asellus intermedius* were reared in the laboratory at four different average temperatures. Two broods were reared in open enameled trays at room temperatures and the others in finger bowls partly submerged in constant temperature water baths. Length measurements were made of selected samples from each brood at monthly intervals (Table 2). The young averaged about 1.2 mm. in length when they first left the marsupia.

Table 1.--Incubation periods for 15 broods of *Asellus intermedius* and five broods of *Asellus militaris* reared in the laboratory at various temperatures

	A. intermedius			*A. militaris*		
Brood number	Temperature °C. Range	Temperature °C. Mean	Incubation period (days)	Temperature °C. Range	Temperature °C. Mean	Incubation period (days)
1	22-35	27	15	20-22	21	11
2	22-35	27	15	20-22	21	11
3	22-35	27	12	20-22	21	10
4	22-35	27	12	20-22	21	10
5	24-26	25	12	20-22	21	10
6	24-26	25	12	...	..	..
7	18-21	21	14	...	..	..
8	18-21	21	14	...	..	..
9	18-21	21	14	...	..	..
10	17-19	18	15	...	..	..
11	17-19	18	15	...	..	..
12	12-14	13	24	...	..	..
13	12-14	13	24	...	..	..
14	12-14	13	24	...	..	..
15	7-9	8	est. 53[1]	...	..	..

[1] The female bearing this brood died after 40 days; total incubation period was estimated after examination of stage of development of the young.

Table 2.--The body lengths, at monthly intervals, as measured in samples from 9 broods of <u>Asellus intermedius</u> reared at different temperatures in the laboratory. Broods 1 and 2 were reared at room temperatures, while all others were maintained in constant temperature baths. N equals number of specimens; M equals mean length in millimeters; and R equals range in length in millimeters

Brood number	Average temp., °C	Age of *Asellus*, in days														
		30			60			90			120			150		
		N	M	R	N	M	R	N	M	R	N	M	R	N	M	R
1	23.9[1]	22	3.8	3.0-4.5	38	5.0	3.5-6.5	47	6.7	5.0-9.0	26	7.0	5.5-9.0	..	...	...
2	23.9[1]	20	3.3	2.5-4.0	35	5.1	3.5-6.5	37	7.3	5.0-9.5	20	7.4	5.5-9.5	8	8.1	7.0-9.0
3	18.3	25	1.8	1.3-2.5	28	2.5	1.6-3.8	7	3.6	3.0-5.0	..	...	...	..	...	...
4	18.3	..	...	...	17	3.3	1.8-5.2	7	4.1	3.0-6.0	3	6.9	6.0-7.8	..	...	...
5	12.8	20	1.5	1.2-1.8	3	2.8	1.6-3.2	..	...	...	..	...	...	..	...	...
6	7.7	14	1.6	1.2-1.8	11	2.0	1.8-3.0	9	2.3	2.0-3.0	..	...	...	..	...	...
7	7.7	28	1.5	1.4-1.6	..	...	...	..	...	...	..	...	...	..	...	...
8	7.7	37	1.2	1.0-1.4	..	...	...	..	...	...	..	...	...	..	...	...
9	7.7	..	...	...	13	1.8	1.5-2.1	6	2.1	1.8-2.4	..	...	...	..	...	...

[1] First 30 days, average 23.3° C., range 15.6°-35.0° C.; second thirty days, average 25.0° C., range 21.1°-32.8° C.; third thirty days, average 25.6° C., range 21.1°-32.8° C.; fourth thirty days, average 23.9° C., range 16.7°-32.2° C.; fifth thirty days, average 22.8° C., range 16.7°-30.6° C.

A semi-logarithmic plot of average length of each brood at monthly intervals was made to ascertain the effect of temperature on growth (Fig. 4). The growth rates (slopes of the lines) of the two broods reared at 23.9° C. (75° F.) were very similar, being quite rapid during the first thirty-day period, somewhat slower during the next sixty days, and markedly slower after 90 days of age. This marked slowing of the growth rate may have been due to age or size and was also coincident with the development of sexual maturity and breeding. Members of both of these broods produced young at an age of about 100 days.

Broods kept at lower temperatures grew less rapidly during the first 30 days than did broods 1 and 2. After this time, the growth of broods 1 and 2 was slower and was about equal the rate of broods at intermediate temperatures (12.8° and 18.3° C.). At the lowest temperature (7.7° C.) either growth did not occur (brood 8) or proceeded at the lowest rate (broods 6, 7 and 9).

A large range in size was evident in all the broods (Table 2). The largest individuals were from 1.1 to 2.8 times as large as the smallest animals measured in the same brood.

Growth rate in the field may be estimated from the length-frequency data of Figure 5. The individuals in the 9-mm. to 15-mm. group in April and May seem likely to have been survivors of the broods which comprised the 4-mm. to 7-mm. group back in August and September. This would imply an average uniform rate of 10 percent per month, linear increase, for 8 months. However, Figure 5 suggests a variable rate, perhaps 19 percent per month until December; then 4 percent per month for three winter months; then about 8 percent per month for March and April. The laboratory

Figure 4.--Rate of growth of nine broods of <u>Asellus intermedius</u> reared in the laboratory at various average temperatures.

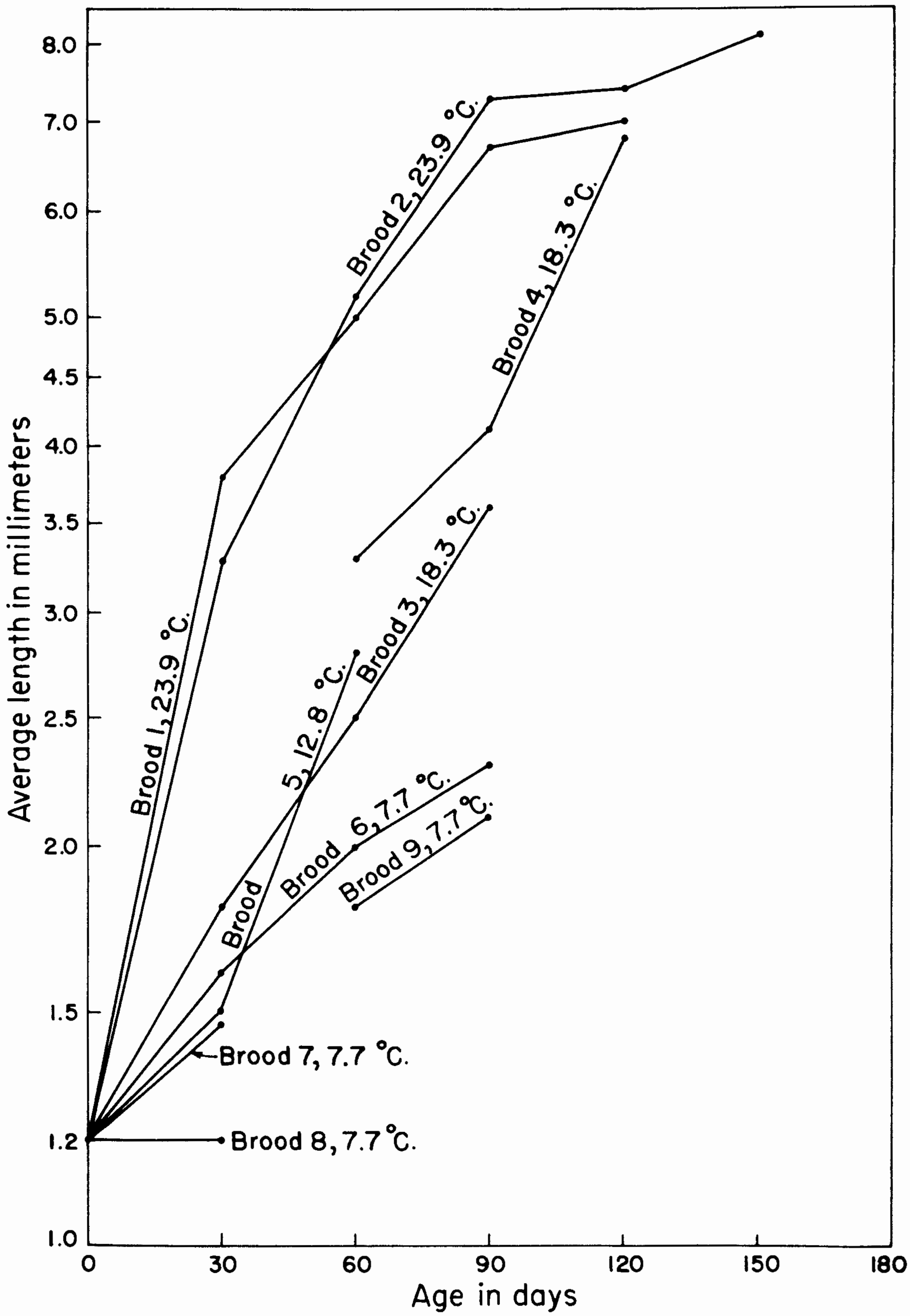
8.0
7.0
6.0
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.2
1.0
0
30
60
90
120
150
180
Average length in millimeters
Age in days
Brood 2, 23.9 °C.
Brood 4, 18.3 °C.
Brood 1, 23.9 °C.
Brood 3, 18.3 °C.
Brood 5, 12.8 °C.
Brood 6, 7.7 °C.
Brood 9, 7.7 °C.
Brood 7, 7.7 °C.
Brood 8, 7.7 °C.

Figure 4

Figure 5.--Length frequency distribution of *Asellus intermedius* from 12 samples taken from gravelly riffles and 12 samples taken from the stream margins of Houghton Creek from April 1955 to May 1956. Animals smaller than 4.0 millimeters were not included.

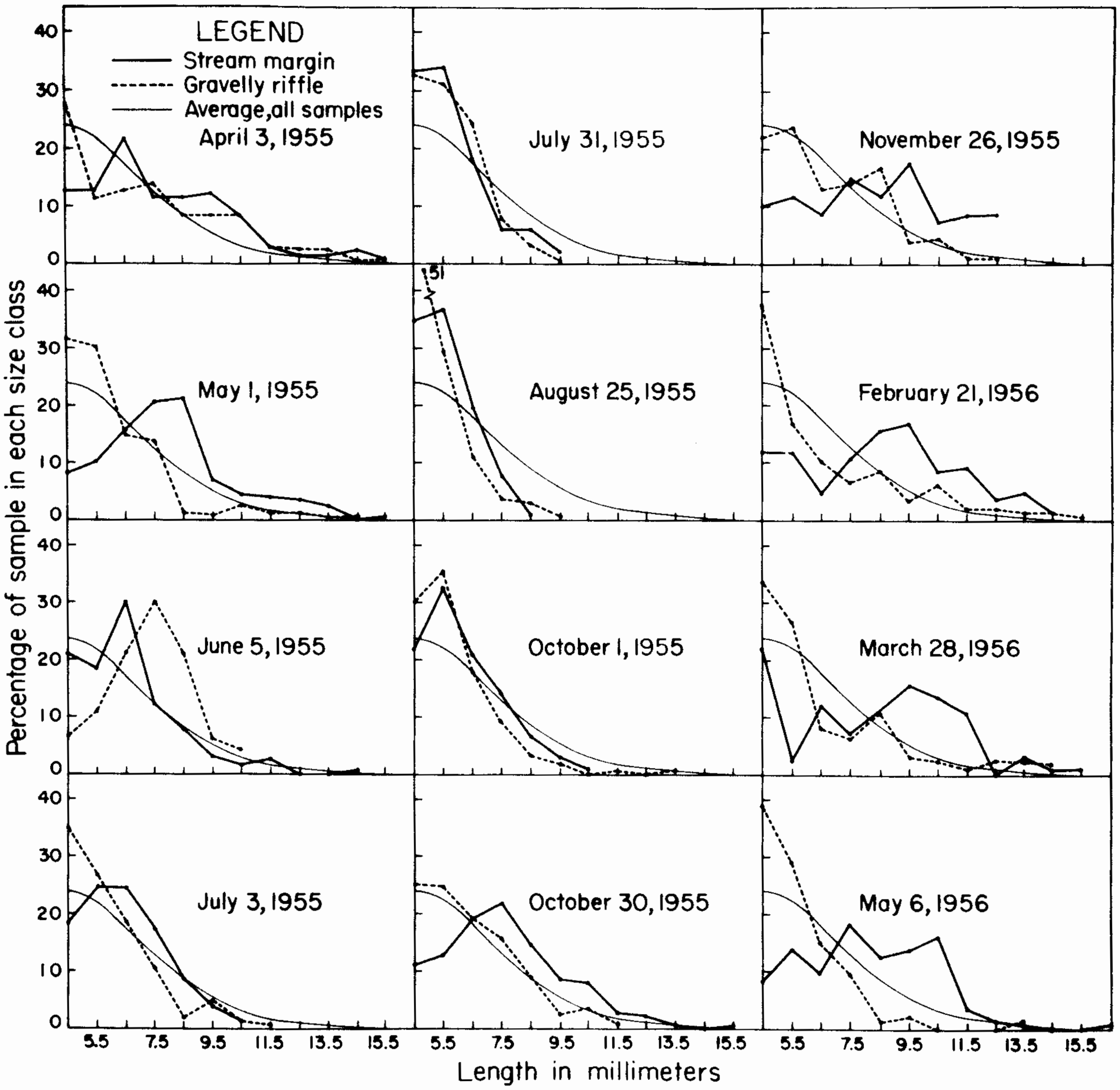
LEGEND
Stream margin
Gravelly riffle
Average, all samples
April 3, 1955
July 31, 1955
November 26, 1955
May 1, 1955
August 25, 1955
February 21, 1956
June 5, 1955
October 1, 1955
March 28, 1956
July 3, 1955
October 30, 1955
May 6, 1956
51
Percentage of sample in each size class
Length in millimeters
0
10
20
30
40
5.5
7.5
9.5
11.5
13.5
15.5

Figure 5

individuals were smaller than those in the field, but their growth rates suggest that the above interpretation of the field data is at least possible since growth in the laboratory averaged 19, 25 and 16 percent for the first, second and third months at 7.7° C.

Hatchett (1947) noted a large variation in growth of individuals within a brood in terrestrial isopods reared in the laboratory. Markus (1930) observed that Mancasellus macrourus reared in the laboratory did not attain a size as large as the largest specimens collected from the natural habitat. He also compared the size of laboratory-reared animals with wild animals at the same instars and found the laboratory animals to be smaller. Markus found an average growth of about 2 mm. per month for Mancasellus maintained in wire cages in a stream from December to May.

Asellus intermedius were able to grow to maturity and reproduce in the laboratory where temperatures ranged from 15.6° C. to 35.0° C. (60° F. to 95° F.) and averaged 23.9° C. In Houghton Creek this species bears young during the winter months when mean monthly temperatures fall as low as 1° C. Thus the range of temperature at which this species may produce young appears to be at least from 1° C. to 23.9° C.

Molting

Molting and growth of Asellus intermedius were observed through as many as nine instars. Individual animals were maintained at room temperatures in watch glasses, with pieces of filamentous algae for food. Results of daily observations of molting and growth in A. intermedius, together with similar data on Mancasellus macrourus (Markus, 1930) and four species of terrestrial isopods (Hatchett, 1947), are summarized in Table 3.

Table 3.--The pattern of molting in Asellus intermedius, Mancasellus macrourus; and 4 species of terrestrial isopods

Molt number	Number reared: Asellus[2]	Number reared: Mancasellus[3]	Days since last molt: Asellus Range	Asellus Average	Mancasellus Range	Mancasellus Average	Terrestrial species[4] Average	Average size of Asellus (mm.)
1[1]	46	14	2-9	4.8	6-7	6.8	1	1.4
2	25	14	2-7	3.7	14-15	14.6	10	1.5
3	14	13	3-9	5.7	10-12	10.5	7	1.7
4	9	7	3-14	5.2	12-13	12.1	10	2.0
5	6	4	3-8	6.6	20-22	21.0	14	1.9
6	5	4	6-10	6.8	30-31	30.5	14	...
7	3	..	5-10	8.0	...	...	14	...
8	1	..	...	6	...	...	14	...
9	1	..	...	2	...	...	14	2.3

[1]This is the first molt after leaving the brood pouch in Asellus intermedius but apparently corresponds to the second molt of the terrestrial isopods.

[2]Present study.

[3]Data from Markus, 1930.

[4]Four species of terrestrial isopods (Hatchett, 1947, p. 66).

Young _Asellus intermedius_ molted more frequently than did young _Mancasellus_. At 31 days of age, _Asellus_ had completed an average of six molts while at the sixth molt, _Mancasellus_ were about 95 days old and the four species of terrestrial isopods averaged 56 days old. Time between molts seems to have been more variable in the present study. At the sixth molt, _A. intermedius_ averaged 2.0 mm. in length and the terrestrial isopods were 4.5 to 6.0 mm. Thus _A. intermedius_ molted more often and grew less between molts.

Pierce (1907) found that there was no regularity in molts after the first one in several species of terrestrial isopods, which is in accordance with present findings for immature _Asellus intermedius_. The only observations on molting in adult _A. intermedius_ were of the post-parturition molts of the mothers (the first molt following departure of the young from the pouch). The time of this molt seems to depend upon environmental temperature. It occurred 4 days after parturition for seven females maintained at 23.9° C. (75° F.) and 8 days after the young departed in the case of a single female maintained at 12.8° C. (55° F.).

Distribution and abundance of _Asellus_

Distribution

The distribution and abundance of _Asellus intermedius_ in Houghton Creek seems to be related to the concentration of domestic sewage. These sowbugs are most abundant in the area from the sewer outfall to the junction of Houghton Creek and Wilkens Creek, and their abundance decreases from this point downstream to the mouth of Houghton Creek. The abundance of _Asellus_ decreases going upstream from the Rose City sewer as the outfalls of several small sewers are progressivly passed. The most upstream source of domestic sewage is believed to be about 25 yards above Sandbach Creek (Fig. 1). Upstream from this point A. intermedius was found only occasionally.

Abundance

Table 4 presents a summary of 154 quantitative bottom samples taken at various times during the year at four locations on Houghton Creek with different concentrations of domestic pollution. Area 1 (Fig. 1) is about 900 yards upstream from Sandbach Creek and receives little or no sewage; area 2 receives a small amount of sewage; area 3 receives the sewage from Rose City; and by the time area 4 has been reached the pollution has been greatly diluted. The comparative abundance of Asellus (ml. per square foot of gravelly riffle or vegetation) in the samples (Table 4) corresponds closely to these concentrations of domestic sewage. The relative abundance of all members of the bottom fauna in these areas closely paralleled the abundance of Asellus.

The abundance of Asellus intermedius varied from one type of habitat to another. Areas of vegetation supported the greatest concentrations. Growths of Fontinalis sp. yielded numbers and volumes as high as 15,600 individuals and 35.0 ml. per square foot (based on a 3-inch by 3-inch sample). The greatest concentration observed in gravelly riffles was 7.5 ml. per square foot (based on a one-half square-foot sample). Asellus occurred only occasionally in bottom samples collected from sand, silt and clay adjacent to the gravelly riffle and the Fontinalis samples mentioned above. The scarcity of sowbugs in these areas appeared to be due to lack of cover or foothold. Leaves, sticks, logs and other debris which offered footing and hiding places often supported large numbers of Asellus when located on silt, sand or clay. No quantitative samples were obtained from areas of leaves, sticks or logs.

Table 4.--Abundance of Asellus intermedius in gravelly riffles and vegetation in four areas of Houghton Creek

Habitat	Area[3]	Samples taken	Samples containing Asellus	Volume of Asellus (ml. per ft.^{2})		Number of Asellus (per ft.^{2})	
				Range	Average	Range	Average
Gravelly riffle[1]	1	12	2	0-trace	Trace	0-3	0.3
	2	60	52	0-0.6	0.1	...	...
	3	60	59	trace-7.5	1.2	...	...
	4	13	12	0-0.8	0.2	0-312	46
Vegetation[2]	1	..	..	...	...	...	...
	2	3	3	0.9-1.6	1.2	116-360	238
	3	3	3	2.7-35.0	16.2	1,370-15,600	6,385
	4	3	3	0.6-1.5	1.0	85-175	130

[1] These figures are from samples taken at various times throughout the year as part of other studies; see Ellis and Gowing, 1957, for information on seasonal abundance.

[2] These samples were collected during summer and fall.

[3] Area 1 is above known pollution, Area 2 is above Rose City sewer, Area 3 is within one mile below sewer, Area 4 is near mouth of stream.

The abundance of Asellus intermedius in the gravelly riffles showed a very marked seasonal fluctuation (Ellis and Gowing, 1957). A peak of abundance occurred in October, November and December. This was followed by a gradual decline until late spring and thereafter a sharp decline to a summer low.

Similar seasonal changes in abundance of Asellus aquaticus were noted by Berg (1948) in Danish streams. He states that seasonal variations in numbers were large, and his data indicate a low abundance in the spring and a high about midwinter. The time of peak abundance of A. aquaticus was influenced by the presence or absence of vegetation in the stream and in one instance possibly by a migration from an adjacent swamp. In streams with abundant vegetation Berg (loc. cit.) found that the peak abundance of Asellus in bottom samples occurred after the vegetation had died and decayed. This caused the sowbugs to seek the stream bottom. In streams where vegetation was not so prevalent, the peak abundance was from August to November rather than from November to February.

A migration of large numbers of Asellus intermedius from vegetation to the stream bottom in Houghton Creek was precluded by the relative scarcity of vascular plants. However, the possibility of a migration of Asellus between other areas, as suggested by Berg and observed by Allee (1926), was considered and the evidence is discussed below.

Population dynamics

Methods

The populations of the stream margin and riffle areas were sampled qualitatively, at approximately monthly intervals from April, 1955 to May, 1956. These samples were taken in order to study seasonal changes occurring in each habitat and to make possible a comparison of the population structure of the two areas throughout the year. The animals of the gravelly riffles were collected with a wire mesh dip net. In making collections the net was held perpendicularly against the bottom while the gravel immediately upstream from the net was stirred. Sowbugs from the stream margin were washed from crevices, and from surfaces of sticks and logs into a pail and concentrated by straining the contents through a wire dip net. The length and sex of animals over 4 mm. in length and the reproductive stage of each female were recorded. These collections are regarded as random samples of the populations in the two types of habitat with respect to sex ratio and size-frequency distribution for lengths exceeding 4 mm.

The sex ratio, percentage of gravid females, average size of females, average size, and number of all Asellus in each sample are presented in Table 5.

General seasonal cycles

The length frequency data for the 12 collections have been summarized in Figure 5, which shows for each month the percentage size distribution of Asellus from the margin and riffle habitats. An average size-frequency curve, based on all collections, is superimposed (for comparison) on the curves for each month.

A general pattern of reproduction and growth appears in Table 5 and Figure 5 when each pair of samples is considered as a unit. In April and May the large, over-wintering adults reproduce and then become proportionately much less abundant. By early June, the smaller, over-wintering individuals and possibly some of the early spring progeny have matured and bred. The average size for pregnant (i.e., gravid) females was 9.3 mm. and 10.0 mm.

Table 5.--Sex distribution, average size (mm.), and percentage of gravid females, for <u>Asellus</u> <u>intermedius</u> in 12 monthly samples, April 1955 to May 1956, from gravelly riffles and stream margins in Houghton Creek

Sample for month	Date of collection	Total <u>Asellus</u> in samples: Number, Riffle	Total <u>Asellus</u> in samples: Number, Margin	Total <u>Asellus</u> in samples: Average size (mm.), Riffle	Total <u>Asellus</u> in samples: Average size (mm.), Margin	Female <u>Asellus</u> in samples: Percentage, Riffle	Female <u>Asellus</u> in samples: Percentage, Margin	Female <u>Asellus</u> in samples: Average size (mm.), Riffle	Female <u>Asellus</u> in samples: Average size (mm.), Margin	Gravid females in samples: Percentage of all females, Riffle	Gravid females in samples: Percentage of all females, Margin	Gravid females in samples: Average size (mm.), Riffle	Gravid females in samples: Average size (mm.), Margin
April	April 3, 1955	149	188	6.7	7.3	50.3	61.2	6.1	7.0	4.0	14.8	10.0	9.3
May	May 1	207	192	5.6	7.4	57.0	67.5	5.4	6.9	16.1	45.0	7.4	7.9
June	June 5	47	124	6.8	6.1	57.4	58.9	6.2	5.9	22.2	56.2	7.0	6.4
July	July 3	149	69	5.4	5.9	46.3	75.4	5.1	5.8	4.4	40.4	6.7	6.1
Aug.	July 31	156	99	5.2	5.2	60.2	60.6	4.9	4.8	39.4	56.7	5.3	5.1
Sept.	Aug. 25	125	171	4.8	5.0	53.6	60.8	4.6	4.8	46.3	31.7	4.8	5.0
Oct.	Oct. 1	210	221	5.3	5.7	50.5	47.5	4.9	5.1	16.0[1]	11.4[1]	5.0	5.0
Nov.	Oct. 30	301	407	5.8	7.0	59.5	39.8	5.5	6.2	0.0	1.2	...	5.5
Dec.	Nov. 26	199	68	7.2	7.8	58.3	47.1	7.6	6.9	0.0	0.0	...	...
March	Feb. 21, 1956	129	83	6.3	8.5	56.6	59.0	5.9	7.4	1.4	8.2	[illegible]	10.0
April	March 28	120	73	6.0	7.8	48.3	60.3	5.6	7.5	1.7	27.3	12.0	9.8
May	May 6	62	131	5.3	7.6	64.5	68.7	4.9	7.6	2.5	65.6	7.0	8.6

[1] Over two-thirds of these females were carrying well developed larvae.

in April as compared to 6.4 mm. and 7.0 mm. in June (Table 5). During the summer the average length of gravid females continued to decline, and on August 25 the average length was 4.8 mm. for riffles and 5.0 mm. for the stream margin. The average length of all individuals (both sexes and the two habitats) in each sample declined from 7.0 mm. in April, to 6.3 mm. in June, to 4.9 mm. on August 25.

The decrease in average length of Asellus from April to September was accompanied by an increase in the proportion of females which were gravid. About 11.3 percent of the females in the April (1955 and 1956) samples were pregnant, 36.0 percent in May (1955 and 1956), 46.1 percent in August, and 37.5 percent in September. The decline, which started in September, continued to 13.7 percent in October and 0.6 percent in November.

During the main breeding season, May to September, the percentage of females that were pregnant tended to be higher among the larger females. A similar relationship has been observed in the terrestrial isopod Cylisticus convexus (Hatchett, 1947) and the marine isopod Idotea emarginata (Naylor, 1955).

The reduction in average size of Asellus from April to September is probably due to several factors, but on only one of these is there definite information here. The large, over-wintering adults appear to have disappeared in April and May, thus reducing the average size at this time.

But why did the size-frequency distribution remain relatively static for the following months of July through October? Since there was much reproduction during most of this time, we must conclude that the static frequency distribution reflects a balance between reproduction, growth and immigration on the one hand, and mortality and emigration on the other.

Discounting any differential movement, then the growth rate must have been reduced and/or mortality rate increased, to account for the observations. Any tendency of fish to feed selectively upon larger sowbugs would have the same effect.

The brown trout of this stretch of Houghton Creek have been shown to feed heavily upon Asellus, and further, to have in their stomachs greater numbers of Asellus during July and August than during April, May and June (Ellis and Gowing, 1957). But this fact cannot be interpreted as changing mortality without more information on the Asellus populations.

The general seasonal cycle of size in Asellus intermedius observed here is similar to those of the fresh-water isopods A. aquaticus (Berg, 1948) and Mancasellus macrourus (Markus, 1930) and the marine isopod Idotea emarginata (Naylor, 1955). The large, over-wintering adults reproduce in the spring and then disappear. A generation of smaller individuals then appears, some of which begin reproduction during the summer. The disappearance of the over-wintering Asellus is gradual (over a period of several weeks). Since a few of these individuals continue to reproduce through late spring and early summer, some reproduction occurs throughout most of the year and there is an overlap in size range and state of maturity. The two species of Asellus differ from Mancasellus and Idotea in that a much larger proportion of Asellus mature and reproduce during the summer.

Thus the life span of Asellus intermedius born in the spring and early summer is about one year, or the same as that of A. aquaticus, Mancasellus macrourus, and Idotea emarginata. It may be somewhat shorter for individuals born in late summer.

Seasonal cycles, stream margin vs. riffle

The monthly length frequency distributions of *Asellus* from stream margin and riffle habitats are shown in Figure 5, along with a base line showing the average distribution for all samples. To test whether the differences in length distribution between margin and riffle were real, rather than due to sampling variations, the numbers in each monthly pair of samples were compared by Chi-square test. These tests, one for each month, demonstrated a reliable difference in the length frequency distributions of the members of each pair of samples, at the 5 percent level of significance, for each month except July, August, September, and October.

On approximately the first of April (March 28-April 3) and the first of May (May 1-May 6) samples were obtained from margin and riffle habitats in 1955 and in 1956. Inspection of Figure 5 suggests that the relative frequency distributions in populations from the margin and the riffle may be similar for the two years, in other words, that the length-distribution pattern was characteristic of the ecological habitat. Repetition of the similar pattern in the second year would, to a limited degree, confirm the adequacy of the sampling procedure. The consistency of these patterns of length distribution was tested by an analysis of variance technique, using an arc-sin transformation of the percentage data which are plotted in Figure 5. For each millimeter length class (pooling all those 12 mm. and over) the variance due to differences between populations of margin and of riffle was contrasted to the average variance between the two yearly values for the margin and for the riffle. Averaged over the nine classes, for April the estimated variance between margin and riffle was 54.8 (9 degrees of freedom) which was not significantly greater than that between years within habitat, which was 37.3 (18 degrees of freedom). For May the respective values were 137.4 and 13.2, and the differences between margin and riffle were significantly greater than those between yearly values for the same habitat. Thus for May the year-to-year consistency of the length distribution pattern is demonstrated, while for April it is not.

Certain other differences were found between the population structures of Asellus in riffle and margin habitats. The samples from the stream margins generally contained a higher proportion of females than those from the riffles, except during the time (October-December) of little breeding activity (Table 5). The proportion of females pregnant increased more rapidly in the stream margins from April to August, and during this period was consistently greater than in the riffles (Table 5). These differences lead one to suspect a movement of part of the population of mature individuals from riffles to stream margins. Such a movement could be due to changes in rheotactic responses as suggested by Allee (1912), or perhaps simply to the inability of breeding pairs and gravid females to maintain their positions in the fast water of riffles.

Sex ratios

The sex of individuals over 4 mm. in length was determined by examining the pleopods of each animal. The sex ratios varied between size classes, within size classes from month to month, and between the two habitats (Tables 5, 6 and 7). However, females were generally more abundant than males in both habitats.

The 4-mm. to 6-mm. size groups of Asellus intermedius were dominated by females, the 7-mm. group was about half females, and the larger size

Table 6.--Percentage of females in each millimeter size group of *Asellus intermedius* from the stream margin

Sample month	Size group, nearest millimeter												
	4	5	6	7	8	9	10	11	12	13	14	15	16
April, 1955	50.0	58.3	67.5	54.5	95.4	73.9	68.8	16.6	0.0[1]	0.0	0.0	0.0	...[2]
May	64.7	70.0	83.3	77.5	73.2	78.6	66.7	12.5	14.3	0.0	...	0.0	...
June	...[3]	56.5	81.1	66.7	30.0	42.8	50.0	0.0	...	...	0.0	...	...
July	76.9	70.6	88.2	91.7	50.0	50.0	0.0	...	...	...	...	...	...
Aug.	72.7	70.6	66.7	0.0	0.0	0.0	...	...	...	...	...	...	...
Sept.	66.7	76.2	38.2	23.1	0.0	...	...	...	...	...	...	...	...
Oct.	57.4	69.4	41.3	25.0	66.7	0.0	0.0	...	...	...	...	...	...
Nov.	57.8	46.0	51.9	48.9	37.3	14.3	9.4	0.0	0.0	0.0	...	0.0	...
Dec.	42.8	75.0	83.3	70.0	50.0	33.3	40.0	16.7	0.0	...	...	...	...
March, 1956	80.0	60.0	75.0	77.8	69.2	57.1	85.7	25.0	0.0	0.0	0.0	...	...
April	68.8	50.0	44.4	40.0	87.5	54.5	80.0	62.5	...	0.0	0.0	0.0	...
May	81.8	50.0	53.8	79.2	82.4	66.7	76.2	60.0	50.0	0.0	...	...	0.0

[1] 0.0 indicates only males.

[2] ... indicates no animals.

[3] Sex not determined.

Table 7.--Percentage of females in each millimeter size group of

<u>A. intermedius</u> from gravelly riffle area

Sample month	Size group, nearest millimeter												
	4	5	6	7	8	9	10	11	12	13	14	15	16
April, 1955	64.3	35.3	57.9	57.1	53.8	66.7	25.0	20.0	0.0[1]	0.0	0.0	0.0	...
May	62.1	55.5	58.1	65.5	0.0	0.0	40.0	66.7	50.0	0.0	0.0	...[2]	...
June	100.0	60.0	80.0	78.6	20.0	0.0	0.0	...	...	...	...	...	...
July	51.9	52.5	42.8	50.0	0.0	0.0	50.0	0.0	...	...	...	...	...
August	66.7	69.4	68.4	0.0	0.0	0.0	...	...	...	...	...	...	...
September	56.2	62.2	57.1	0.0	0.0	0.0	...	...	...	...	...	...	...
October	57.1	64.9	39.5	30.0	12.5	0.0	...	0.0	...	0.0	...	...	...
November	76.0	56.8	53.5	58.3	50.0	42.9	10.0	0.0	...	...	...	...	...
December	68.2	61.7	61.5	60.7	54.5	37.5	22.2	50.0	0.0	...	...	...	...
March, 1956	58.3	59.1	57.1	55.6	81.8	60.0	66.7	33.3	0.0	0.0	0.0	0.0	...
April	51.2	50.0	50.0	62.5	46.2	100.0	0.0	0.0	50.0	0.0	0.0	...	...
May	70.8	77.8	77.8	16.7	0.0	33.3	...	...	...	0.0	...	...	...

[1] 0.0 indicates only males.

[2] ... indicates no animals.

groups were increasingly dominated by males. The male attains a larger maximum size than the female. The largest female was 13 mm., and the largest male was 16 mm.

Hatchett (1948) briefly summarized earlier studies on sex ratio of terrestrial isopods and concluded that females are usually more abundant than males. For *Cylisticus convexus*, he found that the proportion of females varied from week to week but averaged more than 67 percent. He observed that a preponderance of females was associated with periods of gravidity, and suggested that the declines in the proportion of females following the two major periods of gravidity in the terrestrial isopods were due to deaths at the post-parturition molt.

INSTITUTE FOR FISHERIES RESEARCH

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Literature cited

Allee, W. C.

1912. An experimental analysis of the relation between physiological states and rheotaxis in isopods. Jour. Exper. Zool., 13: 270-344.

____

1914. The ecological importance of the rheotactic reaction of stream isopods. Biol. Bull., 27: 52-66.

____

1927. Animal aggregations. Quart. Rev. Biol., 2: 367-398.

Berg, Kaj

1948. Biological studies on the River Sussa. Folia Limnol. Scandinavica, 4: 1-318.

~~Brown, Margaret E.~~

~~1946. The growth of brown trout (Salmo trutta Linn.). III. The effect of temperature on the growth of two-year-old trout. J. Exp. Biol., 22: 145-155.~~

Ellis, Robert J., and Howard Gowing

1957. Relationship between food supply and condition of wild brown trout, Salmo trutta Linnaeus, in a Michigan stream. Limnol. and Oceanog., 2: 299-308.

Faxon, Walter

1882. Part I. Crustacea. In: Selections from Embryological Monographs, compiled by Alexander Agassiz, Walter Faxon, and E. L. Mark. Memoirs of the Museum of Comparative Zoology, Harvard College, IX, No. 1. Fourteen plates with explanations.

Hatchett, Stephen P.

1947. Biology of the Isopoda of Michigan. Ecol. Monog., 17: 47-79.

Jancke, Oldwig

1924. Die Brutpflege von Malacostracen. Zool. Anz., 58: 273-278.

Markus, Henry C.

1930. Studies on the morphology and life history of the isopod, Mancasellus macrourus. Trans. Amer. Micro. Soc., 49: 220-237.

Naylor, E.

1955. The life cycle of the isopod Idotea emarginata (Fabricius) Jour. Anim. Ecol., 24: 270-282.

Pennak, Robert W.

1953. Fresh-water invertebrates of the United States. The Ronald Press Co., New York, 1-769.

Pierce, W. Dwight

1907. Notes on the economic importance of sowbugs, U. S. Dept. of Agr. Bur. Ent., Bull. 64: 15-22.

Unwin, Ernest E.

1920. Notes on the reproduction of Asellus aquaticus. Jour. Linn. Soc., 34: 335-343.

Van Name, Willard G.

1942. A second supplement to the American land and fresh-water isopod Crustacea. Bull. of the Amer. Mus. of Nat. Hist., 80: 299-329.

Wesenberg-Lund, C.

1939. Biologie der Susswassertiere, Wirbellose Tiere. German translation by O. Starch, J. Springer Publishing Co., Vienna, Germany, 1-817.

MICHIGAN DEPARTMENT OF CONSERVATION

INTEROFFICE COMMUNICATION

Ann Arbor, Michigan
July 23, 1959

TO: S. M. Bower, Office Manager, Fish Division

FROM: P. H. Eschmeyer, Assistant Director, I. F. R.

SUBJECT: Institute Report No. 1574

Robert Ellis, the author of Institute Report No. 1574 entitled "A Life History Study of the Aquatic Sowbug, Asellus intermedius Forbes, in Houghton Creek, Ogemaw County, Michigan," has advised us of three minor errors in the text of this report.

At the top of page 15 (line one) the portion of the sentence continued from page 14 which now reads ". . . of A. militaris at two temperatures (Table 1)" should read as follows: ". . . of A. militaris at a single average temperature (Table 1)."

In line 9 on page 15 of the manuscript, the first sentence of the paragraph should read "Markus (1930)" instead of "Markus (1950)."

On page 38 under "Literature Cited" the reference to the 1946 paper by Margaret H. Brown should be deleted entirely.

As you probably know, we ordinarily ask the authors of Institute reports to review the final typed copy in order to detect such errors before the various copies of the report are distributed. In this instance, however, since Bob Ellis is located on the West Coast and since it seemed that there would probably be a considerable delay before he would have an opportunity to proofread the report, the various copies were distributed immediately after final typing.

We should much appreciate your having the above corrections made in the Fish Division and Education-Game copies of this report. A copy of this letter is going to the Rifle River station for their use in making the necessary corrections.

P H Eschmeyer

PHE:gec
cc: Rifle River