

No. 3—*Life-History Studies of East African Achatina Snails*¹

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CONTENTS

	PAGE
Introduction.....	295
Ecology of <i>Achatina</i>	297
1. <i>Achatina zanzibarica</i> Bourguignat.....	297
2. <i>Achatina fulica hamillei</i> Petit.....	298
3. <i>Achatina reticulata</i> Pfeiffer.....	300
4. <i>Achatina albopicta</i> E. A. Smith.....	300
Enemies of <i>Achatina</i>	304
1. Vertebrates.....	305
2. Crustacea.....	305
3. Mollusca.....	306
4. Insecta.....	308
Conclusions.....	317

INTRODUCTION

The giant African land snail (*Achatina fulica* Bowdich) has been introduced mainly by the Japanese — as food and medicine — into many tropical and subtropical islands of the Pacific as far eastward as the Hawaiian Islands. In some of these islands it has increased enormously and is inflicting considerable damage to certain truck crops and to garden plants.

Prior to these introductions by the Japanese, *Achatina fulica* had found its way into other tropical countries: Ceylon, Malaya, Java, etc. And at a later date, it has threatened the Pacific coast of the United States by its temporary appearance there.

Since the United States Navy has taken over the government of the Pacific Islands formerly mandated to Japan, and governs other Pacific Islands as well, it is naturally concerned with the welfare of the inhabitants of these lands. In order to safeguard the agriculture of some of these Micronesian islands, it was necessary to combat plant pests chiefly through biological control, that is, by the introduction of suitable natural enemies of these pests. Hence, entomologists were assigned to this work. I was assigned the field study of the giant

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African snail (*Achatina fulica*) and its enemies, with a view to the possibility of introducing some of its enemies into the Pacific islands.

After a brief stay in Washington, D. C. in November, 1947, in conference with Mr. Harold J. Coolidge, Executive Secretary of the Pacific Science Board of the National Research Council, from whom I received my directions, I went to Cambridge, Massachusetts, for a ten-day tutelage under Dr. Joseph C. Bequaert, Consultant for the giant African snail project, and Entomologist at the Museum of Comparative Zoölogy at Harvard University. Dr. Bequaert is a malacologist, of first standing, particularly as regards species inhabiting Africa, in which continent he has collected extensively.

On November 27, 1947, Mrs. Williams and I emplaned at New York for Africa. We stayed in British East Africa until June 19, 1948, returning to New York on June 21.

With the exception of a week's stay at Amani in Tanganyika Territory, situated in the Usambara Mountains at an elevation of 3,000 feet and about fifty miles by road from the coast, my work on *Achatina* was confined to the coast or within a very few miles of it. Here the rock, as exposed, was of coral formation with pockets or larger areas of soil interspersed. The forest, where still existing, was low and scrubby increasing to fairly lofty and often characterized by many thorny plants such as occur in xerophytic regions where the rainfall is sharply seasonal.

The British East African coast was examined at several points for about 200 miles, beginning at Malindi, some 70 miles north of Mombasa, and extending south through Mombasa and on into Tanganyika to Tanga, about 70 miles south of Mombasa, then to Zanzibar Island still farther south and some 22 miles off the Tanganyika coast, lying in latitude 6°10' S. The longest stay was in the Diani District, about 20 miles south from Mombasa, where most of my observations were made, from March to June. Here the rainy season, though rather abortive in 1948, made conditions favorable for my work. The *Achatina* involved was *A. albopicta* Smith, a species extremely abundant in and about the low coral-base forests around the Diani Beach Hotel, especially. Other species of *Achatina* on which data were secured were *A. fulica hamillei* Petit from Mombasa, Tanga and Zanzibar and *A. fulica rodatzki* Dunker from Zanzibar.

The writer desires to acknowledge his indebtedness here to the Insect Control Committee for Micronesia of the Pacific Science Board of the National Research Council, who selected him for this assignment and rendered every possible assistance. The United States Navy and particularly the Office of Naval Research approved and granted the funds to finance this research project and demonstrated their efficiency

in the matter of transportation and dealing with what is known as "red tape." I am also under obligation to Mr. Harold J. Coolidge, Executive Secretary of the Pacific Science Board of the National Research Council, for his kind personal concern and able management; and to Dr. Joseph C. Bequaert for his encouragement, helpful advice, and generous imparting of useful knowledge of African malacology that I would not have acquired otherwise. All the Mollusks referred to in this paper have been determined by Dr. Bequaert. Also, I wish to make grateful acknowledgement to numerous government officials and scientists who furthered my work in Africa most generously. Some of the photographs of live snails were taken in Cambridge by Miss Ruth Turner; those of material in East Africa are by Mrs. F. X. Williams, to whom I am further indebted for assistance in many ways in the field.

Cambridge, Massachusetts
November 7, 1948

ECOLOGY OF ACHATINA

1. ACHATINA ZANZIBARICA Bourguignat

This rather small to medium-sized species was taken in late January and early February, 1948, a short distance within the forest surrounding the East African Agricultural Research Institute, at Amani, in Tanganyika Territory. It did not appear common. A single well-grown individual was found in the forest in the shelter of a root of a large tree, and three other large ones were secured by agricultural workers. By scraping off the litter in the forest, several dozen living young with shells from 8 to 18 mm. long were found. The great majority of these were in one or more scattered colonies at or near the base of a huge buttressed tree. They were in a resting state, their shells being very generally closed by an epiphragm. Other small *Achatina* shells were cleanly empty and sometimes with the rim broken back, indicating the presence of enemies. Some of the young shells placed in alcohol yielded one or two rather large dipterous larvae, the status of which was not determined.

A large specimen of *A. zanzibarica* was kept for several days in a jar with leaf portions of cabbage, celery and lettuce. The leaf portions remained untouched. But the dark brownish excrement of the snail indicated that it may have fed upon a portion of a fleshy seed pod, which had also been enclosed in the jar. It is quite likely that when the snails are activated by the wet season, green leaves would be eaten.

More than thirty of the young *A. zanzibarica* were kept for over six weeks in a large jar in which leaf trash and paper had been added. Upon the addition of a little water the snails became active and ate holes in the paper, and probably devoured some of the dead leaves, as considerable excrement accumulated in the jar.

2. *ACHATINA FULICA HAMILLEI* Petit

This is a large snail with a very dark foot and a moderate to short spire. It was observed from Malindi to Mombasa, at Tanga and on the island of Zanzibar. Of the several colonies of this mollusk observed at Mombasa, the one occupying an old and abandoned Mohammedan cemetery, amply shaded, and with the monuments and enclosures, of calcareous stone, often in sad disrepair among the weeds, proved the most populous and interesting. This two-acre snail center, so easy of access, would seem an ideal spot for extended biological observations, were it not for the fact that, however neglected, it still was a cemetery, and for one to rummage among graves would be to invite suspicion among the crowded populace as well as instilling a certain feeling of guilt in oneself. However, keeping on good terms with the head grasscutter of this rather unsanitary area, helped a good deal.

When I visited this cemetery in early December, 1947, the weather was hot and dry, and the few *Achatina* that I examined were aestivating, being often slightly buried in the litter, and with a calcareous epiphragm bearing a slit-like groove upon its surface, closing the mouth of the shell. Most of the shells containing mollusks were of considerable size and a number were mature. Some shells had suffered much injury and showed obvious repairs thereto. Several *Achatina* were found at a height of 4 to 6 feet wedged in a deep groove in the trunk of one of the baobab trees there, aestivating. The presence of very young shells, all empty, showed that there had been some oviposition not very long previously. And elsewhere in Mombasa, on December 6, I found a cluster of eggs in a depression, corresponding to about half a tennis ball, in the shelter of a coral stone that bordered a path. The eggs were pale sulphur yellow, short-oval and about 5 mm. long. Some of the eggs occupying the deeper, slightly moist strata had hatched.

On December 13, there was a morning rain sufficient to wet the streets of Mombasa and to cause some of the *Achatina* to cast off their epiphragms. On December 15, a heavy morning shower brought out a number of the big fellows. Night activity probably also took place. A few days later, under the influence of dry weather, snails were again observed slightly buried in the soil. There had been some feeding by

the snails, however, as indicated by green droppings. When, on May 7, 1948, I again visited Mombasa to make observations on *Achatina*, monsoon rains had already fallen and fields and gardens were green. In the cemetery many large *Achatina* were crawling over the ground and one small group was revelling in a meal of damp old paper and cardboard. A large brood of recently hatched young were observed at the base of a sheltered wall and on and in the soil adjoining. Some weeks later a group of young, about double in size of shell than when just hatched, were seen on a wall. Enemies such as beetle larvae of the families Lampyridae and Drilidae and small streptaxid snails had already attacked these baby *Achatina*.

Achatina fulica hamillei was common on the island of Zanzibar. In January, 1948, I secured through the kindness of one of the government officials at the Kizimbani Agricultural Experiment Station, a large quantity of these snails collected when they were on the move at night. Most of these snails were immature. Among them were a few specimens of *Achatina fulica rodatzki*, an albino phase of the species, and some *A. iredalei*, a species of smaller size. *A. f. hamillei* was a familiar sight on the trunks of coconut palms, where they were stationed at heights from near the ground to at least ten feet and rarely ascending to as much as fifteen, as shown by the snail excrement adhering at that height.¹ Some of the snails were in movement on the trunks. I recall seeing on the trunk of a palm two specimens of the yellowish white *A. f. rodatzki* side by side among typical forms.

When I revisited Zanzibar in early June, young *Achatina fulica hamillei* of considerable size were in evidence. The snails, however, were still laying eggs, as shown in cleaning out the shells. On June 10, fair numbers, ranging in size from about 28 to 75 mm., were observed high up on tall cassava (*Manihot*) plants. I was told however, that they did no damage. Farmers in general seemed to pay little heed to these mollusks, although I was informed that years ago *Achatina* had become numerous enough to damage cassava and some other plants.

My few inquiries in East Africa as to whether these snails were ever eaten by man, brought negative replies. In this connection however, it is interesting to quote M. Connolly (A Monographic Survey of South African Non-marine Mollusca, Annals of the South African Museum, **33**, p. 326, 1939). In referring to the wide distribution of *Achatina fulica*, he concludes: "... , a remarkable fact when we remember that in their natural home on the east coast these creatures

¹ In July, 1948, on Koror, Palau Islands, in the tropical Pacific, the writer observed *Achatina fulica* quite commonly on trees and steep rocky banks. It ascended trees to an altitude of perhaps twelve feet, and sometimes small clusters of the snails could be found on the stems. The shells, particularly the last whorl were sometimes much broken due perhaps to falling off their perch.

do no harm whatever, save it to be to give possible indigestion to the indigenes who regard them as a culinary delicacy."

For an account of *Achatina fulica* in Hawaii the reader is referred to an excellent paper by C. E. Pemberton (Hawaiian Planters' Record, **42**, pp. 135-140, 1938). A bibliography referring chiefly to its introduction elsewhere is included. See also Jarrett, V. H. C., The Occurrence of the Snail *Achatina fulica* in Malaya (Singapore Naturalist, No. 2, pp. 73-76, 1923). Further information on this snail in the Pacific (Marianas: Saipan) is given by Dr. W. H. Lange, Field Associate in Entomology, Pacific Science Board, in a mimeographed First Report of the Pacific Science Board of the National Research Council—Insect Control Committee for Micronesia—1947, on pp. 6-8. The most recent account that I have seen is by R. Tucker Abbott: The spread and destructiveness of the Giant African Snail, *Achatina fulica* (The Nautilus, **62**, pp. 31-34, 1948). See also an informative report by E. E. Green on the history of *Achatina fulica* in Ceylon (Report on the Outbreak of *Achatina* in Ceylon; Circulars and Agricultural Journal of the Royal Botanic Garden, Ceylon, **5**, No. 7, Aug. 1910, pp. 55-64).

For damage to crops by *Achatina* in East Africa, see Entomological Leaflet No. 17, Dept. Agric. Tanganyika Territory, Dar es Salaam, 1938; Entomologist's Report (*Achatina craveni* Sm. damaging sesame and coffee).

3. ACHATINA RETICULATA Pfeiffer

Two brief visits to Chwaka Bay, on the east coast of Zanzibar, sum up my acquaintance with this large snail. It was rather common at a few hundred feet in from the seashore in the dense brush growing on a difficult terrain of rough coral formation. All that I recognized as *reticulata* were of large size. In June, one of these in a sheltered place in the rather moist environment still retained its epiphragm. None was observed on bushes or the coral banks. A single fire-killed specimen contained some eggs, well roasted.

4. ACHATINA ALBOPICTA E. A. Smith

On March 12, 1948, we arrived at Mombasa from a scouting trip in Uganda. The monsoon rains had not yet fallen and the country remained dry and very warm. Time was pressing, and we immediately set about looking for a permanent station where I could make extended field studies on *Achatina* and its enemies. One of the important officials of a larger Mombasa hotel kindly gave us a list of likely little country

hotels along the coast adjacent to Mombasa, and of which there were a surprising number tucked away among the trees along the magnificent beaches bordering the Indian Ocean. The first place, a very short distance from Mombasa, proved unsuitable, although dead shells of *Achatina* were found there. Pursuing our way further to the south along a road of very indifferent quality, for a distance of twelve or fourteen miles, we entered a side road, bordered by lantana and other bushes and small trees, that passed through a terrain composed largely of coral. As the rather decrepit vehicle bounced along, I peered over the side and with some difficulty fixed my gaze along the side of the road to perceive *Achatina* shells present in very gratifying numbers. The road soon terminated at the Diani Beach Hotel, in the Diani District. Arrangements were immediately made to occupy one of the bandas, a little two-room cottage plus bath: cement floor, coral-block walls, whitewashed exteriorly, and a roof of coconut palm thatch. The veranda extending along three sides of the building was covered with clean coral sand. We moved in on March 16. The spare room and veranda adjoining constituted the laboratory. Situated among trees, some 200 to 300 feet from the seashore, it was backed by a scrubby forest, much of it being of a thorny character, with many perennial vines and interspersed with large trees, such as the baobab, and an occasional branching palm (*Hyphaene coriacea* Gaertner). Nearby was an area of taller forest. The country, at least for a considerable distance inland, showed a coral formation,¹ with shallow soil and soil pockets. The soil composing these pockets and even that beneath the rather heavy forest litter was somewhat moist, and while the dry season still prevailed, many plants were in flower and tufts of green grass sprang up plentifully. This condition may be attributed in part to the heavy morning dew that was said to be then prevalent.

March 16. The whole forest abounded in *Achatina albopicta*. Most of the shells in full view were empty; some recently so and hence still well marked, while others had weathered over a long period and showed little or no pattern. It was chiefly among the latter that the largest shells, very rarely attaining a length of 175 mm., were found. But living snails were numerous under debris as well as slightly in the soil at the bases of trees and bushes, so that hundreds could be easily collected in a single day. Mollusks with shells over 100 mm. long were found only in moderate numbers, those between 50 and 80 mm. were abundant, while still younger living *Achatina* with shells 22 mm. or less were not commonly found. But there were many very young shells frequently broken and with the mollusk cleanly removed; these probably indicated the presence of enemies, and would also

¹ The coral deposit is so massive that it is quarried into large building blocks.

appear to indicate that, from one to several months previously, there had been considerable oviposition among the *Achatina*. Most of these snails and some other kinds as well, were in the resting condition, with an epiphragm sealing the mouth of the shell. There was however, some little activity among them, probably during the hours of darkness, for droppings and trails of slime were present here and there.

This *Achatina*, though essentially terrestrial, does climb trees and walls. It also climbs down from these heights — the spire then pointing downward —, and I believe, often falls to the ground, from the stress of sheer weight, particularly when it is awakening from its resting stage and would then attempt to seize hold of the substratum. A word here about the epiphragm elaborated by the snail to seal its shell when it is about to aestivate, will be appropriate. When passing the dry season more or less buried in loose soil or debris, it consists only of a calcareous sheet — with a narrow, slit-like groove — that extends conformably across the aperture at a slight distance from its margin. But when *Achatina* aestivates on a tree trunk it must adhere there. Perhaps it glues the margin of the shell to the bark, but this is hardly sufficient, at least in the case of a big heavy shell and mollusk. Hence one finds that the middle of the epiphragm has been widely and ovally extended as a shelly tube — perhaps to one half of an inch in length — to the bark to which it is glued, with a sort of pedestal effect. When the snails awaken and move away, these delicate calcareous objects, often more or less broken, may be quite numerous adhering to the huge trunk of some baobab tree, from a few inches to rarely twelve or thirteen feet up (Pl. 4, Fig. 1). Some of these modified epiphragms may date back to more than one season. I do not recollect seeing very small epiphragms upon the trunks of trees. *Achatina* often rests in the grooves or folds on the trunks of trees (Pl. 3, Fig. 3).

Early April rains at Diani brought out many *Achatina albopicta*. The majority remained on the forest floor, but some were ascending trees and shrubs. Later in the month heavier precipitation activated quantities of snails, so that in sheltered places, such as in the shade of a baobab, many were moving about or feeding until well in the middle of the afternoon. At dusk, numerous *Achatina*, usually not mature, ventured on roads, so that some were crushed by vehicle or pedestrian. On the evening of April 3rd, Mrs. Williams and I counted approximately 150 *Achatina* in a roadside area of about thirty square feet. This was a density greater than usual, in our experience.

These snails were seen climbing trees late in the afternoon or early in the evening. The greatest height at which I have seen one of these *Achatina* was an estimated nineteen feet, up the vertical trunk of a

baobab. Another was observed descending the trunk of such a tree from a height of about twelve feet. On June 3, three large *Achatina* were noted on the straight, relatively smooth trunk of tall forest trees at a height of about eight, ten and fifteen feet respectively. In places in the low forest they became common on the small trees, occasionally ascending to thirteen or fourteen vertical feet. More often than not they were well within the reach of the hand. It was evident that many remained on shrubs or trees for some time and often their excrement was deposited on the tree trunk or branch just above and to one side of the shell. Sometimes snails were found upon the leaves of a bush, the mollusk travelling along so slender a twig that its foot clasping this twig met broadly on the far side. Deposits of excrement, some of it greenish, occurred on bushes, tree trunks and on the ground.

Considerable rain seemed to be required to bring out quite small *Achatina*. They would then emerge from among soil and debris at the base of shrubs and trees and climb up the stems. Decaying heaps of trash thoroughly wetted by drenching rains in late April, produced multitudes of *Achatina*, both large and small.

Feeding. *Achatina albopicta* may eat a great variety of food, its tastes evidently being about the same as those of *Achatina fulica*. When freshly out of aestivation I have observed them many times munching at decaying leaves on the forest floor, their jaw often producing a fine scratching sound as they feed. The rind of an orange and the pulp in the pod of the baobab is to their liking. Yellowing leaves and green ones are also eaten. Among the plants that serve as food are *Commelina* sp., *Haemanthus* (Liliaceae), *Lantana camara* (Verbenaceae), *Carica papaya* (Caricaceae), *Boerhaavia diffusa* L (Nyctaginaceae), a small Euphorbiaceous weed, *Plumeria* (Apocynaceae), a leguminous shrub, a slender weed with a milky juice (Compositae), and lettuce. The leaves of many undetermined plants also served as food. A certain, finely branched shrub with soft leaves that was growing near the beach, was much patronized, particularly by the younger *Achatina*. But the eating of its leaves was not severe. They were often found high up on lantana bushes, while leafy bits of lantana branches that had fallen along the road were sure to be visited by them in the evening. These snails nibbled at fallen wild fruit, including the tough husks of the nuts of *Hyphaene coriacea*. Small groups of *Achatina* were seen feeding upon their fellows crushed on the roadside. They nibbled at the tough droppings of the pigmy deer, and I have seen as many as thirty individuals gathered about human excrement. *Achatina* is known to ingest coral, upon which I have often observed them apparently engaged in eating. Holes that appear to have been rasped, in empty shells suggest the work of *Achatina*. Furthermore, these snails climb the whitewashed coral walls of build-

ings, presumably in their search for lime. To complete this inadequate list of what *Achatina* swallows, the drinking of rain water accumulated in old shells was observed.

In all its feeding *Achatina*, though easily disturbed, impressed me as being leisurely, even desultory, in contrast to the brisk activity of a caterpillar engaged upon the same task. However, they can occasionally do considerable damage to succulent plants.

Breeding. The first observed mating was on April 27, the two snails joined by their sexual organs, lying side by side. Examination at this time of the ovaries of an *Achatina*, showed eggs not yet separating and but slightly developed. The next matings observed in the forest were on the mornings of May 1, 2, 3 and 4. Although some of the snails involved were of considerable size, none was mature. The following are the measurements of the pairs in mm.: 70 and 83, 73 and 117, 75 and 85, 78 and 115, 80 and 100, 82 and 120, 90 and 90, and 93 and 100.

On May 4th I discovered an *Achatina albopicta* with a shell 98 mm. long, in an area recently cleared of weeds. The mollusk, which had probably been sun-killed, contained a number of eggs visible within its last whorl. Further within the shell were numerous fly maggots. On May 31, just off a roadside, I found an overturned *A. albopicta*, its shell being 130 mm. long. It had probably been sickened by the sun for it was still alive. A large quantity of its pale yellow eggs lay alongside on the ground. They numbered approximately 330.

On May 25, and June 3, I examined some cut stems of the papaya "tree." These stems are largely hollow, juicy and brittle, though quite heavy. They had been placed several together on the ground near a pile of weeds alongside a thicket. The tissues of this plant are very attractive to *Achatina*. The rind had been scored rather deeply by their feeding, and where accessible the hollow interior of the stems was crowded with the snails. Even withered and dry papaya leaves were being munched. Under a felled papaya trunk there were numerous tiny *Achatina*, of two broods or sizes, and some young just hatched (May 25), besides a few eggs. Some of the tiny snails were feeding at the rind where it had been scored by the large *Achatina*.

ENEMIES OF ACHATINA

In places disturbed by man *Achatina* may be killed off in large numbers. Fires destroy a great many; quantities are crushed on roads; others that did not retire to a dependable shade by sunrise, may in the open spaces be killed by the heat of the sun.

The enemies of *Achatina* are fairly numerous. Among them are carnivorous snails (Streptaxidae), carabid beetles, and drilid and lampyrid beetle larvae. Certain vertebrates also feed on these snails.

1. Vertebrates

Bdeogale tenuis Thomas and Wroughton, of the Viverridae or civet cat family, is a mongoose-like animal known to feed extensively on *Achatina*. The animal holds the mollusk between its paws and strikes it rapidly against some hard object until the shell is broken. While in Zanzibar, where *Achatina fulica hamillei* is prevalent, some natives showed me five places near their village where the *Bdeogale* broke these shells, the noise of its operations being sometimes heard at night. In two instances the animal used coral outcrops as breaking blocks, in two others the base of a smooth-stemmed tree, while in the fifth instance a stone that had become firmly lodged near the level of the ground between the branches of a small tree served this purpose. Such places may be used over a considerable period, as shown by the quantity of broken shells and by the degree of weathering among them. As many as fifty shells, mostly broken ones, were found strewn about an eight-inch tree trunk, over a diameter of several feet. Generally, the shells were immature and about three inches long with the margin thin, though strong, and quite a task even for a man to break by striking it against some hard object.

At Diani Beach, on the mainland, I found evidence of the work of *Bdeogale* among *Achatina albopicta*. The species involved here was probably *B. crassicauda* Peters; or, it could have been a species of another genus of the Viverridae.

The *Bdeogale*, like some other members of the family Viverridae of shell-breaking habits, no doubt has tastes that would render it undesirable as an introduction elsewhere.

Scattered over the forest floor are many empty *Achatina* — and other shells — particularly quite immature ones, cleanly empty ones and frequently with their thin margins broken back. Among the several factors that may be responsible for the premature death of those mollusks, rodents must play a part here, as they are known to do elsewhere.

2. Crustacea

Land crabs. A sturdy, pinkish or light brown crab living in holes in the sand-mixed soil at some distance behind the beach in the Diani district, is an enemy of *Achatina*. The large mollusk literally swarms

in parts of the scrubby forest that may extend to the seashore, so that it not infrequently falls a victim to the redoubtable crustacean. On three occasions the crab was observed feeding on *Achatina* at the mouth of its burrow, to which it had probably dragged the mollusk. With its strong chelae, it cuts out portions of the shell to enable it to reach the meat within (Pl. 3, Fig. 2; Pl. 5, Fig. 5). One rather small crab, with a carapace one and three-fourth inches across, was found to have overcome an *Achatina* with a shell nearly two and one-half inches long.

Other observed prey of this land crab were a large cylindrical millipede, in this case four inches long, the body of which had been deeply cut into by the crab's sharp nippers, and a stout four-inch long black and brick red caterpillar with strong spines, of a ceratocampid (?) moth. Numerous such caterpillars were observed one morning descending the trunk of a tree to enter the ground or hide beneath debris for pupation.

3. Mollusca

Streptaxidae (Carnivorous or rapacious snails). Probably the most effective enemies of *Achatina* as observed in East Africa, are the carnivorous snails. With this statement Dr. J. C. Bequaert, who has long studied the *Achatinae* in Africa, concurs. Although naturally less abundant than their prey, the Streptaxidae are numerous in species. As far as I have observed, they are of generally secretive habits and very seldom found off the ground. They are frequently active under the cover of dead leaves and sometimes seek their prey barely beneath the loose soil. Some of the small species may occur under logs and large stones. *Edentulina affinis* C. R. Boettger, a large species, was found in a single instance about two feet off the ground on the underhanging side of the partly dead trunk of a sloping tree. It seemed to have followed an *Achatina* there, for the empty shell of the latter was resting on a small projection at a little distance below the streptaxid. Rarely, dead shells of *Edentulina* were found on the spreading roots overlying the ground, of a large tree.

Nearly all my data referring to *Edentulina* and *Gonaxis*, comprising the larger predacious snails, were obtained in the Diani District in the months of March, April and May. Under dry conditions, during the first part of my stay there, many of these snails were in a resting condition, having sealed the aperture of their shell a short distance within with a thin epiphragm. While they kill large numbers of *Achatina*, they are not selective and likewise attack other species of snails — and slugs — in laboratory experiments. They will eat their

own kind in the laboratory and at least sometimes in the field. One species of terrestrial snail that to some extent appeared successful in resisting the attacks of the carnivorous species was *Maizania magilensis* (Craven), which is provided with a strong corneous operculum.

Edentulina affinis has a whitish convexly-conic shell that reaches a length of about 50 mm. The mollusk itself is orange. Empty shells were far more commonly found than living specimens. The former were scattered over the forest floor, so that thirty or more specimens might be collected in half a day. Living *Edentulina* were found under dead leaves, in soil pockets among the coral substratum, and more or less secreted under large root bases overlying the ground. They occurred singly or, as once noted, as a small colony of half-grown, well-spaced individuals. They were not often found in exposed places. On April 2, a young one was noted upon a leaf on the ground; on May 10, an adult was found resting about two feet up the under slope of a tree trunk; and on the same date another grown *Edentulina*, 43 mm. long, was observed on the forest floor devouring an *Achatina* with a shell 55 mm. long, the slender fore part of the carnivore being deeply inserted into the aperture of the shell of its victim (Pl. 3, Fig. 5). On May 2, towards evening, another adult *Edentulina* was taken in the middle of a wooded road where it had been feeding upon the crushed remains of an *Achatina*.

Most of these findings were during the wet season.

Wholly consuming as they may their so often relatively large victims, both *Edentulina* and *Gonaxis* are frequently too gorged to immediately attack another snail. Not only is the mollusk itself devoured but the shell may, in the need for lime, be scraped to a point of local collapse.

It is probable that the biotic potential of *Edentulina* is less than that of *Achatina*. It probably lays fewer eggs, and, being specialized to a diet of flesh, would turn to (greater ?) cannibalism in times of scarcity. These large carnivores have their enemies also. Drilid beetles reduce their numbers, and it was not unusual to find both young and mature shells of *Edentulina* as well as *Gonaxis* containing the bristly, caudally pronged moult skin of a drilid larva.

Along the coast some eight or nine miles north of Mombasa, the empty shells of the smaller *Edentulina obesa* (Taylor) were found.

Gonaxis kibweziensis E. A. Smith. This smaller, apparently more hardy and adaptable species outnumbered *Edentulina affinis* roughly five or six to one. The shell is wide and dorso-ventrally distorted, as if stepped upon obliquely, so that the aperture is far off center. The whorls are delicately ribbed. It is translucent whitish so that the orange mollusk is visible through the shell. The greatest length is about 22 mm.

Gonaxis was for a time rather easy to find under leaf cover and in the loose, often sandy soil at the base of grass clumps; similarly under small low spreading trees, at the base of a coral escarpment and in soil pockets. Usually this snail was more readily found during the dry season when there was less vegetation to interfere with its search. I once found a number of young *Achatina*, from about 15 to 35 mm. long, among dead leaves and slightly moist soil at the foot of a small tree. In this colony were three adult *Gonaxis* each of which was feeding upon an *Achatina* somewhat smaller than itself. Later on, I uncovered two adult *Gonaxis*, the one being devoured by the other, the victor with its fore part deeply inserted into the nearly empty shell of the vanquished. On the other hand, a *Gonaxis* in the laboratory was observed feeding side by side with an *Edentulina* upon an *Achatina* 60 mm. long, which the larger carnivore had overcome. A single *Gonaxis kibweziensis* evidently killed by the heat of the sun was collected on a road, beside an *Achatina* that had been crushed by pedestrian or vehicle.

Gonaxis also feeds extensively on *Pseudoglessula boivini* (Morelet), a rather small snail with an oblong-conic, finely striated shell that dwells among dead leaf cover and soil.

Young *Gonaxis* were not uncommon, but no eggs of this snail were certainly identified as such.

Among the few other species of carnivorous snails observed were some belonging to the genus *Gulella*. These small, often strongly sculptured snails are probably effective enemies of quite young *Achatina*, among which they may sometimes be found.

4. Insecta

Carabidae (ground beetles). A number of Carabidae of large size were found in East Africa. Species representing several genera, including *Anthia*, *Calosoma*, *Galerita*, *Psecadius* and *Tefflus*, were given laboratory tests to determine if they would feed on living *Achatina* snails.

Anthia sp. This black beetle marked with whitish, of rather savage disposition, emits a strong defensive secretion. It would not touch small *Achatina*. Neither would a smaller, roughly sculptured, all-black species of *Anthia*.

Calosoma sp. A swift black beetle over an inch long. It savagely ripped open and devoured the hairy caterpillars I offered it. Under stress of hunger it devoured young *Achatina*. Two of its victims had shells 30 and 38 mm. long, respectively.

Galerita sp. This slender beetle refused small *Achatina*.

Psecadius. Nearly three-fourths of an inch long. Shaped somewhat like a *Cychrus*. Elytra spotted. They refused several freshly hatched *Achatina* offered them.

Tefflus spp. A purely African genus. The fore part is relatively narrow with the thorax heart-shaped and the strongly-grooved wing covers fused together, gently tapering at either end; apex subtruncate in the female. Running with moderate speed. They appear to be rather uncommon.

Three or four species of these rather mild-mannered beetles were found. Smaller species, a little more than an inch long, taken at 3,000 feet in the Usambara Mts., and in the Diani District near Mombasa, would not eat *Achatina*, even quite young ones. It is possible, however, that my tests were not sufficiently extensive and that they, eventually feeling more at home, would have attacked *Achatina*.

But a species of *Tefflus*, somewhat less than two inches long, is definitely a feeder on snails (Pl. 3, Fig. 4). My first acquaintance with it was at Mombasa on the mid morning of December 18, 1947. Here on one of my rounds of inspection of a little colony of *Achatina fulica hamillei* in a small wooded area, I came upon one of these beetles on a coral outcrop, with its head and thorax in part inserted into a 30 mm. *Achatina* shell. The beetle, which lacked one of its middle legs, was very much engrossed in its meal. I pulled it free of the shell and brought it to my room where it again returned to its feeding, turning over the shell with its feet so as to conveniently reach the aperture. After settling down in the Diani District, I kept a constant lookout for this *Tefflus* during my forest ramblings. On a very few occasions portions of its elytra were found showing that it had some enemies. Finally, on April 30, 1948, following some rains, a fine specimen was captured among debris lodged a short distance up a hollow tree trunk in a scrub forest. For some days it refused *Achatina* in its large jar prison, but finally it consumed them regularly, so that by May 31 it had devoured completely or in great measure, eighteen *Achatina* ranging in length of shell from 20 to 50 mm. These were mostly attacked toward and during the evening when *Tefflus* came out of hiding from among the dry leaves in its jar. It would turn over the shell with its legs and quickly bite the withdrawing mollusk. Whether the carabid injected a liquifying fluid into its victim, was not determined; at any rate there was often much liquid at the aperture and the mollusk would eventually become loose from the innermost whorls. If the shell aperture crowded the large beetle, the outer whorl would be broken down sufficiently by means of the stout jaws. It seems that *Tefflus* may not finish its meal at one sitting, revisiting the shell so that we sometimes found it eating in the morning.

As the time for my return to the United States was drawing near and I had hunted in vain for additional large *Tefflus*¹, recourse was had to Native help in the Diani District, for additional live specimens. An offer of a shilling apiece for these beetles soon set a number of eager Africans searching under heaps of weeds, among dead leaves beneath mango trees, etc. Thus, in eight or nine days, about fifteen of the beetles were secured. Male specimens predominated at first.

In addition, a number of smaller species of carabid beetles were brought to me with some confidence. But when I informed the bringers that these were not the kind of beetle desired, my pronouncement was regarded with suspicion, since it was claimed that these smaller specimens were but young of the larger one!

Kept in pairs in large glass jars, *Tefflus* mated readily enough and several individuals lived amicably in one receptacle. Small *Achatina* snails were consumed in some numbers. Apparently no eggs were laid.

A few live *Tefflus* were brought to Honolulu for experimentation under quarantine conditions. Several survived four months in captivity.

I believe that in the coastal regions of East Africa *Tefflus* feeds primarily on *Achatina*.

A taste for snails is of course found in species of large Carabidae in other parts of the world.

Drilidae. Drilid beetles are important enemies of snails. Their peculiar life-history — involving a protracted larval stage interrupted by pseudo-pupal phases — has made them the object of study chiefly in Europe and North Africa.

My first view of a drilid was of a large larva with sickle-like jaws, collected by Dr. J. C. Bequaert from the shell of an *Achatina* in Sodu, Liberia, in 1944. Mention is made of finding Drilidae in *Achatina* in British East Africa in E. Olivier's: *Insectes, Coléoptères, VII, Lampyridae et Drilidae. Voyage Alluaud et Jeannel Afr. Orient. Angl. (1911-12), 1914. With Appendix by P. de Peyerimhoff, Sur deux femelles larviformes de Malacodermes.*

As studied in material from East Africa, the male drilid is of normal malacoderm appearance and is capable of flight; the female is a great heavy wingless creature with short antennae (Pl. 4, Fig. 3). After laying her eggs she contracts a good deal and then suggests, somewhat, a fat wingless cockroach. She is little more than an egg-laying machine. Neither sex appears to eat snails, and I do not know if the adults eat at all. The larva has strong curved jaws and is quite bristly beyond the thorax, the posterior end terminating in a pair of lobes or

¹ On June 7, I found my third specimen. It was under a piece of coral at Mombasa.

more conical processes bearing several stout spines, among the shorter bristles (Pl. 5, Figs. 1, 3, 4). In this stage it spends most of its time in snail shells, devouring first, as befits its size, very small snails, then attacking others of larger and larger size — perhaps not invariably larger — undergoing moults in the shells, and transforming to the adult in the shell of its last victim. The finding of drilid larvae wandering about at large indicates that the desired snail victim is not always soon found.

The last victim of drilids that feed upon *Achatina* may be quite large — up to 115 mm. in length of shell, as observed in the case of *Achatina f. hamillei* at Mombasa. The male drilid being much smaller than the female does not require so large a shell.

The larval stage in drilids is by far the longest part of their existence. I have followed but little of their development and reared none to maturity. Only a few larvae were found, although a considerable number of moult skins, often in poor condition, were obtained. These were chiefly from *Achatina f. hamillei*, rarely from *A. iredalei*. They were common in *Edentulina* and *Gonaxis* and very rare in *Pseudoglossula* and in another very small species of land snail. But to attempt to work out the stages of these Drilidae, constituting perhaps more than one species, on this incomplete data would be to fail in exactness. However, L. C. Crawshay in England has worked out the life-history of *Drilus flavescens* Rossi (Trans. Ent. Soc. London, 1903, pp. 36-51, Pls. 1 and 2), while A. Cros has done the same for *D. mauritanicus* Lucas, in Algeria (Bull. Soc. Hist. Nat. Afrique du Nord, 1926, **17**, pp. 181-206, Pls. VIII, IX (IX) and X). Here the larval stages, involving resting forms, may extend into the third or fourth year. Prior to pupation there is a sort of false pupal stage involving a moult. These two drilids are a good deal smaller than the one in *Achatina* considered here. Other references on North African Drilidae are: Lucas, H., 1842, C. R. Acad. Sci. (Paris), **15**, pp. 1187-1189; Lucas, H., 1870, An. Soc. Ent. France, (4), **10**, Bul. Séances, pp. lvii-lviii; and Lucas, H., 1871, An. Soc. Ent. France, (5), **1**, pp. 19-28, Pl. 1.

With the coming of the rains, the *Achatina* lay their hard-shelled pale sulphur-yellow eggs. These soon hatch and the tiny young, gregarious for a time, are attacked by enemies of several kinds. Thus, during May, I located, chiefly at Mombasa, several perhaps first stage drilid larvae, each within the shell of a young *Achatina*. At Diani Beach, I collected one of these drilid larvae, pale yellowish, 3.5 mm. long, at large in the leaf debris of a tamarind tree. Placing this larva in a vial with a young epiphragmed *Gonaxis* 7.5 mm. in diameter, it showed some interest in the mollusk, attempting to bite through its epiphragm, but soon gave up the attempt and wandered off. The next

day, I offered it a new born *Achatina fulica hamillei*. It took immediate interest in this snail, clinging to the shell and moving about on it. The larva seemed to be chewing at the shell. It remained thus exposed upon the shell for some hours. By the following morning the little drilid, now healthily distended, was located in the last whorl of its host. Small grains of sand, glued to the edge of the shell, suggested that an effort had been made to seal the shell. Another tiny *Achatina* shell that contained a young drilid lay mouth down in its jar of sand, its aperture lightly plugged by a slightly moist ball of sand.

On May 7 I discovered a dead female drilid beetle in the *Achatina* colony in the old Mohammedan cemetery at Mombasa. She appeared rather recently dead, being soft and well preserved, and contracted because she had already laid her eggs. The color was chestnut brown, with the shining tergal plates largely blackish. The length was 32 mm. and the widest part of the abdomen was 18 mm. The dark apical portions of the mandibles were only slightly curved and these organs were hardly as well developed as in the larva. The antennae were seven-jointed with a small conical bristle-bearing tubercle on the last joint. The sides of the abdomen were drawn out rather triangularly and the abdomen terminated in a small subquadrate segment bearing a pair of papilla-like processes. The vestiture consisted of short brown hair. Altogether, this insect somewhat resembled a cockroach of the burrowing type. It was quite likely that she was the mother of some of the tiny drilids infesting the newly hatched *Achatina* nearby.

At least at the beginning of its life, the drilid larva moults at relatively short intervals. A specimen collected on May 27 in an *Achatina f. hamillei* shell 7.5 mm. long, moulted in this shell on May 30, to enter a shell of the same species 14.5 mm. long. This larva was of an orange color, with a dark segmental spot each side of the dorsal line. A larger drilid larva, perhaps 11 mm. long, was found wandering over the ground at Diani Beach on May 4. I placed it in a jar with a small *Achatina* and a mature *Edentulina*. It took no interest in these snails, but finally after some days of crawling and resting it went under the light soil and evidently moulted there. Soon afterward it attacked and entered the shell of a small *Achatina* offered it.

The female drilid larva grows to a considerable size, probably to at least 50 mm. judging from exuviae of the last active larval stage. It is provided dorsally with orange segmental plates with two black spots. These plates are armed with bristly hairs, while laterally on each abdominal segment are slightly curved, chitinized, somewhat finger-like processes that are quite bristly, as is the stout terminal lobate process, each lobe terminating in a stout spine and two smaller subterminal ones. The antennae are short, two-jointed and with a

terminal process; the jaws are stout and evenly curved. This larva eventually moults into what is apparently a non-feeding form, less bristly anteriorly and with the lateral abdominal processes more stubby, and with the bristly hair shorter giving it a coarse velvety appearance, the terminal thorn-tipped lobes being shorter and more or less buried in the stiff hair. The head is less developed and the jaws much weaker than in the previous stage. I found one such larva in an *Achatina* shell at Mombasa on December 19. Its fore part, relatively unarmed, was twisted and crammed quite out of sight in the spire, while the rather depressed abdominal portion was about 22 mm. long. The formidable bristly posterior suggested an adaptation for defence. On about January 5, 1948, it had shed its bristly skin, thereby exposing a delicate pale yellow "pseudopupa." This was capable of some stretching and wriggling and thus varying in length from 38 to 45 mm. It now looked very naked there being only some short hairy vestiture. There appeared to be no eye spots, the antennae were very short and papilla-like, the jaws small and encased, the legs weak. There were eight finger-like lateral abdominal lobes and a single short spine each side of the broad apex of the last segment. By about January 18 or 19, this "pseudopupa" had cast in part its thin exuviae, and showed a pale yellow true pupa with the head better developed, eye spots plainly visible, antennae still short though larger and with many segments, abdominal processes greatly reduced, and cauda hidden by crumpled and adhering skin. This pupa soon died. However, apical portions of pupal skins taken out of other *Achatina f. hamillei* shells show the two-fingered membranous case that envelops the subquadrate segment bearing two papilla-like processes, of the adult female beetle.

Portions of all four of these pre-adult skins were found in one *Achatina* shell. These are: 1, the last stage black-spotted bristly larva; 2, the first resting? stage with shorter but dense bristles having a coarse velvety appearance, jaws probably not functional; 3, the pseudopupa, almost naked and with a single short spine each side of the broad apex of the last segment, jaws still weaker; and 4, the true pupa, with the apical part much as the adult female, jaws stronger.

These beetles are rather effective enemies of *Achatina f. hamillei* and probably other species. At Mombasa, out of 48 empty shells ranging from 53 to 115 mm. long, seven contained drilid exuviae. These exuviae are not usually visible at the aperture of the larger shells, which must be broken down to reveal them, or the skins dislodged by jarring or by means of water. Quite young, thin shells when held up to the light may show the pronged outline of the posterior portion of small drilid exuviae.

Despite the examination of hundreds of *Achatina albopicta* shells in the Diani District, in but one, a doubtful instance, did I find evidence of a drilid, although exuviae of Drilidae were of frequent occurrence in the shells of both *Edentulina* and *Gonaxis* there.

According to excellent authority at the Coryndon Museum at Nairobi, the commonest drilid on the east coast of Africa is *Selasia pulchra* Pascoe. The male of this species is largely yellow with the antennae flabellate. It is to be taken at light.

Lampyridae (Fireflies and glow-worms). The larvae of these beetles are among the best known natural enemies of land snails, and studies on their habits date back to at least the middle of the last century.

Only a few observations were made on these insects in East Africa. Nearly all the lampyrid larvae found there readily attacked quite small *Achatina*, and it seems probable that they are generally non-selective as regards the kind of snail eaten. One larva consumes several snails in its lifetime. In Mombasa, small lampyrid larvae were found among newly hatched *Achatina f. hamillei*, which they were devouring.

In Ceylon, the larva of *Lamprophorus tenebrosus* Walker, a large lampyrid found also in Malaya and India, is predacious on the introduced *Achatina fulica*. Two important papers dealing with its habits are: one by C. A. Paiva, on this glow-worm as occurring in India (Rec. Indian Mus. **16**, pp. 21-28, Pl. 8, 1919), another by J. C. Hutson and G. D. Austin, as occurring in Ceylon (Dept. Agric. Ceylon, Bull. **69**, 16 pp., 1 Pl., 1924).

Histeridae. A small beetle of this family was once found among fly maggots in a dead *Achatina* at Diani Beach. It probably fed on these maggots, as many of the Histeridae are partial to larvae of other insects.

Scarabaeidae, subfamily Coprinae. Beetles of this subfamily were frequent visitors at dead *Achatinae*. A small, brilliant green species was common among crushed snails along the roadside at Diani Beach. One such beetle was observed cutting off a portion of the ovary of an *Achatina*, forming it into a ball which it rolled to the middle of the road, and there dug a hole in which to bury it. This provender would serve as food for its young.

This coprid beetle and a larger one of duller greenish hues, both kinds usually working in pairs, dig a steep hole more or less beneath a dead *Achatina*, the shell aperture of which faces downward. The soil which the beetles bring to the surface often fills a large portion of this shell, in which the coprids may sometimes be found. Presumably, portions of the dead mollusk are detached and buried in the hole.

Diptera (Flies). Although several muscoid flies are definitely known to be parasites of certain land snails, I was unable to prove that the

two or more species of muscoid flies (*Sarcophaga*, *Panaga* and *Aethiopomyia*), that I bred from *Achatina* ever attacked healthy snails.

Here are some findings at Diani Beach:

1. A very sick specimen of *Achatina albopicta* with a few tiny fly maggots on its foot, was found afield. It was taken to the laboratory and placed in a jar somewhat loosely closed with a lid. In about 21 days it yielded *Sarcophaga* flies.

2. An *Achatina* in the laboratory was killed and partly eaten by one of the carnivorous snails (Streptaxidae). I marked it and placed it at the foot of a baobab tree in forest where it remained for two days, after which it was placed in a screw-top jar in the laboratory. In about 15 days after the exposure some *Panaga* flies emerged, and 9 or 10 days later, 2 *Sarcophaga* issued.

3. Two mature *Achatina albopicta* were submerged in water until nearly drowned. Then they were placed at the foot of a baobab tree. They were very weak, but lived well on into the second day. I took them to the laboratory and placed them in a jar, where they soon were seething with maggots. From one or both of these snails *Sarcophaga*, and one *Panaga* fly issued. There was a possibility of contamination in the laboratory by some of these flies.

It seems to me doubtful if the several sick, fly-infested *Achatina* that I found afield had in the first place sickened because of the attacks of these flies. *Achatina* are often killed in exposed situations by the heat of the sun.

A fly of ordinary *Sarcophaga* appearance is often seen on dead *Achatina*, even in the hot sunshine. It appears to deposit its tiny maggots only on sick and dead snails. On reaching maturity these maggots transform into rather slender fusiform puparia. The life-cycle, from larviposition to the hatching of the adult fly, was estimated at about twenty-one to slightly more, days.

There are several species of the *Panaga* complex found at Diani. The commonest of these stout brown flies is about 7 to 8.5 mm. long. A second species is much larger, measuring about 13 mm. long. These flies are shade lovers and are often active towards sunset. They may be of common occurrence on the lower portion of the huge trunks of baobab trees (*Adansonia digitata* L.), about shaded coral cliffs, and in the shade along roadsides where they are often attracted to the crushed *Achatina*. The smaller species was often abundant on the forest floor, often perching among fallen fruit there. Certain individuals fly in zigzags or curves low over the ground, with a shrill buzz. None was ever seen attacking a living *Achatina*, although occasionally alighting on shell or mollusk as a convenience. One of these smaller *Panaga* was observed ovipositing on a drowned *Achatina*. The egg is about

2.25 mm. long, white and tough, fusiform, with a sort of wide flange extending from either side of the length that is to be glued down. The larvae are active in the foul-smelling liquid that accumulates in the shell, and are found on the flesh itself. The puparia are arranged more or less in rows, being glued to the aperture, in view to far out of sight within. They are stout, broadly rounded at the ends and somewhat arcuate from the substratum. In the few cases studied, the time from the laying of the egg to the hatching of the adult fly occupied from fifteen to twenty days. Over eighty flies hatched from a large specimen of *Achatina f. hamillei*, and it is probable that this number may be greatly exceeded.

The smaller of these *Panaga* flies finally became very numerous about the laboratory at Diani Beach where I cleaned out *Achatina* shells. They deposited their strongly adhering eggs, often in large numbers, on the foot, and particularly the shell, of drowned snails, or at the water's edge of a bucket, or where the lid fits the jar that contained these dead mollusks. One of these *Panaga* even entered the aperture of *Cypræacassis rufa* (L.), a large marine shell, the mollusk of which had been dead for at least a week and of which only a small portion remained in the shell. These flies could become a nuisance. The larger, more feral *Aethiopomyia*, was not often seen in the laboratory. It too, breeds in *Achatina* as well as in one or both of the large carnivorous snails, if the large puparia found in these shells belong to this species.

At least some of these snail flies are attacked by wasp parasites. Small chalcids were reared from one *Achatina* shell that contained fly puparia. A large black chalcid with legs in part red, attracted by the odor (?) of dead or sick snails, follows closely upon the ovipositions and larvipositions of these muscoid flies. One of these wasps was observed jabbing at a small fly maggot on the surface of a dead or nearly dead *Achatina albopicta* snail that I had exposed to the attack of these flies. Similarly this wasp is attracted to snails drowned in a bucket of water. And occasionally one finds a *Panaga* puparium with the emergence hole of what may well be this chalcid.

Keilin (Parasitology, 1919, **11**, pp. 430-455, Pls. 22-25) in writing of *Mydaea*, under (2) Carnivorous Forms, remarks: "*Mydaea* sp. allied to *Mydaea bivittata* Macq. In a recent paper by Rodhain and Bequaert (1916, p. 248) we find the following observation on the feeding habit of the larvae of this Anthomyid: "The genus *Mydaea* exists in Central Africa and its larvae are carnivorous; one of us bred at Kivou a great number of a species allied to *M. bivittata* Macq. (identified by Dr. Villeneuve) from the larvae devouring a big terrestrial mollusk (*Burtoa nilotica* Pfeiff.). . . .'"

For a comprehensive paper on the arthropod enemies of mollusks, see J. C. Bequaert (Medical Rept. Hamilton Rice 7th Exped. to Amazon, 1926, pp. 292-303. Harvard University Press, Cambridge).

During the rains many dead and empty *Achatina* shells that rest mouth upwards in the forest, may receive a good deal of water that is retained over a considerable period. Thus, a large number of such containers serve as breeding places for certain mosquitoes (*Aedes* and *Eretmapodites*). In places along the East Coast of Africa, such breeding places for mosquitoes are destroyed by order of the Department of Public Health.

Less commonly, *Achatina* shells at Diani Beach containing rain water provided a breeding place for a species of toad, *Bufo micranotis* Loveridge, subsp. (as determined by Mr. A. Loveridge). Two such shells containing a few tadpoles were found in a well-shaded spot in the forest. Several of these amphibians were reared to the juvenile adult condition.

CONCLUSIONS

The following are the most important conclusions reached from my study of the predacious enemies of *Achatina* in East Africa. No true parasites were found.

The Streptaxidae, or rapacious snails, are ruthless enemies of snails in general. Probably they are the most effective natural control of *Achatina* in Africa. No such snails are native in the Pacific Islands.

The larvae of drilid and lampyrid beetles also destroy a great many *Achatina*. Some of the Lampyridae (fire flies) are able to climb trees.

The adults of the large ground beetle, *Tefflus*, seem to feed principally on *Achatina*, but probably are a less effective control than the Streptaxidae, Drilidae and Lampyridae.

If these predators were successfully established on some of the Pacific Islands where the giant African snail (*Achatina fulica*) is present, undoubtedly they would reduce the *Achatina* population considerably. However, the native terrestrial, but probably not the whole arboreal, land snail fauna undoubtedly also would be reduced, though perhaps not exterminated.

As these predators multiply rather slowly, results would not be apparent for a year or more.

I doubt very much if there are any enemies strictly specific to *Achatina*.

PLATE 1

PLATE 1

- Fig. 1. *Achatina reticulata* Pfeiffer.
- Fig. 2. *Achatina fulica hamillei* Petit.
- Fig. 3. *Achatina iredalei* Preston.

Living snails at Cambridge. Photographs by Miss Ruth Turner. Greatly reduced.

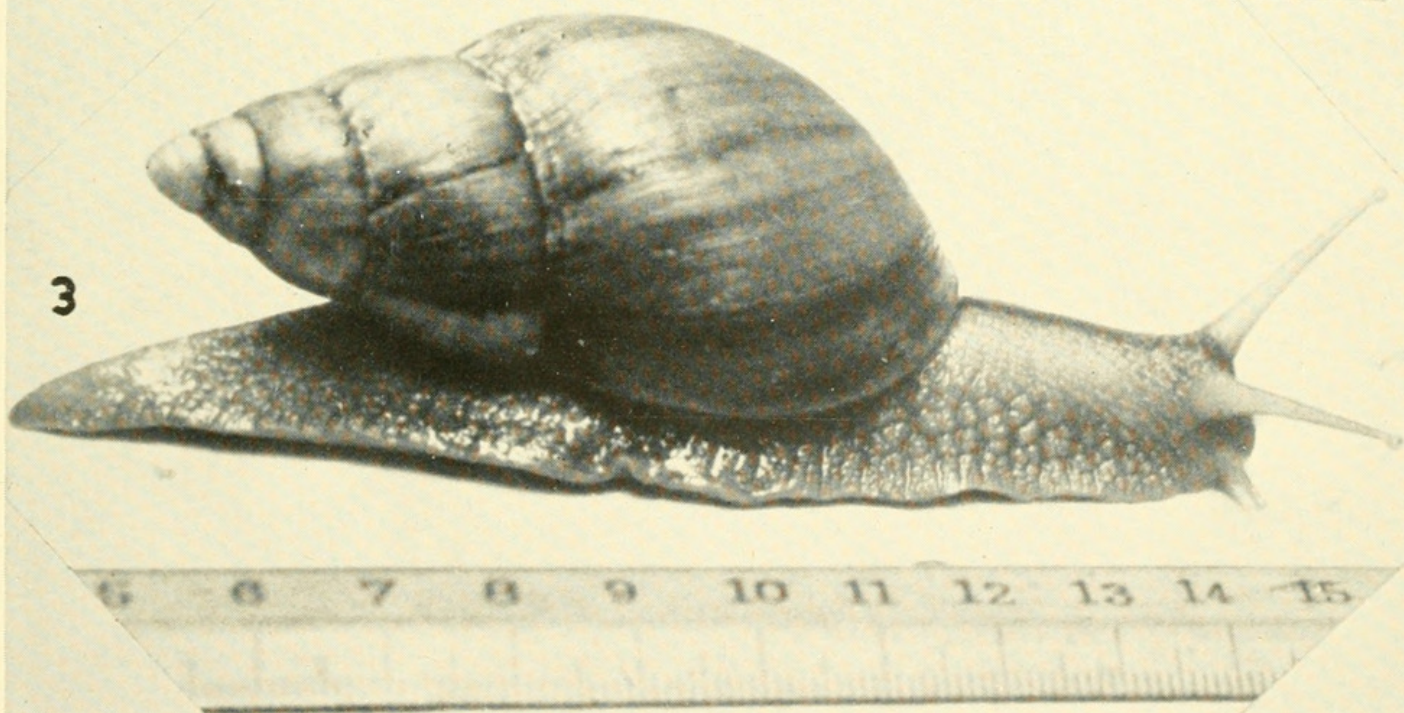
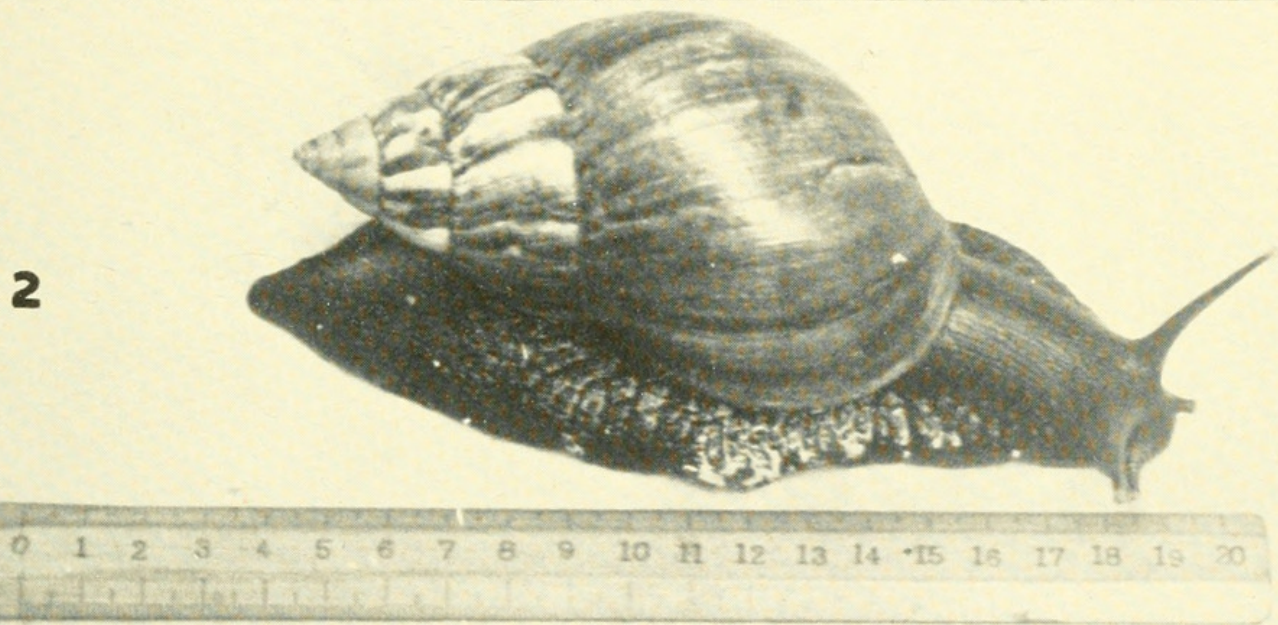
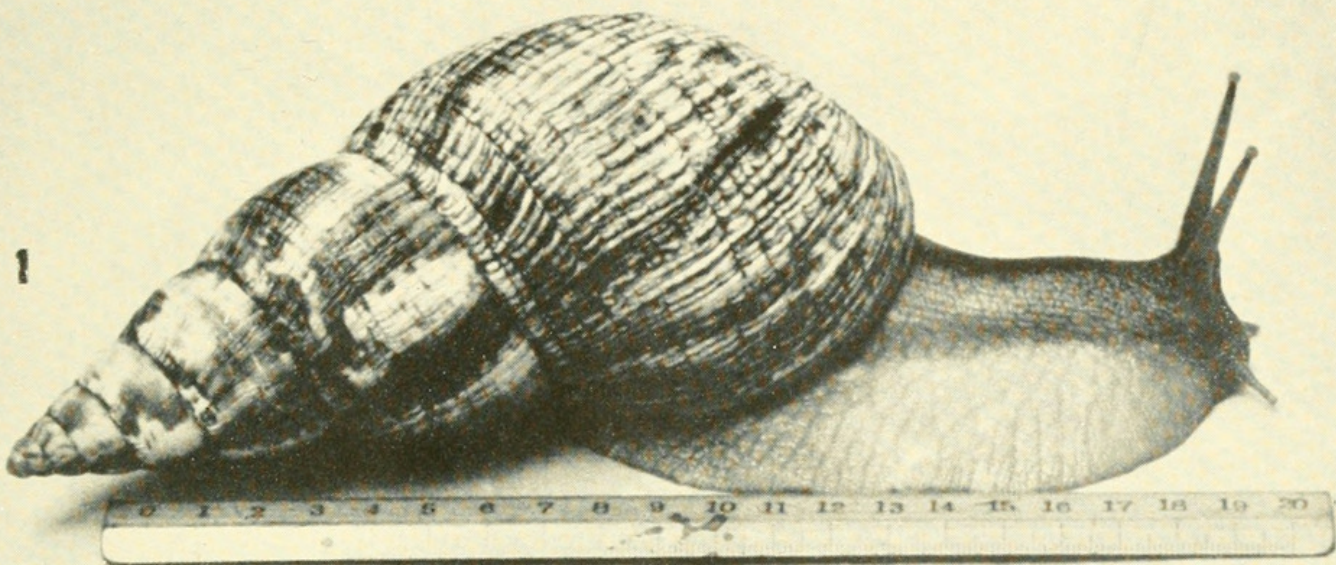


PLATE 2

PLATE 2

- Fig. 1. *Achatina reticulata* Pfeiffer.
- Fig. 2. *Achatina albopicta* E. A. Smith.
- Fig. 3. *Achatina fulica rodatzii* Dunker.

Living snails at Cambridge. Photographs by Miss Ruth Turner. Greatly reduced.

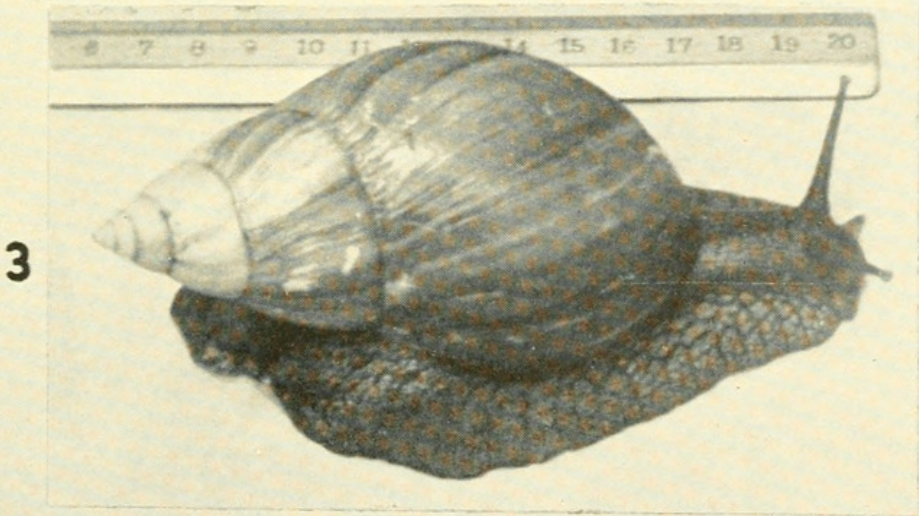
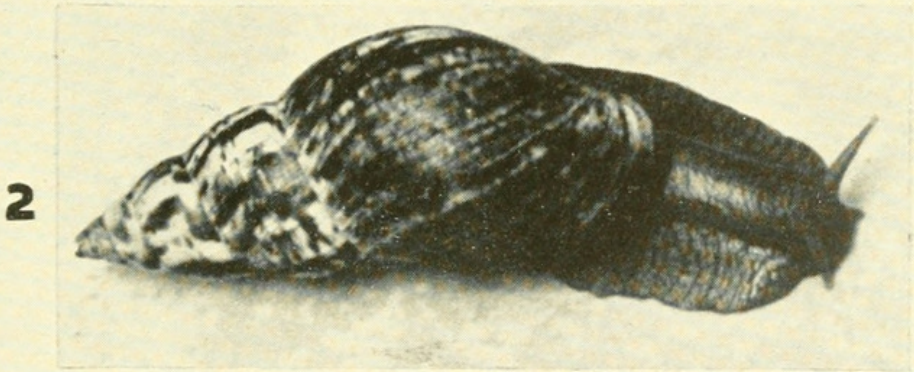
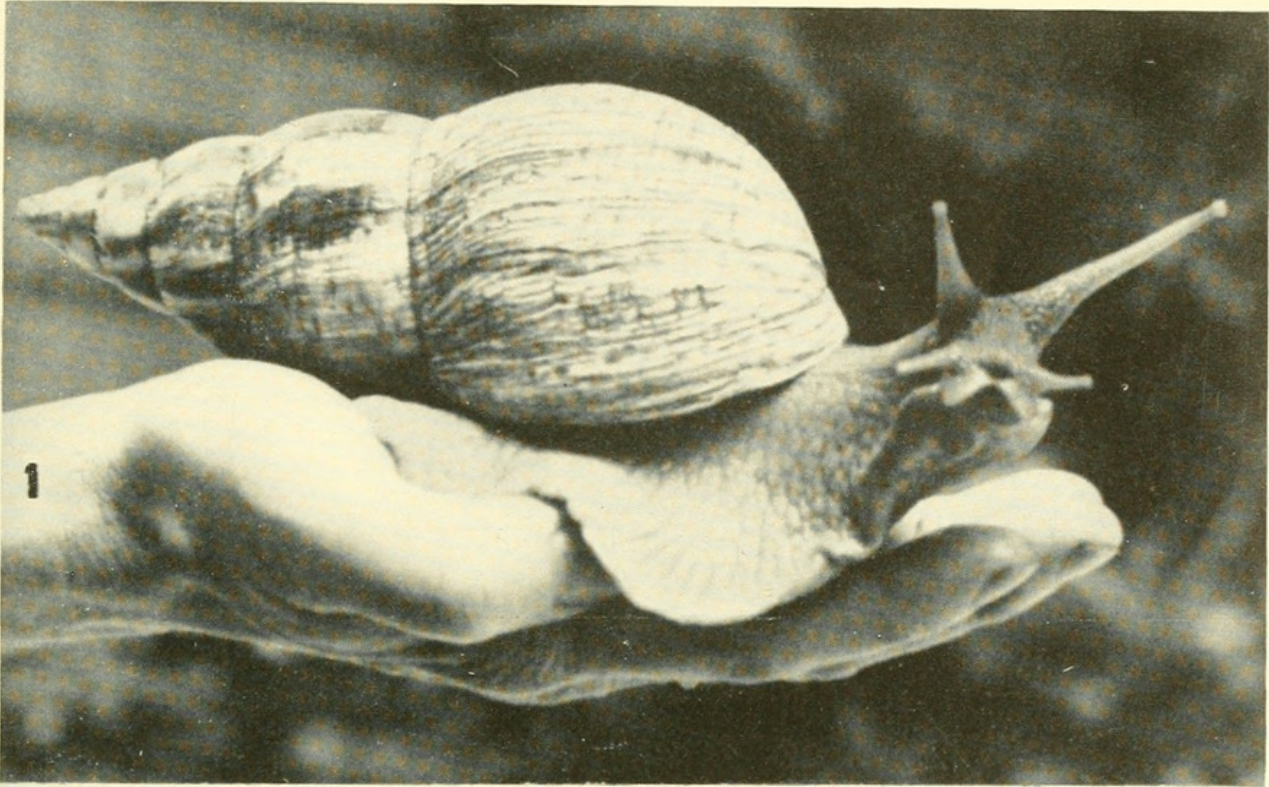


PLATE 3

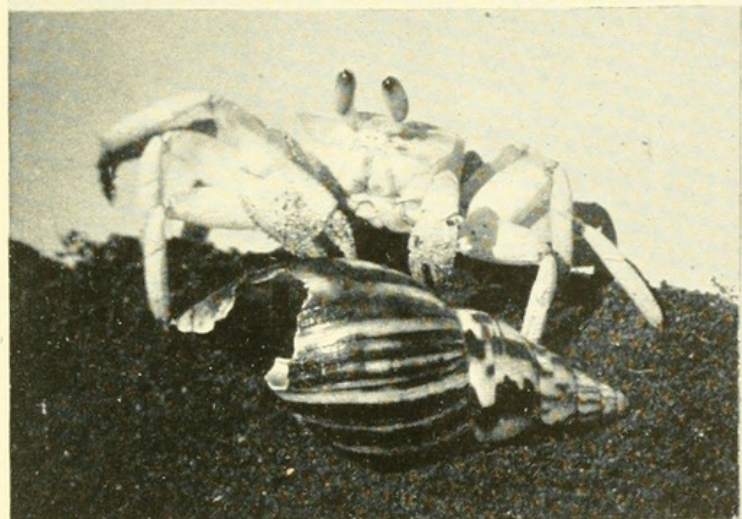
PLATE 3

- Fig. 1. *Achatina albopicta* E. A. Smith. In bush at Diani Beach.
Fig. 2. Land crab attacking *Achatina albopicta* at Diani Beach.
Fig. 3. *Achatina albopicta* wedged in furrow of a tree at Diani Beach.
Fig. 4. *Tefflus* beetle devouring young *Achatina fulica hamillei* at Mombasa.
Fig. 5. *Edentulina affinis* C. R. Boettger devouring *Achatina albopicta* at Diani Beach.

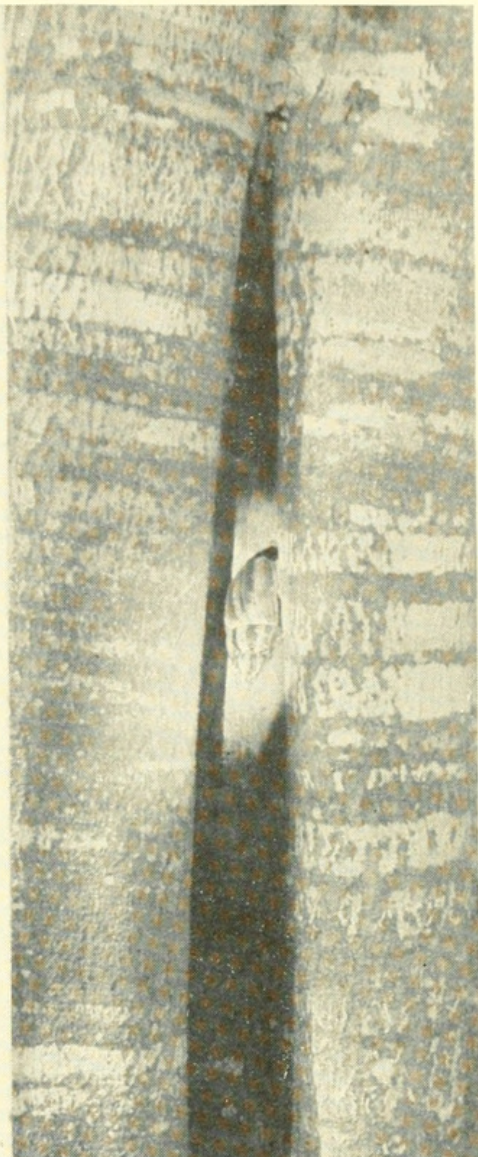
All photographs by Mrs. F. X. Williams.



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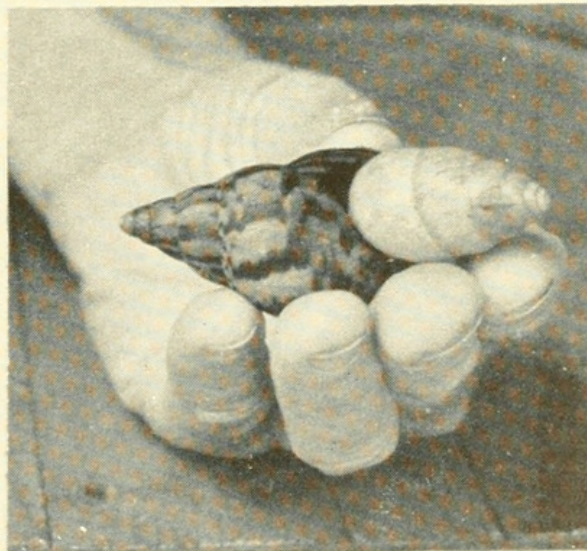
2



3



4



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PLATE 4

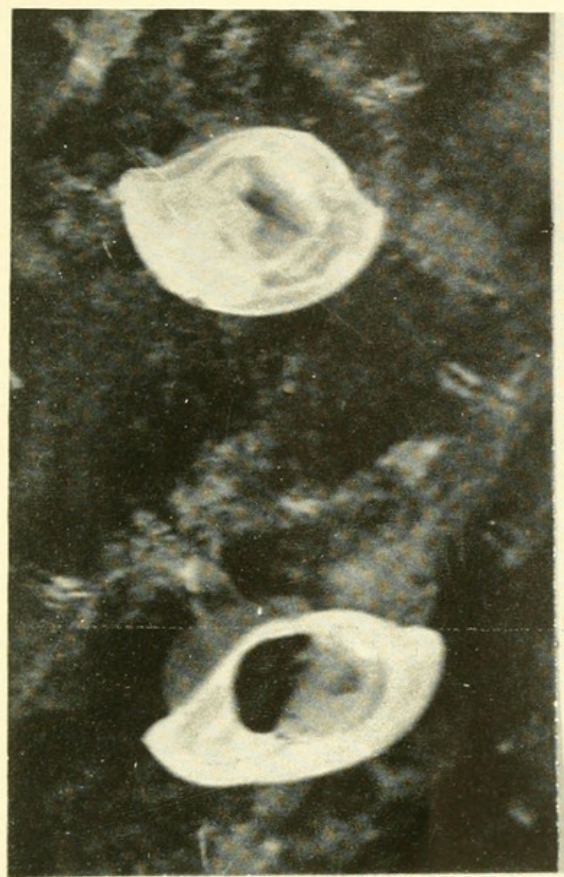
PLATE 4

Fig. 1. Two epiphragms built by *Achatina albopicta* and left behind on a tree trunk after the snails moved away. Lower one shows tubular extension to the bark. Diani Beach. Photograph by Mrs. F. X. Williams.

Fig. 2. Group of *Achatina fulica hamillei* Petit and *A. f. rodatzii* Dunker on trunk of coconut palm about 9 ft. from the ground. Zanzibar Id. Photograph by Mrs. F. X. Williams.

Fig. 3. Adult female, after oviposition, of Drilid which in the larval stages attacks *Achatina*. Diani Beach. X 2.

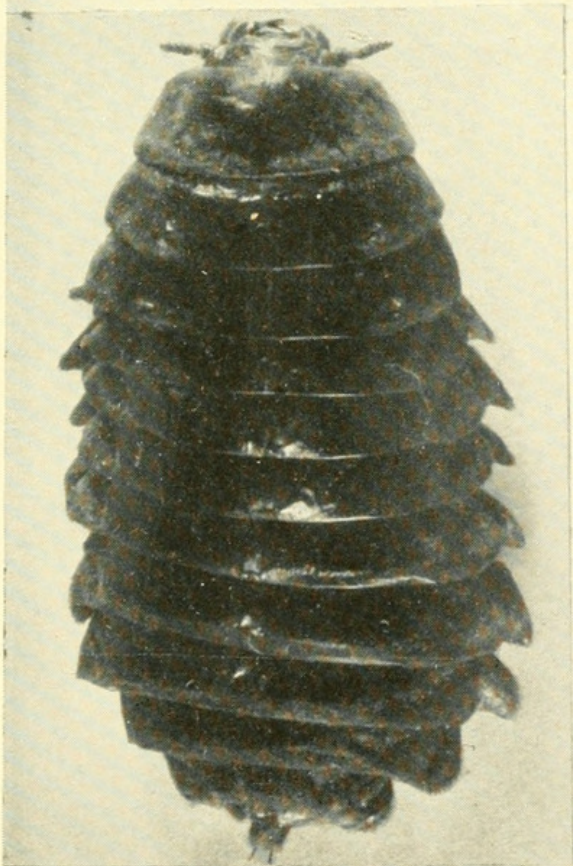
Fig. 4. *Achatina albopicta* showing large numbers of eggs deposited by female *Panaga* flies. Mombasa.



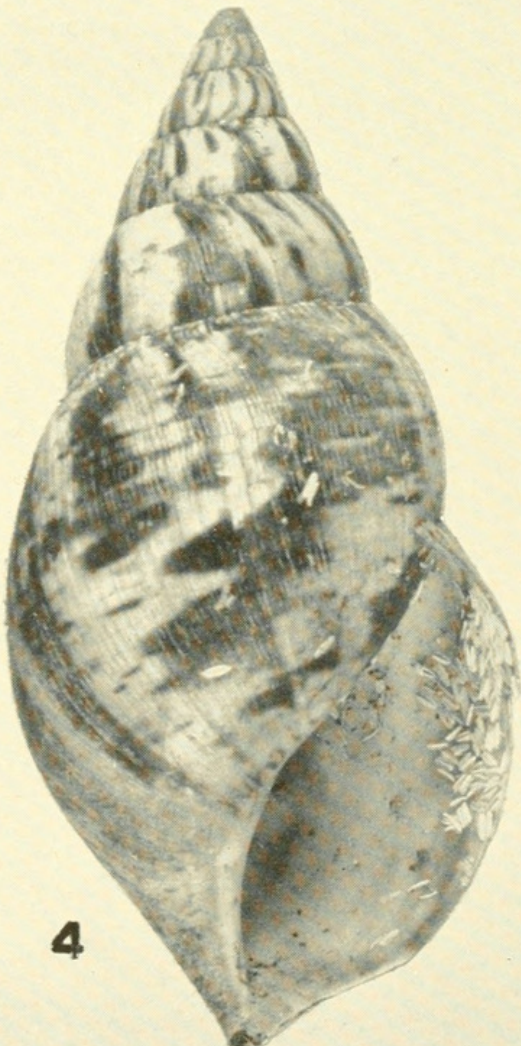
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PLATE 5

PLATE 5

Fig. 1. Exuviae of last active larval instar of Drilid feeding on *Achatina fulica hamillei* at Mombasa. Dorsal view. X 2.

Fig. 2. Top of broken *A. f. hamillei* showing hatched puparia of *Panaga* flies.

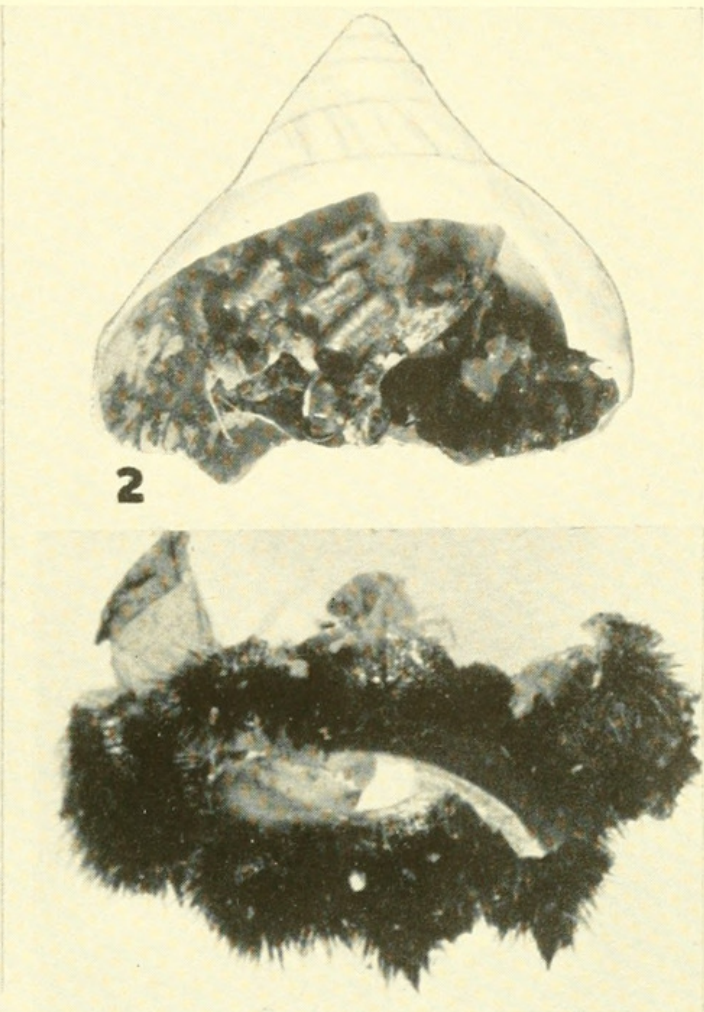
Fig. 3. Caudal portion of a resting stage larva of the Drilid attacking *Achatina*. Dorsal view. X 2.

Fig. 4. Apical portion of abdomen of active larval instar of the Drilid attacking *Achatina*; probably preceding the stage shown in Fig. 1. Dorsal view. X 2.

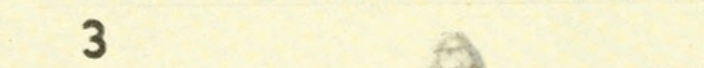
Fig. 5. *Achatina albopicta* cut into at the edge of the mouth by a land crab. Diani Beach. Natural size.



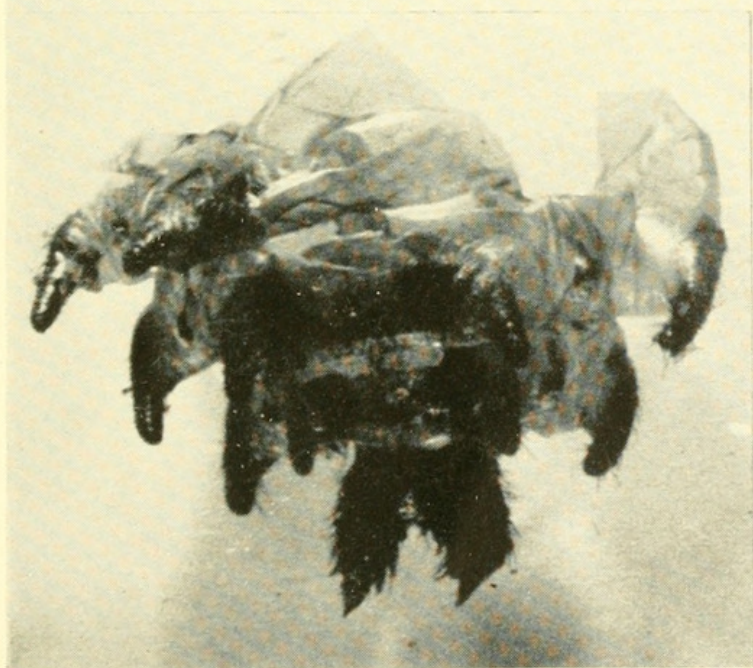
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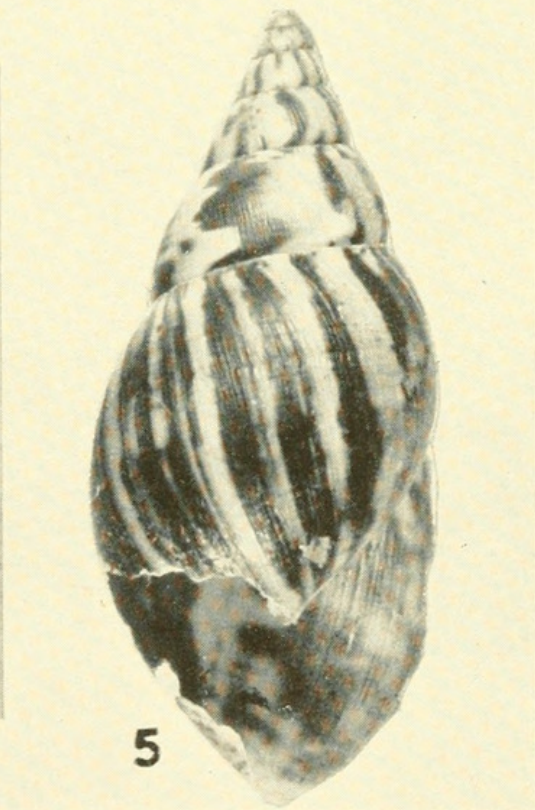
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