

To make islands safe for rare native species, biologists are mounting increasingly complex campaigns to shoot, trap, or poison exotics

Winning the War Against Island Invaders

SANTA CRUZ ISLAND, CALIFORNIA—It is the coldest, blackest hour before dawn, and Norm MacDonald's professional killers are getting ready. In the doorway of a map-filled war room, Ace is cleaning the sight on his .223-caliber rifle and working the bolt. Steve, sipping tea, straps on a pouch of hollow-point ammo good for blowing baseball-size holes in flesh. Then they step outside to the helicopter that will take them to the enemy: 5000 feral pigs roaming this 250-square-kilometer landmass. "The boys," as MacDonald calls his team in his soft-as-rain New Zealand accent, "are not just hunting. This is eradication."

Every day around the world, terminators are pursuing human-introduced creatures accused of threatening island biota, and, increasingly, wiping out every last invader. It's just a dream on the mainland, where exotic invaders such as nutria or zebra mussels can only be controlled, because once a patch of woodland or water is cleared there are always more in the next. But on islands, humans have proven good at finishing the job because space is limited and the exits sealed: Consider the dodo.

Scientists have focused their attention on islands because they are among the richest and most vulnerable of the world's ecosystems.

They cover 3% of Earth but house 45% of bird, plant, and reptile species. Introduced species are endangering many of the natives, because many island creatures are endemic. They have not evolved defenses against the mainland predators and grazers that humans bring—rats, cats, sheep, goats, and pigs. Islanders often get outcompeted or eaten; biologist Bernie Tershy, director of Island Conservation, a California-based nonprofit that specializes in eradications, says that since 1600, islands have accounted for up to 90% of bird and reptile extinctions worldwide, and half those of plants and mammals. Rats, now on 80% of islands, attack plants, insects, birds, and small animals; they are implicated in about half of recorded bird and reptile extinctions. Goats eat whole trees and gnaw plants to bare rock. On Hawaii's remote Laysan, rabbits eliminated 26 plant species within 20 years after arriving in the 1900s. On the Indian Ocean's subantarctic Kerguelen Archipelago, one cat and her three kittens arrived in the 1950s, and by the 1980s, they had reproduced into 3500 felines killing 1.2 million seabirds a year.

Ecologists once thought it impossible to wipe out invaders, even on islands. Into the 1980s, "hardly anyone thought eradication could be done," says Daniel Simberloff, an ecologist at the University of Tennessee, Knoxville, who was an early advocate.

But efforts on hundreds of islands worldwide have proven that mammals, at least, can be taken out, although campaigns against plants, insects, and reptiles are much tougher. Now exter-

minations in the name of conservation are taking place on ever-bigger islands, with ever more military-style planning and hardware.

The key, say experts, is to attack fast and get every last indi-

vidual before they can reproduce, adapt, or escape, because even a few strays can quickly rebound.

New studies show that some threatened species recover spectacularly. "The problems are obvious, and the solutions are obvious," says Tershy. However, this "nasty necessity," as Tershy calls it, is not always simple. Subtracting one invader from an ecosystem can make other components run amok, and the slaughter cannot always bring back rare native species to environments that have been severely altered. Then there is human ecology, as animal-rights protesters increasingly try to thwart extermination efforts. Together, these complications can weave a plot as tangled as a history of the Hundred Years' War. Santa Cruz is Exhibit A.

Extermination island

About 100 kilometers northwest of Los Angeles, Santa Cruz is the largest of the 12 Channel Islands of California and Mexico. Their precipitous canyons, woodlands, and prairies hold some 2000 species and subspecies. Approximately 140 are endemic to one or a few islands, including the gigantic island scrub jay; the island spotted skunk (said to smell nicer than mainland cousins); dozens of flowering plants; and six subspecies of cat-size foxes, each peculiar to its own island. Some 10,000 years ago, Chumash people arrived with imports such as oaks; after 1800, Europeans brought smallpox, pigs, sheep, garden plants, and honeybees. The Chumash disappeared, alien grasses spread to 75% of Santa Cruz, and by the early 1900s, creatures such as the island sparrow and the Santa Cruz monkey flower were extinct.

Attempts at control came as early as 1904 after livestock escaped and started denuding the land. Hunters shot tens of thousands of sheep and pigs. But they never got them all. As soil eroded and nearly a dozen plants approached extinction in the

Coming back. Without rats, Xantus's murrelet chicks are rebounding on Anacapa Island.



1980s and 1990s, The Nature Conservancy (TNC) and National Park Service (NPS) took over Santa Cruz and other islands and got serious.

Research on invasives was just taking off, but most scientists were at first focused on documenting invaders' effects, not designing ways to kill them off. New Zealand's Department of Conservation (DOC) proved the worth of counterattack. Officials enlisted the country's deep-rooted hunting culture to attack large mammals, which are fewest, most visible, and usually the most destructive introduced creatures. Starting with islands of a few acres, New Zealanders hunted and trapped deer, goats, and pigs. They fenced islands into sectors, corralled animals in traps, ambushed them from helicopters, and made skirmish-line ground sweeps with tracking dogs. Eradication became an industry, and Norm MacDonald, a hunter since childhood, started his outfit, Prohunt Ltd. "We try to stay humane," says the teddy-bearish CEO, an expert at shooting from a helicopter. "One shot for the head, one for the body—it's all over really quickly."

As New Zealanders added poisons and traps to the arsenal and moved to smaller prey such as possums and rabbits, the idea caught on. In the past 8 years, Island Conservation has rid 27 Mexican Pacific islands of 41 mammal populations, including hard-to-catch cats. Scientists rarely do the killing themselves, though. "The last thing you want is a bunch of biologists running around with guns," says Josh Donlan, a conservation biologist at Cornell University. Island Conservation's muscle is longtime Oregon fur trapper Bill Wood. "I learned from the old guys," says Wood, co-author of two chapters in the 2002 book *Turning the Tide*, a collection of island-eradication papers. For cats, Wood relies on night shooting with spotlights—a poacher's favorite—and elaborately engineered traps. Rabbits rarely escape Wood's Jack Russell Terrier, Freckles, who finds their burrows and digs them out.

By the 1990s, DOC had shown that even rats can be wiped out, with poison pellets dropped from helicopters. In 2006, the agency hopes to confirm the world's largest rat eradication: 11,300-hectare subantarctic Campbell Island, hit in 2001 with 120 tons of the poison brodifacoum. Seabirds decimated by the rats are coming back fast. To protect nontarget animals, including rare seabirds, teams here and elsewhere tint pellets in bright colors that nontarget species reject, use bait stations they can't get into, or remove them to captivity until baits decay. Toxins deadly only to rats and cats are also in the works.

Most of these strategies are in use in the world's largest eradication project, on Ecuador's Galápagos Islands, funded by \$21 million from the United Nations and



Goat attack. Invasive goats, such as these on Isabela Island in the Galápagos, can strip vegetation completely.

private foundations (*Science*, 27 July 2001, p. 590). The flagship target is 150,000 goats on 458,000-hectare Isabela Island. Project leader Felipe Cruz says that 90% of the job is killing the last, canny survivors; a few goats can elude hunters for years, nimbly roaming over near-impossible terrain and hiding at the sound of a helicopter. So the project employs new methods, including deployment of 600 radio-collared, companion-seeking

"Judas goats" that lead helicopter-borne shooters to holdouts. The group also has sterilized "Super Judas" nannies, implanted with hormones to draw billies. To assure total coverage, aircraft, ground hunters and even dogs are fitted with Global Positioning System units that record their movements, all integrated daily into a Geographical Information System. Final mop-up may involve airborne forward-looking infrared radar to generate thermal images of animals hidden in underbrush, the system used by U.S. Special Forces to hunt guerrillas. Cruz won't say how many goats they have killed so far, but he thinks it will all be over by March 2006. The work is described in the October issue of *Conservation Biology*, and papers are in press at *Wildlife Research* and *Applied Animal Behavior Science*.

In the Channel Islands, many eradications have preceded the war against the pigs, including removals of rabbits, cats, burros, horses, and cattle. TNC had all 37,171 sheep shot from its portion of Santa Cruz by 1987, and NPS, which owns the rest, deported 2000 remainders alive in 2001.

When introduced species are gone, native creatures often bounce back dramatically. NPS reports that with livestock removal, riparian plants on modest Santa Rosa Island have gone from virtually zero in 1995 to 90% coverage today. Since NPS poisoned rats on tiny Anacapa Island in 2001 and 2002, nesting by rare Xantus's murrelets has increased 80%. Further south, on Mexico's Guadalupe Island, a half-dozen species of plants long thought extinct have suddenly reappeared in the last year or so, along with



Judas pig. Hunters put a radio-transmitting collar on a pig so it can lead them to other pigs.

150-some seedlings of nearly extinct endemic Guadalupe pines, even as Island Conservation mops up the last of 7500 goats there. In Alaska's Aleutian Islands, rare seabirds such as fork-tailed petrels have increased four- to fivefold within 10 years of fox removals, says Vernon Byrd, a biologist with the Alaska Maritime National Wildlife Refuge. And in New Zealand, biologists cite dozens of native invertebrates, reptiles, and birds that have rebounded after eradications (68 of the nation's 168 mammal-invaded islands are now cleared). On Korapuki Island, one rare skink increased 30-fold when rats were taken off, according to a review just published in *Biological Invasions*.

Biologists are in fact so convinced of these successes that many do not bother doing extensive studies on the results, writing them up only in conference proceedings or internal reports. "You don't need a guy with a Ph.D. and 10 years of data to tell you the obvious: An insect that was practically nonexistent is now everywhere. Most people put the resources into doing the next job, not proving they did the last one," says C. Richard Veitch, an ex-DOC biologist now with the World Conservation Union. He may be right in some cases, says Cornell's Donlan, but scientists are realizing that as they move to larger, more complex islands with multiple invaders, they need long-term peer-reviewed follow-up, because results can be confusing.

On Santa Cruz, some ecologists think that earlier eradications may actually have helped make the war on pigs necessary. Removing sheep might have helped pigs overmultiply by giving them more forage and cover, says wildlife ecologist Bruce Coblenz of Oregon State University, Corvallis. The pigs till soil to 30 cm or more, making much of the island a lumpy mess, endangering nine species of endemic plants, and preventing gnarly old oaks from having descendants. (Pigs love acorns.)

Worse, says Gary Roemer, an ecologist at New Mexico State University in Las Cruces, it appears that by about 1994, tasty piglets had attracted mainland golden eagles. They may also have come earlier for the tens of thousands of sheep carcasses that TNC left scattered, notes University of California (UC), Santa Cruz, field biologist Brian Latta. (The golden eagles previously were kept out by fierce fish- and

carion-eating bald eagles, but the balds were wiped out in the 1960s by DDT.) Roemer says the golden eagles then discovered a convenient food source in the tiny, unwary Santa Cruz Island foxes, which plummeted from an estimated 1500 in 1994 to 150 today. Nearby islands' foxes nearly disappeared too, and in 2004, three subspecies were declared endangered. TNC biologists say that as long as the fast-reproducing pigs are on Santa Cruz, they will provide abundant food for the golden eagles, which will stick around and eventually extinguish the slow-reproducing foxes. Scientists agree: The pigs must go.

The last pig

Killing the pigs and cleaning up the ecological mess after them is a huge operation. MacDonald and the boys have been living in an isolated old ranch house since this summer, after Prohant was selected for the \$6.2 million, 3-year project. TNC has fenced its land into five kill zones to keep fugitives contained. At the same time, there are programs to live-trap and relocate golden eagles

to the mainland, reintroduce young bald eagles, and breed foxes in captivity.

It is now morning. After dogs and men take off in the copter, MacDonald and TNC official Julie Benson drive to a high hilltop in Zone 2 to watch them disembark. As of today, they have killed 2574 pigs. Except for a few used for pig roasts for the boys, the team piles up the dead in remote spots and covers them to keep off scavengers—and the eyes of visitors, who TNC officials feared may turn against the project if they see the results. Yesterday, MacDonald's crew was pursuing what appear to be the last four pigs in this zone, but they got only three. "Not good; now that pig is educated," said MacDonald. "Every time we see an animal, we try to make sure that's the last time it sees us. If you know what I mean." But as experience suggests, the last pig is not necessarily the end of the story.

After TNC shot the Santa Cruz sheep and removed cattle, 33 of 43 endemic plant species came back, including the endangered Santa Cruz silver lotus and northern island *Hazardia*, spreading outward from cliffside refuges to which the livestock had pushed them. However, for unknown reasons several native plants have actually declined. More significantly, livestock are no longer eating exotic plants either, says Steven Junak, a botanist at the Santa Barbara Botanic Garden. As a result, previously invisible bamboolike fennel, a sheep and cattle favorite, has carpeted 5% of the island, higher than a man's head, perhaps spread in part by pigs. TNC has sprayed the fennel with herbicide, but it only gets replaced by fast-moving alien grasses, according to a recent paper in *Biological Conservation*. Star thistle and hundreds of other plants are coming in elsewhere, defying volunteer crews who pull them up by hand.

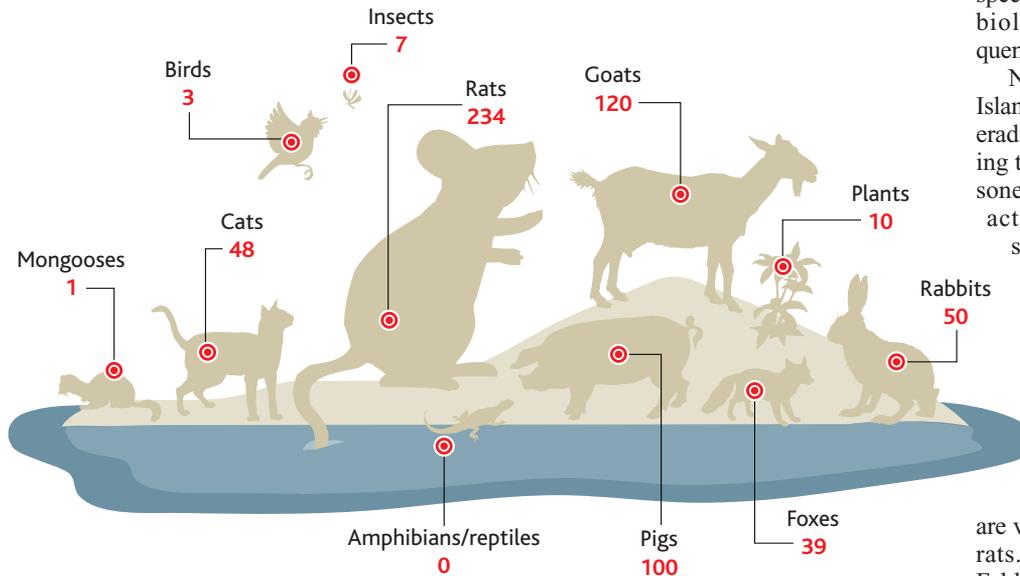
This is especially troubling because plants are nearly impossible to eradicate once they get going, says botanist Marcel Rejmanek of UC Davis. He says infestations of a hectare or less can usually be wiped out, but it takes up to 10 years; those occupying 1 to 1000 hectares might be done in 30 years; and anything bigger is impossible. "Early detection is the only hope; once something is a problem, it's too late," he says. (Reptiles such as the brown tree snake, which has extinguished practically all native birds, lizards, and bats on the Pacific island of Guam, seem



Before and after. Except for an enclosure area, the removal of goats and pigs transformed the highlands of Santiago Island (above) in the Galápagos.

ERADICATION SCORECARD

Number of islands where documented eradications have finished off . . .



equally resistant, along with insects, which have been removed from only a half-dozen islands worldwide.)

Santa Cruz is not the only place to suffer ecological kickback. After goats were removed in 1998 from the Pacific's Sarigan Island, native forests sprouted fast—along with *Operculina ventricosa*, an exotic vine that no one even knew was present until the goats stopped eating it. It has now developed an uninterrupted carpet over parts of the island. Similar plant invasions have occurred on other islands after removal of pigs and rabbits. On various subantarctic islands, cats have been wiped out, leading to rat expansion; rabbits have been killed, expanding exotic grasses that in turn become habitat for rats; exotic possums and rats have been exterminated, but not possum- and rat-eating stoats, which then switch to eating native bird eggs; and so on. In 1979, Amami Island, Japan, imported 30 mongooses to control rats and poisonous snakes, but the mongooses instead ate crops and rare endemic birds, and they have now multiplied out of control, too wily to eradicate.

"There are many instances where common sense tells you that cleaning up one mess may create a second mess, but some things are predictable only in hindsight," says ecologist Erika Zavaleta of UC Santa Barbara. David Wardle, an ecologist at Landcare Research, says long-term predictions are hard to make, because invaders may alter the very chemistry and microbiology of island soils. Out-of-whack ecosystems may reestablish a balance, he says, but it might take hundreds, even thousands, of years. Eradication is only a first step, he says; soil amendments, planting of native flora, and animal reintroductions often must follow. "We should forget the

word 'restoration,'" says UC Davis wildlife biologist Rob Klinger, who has worked on Santa Cruz. "You can never put things back exactly as they were."

It is now late morning, and the boys are heading back to the ranch house in a pickup over a rough dirt track. On the flatbed, a fresh, bloody pig jaw with two sharp tusks jumps up with each big bump—unfortunately, a souvenir from yesterday, not today. That last pig in Zone 2 got away again. "Don't worry," says Steve. "We'll get him."

After that job is done, there may be other challenges, including the golden eagles. It has taken 6 years and close to \$1 million to capture and relocate just 42 with traps. About six holdouts are left—the wariest, says Brian Latta, who led the project until February. Now, with the pigs disappearing, he, Roemer, and others fear that the birds could attack the foxes even harder and finish them off in the wild. Golden eagles are common, so Roemer and others agree that the solution is easy: Shoot them, too (*Science*, 28 November 2003, p. 1532). But eradicating native wildlife—an American icon no less—"is very politically incorrect," says TNC's Benson. TNC and NPS will keep trying to catch the goldens alive, even if it slows the foxes' recovery, she admits. Meanwhile, exotic wild turkeys are on the horizon. They are common on Santa Cruz, and the pigs probably eat their eggs, so biologists fear that once the pigs are gone, the turkeys could become a plague as they are on the mainland, where they vacuum-clean forest floors of amphibians and insects.

All this may seem like a never-ending saga of manipulation, but against the grim backdrop of worldwide extinctions, eradications are worth it, say conservation biologists;

they are one of the few clear success stories. "We're dealing with highly threatened species," says Keith Broome, a senior DOC biologist. "We already know the consequences of doing nothing."

Not everyone agrees. On other Channel Islands, animal-rights protesters have slowed eradications by cutting fences and vandalizing traps. When the Anacapa rats were poisoned, the Fund for Animals sued, and two activists were arrested after landing to spread rat feed laced with an antidote.

Local activists are currently suing over the pigs and flying "save the pigs" banners across the skies. They say that if pig numbers must be reduced, it should be done by means of contraception or relocation. TNC counters that neither of those methods will get every pig.

Protesters say all individual animals are valuable, whether rare foxes or common rats. Santa Barbara businessman Richard Feldman, a co-plaintiff in the pig suit, says scientists have "demonized" the pigs and that evidence linking them to fox declines is thin or fabricated. He adds that pigs are now part of the island, such as oaks and foxes, which also once came from elsewhere. "Ecosystems are always changing. Scientists want to play god," he says.

Conservation biologists tend to side with endangered species. "Animal rightists are a bunch of well-meaning pinheads who just don't understand," retorts Coblenz. However, some biologists agree that deifying science is a mistake. "We shouldn't confuse scientific knowledge with moral authority. Observing extinction and deciding what to do about it are different, and there all human beings have a valid point of view," says Dov Sax, a research biologist at UC Santa Barbara. In a recent essay in *Austral Ecology*, Sax and ecologist James Brown of the University of New Mexico, Albuquerque, call for scientists to take more care in studying how species interact before deciding which ones to declare war on. Many "alien" species are not harmful to natives, points out Sax, and simply become part of the mix. "It is not to suggest that modern humans should . . . elect not to intervene," they say. "It is to plead for more scientific objectivity and less emotional xenophobia."

On Santa Cruz, the story is still in progress. By midafternoon, Julie Benson is bumping along a dirt road in a Land Cruiser heading for the mainland ferry. Suddenly, a flash of hair and legs flits from the scrub on the left side and disappears in the scrub on the right side. It is a black-and-white adult pig, trailed by a baby. Both are running as fast as they can.

—KEVIN KRAJICK

Kevin Krajick is the author of *Barren Lands: An Epic Search for Diamonds in the North American Arctic*.