

occurrence of virus and the distribution within the state. The surveillance serves as an early warning system for possible outbreaks of the disease and provides an overall statewide evaluation of the effectiveness of vector control programs.

## Conclusions

Voluntary cooperation and collaboration between California mosquito control agencies and U.C. scientists on research projects are increasing. The close working relationship between the University of California and the control agencies has stimulated and strengthened the research program toward achiev-

ing a compatible, practical, and economical research effort. An indirect result of the research has been a gradual evolvement of new control strategies being adopted by mosquito control agencies throughout the state. Reliance on chemical control has faded appreciably in recent years, and the trend has shifted toward integrated pest management.

The shift is directly reflected in the records of insecticide consumption of mosquito control agencies. For example, in 1962—the peak year of pesticide application—615,000 pounds of insecticide were used by California control agencies compared with approximately 63,000

pounds in 1976, a tenfold decrease. Much of the reduction is attributed to more judicious and efficient use of chemicals and a shift to more effective oil-type formulations facilitated by University research.

Instead of oils being applied at dosage rates of twenty to fifty gallons per acre of mosquito breeding area, as in the past, control is equally effective at rates averaging two gallons per acre. As a result, labor and material costs have been cut deeply and environmental pollution is negligible.

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# Exotic dung beetles in pasture and range land ecosystems

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**B**ecause they rapidly bury cattle dung pads and thereby reduce pest fly breeding sites, selected species of exotic dung beetles are being imported and used as an integrated pest management tool on California's pasture and range land. These beetles are being mass-produced and released in an attempt to simultaneously manage three pests: the horn fly and the face fly, which breed only in cattle dung, and the dried-out slabs of dung, which become pests that smother the growth of new vegetation for two to four growing seasons. Their digging also may improve pastures by accelerating nutrient recycling and by improving soil stability and permeability. Researchers in other areas also have found that dung beetles reduce the numbers of parasitic gastro-intestinal worms that infect cattle.

Beef cattle have been the leading monetary commodity in California agriculture for many years, with dairy cattle ranking second. This project could thus affect much of the 36 million acres of range land unsuited for other kinds of agriculture, as well as the 700,000 acres of irrigated pasture supporting both beef and dairy cattle. As noted recently by Extension economists, about 65 percent of the nearly three million beef cattle produced annually in California obtain all their feed from range land.

Exotic dung beetles are expected to represent a permanent, self-perpetuating type of pest management. They are

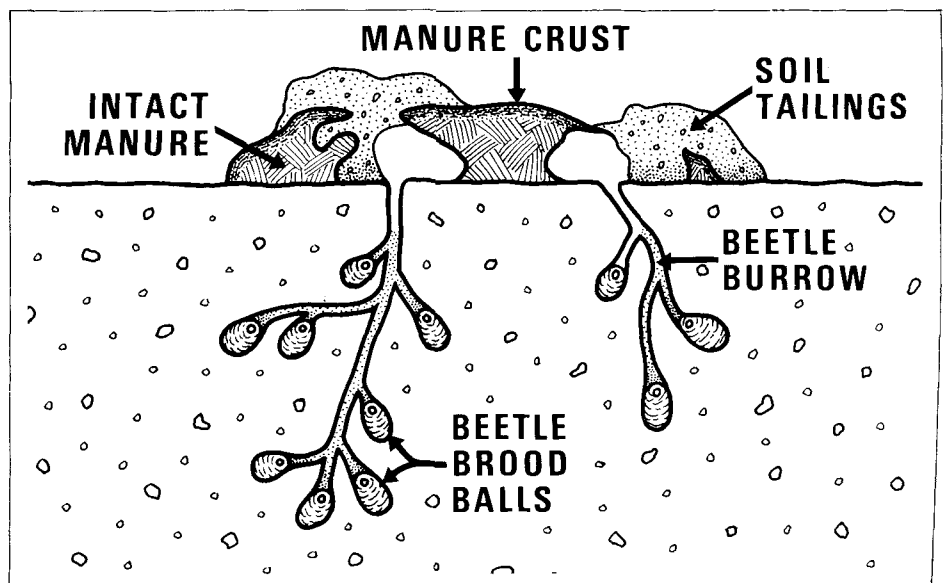
now gradually dispersing and burying more dung pads as they expand their range. Because cattle (and bison) are not native to California, only a few of the native dung beetles have adapted to cattle dung. The small native beetles, unfortunately, have little impact on the vast quantities of cattle dung deposited each year.

The adverse economic impact of parasitic worms and horn and face flies on the cattle industry is well known, but it is not widely recognized that dried-out dung pads also are a major problem. Recent research, however, has revealed that non-degraded cattle droppings are

economically important pests in California, comparable in importance to lice, ticks, or flies.

## Effect on forage

Studies at a U.C. field station near Marysville have shown that because of the smothering of new growth and cattle's rejection of the rank growth surrounding pads, the non-degraded dung pads from one cow cause first-year grazing losses of nearly 0.30 acre, or about \$4.50 per cow. At the rate of twelve, 10-inch dung pads per cow per day, a 5,000-acre ranch supporting 450 cattle loses about \$2,000 in potential conversion of forage to weight



gains the first year. Dried-out dung pads may smother newly sprouting annual vegetation for as long as four years, and the accumulated losses after three and four years can range from \$2,500 to \$3,000. Hence, if exotic dung beetles bury only 25 to 50 percent of existing dung pads, they might have a marked effect on forage production as well as partially reducing parasitic worms and the numbers of horn and face flies. The latter pests are reduced or prevented from developing in dung pads rapidly dispersed and buried by beetles.

The blood-sucking horn fly is associated with reduced milk production and weight gains. The face fly is associated with pinkeye and blindness in cattle and other large mammals, as well as being a general pest of horses, sheep, and humans. Horn-fly-associated weight losses in untreated beef and dairy calves in California would be equivalent to at least \$5 million in a three-month fly season, while pinkeye treatments and resulting blindness cost producers an estimated \$1.5 million per year. Current insecticide costs for both horn and face fly control are estimated at \$1.5 million per year.

From its beginning in 1973, when a few beetles first were reared in a corner

of a greenhouse, the California Dung Beetle Project has expanded to a point where four species of exotic beetles are being mass-reared at U.C. Davis. In 1975, 7,000 beetles of two species were released. In 1976, 38,347 beetles were released, and during 1977 nearly 250,000 beetles were released in California pasture and range lands.

The exotic beetles have a complex life cycle with four stages: egg, larva (grub), pupa, and adult. The nesting adults work in male-female pairs which dig burrows beneath fresh dung pads. Males drop pieces of dung down the burrows where females form the dung into brood balls and deposit an egg in each ball. The brood balls are stored in underground tunnels 2 to 18 inches below the soil surface, with the depth depending upon soil composition and compaction. The eggs hatch into larvae which eat the dung brood balls and rapidly grow.

Field releases have shown that three species—*Onitis alexis*, *Onthophagus taurus*, and *Onthophagus gazella*—have successfully overwintered in different parts of the state. Although overwintered *Onth. gazella* inhabited 40 percent of new dung pads in a southern California release site and subsequently were found

in 100 percent of the dung pads, it is too early to evaluate the reproductive success and dispersal of beetles free-released in other areas. However, experience with similar dung beetle projects in Australia and Texas indicates that beetle populations did not “explode” and disperse widely until several years after mass release.

All dung beetle species being reared and released in California were received from quarantine facilities of the Commonwealth Scientific and Industrial Organization of Australia, and from the U.S.D.A. dung beetle project in Texas. All species being released are scarab beetles of the dung-burying type.

The release of effective dung-burying beetles should establish more productive, balanced pasture ecosystems. But since we have found that systemic insecticides provided in cattle rations render cattle dung toxic to both native and exotic dung beetles, as well as to the fly pests, such pesticides should not be applied in areas where dung beetles are to be established.

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## URBAN PEST MANAGEMENT

The Urban Integrated Control Project under the direction of Dr. William Olkowski is currently funded jointly by the cities of Palo Alto, Berkeley, San Jose, Davis, and Modesto, the Palo Alto Unified School District, the John Muir Institute, and the Environmental Protection Agency. To date an overall pesticide use reduction of over 90 percent has been achieved by the project in each of the street tree systems it has studied. After seven years of being housed in a trailer at the Division

of Biological Control of the University of California at Berkeley, this spring the project will move to new, larger quarters under the auspices of the John Muir Institute, a private, non-profit research institution with headquarters in Napa, California.

Monitoring pest insect and natural enemy populations on the street trees in Berkeley (left), Linda Orthel (holding bag) and John Cordwell (on ladder) check the leaves of the

Tulip trees for Tulip aphids—invaders from the East Coast. Young Klee Orthel watches the process.

In the photo at right, crew members of the Urban Integrated Control project work together with Public Works personnel in San Jose. Carefully timed water washing of the trees is a useful strategy for reducing honeydew accumulations and enhancing beneficial effects of the pest's natural enemies.

