CHAPTER 11

OUTLOOK

In this work so far, definite attempts have been made to determine and evaluate the status of the several aspects of economic malacology and the problem of the giant African snail in particular. At this point, it will be well to look ahead and, on the basis of what is known, to make prognostications which should indicate not only where we are going but what we should be doing in the host of problems presented by economically important snails.

Dispersal A question of great concern in the outlook for the problem of the giant African snail is, "Just how far can and will this snail spread into the uninfested areas of the world?" First of all, we know full well that we have in *Achatina fulica* an exceedingly hardy, tenacious, variable, and adaptable molluscan pest with a high reproductive potential and remarkably few natural enemies. Since the limits of these faculties are not known in any case, the question at hand, unfortunately, can be answered only in speculative terms. Even so, information is available which forms a firm basis for speculation.

Finding *A. fulica* firmly entrenched in Ani Jima (lat. 27° 08′ N.) in the Bonin Islands is of real significance; for it is situated farther north than any other known established population of this species, with a possible exception suggested by the recent discovery of specimens on Amami Oshima (lat. 28° 18′ N.) in the Ryukyu Islands. The well-established populations in Okinawa Jima of the Ryukyu Islands are almost as far north (lat. 26° 03′–51′ N.). Nuttonson (1952) has established for the Ryukyu Islands the agro-climatic analogues in the Northern Hemisphere. From these it can be stated flatly that *A. fulica* could become established in the comparable areas of Florida, Alabama, Mississippi, and Louisiana. Because island climates are characteristically more mild than continental climates at the same latitude, it is to be expected that the northern and southern frontiers of this species will be populations in islands which have a subtropical-temperate climate. If, however, the giant snail adapts itself as a greenhouse pest, it may become established in the more temperate continental areas. Significantly, the populations in the Bonin and Ryukyu Islands are vigorous and thriving. Further, the winter climates in these islands and in the infested areas of Kauloon in Hong Kong Colony, Amoy in China, and interior Formosa, are considerably more vigorous than in some of the areas in East Africa where *A. fulica* is endemic. This suggests that the snails have not yet reached the threshold of minimum tolerance to cold.

From what we know, it is reasonable to assume that the giant snail has the capacity to establish itself in all oceanic islands which have an adequate cover of vegetation and fall between 30° north and 30° south latitude. This embraces the greater share of Oceania and indicates that such uninfested island groups as the Marshall, Gilbert, Ellice, and Line, are vulnerable. Uninfested continental areas which are tropical, subtropical, and, in some cases, subtropical-temperate are similarly vulnerable. This includes northern and much of eastern coastal Australia, as Harrison (1951) agrees. The most extensive of the suitable but uninfested areas, however, are in the New World where they form an essentially continuous belt from the Gulf States of the United States south, through the West Indies and the lower altitudes of Mexico, to the greater share of South America. That this snail, so far as we know, has not yet become established in these vast areas is almost a miracle, especially when one considers the general inadequacy of plant quarantine regulations in the many countries included. In fact, some investigators have been moved to suggest that there is some basically intolerable factor in the tropics of the New World which has kept this snail form becoming established. Under the circumstances, however, it appears that it is merely a matter of time until these areas are invaded.

In the Pan-Indian Ocean area and in Indonesia, the giant snail has already made considerable progress in its spread. It will continue this spread until it is essentially ubiquitous. Australia, northern New Zealand, southern Japan, and continental United States are peripheral areas about which there is considerable doubt because it is not known to what extent *A. fulica* has the genetic capacity to form populations of more hardy individuals. Masahiko Nakada of the blight prevention section of the agriculture-forestry ministry in Tokyo, however, predicted recently that the giant snails will make their appearance in Kyushu, the south island of Japan, in the near future.

In regions where there frequently occurs sudden lowering of the temperature below 50° F., this snail probably will not permanently establish itself except possibly in greenhouses and nurseries. On the other hand, where temperatures are reduced gradually and are not excessively low, it is not unlikely that the more hardy individuals will bury themselves in the ground and survive, as they do in the Bonin Islands. The inordinate sensitivity of this snail to higher altitudes seems to stem not from the factor of cold alone but quite likely from intolerance to a diurnal temperature fluctuation beyond a point where, to survive, it normally would need a period of several days to become conditioned physiologically. Of course, there may be a barometric factor; but it is significant that snails are surviving colder winter temperatures at sea level in Ani Jima than they can at 5,000 feet altitude in Ceylon (Mead 1955*b*, 1957*b*). Green (1910*b*), for example, reported that achatina specimens released at an altitude of 4,000 feet in Ceylon died one by one without reproducing. Other specimens released at an altitude of 6,600 feet in Masuri at the foot of the Himalayas in central India similarly failed to establish themselves (Benson 1858). Reliable correspondents have indicated that specimens have not been encountered much above 2,000 feet in Mauritius and 3,300 feet in Java. This information correlates with the findings of Pilsbry (1919:60) wherein achatinas were not found above 1500 meters in Africa.

Although deserts would appear to be completely forbidding to the establishment of this and other snail pests, it has been emphasized that in the cultivated areas of deserts conditions are surprisingly suitable, as evidenced by the fact that several exotic terrestrial gastropods have become established in the Sonoran Desert of southern Arizona within the past few years (Mead 1952*a, c,* 1953, 1959*a*).

During the past ten years, the threat of establishing the snail in the United States has come chiefly from ships carrying war salvage from the Trust Territory of the Pacific Islands (Messenger 1952:252). The interceptions of the snails have been discussed above under the topic of quarantines. There is essentially no war salvage arriving today in this country as remaining shipments are reportedly being directed to Asia. Concurrent with the tapering-off of these shipments, there has been a greater increase in the spread of the giant snail in Hawaii. The threat, therefore, is still coming in from the west, with the difference that it is now much closer to the United States, and to California in particular. Fortunately, the recently enacted federal quarantine regulations will provide a considerable buffer effect to this threat. But there are no prospects of the threat becoming less in the near future.

The actual threat that this snail presents to the agricultural state of California has been much debated. Bequaert (1950*b*:74) has stated, "It is, in my opinion, extremely doubtful that *A. fulica* could ever become established in California or elsewhere in the continental United States, to judge from the present distribution and the ecology of this snail." In direct contrast, Mead (1949*b, c*) has stated, "It would be especially bad in places like California, the Gulf states, and the Southeastern states." On the other hand, Abbott (1949) has stated, "Fortunately, the climate of that state [California] is not considered to be entirely ideal for the snail." The following year, he modified his stand with, ". . . it is my opinion . . . that the southern third of Florida is the only suitable area for its survival for any great length of time." These differences of opinion are the natural outcome of having to base predictions on woefully inadequate information; and they underscore the advice Bequaert gives in the following words, ". . . controlled experiments, under strict supervision, but under natural conditions in a presumably favorable area, are called for in order to determine once and for all whether or not the snail could survive the winter and reproduce freely in the United States."

Let us assume for the moment that the only place in the United States *A. fulica* could become established is the southern tip of Florida. Let us assume further that at best only an unthrifty outpost population of the giant snail, causing little local damage, could become established. Nothing but a dim view could be taken of such a situation; for the snail pest could use that beachhead as a springboard to start populations elsewhere in more favorable areas in the western hemisphere. Cuba, being nearby, and having vast agricultural areas and a fabulously rich mollusk fauna, would be particularly vulnerable. Aguayo (1950) has already sounded a word of warning in that country.

Since man is the principal agent of dispersal of this snail pest, any measure to check the spread will have to be aimed at man himself. Quarantine regulations have been set up for this purpose; and for this purpose they should be maintained indefinitely. They are far from being universally practicable; but in certain areas they have been eminently successful. Keeping this snail out of California in spite of the frequent interception of live specimens, and restricting it to the two originally infested islands of Oahu and Maui in the Hawaiian Islands for a period of twenty years, are cases in point.

Bionomics We know amazingly little about the biology and ecology of the giant snails—far less than for any other agricultural pest of comparable economic importance. We do not know how long they live, how far they travel, how much heat or cold they can tolerate, why they are limited by altitude, whether they can go into true hibernation as well as estivation, why they move en masse out of a favorable area into an apparently unfavorable one, how important their own diseases are in regulating their numbers, what the biological factor is that accounts for the tremendous vigor early in the invasion of a new territory, or very much about literally a score of other equally significant but unknown factors operative in their existence. These thoughts bring out the obvious realization that just as soon as comprehensive behavioral study can be made of these snails, there will be not only an increase in the efficacy of the existing control measures but new and more effective means of control can be conceived.

The unpublished thesis of Ghose (1960) gives us our most valuable contribution on the anatomy, histology, and embryology of *A. fulica.* Hatai and Kato (1943) made detailed studies of the growth and development of this species. Their ecological observations are valuable, but as is the case in so many other reports based on field observations of *A. fulica,* the bits of information amount to such a pitifully small portion of the needed information that not even speculation will pull the parts together into any sort of even vague picture of the over-all ecology. The work of Takahashi (1942) gives us more specific information on the movement of this snail within a fairly limited area of a recently invaded compound; but like Matsui's report (1942) on the total amount of movement of the giant snail in a diurnal cycle, there apparently has been no translation from the Japanese. Edelstam and Palmer (1950) and Palmer (1951) of Sweden have made significant parallel studies with *Helix pomatia;* but like all parallel studies, they are scarcely more than suggestive.

Control So far as is known, for over one hundred years eradicative measures of all types have been uniformly unsuccessful throughout the areas of the world invaded by *A. fulica.* Even the most intensive control programs, such as those in Oahu, Guam, Koror, and Hong Kong, have proven in the long run only to have impeded the spread of that snail pest. There has been, in fact, only one case where a major land snail pest has been eradicated by man, viz., *Theba pisana* in La Jolla, California. Basinger, who was in charge of the control program, spared nothing in his efforts to eradicate this pest. After a few years, he stated (1923*a*), ". . . the vast majority . . . have long ago been destroyed, but, when it comes to extermination, it is much harder to get the remaining few than the first hordes." Despite the fact that he thought he had virtually accomplished an eradication, as betrayed by the title of his article, it took almost exactly 27 years more actually to accomplish it! And during this time, almost unlimited manpower was made available to the program through federal and state relief administrations. The total cost of eradicating *T. pisana* and attempting to eradicate two other helicine species came to over $500,000. To date, the other two species are still very much at large (Messenger 1950). The factor of "the irreducible minimum," which is the difference between control and eradication, has plagued the program right from the beginning.

With many examples of expensive failures in the past, it is little wonder that Green (1910*c*), South (1926*b*), Garnadi (1951), and others have taken an unequivocal stand against "all out" measures to eradicate *A. fulica.* Certainly their advice warrants serious consideration if the infestation has become firmly established in a favorable environment. If, on the other hand, the infestation is only in its initial phase, or is in a marginally suitable environment, eradicative measures should be undertaken. But in nearly every infestation, at least some measure of control should be exercised. The big problem is: "What control measure, or combination of control measures, should be used?" Naturally, the answer would vary according to the circumstances involved; but in general, *all* practicable control methods should be used where they are not mutually counteractive (e.g., the introduction of predatory snails and the use of molluscicides). Unfortunately, many of the control measures are relatively expensive and they therefore are completely beyond the consideration of most native peoples in the infested and potentially infested areas. Under such circumstances, hand picking, the construction of barriers, and other mechanical devices would have to be resorted to. But these, like any other control measure, must be maintained indefinitely. It is at this point that new difficulties arise. If after a few weeks or months of attempting to control the snail there is little or nothing in the way of tangible results, even the more fastidious people tend to give up and let the snails take over. But what is worse, peoples in many areas show a marked apathy, and even antipathy, for making any attempt to help themselves in this problem. For instance, R. E. Dean writes (*in litt.* Jan. 17, 1952) that in Hong Kong the government offered snail bait free to the people, "but the response was only lukewarm." The prevailing attitude among the people in the Pacific islands is that all responsibility for controlling the giant snail rests squarely upon the shoulders of the government. If anything is done, then, the government must resort to force, inducements through bounties, or government-supported large-scale control programs. All of these measures in the past have proven at best to be of only transient success.

Chemical control has been demonstrated many, many times to be expensive and therefore practicable only on a small scale. In addition to the expense, tropical weather conditions in general are antagonistic to the use of molluscicides. Weather that is particularly favorable for snails is automatically unfavorable for chemical control measures as the rain washes away the molluscicide and encourages the growth of mold on snail baits; the high humidity favors recovery from the paralyzing effect of metaldehyde; and the lack of sun eliminates a killing factor that would ordinarily follow the paralyzing effect of the chemical. Dry weather is unfavorable to snails; but they escape it, and any molluscicides put out at that time, by going into estivation. But even beyond the expense and the weather, the fact remains that the available molluscicides are far from satisfactory in their effects. The tools of analysis devised by Basinger (1935), Thomas (1944), and others; the increasing interest of the bigger chemical companies in the development of new molluscicides; and the continued research by a larger and larger group of investigators, give us new hope that before long a truly effective, inexpensive, safe, and easily used molluscicide will be developed. As it is now, in the vast majority of the cases, after repeated chemical control measures are finally discontinued, the giant snail population builds up to the point where it is just as bad if not worse than it was before. In some cases where population decline is taking place or where there has been a fortuitous concomitancy of several control factors, chemical control measures appear to be decisive. This suggests immediately that there must be a better understanding of both the phenomenon of decline and the effects of combining unfavorable factors.

In the broadest sense, man is an agent of the biological control of *A. fulica* because he is a natural controlling factor. Any hope of making use of the snails on a commercial basis for human consumption rests almost entirely with the native peoples who will readily eat them, viz., the East Africans, the Chinese, and the Formosan aborigines. These people have diets notoriously deficient in protein; and it would seem on the face of it that the giant snails could provide at least a partial answer to the problem. But in spite of the logic involved, the chance is remote indeed that there will be even a modest amount of commercial use of the snail for human consumption in the foreseeable future. The possibility of there being more use of the dried snail meal for poultry and livestock supplemental feeds is becoming steadily greater with continued research. It is only through the use of the snails in this manner that man will become a steady, dependable source of "natural" control. Control of this sort would be on an "individual" basis; and the program as a whole, as in other types of biological control, would be self-sustaining. The single greatest obstacle to this whole approach is the fact that it takes additional time and energy to prepare the snail meal. The native peoples, first of all, have to be convinced that this is worthwhile; and, second, they have to overcome their mutual loathing for handling the slimy snails. Progress is bound to be slow in this aspect of control.

The other aspects of biological control are also in their infancy. The prospects of using radiation-induced sterility of males as a successful biological control weapon in insect control raises the highly provocative question of its possible use in snail control (cf. Knipling 1955, Baumhover *et al.* 1959). Whatever the results of introducing multiple predators of the giant snail in the Hawaiian Islands, they are bound to be significant, particularly since in a number of instances more than one species of predator has been released in the same experimental area. *Euglandina,* and possibly the smaller or both species of *Gonaxis,* will eventually become ubiquitous, spreading in many cases as far as *Achatina* has, but in a shorter period of time. The experimental island of Agiguan is only beginning to reveal its complex ecological story (Mead 1956*b*). With both *Gonaxis* and the phenomenon of population decline being variables in the current experiments on that island, the results are almost certain to be misleading one way or the other. Quite unfortunately, however, the research program on Agiguan Island was scheduled to be brought to a close in 1958 (Coolidge 1955).

Disease at last has entered the picture. Its presence provides the most plausible explanation for the almost universally occurring decline in the older populations. The nature of the pathology and the etiology of the disease should be known in the near future. It is almost a certainty that the predatory snails *Gonaxis, Euglandina,* and other predatory snails used in molluscan biological control, will be found to be susceptible to the disease that has been discovered in *A. fulica.* Ultimately, not one, but many diseases will be found and considered in the light of biological control. Because of their affinity for developing strains of variable pathogenicity, disease agents will always have to be handled with respect and understanding in any biological control program.

Decline When *A. fulica* is in a pronounced state of population decline, it ceases to be any more of a pest than some of the endemic snails. Determining accurately the causes for population decline in *A. fulica* will provide a whole new perspective in the control of this pest. When the entire story is known, it will undoubtedly be found that there are many factors involved, the sum of several of which will produce a decline. Probably the disease factor is the dominant one.

Long ago, McCreery (1890) concluded that extinction was usually brought about by a large number of small conditions. If man is ever to eradicate the giant African snail on anything but the smallest scale, he will do it through the use, augmentation, acceleration, and intensification of the several factors, including disease, operative in producing the decline. The discovery of the secret of population decline in this and other species is of the very first importance, and research in the future should be directed toward this end.