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EXPERIMENTAL STUDIES ON EFFECTIVENESS OF THE PREDATORY LEECH, *GLOSSIPHONIA WEBERI* IN THE BIOLOGICAL CONTROL OF VECTOR SNAIL *LYMNAEA LUTEOLA*

S. K. RAUT*
Zoological Survey of India, Mollusca Section, 8, Lindsay Street Calcutta 700016, INDIA.

AND

N. C. NANDI
Zoological Survey of India, Kakdwip Field Station, Kakdwip-743347, 24-Parganas, West Bengal, INDIA.

ABSTRACT

Effectiveness of predation of the leech, *Glossiphonia weberi*, in the biological control of vector snail, *Lymnaea luteola* has been studied experimentally in the laboratory. Several weekly courses of experiments were conducted with leeches of different size groups by supplying snails of different shell length, together or in various combinations. The results indicate that the leeches preferred juvenile, snails of 3-5 mm size group. A size selective predation was found. In an average, a single 12-15 mm leech killed 1.46 ± 0.09 snails of 3-5 mm, 1.17 ± 0.08 snails of 6-8 mm and 0.14 ± 0.05 snails of 9-12 mm size groups. Groups of leeches proportionately kill more prey of 9-12 mm size groups was found to be statistically significant. An assessment has been made on the efficiency of predation of *G. weberi* as biological control agent.

INTRODUCTION

Although there are many potential predators and parasites of snails (Cooke, 1895; Pelseneer, 1926; Fischer, 1951; Chernin *et al.*, 1956a, b, 1960; Michelson, 1957, 1961, 1963; Malek, 1962; Berg, 1964; Jordon and Webbe, 1969; Abdallah and Tawfik, 1972; Lim and Heynemann, 1972), the part played by predators in prey population regulation has long been debated by ecologists. The fact that considerable disagreement remains is sufficient evidence of the need for adequate assessment of the effectiveness of such biological control agents. In fact, the properties of animals have neither been sufficiently well known before hand to forecast the degree of success, nor have studies after the introduction revealed the mechanisms involved. The interactions that operate between predator and prey populations have largely been ignored and measurements necessary to test the effectiveness of such biotic agents remain unmade. Having established that *Glossiphonia weberi* is predator of snails (Raut and Nandi, 1980), laboratory studies were conducted to evaluate the

*Present address : Zoology Deptt., Calcutta University, 35, B. C. Road, Calcutta-19

effectiveness of leech predation on *Lymnaea luteola* as means of biological control. A study of the prey preferences, number of prey eaten, and the possibility that groups of leeches may proportionately kill more prey has been communicated.

Materials and Methods

The leeches *Glossiphonia weberi* (Blanchard), were collected initially from the Museum pond attached to Indian Museum, Calcutta. Subsequently they were cultured in the laboratory to obtain various size groups.

The snails (*Lymnaea luteola*) were also collected from the same pond and reared in the laboratory so as to maintain a ready stock of various size groups during the course of experiments. The rearing and maintenance of both predator (leech) and prey (snail) were made in enamel trays and polythene buckets. The predators were supplied with prey as food while snails were supplied with lettuce leaves regularly as their food.

Experiments were carried out in transparent plastic containers, specimen jars and polythene buckets containing an equal quantity of water for each set of experiments. The experiments were initiated by supplying a fixed number of snails i. e. higher than what may be killed per day by the leech/leeches even for a particular size group separately. The snails killed per day were counted group-wise during the course of experiments and replaced daily to supply a constant number of prey. Most of the experiments were conducted with 12-15 mm size leeches at which stage they could act as predators (Raut and Nandi, 1980). The leeches were not normally observed to die during experiment and in case death occurred, they were also substituted from the stock.

For convenience the leeches were classified into 4 different categories viz., i) lower size group, 12-15 mm ; ii) middle size group, 16-20 mm ; iii) upper size group, 21-25 mm and iv) older size group, 26 mm and above. The snails were also groupped into i) juvenile, 3-5 mm ; ii) intermediate, 6-8 mm and iii) adult, 9-12 mm on the basis of their shell length. The experiments were categorized as either single predator experiments or multiple predator experiments and designed as follows :

I. *Single predator experiments* : With a single leech of 12-15 mm

Group A. Experiments consisted of 5 replicates and carried out in 3 specimen jars by suppling 3-5 mm, 6-8 mm and 9-12 mm size groups of prey snils separately.

Group B. Experiments carried out in 2 specimen jars by supplying all the 3 size groups of snails together in a proportion of 30 snails a day for the 2 sets.

IIa. *Multiple predator experiments* : With 10 leeches of 12-15 mm size.

Group C. Experiments consisted of 3 sets by separately supplying prey snails of one size group only.

Group D. Experiments consisted of 3 sets by supplying prey snails of 2 size groups together in various combinations.

IIb. *Multiple predator and Mixed prey experiments* : With 10 leeches of 12-15 mm, 16-20 mm, 21-25 mm and 26 mm and above size groups separately.

Group E. Experiments consisted of 4 sets for the 4 size groups of snails together.

OBSERVATIONS

Experiments on predation potentials :

I. *Single predator experiments* : With a single leech of 12-15 mm

Group A Experiments with predator (12-15mm leech) by supplying prey snails of 1 size group only.

Experiments AI-AIII : Three sets (AI-AIII) with 5 replicates for each set, were designed wherein a constant supply of 10 snails was maintained during the course of experiments viz. 10 snails of 3-5 mm size group (expt. AI), 10 snails of 6-8 mm size group (expt. AII) and 10 snails of 9-12 mm size group (expt. AIII).

Results : The single 12-15 mm sized leech, on an average, killed a total of 51 snails of 3-5 mm size in 5 replicates under AI experiment i. e. 10.2 snails weekly or 1.46±0.09 snails per day per leech with the range 1.0-1.8 snails per day per leech (Table 1). While the total kills were 41 snails of 6-8mm and only 5 snails of 9-12mm. The averages of range and mean per day per leech out of the total kill were 0.8-1.6 with a mean of 1.17 ±0.08 snails of 6-8mm (Table 1) and 0.0-0.6 with a mean of 0.14±0.05 snails of 9-12mm (Table 1) respectively. The differcaes in the rate of predation between 3-5mm and 6-8mm was not statistically significant when Wilcoxon Sign test was applied. But the differences in the rate of predation between 3-5mm and 9-12mm and also between 6-8mm and 9-12mm were significant in both the cases. The mean intervals between predation by the leeches were calculated as 17 hours 8 minutes, 20 hours 29 minutes and 168 hours for 3-5mm, 6-8mm and 9-12mm size groups of snails respectively (Figs. 1a-1c).

TABLE 1. Rate of predation (based on 5 replicates) by a single 12-15 mm leech by a constant supply of 10 snails of 3-5 mm, 6-8 mm size groups separately.

Expt. No.	Size group of snails (mm)	Data pooled (from 5 replicates)	No. of snails killed in a week 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	Total kill Weekly	Daily ± SE
AI	3-5	Range	1-3	0-2	0-2	1-2	0-3	0-2	1-2		
		Mean	1.8	1.4	1.2	1.6	1.6	1.0	1.6		
		Total	9	7	6	8	8	5	8	51	1.46±0.09
AII	6-8	Range	1-2	0-2	0-2	0-1	0-2	0-2	0-2		
		Mean	1.6	1.0	1.2	0.8	1.4	1.2	1.0		
		Total	8	5	6	4	7	6	5	41	1.17±0.08
AIII	9-12	Range	0-1	0	0	0-1	0-1	0	0		
		Mean	0.6	0	0	0.2	0.2	0	0		
		Total	3	0	0	1	1	0	0	5	0.14±0.05

Group B. Experiments with predator (12-15 mm leech) by supplying snails of all the 3 size groups together.

Experiments BI and BII : A single 12-15mm leech was offered a constant supply of 30 snails, 10 from each of the 3-5mm, 6-8mm and 9-12mm size groups in expt. BI and by doubling the number of prey snails i. e. 60 snails, 20 from each of the 3 size groups in expt. BII.

Results : In expt. BI, the leech killed a total of 8 snails in a week of which 6 snails from 3-5mm, 2 from 6-8mm and none from 9-12mm size group of snail. The day-wise predations as observed in expts. BI and BII

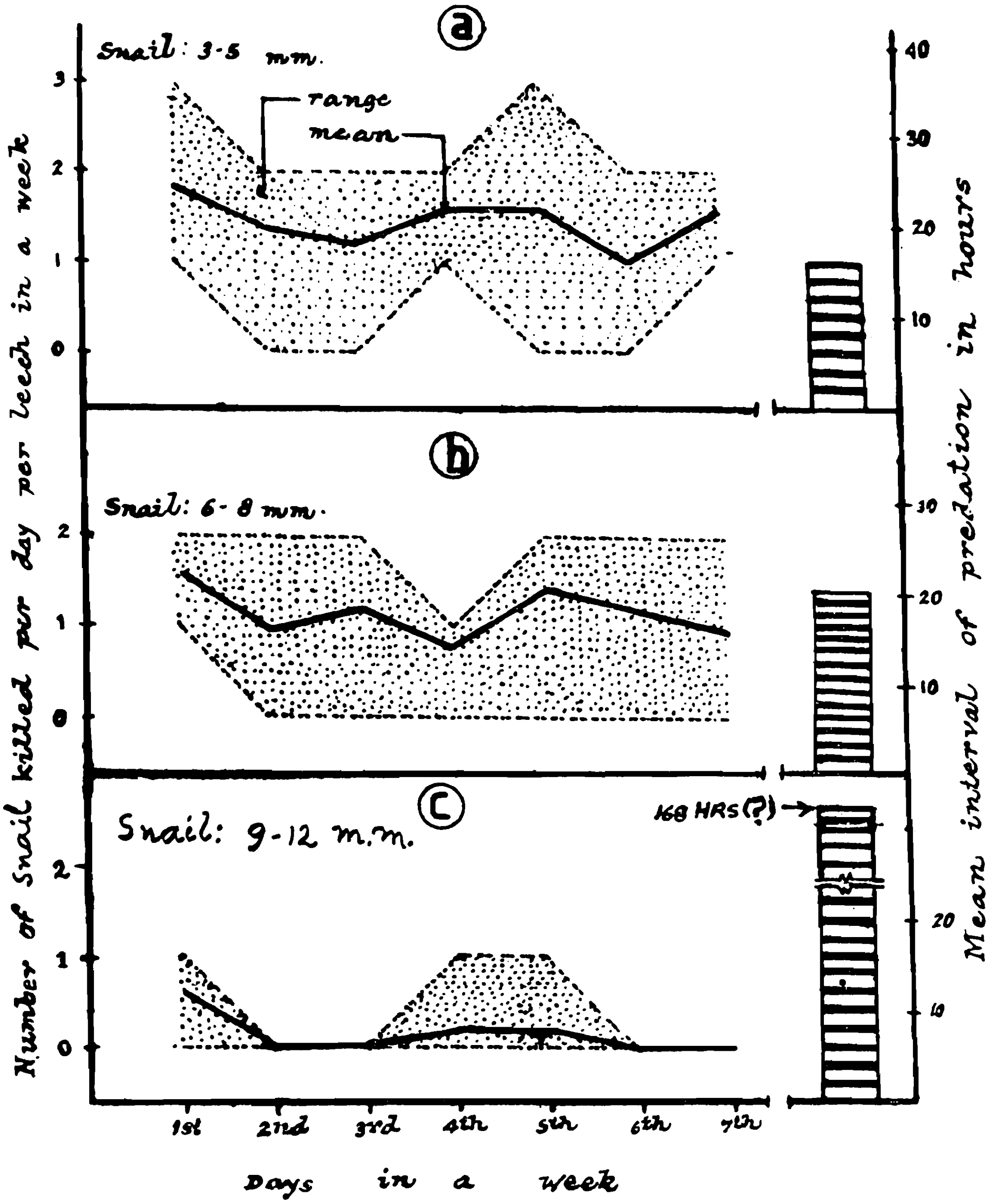

FIG. 1

Fig. 1. Rate of predation (per day per leech) and mean interval of predation (in hours) by a single 12-15 mm leech on snails of 3-5 mm (a), 6-8 mm (b) and 9-12 mm (c) size groups.

TABLE 2. Effect of prey population on predation of a single 12-15 mm leech in a week on snails of 3-5 mm, 6-8 mm and 9-12 mm size groups supplied together in two different proportions.

Expt. No.	Size group of snail (mm)	No. of snails supplied/day	No. of snail killed in a week 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	Total kill Weekly	Daily ± SE
	3-5	10	2	1	0	2	0	0	1	6	0.86±0.03
BI	6-8	10	0	0	1	0	0	1	0	2	0.28±0.14
	9-12	10	0	0	0	0	0	0	0	0	—
	3-5	20	2	0	1	0	0	1	2	6	0.86±0.03
BII	6-8	20	0	0	0	1	0	0	0	1	0.14
	9-12	20	0	0	0	0	0	0	0	0	—

TABLE 3. Predation potentials by 10 leeches of 12-15 mm size group of snails of 3-5 mm, 6-8 mm and 9-12 mm size groups supplied separately in a week.

Expt. No.	Size group of snail (mm)	No. of snails supplied	No. of snails killed (consumed) in a week 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	Total Killed	Consumed
CI	3-5	40	16 (10)	16 (8)	13 (10)	13 (9)	13 (8)	15 (10)	15 (10)	106	65
CII	6-8	40	17 (9)	15 (7)	14 (7)	14 (9)	14 (6)	17 (6)	15 (9)	88	53
CIII	9-12	40	10 (5)	6 (3)	5 (2)	6 (4)	6 (2)	7 (3)	6 (3)	46	22

in a week on the snails of different size groups supplied together in 2 proportions i. e. 30 and 60 snails constantly, are shown in Table 2. The date-wise kill though varied, the amount of total kill per week was more or less alike.

Comments : A preference for snails in the 3-5 mm size group by leeches of 12-15 mm size is shown in Table 1. Though the leeches (12-15 mm size) occasionally kill 9-12 mm snails when no alternate prey exist, but they seem not to prey on snails in the 9-12 mm size group when smaller snails are present i.e. 3-5 mm and 6-8 mm as may be apparent from Group B experiments (Table 2). And these leeches appear to exhibit relatively the same amount of predation per week even if the number of snails supplied per day has been doubled from 10 to 20.

IIa. *Multiple predators experiments* : With 10 leeches of 12-15 mm size group.

Group. C. Experiments with predators (12-15 mm leeches) by separately supplying prey snails of 1 size group only.

Experiments CI-CIII : Three experiments (CI-CIII) were conducted, each with 10 leeches of 12-15 mm size group, in which a constant supply of prey population (40 snails daily in each experiment) was maintained. The experiments CI, CII and CIII were with 40 snails of 3-5 mm, 6-8 mm and 9-12 mm size groups respectively.

Results : In a week the leeches killed 106, 88 and 46 but consumed 65, 53 and 22 snails only in experiments CI, CII and CIII respectively. The daily kill recorded 13-16

(15.14 ± 0.56), 14-17 (12.57 ± 1.0) and 5-10 (6.57 ± 0.52) respectively in CI, CII and CIII. The frequency of predation has been shown in Table 3.

Group D. Experiments with predators (12-15mm leeches) by supplying prey snails of 2 different size groups together.

Experiments DI-DIII. Three experiments were performed, each with 10 leeches of 12-15mm size group, in which 40 snails of 2 different size groups in various combinations, each group consisting of 20 snails, were kept as constant supply daily. The experiment DI consisted of 20 snails of 3-5 mm and 20 snails of 6-8 mm size group. While experiment DII comprized of 20 snails of 3-5 mm and 20 snails of 9-12 mm and experiment DIII with the same number of snails from 6-8 mm and 9-12 mm size groups.

Results : In expt. DI, 10 leeches of 12-15 mm size in a week, killed a total of 101 snails, 77 (76.2%) from 3-5 mm size group and 24 (23.8%) from 6-8 mm size group. While a total of 85 snails, comprising 73 (85.9%) snails from 3-5 mm size group and 12 (14.1%) from 9-12 mm size group, and 89 snails, 68 (76.4%) from 6-8 mm and 21 (23.6%) from 9-12 mm size groups were killed in expts. DII and DIII respectively. Ten leeches in a week consumed 67 (52 from 3-5 mm and 15 from 6-8 mm size group), 60 (54 from 3-5 mm and 6 from 9-12 mm size group) and 51 (45 from 6-8 mm and 6 from 9-12 mm size group) snails respectively in expts. DI, DII and DIII. The number of snails killed daily has been shown in Table 4. The differences in the rate of predation of 12-15 mm leeches between any two of the 3 snail-groups (3-5 mm, 6-8 mm and 9-12 mm) were statistically significant.

Comments : From the above experiments viz., CI-CIII and DI-DIII, it can be stated that the juvenile (3-5 mm) snails are preferred by 12-15 mm leeches as for the single predator experiments, the predation on snails of the adult (9-12 mm) group was comparatively less, even less than a half, than that of juvenile group.

IIb. *Multiple predators and Mixed prey experiments* : With 10 leeches of 4 different size groups separately.

Group E. Experiments with 4 different size groups of predators (12-15 mm, 16-20 mm, 21-25 mm and 26 mm and above size groups of leeches) by supplying prey snails of all the 3 size groups together.

TABLE 4. Predation potentials of 10 leeches (12-15 mm) snails of two size groups supplied together in a week.

Expt. No.	Size group of snail (mm)	No. of snails supplied	No. of snails killed (consumed) in a week: 1ts day	2nd day	3rd day	4th day	5th day	6th day	7th day	Total Killed	Total Consumed
DI	3-5	20	12 (8)	10 (5)	10 (8)	10 (6)	11 (8)	12 (8)	12 (9)	77	52
	6-8	20	4 (2)	6 (4)	3 (2)	3 (3)	2 (1)	3 (1)	3 (2)	24	15
DII	3-5	20	12 (8)	9 (6)	10 (8)	9 (8)	10 (8)	10 (7)	11 (9)	73	54
	9-12	20	4 (1)	2 (1)	3 (2)	1 (1)	0 (0)	0 (0)	2 (1)	12	6
DIII	6-8	20	11 (6)	9 (5)	9 (6)	11 (8)	11 (8)	8 (6)	9 (6)	68	45
	9-12	20	8 (3)	4 (0)	3 (1)	2 (0)	1 (0)	0 (0)	3 (1)	21	6

Experiments EI-EIV. Four experiments, EI-EIV were designed for the 4 size groups of leeches viz., 12-15 mm size group (expt.EI), 16-20 mm size group (expt. EII), 21-25 mm size group (expt.EIII) and 26 mm and above size group (expt.EIV). In each experiment, 10 leeches were given a constant supply of 60 snails of 3 size groups, 20 snails from each of the 3 size groups for a period of one week,

Results : The 10 leeches of 12-15 mm size group in expt.EI killed a total of the 88 snalis ; 58 (65.8%) from 3-5 mm, 20 (22.6%) from 6-8 mm and 10 (11.6%) from 9-12 mm size groups. Of the total kill, the leeches consumed 65 snails comprising of 48, 12 and 4 snails from the aforesaid groups respectively. In experiment EII, 10 leeches of 16-20 mm size group killed a total of 80 snails 46 (57.5%), 24 (30%) and 10 (12.5%) snails from juvenile (3-5 mm), intermediate (6-8 mm) and adult (9-12 mm) groups respectively. However, they consumed 34, 21 and 5 snails, in all 60 snails, respectively from juvenile to adult group. In experiment EIII, 10 leeches of 21-25 mm size group killed 84 snails in proportion of 32 (38.1%) juvenile, 33 (38.1%) intermediate and 19 (22.5%) adult group and they consumed 22, 21 and 14 snails respectively from the three size groups. While in experiment EIV, 10 leeches of 26 mm and above size group killed, in all, 74 snails which constituted of 21 (28.3%) juvenile, 38 (51.3%) intermediate and 15 (20.2%) adult snails. They could consume a total of 53 snails, 16 from juvenile, 26 from intermediate and 11 from adult groups for a period of a week. The daily predation potentials of these 10 predator leeches of 4 different size groups are shown in Table 5. When the leeches were supplied in group the kill of 3-5 mm size of snails was highest by 12-15 mm and 16-20 mm size of leeches. The kill by 21-25 mm size of leeches was significantly higher in 3-5 mm than 9-12 mm size of snails. The other differences among snails in this size of

TABLE 5. Predation potentials of 4 different size groups of leeches on 3 size groups of snails supplied together in a week.

Expt. No.	Size group of leech (mm)	Size group of snail (mm)	No. of snails supplied	No. of snails killed (consumed) in a week: 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	Total: Killed	Total: Consumed	Daily: Killed ±SE	Daily: Consumed ±SE
		3-5	20	11 (9)	8 (7)	8 (6)	9 (8)	7 (6)	6 (5)	9 (7)	58	48	8.28±0.56	6.86±0.47
EI	12-15	6-8	20	2 (1)	3 (1)	4 (2)	2 (1)	4 (2)	2 (0)	3 (3)	20	12	2.86±0.31	1.71±0.26
		9-12	20	1 (0)	0 (0)	2 (1)	1 (0)	2 (1)	2 (1)	2 (1)	10	4	1.43±0.18	0.57±0.32
		3-5	20	7 (5)	6 (4)	5 (3)	8 (6)	6 (5)	6 (5)	8 (6)	46	34	6.57±0.39	4.86±0.37
EII	16-20	6-8	20	4 (3)	4 (4)	3 (2)	3 (3)	3 (3)	3 (2)	4 (4)	24	21	3.43±0.19	3.0±0.32
		9-12	20	2 (1)	1 (1)	2 (1)	1 (0)	2 (1)	0 (0)	2 (1)	10	5	1.43±0.18	0.71±0.24
		3-5	20	5 (4)	3 (2)	4 (3)	4 (2)	5 (4)	6 (4)	5 (3)	32	22	4.56±0.34	3.14±0.49
EIII	21-25	6-8	20	5 (3)	6 (4)	6 (4)	5 (4)	6 (4)	3 (1)	2 (1)	33	21	4.71±0.56	3.0±0.49
		9-12	20	3 (2)	3 (2)	2 (2)	3 (2)	1 (1)	4 (2)	3 (3)	19	14	2.71±0.38	2.0±0.20
		3-5	20	2 (2)	2 (1)	2 (2)	2 (1)	4 (3)	5 (3)	4 (4)	21	16	3.00±0.45	2.28±0.39
EIV	26+	6-8	20	7 (5)	5 (3)	4 (3)	6 (4)	4 (4)	7 (5)	5 (2)	38	26	5.43±0.45	3.71±0.39
		9-12	20	2 (1)	2 (2)	3 (2)	2 (2)	2 (1)	1 (1)	3 (2)	15	11	2.14±0.24	1.57±0.19

leech were not significant. The leeches of 26 mm and above size kill more of 6-8 mm size of snails than other snails. The difference between 3-5 mm and 9-12 mm snails was not significant.

Comments : The weekly predation and consumption rates of 4 different size groups, on prey snails in terms of snail killed and snail consumed have been presented in Figs. 2 and 3. The number of snails killed and consumed from juvenile group is inversely related with the size of the predator. But the predation rate shows positive correlation with the size groups of predators. While the adult snails (9-12 mm) were relatively substantially killed by the 2 older size groups than the 2 lower size groups (Fig. 2). The preference of predation shows a declining trend with snail size so far as the 2 lower size groups (12-15 mm and 16-20 mm) of leeches are concerned. However, the leeches of 21-25 mm size groups showed a different trend of predation by showing almost equal preference for the lower size groups of snails along with relatively higher predation of adult snails. While older predator group, 26 mm and above, sets another trend of predation wherein more than half of the total kill, 38 (51.3%) out of 74, was from intermediate group i.e. 6-8 mm snails (Fig. 3).

Assessment of the efficiency of predation as biological control agent :

Biological control in the economic senss obtains when suppressive effect of natural enemy accounts for the difference between economic and non-economic prey or pest populations. A natural enemy can accomplish permanent biological control only if it has evolved morphological and behavioural adaptations to its host or prey and other components of its life system by means of which it can consistently find, attack and suppress its host's or prey's populations and maintain them at sub-economic densities, and which premit permanent residency with the

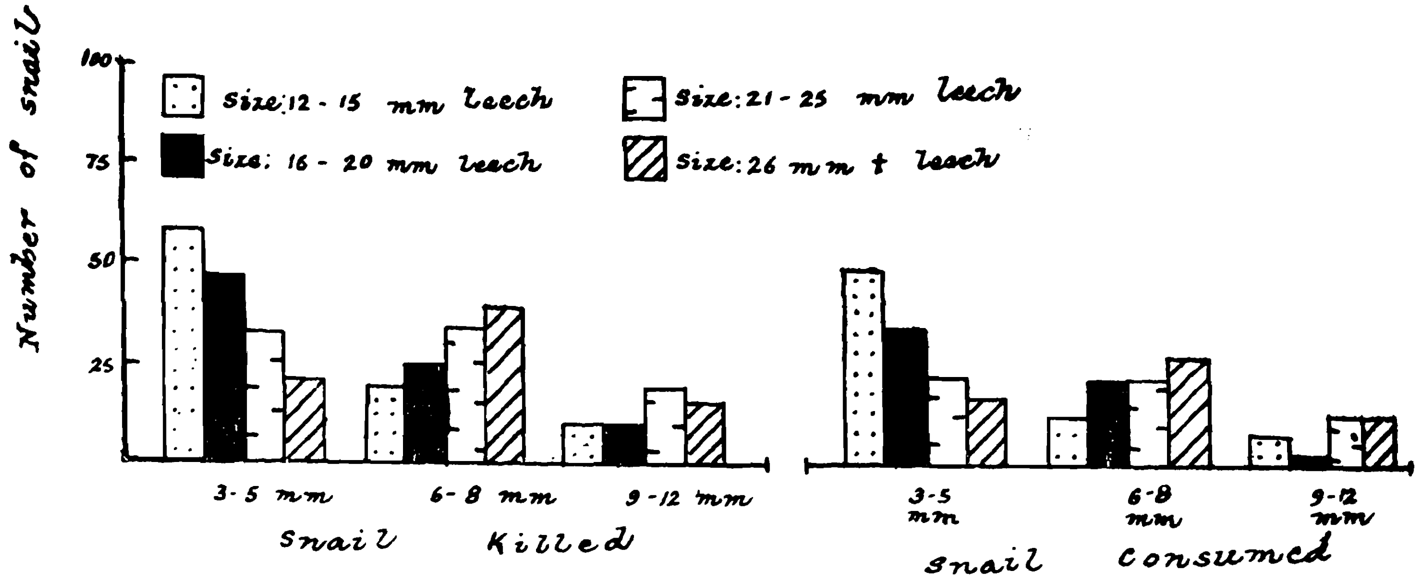

FIG. 2

Fig. 2. Effect and preference of predation (killed/consumed) of 10 leeches of 4 different size groups on prey-snails of 3 size groups in a week.

prey or pest (*vide* Huffaker, 1971a, b). Huffaker *et al.* (1976) summarized the desired characteristics for achieving self-sustaining (permanent) economic control of a pest as follows : (1) fitness and adaptability to the various conditions of the host and host's environment, (2) searching capacity, (3) power of increase relative to that of its host or prey, (4) host or prey specificity, or potential for development of host or prey preference, (5) synchronization with the host or prey, and the habitat, (6) density dependent performance relative to either or both the hosts or prey's density (functionally, reproductively, or aggregatively) and its own density (e. g., mutual interference), (7) detection of responsiveness to the condition of the host (stage and whether parasitized or not), and (8) efficient competitiveness with other natural enemies.

Many of the above characteristics of predator-prey systems may be attributable to the leech, *Glossiphonia weberi* to declare them as effective agents for biological control of snail populations of the species *Lymnaea luteola* which has widely been incriminated to act as vectors for various snail-borne diseases.

Attempts have been made to evaluate the predation potential, predation interval, prey preference, predator-prey relationship, consumption capacity and effect of predator-prey densities in the laboratory. In so far as predation potential, interval time, prey preference and consumption are concerned the glossiphonid leech (*G. weberi*) preferred the juvenile snails.

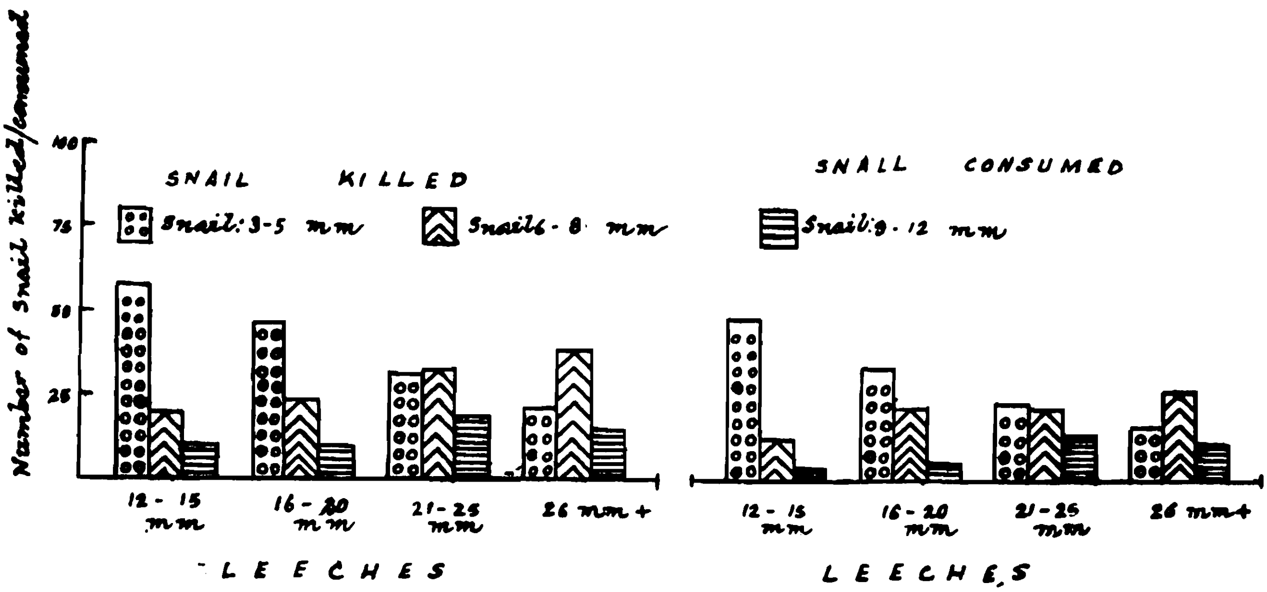

FIG. 3

Fig. 3. Weekly predation and consumption rate of 10 leeches of 4 different size groups on prey-snails of 3 different size groups.

The comparative account of predation and consumption rate of 12-15 mm size leeches of different size groups of snails (Table 6) reveal that they show a higher potential of both predation and consumption by a batch of leeches than by a single leech (Fig. 4). In an average, 7 leeches in a day killed more than that by a single leech in a week from any size group of snails showing a proportion of 10.6 *vs.* 9.0 snails of 3-5 mm size group,

TABLE 6. Predation of single vs. multiple leech (10 leeches) on 3 different snail groups supplied separately in a week.

No. of leech	Size group of snail (mm)	No. of snail supplied	No. of snails killed (consumed) in a week 1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	Total Killed	Total Consumed	Daily Killed ±SE	Daily Consumed ±SE
	3-5	10	2 (2)	1 (1)	0 (0)	2 (1)	0 (0)	2 (1)	2 (1)	9	6	1.28±0.21	0.85+0.17
I	6-8	10	2 (2)	0 (0)	2 (1)	0 (0)	2 (1)	1 (1)	0 (0)	7	5	1.0±0.20	0.71±0.19
	9-12	10	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1	1	0.14±0.12	0.14±0.12
	3-5	40	16(10)	16(8)	13(10)	13(9)	13(8)	15(10)	15(10)	106	65	15.14±0.56	9.28±0.40
10	6-8	40	17(9)	15(7)	14(7)	14(9)	14(6)	17(6)	15(9)	88	53	12.57±1.00	7.57±0.49
	9-12	40	10 (5)	6 (3)	5 (2)	6 (4)	6 (2)	7 (3)	6 (3)	46	22	6.57±0.52	3.14±0.37

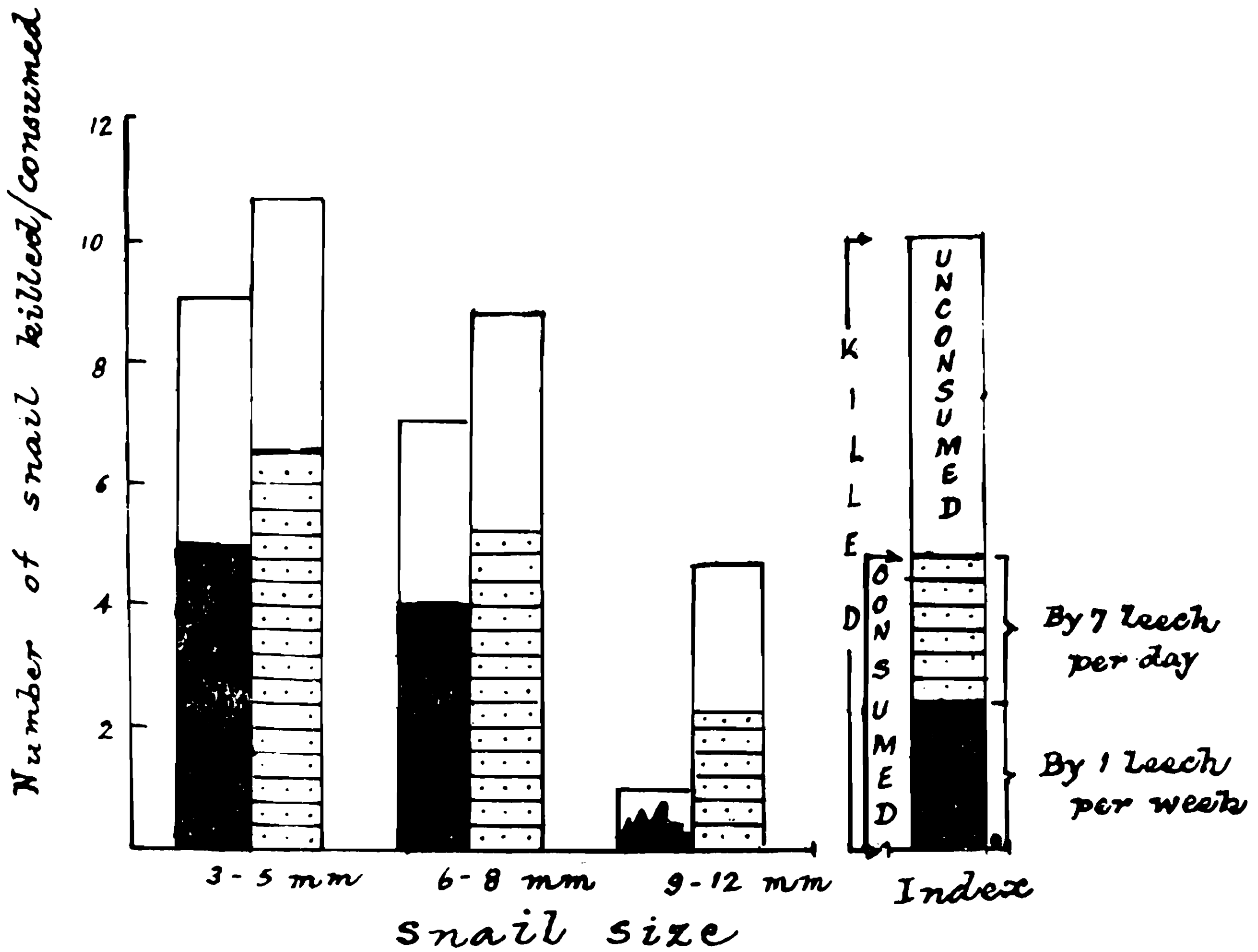

FIG. 4

Fig. 4. Comparative predation and consumption capacity of a single 12-15 mm leech in a week *versus* 7 leeches (12-15 mm) a day on 3 different size groups of snails.

8.8 *vs.* 7.0 snails of 6-8 mm size group and 4.6 *vs.* 1.0 snails of 9-12 mm size group. Similarly the estimated consumption rates of 7 leeches per day *vs.* 1 leech per week are 6.5 *vs.* 5.0 snails of 3-5 mm size, 5.3 *vs.* 4.0 snails of 6-8 mm size and 2.2 *vs.* 1.0 (in partim) of 9-12 mm size. This indicates that predation may be increased with the increase in the number of predators. By applying Wilcoxon Sign test it is seen that the predation of single vs. multiple leech (predator) was not significant for both 3-5 mm and 6-8 mm size groups. But it showed statistically significant result for 9-12 mm size group of snails. It implies that groups of leeches may proportionately kill more prey than single leeches.

From the experiments as conducted above weekly predation and consumption rate of 10 leeches of 12-15 mm size group on prey snails supplied group-wise separately and in various combination with other groups are shown in Fig. 5. The predation rate, if we consider the total kill in number of snails, is always higher when prey snails are supplied separately than when the number of total kill of the different size groups offered in combination with other group(s). However, the consumption rate slightly oscillates when offered prey snails of different size groups separately (Fig. 5). This oscillation in the consumption rate does not follow any definite pattern and might relate to the satiation of the predator under experiments.

If we consider all the 4 experiments of Group E with 4 different size groups of leeches together, the total kill of leeches in a week would be 326 snails (Table. 7).

Thus, in a stable condition, where all the size groups of leeches and snails are present, one leech, in an average, may kill 1.46 snails a day. But this will require field trial and

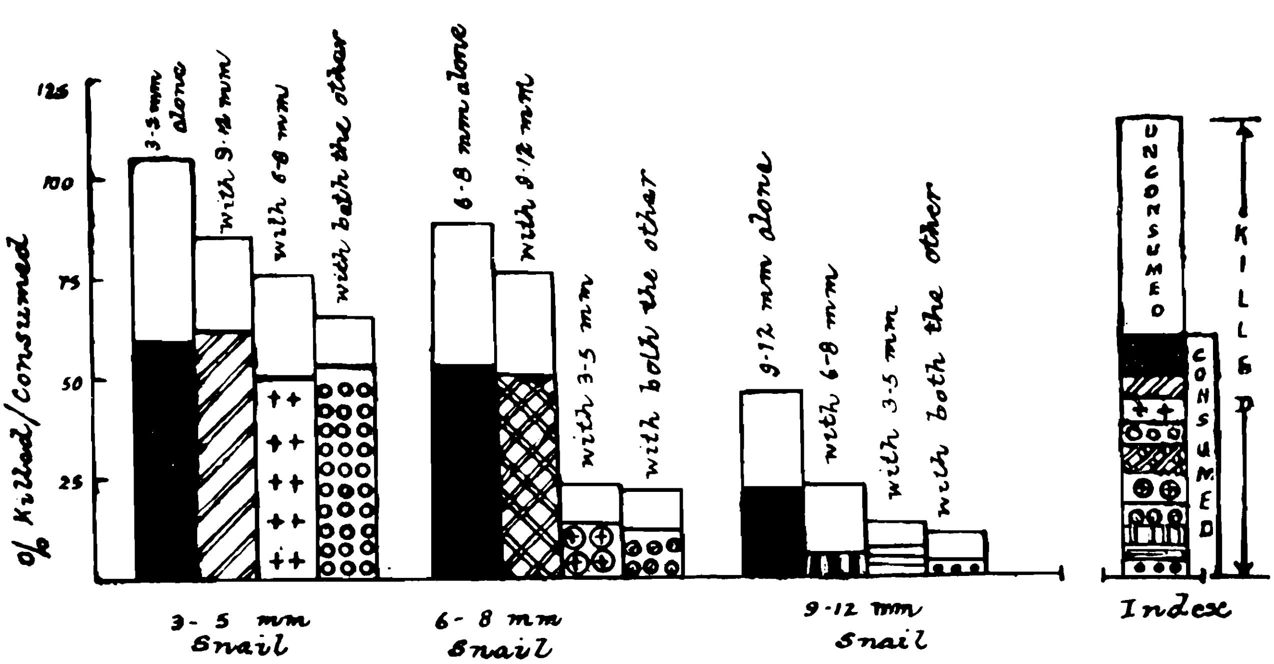

FIG. 5

Fig. 5. Weekly predation and consumption capability of 10 leeches 12-15 mm size groups on prey-snails of 3 different size groups supplied separately or in combination with other size group (s).

assessment of efficiency under field condition as search time, satiation, and various other physical factors of the environment may dampen the process of predation in the field. Still, by considering a potentiality half than that (1.46 snails per leech per day) observed in the laboratory i. e. 0.73 snails per leech per day, a reduction of snail population to a half in a week could be achieved releasing predators at one-tenth the population of snails. For example, more than half of the population of 1000 snails may be killed in a week by 100 (one-tenth of the prey) predators, and they are able to kill $100 \times 0.73 \times 7 = 511$ snails a week. The complete biological control commonly means a density of 1/25 or 1/100 of the pest without the controlling agents.

Discussion

Since the chemical control of medically important snails has not been successful, attention was given to biological control by a number of workers (Nagano, 1927; Bequaert, 1928; Mozely, 1939, 1951; McMullen, 1952) but little detail is known.

Studies on the predation potential of the leech, *Glossiphonia weberi* suggest that they can be employed effectively in regulating the snail (*L. luteola*) populations though the leeches of 4 different size groups killed a varying number of snails of 3 size groups. Since size selective predation was found and since multiple leeches yield better result of predation than single leeches ANOVA was made to study the influence of the size of the predators and preys, and also the combinations of predator and preys (Table 8). It has been revealed from the Analysis of variance (ANOVA) that there is significant interaction between leeches and snails. From the calculation it is clear that the influence of the size of predator and preys were not significant.

TABLE 7. Total predation of leeches of 4 different size groups in a week.

Predator groups (mm)	Number of Predator	Size group of snail killed per week 3-5 mm	6-8 mm	9-12 mm	Total
12-15	10	58	20	10	88
16-20	10	46	24	10	80
21-25	10	32	33	19	84
26 +	10	21	38	15	74
Total =	40 leeches	157	115	54	326

TABLE 8. Analysis of variance (ANOVA) of data on predation of 4 different size groups of leeches on 3 size groups of snails.

Source	D. F.	S. S.	M. S.	F.
L = Leech	3	45.4334	15.1445 (N. S.)	1 (N. S.)
S = Snail	2	2886.9060	1443.4530 (N. S.)	4.84 (N. S)
L X S	6	1789.3732	298.2288*	13.19*
Error	72	1628.4046	22.6167	—

N. S. Not significant; Significant at 1% level.

From the experiments stated above, it appears that the juvenile snails (3-5mm) are highly vulnerable to the leeches. This is in agreement with the findings of Chernin *et al.* (1956b) on the predaceous action of the leeches *Helobdella fusca* on the snail *Australorbis glabratus.* Experimental results revealed that the leeches are more effetive in killing the snails when they occur in groups, and a few predatory leeches collectively would be able to capture a prey-snail of larger size (9-12mm). Further more, it has also been found that the leeches proportionately killed more prey than what they consumed. It might be due to the preference for a selective portion of flesh of the prey and/or the effect of group predation. This is because of the fact that larger snails are attacked by 2-3 leeches whereas one predator one prey is the rule for smaller ones (Raut and Nandi, 1980). This particular point is especially emphasized for statistical significant result obtained for 9-12mm snails. This phenomenon is of greatest interest from the view point of augmentation of natural enemy action that we have much power to manipulate.

Biological control is recognized as a substantial means of pest control even by those who deny that natural enemy action is truly regulating in nature. Coutinho and Coutinho (1968) have assumed in their model that larvae of helminths, including schistostomes, are important in regulating snil populations because they decrease survival and fertility rates of snails. Lie *et al.* (1971) found that the introduction of echinostome eggs into a small pond was followed by a considerable reduction in snail popula ion due to parasitic castration and high mortality among infected snails. However the selective pressures in such a system would favour the development of resistance in the snail population and a decrease in parasite pathogenecity.

Ewers and Rose (1966) and Ewers (1967) have also speculated that snail populations might be genetically polymorphic with respect to resistance to attack by parasites and also to other inimical forces in the environment. This hypothesis appears to be supported by their observations on the littoral prosobranch *Velacumantus australis*, as individuals that are resistant to parasites are more susceptible to predation. However, the possibility of controlling snails (*L. luteola*) by leech (*G. weberi*) in their natural habitat may prove to be encouraging. It may be mentioned here that Chernin *et al.* (1956b) were successful in controlling the growth of *A. glabratus* population through the predaceous action of glossiphonid leeches. Since the present species is a potential predator and a member of the family Glossiphonidae, which habitually and almost exclusively feed upon aquatic snails, one would expect a considerable degree of success in the field too. Moore (1901) also suggested the possibility of control of the schistosome intermediate host-snails through these agents. However, we are to know a great deal more from field studies on the ecology of the predators and prey so that we may more reliably use this glossiphonid leeches in vector control programmes, one of the important goals of medical malacology.

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