TECHNICAL MONOGRAPH No. 11

PESTIFEROUS LAND SNAILS OF INDIA

by

S. K. RAUT AND K. C. GHOSE

ZOOLOGICAL SURVEY OF INDIA 1916

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सत्यमेव जयते

Edited by the Director, Zoological Survey of India, Calcutta

1984

Published in September, 1984

PRICE :	**Inland :**	**Rs. 70.00**
	Foreign :	**£ 8.50 $ 14.00**

PRINTED IN INDIA BY THE BANI PRESS, 16, HEMENDRA SEN STREET, CALCUTTA-700 006 AND PUBLISHED BY THE DIRECTOR, ZOOLOGICAL SURVEY OF INDIA, CALCUTTA 700 012

ZOOLOGICAL SURVEY OF INDIA

TECHNICAL MONOGRAPH

No. 11 1984 Pages 1—151

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Introduction

Over the past few decades, there has been a steadily increasing awareness of the danger of the pestiferous snails in India. There are well over 1500 species of land snails occurring in this country. Of those, 7 species viz. *Achatina* (*Lissachatina*) *fulica fulica*, *Opeas gracile*, *Macrochlamys indica*, *Ariophanta solata*, *Cryptozona* (*Nilgiria*) *semirugata*, *Cryptozona* (*Xestina*) *bistrialis* and *Bensonia monticola* are known to cause damage to agricultural and horticultural gardens in India to a greater or lesser extent. The giant African snail, *Achatina fulica*, though not an endemic species, tops the list of serious mollusc pests. Contrast to this, the indigenous species are mostly localized in distribution and cause a little damage to agricultural crops.

A number of scientific discussions and seminers have been staged in India on the pestiferous snails sponsored by the Indian Council of Agricultural Research (ICAR), Indian Agricultural Research Institute (IARI) and other Government agencies and academic bodies. The funding bodies sponsored by the Government of India are financing a number of research projects that led the way in the programme of delving into some of the deeper problems associated with the economics of land snails particularly of the giant African snail, *Achatina fulica*.

The monograph is aimed at providing an up-to-date information on the land snails which are considered as pests in India. Valuable information on anatomy, microanatomy, physiology and biochemistry, particularly of the enzyme systems of *Achatina* and to a certain degree on *Macrochlamys* though available, have been kept out of the purview of the monograph. We have restricted ourselves to bionomics, distribution, population, aestivation, reproduction and economic status of the pest species. A comprehenssive account on the natural enemies particularly the predators and parasites of the pests have been incorporated. The present state of control measures, both chemical and biological, have been thoroughly discussed with particular reference to the giant African land snail.

Literature Review

Though there are as much as 7 species of pestiferous land snails in India, studies are mostly restricted to the anatomy, microanatomy and physiology of the introduced species *Achatina fulica*. Ghose (1959, 1960, 1961, 1962a, b, c, d, e, f, 1963a, b, c, d, e, f, 1964, 1966) extensively studied *A. fulica* and made some aspects of *Macrochlamys indica*. Contrast to this information on other pest species is totally lacking.

Knowledge on the distribution of Indian land snails is restricted to Godwin-Austen (1883) and Gude (1914).

Behavioural studies on the mating of land pulmonates viz. *Helix* (Tryon, 1882 ; Meisenheimer, 1907, 1912 ; Basinger, 1931 ; Ingram, 1946 ; Frömming, 1954 ; Herzberg and Herzberg, 19c2), *Arion* (Kunkel, 1900) and *Achatina* (Weel, 1948a, b, c, 1949 ; Breckenridge and Fallil, 1973) are on record. Webb (1942, 1947, 1950, 1951a, b, 1952, 1968a, b, c, d) published a detailed account of the sexology in some pulmonates. Observations on the sexual behaviour in limacids by Gerhardt (1933, 1934, 1935), Ferussac and Deshayes (1819), Adams (1898) and Chace (1952) are in exhaustive detail. In India, observations on the reproductive behaviour are restricted to those of Dasen (1933) and Rensch (1955) on *Ariophanta ligulata* and *Macrochlamys pudina* respectively and Biswas *et. al.* (1976) on *Opeas gracile*.

Controversy exists regarding self-and cross-fertilization in molluscs and also in some invertebrates. Self-fertilization does not occur in *Helix* (Frömming, 1954 ; Fretter and Grahm, 1964), *Agriolimax* (Fretter and Grahm, 1964), *Succinea* (Rigby, 1965) and *Limicolaria* (Owiny, 1974). Patterson (1970) reported self-fertilization in Succineidae. Opinions differ on this point in *A. fulica* (vide Mead, 1961, 1979).

The sperms received in copulation are stored temporarily in the storage organ for a considerable period—2 years in *Capaea hortensis* (Lang, 1896) and 4 years in *Helix aspersa* (Taylor, 1900). *A. fulica* isolated after mating laid viable eggs up to 382 days (Mohr, cited in Mead, 1961) while the period extends up to 520 days in *Limicolaria martensiana* (Owiny, 1974).

In general terrestrial pulmonates lay eggs at night in humid places (Hyman, 1967), Egglaying habits in *Helix pomatia* (Meisenheimer, 1912), *Ariophanta ligulata* (Dasen, 1933) and *Helix aspersa* (Ingram, 1947 ; Herzberg and Herzberg, 1962) are on record. Guglar (1963) made extensive observation on the oviposition in some Mid-Western land snails. The number of clutches and the eggs per clutch vary from species to species (Broch, 1886 ; Dasen, 1933 ; Webb, 1950 ; Herzberg and Herzberg, 1962). In *Achatina* the number of eggs per clutch varies from 17 to 442 (Weel, 1948c ; Mohr, 1949b ; Lange, 1950 ; Ghose, 1959 ; Mead, 1961 ; Kekauoha, 1966).

Dormancy to tide over unfavourable environment is common to all land snails. This is termed hibernation in cold countries and aestivation in temperate and tropical zones. An array of literature is available on the dormant state in land snails and the factors influencing it. Hibernation in *Helix aspersa* (Fischer, 1853), *H. pomatia* (Spence, 1911 ; Flossner, 1915 ; Fischer, 1950), *Succinea elegans* (Hadden, 1917), *Allogona profunda* and *Mesodon thyroidus* (Blinn, 1963), and aestivation in *Helix desertorum* and *Xerarionta veatchii* (Stearns, 1868 ; Kew, 1893) ; *Achatina rugosa* (Bequaert, 1919), *Helix hortensis* (Lawson, 1926), *Theba pisana* (Basinger, 1927 ; Pelseneer, 1935). *Achatina albopicta* and *A. fulica hamillee* (Williams, 1951), *Sphincterochila* (*Leucochora*) *hierochuntica* (Meldelssohn, 1963) and *Helicella virgata* (Pomeroy, 1968) are on record. Valuable information on the Indian land snails—*Macrochlamys glauca* and *Ariophanta* sp. (Hora and Rao, 1927), *Glessula hastula* and *Zootecus insularis* (Hora, 1928) and *Opeas gracile* (Rahman *et. al.*, 1975) are also available. The factors that induce dormancy are low temperature (Rees, 1950 ; Kondo, 1964), low humidity (Howes and Wells, 1934a, b ; Kondo, 1964), amount of body water (Duval, 1930 ; Brand, 1931, 1932 ; Kamada, 1933 ; Howes and Wells, 1934a, b), starvation (Kondo, 1964 ; Wilbur and Yonge, 1964) and the body weight of the animals (Howes and Wells, 1934a ; Wells, 1944) have been thoroughly discussed. The duration of dormancy is extremely variable depending on the species and the country where they inhabit. *A. fulica* are known to aestivate for a period of 2 to 10 months (Green, 1910a ; Hutson, 1920 ; South, 1926 ; Corbett and Pagden, 1941 ; Lange, 1950 ; Mead, 1950a, b ; Ghose, 1959 ; Kondo, 1964 ; Butler, 1966). In India, the snails aestivate for a period of 2 months (*Macrochlamys glauca*) to 8 months (*A. fulica*, *M. indica* and *O. gracile*) depending on the climate of the zones.

As a rule larval stages in land snails are completed within the egg and young snails resembling the parents hatch out. Growth in snails and slugs has been studied by a number of workers of which observations on *A. fulica* (Mohr, 1949b ; Lange, 1950 ; Rees, 1950 ; Ghose, 1963b ; Kondo, 1964 ; Kekauoha, 1966), *Arion circumscriptus* (Frömming, 1954) are rather important. Masurekar and Bangalkote (1976) recorded growth in the Indian snail, *Ariophanta maderaspatana*. Information on the growth rate in land snails in the post-aestivating period is totally lacking.

In spite of the fact that the giant snail *A. fulica* is a serious agri-horticultural pest in India for more than a century only few reports are available on its economic status. By 1907 they were very common in the gardens of Calcutta (Annandale, 1907) and by 1910 the infestation reportedly in Bombay (Green, 1910c, d) and further north in Rajkot (Comber). After a long gap Behura (1955) reported that the giant snail is a voracious eater of cabbage, cauliflower, pumpkin and various types of leafy vegetables in Balasore of Orissa. It was for Ghose (1962a) to state that *A. fulica* is a menace to agri-horticultural economy in Eastern India and neighbouring countries. Srivastava (1966) listed a number of fruit, vegetable and flower plants as the food-plant of *Achatina*. Raut and Ghose (1983b) presented a complete list of food-plants of this pest in West Bengal. Phytophagous habit of *Opeas gracile* has been reported by Mitra *et al.* (1976). Damage to important economic plants by the slugs and snails of the family Ariophantidae are on record (Rao and Ramadoss, 1953 ; Lakshminarayana and Subba Rao, 1965 ; Bhat and Viswanathan, 1972 ; Bhat and Shamanna, 1972 ; Bhat *et al.*, 1973 ; Subba Rao, 1975). Necrophagous habit in *O. gracile*, however, has been reported by Mitra and Biswas (1974).

Attack to live plants by the land snails is well known. An array of literature is available on the food and feeding habits of *Achatina* and some other land snails, but the information on the rate of consumption in relation to body weight, and food preference are rather very limited. Possibly Green (1910a) was the first author to describe *Achatina* as a crop pest in Ceylon. Jarrett (1923) mentions that *Achatina* eat "anything that is not too hard and distasteful". Vast amount of damage of agricultural crops caused by the giant snails is on record (Dias and Thamotheram, 1939). Townes (1946) reported that *A. fulica* is a major pest on a number of Micronesian islands. Damage to plants, particularly seedlings of economically important plants—flower plants, vegetables, ornamental shrubs and fruit trees in many countries has been reported by a number of workers (vide Mead, 1961). Information on the food, feeding habit and crop damage by other species of *Achatina* and by snail pests belonging to different genera though limited are very important. Damage of sesame and coffee by *A. craveni* (Salaam, 1938) ; sisal and cotton by *A. zanzibarica* (Tomaszewski, 1949) ; papaya and other plants by *A. albopicta* (Williams, 1951) ; and damage in nurseries by *Limicolaria distincta* and *L. lucalana* (Dartevelle, 1954) are worth reporting. In Europe nearly two-thirds of the cultivated plants are "acceptable" to the snail *Capaea hortensis* (Gain, 1891). Stephenson (1968) considers *Agriolimax reticulatus*, *Arion hortensis* and *Milax budapestensis* as major pests and *Arion circumscriptus*, *A. intermedius* and *M. sowerbyi* as less common amongst crops. Feeding on potato tubers by *Milax budapestensis* and *Arion hortensis* has been observed by Runham and Hunter (1970). Different aspects of feeding in a few species of British snails and slugs have been studied by Grime *et al.* (1968), Grime and Blythe (1969), Grime *et al.* (1970), Mason (1970), Wolda *et al.* (1971), Richardson (1975), Williamson (1975) and Chatfield (1976). *Theba pisana* is a serious pest on citras plants in its native home (Stefani, 1913) and in California (Gorton, 1919 ; Smith, 1919a, b, 1922 ; Basinger, 1923a, b, 1927).

A comprehensive account on the food selection in land snails is however, still lacking.

Chemical, biological and physical measures to control pestiferous snails, especially *A. fulica*, have been tried (Mead, 1961, 1979) ; but all attempts ended in failure. More than 50 molluscicides have been scanned and also a good number of predators introduced in the snail infested areas for biological control failed to monitor the pests (vide Mead, 1961). In India, Varma (1962), Rawat, (1967), Patnaik and Vohra (1967), Srivastava *et al.* (1968), Nair *et al.* (1968), Mandal and Ghose (1970), Saxena and Dubey (1970) and Manna and Ghose (1972) tried to control the giant snails by the chemicals viz. metaldehyde, endrin, DDT. etc. A number of predators viz. millipede Srivastava and Srivastava, 1967) ; hermitcrab (Srivastava, 1968a), carnivorous snail (Srivastava, 1968b), planaria (Raut and Ghose, 1979b) and birds and mammal (Raut and Ghose, 1979a) of the giant snail are also on record. An unidentified microbe causing leucodermia like disease has been reported by Srivastava (1966), Raut and Ghose (1977b) and Raut (1983c).

SYSTEMATIC POSITION AND DIAGNOSIS

The Pestiferous snails (7 spp.), occurring in India belong to several families, viz. Achatinidae (I sp.), Subulinidae (I sp.) and Ariophantidae (5 spp.) of the order Stylommatophora.

Systematic position :

Phylum : MOLLUSCA
Class : GASTROPODA
Order : STYLOMMATOPHORA
Family 1. ACHATINIDAE

Achatina (Lissachatina) fulica fulica Bowdich

(Pl. I, fig. 1)

Helix fulica Ferussac, *Tabl. Syst. Moll.*, Limacons, 1821, p. 49.

Achatina fulica "Lamarck" Bowdich, 1822 (February), *Elements of conchology*, I, pl. 13, fig. 3.

Achatina fulica, Deshayes, 1838, in Lamarck, *Hist. Nat. Anim. Sans. Vert.* 2d Ed. 8, p. 297.

Achatina (*Lissachatina*) fulica fulica Bowdich : Bequaert, 1950, *Bull. Mus. Comp. Zool.* Harvard, 105 (1) : 1-216, pl. 8.

Diagnostic characters :

Shell ovate—conoid, pale yellowish, streaked transversely with brown, somewhat glossy, more or less irregularly decussated with fine spirals, except on last whorl. Spire convex, suture impressed, apex acute. Whorls 8, convex, the last one nearly equal to half the entire length of the shell. Aperture elliptic ovate, white or pale lilac within ; peristome straight, acute, the margins connected by a callus on the parietal wall ; columella slightly concave, truncate.

Family 2. SUBULINIDAE

Opeas gracile (Hutton)

(Pl. I, fig. 2)

Bulimus ? Hutton, *J. A. S. B.*, 3 : 84, 1834, p. 84.

Bulimus ? (*mihi*) *gracilis* ? p. 93 (Type-locality : Mirzapore, Uttar Pradesh).

Opeas gracile : Gude, *Fauna Brit. India*, Moll. vol-11 : 355, 1914.

Shell transparent, thin and pale coloured or rather colourless ; spire gradually tapering ; whorls 12, body-whorl equal to the two preceding ones ; length 6½ lines. Aperture longer than broad, semi-ovate ; pillar lip straight and slightly reflected ; right lip edged.

Family 3. ARIOPHANTIDAE

Macrochlamys indica Godwin-Austen

(Pl. 1, fig. 3)

Macrochlamys indica Godwin-Austen, 1833 *Land and Freshwater Molluscs of India*, 1 : 97, pl. 18, figs. 1-8b.

Macrochlamys indica : Blanford and Godwin-Austen, *Fauna Brit. India*, Mollusca 1908, p. 95, fig. 43.

Shell perforate, depressed, pale brown, surface smooth and polished, translucent, whorls five and half, spire low and conoid, suture slightly impressed, the body whorl slightly convex above, not descending, rounded at the periphery. Aperture slightly oblique, broadly lunate, columellar margin curved, oblique and slightly reflected above, peristome thin.

Ariophanta solata (Benson)

(Pl. II, figs. 1a and b)

Helix solata Benson, 1848, *Ann. Mag. Nat. Hist.*, (2) 2 : 159.

Helix solata Benson, 1853, Preston, Monogr. Helicidae, 3 : 67.

Helix solata Hanley and Theobald, 1876, *Conch. Indica*, pl. 28, fig. 6.

Nilgiria solata, Godwin-Austen, 1898, Moll. India, 2 : 77, pl. 80, figs. 1-4 (anatomy), pl. 82, fig. 2 (radula).

Ariophanta solata Blanford & Godwin-Austen, 1908, *Fauna Brit. India* (Mollusca-Testacellidae and Zonitidae), p. 46, fig. 26.

Shell perforate subglobosely depressed, smooth, striated, white or yellowish-brown, often with a bluish tinge, with a narrow, spiral surfous band inside the suture and traces of other bands, and with numerous small, brownish, translucent spots irregularly distributed, spire very low, whorls $5\frac{1}{2}$, flatly convex above, the last slightly sub-angulate at the periphery. moderately swollen beneath, aperture oblique, lunately ovate, generally rufous within, peristome simple, thin, columellor margin reflected.

Cryptozona (Nilgiria) smirugata (Beck).

(Pl. II, figs. 2a and b)

Galaxis semirugata Beck, Index Moll. 1837, 1, p. 42.

Ariophanta semirugata : Blanford & Godwin-Austen, *Fauna Brit. India,* Mollusca, 1908, p. 35.

Shell globose and solid, generally pale horny brown, surface sculptured with fine, obliquely striae, whorls five to six in number, sutures slightly impressed. Body whorl large, inflated and longer than broad, inclined downwards towards the apertural end. Spire, variable-either elevated and convexly conoid or depressed. Aperture large, broad and obliquely ovate, columellar margin reflected over the umbilicus partly covering it, peristome thin.

Cryptozona (Xestina) bistrialis (Beck).

(Pl. II, figs. 3a and b).

Nanina bistrialis Beck, Index Moll., 1837, 2, p. 2.

Ariophanta bistrialis : Blanford & Godwin-Austen, *Fauna Brit. India,* Mollusca, 1908, 39.

Shell thin, fragile, umbilicus fairly open, depressedly globose and inflated, pale horny brown or brownish white, surface finely striated, decussated above with impressed spiral lines, whorls four to five in number, rapidly increasing from above downwards. Body whorl flattened above, rounded at the periphery, convex below and not inclined downwards towards the apertural end, with two reddish brown spiral lines enclosing in between a broader whitish spiral band. Spire low and depressed. Aperture large, broadly and obliquely ovate, columellar margin slightly reflected over the umbilicus, peristome sharp edged.

Bensonia monticola Hutton

(Pl. II, figs. 4a and b)

Bensonia monticola, Hutton (*Nanina*), *JASB,* Vol. 7, 1, 1835, p. 213.

Bensonia monticola Hutton : Gude, *Fauna Brit. India,* Moll. 1908.

Shell openly perforate, depressed, moderately thin, striated, the epidermis on the inner whorls more or less distinctly minutely decussated, with oblique raised lines, tawny yellow to brown, sometimes with a broad rufous spiral band above the periphery, the lip chestnut with a broad yellowish border behind, some other chestnut and yellow stripes, indicating seasonal arrest of growth, crossing the whorls at irregular intervals ; spire low, conoidal, whorls 6-7, convex, the last rounded at the periphery ; aperture oblique, broadly and subovately lunate ; peristome acute, thickened inside with a white callosity, collumellar margin reflected at the umbilicus.

Habit and Habitats

In nature the active period of the pestiferous land snails *Achatina fulica*, *Opeas gracile*, *Macrochlamys indica*, *Ariophanta solata*, *Cryptozona semirugata* and *Cryptozona bistrialis* is restricted to monsoon only. They aestivate for the rest part of the year, which is usually interrupted on several occasions following heavy shower when they move out and consume food available to them. In Bay Islands the active period is longer extending from 6 to 10 months in a year which coincides with the length of monsoon in those areas. The high altitude snail *Bensonia monticola* behave in the same way, respond to occasional showers during hibernation but resumption of activity even for a short period is inhibited by the low temperature.

The snails always prefer damp and shady places and avoid direct sunlight. They occur mostly in and around villages, though quite a few are often found in open woodlands, parks, gardens cemetaries, hedgerows, borders of marshes and similar habitats. Being nocturnal in habit they hide them in daytime in a retracted and quiescent state, under bricks, rocks, fallen logs, plant mats, holes in trees, decaying leaves and the like or partially buried in loose soil. *A. fulica* climb walls and tree trunks to a height of 400 cm. and spend the day there. Interestingly, a some sort of advance signalling system in response to change in weather is present in *A. fulica*, since in the vast majority of the cases they move to protected sites prior to outbreak of a storm, and climb up some support (Pl. III, figs. 1 and 2) quite ahead of heavy shower.

Distribution and Population

Survey on the distribution and population of *Achatina (Lissachatina) fulica fulica*, *Opeas gracile*, *Macrochlamys indica*, *Ariophanta solata*, *Cryptozona (Nilgiria) semirugata*, *Cryptozona (Xestina) bistrialis* and *Bensonia monticola* has been made for quite some time which gained momentum since 1973. Since they are cryptic in nature, observations were made from all possible niches both in night and day hours. Population study was made in active seasons which are chiefly restricted to monsoon period and a few post-monsoon weaks. Population study of the aestivating snails has been conducted in certain infested areas.

In estimating the population density during active season 5 gardens from each infested zone and 5 sites from each garden were selected at random. The snails present in a square metre (m^2) area in a site were counted between 18-00 to 20-00 hrs, a period in which almost all the snails became active and were moving in search for food or busy in feeding. The mean of 25 readings taken from 5 different gardens was considered as the actual snail population in a m^2 of the infested zone concerned. The mean value has been given in parenthesis.

In the case of aestivating populations the area occupied by each pocket and the number of snails per aestivating pocket were recorded (Abbas and Gautam, 1975 ; Raut, 1978b ; Gupta *et al.*, 1978).

India is a land of varied climates. Since the geographic location and the physical features largely determine the climate of a country, and influence the animal population to a great extent the Indian Union has been divided into 6 regions based chiefly on rain fall and vegetation.

1. Eastern India-Comprising Arunachal Pradesh, Assam, Bihar, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikim, Tripura and West Bengal.

2. Southern India-Comprising Andhra Pradesh, Karnataka, Kerala and Tamil Nadu.

3. Northern India-Comprising Delhi, Himachal Pradesh, Jammu and Kashmir, Punjab and Uttar Pradesh.

4. Western India-Comprising Gujarat, Maharastra and Rajasthan.

5. Central India-Comprising Madhya Pradesh.

6. Bay islands-Comprising Andaman, Car Nicobar and Laccadive islands.

The snail species are fairly common in some States while they are absent in other States (Fig. 1). The abundance also varies with the locality and the species (Table-1). The distribution and population are given specieswise and Statewise in each region, where they are occurring, on the data collected till December, 1982.

Eastern India :

Three species viz. *Achatina fulica, Opeas gracile* and *Macrochlamys indica* are recorded here.

A. fulica :

ASSAM : Information collected by the authors from the local people suggests that the snails were introduced at Gauhati town before 1950 from Coochbehar district of West Bengal along with plants. At present they are common to abundant at Jhalukbari, Ulubari, Lachit Nagar, East Sarani and

Panbazar of Gauhati town, Silonijan, Goalpara, Tejpur, Golaghat and Jorhat. Population density covers a wide range. Twelve to 22 (17) per m^2 have been recorded from Jhalukbari while the numbers were 15-21 (18), 14-22 (19), 17-24 (21.12), 18-28 (20), 19-28 (26) and 12-18 (15) per m^2 at Ulubari, Lachit Nagar, East Sarani, Panbazar, Jorhat and Golaghat respectively (Table-1).

BIHAR : Hornell (1951) stated that *A. fulica* failed to spread elsewhere in India other than Bengal within a period of 80 years since their introduction while Annandale reported their occurrence in and around Rajmahal in 1907, and the snails did not escape the collectors sight in 1938 in Santhal Parganas, Bihar (Ray, 1943). At present the whole of the north Bihar i. e. the northern part of the river Ganga is heavily infested with the snails. Locally it is known as "dapar shankh". Of the districts of south Bihar and Chhotanagpur plateau, Bhagalpur, Santhalparganas, Dhanbad and Singhbhum are facing the giant snail pest problem. Population estimation was made almost from all the infested areas (Table—1). The maximum snail population was recorded from Chaibasa (38 per m^2) while Pakur (32 per m^2), Deoghar (31 per m^2) and Dumka (30 per m^2) are next in order. In other areas the density varies from 6 to 27 for the same unit.

MANIPUR : The snails are restricted only to Imphal town (altitude 850 m). They were first observed in the garden of Police commissioner in 1954. On an average 13 individuals per m^2 have been recorded.

MEGHALAYA : *A. fulica* were seen in some gardens at Nongpoh (altitude 1166 m). The other parts of the State are free from it. On an average 11 snails per m^2 have been recorded.

NAGALAND : The S. D. O. Agriculture, Dimapur, informed that Mr. R. S. Bedi, a Government Officer, brought some snails from Calcutta out of curiosity in 1959 and released those in his office garden at Dimapur. At present it is a serious agri-horticultural problem in whole of the Dimapur sub-division. The other parts of the State are however, free from it. Eighteen to 29 per m^2 have been counted from Dimapur town. At Chumukedima the number is 3 to 5 per m^2.

ORISSA : The year of introduction is not known but Behura (1952) reported that *A. fulica* turned to a serious pest in Balasore in 1948-49. Recent survey revealed that they are most common in the vegetable and kitchen gardens of Balasore, Mayurbhanj and Keonjhar districts. In Cuttack district only Panikoil area is infested with the giant snails. Population density at Baripada town is 32 per m^2 while Balasore, Baliapal and Anandpur are next in order. At Panikoil 7 per m^2 were counted.

TRIPURA : The snails are localised to Kumarghat area of north Tripura. According to Agriculture Officer, Kumarghat Block, the snails made their way to Kumarghat from adjoining Srihatta district of Bangladesh. In the infested pockets the number of snail, on the average, is 17 per m^2.

WEST BENGAL : *A. fulica* were first introduced in Calcutta from Mauritius in 1847 by the conchologist Benson, who released them in the gardens of the Royal Asiatic Society. Within a few years they were very common in the gardens of Calcutta and suburbs. In 1876-77 they were seen at Barackpore (Godwin-Austen, 1908). By 1910 they were recorded from the districts of northern part of West Bengal. At present, of the 16 districts of the State they are occurring almost in all the vegetable and flower gardens of 15 districts except Purulia which is free from infestation. In Darjeeling district they have been recorded from Siliguri subdivision in the adjacent areas to Jalpaiguri district. In northern part of West Bengal the estimated average population is 22 per m^2 while in other parts the same is ranged from 7 to 34 per m^2 (Table-1). On the other hand 5 to 61 snails have been recorded from the aestivating pockets.

O. gracile :

ASSAM : Occurring almost in all the gardens at Ulubari and Panbazar of Gauhati town, Jorhat and Silchar. It is estimated that on an average the number is 48, 41 and 36 m^2 at Silchar, Ulubari and Jorhat respectively (Table-1).

BIHAR : Of the 60 stations surveyed, areas in and around 34 stations are heavily infested (Table-1). The density of snail population ranges from 11.14 per m^2 at Giridih to 44 per m^2 at Dhanbad.

ORISSA : It is a common garden snail in Orissa. However, they were not observed in Kalahandi district. Joshipur is heavily infested (44.44 per m^2) while the population is lowest (15.44 per m^2) in Bhubaneshwar.

MANIPUR : In the gardens of Imphal town they are occurring between 11 to 28 (22) per m^2.

NAGALAND : They are common in the agri-horticultural gardens of Dimapur sub-division. The number per m^2 is estimated to be 21 to 35 (29).

WEST BENGAL : The snails are found in all the districts except the mountain region of Darjeeling. The population ranges from 12.24 per m^2 at Gour of Malda to 49 per m^2 in the gardens in 24-parganas.

M. indica :

ASSAM : *M. indica* were observed at Gauhati (East Sarani, Ulubari, Lachit Nagar), Jorhat and Golaghat. The density of snail population ranges from 22 to 29 per m^2.

BIHAR : They are present in all the districts. In North Bihar the density ranges from 26 to 38 (32) per m^2. It is comparatively higher, 29 to 41 (36.12) per m^2 in south Bihar.

ORISSA : They are very common in eastern Orissa. Highest population was recorded from Nilgiri of Balasore (43 per m^2) while Anandpur (37 per m^2), Jajpur (35.24 per m^2) and Joshipur (33.12 per m^2) are next in order.

WEST BENGAL : They have been observed in all the districts except Purulia. In lower West Bengal the population level is higher, 43 per m^2 than that in other parts where it ranges from 11 to 24 per m^2.

Southern India :

This region is inhabited by 5 species viz. *Achatina fulica*, *Opeas gracile*, *Macrochlamys indica*, *Ariophanta solata* and *Cryptozona* (*Xestina*) *bistrialis*.

A. fulica :

KARNATAKA : They are occurring in and around Bangalore town. The population density is very low (9 per m^2).

KERALA : They are very common in all kinds of gardens of Palghat district. It has also developed some new focii in the adjacent districts like Kozhikode, particularly at Calicut, Malappuram and Trichur. The remaining distrcits of the State are free from this snail species. Population density is maximum at Calicut (34 per m^2) while at Palghat the number was 24 per m^2.

TAMIL NADU : The snails were first introduced at 'My lady garden' in Madras during British period. From there they dispersed to a number of gardens in the city. At present they are found in large number in the Christian College campus, Tambaram. One Mr. Hari Das brought the snails from the 'Snake park' at Madras following an exhibition in 1966 and released them in the Christian College campus. They are also common at Pollachi of Coimbatore and Annamalai Nagar of South Arcot. Dr. Sriramulu of Annamalai University informed the authors that the giant snails were introduced there from Madras by a research worker in 1942. The population density is higher, 34 per m^2 at Tambaram than that at Madras and Annamalai Nagar.

O. gracile :

KERALA : They are common garden snails of south Kerala. They have also been observed in Palghat and Calicut. At Trivandrum population density is 46 per m^2 while Trichur (29 per m^2), Palghat (24 per m^2) and Ernakulum (19 per m^2) are next in order.

TAMIL NADU : Occurring in large number in and around Coimbatore, Madras, Tiruchirapalli and Annamalai Nagar. Thirty four to 42 per m^2 have been counted.

M. indica :

KERALA : The snails are restricted only to Palghat district. On an average 21 per m^2 have been counted.

TAMIL NADU : Occurring in and around Tambaram, Madras and Annamalai Nagar. In these areas 14 to 19 per m^2 have been recorded.

A. solata ;

ANDHRA PRADESH : Occurring only in Eastern Ghats (Subba Rao, 1975).

KARNATAKA : Observed in and around Bangalore.

KERALA : Recorded from Palghat area.

TAMIL NADU : One of the common land snails of Nilgiri, Coimbatore and Madurai districts.

C. (Xestina) bistrialis :

ANDHRA PRADESH : The snails are common in and around Dummagudem, East Godabari (Subba Rao, 1975.)

KARNATAKA : The snails are observed in and around Bangalore, Mandya and Mysore. The population density ranges from 8.44 per m^2 at Bangalore to 9.68 per m^2 at Mandya.

KERALA : Occurring in the rubber growing areas of Kottayam district especially at Karikkattor. Twelve per m^2 have been recorded.

TAMIL NADU : They are very common in Chengalpattu, Tiruchirapalli and Salem district. On an average 9, 10 and 14 snails per m^2 have been recorded from those districts respectively.

Northern India :

This region is represented by 3 species viz. *Achatina fulica*, *Opeas gracile* and *Bensonia monticola*.

A. fulica :

UTTAR PRADESH : They are very common in and around Moradabad, Dhampur and Bijnor. On an average 34, 27 and 19 individuals per m^2 are thriving at Moradabad, Dhampur and Bijnor respectively.

O. gracile :

UTTAR PRADESH : They are common garden snails of Nautnowa, Balia, Mirzapur and Faijabad. The number ranges from 6 to 19 per m^2.

B. monticola :

HIMACHAL PRADESH : One of the commonest land snails of the State, occurring in and around Simla, Kulu, Bilaspur, Mandi, Arki, Darlaghat and Dharamsala. Population density is very low, 8 to 16 m^2.

JAMMU AND KASHMIR : The snails have been observed at Jammu, Srinagar and Mujaffarabad. The population density at Srinagar is 6 per m^2.

UTTAR PRADESH : They are occurring in and around Kumaun, Missouri and Garwal. At Garwal 12 per m^2 have been counted while Missouri (8.32 per m^2) and Kumaun (7 per m^2) are next in order.

Western India :

This region is represented by 4 species viz. *Achatina fulica*, *Opeas gracile*, *Cryptozona (Nilgiria) semirugata* and *Cryptozona (Xestina) bistrialis*.

A. fulica :

It is to be mentioned here that the infestation of the giant land snail *A. fulica* in Bombay (Green, 1910c, d) and Rajkot (vide Mead, 1961) are on record. But the present authors did not observe the giant snails from any part of Bombay and Rajkot. However, they have been observed in certain pockets in Marathwada, Aurangabad (Kulkarni and Nagabhushanam, 1973).

O. gracile :

MAHARASHTRA : It has been observed in and around Nagpur, Bombay and Poona. The population density ranges from 5 to 9 per m^2 at Nagpur.

RAJASTHAN : Distribution of *O. gracile* is limited to Joypur area. The population density varies from 16 to 21 (19) per m^2.

C. (Nilgiria) semirugata :

GUJARAT : One to 5 snails per m^2 have been counted from the gardens in and around Ahmednagar and Bhuj. Subba Rao (1975) also reported the occurrence of this snail species from these oreas.

C. (Xestina) bistrialis :

MAHARASHTRA : They have been observed at Poona and Panchgani. On an average 7.32 per m^2 at Poona and 2.8 per m^2 at Panchgani have been recorded.

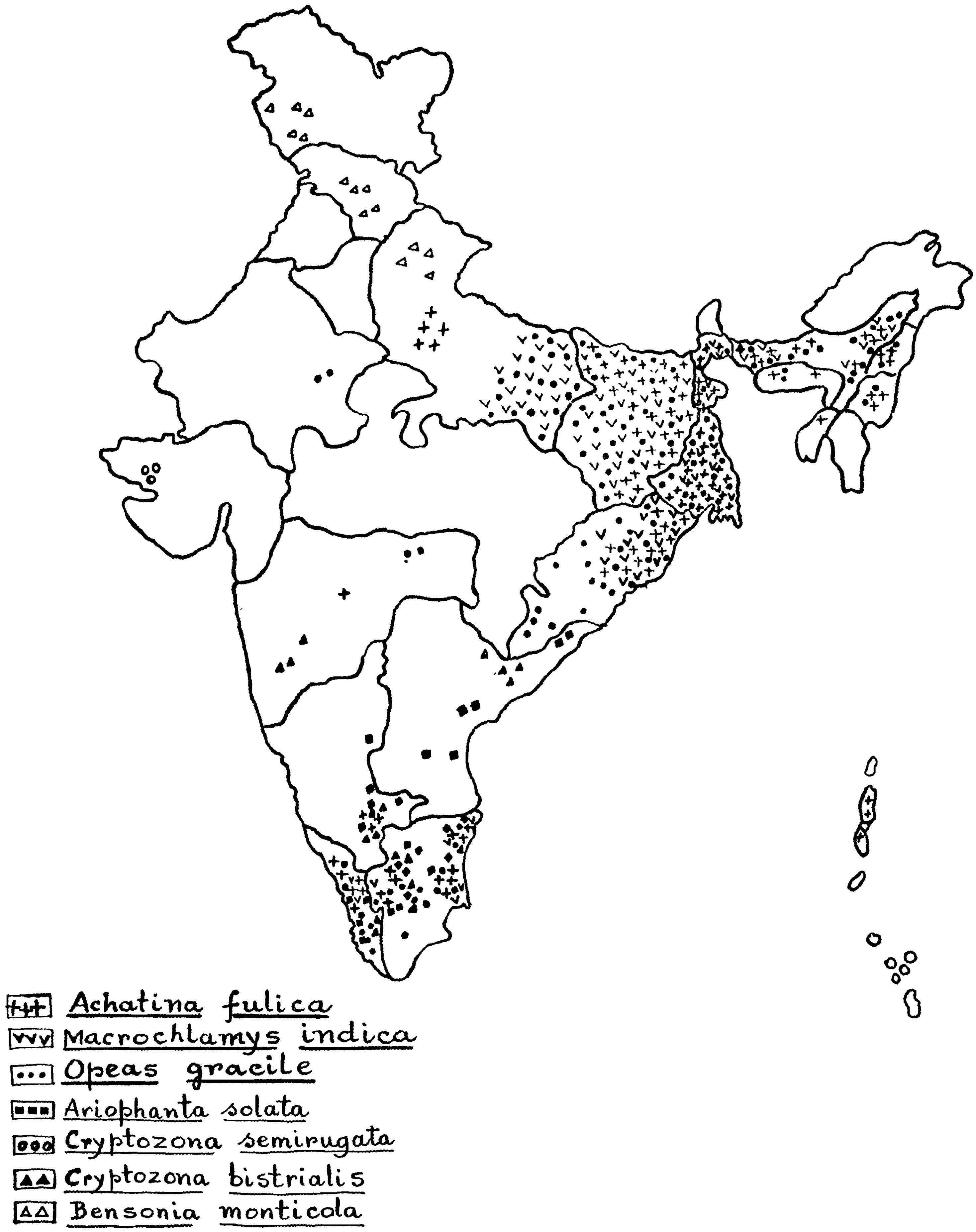

Fig. 1. Distribution of pestiferous land snails in India.

Explanations of Fig. 2.

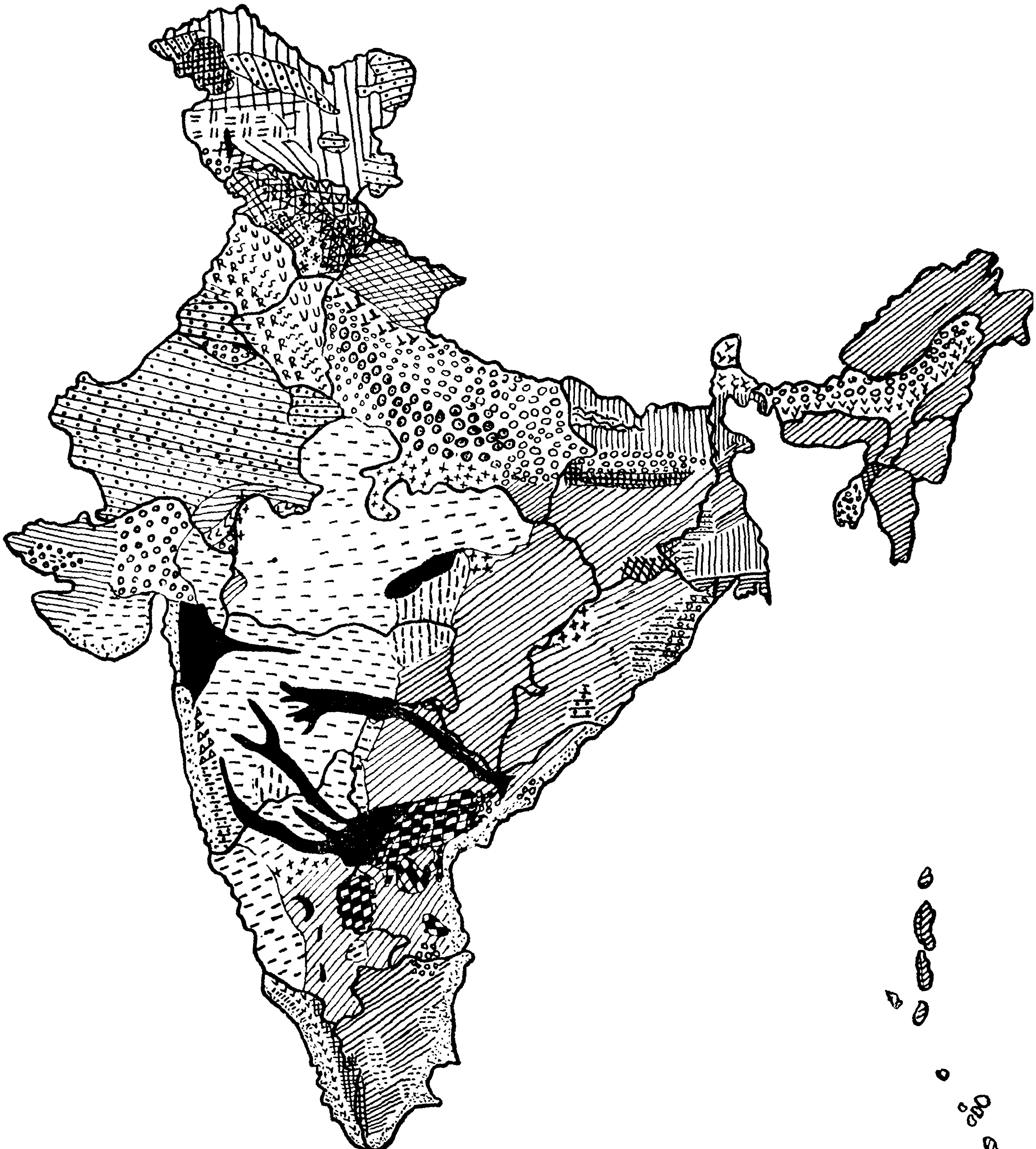

Fig. 2. Soils of India

Central India :

This region is free from pestiferous land snails.

Bay Islands :

Achatina fulica and *Opeas gracile* are occurring in the islands.

A. fulica :

ANDAMAN AND CAR NICOBAR ISLANDS : It is believed that the giant land snails were introduced there by the Japanese soldiers for cutinary purposes during II World War, though they never admitted that they eat the snails. They are now common to abundant in the Andaman and Nicobar group of islands on the main island of South Andamans, Long island, Rangat, Mayabandar, Diglipur, Car Nicobar and Kamota. On an average 42 snails per m^2 have been recorded in and around Port Blair during active period. While during aestivation 14.57 to 102.39 per m^2 have been counted from the aestivating pockets (Abbas and Gautam, 1975 ; Gupta *et al.*, 1978).

O. gracile :

ANDAMAN AND CAR NICOBAR ISLANDS : A common garden snail all over the island.

LACCADIVE ISLANDS : The present status of this snail species is not known. But it has been recorded earlier from the islands (Satyamurti, 1960).

The giant African land snails are occurring in a number of districts of Bangladesh, Bhutan and Nepal.

The following parameters were considered in ascertaining the factors influencing dispersal and multiplication of land snails :

Soil : There are 4 major groups of soils in India- (i) alluvial (ii) black (iii) red and (iv) laterite and lateritic soil. In addition to the above 4 other important groups are—forest, desert, saline, alkali and pitsoil. These 8 groups of soil are subdivided into 32 types (Fig. 2) (Roychoudhury *et al.*, 1963). Alluvial soil covers about 1,500,000 square kilometres of south, north and eastern Indian States. Red soil occupies good portions of Tamil Nadu, Karnataka, south and east of Maharashtra, east of Andhra Pradesh, Madhya Pradesh, Orissa and Chhotanagpur covering a total area of about 350,000 square kilometers. In the north the red soil area enters into and includes the greater part of Santhal Parganas in Bihar, the Birbhum district of West Bengal and the Mirzapur, Jhansi and Hamirpur districts of Uttar Pradesh. Andaman and Car Nicobar groups of islands are covered by red and alluvial soils. The typical soil derived from the Deccan trap is black soil commonly known as regur covering an area of about 546,000 square kilometres. It is

TABLE 1. Population density per m^2 of pestiferous land snails.

STATE	INFESTED POCKET	SNAIL SPECIES						
		A. fulica	*O. gracile*	*M. indica*	*A. solata*	*C. semirugata*	*C. bistrialis*	*B. monticola*
ANDAMAN AND NICOBAR*	Port Blair	36-56 (42)						
ANDHRA PRADESH	Dummagudem						Not studied	
ASSAM	East Sarani	17-24 (21.12)		17-29 (24)				
	Golaghat	12-18 (15)		24-30 (27.24)				
	Jhalukbari	12-22 (17)						
	Jorhat	19-28 (26)	30-42 (36)	22-34 (29)				
	Lachhitnagar	14-22 (19)		19-25 (22)				
	Panbazar	18-28 (20)	12-21 (18)					
	Silchar		36-54 (48)					
	Silonijan	5-10 (8)						
	Tejpur	12-19 (15)						
	Ulubari	15-21 (18)	36-49 (41)	20-27 (24)				
BIHAR	Begusarai	10-15 (12)		27-32 (30)				
	Bhagalpur	6-11 (9)		28-41 (34)				
	Binda	7-16 (11)						
	Chaibasa	27-46 (38)	24-32 (28.22)	19-23 (21)				
	Chakradharpur	21-30 (27.68)	19-30 (26.12)	32-41 (36.24)				
	Chandil		22-31 (27)					
	Chapra	16-23 (20)		24-31 (28)				
	Chhatrapur		34-46 (41)	21-36 (29.24)				
	Daltangunge		14-22 (19.24)	12-17 (13)				
	Danapur			26-38 (33)				

TABLE 1. Continued [2]

STATE	INFESTED POCKET	SNAIL SPECIES						
		A. fulica	*O. gracile*	*M. indica*	*A. solata*	*C. semirugata*	*C. bistrialis*	*B. monticola*
	Darbhanga	19-25 (24)		37-44 (39)				
	Deoghar	27-38 (32)	Not studied	19-24 (21.68)				
	Dhanbad	10-18 (15.88)	39-48 (44)	14-21 (17)				
	Dhruba	10-13 (11.24)	26-38 (32)	18-25 (22)				
	Dumka	24-38 (30)	18-22 (19.68)	27-35 (32)				
	Garhwa		29-41 (36.24)	15-22 (18)				
	Giridih		10-14 (11.14)	19-34 (27.24)				
	Govindpur		19-26 (22.24)	29-14 (37)				
	Gumla	8-12 (10)	Not studied	21-30 (26)				
	Hatia		28-34 (31)	16-24 (19)				
	Hazaribag		11-17 (13.44)					
	Ichri		16-24 (20)	9-14 (11.44)				
	Jamshedpur	8-17 (11.24)	22-30 (26)	17-21 (19)				
	Jhumra		31-38 (34)	18-31 (26)				
	Jogbani	20-26 (22)	19-25 (21.88)	9-17 (14)				
	Joynagar	8-18 (12.48)	16-21 (17.68)	12-16 (14.12)				
	Katibar	20-26 (22)	40-46 (42)					
	Khunti		13-20 (17)	7-12 (9.44)				
	Madhubani	14-19 (16)	Not studied	Not studied				
	Monghyr	14-20 (18.24)	27-38 (33)	19-28 (24)				
	Motibari	15-28 (21)	29-35 (32)	34-40 (37)				
	Musabani	9-12 (10.24)	24-33 (29.24)	18-24 (21)				
	Muzaffarpur	20-32 (26)	27-34 (31)	14-19 (16.88)				
	Nalanda		10-21 (19)					
	Parsudihi	9-16 (12.88)						
	Pakur	24-38 (32.12)						

TABLE 1. Continued [3]

STATE	INFESTED POCKET	SNAIL SPECIES						
		A. fulica	*O. gracile*	*M. indica*	*A. solata*	*C. semirugata*	*C. bistrialis*	*B. monticola*
	Purnia	18-23 (19)	37-42 (40)					
	Pusa	13-23 (18)	29-37 (33.68)	16-21 (18.40)				
	Rajnagar	16-21 (18.88)	32-36 (33.88)	28-34 (31.12)				
	Ramgarh		27-34 (31)	24-38 (32.12)				
	Ranchi		34-43 (38.68)	20-27 (22.44)				
	Saharsa	7-11 (9)	16-20 (18.24)					
	Samastipur	11-14 (12.32)		21-26 (24)				
	Sasaram			17-22 (20)				
	Simdanga	8-13 (10.24)	19-26 (22.32)	13-18 (15.12)				
	Sitamari	19-25 (22)	37-44 (41)	19-24 (22.24)				
	Telcocolony	5-9 (6)		16-22 (19.44)				
	Vaishali	9-20 (15.68)		11-19 (16)				
GUJARAT	Ahmednagar					1-5 (3)		
	Bhuj					2-5 (3.12)		
HIMACHAL PRADESH	Dharamsala							8-14 (12)
	Kulu							10-14 (11.12)
	Simla							8-16 (13.12)
JAMMU AND KASHMIR	Jammu							Not studied
	Majaffarabad							Not studied
	Srinagar							4-8 (6)
KARNATAKA	Bangalore	4-12 (9)					5-11 (8.44)	
	Mandya						7-13 (9.68)	
	Mysore						5-11 (9.88)	

TABLE 1. Continued [4]

STATE	INFESTED POCKET	SNAIL SPECIES						
		A. fulica	*O. gracile*	*M. indica*	*A. solata*	*C. semirugata*	*C. bistrialis*	*B. monticola*
KERALA	Calicut	30-39 (34)	14-23 (17)					
	Cannanore		10-14 (12.12)					
	Ernakulum		14-23 (19)					
	Kottayam		16-20 (18.12)				9-15 (12)	
	Malappuram	12-18 (15)						
	Palghat	19-28 (24)	13-28 (24)	18-24 (21.11)	6-9 (7.12)			
	Shoranur		12-17 (14)					
	Trichur		26-34 (29)					
	Trivandrum		44-51 (46)					
MAHARASHTRA	Nagpur		5-9 (7.12)					
	Panchgani						1-4 (2.88)	
	Poona						3-9 (7.32)	
MANIPUR	Imphal	11-15 (13)	11-28 (22)					
MEGHALAYA	Nongpoh	9-14 (11)						
NAGALAND	Chumukedima	3-5 (4.12)						
	Dimapur	18-29 (24)	16-21 (19)					
ORISSA	Anandpur	20-26 (22.32)		31-42 (37.44)				
	Balasore	19-30 (27)	32-38 (34.68)	20-26 (22.22)				
	Baliapal	21-28 (25)	25-33 (28.44)	18-22 (20.12)				
	Baripada	26-39 (32)	36-45 (39.68)	30-36 (32.44)				
	Bhadrak			29-37 (32)				
	Bhubaneshwar		12-19 (15.44)					
	Champua		28-37 (33.88)					
	Cuttack		36-46 (41)	26-34 (29.24)				
	Jajpur			22-40 (35.24)				

TABLE 1. Continued [5]

STATE	INFESTED POCKET	SNAIL SPECIES *A. fulica*	*O. gracile*	*M. indica*	*A. solata*	*C. semirugata*	*C. bistrialis*	*B. monticola*
	Joshipur		41-48 (44.44)	29-38 (33.12)				
	Kaptipada	24-32 (28)						
	Keonjhargarh		28-35 (32)	13-17 (15.24)				
	Konark		12-20 (17.32)					
	Nilgiri	12-21 (17.24)	26-31 (29.44)	34-48 (43)				
	Panikoil	4-9 (7)	27-36 (33)	21-31 (26.68)				
	Puri		17-24 (21.12)					
RAJASTHAN	Joypur		16-21 (19)					
TAMILNADU	Annamalai Nagar	18-26 (22.11)	38-47 (42)	9-19 (14)				
	Chengalpattu						7-17 (9.24)	
	Coimbatore		26-40 (34)					
	Jolarpettai		11-18 (14.68)					
	Madurai		7-11 (10)		5-10 (7.12)			
	Madras	16-21 (15.12)	31-39 (35.24)	11-19 (16)				
	Coonoor							
	Pollachi	19-27 (22.44)						
	Salem						11-19 (14.44)	
	Tambaram	31-39 (34)		14-22 (19)				
	Tiruchirapalli		29-38 (36.12)				7-13 (10.24)	
TRIPURA	Kumarghat	14-20 (17.22)						
UTTAR PRADESH	Balia		11-18 (14)					
	Bijnor	16-24 (19.22)						
	Dhampur	21-34 (27.32)						

TABLE 1. Continued [6]

STATE	INFESTED POCKET	SNAIL SPECIES						
		A. fulica	*O. gracile*	*M. indica*	*A. solata*	*C. semirugata*	*C. bistrialis*	*B. monticola*
	Faijabad		9-14 (11.24)					
	Garwal							8-15 (12.24)
	Kumaun							4-9 (7.44)
	Mirzapur		16-22 (19)					
	Missouri							6-11 (8.32)
	Moradabad	29-39 (34.40)						
	Nautnowa		4-8 (6.12)					
WEST BENGAL	Alipur Duar	19-24 (22.12)	15-19 (16.24)	19-22 (20)				
	Bagnan	18-24 (21)	32-39 (36.12)	34-44 (39.32)				
	Baharampur	16-29 (23)	11-16 (14.32)	19-24 (22.12)				
	Ballygunge	27-34 (31.24)	42-54 (46.12)	40-46 (42.88)				
	Balurghat	5-12 (8.12)	17-24 (21.24)	41-49 (44.68)				
	Bamungola	9-16 (13.24)	16-21 (19.24)					
	Bangan	26-33 (29)	15-24 (20.24)	36-47 (43.44)				
	Bankuratown	24-32 (27.32)	16-23 (19.32)	15-21 (19.12)				
	Bishnupur	18-27 (24)	14-19 (15.12)	16-24 (19.24)				
	Bolpur	19-27 (24.12)	15-24 (19.68)	31-36 (34.12)				
	Chakda	16-23 (19.24)	11-19 (16.12)	27-34 (32.24)				
	Contai	12-18 (16.12)	17-22 (20)	19-24 (22.12)				
	Coochbihar	29-34 (32.68)	37-46 (41)	26-41 (34.24)				
	Dinhata	17-24 (21.12)	20-29 (24.24)	14-20 (17)				
	Egra	10-16 (14.68)	18-24 (19.44)	14-19 (16.40)				
	Goalpakher	28-32 (29.44)	19-26 (23.24)	28-36 (32.24)				
	Gour	5-12 (8.32)	10-14 (12.24)	12-18 (15.24)				
	Harish-chandrapur	27-36 (30.88)		29-33 (31.12)				

TABLE 1. Concluded [7]

STATE	INFESTED POCKET	SNAIL SPECIES						
		A. fulica	*O. gracile*	*M. indica*	*A. solata*	*C. semirugata*	*C. bistrialis*	*B. monticola*
	Hili	24-32 (28.68)	18-29 (23.44)	22-27 (24.44)				
	Jadavpore	24-29 (26.68)	46-54 (49.12)	38-45 (42.12)				
	Jalpaiguri	25-31 (28.44)	26-33 (27.32)	29-40 (36.44)				
	Jangipur	15-19 (16.44)		19-26 (23)				
	Kakdwip	19-30 (26.24)	40-49 (44.44)	24-31 (27.12)				
	Katoa	24-31 (28.24)	19-24 (21.24)	19-29 (25.68)				
	Kumargunge	11-16 (12.68)						
	Mathabhanga	21-26 (23.12)	12-21 (17.68)	7-16(11.44)				
	Midnapur	24-32 (29.24)	22-30 (27.12)	27-33 (30.68)				
	Raigunge	26-31 (29.40)	20-26 (22)	36-39 (37-88)				
	Ramnagar	7-12 (9.32)	14-26 (19.24)	29-41 (34.24)				
	Saithia	24-31 (28.68)	19-24 (21.24)	19-27 (23)				
	Tapan	8-14 (11.68)						

* Union Territory

common in Maharashtra, west of Madhya Pradesh, part of Karnataka, Andhra Pradesh and Gujarat, and some parts of Tamil Nadu, including districts of Ramnad and Tinna valley to the extreme south. Laterites are especially well developed on the summits of hills of the Deccan, Karnataka, Kerala, Madhya Pradesh, the Eastern Ghat regions of Orissa, Maharashtra, Malabar and part of Assam. The remaining types of soil are limited to some pockets in different States as shown in Fig. 2.

The pH of soil varies with the type and the locality (Table-2). The mineral contents viz. N. Mg, K_2O and CaO are also variable (Table-2).

The texture of the soil varies. In general, alluvial groups of soil are sandy to clay loams, mixed red soil is sandy loam, while mixed black soil is generally black clay. Coastal soils are sandy clay. All these soils are porous and can retain moisture well. On the other hand, laterite, lateritic, and gravelly groups of soil are hard, non-porous and have very limited power of water absorption. These soils become too hot in dry summer.

Vegetation : India is rich in flora. There are luxurient growth of trees towards coastal and hill regions. In addition vegetable crops are grown throughout the year in all parts of India. The vegetation is rather low in central India.

Temperature : Owing to its peculiar geographical conditions India has a rather wide range of temperature (Table-3). The States of the Himalayan ranges are subjected to severe winter and some parts in higher elevations remains snow covered for a few weeks in a year. The temperature fluctuates from 0°C to 4°C (Table-3). On the other hand, close to the sea the weather is damp-hot. The temperature is high, ranging from 5°C to 46°C accompanied by long dry-spells with no rainfall, especially during summer. Temperature prevails between 20 to 30°C in plains and up to an altitude of 300 metres. Above 300 metres but up to 1500 metres the temperature ranges from 7 to 25°C in monsoon.

Humidity : The annual relative humidity (mean) ranges from 51 to 82 in Indian States (Table-3). It is almost similar in the whole of India in monsoon but varies considerably in other seasons of the year depending on the amount of rainfall, intensity of temperature and velocity of wind.

Rainfall : Rainfall is higher in the Himalayan ranges and the coastal regions of India. The total annual preciptation is more than 2000 mm and may reach up to 3000 mm or more in some localities. In monsoon rainfall is almost similar in the greater part of plains but during winter and summer, the amount of rainfall varies greatly. Table-3 shows the number of rainy days in different areas of India. In general, Port Blair, Palghat, Trivandrum, Calicut, Mysore, Bangalore, Coimbatore, Annamalai Nagar, Madras, Gauhati,

TABLE 2. Analysis of soils (% on dry weight).

SOILS	pH	N	Mg	CaO	K_2O
Alluvial	5.5-8.2	0.111	0.051	0.14	0.079
Calcareous	6.0-8.3	0.065	0.001	0.29	0.024
Coastal	6.1-8.2	1.06	0.15	0.56	0.91
Forest	7.0-8.0	0.06	0.16	0.04	0.061
Gravelly	5.5-7.2	0.04	0.005	0.34	0.01
Laterite and Lateritic	5.5-6.5	0.05	0.14	0.02	0.014
Black	4.2-6.0	0.04	0.002	0.7	0.01
Mixed Red	4.7-7.2	0.052	0.34	0.35	0.01
Red	4.5-7.2	0.05	0.002	0.3	0.01
Saline and Deltaic	6.5-7.6	0.32	0.046	0.7	0.77
Terai	4.0-5.8	0.11	0.032	0.15	0.042
Sub-montance	4.6-7.5	0.42	0.036	0.44	0.62
Desert	6.5-8.4	0.07	0.003	0.51	0.33

Jalpaiguri, Coochbihar and some pockets of higher elevations receive 108 to 880 mm rainfall between November to May.

Natural enemies :

A number of predators and parasites of land snail have been recorded from India. These are described under control measures.

REPRODUCTION

Mating :

Sexual congress in land snails is observed from July onwards when the south-west monsoon is rather strong and there are heavy showers in the plains of India. The snails do not awake from aestivation till the soil becomes soft and holds a high per cent of moisture, and the humidity per cent in the air is very high, which require heavy shower for a few days. The snails awakened after a prolonged aestivation exhibit a low rate of activity for several hours. With the approach of dusk the snails become very active which is associated with fast movement. The whole activity appeared to be guided with the purpose of finding out a partner for mating. None of the snails showed interest in feeding. Large scale mating both in nature and in simulated habitat was observed in the evening, though it continues for the whole night in some pairs. Mating is monsoon dependent and occurs for the whole season. In the simulated habitat mating was recorded from all seasons of the year except winter. In cloudy summer days, in day time, the snails copulated in shady places immediately after emergence from aestivation following a heavy shower in their natural and simulated habitats.

TABLE 3. Meteorological data (temperature, humidity and rainfall) from different areas surveyed.

States/Union Territory	Stations	TEMPERATURE (°C) Absolute Max.	Absolute Mini.	Mean Max.	Mean Mini.	Humidity (Mean)	Total Annual Rainfall (mm)	Number of rainy days in a year	Number of rainy days between Nov. to June	Total rainfall between Nov. to June
ANDAMAN AND NICOBAR	Port Blair	36.4	4.3	30.2	7.4	78	3422.5	108.5	51.2	1405.8
ANDHRA PRADESH	Waltair	41.8	10.4	34.8	14.6	64	920.4	44.6	11.1	304.4
ASSAM	Gauhati	41.1	5.0	37.2	7.8	82	1637.2	86.9	32.4	395.0
	Jorhat	43.0	5.9	38.4	11.5	74	1344.3	71.6	23.0	121.5
BIHAR	Chaibasa	46.7	4.5	44.9	7.3	71	1314.4	74.0	15.0	71.4
	Daltangunge	46.7	0	45.1	3.9	66	1234.4	67.4	9.0	58.0
	Darbhanga	43.9	1.1	41.7	6.0	75	1257.5	57.8	7.8	53.5
	Dhanbad	46.1	5.0	44.4	7.6	63	1197.3	68.8	10.2	56.7
	Dumka	46.7	4.4	44.3	6.3	68	1502.2	77.1	12.0	68.4
	Gaya	47.2	3.3	45.7	6.0	62	1096.6	57.8	5.4	48.1
	Hazaribag	43.9	2.2	42.2	4.6	61	1320.2	75.8	12.2	47.3
	Jamshedpur	47.2	3.9	44.8	6.9	70	1391.3	75.7	13.5	39.5
	Motihari	44.4	0	41.6	4.9	74	1214.8	55.9	7.0	38.5
	Patna	46.1	2.2	43.7	6.5	66	1109.8	53.8	4.8	29.0
	Purnea	43.9	1.7	41.1	4.3	76	1483.6	69.8	7.4	41.8
	Ranchi	43.3	2.8	41.8	5.3	63	1462.7	78.5	13.2	98.8
GUJARAT	Ahmedabad	43.8	10.9	34.4	14.9	64	994.9	62.2	18.6	79.3
HIMACHAL PRADESH	Solan	35.4	3.2	20.7	8.2	79	1809.8	119.3	56.2	808.1
JAMMU AND KASHMIR	Srinagar	22.5	0.0	15.3	6.4	84	1335.3	124.9	59.5	404.7

TABLE 3. Continued [2]

States/Union Territory	Stations	TEMPERATURE (°C) Absolute Max.	Absolute Mini.	Mean Max.	Mean Mini.	Humidity (Mean)	Total Annual Rainfall (mm)	Number of rainy days in a year	Number of rainy days between Nov. to June	Total rainfall between Nov. to June
KARNATAKA	Bangalore	36.4	2.7	34.6	8.1	78	1894.5	158.6	40.8	89.1
KERALA	Calicut	37.2	16.1	34.6	19.1	82	3282.7	120.8	24.6	555.7
	Palghat	41.7	15.6	39.9	18.4	79	2058.6	107.9	26.1	450.1
	Trivandrum	36.8	17.4	30.4	19.6	84	1829.3	105.2	36.0	800.0
MADHYA PRADESH	Bhopal	39.3	10.1	30.4	14.4	64	920.4	44.0	11.1	304.4
MAHARASHTRA	Marathwada	41.2	9.2	34.2	15.5	62	775.6	32.8	7.0	200.4
MANIPUR	Imphal	32.2	6.0	26.1	9.5	79	3492.8	128.2	86.2	1243.4
MEGHALAYA	Shillong	30.7	2.8	28.2	0.6	67	2415.3	128.1	49.0	468.0
NAGALAND	Dimapur	41.0	10.8	37.4	15.7	75	1590.2	78.8	31.5	541.2
ORISSA	Balasore	46.7	6.7	42.7	9.6	73	1688.6	77.0	14.4	44.4
	Chandabali	46.8	8.3	42.2	10.1	78	1625.8	73.8	13.0	49.4
	Cuttack	47.7	7.8	44.3	11.3	77	1557.2	78.3	12.0	50.5
RAJASTHAN	Joypur	48.2	5.4	38.6	10.2	54	704.6	14.8	4.4	101.0
TAMILNADU	Coimbatore	40.0	11.7	37.5	15.8	75	612.2	44.5	21.4	300.00
	Cuddalore	43.3	11.1	40.7	17.3	76	1305.2	55.4	27.0	700.0
	Madras	45.0	13.9	41.5	17.4	74	1215.3	56.6	20.0	580.5
	Madurai	42.2	15.6	40.4	18.1	67	904.9	48.9	21.5	340.0
	Salem	42.8	11.1	40.2	15.5	75	965.0	60.4	25.0	300.00
	Tiruchirapalli	43.9	13.9	40.5	17.2	72	867.6	47.8	22.6	350.0
	Vellore	44.4	11.7	41.7	14.1	74	969.2	53.9	14.4	340.0
TRIPURA	Agartala	42.4	12.1	36.8	18.0	77	2016.4	73.5	34.1	421.6
UTTAR PRADESH	Allahabad	47.8	1.1	45.9	4.5	64	1027.3	53.3	4.6	35.8

TABLE 3. Concluded [3]

States/Union Territory	Stations	TEMPERATURE (°C) Absolute Max.	Absolute Mini.	Mean Max.	Mean Mini.	Humidity (mean)	Total Annual Rainfall (mm)	Number of rainy days in a year	Number of rainy days between Nov. to June	Total rainfall between Nov. to June
	Gorakhpur	48.3	1.7	42.3	5.9	70	1274.4	56.8	6.2	37.5
	Lucknow	48.4	1.1	45.5	4.3	68	992.4	47.9	4.8	41.9
	Varanasi	47.2	1.7	45.2	4.7	67	1113.4	53.0	6.6	83.1
WEST BENGAL	Bankura	42.0	7.5	32.8	19.0	76	1602.0	72.0	28.1	48.4
	Burdwan	39.8	9.4	32.1	20.2	72	1815.2	78.1	29.0	84.0
	Calcutta	36.9	2.3	27.4	17.4	73	1908.5	76.4	34.6	102.4
	Coochbihar	36.6	4.3	26.7	14.1	80	3065.0	94.5	41.4	185.5
	Darjeeling	26.6	0.8	12.3	7.7	83	3400.0	154.0	67.5	238.0
	Malda	36.0	8.9	28.0	19.1	78	1331.0	69.3	29.0	56.0
	Midnapur	41.2	5.0	32.1	20.0	79	1965.5	74.6	30.0	61.6

Mating behaviour

Achatina fulica :

As a rule, preference is always for a partner of equal or near equal age.

The maneuvering process starts with a haunt. A snail looking for a mate can easily be identified by its conspicuous genital aperture surrounded by a whitish zone, which becomes quite prominent due to an outward buldging of the area and the protruded penis directed backward. Haunting continues till it meets the partner which may last for an hour or more.

Courtship begins immediately with the meeting of the prospective partner, and they fondle and caress each other with tentacles, labial palps and even by mouth. During courtship both the partners move side by side, close to each other. The extended visceral stalks are in close contact and they often twine each other. They were also noticed to lick up each other's genitalia and at this time a considerable quantity of a slimy substance was discharged through the genital aperture. One of the partners apparently more active and crawls over the shell of the other, starting from the posterior half of the latter. Interestingly the movement to ride over the other was found only in one individual of a copulating pair while such a behaviour was totally lacking in the other partner.

Immediately after securing the position, the partner above twists the extended visceral stalk clockwise and at the same time bends the anterior portion down in such a way that the genital apertures of the two are apposed. In the process the role of the other partner is restricted only to the lifting of the visceral stalk to aid in the operation. During this maneuvering the penis of the 'active partner' protrudes and retracts for a number of times, in an attempt to insert it into the vagina of the other. The pricking of the genital aperture of the 'less active partner' with the penis of the other, induced similar movement of the penis in the former within a few seconds. The whole procedure continued for about 3 to 7 minutes, or even more in some cases. Once the genital apertures are apposed, a certain length of the penis of one was insertsed into the vagina of the other and vice-versa. The penes are placed one above the other and in all cases the penis of the less active partner is dorsal to that of the other partner. Successive stages in process of mating are shown in Pl. IV, figs. 1 to 4.

In about 3.4% copulating pairs of equal shell size the less active partner does not even attempt to insert its penis in the vagina of the other and such mating might be considered as non-reciprocal. This is probably due to the mismatching of the intromitent organ. In mating between snails of unequal sizes each partner tried to insert its penis in the vagina of the other but only the older one succeeded. The younger partner's attempt to do the same at an interval of 20 to 50 seconds during the whole period of mating are without a success. These snails maintained for several months in cages with most favourable environment, grow larger and were able to mate successfully with the older partners. In general, *A. fulica* require 157 days for the attainment of sexual maturity.

The period in copula varied from 6 to 8 hours and 30 minutes with an average of 7 hours 44 minutes. In the first 10 minutes of the last one hour in copula only two to three sexual movements are usual. In the process the whole of the penis was inserted into the vagina, though in some cases only a part of it remains outside. This is immediately followed by withdrawing a greater length of the penis and this is repeated. The basal vagina protrudes through the genital aperture and mucus discharge starts again. At this stage the spermatozoal mass with a mucoid body is discharged from one into the anterior part of the spermathecal duct of the other and vice-versa.

At the close of the coitus one of the partners, either the active or the less active one withdraws its penis. This is followed by a similar act by the other partner. The pneumostome remains fully open during mating, indicating a high rate of respiration.

The copulating pairs are often disturbed, frequently leading to disengagement by the members of the same species presumably in search of partners, which is evidenced by their behaviour. The intruder crawls over the mating pair and starts licking mucus over the genital area and the penes—an act sufficient to cause separation of the mating pairs.

On dissection of specimens immediately after mating a mucoid mass of soft homogenous substance is found in the spermathecal duct at a short distance from its junction with apical vagina. Microscopic examinations revealed that the tails of highly active spermatozoa were embedded in the mucoid mass while the rest were free in the lumen of the spermathecal duct full with mucus.

Opeas gracile :

Information on the reproductive behaviour of *O. gracile* is restricted to courtship only. Biswas *et al* (1976) observed that the individuals ripe for copulation, crawl about seeking partner, sometimes pausing and lifting the anterior part of the body. When two such individuals come across they test each other with their tentacles and oral lappets. After a break for about 3 to 5 minutes the original movement is resumed.

Macrochlamys indica :

In this species the 'active partner' is much more active than *A. fulica* and its haunting movements are also faster. One 'active partner' never copulates with other of the same kind. If, however, two such snails ever meet, while searching for a partner they change their course and move in different direction. During haunting, changes in the genital area of the 'active partner' are similar to those in *A. fulica* but in no case the penis is protruded out. The tip of the amatorial organ, however, is protruded. The 'active individual' selects a 'less active individual' and courtship begins. Unlike *Achatina* the partners place them in opposite directions and their snouts meet against each other. The 'active partner' first starts the oral caress which is reciprocated by the other. Though in a lesser degree, and this continues for a period of about 25 to 40 minutes with only a few seconds break at irregular intervals. In some cases the mutual oral bitings of the partners are almost continuous. In the process the amatorial organ is extruded at intervals of 20 to 50 seconds and immediately withdraws. Within about 30 to 45 minutes since the beginning of courtship the genital area and the adjacent regions are smeared with profuse slimy secretion. In case, the courtship activity is stopped by the less active partner, the active one picks the visceral stalk of the former near the genital area with the amatorial organ.

The organ, to begin with, kept extending and receeding and occasionally shooting out to a length of about 2.2 cm, and suddenly pricking the partner near the genital pore to excite it. Sometimes instantaneously sometimes after few minutes the partner responds by extending its own love dart or amatorial organ, an elongated pearshaped structure. Generally, it is cream coloured but may be pink, purple or even light brown depending on the colour of the content, a fluid secreted during courtship to make the organ turgid and or lubricated.

Riding over the partner, common with *Achatina* is entirely absent in *Macrochlamys*. The snails move their visceral stalk closer as to lie side by side and the genital apertures were apposed. The protruded amatorial organ is never completely withdrawn until coitus is over. In a full grown specimen the amatorial organ measures 14 to 18 mm, which in a fully extended condition during courtship and mating might be as long as 28 mm. The apposition of the genital openings is immediately followed by the insertion of the penis of one partner into the vagina of the other and vice-versa. The penis is a somewhat bent, cream coloured organ, about 8 mm long, and gradually tapering towards the tip.

Since the beginning of copulation the amatorial organs of both the snails extend over the visceral stalk of the other up to the base of the shell aperture and starts pricking the partner at the nuchal region. This presumably excites the partners to move their genital openings still closer to facilitate complete penetration of the penis into others vagina. The pricking is followed by 180° anticlockwise rotation of the shell of each partner. This is followed by a reverse rotation and the shell returns to the original position which repeats with each pricking. The frequency rate of pricking, however, differs with the mating partners. During these operations the snails retract their tentacles completely. In one mating the active partner rotates 62 to 97 times while the passive one rotates 44 to 75 times.

After playing with love darts for a period of about 20 to 40 minutes the snails are presumably exhausted and remain absolutely still. At this stage the straight amatorial organ of one partner is placed against the right side of the other partner and thus offered a mutual pressure bring the partners still closer. Finally the snails become indifferent to external stimuli. After few minutes they extend their tentacles and the foot and visceral stalk are contracted. Coitus is presumably at its highest at this stage. The genital apertures come so close that the penes cannot be seen any more. The pneumostome remains widely open during mating suggesting a fast respiration rate.

After a lapse of about 5 to 8 minutes they again become active and start pricking with the amatorial organs at a slower rate which is associated with the rotation of the shell. This continues for about 3 to 6 minutes. In the meantime one of the partners withdrawn its penis and the other follows it. The time for copulation varies from 24 to 39 minutes with an average of 29.4 minutes. After a few minute the snails move in their own way and the amatorial organ are withdrawn within 4 to 6 minutes. The courtship and mating follows certain sequences which are probably common in all the members of Ariophantidae. Successive stages during mating are shown in Pl. V, figs. 1 to 4.

In *M. indica* reciprocal mating is a general feature. In 14% cases one-sided mating is observed. Repeated mating in one breeding season is also common and choice for a particular partner is absent. In interference in mating the intruder suddenly bites the amatorial organ of one of the partners which ensures disengagement. Spermatozoa embedded in a soft homogeneous mucoid mass as in *A. fulica* are observed in the apical vagina immediately after mating.

M. indica require 130 days for the attainment of sexual maturity.

Mating behaviour in *A. solata*, *C. semirugata*, *C. bistrialis* and *B. monticola* is not on record. Since they all are the members of the family Ariophantidae it is probable that they would exhibit almost similar type of behaviour as described for *M. indica* and some other ariophantids (Dasen, 1933 ; Rensch, 1955). According to Krishnamoorthy and Viswanathan (1972) mating is essential for reproduction in *Ariophanta solata.*

Factors influencing mating :

Temperature : A definite range of temperature is essential for mating. Both in simulated habited and in nature mating takes place in the temperature range 22 to 32°C and 26 to 30°C might be considered as optimum. Mating could not be recorded at temperature both below and above the range 18 to 32°C. Daylight is a stronger inhibitor than temperature as mating in dark was common in both the limits of temperature range, while in daylight it did not occur even at the optimum temperature range. The average night temperature range in summer in the simulating habitat was 23.5°C to 36°C. The temperature dropped with the advance of night and mating starts at 32°C. Depending on temperature, mating starts at midnight or even in the early hours and occasionally the snails in copula are found in the next bright, sunny morning.

Humidity : Humidity is presumably the most important factor for the activity of the mating. As a rule, in nature, copulation takes place after rain. Snails acti vated by heavy showers, and continuous cloudy weather during normal aestivating period, started mating sometimes after the shower. In rainy season frequent mating was observed after rains, but no mating was ever recorded in humidity below 86% which appears to be the lower limit of humidity for mating.

Rainfall : Rain encourages mating. Snails were often found in copula in daytime, in cloudy days after shower. Drizzling in monsoon is presumably the ideal condition for mating, while heavy showers and stormy weather inhibit pairing. Copulating pairs exposed to heavy showers disengaged themselves before completion of mating.

Fertilization :

Stylommatophores are hermaphroditic molluscs and the possibility of self-fertilization has not been ruled out by some workers, though majority hold that self-fertilization is absent.

A number of *A. fulica* and *M. indica* were reared in isolation since hatching for a period of 560 days. None of them laid eggs. On 561st day they were released in one cage to study the possibility of mating. Some of the specimens mated on the same day while others were found in copula in the next day. However, in *Opeas gracile* self-fertilization is a common occurrence (Biswas *et al.*, 1976 ; Subba Rao *et al.*, In press)

From dissection it is observed that in *A. fulica* the spermatheca and the talon and in *M. indica* only the spermatheca are the possible sites of storage of sperms received from other partner. It is generally accepted that sperms stored in talon fertilize the eggs in *Achatina*. The sperms could not be recorded from the talon of sexually matured *A. fulica* reared in isolation since hatching. The sperms received in mating remain viable for 341 and 476 days in active period (Raut and Ghose, 1979c) and for 105 and 150 days in aestivation (Raut and Ghose, 1982) in *A. fulica* and *M. indica* respectively.

To ascertain the course followed by the sperms received in mating, from the first part of the spermathecal duct or from the basal vagina to carrefour, the site of fertilization, a number of snails were sacrificed at certain intervals following mating.

The mucoid mass with embedded sperms was recorded in the first part of the spermathecal duct in *Achatina* dissected immediately after mating. However, by two hours, it reached the spermathecal sac in some cases while the maximum period required to reach the site was five hours. Subsequently the sperms separated themselves from the mucoid body and headed towards the talon individually. The shortest time taken in the journey was three hours, but it was delayed as long as twenty five hours in some snails. By this time the spermatheca was emptied of live sperms and what remained there was the abandoned, some what harden mucoid mass with a few dead sperms.

In *Macrochlamys* the mucoid mass with sperms received from the other partner in mating was similar to that in *Achatina*. In specimens dissected immediately after mating, the mucoid body was found in the apical vagina. From there it reached the sac of the spermatheca within two to four hours which varied with snails. A structure like talon is absent in *Macrochlamys* and viable sperms were recorded from the spermatheca, even in aestivating snails. It appears that unlike *Achatina*, sperms move to the site of fertilization from there at the time of need.

Ovulation presumably starts with the arrival of the spermatozoa (allosperms) in the talon and spermatheca of *A. fulica* and *M. indica* respectively and fertilization is effected in the carrefour. The zygote is surrounded by albumen, secreted from the albumen gland, which reaches carrefour through its duct. A delicate but tough and semi-transparent membrane is formed and the zygote enters the apical uterus. The process of fertilization continues for about a fortnight in *A. fulica*. The egg in its downward course receives deposition of calcium carbonate in both the apical and basal uteri and yellow pigment in the basal uterus, and majority of the eggs are laid with hard, yellow shell, while a few egg with whitish and fragile shell are found almost in all broods. In *Macrochlamys* fertilization continues for about a week and leathery shell with certain amount of calcic substance is secreted in the uterus.

OVIPOSITION

Achatina fulica :

A. fulica lay eggs usually after 20 days of mating (Raut and Ghose, 1980b). Laying of eggs in an isolated mass is common. This is essential for hatching as the egg mass is to be covered with sufficient amount of mucus to prevent desiccation. In isolated eggs, due to loss of water the albumen becomes viscous and the developing embryo dies.

Site selection :

Selection of a suitable site for oviposition is a must. The gravid snail crawls for hours to select a site for laying eggs. Generally loose soil with high per cent of moisture, inside bushes, in the interspaces of stones and bricks, and the litters and decomposed leaves are always preferred. During full monsoon, litters and heaps of decomposed leaves are preferred sites in most cases. Sites are always protected from direct rainfall, sunlight and predators.

Field observations at Garia, Jadavpur, Baruipur, Ballygunge, Uttarpara, the suburbs of Calcutta and Serampore, Jalpaiguri and Coochbehar of West Bengal, in the districts of North Bihar and Assam, with heavy *Achatina* population revealed that in the areas likely to be flooded after heavy showers the snails usually prepare the nests on high lands though excellent sites were available in the low areas where they lay eggs in post-monsoon period.

Nest preparation :

Site selection was immediately followed by digging a shallow hole with the help of the snout and the anterior part of the foot. In the process the snout and the foot were pressed steadily in the soil and a deep narrow hole was made. This was followed by pressing out the soil from the wall of the hole to widen it. In case the soil was loose and could not be pressed to a compact mass, it was drawn out with the help of snout and foot and thus the diameter of the hole increased. The whole operation required about 3 to 7 hours depending chiefly on the nature of the soil and only partly on the size of the snail.

The holes were wide at the bottom and gradully narrowed towards the surface. On the average a hole is 3 to 5 cm deep and 2.5 cm wide at the top. In cases, loose soil from the sides rolled down in the holes, it was either pressed to a compact mass by the snout and foot or removed out of the hole, leaving the latter clean and smooth. It was occasionally found that a snail prepared the nest but did not lay eggs for some unknown reasons was utilised by other snails for egg laying.

Egg laying :

Immediately after the nest was built, without withdrawing its head the snail started laying eggs. In the process the snail twisted the anterior end of its visceral stalk in a clockwise manner to bring the genital pore as near the ground as possible. The movement of an egg from the basal uterus to the genital pore could be traced as a bulging appears on the right side of the visceral stalk close to the oviduct, and muscular waves on the former were associated with the movement of the egg. The eggs were laid one by one with a profuse quantity of mucus. The eggs (Pl. VI, figs. 1a and b) were always laid in heaps. After a number of eggs were laid, the snail temporarily stops further egg laying and collects the eggs together with the help of the snout, labial palps and the anterior end of the foot. A large amount of mucus was discharged from the pedal gland through its opening at the anterior end of the foot. The mucus largely helps in keeping the egg mass together. This was followed by resumption of egg laying and the whole process was repeated till the oviposition was complete. Ordinarily egg laying starts at night and rarely in daytime. The time required in one oviposition was extremly variable. A brood of 41 eggs was laid in more than two hours while a brood of 131 eggs required 20 minutes and that of 314 eggs only 46 minutes. Occasionally the eggs were laid in two batches. In a brood of 207 eggs 191 were laid in the first batch, and a second batch of 16 eggs was laid after an interval of 41 hours, the total period covering 43 hours. The interval between laying of successive egg also varied considerably. On the completion of egg laying the snails cover the eggs with its partly extended foot for a period varying between 3 to 32 hours, presumably to protect the brood. This was followed by pushing down loose soil over the brood from the sides of the nest, and covering the eggs with an even layer of soil with the help of the snout and the anterior end of the foot.

Though rare, *Achatina* lay eggs on the soil surface and in such case the eggs usually separate from one another.

Ovulation frequency, egg laying capacity and gestation period :

Twenty four copulating pairs of different size groups, viz. 56.4 to 66.2 mm, 75.4 to 80.1mm, 90.1 to 94.0 mm and 100.1 to 104.9 mm, were collected at random and kept in isolation for the whole of the breeding season, June to October, 1975. It is to be mentioned that the snails of the smallest size group mated for the first time after the attainment of sexual maturity. During the period of observation either one of the partners or both of them died in some cases, and eight pairs affected in this way were not considered for the study. Observations are expressed in Tables—4a to d. From the studies on the growth rate it is known that the snails reach up to 55.0 mm

TABLE 4a. Broods, total number of eggs and the intervals between mating and first brooding, and successive broods, hatching period and number of viable embryos in 56.4 to 66.2 mm. *A. fulica* when each pair kept in isolation for one breeding season (June—October).

Serial No.	Pair index	Date of first mating	Shell size (mm) at first mating	Date of brooding	Shell size (mm) during each brooding	Period between clutches (days)	No. of eggs per brood	Total no. of eggs in one breeding season by Individual	Pair	Hatching period (days)	No. of embryos per brood	Production per snail	Production per pair
1	A×A′	July 6, 1975	56.4×62.1	July 26, 1975 Sept. 3, 1975	A 59.6 69.2	0 (20)* 39	70 104	174	343	1—16 1—14	65(92.8%) 98(94.2%)	163(93.6%)	321(93.5%)
		July 6, 1975		July 30, 1975 Aug. 27, 1975	A′ 64.4 71.3	0 (24)* 27	58 111	169		2—16 1—13	49(84.4%) 109(98.1%)	158(93.4%)	
2	B×B′	June 25, 1975	62.0×64.4	July 19, 1975 Sept. 11, 1975	B 64.4 75.0	0 (24)* 53	62 111	173	349	1—17 1—13	62(100%) 108(97.2%)	170(98.2%)	334(95.7%)
		June 25, 1975		July 24, 1975 Aug. 24, 1975	B′ 66.1 70.4	0 (29)* 30	56 120	176		1—14 2—17	50(89.2%) 114(95.0%)	164(93.1%)	
3	C×C′	July 16, 1975	61.6×66.2	Aug. 5, 1975 Sept. 21, 1975	C 65.0 73.1	0 (20)* 46	51 118	169	352	1—17 1—17	50(98.0%) 111(94.0%)	161(95.2%)	336(95.4%)
		July 16, 1975		Aug. 8, 1975 Sept. 9, 1975	C′ 68.2 71.6	0 (23)* 31	68 115	183		1—16 1—11	63(92.6%) 112(97.3%)	175(95.8%)	
4	D×D′	July 21, 1975	58.2×62.5	Aug. 16, 1975 Sept. 12, 1975	D 61.4 63.1	0 (26)* 26	46 97	143	309	1—12 1—14	44(95.6%) 95(97.9%)	139(97.6%)	297(96.1%)
		July 21, 1975		Aug. 19, 1975 Sept. 28, 1975	D′ 66.6 74.4	0 (29)* 39	66 100	166		2—17 2—12	62(93.9%) 96(96.0%)	158(95.2%)	

*indicates the period between first mating and first brooding.

TABLE 4b. Broods, total number of eggs and the intervals between mating and first brooding, and successive broods, hatching period and number of viable embryos in 75.2 to 80.1 mm, *A fulica* when each pair kept in isolation for one breeding season (June—October).

Serial No.	Pair Index	Date of mating	Shell size (mm) at mating	Date of brooding	Shell size (mm) during each brooding	Period between clutches (days)	No. of eggs per brood	Total no. of eggs in one breeding season by: Individual	Total no. of eggs in one breeding season by: Pair	Hatching period (days)	No. of embryos per brood	Production per snail	Production per pair
1	E×E′	June 29, 1975	75.4×73.0	July 19, 1975	E 78.1	0(20)*	117			1—14	107(91.4%)		
				Aug. 16, 1975	83.6	27	166	472		1—14	161(96.9%)	449(95.1%)	
				Sept. 26, 1975	89.7	40	189		980	1—17	181(95.7%)		933(95.2%)
		June 29, 1975		July 21, 1975	E′ 78.0	0(20)*	148			2—17	141(95.2%)		
				Aug. 14, 1975	83.2	23	169	508		1—16	157(92.9%)	484(95.2%)	
				Oct. 1, 1975	90.0	54	191			1—12	186(97.3%)		
2	F×F′	June 28, 1975	76.4×75.2	July 18, 1975	F 79.0	0(20)*	139			2—16	131(94.2%)		
				Aug. 20, 1975	83.3	32	105	432		2—12	96(91.4%)	409(94.6%)	
				Oct. 3, 1975	87.4	43	188		940	1—16	182(96.8%)		897(95.4%)
		June 28, 1975		July 18, 1975	F′ 78.2	0(20)*	190			1—16	182(95.7%)		
				Sept. 5, 1975	85.2	48	146	508		2—14	140(95.8%)	488(96%)	
				Oct. 3, 1975	87.2	27	172			1—17	166(96.5%)		
3	G×G′	Juue 19, 1975	75.2×80.1	July 10, 1975	G 76.8	0(21)*	184			1—14	178(96.7%)		
				Aug. 14, 1975	80.6	35	196	485		1—12	182(92.8%)	457(94.2%)	
				Oct, 4, 1975	89.2	48	105		1053	2—16	97(92.3%)		997(94.6%)
		June 19, 1975		July 9, 1975	G′ 82.0	0(20)*	201			1—15	200(99.5%)		
				Aug. 2, 1975	85.3	24	147	568		2—16	140(95.2%)	540(95.0%)	
				Sept. 1, 1975	89.6	29	220			2—12	200(90.9%)		
4	H×H′	June 16, 1975	76.2×80.0	July 6, 1975	H 77.2	0(20)*	164			1—12	159(96.9%)		
				Aug. 13, 1975	80.6	38	100	495		2—16	94(94.0%)	473(95.5%)	
				Sept. 29, 1975	86.2	47	231		849	1—15	220(95.2%)		805(94.8%)
		June 16, 1975		July 9, 1975	H′ 82.0	0(23)*	199	354		1—10	191(95.9%)	332(93.7%)	
				Aug. 14, 1975	85.5	36	155			2—14	141(90.9%)		

* indicates the period between mating and first brooding.

TABLE 4c. Broods, total number of eggs and the intervals between mating and first brooding, and successive broods, hatching period and number of viable embryos in 90.1 to 94.0 mm *A. fulica* when each pair kept in isolation for one breeding season (June—October).

Serial No.	Pair index	Date of mating	Shell size (mm) at mating	Date of brooding	Shell size (mm) during each brooding	Period between clutches (days)	No. of eggs per brood	Total no. of eggs in one breeding season by Individual	Total no. of eggs in one breeding season by Pair	Hatching period (days)	No. of embryos per brood	Production per snail	Production per pair
1	K×K′	June 16, 1975	90.1×90.2	July 6, 1975	K 91.6	0 (20)*	198			1—10	181(91.4%)		
				Aug. 11, 1975	93.5	36	167	611		1—10	162(97.0%)	577(94.4%)	
				Sept. 29, 1975	96.6	41	246		1210	1—14	234(95.1%)		1136(93.8%)
		June 16, 1975		July 19, 1975	K′ 92 2	0 (33)*	220			1—16	207(94.0%)		
				Aug. 26, 1975	95.0	37	185	599		1—14	166(89.7%)	559(93.3%)	
				Oct. 2, 1975	97.7	36	194			1—12	186(95.8%)		
2	L×L′	June 23, 1975	92.3×93.5	July 17, 1975	L 93.5	0 (24)*	211			1—11	207(98.1%)		
				Aug. 29, 1975	95.4	43	182	634		1—16	177(97.2%)	618(97.4%)	
				Sept. 21, 1975	98.8	22	241		1097	1—10	234(97.0%)		1066(97.1%)
		June 23, 1975		July 19, 1975	L′ 94.8	0 (26)*	207	463		1—10	201(97.1%)	448(96.7%)	
				Sept. 24, 1975	99.0	66	256			1—16	247(96.4%)		
3	M×M′	June 11, 1975	92.0×94.0	July 21, 1975	M 93.7	0 (41)*	246			1—10	232(94.3%)		
				Aug. 29, 1975	95.0	38	230	732		2—14	201(87.3%)	677(92.4%)	
				Oct. 3, 1975	99.7	44	256		1431	2—10	244(95.3%)		1330(92.9%)
		June 11, 1975		July 12, 1975	M′ 95.5	0 (28)*	246			2—16	230(93.5%)		
				Sept. 1, 1975	98.1	54	181	699		1—10	167(92.2%)	653(93.4%)	
				Oct. 3, 1975	100.0	31	272			2—17	256(94.1%)		
4	N×N′	June 25, 1975	91.1×93.3	July 17, 1975	N 93.1	0 (22)*	244			2—10	228(93.4%)		
				Aug. 27, 1975	96.0	31	201	714		2—10	186(92.5%)	675(94.5%)	
				Oct. 1, 1975	100.0	35	269		1445	1—16	261(97.0%)		1353(93.6%)
		June 25, 1975		July 16, 1975	N′ 94.0	0 (21)*	212			2—10	198(93.3%)		
				Aug. 16, 1975	97.1	41	247	731		1—12	226(91.5%)	678(92.7%)	
				Sept. 30, 1975	100.0	34	272			1—16	254(93.4%)		

*indicates period between mating and first brooding.

TABLE 4d. Broods, total number of eggs and the intervals between mating and first brooding, and successive broods, hatching period and number of viable embryos in 100.1 to 104.9 mm *A. fulica* when each pair kept in isolation for one breeding season (June—October).

Serial No.	Pair Index	Date of mating	Shell size (mm) at mating	Date of brooding	Shell size (mm) during each brooding	Period between clutches (days)	No. of eggs per brood	Total no. of eggs in one breeding season by: Individual	Total no. of eggs in one breeding season by: Pair	Hatching period (days)	No. of embryos per brood	Production per snail	Production per pair
1	P×P′	June 22, 1975	100.1×100.3	July 18, 1975	P 102.0	0(26)*	214	506		2—10	204(95.3%)	488(96.4%)	1049(95.6%)
				Sept. 5, 1975	105.1	49	292			2—16	284(97.2%)		
		June 22, 1975		July 24, 1975	P′ 102.5	0(32)*	310	591	1097	1—10	297(95.8%)	561(94.9%)	
				Oct. 1, 1975	108.2	69	281			2—10	264(93.9%)		
2	Q×Q′	July 4, 1975	102.0×102.6	July 24, 1975	Q 104.0	0(20)*	304	590		1—10	300(98.6%)	581(98.4%)	1190(95.7%)
				Sept. 1, 1975	107.0	39	286			1—12	281(98.3%)		
		July 4, 1975		Aug 2, 1975	Q′ 106.7	0(28)*	344	653	1243	1—10	319(92.7%)	609(93.2%)	
				Sept. 19, 1975	108.5	48	309			1—15	290(93.8%)		
3	R×R′	July 6, 1975	102.0×104.1	July 26, 1975	R 104.4	0(20)*	300	602		1—12	284(94.6%)	560(93.0%)	1122(93.7%)
				Sept. 20, 1975	108.8	56	302			1—14	276(91.3%)		
		July 6, 1975		July 27, 1975	R′ 105.3	0(21)*	266	595	1197	1—16	258(96.9%)	562(94.4%)	
				Sept. 4, 1975	108.0	44	329			1—16	304(92.4%)		
4	S×S′	June 22. 1975	102.3×104.9	July 12, 1975	S 103.9	0(20)*	342	642	1266	1—16	327(95.6%)	619(96.4%)	1239(97.8%)
				Aug. 27, 1975	108.0	46	300			1—16	292(97.3%)		
		June 22, 1975		July 19, 1975	S′ 105.9	0(27)°	314	624		1—14	311(99.0%)	620(99.3%)	
				Sept. 2, 1975	108.5	45	310			1—16	309(99.6%)		

* indicates the period between mating and first brooding.

in the first year, if hatched in early July and grow 56.0 to 75.0 mm, 76.0 to 90.0 mm, 91.0 to 100.0 mm and 101.0 to 108.0 mm in the successive years.

The snails do not attain sexual maturity in the first year. Egg laying starts in the second year and continues for the whole life, which usually does not exceed five years. The number of broods laid by an individual snail gradually increased with age till the fourth year, which was followed by a decline in the fifth year. The number of broods were two for each of the second and fifth year and it was three for each of the third and fourth year (Fig. 3). On the other hand, the number of eggs steadily increased with the age of the snail reaching a maximum in the fourth year (Fig. 4). On an average the lowest number was 46 in the first laying and 344 in the last brooding. It is estimated that a pair of snails produced 338, 955, 1295, 1200 eggs in the second, third, fourth and fifth year respectively. Laying of

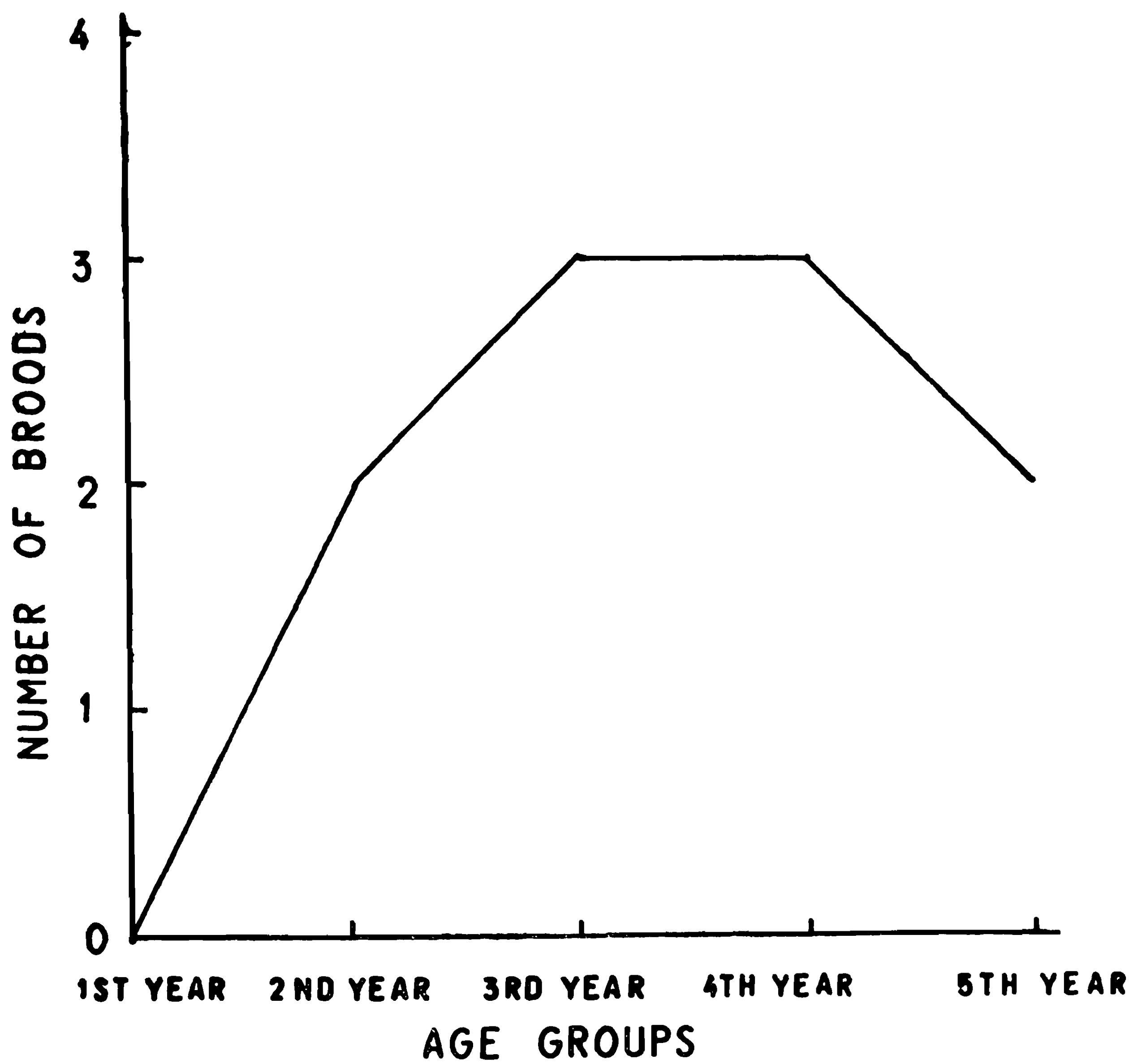

Fig. 3. Brooding frequency in *A. fulica*.

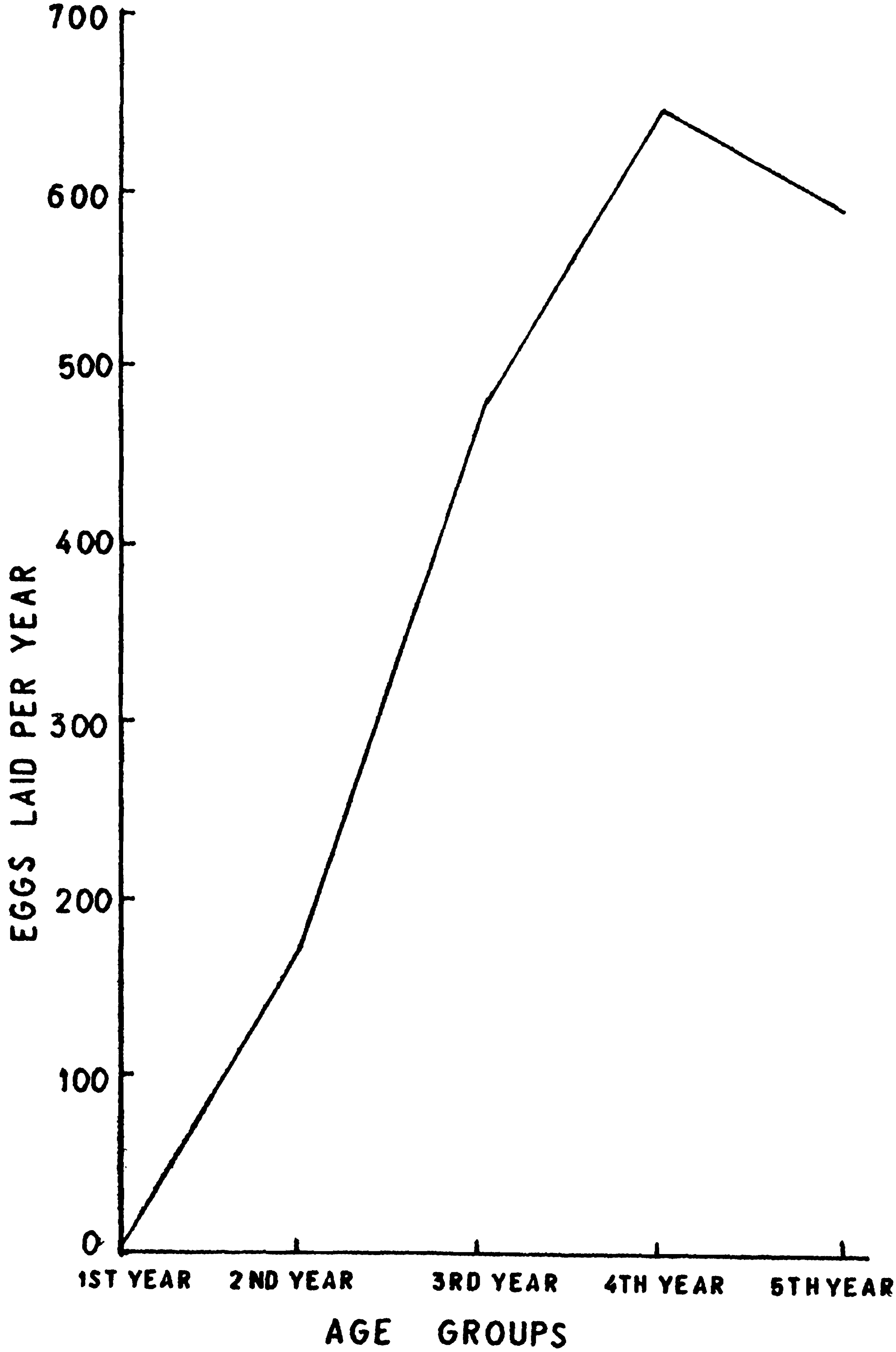

Fig. 4. Number of eggs laid per year by a single *A. fulica*.

eggs at frequent intervals is not rare. The minimum period between two broods was 23 days while the maximum was 69 days.

Gestation period is 20 days for healthy individuals but may be as long as 69 days in rare cases. Isolated individuals laid eggs within 20 to 32 days of mating.

Eighty four to 98% eggs were viable.

Colour and size of eggs :

The eggs of 1000 broods were measured. Most of the eggs are ovoid, measuring 4.0 to 6.2 mm × 3.0 to 5.1 mm the average being 5.8 × 4.3 mm. About 3.1% eggs were smaller in size, 2.7 × 1.9 mm, and round in shape.

From the colour of the egg shell three distinct types of broods could be distinguished. On an average 73% were deep yellow, 21% light yellow and 6% whitish. In almost all the broods, with deep yellow eggs, on the average 10 to 15% were light yellow and 5 to 10% whitish. The deep yellow eggs are always laid first, which is followed by light yellow and whitish eggs.

Hatching :

Hatching starts 1 to 17 days after egg laying. The period largely depends upon the period for which the eggs were retained in the uterus (Ghose, 1960). Deeper the yellow colour of the eggs less was the period of hatching. Embryos in the deep yellow eggs hatched out within 1 to 12 days while those in the light yellow eggs came out within 4 to 17 days, and from about 8% whitish eggs embryos hatched out between 15 to 17 days. Embryos in the rest of the whitish and the small yellow eggs did not come out.

The egg-shell looses its brilliance and toughness considerably during incubation. The fragile eggs were easily broken down by the pressure of the foot of the hatching embryos. About 4 to 9 hours prior to emergence of the young snail a crack appeared on the egg shell, which gradually widened and the snail crawled out of the egg shell carrying a fragment of it on its back in most cases.

Influence of moisture and temperature on hatching :

Moisture too great or too low is harmful to developing embryos. In the first case, excess water in the soil prevents exchange of gases through the egg shell, while in the later case the water content of the albumen is lowered and it turns to a viscous mass, which the embryo can not utilise.

The ideal condition for development is moist soil with 78 to 95% humidity. Temperature also considerably influences the development. The most favourable range is 22 to 32°C though normal development was recorded in temperature a few degree above and below the range.

In the study of the role of temperature on hatching, broods were collected in monsoon, placed in wooden boxes containing loose, moist soil. The eggs were covered with loose soil and the boxes were placed in humidity and temperature controlled chamers. The experiment was conducted for 30 days. The optimum temperature range for hatching is 22°C-31°C. The embryos did not hatch out below 15°C ; hatching was delayed by 3 to 7 days at temperature 16°C to 24°C ; slightly faster at 30°C to 35°C and failed at above 35°C.

Opeas gracile :

O. gracile lay eggs in night but rarely in daytime (Biswas *et al.*, 1976). Nest preparation is absent. The eggs are usually laid under leaves, stones, bricks and like wise. Biswas *et al* (1976) reported that in a glass jar containing many snails the eggs were laid on the walls and the lid.

The eggs are rounded, enclosed in a thick, tough, calcareous shell, white in colour and not easily breakable. The diameter of the eggs varies from 0.9 to 1.1 mm. Once laid, the eggs are not cared for by the mothers although they are sometimes found to wait near them for a few minutes, presumably to overcome the exhaustion of egg laying.

On an average *O. gracile* lay 131 eggs in its life span. The inter-brooding period ranges from 1 to 13 days. The number of eggs laid on the first day ranges from 1 to 3 while the highest number of eggs laid by a snail on any one day is 17 (Subba Rao *et al*, In press).

Hatching :

Hatching starts on the 10th day after laying. Freshly hatched snails become active after a brief period and crawl up the walls of the container before starting feeding.

Macrochlamys indica :

Site selection : Site for egg laying in *M. indica* are similar to those reported in *A. fulica*, though laying of eggs in the interspaces between the bricks of old and moist walls, as high as 130 cm was recorded in some cases.

Nest preparation : With the help of their snout and anterior end of the foot the snails dig hole in the moist soil. The hole is about 1.5 to 2.3 cm deep and 0.7 cm in diameter.

Egg laying : Ovipositing behaviour is almost similar to that of *A. fulica* but egg laying on the soil surface is totally absent in this species. Immediately after the nest is made the eggs are laid close to one another or in a mass, one above the other. Mucus secretion is not sufficient to fill the spaces between the eggs. Laying is generally completed in 10 to 24 minutes. The number of eggs in a brood varied widely. It was 2 to 12 with an average of 7 eggs per brood. The eggs were covered with loose soil particles and the snails stayed on the nest for about 5 to 18 minutes, the average being 11 minutes.

Ovulation frequency, gestation period and egg laying capacity :

Eighteen copulating pairs of different size-groups viz. 10.5 to 11.5 mm, 13.4 to 15.4 mm and 18.0 to 19.5 mm, were collected at random and kept in isolation for the whole breeding season, June to October, 1975. Either one of the partners or both of some of the pairs died in this period, and those pairs were not considered. Observations on the frequency of ovulation, gestation period, egg laying capacity and the viability of eggs in 12 pairs are expressed in Tables 5a—c.

The snails attain 10 mm in the first year, 10 to 14 mm, 14 to 18 mm and 18 to 21 mm in the second, third and fourth year respectively. Egg laying started in the second year with the shell length 10.5 mm and continued for the whole life, which usually does not exceed four years. The number of broods laid by an individual gradually increased with age till the third year, which was followed by a decline in the fourth year. The number was same, 4 broods, both in the second and the fourth years (Fig. 5). A total of 6 broods was laid in the third year. On an average a pair produced 33 to 38 (average 36) eggs in the second year, 63 to 76 (average 69) eggs in the third year and 69 to 93 (average 83) eggs in the fourth year. The number of eggs steadily increased with age reaching the maximum in the oldest snails (Fig. 6). In general, there were 2 eggs in the first brood and 12 in the last brood. The eggs were laid at an interval of 12 days but the period was as long as 49 days in some cases. Gestation period is usually 10 days but it may extend up to 17 days. Fifty to 100% eggs were fertile.

Size and colour of eggs :

The eggs are translucent, round and with a tough elastic leathery egg shell impregnated with a certain amount of calcic material. The diameter of an egg on the average is 3.0 to 3.5 mm.

Hatching :

Incubation period varied from 8 to 12 days with an average of 9.9 days from the date of laying. The egg shell gradually becomes somewhat trans-

TABLE 5a. Broods, total number of eggs and the intervals between mating and first brooding, and successive broods, hatching period and number of viable embryos in 10.5 to 11.5 mm, shell diameter *M. indica*, each pair kept in isolation for one breeding season (June—October).

Serial No.	Pair index	Date of first mating	Shell size (mm) at the first mating		Date of brooding	Shell size (mm) during each brooding	Period between clutches (days)	No. of eggs per brood	Total no. of eggs in one breeding season by Individual	Pair	Hatching period (days)	No. of embryos per brood	Production per snail	Production per pair
1	a×a′	July 4, 1975	10.5×10.5	a	July 14, 1975	10.9	0(10)*	4			8—12	4(100.0%)		
					July 30, 1975	11.4	15	4	19		8—12	4(100.0%)	17(89.4%)	
					Aug. 21, 1975	12.0	21	5			9—11	5(100.0%)		
					Sept. 16, 1975	13.2	25	6		38	8—12	4(66.6%)		34(89.4%)
		July 4, 1975		a′	July 14, 1975	10.9	0(10)*	4			8—12	3(75.0%)		
					Aug. 12, 1975	11.8	28	5	19		8—10	5(100.0%)	17(89.4%)	
					Sept. 2, 1975	12.5	20	6			9—10	5(83.3%)		
					Sept. 24, 1975	13.7	21	4			9—12	4(100.0%)		
2	b×b′	July 10, 1975	10.6×11.2	b	July 24, 1975	10.9	0(14)*	3			9—10	3(100.0%)		
					Aug. 13, 1975	11.6	19	6	13		9—12	5(83.3%)	12(92.3%)	
					Oct. 2, 1975	13.8	49	4		33	9—12	4(100.0%)		30(90.9%)
		July 10, 1975		b′	July 21, 1975	11.6	0(10)*	4			9—12	4(100.0%)		
					Aug. 18, 1975	12.8	28	4	20		9—10	4(100.0%)	18(90.0%)	
					Sept. 4, 1975	13.3	16	6			8—12	4(66.6%)		
					Sept. 27, 1975	14.0	22	6			8—12	6(100.0%)		
3	c×c′	June 29, 1975	10.8×11.0	c	July 11, 1975	11.3	0(12)*	4			9—11	4(100.0%)		
					July 29, 1975	11.9	17	4	19		9—10	4(100.0%)	18(94.7%)	
					Aug. 29, 1975	12.9	30	5			9—12	4(80.0%)		
					Sept. 22, 1975	13.8	23	6		37	9—12	6(100.0%)		33(89.1%)
		June 29, 1975		c′	July 13, 1975	11.6	0(13)*	4			9—12	3(75.0%)		
					Aug. 3, 1975	12.8	20	3	18		9—12	3(100.0%)	15(98.3%)	
					Sept. 1, 1975	13.4	28	4			8—12	4(100.0%)		
					Oct. 3, 1975	14.0	31	7			8—12	5(71.4%)		
4	d×d′	July 10, 1975	10.6×11.5	d	July 20, 1975	10.8	0(12)*	4			9—19	2(50.0%)		
					Aug. 7, 1975	11.4	17	5	20		9—11	5(100.0%)	17(85.0%)	
					Aug. 28, 1975	11.9	20	6			9—12	5(83.0%)		
					Sept. 29, 1975	13.7	31	5		38	9—12	5(100.0%)		32(84.2%)
		July 10, 1975		d′	July 24, 1975	11.9	0(16)*	5			9—10	5(100.0%)		
					Aug. 20, 1975	12.9	26	6	18		9—12	3(50.0%)	15(83.3%)	
					Sept. 15, 1975	13.6	25	4			9—12	4(100.0%)		
					Oct. 13, 1975	14.0	27	3			9—12	3(100.0%)		

*indicates the period between first mating and first brooding.

TABLE 5b. **Broods, total number of eggs and the intervals between mating and first brooding, and successive broods, hatching period and number of viable embryos in 13.4 to 15.4 mm shell diameter *M. indica*, each pair kept in isolation for one breeding season (June—October).**

Serial No.	Pair index	Date of mating	Shell size (mm) at mating	Date of brooding	Shell size (mm) during each brooding	Period between clutches (days)	No. of eggs per brood	Total no. of eggs in one breeding season by		Hatching period (days)	No. of embryos per brood	Production per snail	Production per pair
								Individual	Pair				
1	e×é	June 29, 1975	13.4×14.1	July 9, 1975	13.8	0(10)*	5			9—11	5(100.0%)		
				Aug. 3, 1975	14.9	24	6			9—10	5(83.3%)		
				e Aug. 19, 1975	15.4	15	5	31		9—10	5(100.0%)	28(90.3%)	
				Sept. 20, 1975	16.6	31	9			9—12	8(88.8%)		
				Oct. 6, 1975	17.2	15	6		67	9—12	5(83.3%)		58(86.5%)
		June 29, 1975		July 12, 1975	14.7	0(13)*	5			9—10	5(100.0%)		
				July 30, 1975	15.3	17	5			8—12	5(100.0%)		
				é Aug. 17, 1975	16.0	17	6	36		9—12	6(100.0%)	30(83.3%)	
				Sept. 8, 1975	17.3	21	8			9—12	6(75.0%)		
				Oct. 2, 1975	18.2	23	5			8—12	3(60.0%)		
				Oct. 24, 1975	19.0	21	7			9—12	5(71.4%)		
2	f×f′	June 29, 1975	14.0×14.3	July 16, 1975	14.4	0(17)*	6			9—12	6(100.0%)		
				July 31, 1975	15.0	14	6			9—10	4(66.6%)		
				f Aug. 22, 1975	15.8	21	4			9—10	4(100.0%)		
				Sept. 5, 1975	16.4	13	6	33		9—10	5(83.3%)	28(84.8%)	
				Sept. 24, 1975	17.0	18	6			8—12	6(100.0%)		
				Oct. 15, 1975	17.6	20	5		63	8—10	3(60.0%)		53(84.1%)
		June 29, 1975		July 9, 1975	14.6	0(10)*	5			9—11	5(100.0%)		
				July 28, 1975	15.3	18	6			8—10	6(100.0%)		
				f′ Aug. 14, 1975	15.9	16	6			9—12	3(50.0%)		
				Sept. 6, 1975	16.2	22	5	30		9—10	5(100.0%)	25(83.3%)	
				Sept. 27, 1975	17.1	20	2			9—10	Nil		
				Oct. 20, 1975	18.8	22	6			9—12	6(100.0%)		

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TABLE 5b. Concluded

Serial No.	Pair index	Date of mating	Shell size (mm) at mating	Date of brooding	Shell size (mm) during each brooding	Period between clutches (days)	No. of eggs per brood	Total no. of eggs in one breeding season by: Individual	Total no. of eggs in one breeding season by: Pair	Hatching period (days	No. of embryos per brood	Production per snail	Production per pair
3	g×g′	July 6, 1975	14.2×15.0	g { July 17, 1975	14.6	0(11)*	7	37		9—10	7(100.0%)	35(94.5%)	
				Aug. 6, 1975	15.4	19	6			8—11	5(83.3%)		
				Aug. 22, 1975	15.8	15	4			9—12	4(100.0%)		
				Sept. 6, 1975	16.3	14	8			9—11	8(100.0%)		
				Sept. 27, 1975	17.0	20	6			9—10	6(100.0%)		
				Oct. 27, 1975	18.0	29	6		73	8—12	5(83.3%)		68(93.1%)
		July, 6, 1975		g′ { July 16, 1975	15.4	0(10)*	6	36		9—10	4(66.6%)	33(91.6%)	
				July 30, 1975	16.0	13	8			9—12	8(100.0%)		
				Aug. 20, 1975	16.6	20	8			9—10	7(87.5%)		
				Sept. 14, 1975	17.8	24	6			8—10	6(100.0%)		
				Oct. 7, 1975	18.3	22	8			8—12	8(100.0%)		
4	h×h′	June 29, 1975	14.6×15.4	h { July 9, 1975	14.9	0(10)*	8	42		9—12	8(100.0%)	38(90.4%)	
				July 27, 1975	15.4	17	8			9—12	7(87.5%)		
				Aug. 19, 1975	16.1	22	6			9—10	6(100.0%)		
				Sept. 11, 1975	16.8	22	7			9—11	7(100.0%)		
				Oct. 1, 1975	17.7	19	3			9—11	2(66.6%)		
				Oct. 22, 1975	18.2	20	10		76	8—12	8(80.0%)		68(89.4%)
		June 29, 1975		h′ { July 11, 1975	15.8	0(12)*	5	34		8—12	5(100.9%)	30(88.2%)	
				July 24, 1975	16.7	12	8			8—12	7(87.5%)		
				Aug. 10, 1975	17.3	15	6			8—10	5(83.3%)		
				Aug. 30, 1975	17.8	19	6			8—12	6(100.0%)		
				Sept. 21, 1975	18.0	21	9			9—12	7(77.7%)		

*indicates period between mating and first brooding.

TABLE 5c. Broods, total number of eggs and the intervals between mating and first brooding, and successive broods, hatching period and number of viable embryos in 18·0 to 19·5 mm shell diameter *M. indica*, each pair kept in isolation for one breeding season (June—October).

Serial No.	Pair index	Date of mating	Shell size (mm) at mating	Date of brooding	Shell size (mm) during each brooding	Period between clutch (days)	No. of eggs per brood	Total no. of eggs in one breeding season by: Individual	Total no. of eggs in one breeding season by: Pair	Hatching period (days)	No. of embryos per brood	Production per snail	Production per pair
1	j×j′	July 3, 1975	18.0×18.6	j: July 16, 1975	18.5	0(13)*	12			9—12	10(83.33%)		
				Aug 8, 1975	19.0	22	12			9—11	9(75.0 %)		
				Aug 24, 1975	19.9	15	12	48		9—11	10(83.33%)	41(85.42%)	
				Oct. 3, 1975	21.2	39	12			9—10	12(100.0%)		
		July 3, 1975		j′: July 15, 1975	19.0	0(12)*	12		93	9—12	10(88.33%)		81(87.09%)
				Aug 19, 1975	20.2	34	10			9—12	9(75.0 %)		
				Sept. 4, 1975	20.9	15	12	46		9—12	10(83.33%)	40(86.96%)	
				Oct. 18, 1975	21.6	43	12			9—12	11(91.67%)		
2	k×k′	July 4, 1975	18.2×18.5	k: July 14, 1975	18.6	0(10)*	12			9—12	10(83.33%)		
				Aug 12, 1975	19.2	28	11			9—12	9(81.82%)		
				Sept. 16, 1975	20.1	34	12	47		9—10	11(91.67%)	40(85.11%)	
				Oct. 19, 1975	21.8	32	12			8—12	10(83.33%)		
		July 4, 1975		k′: July 14, 1975	18.9	0(10)*	12		92	9—12	9(75.0 %)		77(83.69%)
				Aug 16, 1975	19·7	32	12			9—11	10(83.33%)		
				Sept. 6, 1975	20.3	20	11	45		8—10	10(90.9 %)	37(82.22%)	
				Oct. 21, 1975	21.9	14	10			8—12	8(80.0 %)		
3	m×m′	July 10, 1975	18.4×19.0	m: July 21, 1975	18.7	0(11)*	11			8—11	9(81.82%)		
				Aug 7, 1975	19.3	16	10	33		9—12	8(80.0 %)	29(87.89%)	
				Oct. 2, 1975	21.2	25	12			9—10	12(100.0%)		62(89.85%)
		July 10, 1975		m′: July 26, 1975	19.5	0(16)*	12		69	9—12	10(83.33%)		
				Aug 29, 1975	20.6	33	12	36		9—10	11(91.67%)	33(91.67%)	
				Sept. 30, 1975	21.4	30	12			9—12	12(100.0%)		
4	n×n′	July 4, 1975	18.4×19.5	n: July 14, 1975	18.8	0(10)*	10			9—12	9(90.0 %)		
				Aug 3, 1975	19.6	19	12			8—10	7(58.33%)	35(76.09%)	
				Aug 26, 1975	20.9	22	12	46		8—11	11(91.67%)		64(80.0%)
				Sept. 30, 1975	21.7	35	12			9—12	8(66.67%)		
		July 4, 1975		n′: July 15, 1975	19.9	0(11)*	10		80	9—12	10(100.0%)		
				Aug 9, 1975	20.7	24	12	34		8—12	9(75.0 %)	29(85.29%)	
				Sept. 14, 1975	21.8	35	12			9—12	10(83.33%)		

*indicates period between mating and first brooding.

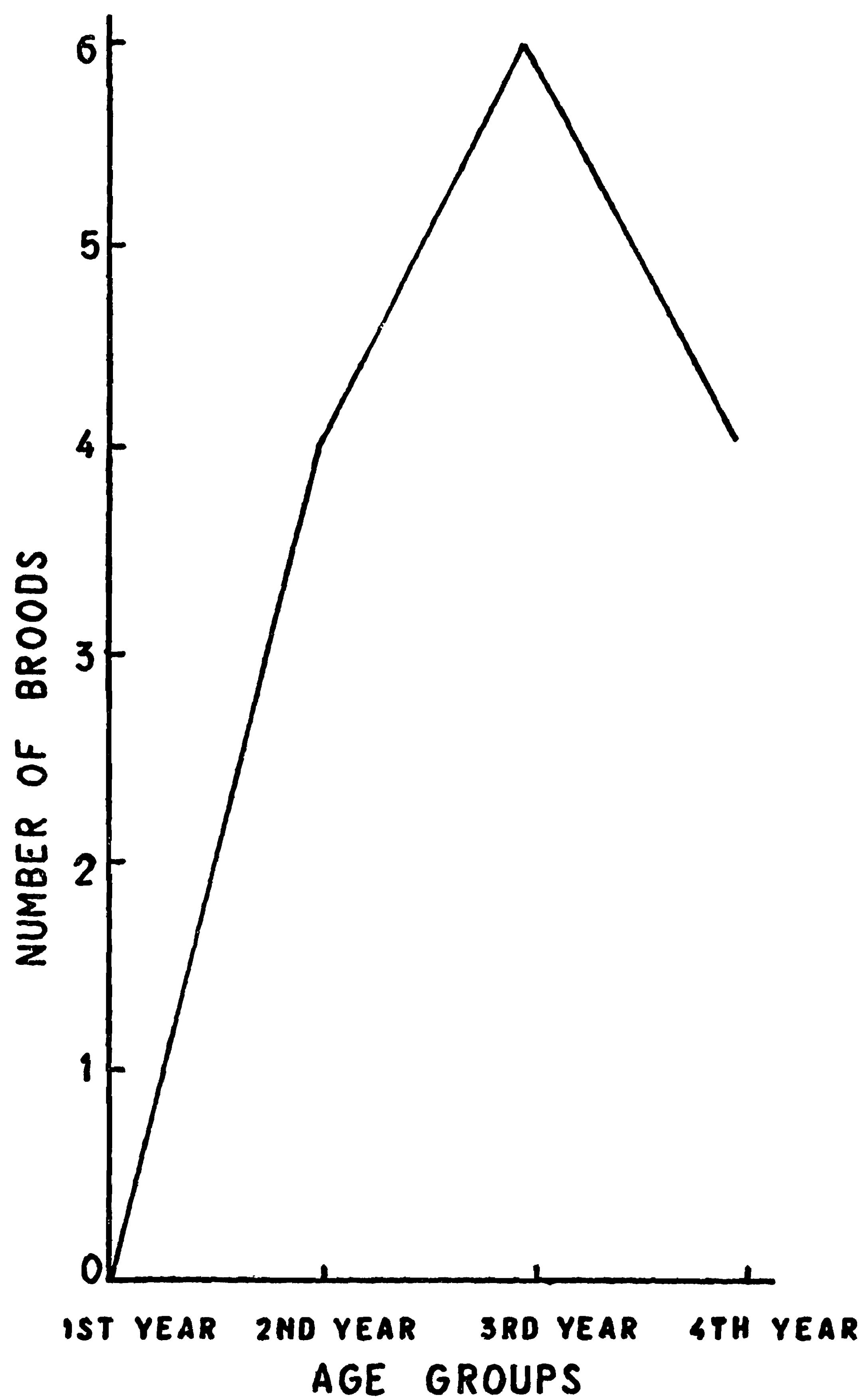

Fig. 5. Brooding frequency in *M. indica*.

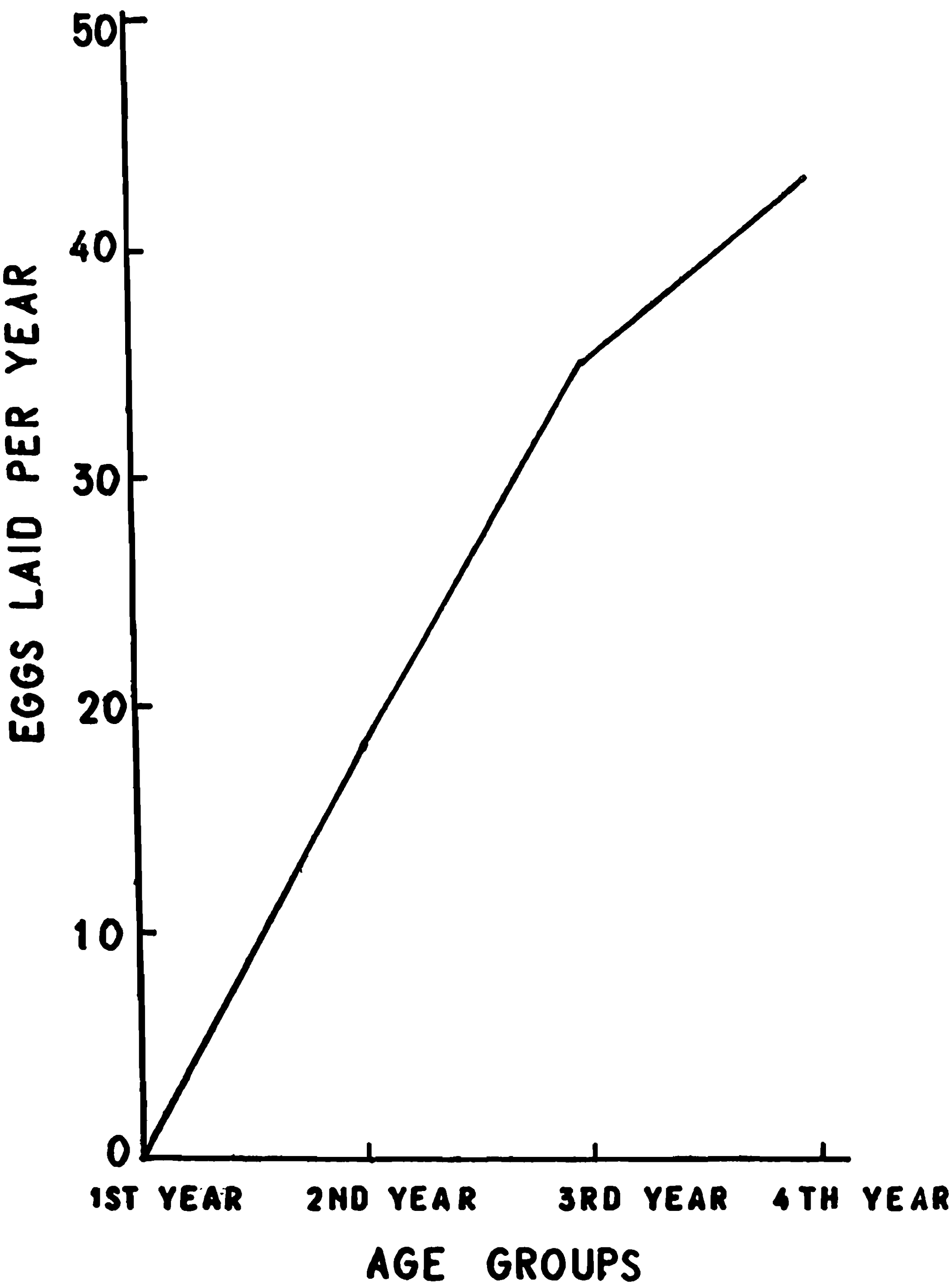

Fig. 6. Number of eggs laid per year by a single *M. indica.*

parent and the young snails were found to come out rupturing it. The young snails were never found to eat the egg shell. After emergence the young snails were inactive for a period of 14 to 20 hours, and subsequently crawled out of the nest.

The influence of moisture and temperature on hatching was almost similar to those states for *A. fulica.*

Influence of unfavourable environment on oviposition :

As a rule, land snails in temperate and tropical countries undergo aestivation to tide over unfavourable conditions. Raut and Ghose (1980a) studied the impact of such a situation on oviposition in *A. fulica, O. gracile* and *M. indica.* In all cases *A. fulica* and *M. indica* laid eggs prematurely before undergoing aestivation and many of the eggs were not fully formed. Only 45% eggs were viable. *O. gracile* could not lay premature eggs nor they underwent aestivation and died with the eggs in the uterus.

AESTIVATION

Dormancy to tide over unfavourable environment is common to all land snails. This is termed hibernation in cold countries and aestivation in temperate and tropical zones of the globe. From the physiological stand point hibernation is a state in which the body temperature is greatly lowered and the metabolism, respiration and heart rate, and so on, are correspondingly reduced. There is no clear distinction between hibernation and aestivafion, and it is not the same physiological preparation as in hibernation is associated with aestivation. Hibernation is primarily due to low temperature while aestivation is due to low moisture content of the surroundings. The term aestivation is being used for the dormant state of the land snails during dry periods, living in the planes of India and in the areas up to a height of 2000 m altitude from the sea level.

From the data collected in the period 1974 to 1982 it might be said that in India *Achatina fulica, Opeas gracile, Macrochlamys indica, Ariophanta solata, Cryptozona semirugata* and *C. bistrialis* usually aestivate at a temperature -mean maximum 28 to 30°C and mean minimum 19°C with a humidity range-mean maximum 80 to 82 and mean minimum 46 to 48%. In a simulating habitat they were active at the same temperature range only at 80 to 100% humidity. In spite of favourable humidity at a temperature 8.3°C in winter 58% *A. fulica*, 63% *O. gracile*, 70% *M. indica*, 73% *A. solata*, 67% *C. semirugata* and 76% *C. bistrialis* underwent aestivation, some burying them in the soil and others remaining on the surface. *B. monticola* hibernate at a temperature range 7 to 12°C.

Aestivating period varies with the species and the country depending on the length of the dry-hot period. The period is 8 months, November to June, in southern part of West Bengal, Bihar, Orissa, Tripura, Maharashtra, Andhra Pradesh and eastern part of Assam ; 4 to 6 months in northern part of West Bengal, western part of Assam, Nagaland, Tamil Nadu, Kerala, Karnataka and Uttar Pradesh ; 2 to 3 months in Meghalaya, Manipur, Himachal Pradesh and Andaman, and Car Nicobar islands. The period of aestivation is dependent on the arrival and extent of monsoon. In laboratory conditions, under aestivation *A. fulica* and *M. indica* survived for 11 and 9.5 months respectively.

Site of aestivation :

Apparently, the selection of a suitable site for aestivation is present in all land snails. They test the substratum and the surroundings with their tentacles for a few minutes before preparation for aestivation. Aestivation in exposed condition is always avoided.

A. fulica prefers moit soil for aestivation. Majority of them aestivate on ground in a shady or covered place and the preferred sites are bushes, crevices, cortches of tree (Pl. VII, fig. I), inside the leaf bases of young coconut tree (Pl. VII, fig. 2), empty pot (Pl. VII, figs. 3 and 4), under bricks (Pl. VII, figs. 5 and 6 ; Pl. VIII, fig. 1) and decaying twigs and leaves (Pl. VIII, figs. 2 to 4). Aestivation at a height of about 400 cm is also common. *Opeas gracile* being a small creature usually aestivate in any protective pocket near periphery of the garden.

The members of the family Ariophantidae viz. *M. indica*, *A. solata*, *C. semirugata*, *C. bistrialis* and *B. monticola* prefer to aestivate on a hard support and the favourable sites are under or lateral surfaces of stones, boundary walls of the garden, bricks (Pl. IX, figs. 1 and 2), in between the bricks in naked wall, logs of wood but not the decomposing ones, between the roots and lower branches of shrubs etc. Ordinarily they do not aestivate above 150 cm from the ground. They always avoid aggregation and one, though close to the other is never in contact with it.

Aestivating behaviour :

Aperture orientation is a characteristic feature of aestivating *A. fulica*. In almost all the snails the shell aperture is directed downward and placed against the support. In those aestivating on the ground the outer lip of the shell is buried in the soil. The behaviour is an adaptation for conservation of body water which is essential for their survival during aestivation. It was recorded that in the snails with the above orientation the death rate was 68.5% under similar conditions (Raut and Ghose, 1977a). Similar apertural orientation is observed in *O. gracile*. Such a behaviour is absent in Ariophantidae since they aestivate on the substratum by the help of "attachment epiphragm".

Mode of aggregation :

In active period the snails are usually found almost at all sites in their habitat, be it a garden or a vegetable field, but they congregate in their aestivating home. *A. fulica* and *O. gracile* hurdled together, one above the other.

Raut (1978b) reported 3 types of aestivating homes for *A. fulica*. In large pocket 15 or more individuals have been observed under aestivation. In a garden measuring 135 m^2 in West Bengal about 4 to 9 large aestivating pockets may be found in which 17 to 61 individuals can aestivate safely. The number of small pockets might be as high as 18, and 5 to 14 snails may rest there. Aestivation of 5 to 19 snails in a m^2 area is rather common in sparsely distributed populations. In the large and small pockets the whole available space was fully utilised and there was no room for accommodation of more snails. Similar observations were made by the authors from Tamil Nadu and Kerala. Abbas and Gautam (1975) and Gupta *et al* (1978) reported the aggregation of 14.57 to 102.39 snails per m^2 for aestivation in South Andaman. A some sort of age dependent aggregation is pronounced. The aggregating behaviour is most probably related with moisture, security and also to escape the sight of the predators. Similar mode of aggregation in the aestivating home is also observed in *O. gracile* and ariophantids though in the latter, the individuals never come in contact with one another.

Epiphragm secretion :

Achatina fulica

Sometimes after the selection of sites the snout and the visceral stalk are retracted into the shell which is followed by the retraction of the anterior and posterior end of the foot respectively. The mantle slowly covers the foot leaving a small triangular area at about the middle where the foot remains exposed. At this stage the soft mass of the snail remains 3 to 6 mm inside the shell (Pl. IX, fig. 3, snail number 1, 5, 6 and 7).

In epiphragm secretion both the foot and the mantle take part, the latter playing a major role in the process. A heavy amount of mucous is secreted from the mantle collar while the amount of secretion is much less from the mantle and still less from the foot. A considerable amount of mucous spreads as a thin film over the mantle and the foot, and within two hours a thin, almost transparent membraneous epiphragm, covering the organs except the pneumostome and perfectly fitting with the shell is formed. During the process active respiration continues and the pneumostome opens and closes rhythmically. Towards the completion of epiphragm secretion which lasts for about four hours the pneumostome remains open and a slit-like opening (Pl. IX, fig. 4) with a thick collar guarding the opening of the latter is left in the epiphragm.

In snails aestivating on fairly moist soil the body is retracted only up to the latter (Pl. IX, Fig. 3, snail number, 2, 3 and 4). The epiphragm is thin and fragile. In *Opeas* epiphragm secretion and the structure of the epiphragm are almost similar to those described in *A. fulica*.

A detailed observation on aestivation and epiphragm formation in Ariophantidae is restricted to *M. indica* only. Preparation for aestivation starts with anchoring itself to a support with a much contracted foot. The mantle is stretched and covers the anterior end of the foot leaving the tip of the posterior end exposed. The whole process of epiphragm secretion consists of two distinct steps—the "attachment epiphragm" and epiphragm formation. A thick, light yellow mucous is secreted from the mantle collar and its adjoining region. During the process the muscles of the mantle collar are retracted and relaxed rhythmically which help in spreading the mucous over the support extending about 5.0 mm in some cases. On exposure to air numerous fine depressions appear on the surface of the mucous layer giving it a pitted appearance.

On drying the mucous turns to a coarse fragile, structure with which the snail remains attached to the support and it may be termed as the "attachment epiphragm" (Pl. X, figs. 1 and 2). The whole process is completed within 30 to 50 minutes. In *Bensonia monticola* the period was about 65 minutes. The "attachment epiphragm" of *B. monticola* is considerably larger in size than that of the other members of the family.

Shortly after the formation of the "attachment epiphragm" the anterior and the posterior ends of the foot and the mantle collar are retracted into the shell in succession leaving about 1 to 5 mm space between the support and lip of the shell aperture (Pl. X, fig. 1). In about 90% cases the space is in communication with the exterior through a narrow aperture (Pl. X, fig. 1) at the place occupied by the tip of the posterior end of the foot during the formation of "attachment epiphragm" while in the rest it is plugged latter with a fresh secretion of mucous.

After a few hours the snail retracts itself further, about 2 to 7 mm inside the shell and the mantle collar always occupy a forward position completely covering the foot. Shortly after, the secretion of the epiphragm starts and it continues for 6 to 30 hours. The epiphragm is devoid of any opening for communication with the pneumostome. During the total period of aestivation several epiphragms are formed one after another and enclose narrow spaces or epiphragm chambers between them.

Epiphragm secretion potential :

The capability of secretion of a series of epiphragm has been studied both in nature and in the laboratory in *A. fulica* and *M. indica.*

Natural environment :

With the progress of aestivation the snails lose weight mainly due to dehydration, and the volume of the body is gradully reduced, leading to further retraction into the shell. An epiphragm only in contact with the soft tissue is an effective defence against desiccation and this creates the need for fresh epiphragm formation. *In Achatina,* the old epiphragm is rejected prior to the formation of a new one while in *Macrochlamys* all the epiphragms are retained. In both the species, however, the epiphragm secreted subsequently are thinner. The snails never repair the damaged epiphragm, if it happens accidentally, but always secrete a new one just below it (Pl. X, fig. 3). In the whole period i. e., 8 months of uninterrupted aestivation *Achatina* produced 6 to 8 (Pl. X, fig. 4) and 10 to 12 epiphragms in 1974-75 and 1975-76 respectively. In each case the subsequent epiphragms were thinner and smaller in size. On the other hand, in specimens with interrupted aestivation due to occasional shower and feeding, the number reached as high as 14.

In *Macrochlamys* the maximum number of epiphragm produced under similar condition was 4 and 1 respectively in 1974-75 and 1975-76. The less number of epiphragm secretion is probably caused by two factors (a) the body volume being small, size reduction due to desiccation must be proportionately less and the consequent retraction into the shell would be little, and (b) retention of old epiphragms minimises the need for secretion of fresh epiphragms since the old ones were not totally ineffective. In specimens with interrupted aestivation caused by occasional rains the whole process including the formation of the attachment epiphragm was repeated on each occasion. In 1974-75, out of 1475 aestivated snails 6 had 4, 14 had 3, 1165 had 2 and 290 had one epiphragm while the corresponding numbers in 1975-76 were 12, 60, 1274 and 129. There was no rain for a continuous period of 5 months in 1975-76 during aestivation period.

Laboratory environment :

Thirty adult *A. fulica* each weighing about 30g and of near equal shell length were selected and divided into 3 groups-I, II and III, 10 in each. Each group was released in a terrarium measuring 75×30×70 cm in the first week of November, 1975. The terrarium was covered with polythene net of 1.0 mm mesh. The snails underwent aestivation within 48 hours.

On the 7th day they were weighed and the distance between the outer lip of the shell aperture and the point of attachment of the epiphragm with the shell was measured. This was followed by the removal of the epiphragm with a fine forceps. The snails in different terraria were treated differently. Group—I was simply left to aestivate, group-II and group-III were sprayed with required amount of water for awakening and to keep them active, and group-III alone was supplied with food for a period of 48 hours. Snails of group-II and group-III were transfered to dry terraria to induce aestivation after the said period.

In group-I, the snails produced 1 to 10 epiphragms which was followed by death. The weight loss was 46.6% and the retraction was up to 48 mm in an average (Fig. 7). Sanils of group-II produced 17 epiphragms, weight loss was 35.4% and the retraction was 16 mm in an average (Fig. 8). Snails in group-III produced as much as 30 epiphragms in 241 days and the process

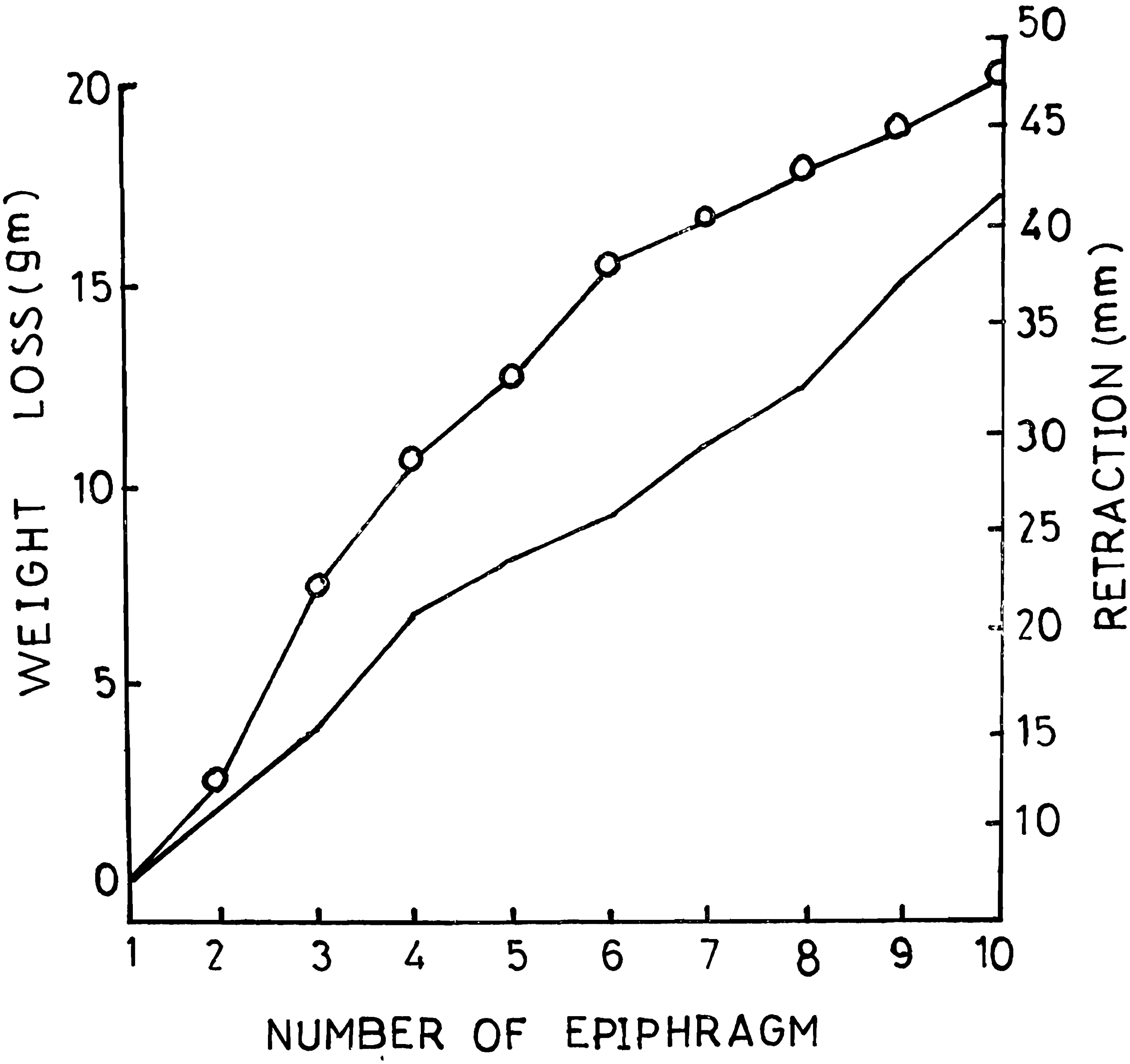

Fig. 7. Relation between the number of epiphragm secretion and the loss of body weight (—), and retraction of the visceral mass (0—0) inside the shell cavity in adult *A. fulica* of near equal body weight and shell length, supplied no food and water.

was still continuing. Loss in body weight was recorded during the formation of first and third epiphragm and again after the formation of 9th epiphragm. The retraction of visceral mass was only 14 mm at 241 days (Fig. 9).

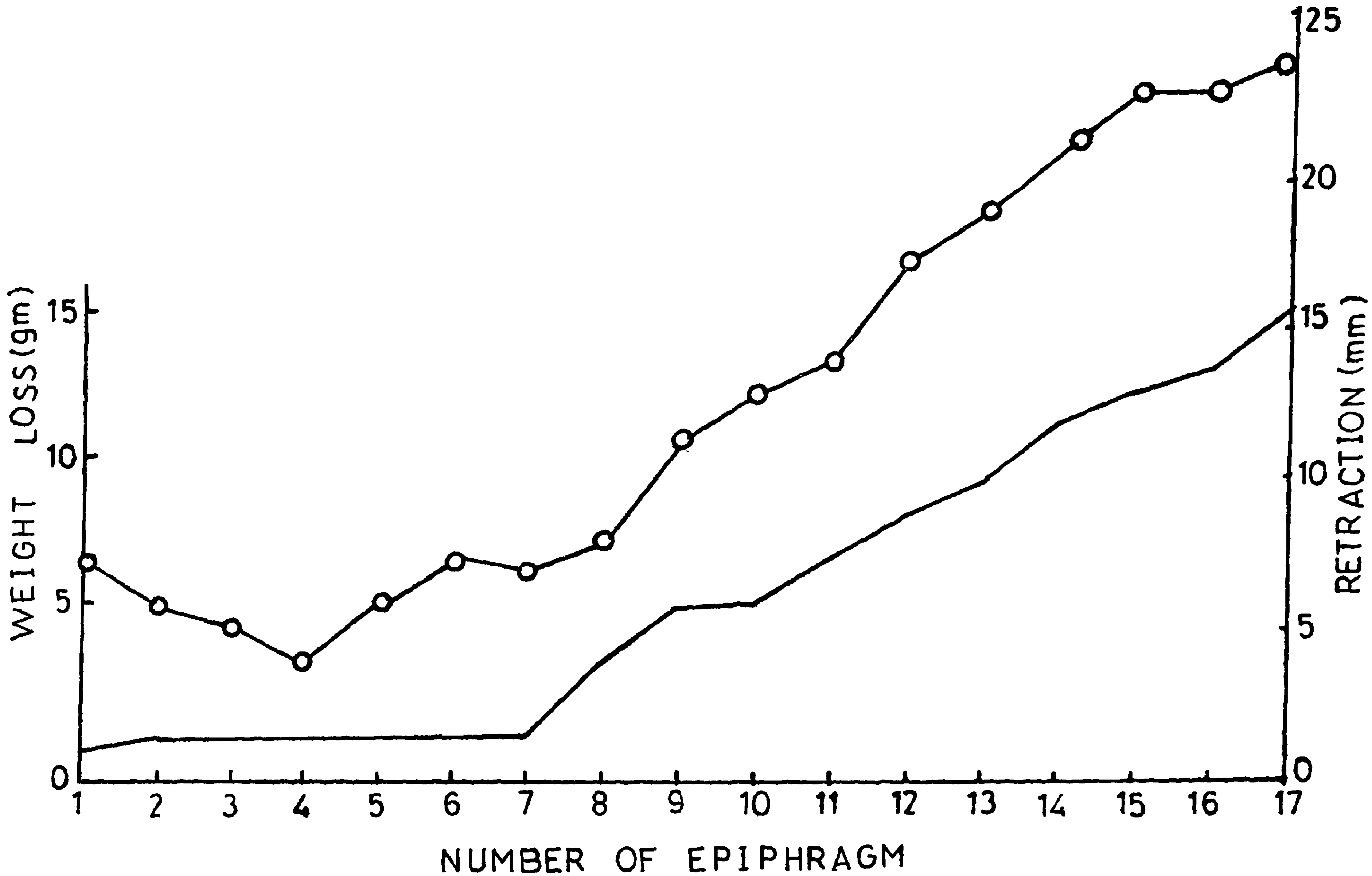

Fig. 8. Relation between the number of epiphragm secretion and the loss of body weight (o—o), and retraction of the visceral mass (—) inside the shell cavity in adult *A. fulica* of near equal body weight and shell length when supplied only water but no food.

Effect of temperature and humidity on aestivation :

In monsoon simulated habitat both *A fulica* and *M. indica* maintained at a temperature range, mean maximum 28 to 31°C and mean minimum 19°C with a humidity range 85 to 100% did not aestivate.

To study the effect of food on aestivation the snails were maintained at a favourable temperature range 22 to 31°C with a humidity range 85 to 100% but without food. Under such conditions *A. fulica* aestivated on the 17th day and *M. indica* on the 11th day.

Humidity and food considerably minimised the adverse effects of temperature on aestivation. In a high humid environment with required amount of food supply 86% *A. fulica* and 60% *M. indica* were active in a temperature range 9 to 43°C.

Effect of aestivation on population :

It is generally accepted that mortality in land snails during aestivation in temperate and tropical countries, and hibernation in cold regions is higher than that in the active period but no data is available on the rate of mortality and the roles play by humidity, temperature and duration of dormancy in it, except for that of Carney (1966) in *Allogona ptychophora*. The solitary attempt by Cleave (1935), to correlate population density with humidity in a particular area in different seasons and years does not throw light on the relationship between the per cent of mortality and humidity though it indirectly suggests that lower the per cent of moisture, higher is the rate of mortality in the amphibious *Fossaria modicella*.

Mortality in *Achatina fulica* and *Macrochlamys indica* during aestivation was studied for two years 1974-75 and 1975-76 (Raut and Ghose, 1979d). One hundred healthy snails of each age group 10-15 days, 70-75 days and 100-105 days of each species were released in cages in November 1974 and 1975. Favourite food was supplied regularly in excess and strict hygienic condition was maintained. Snails older than 105 days were not considered as the maximum active period available even to those hatched in the early monsoon of the year before aestivation does not exceed the limit. Within a period of 2 to 3 days the sanils of all ages in the cages, and the snails in the garden underwent aestivation. The percent of moisture and temperature were comparatively lower than those in the active seasons. Rainfall above 50 mm awaken aestivating snails and food was supplied to caged specimens on all such occasions. To evaluate the influence of humidity on aestivation the duration of three arbitrary humidity grade i. e. 40 or below, 41-84 and 85-100 was calculated (Fig. 10) and the average was estimated for 24-hours period. The period of exposure to 40% and or below, 41-84% and 85-100% humidity prevailed for 4.0, 10.3 and 9.7 hours in 1974-75 and 7.2, 7.2 and 9.6 hours

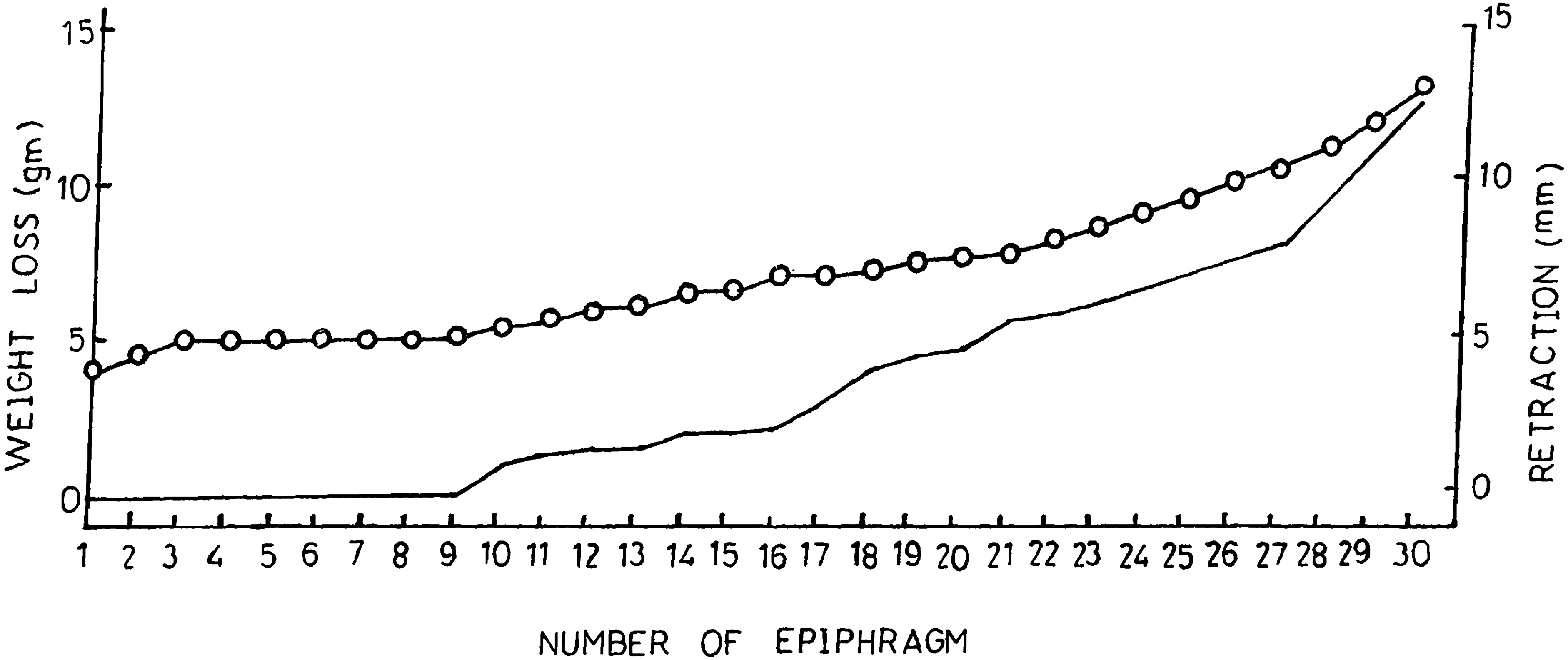

Fig. 9. Relation between the number of epiphragm secretion and the loss of body weight (0—0), and retraction of the visceral mass (—) inside the shell cavity in adult *A. fulica* of near equal body weight and shell length when supplied both food and water.

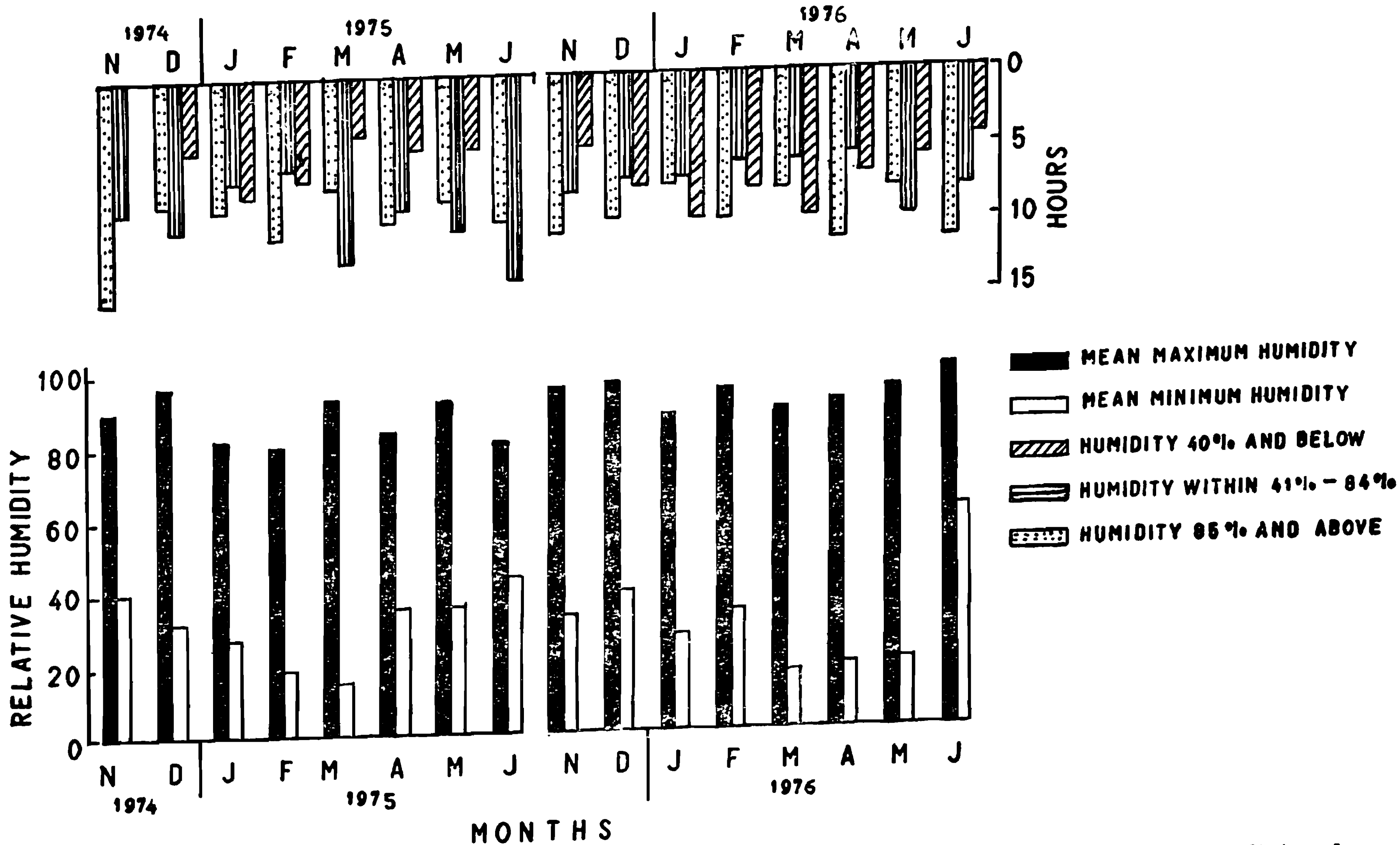

Fig. 10. Monthly mean maximum and mean minimum humidity and the duration of 40% and below, 41-84% and 85% and above humidity in hours per day in cage environment in the years 1974-75 and 1975-76 (from Raut and Ghose, 1979d).

in 1975-76 respectively (Fig. 10). The number of cloudy days and the amount of rainfall (Fig. 11) during the period November to June were considerably more in 1974-75 than those in 1975-76. Observations were made on aestivating snails twice in a month, i. e., 13th and 28th in both the years (Tables 6-9) (from Raut and Ghose, 1979d).

λ^2 test was applied to ascertain the variation in survival rate over age groups. The age groups differed significantly with respect to survival rate, the level of significance being 0.1 per cent in the four cases. Or in other words, the variation in the survival rates across age groups was very highly significant for each species and in each year. As regards the pattern of variation, the proportion of surviving rises by 34-35% in *A. fulica* and 30-46% in *M. indica* as one passes from those in 40-45 days age group to those in 100-105 days age group.

TABLE 6. Mortality in 400 *A. fulica* of four different age groups (100 for each age group) in months during the total period of aestivation in 1974-75.

Age groups (days)	MONTHS OF AESTIVATION Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total number of dead snails
10—15	0	3	6	12	79	—	—	—	100
40—45	0	4	4	6	45	6	3	0	68
70—75	0	1	4	4	34	4	5	0	52
100—105	0	0	2	5	23	1	2	0	33

TABLE 7. Mortality in 400 *A. fulica* of four different age groups (100 for each age group) in months during the total period of aestivation in 1975-76.

Age groups (days)	MONTHS OF AESTIVATION Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total number of dead snails
10—15	0	4	8	10	78	—	—	—	100
40—45	1	4	5	8	60	8	2	0	88
70—75	4	2	5	6	42	9	0	0	68
100—105	3	4	3	6	26	8	4	0	54

TABLE 8. Mortality in 400 *M. indica* of four different age groups (100 for each age group) in months during the total period of aestivation in 1974-75.

Age groups (days)	MONTHS OF AESTIVATION Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total number of dead snails
10—15	0	4	4	18	74	—	—	—	100
40—45	1	3	5	9	67	2	3	0	90
70—75	2	3	3	8	40	4	1	0	61
100—105	2	1	0	5	28	7	0	1	44

TABLE 9. Mortality in 400 *M. indica* of four different age groups (100 for each age group) in months during the total period of aestivation in 1975-76.

Age groups (days)	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total number of dead snails
10—15	0	5	8	17	70	—	—	—	100
40—45	3	5	6	9	70	5	0	0	98
70—75	1	1	2	9	51	15	3	0	82
100—105	0	1	3	7	28	24	4	1	68

λ^2 test was applied to estimate the variation in survival rate between the two years under consideration. This was done separately for each species and for each age group. The rate of survival was considerably different, being minimum for both the species in 1975-76.

λ^2 test was applied to estimate the variation in survival rate between the two species. This was done separately for each species and for each age group. The rate of surrival was always lower in *M. indica* than that in *A. fulica.* The difference in this rate is significant for each age group of both the species in 1975-76 and for the their youngest age group in 1974-75 although this difference for the two older age groups of both the species in 1974-75 is not statistically significant. The rate varied from 9 to 14% with one exception where it was 22%.

Table 10 is based on the specimens actually dying in November to June period and records the distribution of their death over the successive months through cumulative percentages. The figures in the first row are the numbers

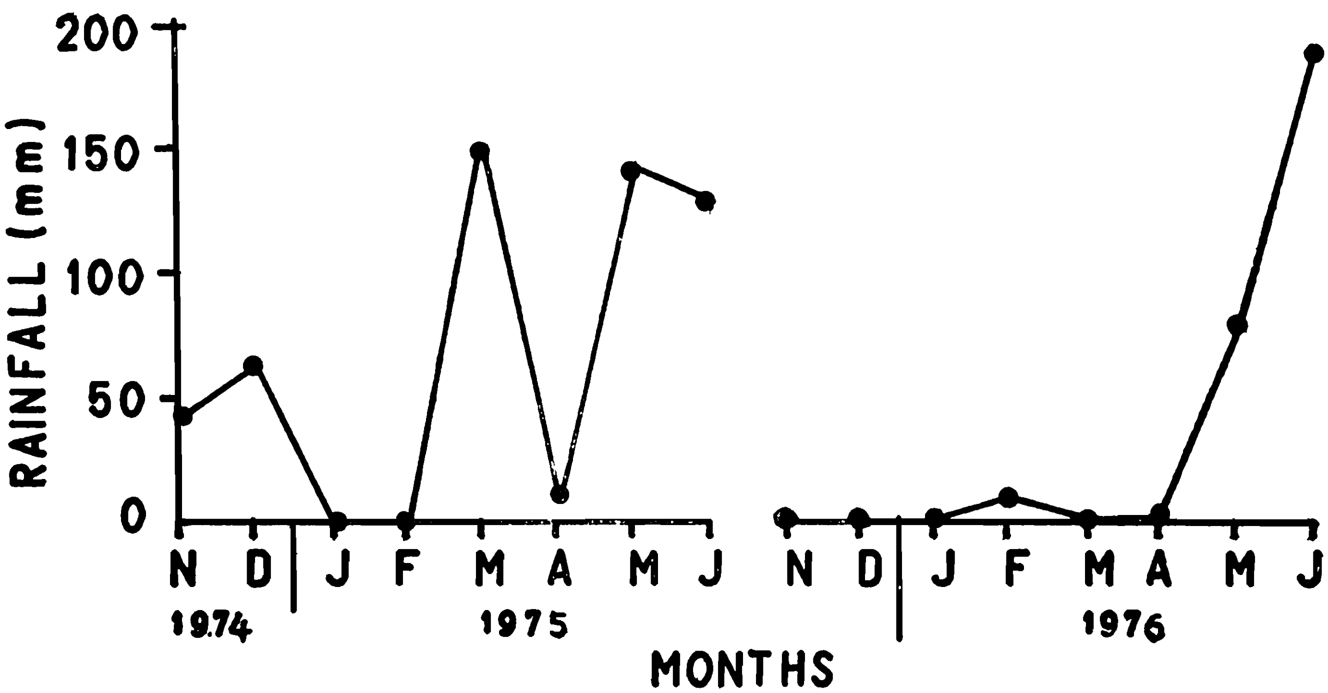

Fig. 11. The total monthly rainfall in the Calcutta University campus, Ballygunge, for the years 1974-75 and 1975-76.

TABLE 10. Distribution of cumulative percentages of deaths by species by year of observation by age groups and by months of aestivation.

Type of species	Year of observation	Age group (days)	MONTHS OF AESTIVATION Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
Achatina fulica	1974-75	10-15	0.00	3.00	9.00	21.00	100.00	100.00	100.00	100.00
		40-45	0.00	5.88	11.76	20.56	86.74	95.59	100.00	100.00
		70-75	0.00	1.92	9.62	17.31	82.69	90.38	100.00	100.00
		100-105	0.00	0.00	6.00	21.21	90.91	93.94	100.00	100.00
		All	0.00	3.16	9.49	20.16	91.70	96.05	100.00	100.00
	1975-76	10-15	0.00	4.00	12.00	22.00	100.00	100.00	100.00	100.00
		40-45	1.14	5.68	11.36	20.45	88.64	97.73	100.00	100.00
		70-75	5.88	8.82	16.18	25.00	86.76	100.00	100.00	100.00
		100-105	5.56	12.96	18.52	29.63	77.78	92.59	100.00	100.00
		All	2.58	7.10	13.87	23.55	90.00	98.06	100.00	100.00
Macrochlamys indica	1974-75	10-15	0.00	4.00	8.00	26.00	100.00	100.00	100.00	100.00
		40-45	1.11	4.44	10.00	20.00	94.44	96.67	100.00	100.00
		70-75	3.28	8.20	13.11	26.23	91.80	98.36	100.00	100.00
		100-105	4.55	6.82	6.82	18.18	81.82	97.73	97.73	100.00
		All	1.69	5.42	9.49	23.05	93.90	98.31	99.66	100.00
	1975-76	10-15	0.00	5.00	13.00	30.00	100.00	100.00	100.00	100.00
		40-45	3.06	8.16	14.29	23.47	94.90	100.00	100.00	100.00
		70-75	1.22	2.44	4.88	15.85	78.05	96.34	100.00	100.00
		100-105	0.00	1.74	5.88	16.18	57.35	92.65	98.53	100.00
		All	1.15	4.60	10.06	22.13	85.06	97.70	99.71	100.00

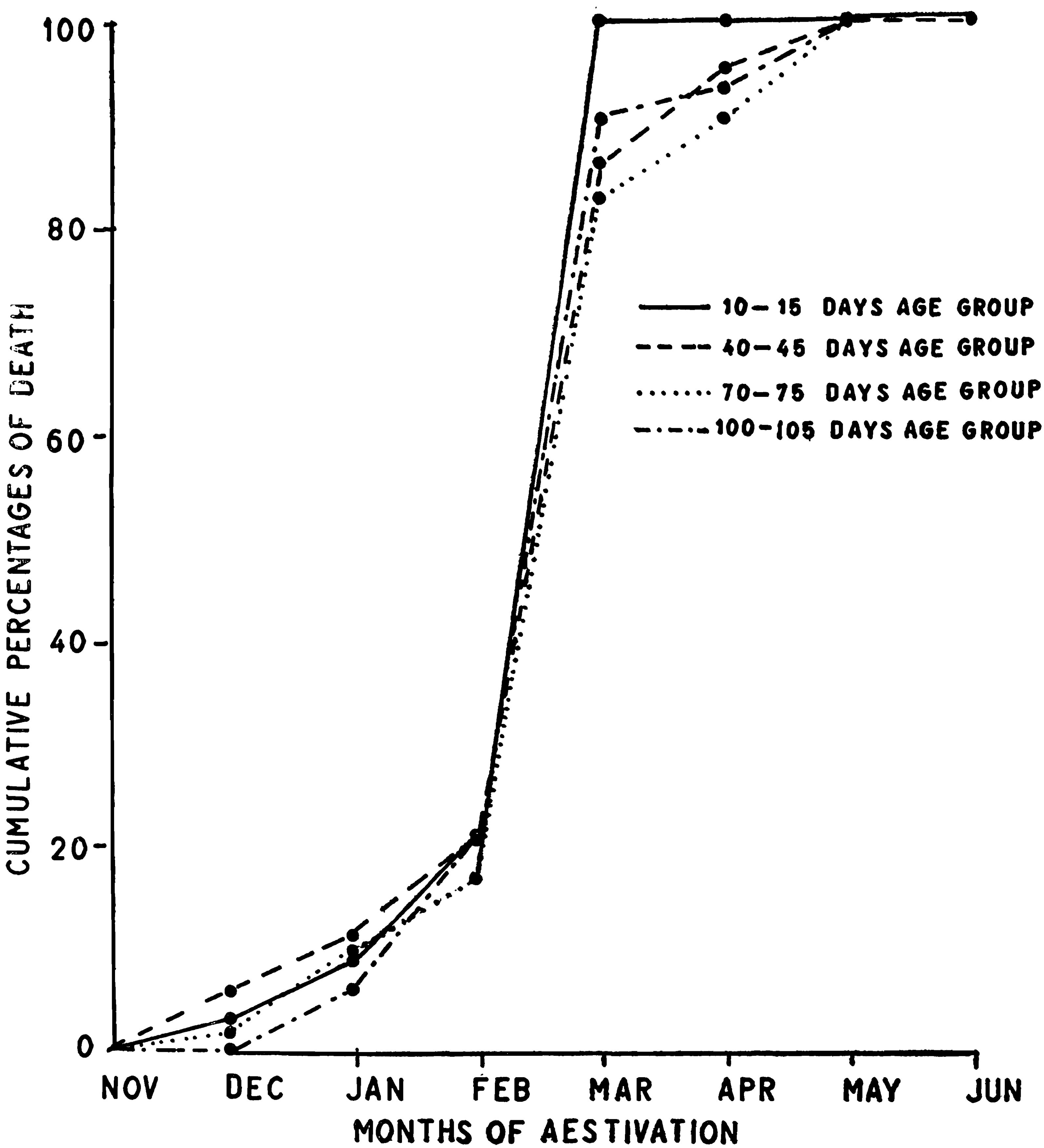

Fig. 12. Ogive of *Achatina fulica* for 1974-75.

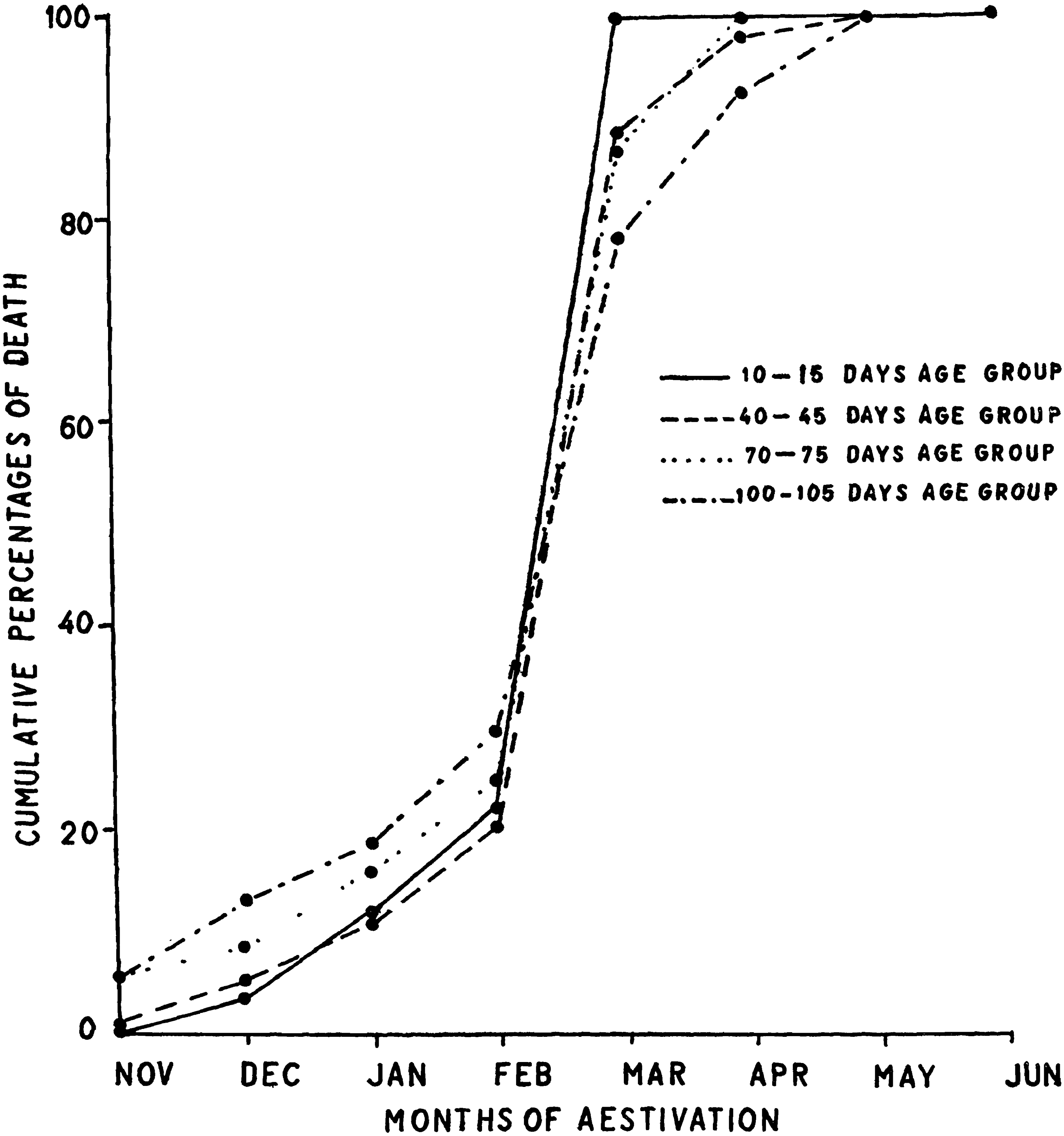

Fig. 13. Ogive of *Achatina fulica* for 1975-76.

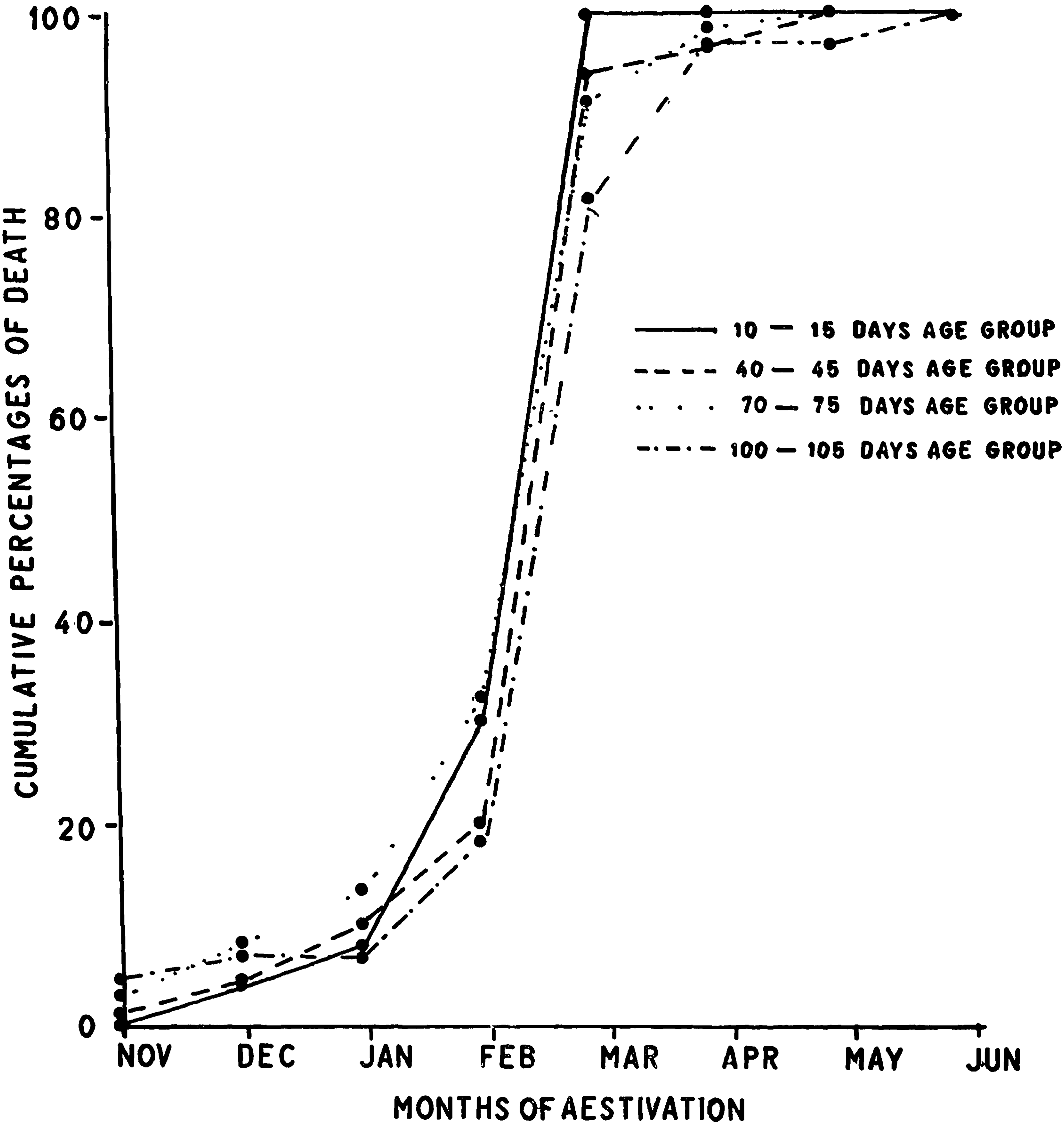

Fig. 14. Ogive of *Macrochlamys indica* for 1974-75.

of snails studied. The period required for activation since the beginning of rain is one to three hours in *A. fulica*, one to two hours in *O. gracile* and three to nine hours in ariophantids in summer and rainy seasons, while in other seasons the period is longer, approximately by two hours. Direct rain drops on the shell, particularly close to the shell aperture cause quick awakening. The aestivating snails do not respond to a prolonged cloudy weather with a little or no rainfall. Rahman *et al* (1975) reported that *O. gracile* awaken between the middle of May and the first half of June, i. e., before the onset of monsoon an observation quite different from that of the present authors. The snails become active only after sufficient rain in any time of the year.

The awakening behaviour is similar in response to rains or spraying of water on aestivating snails in both *A. fulica* and *M. indica*. The snails push out their epiphragms by their foot and the epiphragm is dislodged intact or break down into pieces. The epiphragm is almost immediately eaten up by the same individual or individuals of the same species, but in no case a snail was found eating the epiphragm of other species. The epiphragm is consumed so greedily (Pl. X, fig. 5) that in *Achatina* a chuckling sound is audible from a distance.

In case of raining at the time of awakening, the snails stretch their foot and visceral stalk, withdraw the tentacles and ramain in a quiescent state for about an hour or more to receive the maximum amount of rain on its body. It has been observed that if water accumulates in the adjacent region, the snails move and dip their snout with the visceral stalk and foot in water for about 30 minutes. The behaviour is an attempt to absorb maximum amount of water possible in the shortest period presumably to compensate the loss during aestivation.

GROWTH

The larval stage in land snails are completed within the egg and the young snails resembling the parents, except for the reproductive organs, hatch out. To overcome adverse environmental factors the snails undergo hibernation or aestivation, as the case may be, for a major part of the year except the monsoon and a short post-monsoon period. Since the inactive period is a long one, studies were undertaken to determine the existence of compensatory mechanism for growth if any, in the post aestivating phase of the snails. The period for which the snails were active, both in natural and monsoon simulated environments were considered as active period.

Achatina fulica :

On the average, in an active period of 3 months the shell of young snails developed 6 whorls and the shell size attained 36.25×21.0 mm. The shell aperture measured 21.5×12.75 mm and the weight was 6.89 g (Ghose, 1963b). Growth continued uninterrupted if kept active up to 55 mm in shell length within 160 days. Growth rate slowed with age, and especially after the attainment of sexual maturity.

Growth rates were different at different temperature range in spite of maintenance of the optimum humidity range, i.e., 85 to 95% (Sadhukhan and Ghose, unpublished). Starting with the shell size 4.7×4.1 mm and total body weight 0.039g at hatching it is recorded that the snails attained a shell size 12.5×9.0 mm and body wieght 0.28g at 20°C ; 16.5×11.5 mm and 0.85g at 25°C ; 18.56×12.5 mm and 0.984g at 30°C and 12.3×9.0 mm and 0.3g at 35°C on the 50th day. Maintained for the same period in the same humidity range, at a temperature range 28-32°C, which was close to that in nature in active period, the snails attained a shell lengtht 22.5×13.3 mm and body weight 1.8g in the 50 days period. This is suggestive of stimulation of growth factors in a temperature range rather than that of particular temperature.

Opeas gracile :

Subba Rao and coworkers (1981) recorded that the newly hatched *O. gracile* with a shell length 1.34 to 2.19 mm, on an average 1.84 mm and with one whorl attained 4.25 mm in shell length and 4.68 whorls at the end of 6th week. Growth was faster in the first two weeks while the rate was slow in the third week.

Macrochlamys indica :

The snails with 1.2 mm and 0.6 mm shell diameter and aperture length respectively at hatching attained 11.1 mm and 5.05 mm by the end of 18th week (Raut and Ghose, In press). Growth rate was faster in the first, 18 weeks, followed by a decline. The shell diameter and the length of the aperture measured in 57 weeks old snails was 14.5 mm and 7.25 mm respectively. A constant ratio, 2 : 1, between the shell diameter and aperture length is maintained.

Growth rate following awakening :

Raut and Ghose (1978) reported that both *A. fulica* and *M. indica* can compensate the loss in growth imposed by aestivation within a few weeks after awakening from aestivation.

Information on the growth rates in other species of pestiferous snails is entirely lacking.

Economic Status

It is rather difficult to assess the damage to economy caused by a pest in a vast country like India, since both the consumer and the cultivation of economic plants on which the pest population survive vary from State to State. Studies on the survey of the food-plants, preference for food-plants and feeding habits of the snails in the natural and simulated habitat and in the laboratory have been made. In general the land snails prefer fallen and decomposing parts of plants than others. As a rule, the young snails go for soft portions while the grown up ones avoid only the hard parts, and that again depends on the plant species.

The findings are reported under 3 categories.

Natural habitat :

Achatina fulica

The giant African snail *Achatina fulica* prefer vegetables and garden plants, but in wild areas where crop and garden plants are not grown, they thrive equally well on wild plants. The preference is always for the same plant species, cultivated or wild, if it is available, in spite of extreme variations in the amount of rainfall, temperature and humidity in different zones of India. The plants consumed and the nature of damage caused by a species have been recorded from heavily infested areas and are presented in alphabetical order, ignoring preference.

Amaranth (*Amarantus gangeticus, A. viridis*) : A seasonal crop plant, sometimes bushy in nature, widely cultivated throughout West Bengal, Bihar, Uttar Pradesh, Orissa and Kerala usually in monsoon. A preferred food plant all over the country. *A. gangeticus* is more susceptible to attack. The snails feed on leaves, twigs and stem body. The damage is rather serious as the stem is often cut into pieces. Seedlings are favoured by snails of all ages.

Amorphophallus campanulatus : This is found in monsoon mostly in the uncultivated areas of West Bengal, Bihar and Orissa. Morphologically the plant is similar to arum and the nature of damage is also similar.

Antigonon (*Antigonon leptotus*) : A wild climber, grown mostly in the districts of lower West Bengal and Bihar in monsoon. Only the leaves are favoured. The twigs and flowers are not eaten.

Arum (*Colocasia antiguorum, Alocasia indica*) : Wild, seasonal herb with smooth extended petiole terminated by a flattended lamina. The plants grow all over the country in moist and shady places. Not a preferred plant. Only laminal portion of young leaves are rarely eaten. The decomposing leaves are often consumed. Both the species are a good shelter in day time.

Ballabhi-anga (*Allangana lamarcana*) : It is a bushy perennial plant growing largely in the uncultivated land in south West Bengal, Bihar and Orissa. The leaves are the chief source of food for the snails established in wild areas. Twigs are devoured during heavy infestation. It is a good shelter-plant in day time.

Balsam (*Impatiens balsamina*) : Monsoon flower plant ; leaves and flowers are attacked ; twigs are rarely eaten ; fallen leaves and flowers are preferred.

Banana (*Musa sapientum*) : The snails sheltered them in the leaves and other parts of the plant. They may work their way deep into the bunches of fruit. Occasionally young bananas are rasped and the skin is badly scarred. The mature fruits are less valuable, though the edible part is unaffected. Snails younger than 60 days in age usually do not attack the plant.

Basella rubra : This climber vegetable is a preferred food plant. The whole plant is consumed by the snails. Leaves are favoured to stem.

Bauhinia (*Bauhinia accuminata*) : Perennial, bushy garden flower. Only leaves are occasionally eaten. Fallen leaves are preferred.

Beans (*Dolichos* spp., *Glycine* spp.) : A group of most economically important plants cultivated all over the country including Andaman and Car Nicobar group of islands almost throughout the year. These are most preferred food plants. In the whole of the mainland and Andaman and Car Nicobar group of Islands of Indian Union. The snail eat the leaves and twigs voraciously ; sometimes fruits are eaten completely. The snails reach even the top of the plants climbing up the support provided to the clumbers. Older snails consume the whole leaf while the young ones skeletonise it leaving the veins only. Preference is always for growing regions and seedlings to snails of all ages. Old snails do not even spare the stem. The degree of damage is serious.

Bitter gourd (*Momordica charantia*) : Leaves of this climber are casually eaten.

Boerhavia (*Boerhavia diffusa*) : It is a wild climber of eastern India. Leaves, twigs, flowers and fruits are favourite food.

Bougainvillea (*Bougainvillea spectabilis*) : Only leaves of this perennial woody climber are eaten.

Cabbage (*Brassica oleracea* var. *capitata*) : Economically an important vegetable plant extensively cultivated in all the States of Indian Union. It is a most preferred plant and all stages, from seedings to old ones are completely devoured. Behura (1955) listed it as one of the most favourite food plants in Orissa.

Canna (*Canna indica*) : Inflorescence and rarely leaves are eaten. The damage is not serious. Fallen flowers are preferred food. It is a good shelter.

Carum carui (*Momordica cochinchinensis*) : It is a seasonal climber largely grown during monsoon in the vegetable gardens in the districts of Malda, Murshidabad, 24-Parganas and Midnapur of West Bengal, throughout north Bihar and in parts of Orissa. It is one of the most preferred food plants in these areas. The whole plants is eaten by the snails of all ages. The fruits are rarely eaten. The damage is rather serious in the district of Malda in West Bengal and Purnea in Bihar.

Castor (*Ricinus communis*) : It is an important, widely cultivated perennial plant. The seed is valued for oil and fertilizer. Damage is largely restricted to young plants, leaves, bark, twigs and fruit coat. Young snails generally skeletonise the leaves. Seedlings are completely devoured by older snails, while the young causes serious damage to them (Pl. XI, figs. 1 and 2).

Cassia (*Cinnamomum tamala*) : Perennial bushy tree with medicinal value. Very little damage is done to leaves ; serves as a good shelter.

Cauliflower (*Brassica oleracea* var. *botrytis*) : Favourite plant cultivated throughout the country. In Balasore (Behura, 1955) and Mayurbhanj districts of Orissa, and in the districts of north Bihar (Singh and Birat 1969) *Achatina* is a serious threat to this vegetable.

Cassia sophera : It is a monsoon dependent wild plant. No damage is done to the plant. The fallen leaves are a good source of food.

Chilly (*Capsium* spp.) : Seasonal, sometimes perennial, economically important, bushy plant largely grown all over the country. Leaves and skin are eaten. Srivastava (1966) also listed this as a food plant.

China rose (*Hibiscus rosasinensis*) : It is a most common bushy, perennial garden flower plant. A favourite plant, all parts are attacked, the damage being more to flowers and leaves. Fallen leaves and flowers are preferred most. Giant snails are often found in hedges of china rose plants in large number.

Chrysanthemum (*Chrysanthemum* sp.) : The snails have a definite choice for the leaves and flowers of this seasonal, bushy flower plant.

Clitoria (*Clitoria ternatea*) : A common climbing flower plant in all gardens. The snails below the age of 120 days attack the plants seriously. Leaves, twigs and flowers are favourite food.

Coccinea (*Coccinea cordiforia*) : It is a climber found in wild areas of south West Bengal and Orissa. The leaves are bitter still these are consumed.

Cosmos (*Cosmos* sp.) : Most common garden flower plant, bushy in nature. A choice plant for snails of all ages. Twigs are highly preferred. The plants are completely defoliated the skin denuded and the stem cut into pieces. The damage is serious (Pl. XI, figs. 3 and 4). Heavy infestation is fatal to the plants.

Cotton (*Gossypium herbaceum*) : It is an important plant, mostly seasonal and rarely perennial. Widely cultivated throughout eastern India. Leaves, flowers, floral buds and fruits are attacked. Young plants are completely destroyed ; older ones are defoliated.

Cucumber (*Cucumis sativus*) : An important vegetable plant extensively cultivated throughout the country almost throughout the year. It is one of the most preferred plant and the damage is rather serious. Seedlings are eaten up completely ; young plants are damaged beyond survival, older ones are almost totally defoliated. Twigs, stem body and often flowers are equally liked ; the ovary is eaten completely. Young snails skeletonize the leaves only. The stem is often cut into pieces and as a result the crop is completely lost.

Dhalia (*Dhalia* spp.) : Leaves of this seasonal garden flower plant are susceptible to attack. Seedlings are totally devoured but the damage is not serious to grown-up plants.

Dioscorea alata : Leaves of this biannual climber are most preferred food item. Bulbils are often scrapped.

Drum stick (*Moringa olifera*) : Only the leaves of this perennial vegetable plant are eaten ; occasionally the snails are found high up on the tree (Pl. XII, fig. 1). Fallen leaves are eaten by the young snails.

Euphorbia (*Euphorbia pulcherrima*) : Young leaves of this wild climber are attacked only in absence of other food.

Fig (*Ficus hispida*) : Of the large wild plants the leaves of this species are item of choice. Young snails consume the lamina leaving only the ribs (Pl. XII, fig. 2) while the older ones devour the whole leaf except the petiole. Often denude the soft branches if the leaves are not available. Fruits are not damaged.

Gardenia (*Gardenia florida*) : Leaves of this bushy, perennial flower plant are rarely attacked but the fallen leaves and flowers are preferred food items.

Garden spinach (*Spinacea oleracea*) : It is a least liked garden vegetable. In the absence of preferred food plants the whole garden is destroyed.

Gourd (*Cucurbita maxima, Lagenaria vulgaris*) : *C. maxima*, one of the most preferred vegetable food plants are extensively cultivated both in the monsoon and spring. Leaves, twigs, flowers and floral buds are avidly eaten. Chewing down the stem is also common. In densely populated area the plants are completely defoliated and the stem is often cut into pieces (Pl. XII, fig. 3). Seedlings attract snails of all age groups in a large number and crop protection assumes a serious problem. *L. vulgaris* is not so preferred but the leaves are occasionally eaten. *A. fulica* is a serious pest of gourd plants all over the country including Andaman Islands.

Grass : The grasses are practically immune to the attack of snails. In the absence of other food plants only the leaves of *Commelina benghalensis* are consumed.

Guava (*Psidium guava*) : A perennial fruit tree. Only negligible damage to live leaves while decaying leaves are eaten up readily.

Hiptage : The snails occasionally feed upon the leaves of this woody, flowering creeper ; no serious damage ; serves as an ideal shelter.

Jasmin (*Jasmin sambac*) : No severe damage has been observed to this bushy garden flower plant but the fallen leaves and flowers are eaten. A good hiding for snails during day time.

Jute (*Corchorus* spp.) : Economically most important seasonal fibre plant, widely cultivated in West Bengal and Bihar during monsoon. The young plants are seriously attacked ; leaves of grown-up plants are eaten only by young snails. The skin is scrapped occasionally but the twigs are never consumed.

Lady's finger (*Hibiscus esculentus*) : A common vegetable plant mostly grown in monsoon. Young plants are eaten up completely ; leaves of older plants except mid ribs are consumed ; flowers and fruits are food of choice ; sometimes the plant is denuded.

Land-lily (*Hibiscus mutabilis*) : Leaves and flowers of this perennial flower plant are very rarely attacked, the fallen leaves and flowers are usually eaten.

Lettuce (*Lettuca sativa, L. indica*) : Most preferred vegetable plant. The snails devour the whole plant ; young snails attack the leaves only (Pl. XII, fig. 4).

Maize (*Zea mays*) : Seedlings are often attacked.

Marigold (*Tagetes patula*) : A most common seasonal flower plant grown in autumn to winter. This is one of the most preferred plants to snails of all ages. The whole of the plant is consumed by older snails while the young ones avoid the hard portions. Leaflets are avidly consumed by the snails of 20 to 50 days in age. Juvenile snails prefer the twigs and floral buds. Cultivation of the species is being abandoned due to high snail population in some pockets of the districts 24-Parganas, Howrah, Midnapore and Calcutta of West Bengal and Balasore district of Orissa—the chief sources of flower supply to Calcutta.

Moss (*Semibarbula orientalis*) : Only young snails feed upon this species.

Nine O'Clock (*Portulaca* sp.) : One of the most favourite plants usually grown in monsoon. Seriously attacked by the snails older than 30 to 40 days. The succulent plant body is avidly eaten. Snails less than 30 days old feed upon the decomposing flowers. Complete destruction of the plant has been recorded from some gardens in Kerala, West Bengal, Assam and Bihar.

Nut : Nuts are unbranched perennial plants common in south and eastern parts of India. No damage to *Cocos nucifera*. Only slight scratches were recorded from the soft bark of *Areca catechus*. Young snails are found in large numbers on the decomposing leaves and in the inflorescence of both the species. The snails often rest on the trunks in daytime.

Oleander (*Nerium odorum*) : It is a common perennial flower plant. The leaves and rarely the flowers are eaten. Fallen leaves and flowers are eaten more often.

Ornamental garden plants : A good number of ornamental plants viz. *Rheo discolor*, *Trichosanthus anguina*, *Sansevieria trifascita*, *Crinum asiaticus*, *Bryophyllum pinnetum*, *B. calycinum*, *Aloe indica*, *Setcraesca* sp., *Codaeum varaigata*, *Thuja orientalis*, *Gamphrena globosa*, *Pothos scandens* and *Dieffenbachia picta* are the main sources of food of the snails living in gardens. The succulent leaves of the first 7 species are completely eaten. The damage to *R. discolor* (Pl. XIII, fig. 1) and *P. scandens* (Pl. XIII, fig. 2) is rather serious. Srivastava *et al* (1968) reported that *A. fulica* is a serious threat to ornamental plants in Andaman islands while Veeresh *et al* (1979) and Veeresh and Rajagopal (1980) reported the same from Bangalore.

Papaya (*Carica papaya*) : Snails feed greedily on the leaves, floral buds and flowers ; seedlings are eaten up completely ; fruits and skin are also damaged. They crawl high up on the tree, and rest on the ventral surface of the leaf during day time. Papaya cultivation has failed due to the attack of giant snails in the districts of 24-Parganas, Jalpaiguri, Calcutta and parts of Midnapore district in West Bengal and to some extent in the Palghat district of Kerala, Moradabad district of U. P. and Andaman group of islands.

Pluchea (*Pluchea indica*) : It is a seasonal herb growing largely in the uncultivated areas in all the districts of West Bengal, Bihar and Assam. Not a preferred food plant, only leaves are eaten.

Plumeria acutifolia : Less susceptible to attack, fallen leaves and flowers of this perennial flower plant are eaten.

Radish (*Raphanus sativus*) : Seasonal vegetable grown in selected areas. The leaves (Pl. XIII, fig. 3) and the exposed portion of the modified stem are eaten.

Rose (*Rosa* spp.) : Perennial bushy garden flower plant. The sharp spines prevent the snails climbing the plant. The snails, on some adjacent support extend their visceral stalk to eat the leaves.

Squash (*Edgaria darjeelingensis*) : Largely grown in the districts of north West Bengal, Assam, Nagaland, Meghalaya and Manipur. The leaves are most preferred.

Star apple (*Eugenia* sp.) One of the most important perennial fruit plant, usually bushy. No damage to fruits, only the foliage is sparingly eaten. A large number of snails rest on the branches in day time.

Sunflower (*Helianthus annuus*) : A common seasonal flower plant. It is being extensively cultivated in south India and in south and central West Bengal for edible oil. The snails climb up the top of the plant and consume the floral buds and flowers but the ray florets.

Synedrella (*Synedrella nordiflora*) : A common wild plant growing in the districts of lower West Bengal and Assam. The leaves and twigs are palatable food.

Tea (*Thea sinensis*) : This important commercial plant is extensively cultivated in the districts of Darjeeling and Jalpaiguri in West Bengal and in parts of Tamil Nadu and Kerala States. No serious damage. In absence of other food plants only the leaves in some gardens at Jalpaiguri are eaten. The seedlings in the nursery are attacked.

Tomato (*Lycopersicum esculentum*) : Seasonal vegetable plant, less susceptible to attack, feed occasionally when no other preferred food plants are available. Nurseries are extensively damaged.

Vegetable sponges (*Luffa aegyptica* ; *L. autanqula* and *L. cylindrica*) : Most common vegetable plants, chiefly confined to monsoon ; favourite food plants of snails. The plants are often defoliated, the stem is occasionally chewed up causing a serious damage. The fallen leaves are also consumed readily.

Vernonia (*Vernonia scandens*) : Occasionally the leaves and twigs of this perennial climber are attacked.

Vinca (*Vinca rosea*) : Perennial garden flower cultivated only in monsoon. It is not a preferred species, leaves are rarely eaten. Fallen leaves are more preferred.

Zinnia (*Zinnia linearis*) : Seedlings are grown in autumn and flowering takes place in winter. The seedlings are one of the most favoured food ; occasionally the grown up plants are attacked in winter following rain.

Opeas gracile :

They feed on fallen and decomposed leaves of garden plants and rarely attack live ones. The damage is negligible. Mitra *et al* (1976) observed that the snails feed normally on freshly fallen or slightly decomposed littered leaves of *Clitoria ternatea*, *Limonia crenulata*, *Nerium indicum*, *Hiptage benghalensis*, *Ixora coccinea*, *Dolichos lablab*, *Capsicum* sp. In addition, decomposed leaves of *Hibiscus rosasinensis*, *Ipomoea pescaprae* and *Vinca rosea* were also consumed. *O. gracile* is considered as a pest of potted plants and garden plants by Roy and Mukherjee (1969).

Macrochlamys indica :

The list of plants in the menu of *M. indica* though quite large, is much less than that for *A. fulica*. Leaves of cucurbita, gourds, beans, lettuce, *Luffa*, cabbage, cauliflower, amaranth, castor, chrysanthemum, *Hiptage*, marigold, clitoria, *Pothos*, drum stick, *Pedilanthus*, cosmos, *Dioscorea alata* and some wild plants are their favourite food. Damage to money plants in Hooghly district of West Bengal has been reported by Subba Rao (1975).

The snails generally make small holes on the lamina (Pl. XIII, fig. 4) of the leaves. They never eat the midrib or petiole. The twigs of castor, lettuce, *Hiptage*, clitoria, cosmos and marigold and leaflets of marigold, cosmos and drum stick are eaten completely. No damage to stem or bark of any plant has been recorded. *M. indica* are common in wild areas, where they thrive well on the wild plants like clitoria, *Allangana* and *Synedrella*. Decomposed or fallen leaves and flowers of papaya, balsam, rose, china rose, citrus and many other plants are most preferred. The snails living in the spaces between the bricks of the damp wall of old and delapilated buildings feed exclusively on the moss *Semibarbula orientalis* growing there.

Cannibalism is found in *M. indica* though they never try to kill other members of the community. The snails often feed on the dead individuals of their own species. During behavioural studies some of the snails were accidentally crushed under shoes and within a few minutes the snails from the adjoining area moved there and avidly fed on the flesh (Pl. XIV, fig. 1). Flesh of freshly crushed snails are better choice than the most preferred plant food (Raut and Ghose, 1983c).

Ariophanta solata :

It causes damage to *Coffea arabica* and *Erythrine lithosperma* in Nilgiris and Western Ghats of South India. The snails rasp the epidermis and eat the mesophyll tissue of leaves. Feeding on green portions of tender stem, leaves and also berries is common. The tender stem attacked by snails breaks in the damaged part when it is exposed to strong wind (Subba Rao, 1975).

Cryptozona (Nilgiria) semirugata :

This species feeds on the economic plants like *Thevetia* sp. (Lakshminarayan and Subba Rao, 1965) and *Adathoda vasica*, the leaves of which are used in the preparation of cough syrup (Laksminarayana and Subba Rao, 1971). A real threat to garden plants wherever it occurs in abundance (Subba Rao, 1975).

Cryptozona (Xestina) bistrialis :

The snails feed on a number of wild plants and weeds. The only report of attack on rubber plant is from the Central Nursery Rubber, Karikkattor, Kottayam District, Kerala (Subba Rao, (1975).

Bensonia monticola :

The snails are serious pest of beans at Solan, Himachal Pradesh in July and August and feed exclusively on the leaves of bean plants. In absence of bean plants they feed on lady's finger, *Ipomoea* and occasionally on maize (Bhardwaj and Thakur, 1973). Also they have been observed to feed on vegetables, papaya, plum, peach and citrus in Bilaspur and Mandi districts (Bhalla and Pawar, 1977) and Arki and Darlaghat of Solan.

Simulated habitat :

For the study of food preference and feeding in *A. fulica* and *M. indica*, individuals of 5 different age groups viz. newly hatched, 60, 120, 365 and 730 days old were selected. Initially 200 newly hatched individuals of each age group from each species were taken. The number was reduced to 100 when they were 30 days old. Five cages measuring 200×200×240 cm were used for each batch. To maintain a near monsoon condition in the cages the following measures were adopted. The range of humidity, 80 to 95% for optimum activity of the snails was maintained by spraying water with a low volume sprayer. The desired level, however, could not be maintained and the humidity came down as low as 70 to 75 in most of the days at about zero hour. The temperature range was 8.6 to 26°C but in most of the days in winter it was 8.6 to 10.4°C during feeding hours.

The following 22 plant species comprising vegetables, fruit plants, fibre and oil producing plants, flower and ornamental plants and wild plants including their flowers and fruits were selected for the study of food preference.

Vegetable plants :

1. Amaranth (*Amarntus viridis*)
2. Black bean (*Dolichos lablab*)
3. Cabbage (*Brassica oleracea*)
4. Drum stick (*Moringa indica*)
5. Garden spinach (*Spinacea oleracea*)
6. Gourd (*Cucurbita maxima*)
7. Lady's finger (*Hibiscus esculentus*)
8. Lettuce (*Lettuca sativa*)
9. Radish (*Raphanus sativus*)
10. Soybean (*Glycine max*)
11. Tomato (*Lycopersicum esculentum*)

Fruit plant :

12. Papaya (*Carica papaya*)

Fibre plants :

13. Cotton (*Gossypium herbaceum*)
14. Jute (*Corchorus* spp.)

Oil producing plant :

15. Castor (*Ricinus communis*)

Flower plants :

16. Marigold (*Tagetes patula*)
17. Zinnia (*Zinnia linearis*)

Ornamental plants :

18. Vernonia (*Vernonia scandens*)

Wild plants :

19. American life plant (*Bryophyllum pinnetum*)
20. *Cassia sophera*
21. *Ipomea sp.*
22. *Synedrella nordiflora*

Achatina fulica :

Feeding and the choice of food plant varied with the age of the snail and also with the seasons viz. monsoon, winter and summer. The choice of food plants by the snails kept active artificially in other seasons was similar to that in monsoon.

The snails upto the age of five days ate only the broken and abandoned egg-shells of the same brood. Feeding on plants started from the 6th day with the tender leaves of lettuce, beans (Pl. XIV, fig. 2) and marigold. The veinules, veins and the petioles were not attacked till the snails were 14 days old. With age the snails consumed larger veinules and veins of bean leaf (Pl. XIV, fig. 3) and by the 25th day they started feeding on coarser leaves like those of gourd (Pl. XIV, fig. 4) *Synedrella* and amaranth. At this age they could scrap the petioles of lettuce, beans and marigold. Forty days old specimens were voracious eater. The leaves of lettuce, marigold, beans, *Synedrella* and *Dioscorea* were eaten completely but the veinules and veins of coarser leaves like those of amaranth, papaya, jute and cotton were not attacked. Of the plant species the most favoured ones were gourd, beans and marigold. However, in spite of adequate supply of the favoured plants, the less favoured plants like *Synedrella*, lettuce, papaya, tomato and zinnia, were also consumed.

Selection and preference for food plants and the nature of damage were almost similar in the snails 60 to 730 days old, but the younger ones restricted themselves mostly to soft plants since hatching showed similar food preference. In monsoon, the preferred food plants in order of priority were gourd, marigold, lettuce, beans, synedrella and American life plant over others.

The portions favoured were the leaves, flowers, twigs and stem of gourd ; leaves, skin and growing regions of marigold ; the whole bean plant ; leaves, skin and growing parts of American life plant and leaves and tip of *Synedrella*, The amount of food consumed in a 24 hour period was about 65% of that in monsoon. The cabbage was not a preferred food in monsoon but starting from November, the amount of cabbage consumed was greater than that of gourd, though the snails severely damaged gourd, castor, papaya, radish and cotton leaves. From about the beginning of the second week of December the snails restricted them to succulent plants like cabbage, lettuce and American life plant and succulent parts of gourd and papaya. With the advance of winter and lower humidity the snails lived on the ribs of cabbage (Pl. XV, fig. 1) and growing regions, floral buds and chiefly the thalamus of flowers of gourd. By the third week of February, with the rise of temperature a change in food selection was recorded. From the third week of February till the next monsoon, the preferences were similar to those in monsoon. The cabbage was not a preferred food for any age group of the snail.

Macrochlamys indica :

Contrast to *Achatina fulica* newly hatched *Macrochlamys indica* did not eat anything till they were four days old. On the fourth day they swallowed soil particles. Feeding on plants started on the fifth day and the first consumed plant food were young bean leaves (Pl. XV, fig. 2). Marigold was eaten from the ninth day and consumption rate of bean leaves except the ribs increased considerably. *Synedrella* and amaranth eaten by the snails three weeks old. By this time they started feeding upon coarse leaves like those of gourd, castor and papaya. In snails 30 days old, plant species in order of preference were beans, marigold and gourd.

The number of plant species consumed by *M. indica* of about 60 days age group was more than that on which *A. fulica* of the same age group fed. The order of preference was gourd, bean, marigold, papaya and *Synedrella*. Even the fairly old snails, above 120 days in age did not take principal veins of the leaves. The snails of higher age groups showed similar food preference, and the amount of food consumed was maximum during the period—middle of June to the middle of November.

In winter selection of food was similar to that in *A. fulica* and the preferred zones were veins of succulent palnts. The stem of lettuce was avidly eaten by snails of all ages. The rate of food consumption was much less, 45% of that in monsoon on the average, in cooler months.

Feeding and food preference during summer were similar to that in monsoon.

Laboratory condition :

The food preference and the rate of consumption in *A. fulica* and *M. indica* exposed to 21-25°C and 26-30°C, and a humidity range 85-95% were similar to those in monsoon and summer in snails maintained in simulated habitat. In the same temperature range but 71-84% humidity the snails of all age groups were active only for 2-3 days, and ate only the succulent plants at a much slower rate. The rate of consumption declined gradually from the second day and they under went aestivation on the third day.

Feeding hours and duration :

In sunny days during monsoon *A. fulica* starts feeding at dusk, which may continue till 03-hour next day depending on the abundance of food. In cloudy rainy days they feed in day-hours, and both in summer and winter feeding continue quite a few hours in shady places, after a heavy shower.

In *M. indica* feeding starts after one to one and a half hour of that in *A. fulica*. They feed for a short period, from 19 to 01 hours next day. Post-shower feeding behaviour in summer and winter is similar to that in *Achatina* but they do not go beyond a distance of about 100 cm from their shelter.

In the simulated habitat feeding starts much earlier than that in the natural habitat. During day-hours spraying of water induced feeding for a few hours in some of the snails.

Feeding activity in day-hours was recorded from snails kept in dark in the laboratory, though at a lesser degree.

Feeding mechanism and behaviour :

As a rule the snails of all ages start feeding from the margins of the leaves. In case the mouth can not reach the margin, a hole is first made on the lamina.

The food is drawn towards the mouth with the help of extended labial palps. Occasionally the foot helps in the operation.

The labial palps, jaws and the radula, all work together in a coordinated way and the snails feed at a fast rate. The structure and function of organs involved in feeding in land snails have been described in *Cryptozona semirugata* (Mantle, 1973) ; *Monacha cantiana* and *M. cartusiana* (Chatfield, 1976) and *Macrochlamys indica* (Das, 1977).

Feeding movement is rather fast, probably only second to breeding movement. The occular tentacles extend to their maximum limit at a 15°C angle with the substratum (ground). Momentary retrovertion of the tip of the tentacles in contact with food is spontaneous. In the next moment the tentacles extend and the nature of the food is tested. By this time the labial palps are in contact with food and feeding starts immediately.

A competition for food is conspicuous in both the species. Fighting in the sense is absent owing to lack of offensive organs. This has been largely compensated by consuming a large amount of food in a short time.

A new arrival often tries to dissuade others from feeding by crawling over the snails busy in feeding or pushing the snout against it (Pl. XV, fig. 3). In the struggle stronger snails always win.

A soft chuckling sound is often audible from a few feet distance when several snails eat on the same food plant, but no such sound is heard when the same number of snails feed upon separate plants even in the same area, indicating fast eating rate in the case of a competition for food.

Evaluation of the damage—a quantitative estimation :

Workers (vide Mead, 1961) are unanimous with the fact that *A. fulica* are causing considerable damage to economic plants and the farmers are facing a great annual loss. While evaluating the damage caused by this snail pest, Mead (1961) stated "We know what the snail will attack, but we do not know to what extent the snail will attack it. Studies of quantitative damage therefore must be made.".

With a view to evaluate the damage a snail infested garden at Joynagar (40 KM. south- east of Calcutta) with an area 419 m^2 was selected. The garden was separated from other plots of land by different means—two sides were protected by high boundary walls, while the other two sides were separated by small water canals. These protections were the barriers for new invaders (snails).

The garden was cultivated with a number of economic plants, viz. bean (*Dolichos lablab*), gourd (*Cucurbita maxima*), sponge gourd (*Luffa cylindrica*), Cucumber (*Cucumis sativus*), marigold (*Tagetes patula*), lady's finger (*Hibiscus esculentus*), papaya (*Carica papaya*) and puni (*Basella rubra*) of different ages ; and of different kinds of wild plants. There were a few large fruit trees viz. mango, coconut, jackfruit etc. in the garden providing a shady and humid environment throughout the day.

All the snails (*A. fulica*) present in the garden were counted. It is to be noted here that no other species of land molluscs or insect pest was observed in the garden during the period of study. The snails were measured individually and according to age they were grouped in six age groups viz. 10 to 25 days, 50 to 80 days, 100 to 120 days, 150 to 240 days, 280 to 350 days and 365 days and above for the convenience of the study.

Observations were made on the feeding habits of the snails and the amount of consumption of a particular plant species regularly. Selection of plant species in respect to the snails' age was also noted. For the study on the rate of consumption by a particular age-group a good number of cages, each measuring 80×80×80 cm were taken. One side of the cage was left open and the other sides were protected by polythene net of 0.1 mm attached by a wooden frame.

During evening when the snails were about to start feeding on their selective plant species a few plants or leaves, twigs, flowers and fruits as the case may be were collected from the garden and weighed. These weighed plant food materials were supplied to the particular age group/age groups of snail feeding on that plant species separately. For each experiment 10 healthy snails of each age group were taken and excess amount of food materials of the particular plant species were supplied to the snails. A cage was placed over the snails of each age group with supplied food materials and were left open to the air and rain till next morning. The remaining food materials were again weighed in the next morning to ascertain the amount consumed by the snails. Data on the amount of consumption was noted for a period of 4 weeks, August 1 to August 28, 1977 ; and for each week a mean was calculated from the total amount of consumption per day.

Observations on the extent and nature of damage to a particular plant species by a particular age group of snails was made everyday with a view to evaluate the total loss (Raut, 1982).

Mortality of the snails in the garden was also noted by counting the snails of each age group at the end of each week.

In the first week i. e. from August 1 to 7, the frequency of infestation on plants was variable but all the 8 cultivated plant species—bean (*D. lablab*), gourd (*C. maxima*), cucumber (*C. sativus*), sponge gourd (*L. cylindrica*), marigold (*T patula*), lady's finger (*H. esculentus*), papaya (*C. papaya*) and puni (*B. rubra*) were attacked by the snails. Daily readings were taken both on the number of snails feeding on different plants and the age of the snails. The rate of infestation and the amount of consumption varied with the plant species and with age of the snails (Table 11).

TABLE 11. Mean infestation of snails to different plants and mean amount of consumption by *A. fulica* of 6 different age groups in a period of 7 days, August 1 to 7, 1977 (1 = Number of infested snails, 2 = Amount consumed in gm.).

PLANTS	AGE GROUPS (in days)											
	10—25		50—80		100—120		150—240		280—360		365+	
	1	2	1	2	1	2	1	2	1	2	1	2
Bean	1275	200	105	158	385	963	81	285	33	120	97	420
Cucumber	—	—	85	126	95	228	—	—	41	149	41	148
Gourd	—	—	410	580	309	750	116	448	86	298	184	750
Lady's finger	—	—	—	—	—	—	—	—	9	30	21	85
Marigold	340	55	120	180	129	325	—	—	40	162	94	435
Papaya	—	—	—	—	—	—	61	192	10	36	30	142
Puni	—	—	—	—	—	—	—	—	—	—	31	129
Sponge gourd	—	—	60	84	51	115	—	—	—	—	49	215

Unlike that in the first week observations in the second, third and fourth week were made on the frequency of snail infestation to different plant species as well as on the amount consumed by different age groups (Tables 12-14) (Raut, 1982).

The nature and extent of damage to the plant species caused by the giant snails during the period under observations were rather of serious concerned. However, the degree of damage is dependent on the rate of snail infestation to a particular plant species. In fact, it is not only dependent on the infestation rate but also on the age of these snails.

TABLE 12. Mean infestation of snails to different plants and mean amount of consumption by *A. fulica* of 6 different age groups in a period of 7 days, August 8 to 14, 1977 (1 = Number of infested snails, 2 = Amount consumed in gm).

PLANTS	AGE GROUPS (in days)											
	10—25		50—80		100—120		150—240		280—350		365+	
	1	2	1	2	1	2	1	2	1	2	1	2
Bean	1206	248	121	188	358	905	83	293	38	141	92	396
Cucumber	—	—	71	99	98	240	—	—	35	115	36	134
Gourd	—	—	392	560	324	808	119	465	91	319	178	765
Lady's finger	—	—	—	—	—	—	—	—	11	31	26	105
Marigold	414	84	123	189	131	334	—	—	39	153	95	430
Papaya	—	—	—	—	—	—	53	185.5	10	37	21	92
Puni	—	—	—	—	—	—	—	—	—	—	26	118
Sponge gourd	—	—	53	77	56	130	—	—	—	—	44	195

TABLE 13. Mean infestation of snails to different plants and mean amount of consumption by *A. fulica* of 6 different age groups in a period of 7 days, August 15 to 21, 1977 (1 = Number of infested snails, 2 = Amount consumed in gm.).

PLANTS	AGE GROUPS (in days)											
	10—25		50—80		100—120		150—240		280—350		365+	
	1	2	1	2	1	2	1	2	1	2	1	2
Bean	1301	408	103	159	372	945	88	315	43	160	91	400
Cucumber	—	—	69	102	90	222	—	—	38	130	35	134
Gourd	—	—	399	586	321	802.5	118	472	85	304.5	178	765
Lady's finger	—	—	—	—	—	—	—	—	8	27	26	105
Marigold	382	124	111	178	127	326.5	—	—	36	148	87	400
Papaya	—	—	—	—	—	—	53	196	8	24	23	105
Puni	—	—	—	—	—	—	—	—	—	—	29	132
Sponge gourd	—	—	53	81	49	119.5	—	—	—	—	41	176.5

At the end of the 4th week it was observed that there was no trace of young bean plants ; in older plants the leaves were skeletonized and the twigs were eaten in most cases ; some plants were cut into pieces. It is to be noted here that the bean plants were infested mostly by the snails of 10 to 15 days age group and these snails, being smaller in size were able to crawl up to the twig and attack the foliages. The entire fruit capsule was often eaten by the snails of older age groups. As this plant species was one

TABLE 14. Mean infestation of snails to different plants and mean amount of consumption by *A. fulica* of 6 different age groups in a period of 7 days, August 22 to 28, 1977 (1 = Number of infested snails, 2 = Amount consumed in gm.).

PLANTS	AGE GROUPS (in days)											
	10—25		50—80		100—120		150—240		280—350		365+	
	1	2	1	2	1	2	1	2	1	2	1	2
Bean	1235	669	108	173	381	979.5	84	310	41	150.5	91	400
Cucumber	—	—	66	103	103	154	—	—	39	136	36	134
Gourd	—	—	407	635	326	832	113	475	83	324	179	770
Lady's finger	—	—	—	—	—	—	—	—	10	36	22	97
Marigold	409	211	116	182.5	127	342	—	—	30	129	88	409
Papaya	—	—	—	—	—	—	57	223	8	31	26	115
Puni	—	—	—	—	—	—	—	—	—	—	24	108
Sponge gourd	—	—	47	73	45	111	—	—	—	—	40	176

of the favourite food plants of the snails of all ages the damage was maximum. Puni was not preferred by the snails of all ages and the damage was obviously not so serious because the snails mostly restricted themselves to eating leaves only. However, twigs were also preferred by some individuals and in that case the damage was remarkable. Cucumber, gourd and sponge gourd were food items to the snails of higher age groups and the plants were damaged very badly, in some cases the plants were defoliated completely. Twigs, stems, flower, floral buds and young fruits of cucumber and gourd were eaten by snails voraciously. Of the 16 grown up gourd plants of the garden the leaves, twigs and floral buds of 11 plants were completely eaten while the remaining plants were affected partly. Cucumber, though eaten up by the snails of different ages, the damage was not so serious in comparison to those of gourd plants. Leaves of sponge gourd were preferred by the snails of different age groups but the damage was not so significant, probably due to the presence of 201 grown up plants in the garden. Out of 139 lady's finger plants 83 became unproductive due to the attack of floral buds. Papaya were also equally suffered as the snails were regular feeders of the floral buds. The snails were even found to drink latex from the young fruits which became unmarketable. Marigold plants were completely defoliated and denuded.

To ascertain a true picture of snail infestation to particular plant species by a particular age group a mean was calculated from the data collected during the period of four weeks (Table 15). It was estimated that bean plants were infested by 1254.25 snails of 10 to 25 days age group while

TABLE 15. Mean infestation of snails of different age groups to different plant species per day.

PLANTS	AGE GROUPS (in days)					
	10—25	50—80	100—120	150—240	280—350	365 +
Bean	1254.25	109.25	374.0	84.0	38.75	92.75
Cucumber	—	72.75	96.5	—	38.25	37.0
Gourd	—	401.75	320.0	116.5	76.25	179.75
Lady's finger	—	—	—	—	9.5	23.75
Marigold	386.25	117.5	128.75	—	36.25	91.0
Papaya	—	—	—	56.0	9.0	25.0
Puni	—	—	—	—	—	27.5
Sponge gourd	—	53.25	50.25	—	—	43.5

386.25 snails of the same age group concentrated to marigold plants. Snails of 50 to 80 days and 100 to 120 days age group have shown similar preference to the plant species but the infestation rate showed slight difference. Beans were infested by 109.25 snails of 50 to 80 days age group while the number was higher i. e. 374 in case of 100 to 120 days age group. Cucumber were infested by 72.75 and 96.5 snails ; gourd were infested by 401.75 and 320 snails ; marigold were infested by 117.5 and 128.75 snails ; sponge gourd were infested by 53.25 and 50.25 snails of 50-80 and 100-120 days age groups respectively. No infestation to puni, lady's finger and papaya plants by the snails of these two age groups was observed. Infestation by the snails of 150-240 days age group was restricted only to the three plant species out of eight economic plants. The maximum infestation observed in gourd i. e. 116.5 snails while bean (84 snails) and papaya (56 snails) were next in order. With the increase in age the snails have shown a wide range of food acceptibility. Out of 8 plant species 6 were infested by the snails of 280-350 days age group. The rate of infestations was 38.75 snails for beans ; 38.25 snails for cucumber ; 76.25 snails for gourd ; 9.5 snails for lady's finger ; 36.25 snails for marigold and 9 snails for papaya. Infestation to all the plant species was recorded by the snails of 365 days and above age group. It was estimated that bean plants were infested by 92.75 snails, puni plants were infested by 27.5 snails ; cucumber plants were infested by 37 snails ; gourd plants were infested by 179.75 snails ; lady's finger plants were infested by 23.75 snails ; marigold plants were infested by 91 snails ; papaya plants were infested by 25 snails and sponge gourd plants were infested by 43.5 snails in average.

Table 16 shows the Analysis of variance for infestation of snails of different age groups to different plant species. It is interesting that the intensity of infestation was significant at 1% level to all the plant species by all the age groups. Consumption rate by each snail of each age group to each plant species was also estimated and mean of the same is shown in Table 17. Consumption rate was equal for beans and marigold for the snails of 10-25 days age group. Interestingly this age group did not consume other plants. With the increase in age of the snails the consumption rate was found to

TABLE 16. Analysis of variance for infestation of snails of different age groups to different plant species.

SOURCE OF VARIATION	AGE GROUPS (in days) 10—25 D.F.	M. S.	50—80 D.F.	M. S.	100—120 D.F.	M. S.	150—240 D.F.	M. S.	280—350 D.F.	M. S.	365 + D.F.	MS
Replication	3	481.5	3	77.4	3	17.9	3	1.889	3	67	3	42.86
Plant species	1	1506848**	4	81418.95**	4	82703.8**	2	3667**	5	2442.667**	7	11752.96**
Error	3	2438.2	12	46.82	12	59.89	6	14.22	15	79.93	21	6.56

**Significant at 1% level.

TABLE 17. Mean consumption rate (in gm.) of different plant species by each snail of different age groups per day.

PLANTS	AGE GROUPS (in days) 10—25	50—80	100—120	150—240	280—350	365 +
Bean	0.29	1.53	2.53	3.57	3.66	4.35
Cucumber	—	1.45	2.49	—	3.44	3.6
Gourd	—	1.46	2.49	3.95	3.59	4.02
Lady's finger	—	—	—	—	3.27	4.1
Marigold	0.29	1.57	2.55	—	4.09	4.58
Papaya	—	—	—	3.56	3.54	4.5
Puni	—	—	—	—	—	4.4
Sponge gourd	—	1.47	2.36	—	—	4.4

vary from one plant species to other. Consumption rate by the snails of 50-80 days age group was 1.57 gm. for marigold, 1.53 gm for bean, 1.47 gm for sponge gourd, 1.46 gm for gourd and 1.45 gm for cucumber plants. Consumption rate was 1.0 gm higher for each plant species by the snails of 100-120 days age group than that of the snails of 50-80 days group. Snails of 150-240 days age group showed 3.95 gm, 3.57 gm and 3.56 gm consumption rate for gourd, bean and papaya respectively. Higher consumption rate was recorded for marigold by the snails of 280-350 and 365 days and above age groups. In the former age group 4.09 gm and in the later 4.58 gm per snail were calculated. Consumption rates were 3.66, 3.59, 3.54, 3.44 and 3.27 gm per snail of 280-350 days age group for bean, gourd, papaya, cucumber and lady's finger respectively. Snails of 365 days and above age groups were voracious eater and the rates of consumption were 4.5, 4.4, 4.35, 4.1, 4.02 and 3.6 gm for papaya, sponge gourd, puni, bean, lady's finger, gourd and cucumber respectively.

TABLE 18. Analysis of variance for consumption rate of different plant species by each snail of different age groups.

SOURCE OF VARIATION	AGE GROUPS (in days)											
	10—25		50—80		100—120		150—240		280—350		365+	
	D.F.	M. S.	D.F.	M. S.	D.F.	M. S.	D.F.	M. S.	D.F.	M. S.	D.F.	M.S.
Replication	3	.0477743	3	.0204933	3	.01[illegible]98	3	.1249433	3	.111697	3	.01297
Plant species	1	.000098*	4	.0103125 N. S.	4	.0232125**	2	.1953**	5	.292444 N. S.	7	.3814842**
Error	3	.0000051	12	.1803308	12	.0008991	6	.0156116	15	.113338	21	.0155804

* Significant at 5% level
** Significant at 1% level
N. S. Not significant.

Table 18 shows the Analysis of variance for consumption rate to different age groups. It is interesting that consumption rate was significant at 1% level in the three age groups. viz. 100-120 days, 150-240 days and 365 days and above age groups while for 10-25 days age group it was significant at 5% level.

CONTROL

The giant African snail populations turned to a serious agrihorticultural pest in many countries in the early twentieth century. Measures to check the ever increasing snail population were adopted only at late 60's. Target of the whole programme is to manage *Achatina*. Other pestiferous snails have been left out, at least in India. The control methods tried or proposed in India so far can be categorised under 4 major groups.

1. Chemical control
2. Biological control
3. Physical control
4. Miscellaneous

Chemical control :

Aromax : From the field studies Saxena and Dubey (1970) reported 98% mortality in *Achatina* using aromax at a proportion of 60.0 litres per acre. The chemical had a very little adverse effect on vegetations and the cost per acre was ninety rupees only.

Calcium arcenate ; Mandal snd Ghose (1970) reported cent percent mortality in *A. fulica* in 56 to 70 hours following calcium arcenate dusting. The marked lesions appeared in the body of the snails and the death was presumed primarily due to immobilization of glucose from the digestive gland.

Common salt : Land snails as a rule can not withstand salinity. During the course of survey the authors were informed that common salt had been the only chemical that was used by the people in eastern India to control *Achatina*. Crystals of common salt are sprinkled on the extended visceral stalk and foot while the snail moves. The snail retracts immediately in the shell and later dies. Using 80 kg salt per acre Saxena and Dubey (1970) reported 90% mortality. Spraying of saturated salt solution gave a very good result (Hoda, 1971). Dusting common salt crystals over crawling snails has proved to be effective (Singh and Birat, 1969).

Copper sulphate : In Tejpur, Assam 98% mortality in *A. fulica* was recorded following application of 4.4 kg per acre. The estimated cost was Rs. 35.00 per acre. Its effect on the vegetation was only slight. Dusting a mixture of copper sulphate (4 parts) and lime (1 part) gave a good result (Hoda, 1971). Srivastava (1976) applied copper sulphate mixed with lime (1.5) on *A. fulica* populations in Andaman islands but failed to get a result because of the hygroscopic nature of the chemicals.

D. D. T. ; Dusting DDT-50 W D P was not effective on *A. fulica* (Saxena and Dubey, 1970). Molluscicidal activity was observed only when 40.0 kg per acre was used.

Diazinon : Baits prepared with wheat bran and mollasses at different concentration of diazinon, an organophosphate compound were used to control *A. fulica* (Manna, 1976). Desired concentration of the substance was prepared by diluting acetone disolved i.e. with distilled water. *A. fulica* feed on poison baits usually 15 to 30 minutes after broadcasting. On the average a batch of 10 snails consumed 4.0 to 4.5 g diazinon. The mortality rate was 70% with 2.0%, 60% with 1.0%, 40% with 0.5%, 30% with 0.25%, 20% with both 0.1 and 0.05% concentration of diazinon. The author did not consider diazinon as a good molluscicide.

Endrin : Endrin, an organochlorine compound is an effective gut poison against *A. fulica* (Manna and Ghose, 1972). Baits were prepared both with commercial preparation and active ingradient of endrine (1, 2, 3, 4, 10-10-hexachloro-6-, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a, octohydro-endo -1, 4-endo-5, 8-dimethanonaphthaline) at different concentration viz. 0.05, 0.1, 0.25, 0.5, 1.0 and 2.0%. In a seven days period the mortality was 100% with 2%, 90% with 1%, 40% with 0.5% and 10% with 0.25% and 0.1% concentration of endrin. Varma (1965) found it less effective than 5% metaldehyde against *A. fulica.*

Fenitrothion : Efficacy of fenitrothion, an organoposphate compound, as a molluscicide was screened by Manna (1976). The baits were prepared following the same method as in diazinon. The mortality rate was 50% with 2.0%, 40% with 1.0%, 30% with 0.5%, 20% with 0.25%, 10% with 0.1 and 0.05% concentration of fenitrothion. The author did not suggest application of this chemical in the control of pestiferous snails.

Metaldehyde : Reports available (Nair *et al*, 1968 ; Srivastava *et al*, 1968 ; Saxena and Dubey, 1970 ; Srivastava, 1970 ; Hoda, 1971) indicate that metaldehyde is an effective agent against *A. fulica.* Nair *et al* (1968) reported that the suspension containing 4, 2 or 1% metaldehyde causes complete mortality to the snails in 2 days and 0.5% in 4 days. In field cages 2% dust and 1% suspension give cent per cent mortality of the snails. In the field 1% suspension gives 93.3% mortality of the snails in 24 hours after spraying, survivals being those which escape contact with the toxicant. Metaldehyde when sprayed as 1% suspension persisted in the field at a toxic level for 4 days (Nair *et al*, 1968). Using metaldehyde pellets of two different concentrations against *A. fulica* at Port Blair, Andaman island Srivastava *et al* (1968) recorded that 5% bait was more effective than 3% bait, and mortality was higher in rainy days. Saxena and Dubey (1970) used three types of bait in their studies, bait A-with metaldehyde and a herbaceous, bait B-with metaldehyde and another base and bait C-with met-mercapturon. The mortality was 96% with bait A, 89% with bait B and 80% with bait C when used at the rate of 40 kg per acre. Bhardwaj (1973) reports a 96.7% kill of *A. fulica* when a 5% bait was used. Hoda (1971) reported that a bait containing 5% metaldehyde prepared with bran was highly effective against snails. Seedlings and or saplings treated with 5% metaldehyde dust prior to transplantation is considered as a good protection against snail attack (Srivastava and Abbas, 1973).

Mixture of 2, 4-D and 2, 4, 5-T (2 : 1) : The mixture of these two weedicides sprayed in *Achatina* infested field at the dosage of 20 litres per acre produced 91% mortality (Saxena and Dubey, 1970). The vegetation was completely destroyed, since these two are most powerful weedicides. Such experiments are examples of folly of workers.

Sevin : Saxena and Dubey (1970) reported 98% mortality of *A. fulica* by applying 40 kg sevin per acre, at a cost of one hundred and twelve rupees. A 5% Sevin bait was reported by Bhat and Shamanna (1973) to be 100% effective against snails.

Simazine : Application of simazine at the rate of 60 kg per acre produced 82% mortality in *A. fulica* (Saxena and Dubey, 1970). The cost of this chemical is very high and its use is not practicable.

Biological control :

Biological control of pestiferous snails has been suggested from time to time in the past few years but no serious attempt has been made in this direction. A number of parasites and predators have been recorded from India, a comprehensive account of which is given.

Protozoans : An unidentified species of trichodin ciliate from the spermatheca of *A. fulica* has been observed in about 34% snails. The infesta tion is very low, restricted 2 to 8 individuals in a snail. It is still not known whether they are parasites or symbionts.

Helminths : Planaria—The terrestrial planaria, *Bipalium indica* (Pl. XVI, fig.1) predate upon the juvenile *A. fulica* with 15 to 25 mm shell size (Raut and Ghose, 1979b). The worm crawls on a moving snail and suporting either the anterior or the posterior end of its body on the soil, turns the snail upside down. Immediately it reaches the exposed flesh in the upwardly directed shell aperture and paralyse the victim with a toxic fluid. The snail reacts violently with the spontaneous secretion of a considerable amount of mucous and quick withdrawl of the body inside the shell. The planaria thursts the pharynx in the flesh of the snail, and sucks the fluid for about 20 to 30 minutes. The snail did not resume activity and died afterwards.

Nematodes : A rhabditoid nematode has been recorded from the gut of about 35% individuals of *A. fulica* and *M. indica.*

Arthropods : Hermit crab—The hermit crab, *Coenobita cavipes* feed upon the giant African snail in Andaman Islands (Srivastava, 1968). Recognising their effectiveness (Srivastava, 1968), the predatory crabs were released in good numbers in the Shade Garden (Haddo) in the South Andamans in November 1966. The *Achatina* population declined considerably by May-July 1967.

Ant—The predaceous ants of the genus *Oecophyllus* usually carry away the eggs of *M. indica* and newly hatched *A. fulica*. But, they have never been observed to attack the adult snails.

Flies—The flies of the genera *Phoria* and *Megaselia* though have nothing to do with the live snails, lay eggs on the dead and decomposed animals, where further development proceeds. They are not parasitic on snails.

Beetles—The most important arthropod predator, the Indian glow-worm *Lamprophorus tenebrosus* feeds on *A. fulica* and ariophantids. The Indian glow-worms are very common and a good number of snails especially *A. fulica* are devoured by its larvae. Like land snails, the lympyrid is nocturnal by habit and the reduced prevalence of the snail in various parts of Tamil Nadu and Kerala seems to be an indication of this beetle larval activity in keeping down the snail population. Paiva (1918) reported the feeding habits of lymprid larvae on the snails.

Millipedes : Srivastava and Srivastava (1967) observed a millipede, *Orthomorpha* sp. to predate on *A. fulica* in the Andamans. It secretes hydrocyanic acid and paralyzes the prey before feeding. The predator population, however, is very low there and much more individuals are needed for an effective control measure.

Molluscs : Srivastava *et al* (1975) introduced *Gulella* (*Indoenna*) *bicolor*, the only Indian carnivorous land snail in South Andamans to control *A. fulica*. The authors are silent on the effectiveness of *Gulella* in controlling the natural snail populations but reported that the predatory snails preferred juvenile *A. fulica* in laboratory. The present authors never observed *Gulella* attacking *A. fulica*, though they attacked *O. gracile* in the field.

Birds : Two species of birds, *Dendrocitta vagabunda* and *Centropus sinensis*, predate on the land snail (Raut and Ghose, 1979a). The birds are active in daytime and try to locate moving snails after showers in rainy season. Both the species of birds either carry the snails or devour them in the garden. *D. vagabunda* turns the shell aperture upside and pulls out the flesh with the help of beaks without damaging the shell. *C. sinensis*, on the other hand, breaks the shell and tear up the flesh in small fragments. Domestic ducks often attack young *A. fulica*, but occasionally they eat the flesh. The snails, however, die due to damaged shell. In our attempts to use the snails as a poultry feed, dried snails were powdered and offered to birds. Neither the whole powder, nor the food grains mixed with the powder was eaten by the birds. Contrast to this Srivastava (1970) reported that for some years the Live Stock Department at Port Blair, used snails as poultry feed. The ducks reduced the snail population to a considerable degree in Andamans

(Srivastava, 1976). Srivastava (1976) observed ducks to feed on the eggs and young ones up to 30 mm shell size. In Andamans certain residents used to keep ducks to get rid of the giant snails (Srivastava *et al.* 1971).

Mammals : Rat—The bandicoot rat, *Bandicota indica* is an effective predator of *A. fulica* (Raut and Ghose, 1979a). In feeding, the snail, active or in aestivation, is turned upside down by the rat with its fore paws and holding the outer lip of the shell aperture with incisor teeth the prey is carried to a place near its burrow (Pl. XVI, fig. 2) or to an isolated site. The lower incisors are pushed inside the shell aperture while the upper ones are placed outside the body whorl of the snail and the shell is either pierced or broken and the flesh is drawn out. The pattern of damage to the shell is almost similar in snails of all age groups (Pl. XVI, fig. 3). In most cases the rat rejects the digestive gland and devours the rest. The rat usually prefers the snails with 50 to 80 mm shell size, though the older ones are also not spared. Contrast to *A. fulica* the shells of *Macrochlamys*, *Ariophanta*, *Cryptozona* and *Bensonia* are fragile. The rat breaks the shell easily and the flesh is eaten within a few seconds.

In our attempt to evaluate the role of bandicoot rats in biological control of snails, rats of known weight were kept in separate cages to estimate the daily consumption of snails. On an average in a 24 hours period a bandicoot of 800 g body weight consumed about 100 g of flesh for which 7 to 8 *Achatina* of 50 to 70 mm shell size were killed. Raut and Ghose (1979a) suggested that the bandicoot rat could be effectively used in the control of *Achatina* provided the population density of the predator does not cross a certain level and itself turns to a major pest.

Pig—Srivastava and coworkers (1971) reported that the pigs in Andamans feed on the giant snails, and the natives collect the snails in night to feed the pigs.

Diseases : The first report on the disease of *A. fulica* was that of Annandale (1919) from India. It simply stated the out-break of fatal epidemic in the snails. Srivastava (1966), Raut and Ghose (1977b) and Raut (1983b) reported a leucodermia-like disease in the giant snails from different parts of India. It first appears as leucodermic lesions on the tentacles (Pl. XVII, fig. 1), snout and foot (Pl. XVII, fig. 2). With the progress of the disease the tentacles gradually degenerate and tuberculated spots increase in all sites of infection. Feeding is suspended and the snails become sluggish. Usually the disease appears in the early monsoon each year and prevailed for about 6 weeks, and a gradual decline is followed. The rate of mortality was 28% in natural environment while in monsoon simulated environment it was about 50%. Raut and Ghose (1977b) opined that the high temperature, 25 to 34°C and high moisture, 90-96% are responsible for the out-break of the disease in epidemic form. Srivastava (1966) believes that the disease spreads through contact. Srivastava (1968) further reported that spraying of the aqueous extract of the diseased snail led to the spread of the disease.

Physical control :

Hand-picking : The large size and the brilliantly coloured shell make *Achatina* conspicuous. The snails are found in abundance and moving state especially in the evening and the morning. The snails are collected, thrown into pond or killed by damaging the shell. In daytime one can collect them from resting sites like boundary walls of the gardens, tree trunks and aestivating homes. The snails could be lured to trap made of rubbish, bricks or stones in suitable places for large collections. Snails should be collected daily from the traps and destroyed. It is claimed that following this method the population was controlled in Balasore in 1948-49 (Behura, 1955) and in Dimapur in 1977. Killing by drowning though recommended by some workers, is not an effective method since a healthy snail can withstand drowning for 36 hours. On the contrary, throwing snails in flowing water bodies has helped in rapid distribution of the snails to new areas.

Miscellaneous control measures :

Destruction of garbage and house refuse : *A. fulica* is largely a scavenger, and usually take shelter in garbage and refuse around houses. The destruction of garbage and house refuse might help in minimising the snail population.

Cleaning of the gardens : In villages and also in towns the boundary areas of the gardens are usually left uncared for and covered with thick growth of weeds and garden refuse. The snails hide there in daytime and also lay eggs under these covers. A clean garden by removing the refuse and weeds or burning those would reduce the hiding and egg laying sites of the snails.

Barriers : A small water canal about 59 cm in breadth and depth dug around nursery plots and orchards limits the entry of *Achatina* and other terrestrial snail pests. Gupta *et al* (1980) reported on the feasibility of the use of *A. fulica* as manure.

Discussion

The dispersal, distribution and survival of pestiferous snails viz. *Achatina fulica*, *Opeas gracile*, *Macrochlamys indica*, *Ariophanta solata* *Cryptozona semirugata*, *C. bistrialis* and *Bensonia monticola* are largely dependent on the ecological conditions of the areas concerned. Of the endemic species only *O. gracile* has succeeded in populating most of the States in the plains of India. *M. indica* is common in the States of eastern India and Tamil Nadu in the south. *A. solata* is restricted only to south-west India while *C. semirugata* is available in south and north-west of India. *B. monticola* is adapted for high altitude conditions and found only in the Himalayan ranges of India. The variation in population density from area to area is probably due to a number of factors—biotic and abiotic which is true for all animals.

Presumably the nature of soil does not influence snail population directly. It is the capability of holding water and thereby restricting temperature and humidity fluctuation to a great extent make the alluvial groups and black soils most suitable for the survival of the snails. The red soil is next in order. The laterite, gravelly and desert soils can not retain moisture and consequntly the temperature fluctuation is rather high and moisture percentage is low. Further, luxuriant growth of vegetations is encouraged in alluvial, black and mixed red soil for their water holding capacity and in turn, offers suitable humid environment to the snails. The density of snail population particularly of the giant African snail is higher in areas with alluvial soils and a gradual decline is recorded in black and mixed red soils. The looseness of alluvial soil makes digging of burrows easier for egg laying and aestivation. This ensures both rapid multiplication and low mortality. The hardness and capability of holding less amount of water make the red soils not much favourable for propagation and survival. Survival through the long aestivation period for about 8 months (Raut and Ghose, 1977a ; Raut, 1978a, b) is possible only in humid areas, since dehydration increases with the length of time, and the snails can not survive laterite and lateritic and gravelly soils.

The impact of factors like pH, N, Mg, K_2O and CaO on the distribution of land snails is insignificant. *A. fulica* can survive equally well in acid and alkaline soils with a varying percentage of N, K_2O, Mg and CaO, though a preference for soils with high percentage of calcium has been noted. In eastern virginia Burch (1955) recorded an increase in number of land snails with increase of calcium, magnesium, potassium and organic contents of the soil. Frömming (1956) noted no effect on the addition of trace metals to the soil. The grey field slug *Agriolimax agrestis* stands a wide range of pH (Carrick, 1942) while land snails are most abundant at pH 6.3 to 6.7 (Burch, 1955). Three green house snails flourished on acid soil with a range of pH 5.5 to 6.2 (Karlin, 1956). In Britain, Boycott (1934) listed 8 to 12 species as obligatory calciphiles, 11 more species as nearly so, and 45 species of land pulmonates indifferent to a calcareous substrate. One species *Zonitoides excavata*, is actually negative to limy soil, inhabiting acid heaths and wood. Bishop (1977) suggests that abundance of litter feeding animals may be related to the carbon to nitrogen ratio and the calcium content of the litter. Pilsbry and Bequaert (1927) reported a direct correlation between limy soil and abundance of *Achatina* in former Belgian Congo, while Oughton (1948) believes that the sole nutritional factor limiting the distribution of snails is the availability of calcium which were contradictory to that of Hagen (1952). The European snails fed with added calcium diet produced shells three to four times longer than the expected size (Oldham, 1929, 1934). Schmidt (1955) has experimentally shown that calcium carbonate is essential for the development of gastropod fauna. Lozek (1962) reported that in central Europe the distribution of terrestrial gastropod is closely correlated with the soil conditions. Calcium is a vital need for the growth of shell and also the formation of egg shell in addition to other nutritional and physiological requirements. It has been suggested that the snails make the soil calcium rich by different means. The empty shells are rasped by the living snails and a part of it finally reach the soil with excreta and get mixed with it absorbed by the plants as one of the important macro elements. Cleave (1953) went to the extreme to suggest that the presence of the snails is an indicator of available lime supply. The snails meet up their calcium demand from the plant food and sometimes by rasping the lip of their own shell immediately after awakening from aestivation. An analysis of the data available suggests that the role of soil governing the distribution of land snails particularly *Achatina* in the Indian subcontinent is subordinate to other factors.

Vegetation is possibly the most important factor for the distribution of animals since in addition to food supply it helps in maintaining a near constant range of temperature and humidity. Distribution of land snails in wild areas does not minimise the role of vegetation as suggested by some workers, rather it points to their adaptability by switching over to wild plant food. Boycott (1934) did not consider vegetation as an important limiting factor for land snails since it is usually available in excess and snails accept an array of different vegetable foods, which has recently been supported by Wolda *et al* (1971) for *Capaea* populations. We are not in agreement with them as this points to the flexibility of the snails in the selection of food plant rather than the role of vegetation.

The land snails, as a rule, turn to a pest only when their population crosses a certain level. With the increase in population they invade more vegetable gardens and orchards, and the risk of populating new areas becomes greater as the snails with the products are transported to far off places. Areas are still there in all the States of Indian Union not infested with snails and slugs. It is quite likely that with the increased agricultural production and quite transport facilities the land snails, particularly *Achatina* would soon populate new areas if adequate quarantine measures are not adopted, which might call for legislation.

The temperature is an important factor in the distribution of animals. In a number of land snails tolerance to temperature variation is great owing to their ability to undergo quick aestivation or hibernation ; but for a population build up the temperature range is rather narrow, 22 to 32°C. The giant snails survive in a temperature range 0°C to 45°C. This is also true for *O. gracile*, *M. indica*, *A. solata*, *C. semirugata* and *C. bistrialis*. *B. monticola*, on the other hand, possibly will not be able to populate the plains of Indian Union as they are adapted to low temperature prevailing in the mountain ranges. Recently, Raut (1983a) reported that *Achatina* population is reversely proportional with the altitude, and they were not recorded from above 1200 m in India. In an altitude beyon 1200 m the snails are immobilised and do not survive. This immobilization effect is supposed to be the result of persistent low temperature, atmospheric pressure and oxygen tension. Chock and Nakao (1951) studied the effect of temperature tolerance in *A. fulica*. They stated that 19 out of 20 dormant snails, exposed to 40°F for 24 hours, were alive after 5 days ; 70 out of 10 active snails, exposed to 30°F for 8 hours, were also alive after 5 days, and one out of 10 dormant snails, exposed to 20°F for 8 hours, were alive after 5 days. Information on the influence of temperature on the natural population of *A. fulica* is very limited. Mead (1961) reported that the giant snails successfully weathered winter temperature as low as 45°F in Florida. He holds that this snail probably may not permanently establish itself in regions where there frequently occurs sudden lowering of temperature below 45°F. In this context, it is most likely that *A. fulica* may not be able to establish itself in the hilly areas of eastern and nothern part of India above 1500 m, as sudden lowering of temperature is common in those regions.

In plains of India, the night temperature in winter is around 12°C while at 850 m and 1166 m altitudes it is 4 to 6°C. Low temperatures inhibit normal activities and a continuous exposure to it is fatal to the snails. This explains the decline in the population density of *A. fulica* with the altitude gain and lowering of temperature. Their survival in such altitude has been possible owing to their burrowing habit and living under layer of soil at night. The idea is supported by the presence of *Achatina* in Nongpoh and other areas (Raut, 1983a), and from the deaths of snails at an altitude of 1219.2 m in

Ceylon (Green, 1910b), and failure to reproduce at an altitude of 2211.6 m at Musuri in India (Benson, 1858). They are confined to 609.6 m and 913.6 m in Mauritius and Java respectively (Mead, 1961). If *A. fulica* ever succeeds in adjusting its physiological activity at low temperatures as in *A. machachensis*, occurring in the mountains of Basutoland at an altitude of 1700 m, it would pose a greater threat to our agriculture.

Humidity is the prime need for terrestrial animals and it is chiefly regulated by rainfall, temperature and velocity of wind. From the collected data it has been observed that there is a great fluctuation in rainfall from area to area which has got a tremendous impact on the moisture content of the soil and atmospheric humidity. It appears that the annual rainfall above 1400 mm usually encourages snail population. And the populations of *A. fulica* and *M. indica* are at an increasing rate with the increase of rainfall. Interestingly, in spite of sufficient amount of rainfall, snail population is appreciably low in some infested pockets which may be explained by analysing the amount of rainfall in different seasons of the year. It shows that the snail population is governed not by the amount of rainfall but by the number of rainy days throughout the year. The summer and winter rainfall are important of all the factors which are held responsible in maintaining the population level. This explains why the giant snail populations are higher in Andamans and also in Palghat and Calicut of Kerala, Tambaram of Madras, Moradabad of Uttar Pradesh, districts of nothern West Bengal and Gauhati of Assam. Populations of other pest species except *B. monticola* are similarly influenced by the same factor. Rain throughout the year not only helps in keeping a favourable soil moisture and humid environment but also stimulates the growth of vegetation which serves as food and shelter of land snails. However, according to Bhattacharjee (1980) temperature and rainfall have no direct effect on the contagious distribution pattern formation in *A. fulica* whereas the atmospheric humidity showed strong influence in Gauhati.

There are areas where factors are quite favourable to encourage snail population but the snails are not there. This is presumably due to the fact that the snails have not been introduced there and necessary steps should be taken to prevent that. Since the natural enemies have no significant impact on population size (Raut and Ghose, 1977b, 1979a, b ; Raut, 1980, 1983b) it appears that it is chiefly dependent on the environmental factors, particularly the nature of monsoon and also rainfall in other seasons of the year. A long dry spell without any interruption by occasional rains is possibly the strongest selective agent and is responsible for mortality of many individuals. Rains in this period somewhat smoothens the rigour of the factor and the mortality rate is lower in such years. The data on rainfall in some districts of Bihar, Orissa, West Bengal and Assam reveal that the dry spell unbroken by rains occur once or twice in a span of five years. Aestivation, the adaptation to conserve moisture is not sufficient to prevent dehydration in such years which results in the death of the majority, though it is really not mass mortality. These findings support the contention "the longer the dry spell the higher the mortality rate" (Raut and Ghose, 1979d).

The first pre-courtship behaviour is the enlargement of the genital opening, which becomes very conspicuous in both *A. fulica* and *M. indica.* Such a behaviour has been reported from *Helix* (Herzberg and Herzberg, 1962) and *Ariophanta* (Dasen, 1933). In *A. fulica* search for its mate starts with a partly protruding penis since the amatorial organ is absent, while in *M. indica* the amatorial organ is protruded, and the penis remains in its usual state. Similar observations on species with amatorial organ, viz. *Ariophanta* (Dasen, 1933) and *M. pudina* (Rensch, 1955) are on record. In both the species, *A. fulica* and *M. indica,* one of the partners is 'active' while the another is 'passive' As a rule there is a preference for a partner of near equal age and shell size though deviation from this is not wanting.

Workers (Tryon, 1882 ; Meisenheimer, 1907, 1912 ; Dasen, 1933 ; Webb, 1950, 1951a, b, 1952, 1968a, b, c, d ; Herzberg and Herzberg, 1962) are unanimous that preliminary maneuvering, following the selection of partner, is associated with active crawling around each other for a considerable period. The period lasts for 30 to 60 minutes in *Ariophanta ligulata* (Dasen, 1933), 20 to 45 minutes in *Helix aspersa* (Herzberg and Herzberg, 1962), hours together in *Mesodon sargentianus* (Webb, 1968a) and *Anguispira alternata* (Webb, 1968b) and 30 minutes to two hours and 30 minutes in the slug, *Limax maximus* (Férussac and Deshayes, 1819 ; Adams, 1898 ; Chace, 1952). The average maneuvering period was 10 to 20 minutes in *A. fulica* and 30 to 45 minutes in *M. indica.* The variations in maneuvering period is possibly associated with the physical features and the physiological state of the reproductive organs and gametes.

Preliminary maneuvering is followed by fondle and caress in *H. pomatia* (Meisenheimer, 1907, 1912), *Ariophanta ligulata* (Dasen, 1933), *H. aspersa* (Herzberg and Herzberg, 1962) and *O. gracile* (Biswas et al., 1976). Similar observations were made both in *A. fulica* and *M. indica.* During caress a watery fluid, chiefly secreted from the prostate glands is discharged through the genital pores for lubrication, which has also been reported from *Helix* (Meisenheimer, 1907, 1912).

Maneuvering behaviour in naked pulmonates is more elaborate. When two sexually ripe *Arion empiricorum* meet, they start trailing each other in circles, each licking the caudal gland of the other (Künkel, 1900). Members of the family Limacidae resemble *Arion* in this respect (Gerhardt, 1933, 1934). In *A. fulica* and *M. indica* the trailing behaviour is different as the snails crawl parallel to each other and lick the gential apertures. Such a behaviour has not been reported from other stylommatophores though some sort of trailing is associated with the maneuvering behaviour in all land pulmonates.

Sudden pricking by the amatorial organ is common in the snails having such an organ, viz. *Ariophanta* (Dasen, 1933) and *M. pudina* (Rensch, 1955) presumably to excite the partner. *M. indica* behaves in the similar way. In *A. fulica*, where the amatorial organ is lacking, the pricking is done with the penis for the same purpose. No such behaviour in other land snail is on record. It is reasonable to believe that the behavioural orientation in different species of Pulmonata is mostly related with their morphology and the degree of preparation for mating.

Copulation in Stylommatophora is mostly reciprocal (Herzberg and Herzberg, 1962 ; Fretter and Peake, 1975). The time required varies from species to species, 30 minutes to one hour in *Ariophanta ligulata* (Dasen, 1933) 2 to 3 hours in *Helix pomatia* (Meisenheimer, 1907, 1912), 4 to 10.5 hours with an average 6.25 hours (Herzberg and Herzberg, 1962) and 4 to 12 hours (Basinger, 1931) in *H. aspersa*.

Different lengths of mating period have been reported from *A. fulica* by different authors. It was 1 to 1.5 hour (Mohr, 1949b) and 6 to 8 hours (Weel, 1948c). Variation in the duration of copula was 6 hours to 8 hours and 30 minutes and we are in agreement with the findings of Weel (1948c). The copulation period for *M. indica* was 24 to 39 minutes with an average 29.4 minutes. Information on the duration of mating in *M. pudina*, *A. ligulata* and other closely related species would have been interesting to analyse possible correlation of breeding in stylommatophores. The variations in the duration of copulation in different species of land snails may be due to the combination of different factors, viz. the length of the sulcus and vas deferens, muscular activity and also some unknown factors.

Workers are not unanimous on self-or cross-fertilization in land molluscs. Larambergue (1939) presented a thorough account of self-fertilization in which he cited twenty one proven cases of development without copulation in stylommatophores. Most of these are slugs, belonging to the families Arionidae (6 species), Limacidae (8 species), Philomycidae (1 species) and Testacellidae (1 species). The other five species belong to the families Helicidae, Zonitidae and Vitrinidae. Recently, Patterson (1970) reported self-fertilization among the members, comprising five genera of the family Succineidae. On the other hand, it has been pointed out that self-fertilization does not occur in Helices, *Agriolimax reticulatus*, *Capaea hortensis* and *C. nemoralis* (Fretter and Graham, 1964), *Succinea putris* (Rigby, 1965), *Ariophanta solata* (Krishnamoorthy and Viswanathan, 1972) and *Limicolaria* *martensiana* (Owiny, 1974). Opinions differ on the mode of fertilization in *A. fulica*. Weel (1948c), Kekauoha (1966) and Breckenridge and Fallil (1973) hold that mating is essential for reproduction in *A. fulica* while Mobr (1949b) and Ghose (1959) reported self-fertilization a common feature in the species. Later, Mohr revised his opinion as virgin specimens kept in isolation for two years (cited in Mead, 1961) failed to lay eggs. Biswas *et al.* (1976) reported the possibility of both self- and cross-fertilization in *O. gracile*.

Present investigations rule out differences of opinion and confirm that mating is essential for reproduction in *A. fulica* and *M. indica* as the snails failed to lay eggs for a period of 21 months, kept in isolation since hatching, and laying of eggs followed mating in all cases. Mating is a must for ovulation in *A. fulica* and *M. indica* and possibly this is true for most stylommatophores.

Self-fertilization is a physiological adaptation for perpetuation of species living in adverse conditions. Large number of molluscs living in different habitat are hermaphrodite and the possibility of self-fertilization in some of them can not be ruled out. So far anatomy of those snails is concerned, there is no barrier to the union of male and female gametes in any of the hermaphrodite molluscs. This, however, can be prevented in a number of ways but autosterility seems to be prevalent in the molluscs. Autosterility has been reported in *Helix aspersa*, *H. arbustorum*, *H. pomatia*, *H. vindobonensis*, *Capaea hortensis*, *C. nemoralis* and *Agriolimax reticulatus* (Fretter and Graham, 1964). It may be presumed that the spermatozoa in the ovotestis duct (seminal vesicle) and carrefour are incapable of fertilizing the ova of the same individual passing through them. In opisthobranchs, the sperms produced in the ovotestis are stored in the ampulla (really a seminal vesicle) and remain inactive ; therefore they can not fertilize the animal's own eggs, which must pass through the ampulla during spawning (Hyman, 1967). Similar views are held by other authors as well. In *Aplysia* sperms in the seminal vesicle (autosperms) are generally non-motile and inactive while the sperms in the seminal receptacle (allosperms) are vigorously active. Açcording to these workers, the sperm activation, and the attainment of fertilizing power occur only after spermatozoa are exchanged at copulation. It is this phenomenon which prevents self-fertilization (Thompson and Bebbington, 1969). In *Succinea putris*, a terrestrial opisthobranch, ova and sperm pass down the hermaphrodite duct together, but it is believed that fertilization does not occur here (Rigby, 1965). It might be possible that a phenomenon analogous to the capaciation of mammalian sperm occurs in some hermaphrodite molluscs.

Controversy exists over the functions of spermatheca in *A. fulica*. Mead (1950a) suggests that the substance in the spermatheca of *A. fulica* is probably nutritive and that "it sustains the life and viability of the otherwise short-lived spermatozoa," while Ghose (1960) states that the spermatheca has no function. Breckenridge and Fallil (1973) believe it "(a) as the site where sperms are received in copulation and temporarily stored before they moved to the receptaculum seminis, (b) as the site where excess sperms and ova broken down through enzymatic degradation, and (c) a combination of (a) and (b)". The presence of the mucoid mass with the spermatozoa in the spermathecal duct close to the apical vagina immediately after mating and the complete absence of sperms in the spermatheca after 24-hours strongly suggest the storage function of the organ. The mucoid mass with the spermatozoa slowly moves to the spermathecal sac and the movement of the sperms in the spacious fluid filled sac becomes vigorous which causes release of the embedded portion of the tail from the mucoid mass and the sperms are set free. The mucoid mass is abandoned and the sperms start moving to the carrefour, the site of fertilization, through the oviduct and uterus. This adaptation not only facilitates the release and movement of the sperms but also keeps the basal oviduct free from being blocked by the abandoned mass which has been considered to be a collection of dead sperms, ova, mucoid mass (semen) and stray gametes. The abandoned pinkish mass in the spermathecal sac of *Achatina* is similar to that reported by Mead (1950a) and Breckenridge and Fallil (1973), and in *Physa fontanalis* (Duncan, 1958), *Bursatella leachi* (Bebbington, 1969) and *Aplysia* sp. (Thompson and Bebbington, 1969).

Sperms received in copulation are stored in the female genital organ till fertilization of the ova. The viability of the sperms varies with the species and also with the environmental factors. The viable period of sperms is 520 days in the equatorial land snail, *Limicolaria martensiana* (Owiny, 1974), 1460 days in *Helix aspersa* (Taylor, 1900) and 382 days in *A. fulica* (Mohr, 1949b). From the present studies it may be concluded that in *A. fulica* and *M. indica* the stored sperms remain viable for a period of at least 341 and 476 days, which has been confirmed from the production of broods since first mating and also from the presence of viable sperms in the talon and spermatheca of *A. fulica* and *M. indica* respectively.

Information on the period of viability of sperms in aestivating snails is almost absent. The lone report is that of Rees (1951) that *A. fulica* can lay viable eggs even after months of aestivation. Studies on the aestivating *A. fulica* and *M. indica* lend support to the contention of Rees, as *A. fulica* laid viable eggs after 105 days of aestivation while the period was still longer i. e., 150 days in *M. indica*. The gradual decline in the number of eggs laid by the specimens in their natural state of functioning and also by those subjected to aestivation is presumably due to the inability of the individuals to produce ova at equal tempo, rather than the shortage of viable sperms. The ability of the land snails to retain sperms received in mating, viable for a pretty long period and laying fertilized eggs at a much later date enable even a single introduced specimen to establish a colony in an uninhabited area (Raut and Ghose, 1982).

The age of attainment of sexual maturity in pestiferous snails varies with the species and the climate of the country. *A. fulica* requires about one year (Rees, 1950 ; Ghose, 1959), 8 months (Garnadi, 1951), 7 to 8 months (Weel, 1948c), 5 to 8 months (Dun and Longford, cited in Mead, 1961) and 5.5 months (Lange, 1950). Earlier, Leefmans (1933c) reported that with an abundant supply of $CaCO_3$ the first eggs were laid by 6 months, and without it the required period was 9 months. The shell length at which *A. fulica* laid eggs was 60.0 mm (Mohr, 1949b) and 59.0 mm (Ghose, 1959). *Helix* were became sexually mature within 6 months (Webb, 1942) ; *Polygyra septemvolva* required 144 days (Webb, 1950) and it was 13 weeks for *Opeas gracile* (Biswas *et al.*, 1976). In India, *A. fulica* are sexually mature by 5.5 months when kept active by artificial means. Most of the workers from other countries are of the opinion that *A. fulica* required 5.5 to 9 months for sexual maturity. Under monsoon simulated environment Ghose (1959) recorded sexual maturity in *A. fulica* with 59.0 mm. shell length in Calcutta. In the natural environment the smallest snails pairing for the first time were of 56 mm shell length. The small variation in age at which sexual maturity is reached is possibly the result of environmental factors varying from place to place. *M. indica* becomes sexually mature by 130 days. Knowledge on attainment of sexual maturity in closely related species would have been of significance in the population studies of land snails.

Of the many factors influencing breeding in land snails in temperate and tropical countries, rainfall, humidity and temperature presumably play most important role. Authors are unanimous on this point but detailed observations are lacking in most cases. In the tropics seasonal rainfall and variation in relative humidity are important proximate factors (Baker, 1938 ; Lack, 1954 ; Owen, 1966). In the plains of India the rainy season usually extends from July to September, though occasional showers are common in summer and winter. In most cases the off season rain in the Indian States is not sufficient to establish a desired humidity level for the required length of time, which is necessary for reproduction of the land snails, consequently breeding in land molluscs is restricted chiefly to the rainy season. The snails showed a discontinuous distribution, and naturally variation in the amount of rainfall in a particular season in an area alters the immediate environment, which in turn influences breeding of the species concerned. Seasonal rainfall influences breeding in *Gyliotrachela depressispira* (Berry, 1963), *Opisthostoma retrovertens*

(Berry, 1964) and *Hydrocena monterosatiana* (Berry, 1965), while reproductive activity is closely associated with rainfall in any season of the year in *Polymita muscarum* (Diaz-Piferrer, 1964). *A. fulica, O. gracile, M. indica* and other Indian land snails are seasonal breeders but the potential for breeding throughout the year except winter is present in them. This has been substantiated by collecting viable broods, even in summer when the temperature ranges from 32 to 43.5°C, from snails maintained in monsoon simulated environment. This signifies the importance of humidity which is dependent on rainfall. The role of temperature on breeding in land snails is significant as no brood was obtained even from specimens maintained in optimum favourable conditions in winter except the temperature.

Some sort of nest preparation, a device to protect the eggs from enemy and prevent desiccation is prevalent in the majority of the terrestrial gastropods. They lay eggs at night in humid places such as depressions in soil, crevices in logs, under fallen logs, beneath loose bark, and below the layers of fallen leaves on the forest floor (Hyman, 1967). Kunkel (1910) reported that *Campylaea cingulata* generally deposit its eggs in mosses. Curious breeding habits in some land snails are also on record. *Cochlostyla leucophthlma*, a tree living snail deposits egg in leaves rolled up into a cornucopia, stuck together with mucus and lined with mucous (Sarasin and Sarasin, 1899). The Java land snails, *Amphidromus purus* and *Nanina javana* build nests for their eggs by plastering leaves together (Paravicini, 1921). *Pomatias elegans*, a land prosobranch deposits the eggs singly beneath the soil particles (Creek, 1951). Gugler (1963) gives a detailed account on the eggs and egg-laying habit of some Midwestern land snails from Nebraska. The snails deposit their eggs either inside the loose soil or beneath the debris. *Helix pomatia* (Meisenheimer, 1912), *H. aspersa* (Herzberg and Herzberg, 1962) and *Ariophanta ligulata* (Dasen, 1933) dig a hole 1 to 3 cm deep pushing the soil out with the foot, while *Limicolaria martensiana* lays eggs either in a 'nest' dug in the ground, or under dead vegetations. *A. fulica* dig a whole before egg laying (Weel, 1948c ; Rees, 1950 ; Ghose, 1959) or deposit eggs in crevices, under stones and decaying vegetation (Rees, 1950). The observations on *A. fulica* and *M. indica* and other land snails are almost similar to those reported by previous workers on these and other land snails.

The number of broods produced by a land snail in a year depends on the length of damp, humid environment. In Pacific islands *Achatina* breeds for seven months or more (Kekauoha, 1966 ; Mohr, 1949b). In plains of India the single monsoon lasts for about four months—July to October, and one *A. fulica* lays 2 to 3 broods. But the number is high in the south Indian States and Andaman islands where the rains cnntinue as long as 6 to 8 months.

The gestation period in *A. fulica* is 20 days, an observation similar to that of Kekauoha (1966). The gestation period or the time required for the development of fertilized egg is 16 to 17 days. The snails hatched out from the egg in the second day of laying and it continued for 16 to 17 days. It is reasonable to conclude that the first egg was fertilized about 4 to 5 days after mating and fertilization continued for a little more than a fortnight. The period of retention of fertilized eggs in the uterus is also variable as in some broods hatching started on the 11th day since laying of eggs. In *Achatina*, the production of a second brood, following one mating, on 22nd day after the laying of the first brood suggests that an interval of atleast 6 to 7 days is essential for the release a second batch of ova. The gestation period in *M. indica* is about 10 days and the development does not proceed beyond 4-cell stage at the time of laying. The interval between the successive ovulation is about 2 to7 days as the second brood is laid after 12 days of the first one. It may be suggested that *A. fulica* has progressed considerably towards ovo-viviparity, while no such adaption is present in *M. indica*.

Information on the metabolic changes leading to dormancy (aestivation and hibernation) and also during dormancy in land snails is totally wanting. We only know of the abiotic agents, viz. humidity and temperature, forcing dormancy, and the loss of body weight due to dehydration and use up of stored materials and showing down of the activities of all the organ-systems except that of the reproductive system.

Of the two powerful agents, temperature and humidity the second one seems to be more significant. *Achatina fulica* and *Macrochlamys indica* exposed to environmental hazards aestivate in the humidity range lower than mean maximum 86% and mean minimum 44% and the temperature range 15°C-30°C, a situation prevalent in November in West Bengal. The snails are active, though the rate is somewhat less at temperatures as low as 9°C and as high as 43°C in a high humid condition.

Denial of food supply caused aestivation in snails kept in most favourable environment after a certain period. A relationship exists between weight loss and aestivation and our observations lend support to those of Howes and Wells (1934a, b) in *Helix pomatia* and *Arion ater*.

Contrary to our findings in *A. fulica* and *M. indica* Kunkel (1916) failed to prevent hiberation in *Helix pomatia* with warm temperature, adequate humidity and sufficient food supply. Blinn (1963) could not activate hibernating *Allogona profunda* in winter by creating a favourable environment but hibernating snails activated in summer continued activity in artificial condition. This led him to conclude that a preparation for hibernation is a necessity and the biological clock is genetically fixed.

In West Bengal aestivation could be prevented in both the species under investigation ; the aestivating snails could be awakened and kept active of any period of the year with the creation a favourable environment. This points that no physiological preparation is required for going to dormancy in snails in temperate and tropical countries, a situation somewhat confusing. Our preference for the terminology 'aestivation', for the dormant state in land snails in tropical and temperate countries, signifies that it is simply an adaptation without any physiological preparation to tide over unfavourable conditions.

Land snails have been reported to aestivate in a variety of sites, from a few inches below the soil to a height of 400 cm on trees, in moist and shady places and under cover where sunlight doe not reach. Majority of them, however , prefer the sites close to the soil and under some sort of covering. Aestivation on the tree trunks at different heights in an exposed state has been reported from *Achatina albopicta*, *A. fulica hamillee* (Williams, 1951), *Ariophanta* (Hora, 1928), *Indosuccinea semiserica* (Rao, 1925) *Helicella virgata*, *H. neglecta*, *Theba pisana* and *Cochlicella acuta* (Pomeroy, 1968). A large number of species of snails, viz., *A, fulica* (Bequaert, 1919 ; Mead, 1961) *Theba pisana* (Basinger, 1927 ; Pelseneer. 1935 ; Pomeroy, 1968). *Sphincterochila hierochuntica* (Mendelssohn, 1963) and *Allogona profounda* (Blinn, 1963) aestivating on surface in an exposed state are on record. Majority of the aestivating snails are however, found under some sort of protection. Aestivating *A. fulica* (Mead, 1961), *A. albopicta*, *A. fulica hamillee* (Williams, 1951), *Macrochlamys glauca*, *Pupisoma evezardi*, *Succinea arboricola*, *Buliminus* (*Subzebrinus*) *dextrosinister* (Hora, 1928) and *Succinea elegans* (Hadden, 1917) have been recorded from under rocks, deep in hollow trees, in rotten logs, in the crotches of trees, under plant debris and man made litters. They have collected from—*A. fulica* 4-5 inches below the ground (Mead, 1961), *A. rougosa* 4 inches below the dry soil (Bequaert, 1919 ; Lang, 1919), *A. albopicta*, *A. fulica hamillee* half buried in the soil, litter and debris (Williams, 1951) and *Mesodon thyroidus* partly buried in the soil (Blinn, 1963).

The snails capable of secreting an attachment epiphragm have their own way in the selection of aestivating sites, irrespective of the locality. *Helicella virgata* (Pomeroy, 1968), *Ariophanta*, *P. evezárdi*, *S. arboricola*, *B.* (*Subzebrinus*) *dextrosinister* and *Indosuccinea* (Hora, 1928) aestivate on the lateral or lower surfaces of stone or other hard substrate either close to or above the ground. *A. albopicta* (Williams, 1951) is the only species belonging to the family Achatinidae having a tube epiphragm. Other members of the family however, though less in number aestivate on trees or posts high above the ground even though they are incapable of secreting an attachment epiphragm.

A resume of the aestivating sites in land snails in different countries having different geographical and climatic conditions indicates that the major factors guiding the selection of site for aestivation in land snails are moisture and security which includes to escape the sight of the predators. This is possibly true for all land snails throughout the world.

Aestivation reported from aberrant sites by some workers is not of any significance. For some reasons the snails failed to the reach the preferred sites and underwent aestivation there.

An attempt has been made by Pomeroy (1968) to correlate the selection of aestivating sites with the origin of the snail from his studies on introduced helicids in South Australia and in Europe, their native place. This suggests that the aestivating behaviour in helicids at the time of their origin still predominate over ecological condition where the snails are found at present. Our observations on *A. fulica* and *M. indica* and those of many other land snails are not in agreement with his conclusion.

The aestivating period in stylomatophores differs with the species and the climate of the country where they live. The period ranges from 2 to 10 months in *A. fulica* presumably depending on the duration of dry spell (Green, 1910a, b, c, d ; Hutson, 1920 ; South, 1926 ; Corbett and Pagden, 1941 ; Lange, 1950 ; Mead, 1950b, c ; Ghose, 1959 ; Kondo, 1964 ; Butler, 1966). *Archachatina degneri* usually aestivate for a period of 6 months (Mead, 1950a) in Africa.

Helicella virgata aestivate for about 5 months (Pomeroy, 1968) while the same species was kept alive for one year in dormant state (Taylor, 1894-1921 ; Pelseneer, 1935). Dormancy in *Opeas gracile* is 7 months (Rahman *et al.*, 1975). It is only 2 months, presumably the shortest one, in *M. glauca* (Hora, 1928).

Some interesting reports on abnormally long aestivation are on record ; 23 years (*Oxystyla capax* ; Baker, 1934), 4-6 years (*Helix desertorum* and *Xerarionta veatchii* ; Stearns, 1868 ; Kew, 1893), more than 4 years (*H. desertorum* ; Baird, 1850 and *Otala lactea* ; Gaskoin, 1850), 2 years (*Bulimulus pallidior* ; Stearns, 1877) and one year (helicine species ; Hartely, 1898 ; Lockwood, 1880 ; Sivers, 1872 ; Ward, 1879). However, the scientific value of these reports have been seriously questioned.

Our observations on the duration of aestivation in *A. fulica* and *M. indica* in different years with varying amount of rainfall indicate that the majority of the snails are able to withstand the rigours of unfavourable conditions through aestivation, which continues for about eight months in West Bengal. These are in complete agreement with those of Ghose (1959) on *A. fulica* and *M. indica* in Calcutta. The longest period of survival for *A. fulica* and

M. indica with uninterrupted aestivation under experimental conditions was 13 and 11 months respectively. They resumed normal activities following awakening.

The observation of a large number of workers and also those of ours make us to believe that the ecological factors control the duration of aestivation in stylommatophores in temperate and tropical countries, and the majority of the snails are endowed with the wonderful capability to survive the hazards of summer and winter. This coupled with a high rate of reproduction have enabled them to invade new territories and thrive successfully within rather a short period.

The structure of epiphragm and its formation, and behaviour during the formation of epiphragm have been described in a number of species— *Achatina immaculata* (Smith, (1899), *Thaumastus sangoae* and *T bitaeniatus* (Smith, 1904), *Macrochlamys glauca* (Rao, 1927), *Glessula hastula* and *Zootecus insularis* (Hora, 1928). The attachment epiphragm, however, has not been described by previous investigators.

Authors are unanimous that both the mantle and the foot take part in epiphragm formation. *M. indica* is unique in their attachment epiphragm formation. Rhythmic contraction and relaxation of the muscles in the mantle collar drives the mucus from the site of secretion to the support covering a distance of about 5.0 mm. Information on the formation of attachment epiphragm, if any, in allied species would have been much interest and an investigation in this direction may through much light on the behaviour during the process.

Epiphragms are formed almost in the same way in *A. fulica* and *M. indica*, with the only difference that a small exposed portion of the foot in the former occupying the central portion of the shell aperture being surrounded by the mantle collar plays an important role in it. It is most likely that epiphragm is formed in the same way in all known cases.

A series of epiphragms have been recorded in *G. hastula* and *Z. insularis* (Hora, 1928), *Succinea arboricola* (Hora, 1925), and *Helix pomatia* (Flössner, 1915). The number of epiphragms in *H. pomatia* was as many as 7 in one individual but 33 had 3, 27 had 4, 20 had 5 and 3 had 6 each (Flössner, 1915). Hora (1928) did not mention the number of epiphragms in *Z. insularis*. Rao (1927) observed the formamation of a series of epiphragm by *M. glauca* kept in the laboratory while Hora (1928) reported only one in the field specimens. The controversy over the formation of one epiphragm (Hora, 1928) and a series of epiphragms (Rao, 1927) in *M. glauca* was possibly the result of different lengths of aestivating periods in different years and the aestivation might also have been interrupted by rain in natural condition. The one epiphragm condition was recorded by Hora (1928) in snails aestivating for only two months in North India. No report is available on the rainfall during the period of observation. On the other hand, Rao (1927) might have kept his specimens in the laboratory, for a longer period which leads to the formation of a series of epiphragms.

Our observations on *M. indica* were somewhat different from those of previous workers in the allied species. In 1475 specimens studied in the year 1974-75 only 14 individuals secreted 3 epiphragms each in addition to the attachment epiphragm, 1165 had 2 and the rest had only one. In 1975-76, with a longer rainless period in the same number of specimens the corresponding figures were significantly higher. It is quite reasonable to believe that the formation of a series of epiphragm is much dependent on the climate of the period concerned. The long dry spell in 1975-76 and the consequent higher rate of evaporation than that in 1974-75 caused greater reduction in the volume of the visceral mass, which retracted more inside the shell cavity and the succeeding epiphragms were formed. The findings clearly suggest that the number of epiphragms formed is dependent on the length of the dry period and a series of epiphragm secretion is a better mode of protection against desiccation than only one.

In *Achatina*, the number of epiphragms formed in nature varied from 6 to 12 in an individual. In the species the old epiphragm is thrown out prior to the secretion of a new one and the number was ascertained from rejected epiphragms, a method in which a certain degree of error is inherent as some of the epiphragms might be destroyed or carried away by other animals.

Decrease in volume of the body is greater with the progress of aestivation, and the snail recedes in the shell cavity more and more. The epiphragm is always in contact with the body and this creates a need for a fresh epiphragm at certain intervals.

Both *A. fulica* and *M. indica* awakened at certain intervals with water spraying, secreted greater number of epiphragm than those unattended. The awakened specimens supplied with food for 48 hours and sprayed with water produced still greater number of epiphragms. This clearly indicates that occasional availability of water and food in the normal aestivating period increase epiphragm secretion potentiality.

The epiphragm chambers contain air saturated with moisture and probably act as some sort of insulation against desiccation (Warburg, 1965). Our observations on *M. indica* are in complete agreement with Warburg (1965).

A slit like opening on the epiphragm corresponding to the pneumostome has been reported from *A. fulica* (Mead, 1961), *A. immaculata* (Smith, 1899), *Rumina decollata* (Rees, 1964), *G. hastula* and *Z. insularis* (Hora, 1928).

Minute perforations are present on the epiphragm in *T sangoae* and *T bitaeniatus* (Smith, 1904) while these are lacking in *M. glauca* (Hora, 1928). Contradictory observations have been recorded from *Helix aspersa.* Allman (1894-95) reported the presence of a perforation on the epiphragm immediately over the site of the respiratory orifice, while Smith (1899) examining a hundred specimens could not record such perforation, an observation supported by Hora (1928).

Macro pores are absent in the epiphragm of *M. indica* but numerous micropores present permit the flow of air, though to a limited extent. Death in epiphragm sealed animals is a common phenomenon.

The total amount of rainfall and the length of dry spell between successive rains greatly influence the temperature and humidity which is correlated with the mortality rate in aestivating specimens of both the species. Majority of the *Achatina* and only a few *Macrochlamys* awaken and start feeding in the normal aestivating period in a cloudy weather accompained by rainfall continuing for a few days, and the rainfall exceeding about 50.0 mm. Awakening of all snails of both the species is induced by the persistence of a cloudy weather for a few more days and a higher amount of rainfall. Such a situation not only reduces desiccation but helps the snails to regain body water and the mortality rate becomes lower as was evidenced in 1974-75 while a less amount of rainfall and higher temperature in 1975-76 were responsible for higher mortality in that year.

Hundred per cent mortality in 10-15 days age group in both the species and a gradual decline in the per cent of mortality with age suggest that adverse environmental conditions during aestivation are stronger selective agents against the snails of lower age groups than on those of higher age groups. And again the level of tolerance is much less in *M. indica* than that in *A. fulica* of the same age group.

Humidity, 40% or below is critical for survival of aestivating snails. It is supported by the fact that the low grade humidity viz. 7.2 hours per day during aestivating period in 1975-76, which was 3.2 hours longer than that in 1974-75 accelerated the rate of mortality in the year 1974-75.

The per cent of moisture in the atmosphere in November to March period in 1975-76 was much less than that in the corresponding period of 1974-75 owing to a total lack of rainfall during the period in that year. This caused a little higher rate of mortality in March 1976 than in 1975. On the other hand the high mortality fugure in March of both the years is the result of a continuous exposure to adverse conditions to which the snails were subjected since aestivation.

The adverse effect of still higher temperature in April and subsequent months of aestivation was largely compensated by higher per cent of humidity owing to occasional showers which helped the snails to regain activity for some period and consume the maximum amount of food available. This explains the sudden fall in the mortality rate in both the species in April and subsequent months.

Higher mortality have been recorded in hibernating *Allogona ptychophora* exposed to a lower temperature (Carney, 1966) around 0°C. The snails are not likely to meet with such a situation in temperate and tropical countries and no information is available on this point. Marked population fluctuation in *Fossaria modicella* (Cleave, 1935) in a particular locality was associated with the amount of rainfall, and moisture in the air, an observation similar to the present findings on *A. fulica* and *M. indica.*

Both in *A. fulica* and *M. indica* the mortality rate was fairly high at a temperature above 36°C in day time, and mean minimum humidity 40 persisting for more than 7 hours and mean maximum 85 for 8 hours or less in a 24 hours day, persisting for a few days, a situation which is likely to be met within most of the tropical and temperate regions. These factors keep population explotion in *Achatina* in a check in Indian Union except for several pockets, and Andaman and Car Nicobar Islands where conditions are favourable for survival and multiplication of the giant and other land snails for a greater part of the year.

Studies on the growth rate in gastropod molluscs are mostly restricted to aquatic forms, and information on the same in land snails is somewhat limited and restricted to *Arion circumscriptus* (Frömming, 1954) and *Achatina fulica* (Mohr, 1949 ; Lange, 1950 ; Ghose, 1963 ; Kondo, 1964 ; Kekauoha, 1966) and *Helix aspersa* (Herzberg and Herzberg, 1960). The solitary investigation in India on the growth of the lone pestiferous snail *A. fulica* is that of Ghose (1963). Masurekar and Bangalkote (1976) recorded growth rate in *Ariophanta maderaspatna.* Slow growth after the attainment of sexual maturity and a little or no growth during cooler months of the year as reported by previous workers are supported by the present investigation.

Faster growth rate in the second fortnight of post-aestivating period after emergence from a long aestivation is rather interesting. Rahman (1975) reported that endomitosis produces various types of nuclei due to high number of divisions and during aestivation it occurs at a faster rate in *A. fulica* than that in the normal active period (Rahman, personal communication). It has been reported that endomitosis results through a process in which chromosomes undergo a normal process of duplication, condensation and reassemble into an interphase nucleus ; the sister chromosomes separate visibly but do not move to distant poles, the nucleus increases in volume, and no cytokinesis take place (Mazia, 1961 and De Robertis *et al*, 1965). Rahman (personal communication) recorded similar phenomena in *A. fulica* and *Opeas gracile*.

It may be presumed that endomitosis during aestivation results in cell division at a faster rate after the emergence from dormancy and the production of a large number of cells is manifested in a faster growth in the second fortnight in *A. fulica* and *M. indica*, a condition which is expected to occur in all snails undergoing dormancy for a long period.

Observations on food and feeding habits in land snails have been made by a number of workers in different countries where the snails are present in considerable number, but no systematic study has been carried either on selection of food in favourable environment or the influence of temperature and humidity in this process. The species of plants consumed by *Achatina fulica*, *A. craveni*, *A. albopicta*, *A. zanzibarica*, *Arianta arbustorum*, *Capaea hortensis*, *C. nemoralis*, *Hygromia striolata*, *Helix aspersa*, *Limicolaria distincta*, *L. lucalana*, *L. zebra*, *Mariaella dussumieri*, *Monacha cantiana*, *M. cartusiana*, *Opeas gracile*, *Parmarion reticulatus* and *Theba pisana*, have been enlisted by previous workers, Green (1910b, 1910c, 1911), Stefani (1913), Gorton (1919), Smith (1919a, 1919b, 1922), Hutson (1920), Paravicini (1922), Charmoy and Gebert (1921), Basinger (1923a, 1923b, 1927), South (1923b, 1926b), Mohr (1924, 1949a), Spence (1938), Bertrand (1928, 1941), Anon (1929), Dammerman (1929), Corbett (1933, 1937), Leefmans (1933a, 1933b), Leefmans and van der Vecht (1933a, 1933b), Riel (1933), Benthem—Jutting (1934, 1952), Beeley (1935, 1938a, 1938b), Fairweather (1937), Heubel (1937, 1938), Salaam (1938), Cotton (1940), Feij (1940), Macmillan (1943), Hatai and Kato (1943), Townes (1946), Anonymous (1947), Herklots (1948), Otanes (1948), Weel (1948a, b, c, 1949), Pangga (1949), Kondo (1950a, 1952, 1954), Lange (1950), Milsum (1950), Rees (1950), Williams (1951), Chamberlin (1952a), Jaski (1953), Rao and Ramadoss (1953), Alphen (1954), Dartevelle (1954), Holmes (1954), Weber (1954), Frömming (1954, 1956), Graham (1955), Karlin (1956), Lakshminarayana and Rao (1965) Subba Rao (1975), Owen (1965), Mead (1961), Hyman (1967), Grime *et al.* (1968), Grime and Blythe (1969), Grime and Thornton (1970), Bhat and Viswanathan (1972), Bhat and Shamanna (1972), Bhat *et al* (1973), Chatfield (1973, 1975, 1976), Owiny (1974), Richardson (1975), Williamson (1975) and Mitra *et al* (1976), but *Macrochlamys* did not draw their attention.

Species of the family Cucurbitaceae have been reported as preferred food-plants of *A. fulica* in Ceylon (Green, 1910c), Chichi Jima (Mead, 1961), New Britain (Dun, 1949, 1953, cited in Mead, 1961), Saipan (Lange, 1950), Tinian (Chamberlin, 1952a) and India (Srivastava, 1966) while in Philippines the preferred plant of the group was *Langenaria leucantha* (Pangga, 1949).

Present observations on the snail pests of India suggest that *Cucurbita* sp. is the preferred food plant of *A. fulica*, *M. indica* and *B. monticola*. However, in absence of *Cucurbita* the snails feed upon *Langenaria vulgaria*, though at a much lower rate indicating that *Langenaria* is a choice of a lower order.

Beans, the highly valued economic plant for high protein content in the seed have been recorded as a favourite food of *A. fulica* in Philippine Islands (Pangga, 1949) and Saipan (Lange, 1950). Report on the damage of bean by land snails in other countries are not available but it seems probable that it would also be a plant of considerable preference to snails in other countries. Interestingly, in India *Achatina* preferred gourd over beans while *Macrochlamys*, *Ariophanta*, *Cryptozonu* and *Bensonia* liked beans more than the gourd when both species of plants were available in sufficient quantity. The radular apparatus in ariophantids though efficient, cannot scrap coraser vegetations in the same order as in *Achatina* and the preference for bean might be due to the soft texture of the latter.

Damage to papaya, the widely grown fruit plant by *A. fulica* has been reported from many countries, Ceylon (Green, 1910c). Sumatra (Heubel, 1937, 1938), Saipan (Esaki and Takahashi, 1942 ; Lange, 1950), Palaus (Hatai and Kato, 1943), Micronesia (Townes, 1946), Philippines (Pangga, 1949), Koror (Kondo, 1950a, 1950b) and Tinian (Chamberlin, 1952). *A. albopicta* is a pest on papaya in East Africa (Williams, 1951). The snails feed upon the floral buds in addition to leaves and twigs. *Achatina* has been observed to drink latex of rubber plant from collecting cups (Paravicini, 1922 ; Philbrick, 1949 ; Rees, 1950). In India, of the different organs of papaya plant preference was for young fruits which when damaged secretes considerable amount of latex. This might have been additional attraction for *Achatina*. In the districts of 24-Parganas, Calcutta, Hooghly and Midnapore in the State of West Bengal, Palghat in Kerala State and Balasore in Orissa the damage to papaya cultivation by *Achatina* has reached an alarming proportion and is nearly on the verge of collapse. Ariophantids though recorded in sufficient number in agrihorticultural gardens were never found climbing papaya plants and damaging any part of it.

Damage to banana though limited to rasping of the skin of the fruit by *Achatina* and *Ariophanta* is sufficient to make the fruits less valuable especially in eastern and southern India. Similar damage caused by *A. fulica* has been reported from Ceylon (Green, 1910c), Java (Riel, 1933), Palau Islands (Hatai and Kato, 1943), Hawaii Islands (Weel, 1948-49), Philippines (Pangga, 1949), Koror (Kondo, 1950a) and Saipan (Lange, 1950). Contrast to this Chamberlin (1952) failed to observe any damage to banana by *A. fulica* in Tinian. The present observations on the damage to banana by *A. fulica* are in agreement with the majority of the workers and departure from this in Tinian (Chamberlin, 1952) is rather interesting. Banana garden is an excellent habitat for *M. indica* but they were never found to damage it.

Reports on the damage of beverages viz. tea and coffee by land snails are scattered and scanty though these constitute important agricultural products in a number of countries. *Achatina* is not considered as a serious pest of tea but they have been found to devour shoots and flowers in Netherlands (Benthem—Jutting, 1934, 1952). Heubel (1937, 1938) holds that in Sumatra *Achatina* feeds upon the young leaves of tea only when there is little else to eat. On the other hand, though tea is extensively grown in Ceylon no damage by *Achatina* has been reported (Hutson, 1920 ; Mead, 1961). In India, damage to tea seelings by *A. fulica* in nurseries on some occasions is a serious threat to tea industry. The grown up plants are rarely attacked and that only when no alternate food-plants are available as reported from Sumatra (Heubel, 1937, 1938). Coffee is attacked by *Achatina cravini* in Tanganyika (Salaam, 1938) and by *Ariophanta solata* and *Mariaella dussumieri* in India (Bhat and Viswanathan, 1972 ; Bhat and Shamanna, 1972 and Bhat *et al.* 1973). Fortunately, *A. fulica* have not yet spread to the coffee growing areas of India.

Of the land snails and slugs in California only *Theba pisana* is a serious pest on citrus (Gorton, 1919 ; Smith, 1919a, 1919b, 1922 ; Basinger, 1923a, 1923b, 1927). *A. fulica* and *M. indica* are found in larger number in the citrus growing areas of India but they are not pest on citrus, while *B. monticola* is a serious threat to citrus plantation in Solan of Himachal Pradesh. However, in captivity *A. fulica* and *M. indica* fed upon citrus leaves. The citrus plantation is not attacked by them presumably due to the availability of a number of favourite food plants in abundance.

Damages to garden flower and ornamental plants by *A. fulica* have been reported by a number of workers from Malaya (South, 1923b, 1923c, 1926b), Sumatra (Feiji, 1940), Ceylon (Macmillon 1943), Hawaii (Weel, 1948-49), Philippines (Pangga, 1949) and Seychelles (Milsum, 1950). In India the damage to garden flowers and ornamental plants by *A. fulica* are similar to those in other countries. The most favoured flower plants of *A. fulica* and *M. indica* are marigold, *Portulaca*, cosmos and zinnia. Of the ornamental plants *Bryophyllum*, *Rheo*, *Trichanthus*, *Aloe*, *Setcreasea* and *Crinum* are preferred. Pangga (1949) holds that in Philippines ornamental plants are preferred to flower plants by *A. fulica.* Barring marigold observations in India are similar to those of Pangga in Philippines. The ornamental plants are preferred presumably due to their succulent nature. This is supported from the fact that *Bryophyllum pinnetum* which is less succulent is not devoured by *Achatina* when *B. calynacium* are available.

Attack on vegetable plants viz. amaranth in Saipan (Lange, 1950) and Hawaii (Weel, 1948-49), Cabbage in Philippines (Pangga, 1949) and Saipan (Lange, 1950), bitter gourd (*Momordica charantia*) in Philippines (Pangga, 1946), Chilly in Sumatra (Heubel, 1937, 1938), Rota (Kondo, 1952) and Saipan (Lange, 1950), lettuce in Saipan (Lange, 1950) and Hawaii (Weel, 1948-49), radish in Sumatra (Heubel, 1937, 1938) and Saipan (Lange, 1950), lady's finger (okra) in Ceylon (Green, 1910c) and Saipan (Lange, 1950) and tomato in Guam (Mead, 1961) by *A. fulica* are on record. Similar observations have been made in India but sponge gourd (*Luffa* spp.) and carum carui (*Momordica cochinchinensis*), not reported by previous workers are consumed by *A. fulica* avidly. Serious damage to winter vegetables and seedlings has been reported by Singh and Birat (1969) from Bihar. On the other hand *M. indica* chiefly restrict them to amaranth, cabbage, lettuce and sponge gourd, as the required amount of food is met with the above four plant species. Lady's finger, though not a preferred food plant is liked by *B. monticola* in Solan when other vegetable plants are not very common.

A number of wild plants are consumed by land snails *Achatina fulica*, *Arion empiricorum*, *Arion circumscriptus* and *Rumina decollata* but nothing is known on the same point from other molluscan pests. *R. decollata* ate 73 of 90, *A. empiricorum* 158 of 197 and *A. circumscriptus* 33 of 193 wild plants offered (Frömming, 1954, 1956). In Britain, majority of land molluscs feed on wild plants (Chatfield, 1976). In India both *A. fulica* and *M. indica* feed upon a large number of wild plants, the preferred ones even over the cultivated plants are fig, *Synedrella*, and *Allangana*. It is to be mentioned here that *C. semirugata*, *C. bistrialis* and *A. solata* depend mostly on the wild plants.

Dependence on wild plants by pestiferous snails minimises the damage to crop plants to a considerable extent but this often creates other problems. In off season, when crop plants are not available or available only in localized areas, the snails survive on the wild plants. Further the wild plants offer them good shelter and thereby rapid increase in population is encouraged and at the same time making the control measure rather ineffective.

Majority of the members of the grass family are immune to pestiferous snails (Green, 1910c ; Hutson, 1929 ; South, 1926b ; Heubel, 1937, 1938 ; Herklots, 1948 ; Weel, 1948-49 ; Mead, 1961), probably except *Commelina* sp. (Owen, 1965). However, reports to the damage of corn (*Zea mays*) are available from Chichi Jima (Mead, 1961), Tinian (Chamberlin, 1952a), Sumatra (Heubel, 1937, 1938), Guam (Kondo, 1950a), Saipan (Lange, 1950) and Hawaii (Weel, 1948-49). In India, both *A. fulica* and *M. indica* consume *Commelina benghalensis* and maize seedlings while *B. monticola* are serious pests of maize in Solan.

Eating of algae and moss by pestiferous snails is rather important from the point of crop production. Chatfield (1973) recorded feeding of algae by *Discus rotundatus*. Fungi is consumed by *A. fulica* (Kondo, 1964), *Rumina decollata*, *Arion circumscriptus* and *Arion empiricorum* (Frömming, 1954, 1956). The present observations on moss, *Semibarbula orientalis* constitutes only a very small amount of food for adult *M. indica*, and young *A. fulica* occasionally. All land snails prefer decomposed plant matter, possibly due to the growth of fungal hyphae on them. A number of fungi and bacteria secrete strong cellulolytic enzymes which degrade the cell membrane (Ghose *et al*, 1969 ; Ghose and Halder, 1969) and considerable amount of nutrient materials locked in plant cells are available to animals feeding on decomposing plant matters. Chatifield (1976) suggested that feeding on micro-organisms is associated to some extent with snails nutrition.

In additon to the food of plant origin a number of land snails use animal materials also as their food. The classic example of omnivorous snail is *Oxychilus* (Chatfield, 1976). Small worms, eggs of *Arion ater* and other molluscs are eaten by *Oxychilus cellarius* (Taylor, 1900). Significantly greater amount of animal materials have been reported in the faeces of *O. cellarius* and *O. alliarius* than those in the faeces of other species of snails living in the same habitat (Mason, 1970). Pallant (1969, 1972) and Mason (1970) reported dead animal materials including earthworm chaetae and arthropod fragments in the faeces of land molluscs. Carnivorous habit of *Testacella* has been confirmed from its feeding on earthworm (Runham and Hunter, 1970). A number of stylommatophores have been described as carnivores (Hyman, 1967), while Mitra and Biswas (1974) reported necrophagous habit of *Opeas gracile* in Calcutta. *M. indica* feed upon dead and crushed individual of the same species, an observation similar to that of Boycott (1934) in the slug *Arion ater*. It may be concluded that *M. indica* is a saprophagous land snail helping in break down of leaf litters and at the same time attacking soft parts of small dead animals and thus acting as an effective scavenger. Das and Sharma (In press) reported the feeding habits of *A. fulica* on a dying house lizard, *Hemidactylus frenatus* from Port Blair, Andaman.

From the studies on food selection and food preference in *Achatina*, *Macrochlamys*, *Ariophanta*, *Cryptozona*, *Bensonia* and a number of land snails it is evident that the cultivated plants of economic importance constitute major part of the preferred food of vegetable origin. Gourd, beans, lettuce, cabbage and a number of other plants, the chief sources of vegetables of man are highly preferred by the snails. Gain (1891) considers that nearly two-thirds of the cultivated plants are 'acceptable' to the snail *Capaea hortensis*. In agricultural and horticultural lands of Europe most of the damage to crops is caused by *Helix aspersa* and eight to ten species of common slugs.

Agriolimax reticulatus, *Arion hortensis* and *Milax budapestensis* are considered as major pests while *Arion circumscriptus*, *A. intermedius* and *Milax sowerbyi* are less common in the fields (Stephenson, 1968). Preference to crop plants in the gardens around Calcutta has been reported in *Opeas gracile* (Mitra *et al*, 1976).

From the observations for a period of six years in different districts of Indian States, we are in a position to state that nearly 90% of the plants cultivated in India are acceptable to *A. fulica* and *M. indica*, 70% to *Ariophanta solata*, *C. semirugata*, *C. bistrialis* and 80% to *B. monticola* causing considerable economic hardship to the growers, particularly in the areas with a rather heavy snail population.

Damage to crops by land snails are caused in a number of ways other than eating parts of plants or fruits. Damage to potato in British Islands by slugs is on record (Runham and Hunter, 1970 ; Chatfield, 1976). *Milax budapestensis* and *Arion hortensis* burrow into the soil and feed upon ripe potato tuber. Germination of winter wheat is prevented by eating the 'wheat germ' and the tiny seedlings are destroyed due to the damage of small leaves (Runham and Hunter, 1970). In general, the present findings on the damage to crop plants caused by the snail pests in India are similar to those of others in different countries. However, potato is not attacked by any snail species in India, though slugs sometimes caused damage to it in Otacamund, Tamil Nadu.

Feeding on fallen or decomposed plant matters by snails and slugs are on record (Mead, 1961 ; Chatfield, 1976 ; Mitra *et al*, 1976). Similar observations have been made on *A. fulica* and *M. indica*, the latter showing greater perference for decomposing plant matters. The radula in *M. indica* is much less efficient than that in *A. fulica* in rasping plant food particularly of coarser types. Feeding upon decomposing materials enables consumption of more amount of food in shorter time and at the same time digestion is also somewhat easier. Presumably this had led *M. indica* to depend more on decomposing plant matters. A number of workers (Mason, 1970 ; Chatfield, 1976) consider this type of feeding in snails play an important role in the ecosystem by transferring a considerable amount of resistant plant matters to a state in which those could be easily degraded biologically by microorganisms in the soil.

Information on food preference in land snails under captivity is very limited and scattered. No report is available on the subject in snails kept in an environment simulating nearly the conditions met with during the period of highest activity in natural habitats. In captivity, the preferred plants for *Achatina* were sweet potato and cucumber (Mohr, 1949) and lettuce, carrot and head cabbage (Kondo, 1964) while cabbage and lettuce for

Limicolaria martensiana (Owen, 1965). Rees (1950) reported *Achatina fulica* were fed in the laboratory on lettuce, carrot, apples and occasionally cabbage leaves. It is not clear whether these were plants of choice or selected by the author.

From the observations on food preference with the 22 species of selected plants comprising vegetables and beans, oil seed, fibre, flower, fruit and wild plants it can be presumed that a high degree of choice exists both in *A. fulica* and *M. indica*, though they can live upon a large number of plant species. The plants of choice were gourd, beans, marigold, lettuce, cabbage and *Synedrella* though they were often found to consume small amount of other plants viz. amaranth (*Amarantus* sp.) radish (*R. sativus*), garden spinach (*S. oleracea*), papaya (*C. papaya*), cotton (*G. herbaceum*), Jute (*Corchorus* sp.) and castor (*R. communis*). The snails did not take Kalkasunada (*C. sophera*), berakalmi (*Ipomea* sp.), lady's finger (*H. esculentus*) and tomato (*L. esculentum*), so long food-ptants were available.

Survival of land slug *Agriolimax reticulatus* (Frömming, 1954; Pallant, 1969, 1972) on wild plants is on record. Chatfield (1976) reported that majority of land molluscs in Britain feed harmlessly on wild plants. *A. fulica* and *M. indica* thrive quite successfully on a number of wild plants available in India and presumably this will be the situation in different countrie. Studies on the evaluation of damage caused by *A. fulica* in the garden at Joynagar are rather interesting. This suggests that the rate of damage is dependent on the type of food plants and also the numbers of snails. As almost all cultivated plants are 'acceptable' to *A. fulica* it is certain that a some sort of monetary loss is a must but the amount may vary depending on the economic value of the plant species.

It may be suggested that planting of flower plant like marigold and wild plants viz. *Synedrella* and *Bryophyllum* along with vegetable and crop plants might reduce the damage to the latter by snail, especially the giant snails to a considerable degree (Raut and Ghose 1983a).

The solitary report on the selection of food plant in respect to snails age is that of Jaski (1953) who reported that young *A. fulica* feed almost exclusively upon young shoots and succulent leaves up to the age of about four months. Observations on the feeding of young *A. fulica* and *M. indica* are somewhat similar to those of Jaski (1953) up to the age of 60 days in the former and 50 days in the latter.

It is noteworthy that during this period both the specics of snail changed their preference for plant species—beans—lettuce—gourd—marigold with age. Switching over to coarser type of food in snails older than the above age indicates the development of stronger feeding apparatus.

The activity of land snails depend on two main factors—humidity and temperature. Eating of succulent plants during dry weather has been reported by Dowdeswell (1961). Association of feeding upon succulent plants with the fall in humidity per cent as found in *A. fulica* and *M. indica* is an adaptation in the land snails where conservation of water is a major problem. The present observations indicate that both the snails under investigation are highly adapted to compensate the lose of body water up to a certain limit by changing their food habit temporarily.

From the study of food preference in *A. fulica* in their natural habitat it appears that there is a marked preference for food plants in the snails of different age groups. Of the six age groups, 10-25 days age group consumed only two plant viz., bean and marigold, while the next two higher age groups (i. e. 50-80 days and 100-120 days age groups) consumed three other plants viz., cucumber, gourd and sponge gourd in addition to bean and marigold. However, eating restrictedly to three plant species only (bean, gourd and papaya) and no infestation to gourd and marigold by the snails of 150-240 days age group is really suprising as these two plants were avidly consumed by snails of all ages, both young and old. It may depend either on the non-availability of other food plants in the feeding zone or on the specific choice by this age group, but more probably be attributed to the former in so far as the experience of the authors with the snails and the garden is concerned. The snails of the two higher age groups consumed a variety of plant species particularly the 365 days and above age groups consumed all the 8 plant species in the garden.

The snails of 10-25 days age group mostly preferred eating bean, while all other higher age groups preferred eating gourds in addition to others. Moreover, *A. fulica* of 10-25 days age group restricted themselves to eating leaves of bean and marigold only but the higher age groups consumed a a variety of plant species which reached maximum with 365 days and above age groups. The preference for bean and marigold only by the young snails and for gourd by most of the higher age groups, may be associated with the taste and texture of the food plants consumed because the radula, the feeding apparatus, of the young snails are not so well devoloped to scrap other plants of hard texture. With the increase in age the snails consumed a variety of plant species (all the 8 plant species by the 365 days and above age groups) which indicates a wide range of food acceptability by more mature or aged snails—an advantageous adaptation for successful survival and distribution.

The rate of consumption by the snails of different age groups to the same plant increases with the age but the amount of consumption for different plant species is more or less same. The proportionately higher rate of consumption with the age is quite expected and omnipresence in nature. The slight variability in the amount of consumption is presumably associated with the food value of the food-plants concerned.

Whatever be the degree of infestation, the amount of consumption of a particular plant species is always related with the age group involved. The bean plants were attacked by maximum number of snails (average 1953 snails consumed 2350 gm per day) but the amount of consumption was maximum for gourd (average 1104.5 snails consumed 2929 gm. per day) as this plant species was mostly preferred by the higher age groups. However, it would be frustrating if we want to analyse the loss to our agri-horticultural economy with the degree of infestion and the amount of consumption by the snails to a particular plant or to different plant species. Because the extent of damage is neither related with the number of snails infested nor with the amount consumed, but the damage or loss is principally dependent on the commercial value of the food-plants consumed and more particularly with the site of infestation or on the parts of the food-plants preferred. For example, the damage to papaya, though consumed by 90 snails, was very serious as the snails were regular feeder of the floral buds and also were found to drink latex from the young fruits rendering it unmarketable. The cultivation of papaya in snail infested areas should therefore, be avoided or may be cultivated taking adequate measures as may be applicable. Similarly, cultivation of bean and gourd should also be taken with adequate measure in snail infested areas as the maximum infestation rate and maximum consumption rate were observed in those two plant species respectively. It would be worth pointing out here that the control of this snail-pest through chemical agent is not encouraging (Mead, 1961) and thus preventive measures are to be employed. It is recommended here that a permanent water canal around the cultivated plot should be constructed in addition to periodical checking of the garden to prevent infestation of snails from miscellaneous sources like transportation by human and animal agents or through infested seedlings.

Nothing is known about the biological clock regarding feeding in land snails. Active feeding during night in their natural habitat and in day time when kept in darkness in laboratory, indicate that they prefer to feed in dark, a behaviour fixed in them. Active feeding during day hours in cloudy, rainy days lends support to the above contention.

Although a number of chemicals have been used to control the giant snail pest the snail population could not be controlled or reduced to an appreciable extent (vide Mead, 1961). In India, Saxena and Dubey (1970) have applied aromax, common salt, copper sulphate, DDT, metaldehyde, mixture of 2, 4-D and 2, 4, 5-T (2 : 1), sevin and simazine, and reported that aromax, common salt, copper sulphate, metaldehyde, sevin and simazine have produced 80% and or more mortality while they did not consider DDT and mixture of 2, 4-D and 2, 4, 5-T (2 : 1) as effective molluscicides. Of the effective chemicals common salt is by far the best one as it is very cheap. Hoda (1971) is of the opinion that spraying of saturated solution of common salt is effective to the snails. The efficacy of the application of common salt either in the crystal form or in solution which is true for all chemicals, is dependent on the weather. The land snails are active in monsoon and there is every likelyhood of the chemicals being washed away. But the technique adopted by Saxena and Dubey (1970), however, is not quite clear in this point. Metaldehyde and calcium arsenate unquestionably are, to date, the chemicals of choice in attempts to control *A. fulica.* Endrin when applied was also effective as reported by Manna and Ghose (1972) but the bait mixed with endrin was not attractive to snails. Manna (1976), however, ruled out the possibility of controlling the giant snails with systematic poisons like diazinon and fenitrothion. Mead (1961) discussed the advantages and disadvantages of the use of different chemicals against *A. fulica* and other molluscan pests and concluded that no chemical is effective for the control of giant snails so far. However, some of the chemicals have been proved effective to the snails like *Theba pisana*, *Strophocheilus oblongus* and slugs *Deroceras reticulatum* and *Milax sowerbii.*

South (1926b) first suggested the possibility of control of *A. fulica* with its natural enemies. A series of studies were conducted by the Pacific Science Board of the National Research Council and subsequently by the Insect Control Committee of Micronesia (ICCM, 1947). A total of nineteen enemies—9 species of beetles, 2 parasitic flies and 8 species of predatory snails were employed to control the giant snails but there was no positive report on the effectiveness of these enemies in monitoring this snail pest.

In India, the planaria (*Bipalium indica*) is an effective predator of *A. fulica* but its role in the control of the giant snail is not significant due to imbalanced predator-prey population, the predator being much less in number. The possibility of utilising *B. indica* in the control of the giant land snail would be encouraging if the population density of the former can be raised to a certain level (Raut and Ghose, 1979b). The role of millipedes (Srivastava and Srivastava, 1967) and hermit carb (Srivastava, 1968a) as predators is not encouraging. Hermit crabs of the genus *Cenobita* have been reported as predators of *A. fulica* from Micronesian islands (Mead and Kondo, 1949 ; Mead, 1950b, c) but the coconut crabs produced greater kill of the giant snails in Micronesian islands (Mead, 1961). Williams (1951) observed a land crab, later on identified as *Ocypode* sp. by Dartevelle (1954), feeding on live achatinas in the Diani Beach area of Kenya. However, Somanader

(1951) and Davis (1954) are not in agreement regarding predation by hermit carbs. Even if they are predators the operation is limited only to the periphery of coastal zones, and the possibility of their use in the control of *A. fulica* is remote. The role of millipedes (*Orthomorpha* sp.) in destroying the giant snail pests is not significant. All these lead Srivastava (1970) to suggest an integrated control rather than control through a single agent. The flies of the genera *Phoria* and *Megaselia* though have been found in association with the snail pests, they are rather saprozoic than psrasitic. A number of flies have been listed by *Mead* (1961) in connection with the enemies of *A. fulica* but not a single species is known to be effective in the control programme.

Of the beetles the larvae of Indian glow-worm *Lamprophorus tenebrosus*, endemic in India, Malaya and Sri Lanka is famous for its predaton on *A. fulica*. Paiva (1919) reported that the larvae of *L. tenebrosus* attack both *A. fulica* and *M. indica*. The findings of Hutson and Austin (1924) and Austin (1924) are very pertinent as they reported that a male larva may consume 20 to 40 achatinas and a female larva can consume 40 to 60 during their development. A good number of *A. fulica* are being killed by *L. tenebrosus* in India and perhaps it plays an important role in the control of the pest. The giant snails were introduced in India in 1847 and except in certain small pockets the population has not yet reached an alarming state, as in some Indo-Pacific Islands. This is presumably due to the presence of certain factors which are stronger in India and Ceylon (Hutson, 1920) than those in the Indo-Pacific Islands. Mead (1955, 1956) reported that in Area Seven of the Pallekelle division of the Pallekelle estate in Central Ceylon, both *L. tenebrosus* and *A. fulica* have been together for a minimum of twenty five years, and yet the giant snails is still common to abundant. Similar is the case in India too.

The other lampyrid of genus *Diaphanes* and members of the family Drilidae have also been considered for biological control measures (Desmarest, 1824 ; Lucas, 1842). There is strong evidence that *L. tenebrosus* is not limited to a single seasonal cycle as suggested by Hutson and Austin (1924). While Somanader (1951) reports that the glow-worm dies after a straight diet of *A. fulica*. According to Peterson (1957) the full grown glow-worms never attack *Achatina* longer than 40 mm in length. However, it is true that *L. tenebrosus* are effective predators of *A. fulica* but its effectiveness is most probably affected due to a number of faits : (i) short duration of larval stage, (ii) imbalanced predator-prey population and (iii) the presence of some other preferred snail species in the same area. The possibility of controlling *A. fulica* by *L. tenebrosus* deserves further study.

A good number of Vertebrate enemies of *A. fulica* and other pestiferous snails have been reported by different workers from time to time (vide Mead, 1961). The birds—"Pheasant crow" *Centropus sinensis* and the "Tree Pie" *Dendrocitta vagabunda* are the effective predator of *A. fulica* in eastern and southern India. But they are active only in daytime when the snails hide under any protective sites though the predation may take place in daytime following rain. The bandicoot rat, *B. indica* on the other hand acts as an effective predator especially for its nocturnal habit and the ability to locate both active and aestivating snails. However, to employ a serious pest in controlling another pest is not wise at all. But undoubtedly, bandicoot rats are a serious biological agent in reducing the giant snail population in some areas of eastern India.

From the present study and from a perusal of literature it is clear that only parasites can solve the problem. Protozoans and nematodes, most probably, are not parasitic but symbionts but this requires further study before considering them as biological control agents. The best possibility lies with the aeromonas bacterium, (*Aeromonas hydrophila* (=*liquefaciens*) which caused leucodermia like diseases in *A. fulica* (Dean *et al*, 1970). From the reports of Zwaluwenburg (1955), Mead (1958, 1961, 1967), Srivastava (1966) Raut and Ghose (1977b) and Raut (1983b) it is evident that this infection is occurring in achatina populations every where round the globe. However, a detail study of the disease, its nature and mode of transmission is essential before utilizing the bacterium in biological control. In India, Srivastava and Srivastava (1968) reported that the disease is contageous and they were successful in diseminating the disease in *A. fulica* both in the field and laboratory by spraying the aqueous extract of the diseased snails over healthy snail population. Unfortunately, to date, no report is available from Andaman Islands that the snail population has been reduced due to the spread of this disease. On the contrary in a later publication Srivastava (1970) stressed of on the integrated control approach and also claimed that as a result of the integrated effect of the release of hermit crabs and millipedes, the use of pathogen in the form of aqueous extract of diseased snail, the use of 5% metaldehyde pellets and mechanical destruction, the population of the giant African snail has been declined considerably on the main island of South Andamans. Indeed, as no method is being fruitful, integrated approach should be applied. But this sort of control programme would be variable from one infested area to other and may not serve the purpose well. Therefore, any method, obviously with the help of predators or parasites must be find out which would be effective to control the giant snail population round the globe. And this is only possible through the pathogen like that creates the leucodermia like disease. The bacterium 'strain' which is at present associated with *A. fulica* in nature may not be able to control the snail population in the long run. It is, therefore, suggested to culture *Aeromonas* bacterium species in the laboratory so that a more "Virulent strain" may evolve which could be able to control *A. fulica* and other pestiferous snails and slugs.

ACKNOWLEDGEMENTS

The authors wish to express their most sincere thanks to the Director, Zoological Survey of India for extending all possible facilities and also to the Head, Department of Zoology, Calcutta University for the necessary laboratory facilities in connection with the execution of their research programme.

They deeply appreciate the assistance received from the following persons in the way of providing certain important information and also helping in diverse ways, and woe their thanks to

1. Professor A. Choudhury, Drs, G. Mondal, G. P. Ghosh, S. Das, B. Dasgupta, B. Manna, R. Sur, Aparna Sur and S. C. Sadhukhan of Zoology Department, Calcutta University.
2. Dr. N. V. Subba Rao, Mr. K. V. Surya Rao, H. P. Mukherjee, Shri D. K. Thakur, A. Dey, R. N. Manna, S. C. Mitra, S. Barua and P. K. Bala of Malacology Division, Dr. C. B. Srivastava and Mr. R. K. Ghosh of Helminth Section, Drs. A. K. Mandal and A. K. Das of Protozoology Section ; Dr. N. C. Nandi of Kakdwip Field Station, Zoological Survey of India.
3. Dr. (Mrs.) Uma Ghose, National Medical College and Dr. C. R. Ghose, Calcutta Medical College, Calcutta.
4. Professor P. D. Srivastava, Indian Agricultural Research Institute, New Delhi ; Professor P. B. van Weel, Hawaii University ; Professor A. R. Mead, Arizona University and Professor T. N. Ananthakrishnan, Loyla College Madras and Professor O. P. Bhalla, College of Agriculture, Solan, Himachal Pradesh.
5. Professor N. Bhattacharya, Mr. M. De of Economic Reserach Unit, Indian Statistical Institute, Calcutta ; Dr. P. K. Bhowmick, Department of Agriculture, Calcutta University and Mr. G. Mukherjee, Zoological Survey of India.

Thanks are also due to ICAR, UGC and DST for rendering financial assistance.

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ERRATA

Page	*Line*	*Instead of*	*Read*
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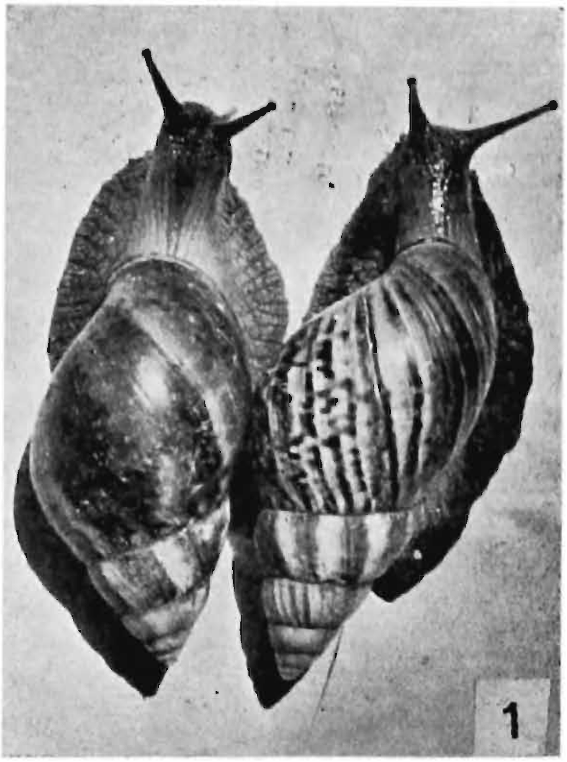
PLATES



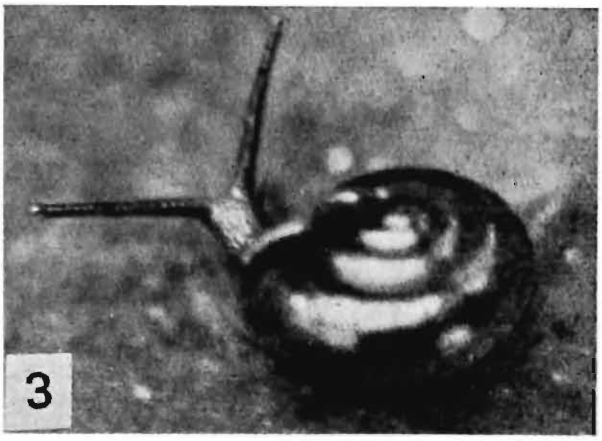


Fig. 1. *Achatina (Lissachatina) fulica fulica.* (Note the differences in the pattern of shell streak and colour).

Fig. 2. *Opeas gracile*

Fig. 3. *Macrochlamys indica*

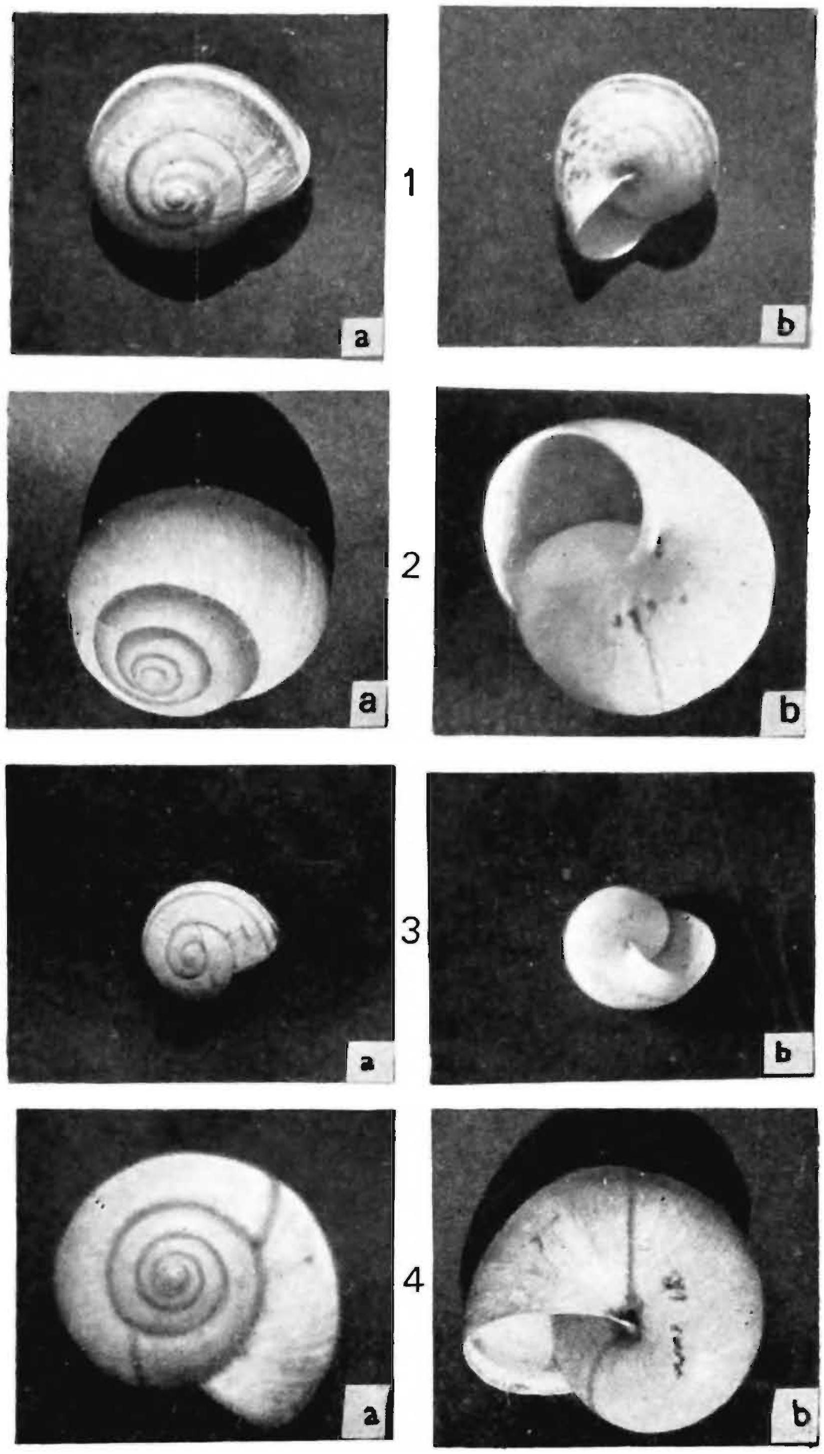


Fig. 1. *Ariophanta solata* a. Dorsal view b. Ventral view

Fig. 2. *Cryptozona* (*Nilgiria*) *semirugata* a. Dorsal view b. Ventral view

Fig. 3. *Cryptozona* (*Xestina*) *bistrialis* a. Dorsal view b. Ventral view

Fig. 4. *Bensonia monticola* a. Dorsal view b. Ventral view

Fig. 1. Young *Achatina fulica* climbing the wall.
Fig. 2. Juvenile and adult *A. fulica* resting on a large boulder.

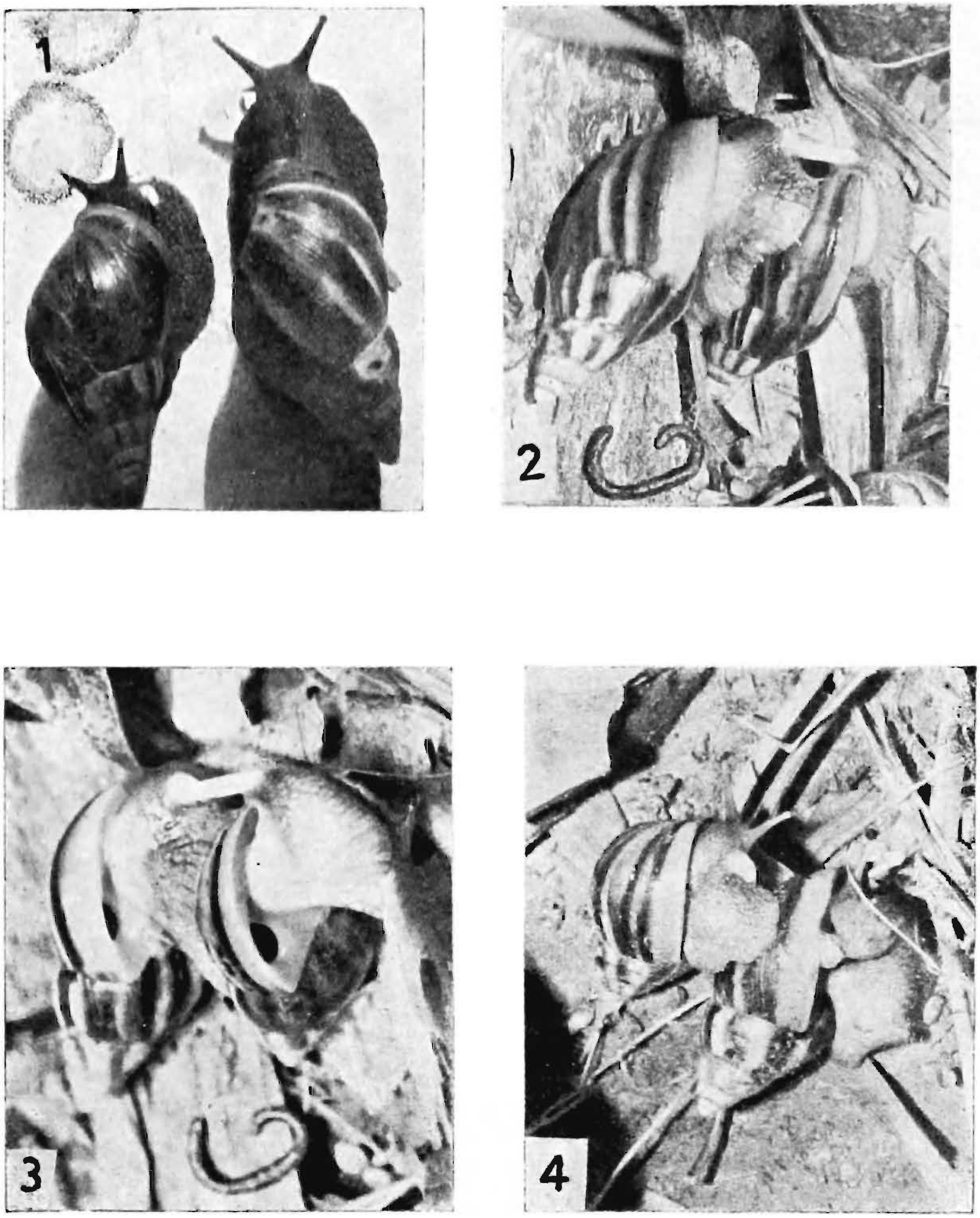
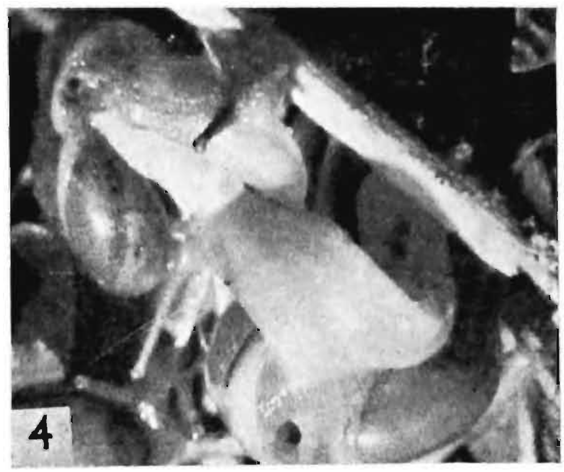
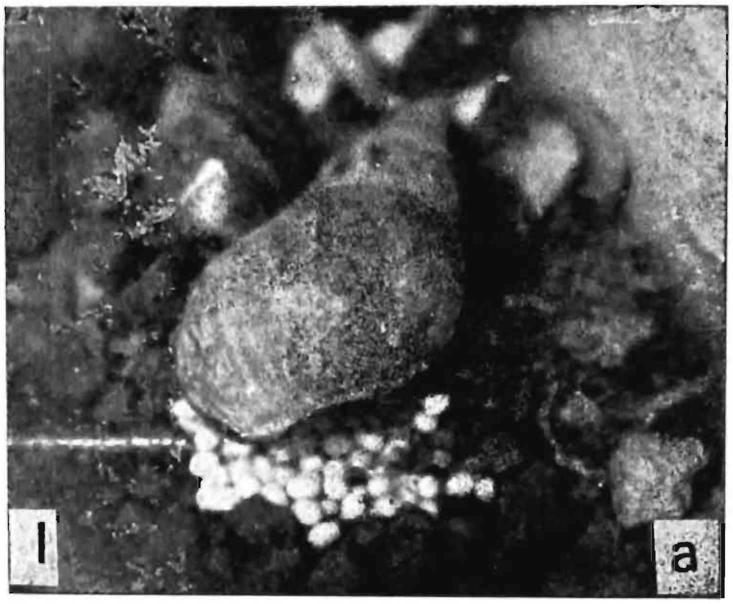


Fig. 1. Courtship in *Achatina fulica* Fig. 2. *A. fulica* in copula. Fig. 3. Copulating *A. fulica* showing part of the penes and pneumostomes wide open. Fig. 4. *A. fulica* (pair) just after mating.



Figs. 1-3. Courtship in *M. indica*. Prospective partners approaching close to each other,

Fig. 4. *M. indica* in copula. The amatorial organs are fully extended and the pneumostomes are wide open.



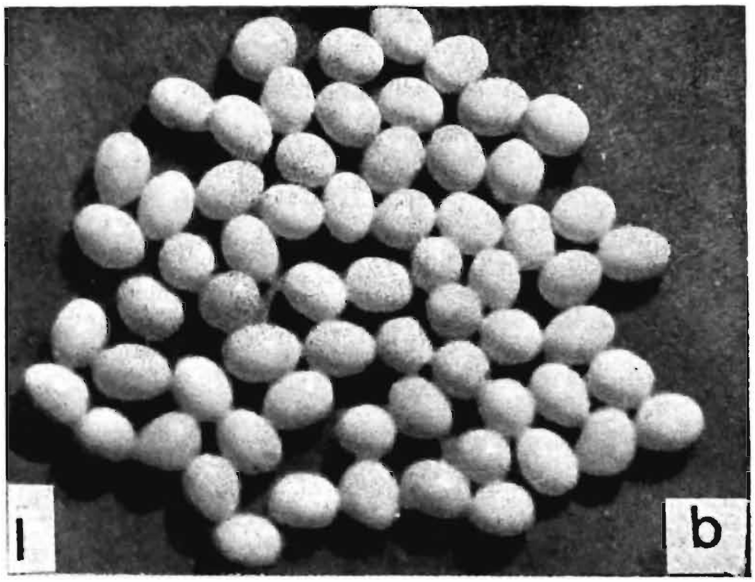
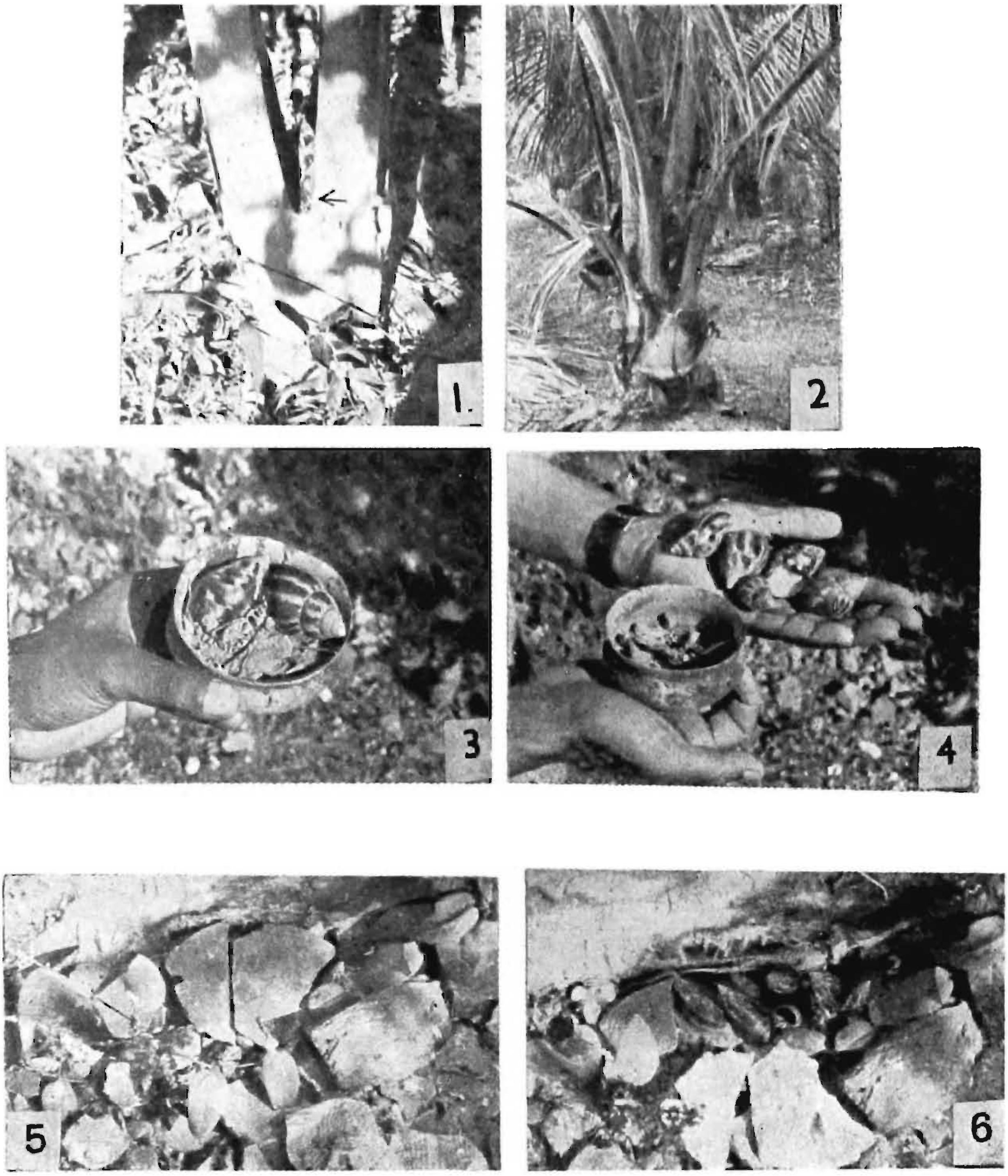
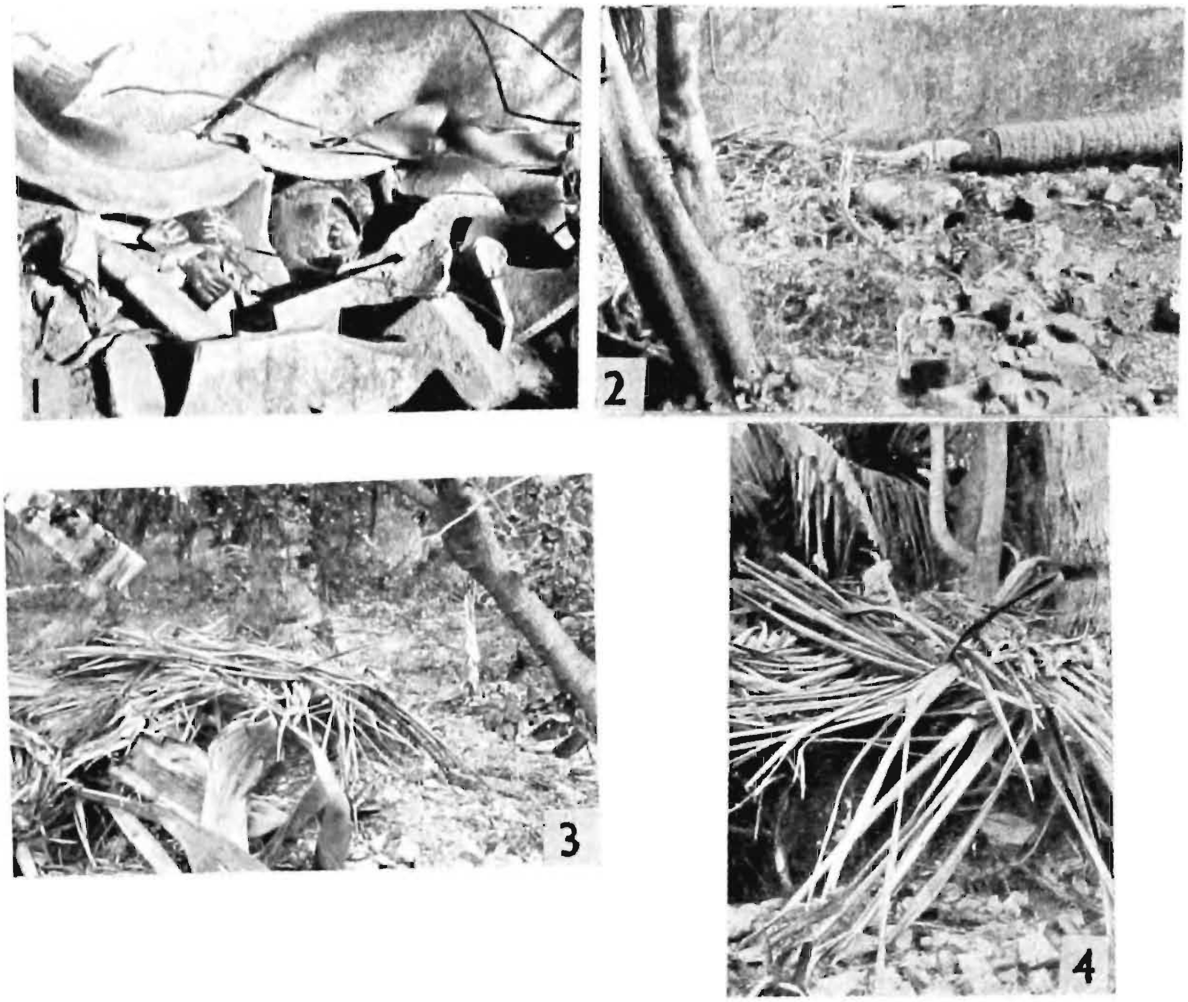


Fig. 1a. *A. fulica* after oviposition
Fig. 1b. The eggs of *A. fulica*



Figs. 1-6. Different sites for aestivation in *A. fulica*.



Figs. 1-4. Different sites for aestivation in *A. fulica*

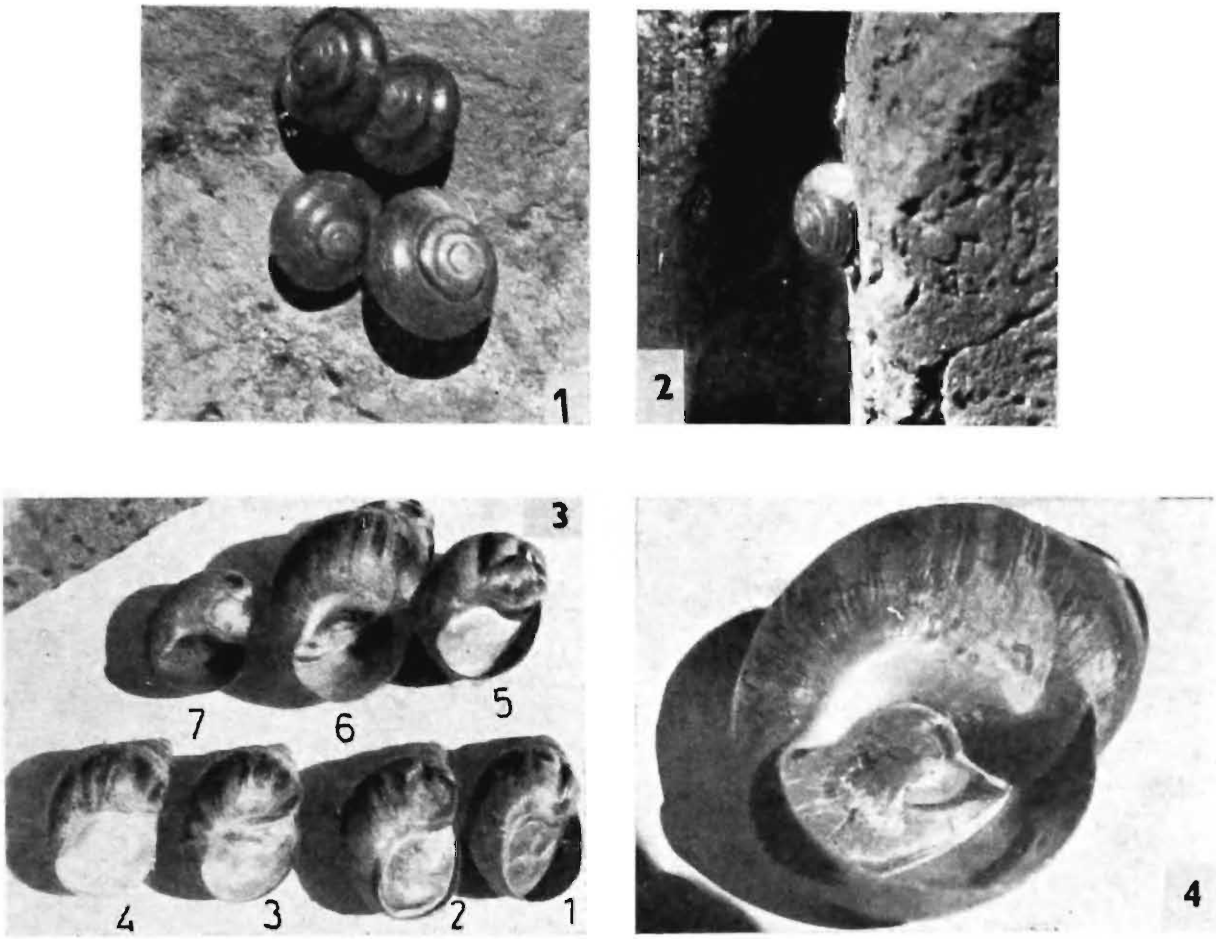


Fig. 1. Aestivating *M. indica* attached to the under-surface of a stone. (The snails exposed by turning the stone upside down).

Fig. 2. *M. indica* aestivating on the side of a stone.

Fig. 3. Degree of retraction of visceral mass within the shell cavity in response to humidity at the time of aestivation of *A. fulica*. The snails 2, 3 and 4 aestivating on damp soil and the epiphragm is along the margin of the outer lip of the shell aperture. The snails 1, 5, 6 and 7 aestivated in the soil at a different depth.

Fig. 4. The slit in the epiphragm corresponding to the pneumostome in *A. fulica*.

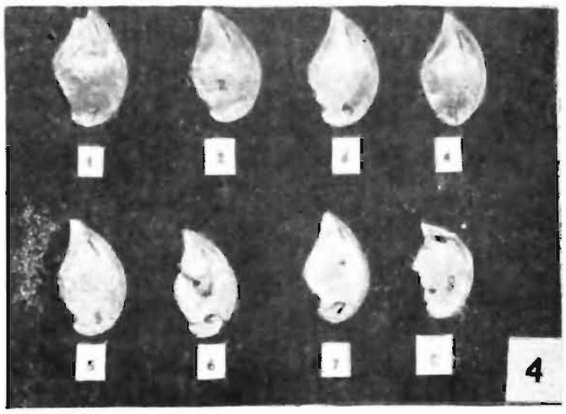


Fig. 1. Aestivating *M. indica* (arrow indicating the aperture on the 'attachment epiphragm').

Fig. 2. The 'attachment epiphragm' of *M. indica* detached to expose the space between the 'attachment epiphragm' and first epiphragm.

Fig. 3. Secretion of a second epiphragm (2) in *A. fulica* beneath the damaged epiphragm (1).

Fig. 4. Secretion of eight epiphragms in succession in *A. fulica*.

Fig. 5. The epiphragm is being eaten by *A. fulica* immediately after awakening from aestivation.

Figs. 1-2. Leaves of castor plant damaged by *A. fulica*.

Fig. 3. *A. fulica* feeding upon the apical bud of cosmos plant at the initial stage of attack.

Fig. 4. Cosmos plants completely defoliated and denuded by *A. fulica*.

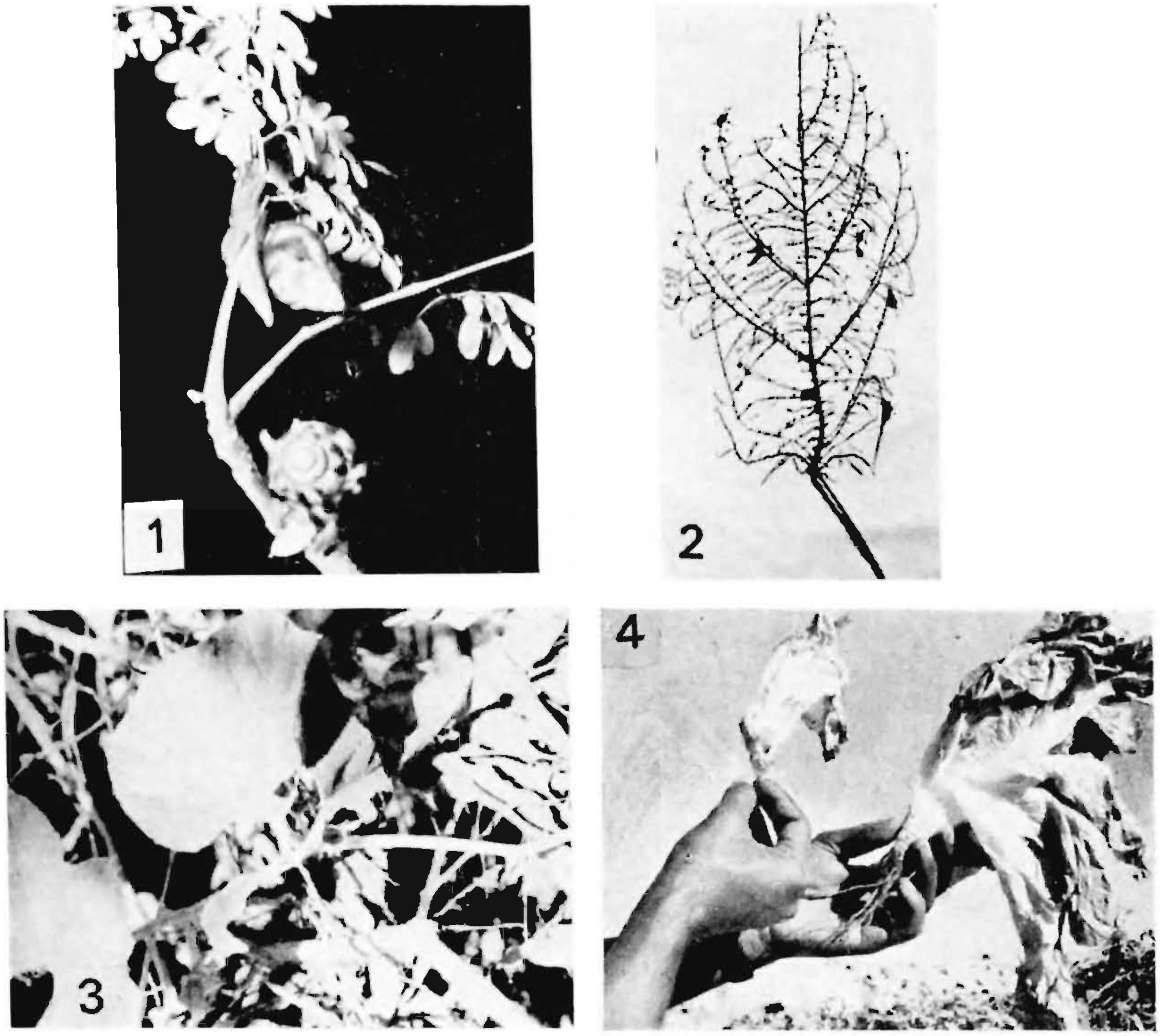
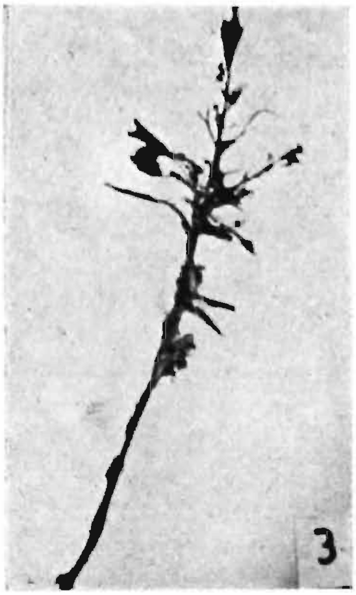


Fig. 1. *A. fulica* in the branch of drum stick plant at night. The upper one started feeding on the leaves.

Fig. 2. A leaf of fig completely skeletonized by *A. fulica*.

Fig. 3. Nature and extent of damage of gourd plants caused by *A. fulica*.

Fig. 4. Damaged to lettuce plant (right hand) caused by *A. fulica*.



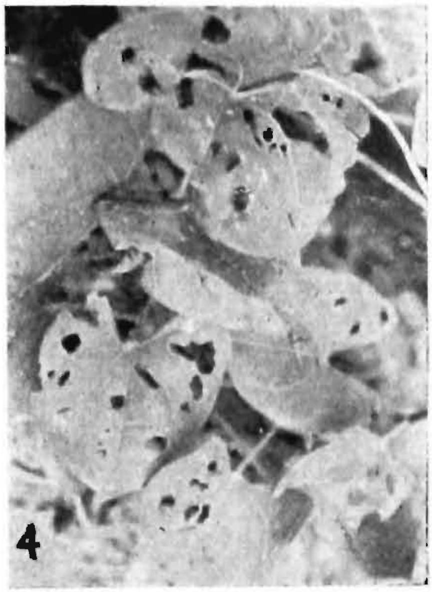


Fig. 1. Damage to ornamental plant, *Rheo discolor* caused by *A. fulica.*

Fig. 2. Damage to ornamental plant, *Pothos* sp. caused by *A. fulica.*

Fig. 3. Damage to the leaf of radish plant caused by *A. fulica.*

Fig. 4. Damage to vegetable plant, *Dioscorea alata* caused by *M. indica.*

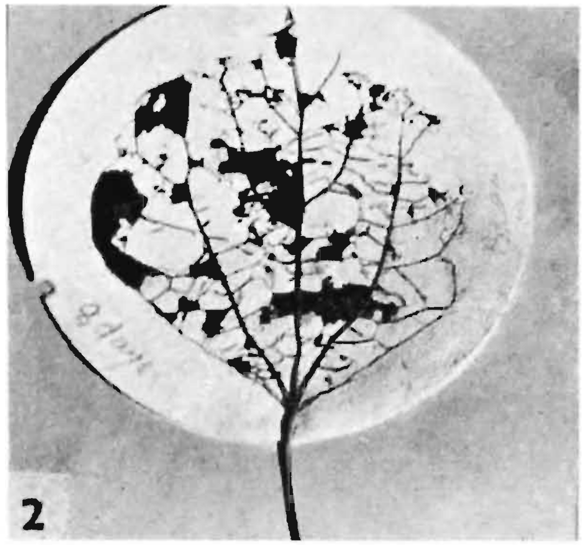


Fig. 1. *M. indica* feeding upon a crushed member of its own kind.

Fig. 2. Leaf of been plant skeletonized by *A. fulica* of 8 days old.

Fig. 3. Leaf of bean plant damaged by *A. fulica* of 14 days old.

Fig. 4. Leaf of gourd plant damaged by *A. fulica* of 25 days old.

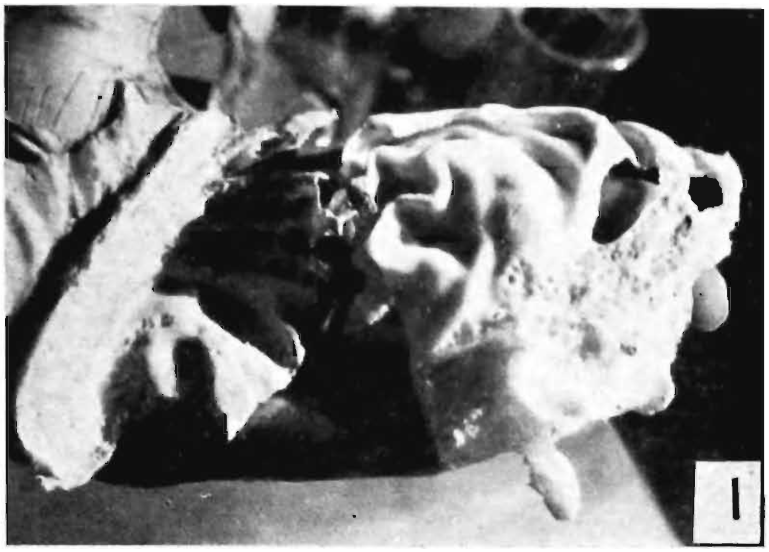


Fig. 1. Damage to cabbage leaf caused by *A. fulica.*

Fig. 2. Nature of damage in bean leaf attacked by *M. indica.*

Fig. 3. A group of *A. fulica* struggling for food.

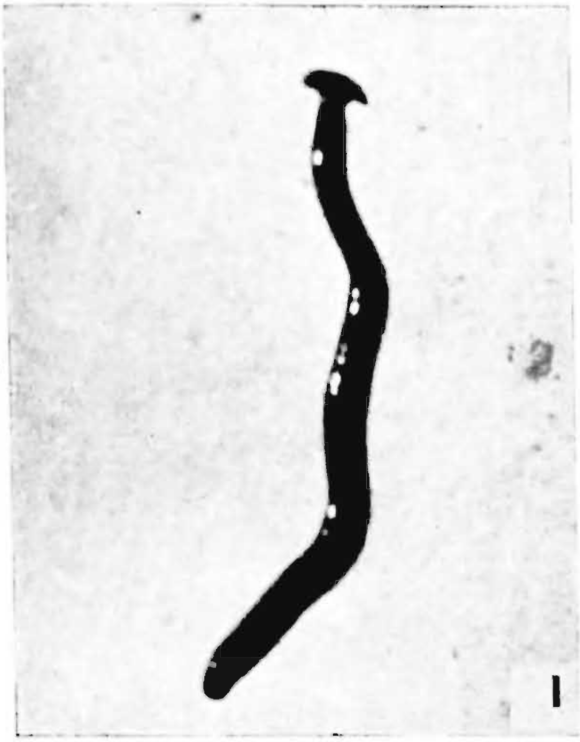
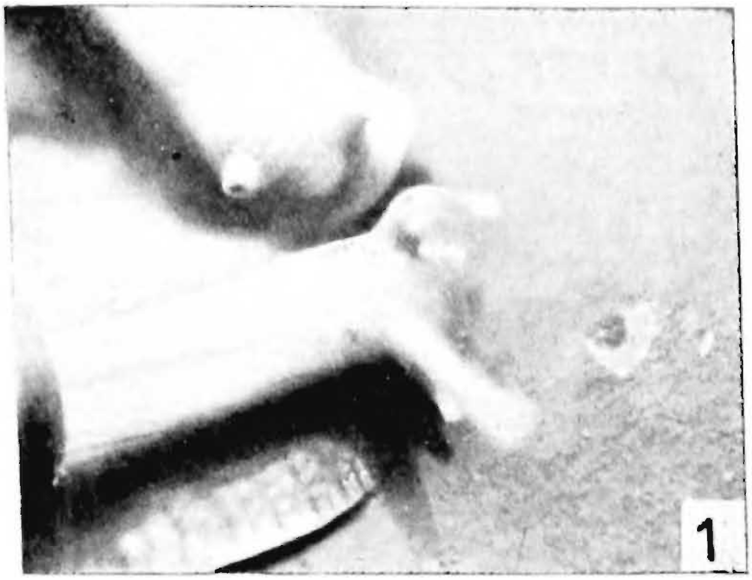


Fig. 1. The planaria (*Bipalium indica*).

Fig. 2. Burrow of bandicoot rat with damaged shells of *A. fulica* around.

Fig. 3. Shells of *A. fulica* of different sizes showing characteristic damage caused by the rat *Bandicota bengalensis*.



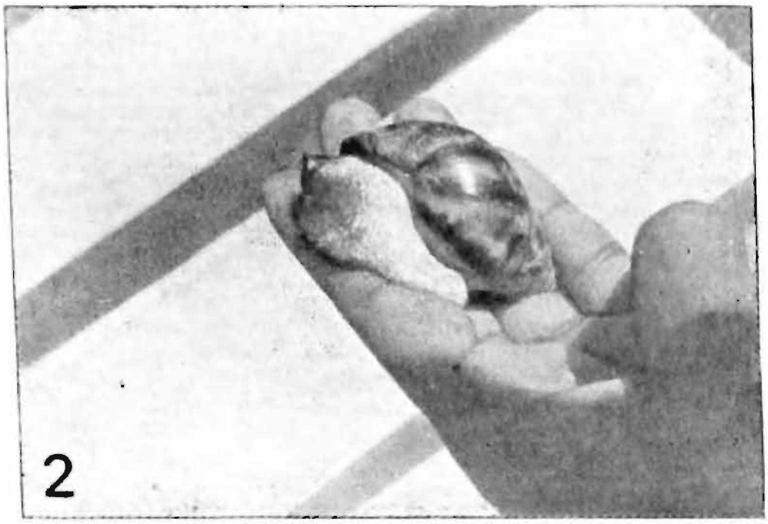


Fig. 1. *A. fulica* showing leucodermic lesions on the tentacles.

Fig. 2. *A. fulica* showing tuberculate-like lesions on the foot.