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Differential susceptibility of

BROWN GARDEN SNAIL TO METALDEHYDE

IN SOUTHERN CALIFORNIA, *Helix aspersa* (Müller), or brown garden snail (BGS), is the most obvious introduced land mollusk. Outdoors, as opposed to a glasshouse environment, BGS occupies the same general habitat as several species of introduced slugs. Native land mollusks seldom invade cultivated areas, preferring undisturbed natural habitats.

A BIOSIS Retro search (Biological Abstracts, Philadelphia, Pa) of the literature covering from 1959 to 1974 revealed 21 titles linking metaldehyde resistance to slugs. No reference had been indexed during that period whose title or descriptors linked metaldehyde resistance to snails. Similar scans of the National Technical Information Service from 1964 to date and CAIN (Bibliography of Agriculture, USDA) from 1970 to date produced the same result. Thus, it appears that snail resistance to metaldehyde has not heretofore been reported.

Field observations in San Bernardino, California, in 1973–74 indicated pronounced nonsusceptibility of BGS to metaldehyde/bran bait. The BGS had increased to such large numbers in a two-year-old well-established section of freeway landscaping that it became necessary to mechanically prevent them from moving onto the pavement where they could have created a skid hazard to passing vehicles. A prophylactic baiting program by CALTRANS (State of California Department of Transportation) had been conducted by hand application during most of the two-year period but, when it became apparent that the snails were not being controlled, broadcasting bait by air blower systematically after each sprinkling was initiated in late summer, 1973, and continued through 1974. However, the snail population was not controlled until the vegetation, principally trailing African daisy (*Osteospermum fruticosum*), began dying from a disease. Consequently sprinkler irrigation was reduced, creating a drier habitat. The cost of the snail control program for the three miles of problem area was approximately $10,000 for bait and application in 1973 alone. The daisy was subsequently replaced by a *Mesembryanthemum* sp. at an additional cost of $50,000. The history of treatment and the evidently poor level of control suggested that BGS were resistant to metaldehyde, and laboratory tests were initiated to test that hypothesis.

Two populations were selected for the resistance comparisons—one from the freeway area in San Bernardino and one from a private residence in Rubidoux (near Riverside), whose owners had not followed a systematic baiting program. In separate tests, groups of 30, 54, 90, and 320 BGS were offered one to three brands of pelletized bran baits containing 2.75, 3.25, and 4.0% metaldehyde, respectively. Testing arenas were hard plastic containers provided with 3 cm of moist sterilized soil. A laboratory temperature of 75°F, ± 2°F, prevailed throughout the tests. All snails were held without food for 24 hours before placing them in the arenas. Control groups in each test series received pelletized dry dog food. Since the control groups fed readily on the dog food, it was assumed that the test snails also were ready to commence feeding.

Tests were evaluated at 24, 48, and 72 hours and snails were classified as healthy, dead, or sick. Snails in the healthy category were either active in the test arenas or had sealed themselves to the sides or tops of the containers. Snails were considered dead if they did not respond to a gentle probe with a blunt needle, or if the odor of putrefaction was evident. Snails were classed as sick if they exhibited frothing or were lying on their side or back in a state of torpor with the foot partially retracted into the shell. This reaction developed rapidly and snails so affected remained in the immediate vicinity of the bait. After 48 hours constant exposure to metaldehyde, 20–45% of the snails were sick and about half of these subsequently died. The survivors, i.e., approximately 50% of the sick, formed epiphragms. When placed in clean containers with moist soil, nearly all resumed feeding in 3–10 days in the laboratory.

Typical results achieved in laboratory tests are shown in the table. Snails from a regularly baited orange grove expressed even greater tolerance and recovery.

Snails sickened by metaldehyde and left exposed in the field probably are killed by the elements, particularly high temperatures resulting from direct sun exposure. However, those which fed on bait pellets broadcast into the ground cover—hence, semi-protected from the elements—might respond as did those in the laboratory, or roughly 50% recover. It seems reasonable that these individuals possessed the genetic traits which permitted survival and that factor conceivably could be passed on, reinforced, to following generations whose progeny would thus be progressively less susceptible to the metaldehyde until well over 50% could survive in each generation, and the population would increase exponentially. This would seem to explain the observed outbreak which occurred in 1973–74.

Some of the complexities to be considered when interpreting the resistance phenomenon in mollusks were shown in a laboratory study in England by Crawford-Sidebotham (1970), who compared differential susceptibility of nine species of slugs to metaldehyde/bran and methiocarb (Mesural) baits. In that study *Arion hortensis* Ferussac was least susceptible to metaldehyde (showed greatest recovery); *Agriolimax caruanae* Pollonera was the most susceptible (showed poorest recov-

ery); and bait resistance was a recognized variable to be avoided, especially among species of *Arion*. Curiously, in groups of mixed species, the numbers of a species poisoned with metaldehyde baits depended upon the other species present. As an associated species, *Agriolimax reticulatus* (Müller) particularly tended to significantly increase the numbers poisoned.

It remains to be demonstrated whether or not the presence of slugs and/or other snail species can influence the response of BGS to metaldehyde. Another question relates to the approximately 20 species of slugs, including 10 of foreign origin, in California. Are they less susceptible to metaldehyde than in earlier years? Will they, too, evidence differential susceptibility of potential economic significance as we now have reason to think occurs in BGS?

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DEER PRODUCTION at Hopland Field Station

Hunters and research workers took 2,267 deer from the 5,000-acre Hopland Field Station in southeastern Mendocino County from 1951 through 1974. About half of the deer were bucks taken by hunters and the remainder were antlerless deer shot or trapped for various scientific studies. Compared with this harvest of 12 deer per square mile of range per year, the average hunting kill for Mendocino County during the same period was only two deer per square mile per year. The heavier removal from the Hopland Field Station had no discernible effect on deer numbers, but fawn production and survival on the station were higher than elsewhere in the county. These records show that California deer populations can produce many more deer than are currently being taken with bucks-only hunting and very limited antlerless hunting.

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DEER MANAGEMENT has been a controversial political issue in California for many years. Biologists generally feel that the full productive capacity of deer populations can be utilized only by taking does as well as bucks, and this concept has been endorsed as Fish and Game Commission policy since 1950. However, few antlerless deer have been hunted in California because of political constraints. The University and the Agricultural Experiment Station have tried to help resolve this controversy by developing the biological facts needed for intelligent deer management. The Hopland Field Station in Mendocino County has been a primary site of the University's deer studies since 1951. In connection with these studies, complete records have been kept of the number of deer removed from the station. These records are summarized here to illustrate the potential for increased deer hunting elsewhere in California.

Hopland Field Station

The Hopland Field Station consists of 5,300 acres of oak woodland and chaparral range lands in the Russian River drainage east of Hopland. Numerous fenced exclosures reduce the range area actually supporting the wild deer population to approximately 5,000 acres. Domestic sheep also graze most of the station. Censuses indicate that deer population varies seasonally between 600 and 900 animals—these figures are average minimum (before fawning) and maximum (after fawning) estimates. The station is bounded by conventional livestock fences which deer cross readily. Even though there is continual movement of deer back and forth across the station boundaries, long-term studies of marked animals on the station and adjoining areas show that the deer are quite resident and most spend their lives in areas ½ to ¾ miles in diameter. Therefore, we believe we are dealing with a well-defined population, and that immigration onto the station has been negligible, even though deer on the station have been removed at a higher rate than from surrounding areas.

Buck hunting

Prior to 1951 the land was privately owned and was operated as a commercial sheep ranch. Deer hunting was restricted and only the owner's family, employees, and a few friends were allowed to hunt. As a rule only a few bucks were taken and the kill was less than 20 per year. In the early years of the Hopland Field Station (1951–53), hunting was restricted to university employees; public hunting was initiated in 1954 and has continued to the present time (1975). The public hunting is limited to 20 hunters per day, Saturdays and Sundays only. Only bucks with forked antlers or larger are legal game in this part of the state. Since 1967 a daily fee of $5 per hunter has been assessed to defray the cost of managing the deer hunt. The deer hunting season in this area is normally open for six to seven weeks during August and September.

Bucks taken

As shown in the table, 959 bucks were taken by deer hunters from 1951 through 1974. During the 21 years of public hunting (1954–1974) the average recorded kill was 42 bucks per year. Additional bucks were crippled and lost, and occasional spike bucks or does were killed illegally. These losses, recorded since 1957, averaged 8 deer per year or about 20 percent of the recorded buck kill. The estimated cripple loss and illegal kill is based on voluntary reports from hunters and carcasses discovered in the field. Most of these carcasses were reported by hunters or found by research workers investigating sites of turkey vulture activity. Additional cripple losses undoubtedly occurred, so the figures shown here are only minimum estimates of deer mortality resulting from sport hunting. Approximately 45 percent of the legal bucks present at the start of the hunting season were killed by hunters each year. Hunter success over the years has averaged one buck taken for every 12 hunter days of effort (ranging between 6 and 26 hunter days per buck taken in various years).