A FLATWORM PREDATOR OF THE GIANT AFRICAN SNAIL *ACHATINA FULICA* IN HAWAII[1]

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ABSTRACT

The endemic, terrestrial, triclad turbellarian flatworm, *Geoplana septemlineata* Hyman, 1939, has been found to prey upon the introduced Giant African Snail *Achatina fulica* in Hawaii killing even the largest specimens. The slender worms, attaining a length of 40 - 60 mm, often attack in groups; 51 worms, totaling a length of nearly 2,000 mm, were removed from a single 50 mm giant snail specimen. The intense suction of the worm's proboscis removes flesh from the exposed parts of the snail; and the invasion of the lung cavity subjects the vital pallial organs to attack. Probably their greatest efficacy in biological control lies in the destruction of the newly hatched snails. These worms have also been observed to kill the introduced predatory snails *Euglandina rosea* and *Gonaxis quadrilateralis* and the slug *Deroceras laeve*. A related form is reported to attack *A. fulica* in Java. The geoplanid worms and their allies unquestionably form an important factor in the ecology of terrestrial mollusks. In Hawaii, a chain-reaction is in progress: The introduction of foreign snails has increased the population of *Geoplana; Geoplana* is in consequence providing a greater threat to the indigenous snails; and since *Geoplana* has been found to carry eosinophilic meningocephalitis to humans, its greater numbers might moreover intensify a public health problem.

An unsuspected endemic predator of the Giant African Snail, *Achatina fulica* Bowdich, has been found in Hawaii. Oddly enough, it is not another beetle or "cannibal snail", of which several have been introduced recently in Hawaii (see Mead 1961: 102-45), but a terrestrial flatworm -- a triclad turbellarian or so-called "planarian"-- which Hyman (1939) has described as *Geoplana septemlineata* and which is apparently limited to the Hawaiian Islands. Swezey (1907: 54) and Williams (1931:339) probably refer to this species.

In contrast to all other known invertebrate predators of the snail pest, *Achatina fulica*, the worm can kill even the largest snail specimens; e.g. one experimental specimen 128 mm long and weighing 168 gm died from the attack of these worms. All but the smaller Giant African Snails (less than ca. 50 mm long) usually survive the attacks of the purposely introduced predatory snails *Euglandina rosea* (Férussac), *Gonaxis quadrilateralis* (Preston) and *G. kibweziensis* (E. A. Smith). When these predatory snails attack a medium or large size *Achatina*, the latter will invariably keep crawling and evading in an attempt to escape. The predator will remove a considerable amount of mucus and epidermal and dermal tissue; and then with its appetite satiated, it allows its prey to escape. Within a very few weeks, new tissue regenerates and the snail appears no worse for its experience. In effect, then these predatory snails together are able to destroy the eggs and the young African snails up to about four months of age (also the older "pygmy" forms that remain essentially at the four month size); but, with relatively few exceptions, they merely "harvest" the tissue of the body wall of the older and larger specimens.

At first glance, it would not seem possible for *Geoplana* to be an effective and even lethal predator of a host several hundred

[1]This work was supported (in part) by a research grant, E - 1245(C4), from the National Institutes of Health, U. S. Public Health Service.

times its mass. In fact, although these worms had frequently been observed in the field previously, their close association with *Achatina fulica* was not considered anything more than incidental. Specimens of *A. fulica* dead and covered with the worms did not raise any more serious question than did the numerous maggots and adult flies, of several species, busily consuming the carcass. But when fifty full-grown, caged, experimental specimens of the Giant African Snail died, one after another, over a period of a very few weeks, the suspicion that the worms were the direct cause of death steadily grew. It was then a simple experiment to place a couple of snails in a one-gallon terrarium with a number of these worms. The observations conclusively confirmed the fact that the worms would not only consume a crushed or dying snail, but that they would attack and kill a healthy, vigorous snail in a matter of a very few hours, at the most.

These shiny-black, flat, leech-like, nocturnal worms usually measure about 40 x 2 mm in the extended state, although specimens up to 60 mm are not infrequently encountered. In spite of their extremely tenacious slime, they move with remarkable speed and agility over even a dry substrate. Very frequently their anterior end is attenuated, elevated, and flailed about in an apparent effort to locate prey. Both in the field and in the laboratory they seem sensitive to the slime trail of a snail; and, in the vicinity of these worms, a snail is soon seen with a number of worms crawling almost frantically in its wake. The directive motion of the worms permits them soon to overtake the snail with its hesitant, probing locomotion. One after another crawls upon the hapless victim until it is apparent that one of the most effective factors in the attack is the "ganging up" of the worms on a snail whose escape reaction succeeds only in carrying its attackers with it and picking up still more en route.

Froehlich (1955) suggests that in the attack of geoplanids an extro-gastrovascular digestive enzyme may be released at the feeding site. This suggestion seems reasonable, for it is obvious that the prey is unduly sensitive to physical contact with these worms, since it elaborates a considerable amount of heavy, greenish, frothy mucus. This discharge does not discourage the worms. The proportionately long, white proboscis of the worm is extruded from near the mid-ventral surface of the body; it appears capable of of strong suction, for many deep holes (ca. 0.75 mm in diameter) and grooves appear at the sites of attack. Under the microscope the translucent proboscis, in carpet sweeper fashion, is observed to be sucking in everything in its path -- mucus, fluids, debris, air bubles -- as it moves and probes about. The sensitivity of the snail grows more acute with more worms moving into position; and the victim withdraws into its shell, dragging the worms in with it and embracing them in the folds of the invaginated head and tentacles. When many worms are present these all move onto the exposed parts of the snail (the mantle and left side of the foot) until nothing but worms can be seen. The harassed snail opens the pneumostome in a desperate effort to get more air; and some of the worms crawl into the lung cavity. Soon the irritation and congestion in the lung, as evidenced by the copious amount of mucus produced in the lung and the bubbling from the pneumostome, causes the pneumostome to remain open, only to permit still more worms to enter until a veritable webbing of black worms can be seen within.

One 50 mm *Achatina fulica* specimen was found in the field with 51 worms on it, totaling a length of nearly 2,000 mm, or somewhat over six feet of worms. It is little wonder that the snails are quickly killed under such an attack. Attempts have been made to rescue snails by removing all the worms as quickly as possible. If caught in time, the snail will survive and eventually regenerate the lost tissue; however, if the snail was under heavy attack, it will not survive. Such a snail appears emaciated, drawn, and almost "dry" on the surface of the body, undoubtedly from the great loss of mucus; it seems exhausted and appears to move

voluntarily only with the greatest effort; it retracts violently on the slightest stimulation; and it finally remains lethargic and partly extended from its shell until overtaken by death. When only one or two worms attack a snail, the damage is often limited to the removal of tissue from the exposed mantle and the posterior margins of the foot, parts which are vulnerably exposed to the marauding worm when the snail is in resting position on the ground. In environments where the worms are most abundant, *Achatina* specimens are often seen with either freshly removed tissue or regenerating tissue in these regions of the body, thus probably offering a fair index of the incidence of attack by the worms.

The strongest preference is shown for the newly hatched achatinas; and *Geoplana* undoubtedly is having its greatest effect in biological control by destroying the juveniles. Time after time, it has been observed both in the field and in experimental cages that these worms will congregate in great numbers in the egg masses. In fact, they are found laced all through the eggs and adjacent debris; and even the intact soil around the "nest" invariably contains a few more specimens. In attacking the newly hatched snail, the worm either embraces it in its folds so that the proboscis can enter the aperture of the shell, or it crawls into the shell and out again, forming a U-shaped fold that carries the proboscis deeply into the body whorl. The small shell characteristically is left intact and completely clean of any flesh.

Just how important is *Geoplana* in the economy of snail populations? There is no question that this worm is amazingly hardy and persistent, in spite of its apparently delicate nature. It has been found in very dry environments curled up in the deep folds of leaf debris. In a given area, even with diligent searching none may be found; but soon after a rain, the large, full-grown worms may be found in quantity -- suggesting that they had successfully weathered the dry period by secreting themselves in the ground and in deep recesses. Asexual reproduction through autotomy, apparently triggered by the slightest stimulus, contributes substantially to the increase in these worms. Picking up the worm with forceps will almost invariably cause the worm to break in two or more parts; and careless handling may cause it to fragment into many small pieces. Even with gentle handling, the worm may seem to remain intact, only to autotomize seconds or minutes later.

Geoplana is most abundant in the more moist sections of Oahu and Kauai islands, although it has been encountered in some areas that are comparatively dry the year around. *Achatina fulica* tends to become nearly ubiquitous in Hawaii, but it still remains conspicuously unsuccessful in its attempts to invade some of the more lush, deep valleys and higher peaks, in which areas the worm abounds. It is significant that nearly 50% of the giant snails found alive in the very wet upper Manoa Valley in Oahu have had one or more worms on them. The predators *Gonaxis quadrilateralis* and the smaller *G. kibweziensis* reflect adaptations to their native East Africa by settling in the drier areas; in contrast, *Euglandina rosea* seeks the more moist areas and hence is brought in greater contact with *Geoplana*. Of the four snails, *Euglandina* doubtless suffers the greatest loss from attacks by *Geoplana*. *Gonaxis* tends to burrow into the ground and the worms therefore probably encounter it more frequently than the normally drier environment would suggest. Other introduced snail pests, *Bradybaena similaris* (Férussac), *Subulina octona* (Bruguière) and *Opeas* sp., within the past few years have virtually vanished in some areas of Oahu. The explanation for the disappearance probably rests in a combination of disease, predatory snails and these predatory worms. At the Kalalau Lookout in Kauai, this species of *Geoplana* was found feeding in characteristic fashion on a live specimen of the introduced slug *Deroceras reticulatum* (Müller).

Although Froehlich (1955) mentions the snail-eating habits of Brazilian geoplanids and refers to earlier, more brief, accounts in the literature, the terrestrial turbellarian flatworms, in general, have been

almost completely unsuspected as an important ecological factor in snail populations. The geoplanids and their allies are widespread and there is little doubt that in many places, their presence has a pronounced effect upon snail distribution and abundance. These worms must be taken into consideration in the analysis of land snail ecology. But their presence does not necessarily mean snail predation, for Froehlich indicates that some species have a greater affinity for isopods and other arthropods; and in Hawaii, the introduced *Bipalium kewense* so far has not been implicated in attacks on the giant snail, although probably the scarce, endemic *Geoplana subpalida* Hyman (1939) eventually will be. However, in a recent communication Dr. Ir. J. Ruinard, of the Institute for Agricultural Research in Manokwari, Dutch New Guinea, reports seeing large, black, leech-like worms on the bodies of *A. fulica* in that area. Specimens of these worms have been examined by the author, and while they are being definitely identified by the proper authorities, it is already quite apparent that these large worms (ca. 75 x 7 mm in the contracted state) are geoplanids that could indeed be formidable predators of the giant snail. Dr. Ruinard interestingly reports, "We have found some of these black animals inside the shell of a living giant snail; however the body of the snail was damaged. Another time [it] was seen that such a black 'leech' was crawling on the back of a healthy looking slug.... One or two hours later on the back of the slug 3 or 4 big, light colored blisters appeared, which turned to black. The next day the slug was dead. We observed that the leech pierced into the slug [with] a white cylindric organ."

But the effect of this worm upon the snail populations may have its more subtle aspects. A disease of unknown etiology occurs in the giant African snail (Mead 1956). *Geoplana* looms as a possible incidental or secondary vector of this infection particularly in view of its affinity for crawling into the pneumostome where it can come in direct contact with such vital organs as the lung, kidney and pericardium. Further, since the worm is cannibalistic, transmission from one worm to another appears easy. On the other hand, the attacks by *Geoplana* could conceivably provide sufficient stress to cause an enzootic disease in the snails to go from the chronic to the acute-lethal phase. In this connection it should be noted that, after removing the worms, some snails would appear to be recovering from the attack and then suddenly go into a decline and die, despite isolation and ample food and moisture.

It is provocative to contemplate the ecological "chain reactions" that are taking place as a result of the changes that have taken place in the past few years. *Geoplana septemlineata* in its unaltered endemic state is apparently not a common animal. It has been seen feeding on earthworms and small insects. Snails originally did not figure importantly in its diet as approximately half of the Hawaiian endemic snails are tree dwellers; and the geophilic forms are characteristically sparse in their distribution. This ecological picture was changed with the arrival of *Achatina fulica* when an abundant supply of acceptable food became available. With the introduction of the predatory snails, still more food became available, particularly with *Euglandina* quickly invading the deeper valleys and higher areas not yet reached, and perhaps never to be reached, by the Giant African Snail. The population of *Geoplana* has unquestionably increased considerably as a result. This opinion is supported by experimentation on a small scale and by my observations in the field. One cannot but wonder what the increased worm population is doing to the scarce ground-dwelling endemic snails. And, as an interesting sidelight, it should be noted that *Geoplana*, along with the introduced snails and slugs, has been shown to be the intermediate host of the nematode worm *Angiostrongylus cantonensis*, which causes the frequently fatal eosinophilic meningocephalitis in humans (Alicata 1962; see Mackerras and Sandars 1954). The greater numbers of *Geoplana* and the proclivity in this species for resting on

the leaves of lettuce, automatically increases the danger of humans accidentally ingesting infected worms. In fact, a full-grown *Geoplana* was recently found curled up on a bit of lettuce in a tossed salad served at one of the better Waikiki restaurants.

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ZUSAMMENFASSUNG

EIN PLATTWURM ALS FEIND DER AFRIKANISCHEN RIESENSCHNECKE *ACHATINA FULICA* AUF HAWAII

Es wurde beobachtet, dass der auf Hawaii einheimische triclade Landturbellarier *Geoplana septemlineata* Hyman, 1939, die eingeschleppte afrikanische Riesenschnecke *Achatina fulica* anfällt und sogar die grössten Individuen dieser Art zu töten vermag. Diese schlanken Würmer, die eine Länge von 40-60 mm erreichen, greifen oft gruppenweise an: 51 Würmer, mit einer Gesamtlänge von fast 2000 mm, wurden von einer einzigen 50 mm langen Riesenschnecke entfernt. Das Fleisch exponierter Körperstellen wird durch die intensive Saugkraft des Wurmrüssels abgetragen; auch die lebenswichtigen pallialen Organe sind durch die Invasion der Lungenhöhle dem Angriff ausgesetzt. Wahrscheinlich aber üben diese Würmer ihren wichtigsten Einfluss in der biologischen Kontrolle dieser Schnecken dadurch aus, dass sie die frischgeschlüpften Jungschnecken vernichten. Ebenso töten sie die eingeschleppten Raubschnecken *Euglandina rosea* und *Gonaxis quadrilateralis* sowie die Ackerschnecke *Deroceras laeve*. Eine verwandte Form greift auf Java *A. fulica* an. Die geoplaniden Würmer und verwandte Formen stellen zweifelsohne in der Okologie der Landmollusken einen ganz unerwartet wichtigen Faktor dar. Auf Hawaii ist eine Kettenreaktion im Gange: die Einschleppung der ausländischen Schnecken hat die Geoplanidenbevölkerung vermehrt, welche daher eine grössere Gefahr für die einheimischen Schnecken bildet. Da *Geoplana* sich auch als ein Träger der menschlichen eosinophilen Meningocephalitis erwiesen hat, könnte weiters die Vermehrung dieser Gattung einen gewissen Einfluss auf eine Frage der öffentlichen Gesundheit des Landes ausüben.

RÉSUMÉ

UN VER PLAT PREDATEUR DU PULMONE GEANT AFRICAIN *ACHATINA FULICA* A HAWAII

Nous avons pu établir que le turbellarié terrestre triclade *Geoplana septemlineata* Hyman, 1939, indigène à Hawaii, attaque le Pulmoné géant *Achatina fulica* importé de l'Afrique, tuant les spécimens même les plus grands. Ces vers sveltes, qui atteignent une longueur de 40 à 60 mm, attaquent souvent en groupe; 51 vers, mesurant au total 2000 mm, ont été recueillis sur un seul spécimen d'*Achatina* de 50 mm de long. La chair des parties exposées de l'animal est ôtée par la succion intense du proboscide de ces vers; les organes vitaux palléaux sont aussi exposés à l'attaque par une invasion de la cavité pulmonaire. Mais c'est sans doute la destruction des Achatines nouvellement éclos es qui agit le plus efficacement dans le contrôle biologique de l'espèce. De même ces vers tuent aussi les Pulmonés prédateurs importés *Euglandina rosea* et *Gonaxis quadrilateralis* ainsi que la limace introduite *Deroceras laeve*. Une forme alliée attaque *Achatina fulica* à Java. Les vers géoplanides et leurs alliés sont incontestablement un facteur important et inattendu dans l'écologie des mollusques terrestres. A Hawaii une réaction en chaine est en cours: l'introduction des Pulmonés étrangers a augmenté la population de *Geoplana* qui, en conséquence, devient une menace plus grave pour les Pulmonés indigènes. D'autre part, puisque *Geoplana* a été constatée être un vecteur de la méningocéphalite éosinophile humaine, la multiplication de cette espèce contribue à aggraver ce problème de l'hygiène publique.

RESUMEN

UNA PLANARIA PREDADORA DEL CARACOL GIGANTE DE AFRICA, *ACHATINA FULICA*, EN HAWAII

El turbelario tricládido terrestre endémico, *Geoplana septemlineata* Hyman, 1939, se indica como predador del caracol gigante africano *Achatina fulica*, introducido en Hawaii, siendo capaz de matar hasta los más grandes individuos. Estas delgadas planarias, que alcanzan una longitud de 40 a 60 mm, frecuentemente atacan en grupos: 51 de ellas, totalizando una longitud de cerca de 2.000 mm, fueron extraidas de un solo caracol gigante de 50 mm. La intensa succión proboscidal del turbelario arranca pedazos de las partes expuestas del caracol, y la invasión de la cavidad pulmonar abre el ataque a los órganos paleales vitales. Probablemente su mayor eficacia en el control biológico reside en la destrucción de caracoles recién salidos del huevo. Estas planarias también se han observado matando los caracoles predadores *Euglandina rosea* y *Gonaxis quadrilateralis*, introducidos en Hawaii, y la babosa *Deroceras laeve*. Se ha observado que una forma emparentada ataca *Achatina fulica* en Java. Los geoplánidos y sus aliados constituyen incuestionablemente un factor de importancia insospechada en la ecología de los moluscos terrestres. En Hawaii está progresando una reacción en cadena: la introducción de caracoles exóticos ha incrementado la población de *Geoplana*, la cual, en consecuencia, se convierte en una amenaza creciente para los caracoles endémicos; y desde que se ha verificado que *Geoplana* es transmisora de la meningoencefalitis eosinofílica al hombre, su incremento produciría además la intensificación de un problema de salud pública.

АБСТРАКТ

РЕСНИЧНЫЙ ЧЕРВЬ ХИЩНИК У ГИГАНТСКОЙ АФРИКАНСКОЙ УЛИТКИ *ACHATINA FULICA* НА ГАВАЙСКИХ ОСТРОВАХ

Альбэрт Р. Мид

Эндемический земноводный, трикладный ресничный червь *Geoplana septemlineata* Hyman, 1939 был найден нападающим на ввезенную туда гигантскую африканскую улитку *Achatina fulica* на Гавайских островах, убивающим самые крупные ее экземпляры. Тонкий червь, достигающий до 40 - 60 мм длины, зачастую аттакуют группами; 51 червь, общей длиной в 2,000 мм, был найден в одной улитке в 50 мм длиною. Сильное присасывание хоботка этого червя снимает наружные покровы с обнаженных частей тела улитки; а проникновение

его в полость легких поражает его мантийную полость. Вероятно, самым действительным значением его биологического контроля является уничтожение им свежевылупившихся улиток. Наблюдения показали, что эти черви убивали также иввезенных для контроля хищных улиток *Euglandina rosea* и *Gonaxis quadrilateralis*, а также и слизняка *Deroceras laeve*. Родственная форма этого червя, атакующая *A. fulica*, найдена на острове Ява. Геопланидные черви и их союзники несомненно представляют собою неожиданно важный фактор в экологии наземных наземных моллюсков. На Гавайских островах наблюдается прогресс цепной реакции: ввезенные иностранные улитки повысили население геопланидных червей; этот род в результате является большей угрозой эндемичным моллюскам; но так как *Geoplana* является носителем косинофильного менингоцефалита человека, то его дальнейшее размножение может создать угрозу здравоохранению.

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