ONE

An Ecological Catastrophe

> A careful observation of Nature will disclose pleasantries of superb irony. She has for instance placed toads close to flowers.
>
> HONORÉ DE BALZAC, *Massimilla Doni,* 1837

This book tells a story of warfare, at several levels and among several combatants. It's a tale of an invasive amphibian that has devastated native wildlife in Australia; of how the ecosystem fought back to get the invader under control; of battles between scientists who championed the the toad's introduction and those who opposed it; of claims and counterclaims regarding toad impact and management, fought out in the public arena by scientists and community toad-busting groups; and of how my research team developed a new arsenal of weapons to control the Cane Toad. Ironically, we stole most of those weapons from the toads themselves, by eavesdropping on tricks they use to kill their competitors—the fiercest battles involve Toad against Toad.

But I was blissfully unaware of all those complexities when I became embroiled in the War of the Toad. All I knew was that the toad invasion was rolling westward across tropical Australia and would soon arrive at my doorstep; that the arrival of Cane Toads spelled doom for many native animals; and that vast energy and effort from other scientists, as well as from the general community, had failed to slow the toad's progress.

At its worst, a biological invasion is a nightmare. Suddenly confronted by a new type of enemy, even abundant and widespread species may be faced with ecological Armageddon. We see it most clearly with emerging diseases: plagues like the Black Death wiped out one-third of Europe's human population in the fourteenth century; the Chytrid Fungus is obliterating frogs on every continent; and Chestnut Blight Fungus kills even century-old trees. But larger invaders wreak havoc as well. All around the world, the arrival of rats, cats, and people has eradicated unique wildlife. And in Australia, Cane Toads are writing a new chapter in the dismal history of invader devastation.

Isolated from the other continents for millions of years, Australia evolved its own unique fauna. Instead of deer, squirrels, and beavers, we have Red Kangaroos, Koalas, and Platypuses. Instead of drab little songbirds, my front garden in Sydney is home to raucous Sulphur-crested Cockatoos and ornate Rainbow Lorikeets. And instead of garter snakes, rattlesnakes, and adders, I find Red-bellied Black Snakes and Diamond Pythons. (Species' common names are capitalized throughout, whereas common names that refer to groups of species are uncapitalized. All common names of species are listed in alphabetical order in the appendix, alongside their scientific names.) Geographically inaccessible to the animal groups that dominate other continents, Australia has been a cradle for the development of life-forms and ecological dynamics found nowhere else. But that uniqueness has a downside: a vulnerability to invasion. If introduced to Australia, animals and plants from North America, South America, Europe, and Asia can blindside the native species. Species within an ecosystem evolve side by side, which gives them an opportunity to adapt to each other. Predators, prey, and parasites are locked in evolutionary "arms races," each finely tuned to the threats and opportunities posed by the other species.

Invasion breaks those rules. It exposes an entire fauna and flora to a type of organism they have never encountered before. That newcomer can be devastating. So it was with the Cane Toad. It has no close relatives in Australia—members of its lineage (the "true toads": Family Bufonidae, or "bufonids") never reached our continent, though they occur widely on others. And early in their long evolutionary history, the bufonids developed a powerful defense against predators: a potent poison. In the toads' native range, local predators adapted to that chemical via a gradual arms race; they can eat toads without dying. But Australian predators never had that evolutionary opportunity. Even a drop of toad poison is deadly.

As a result, native wildlife is being massacred across Australia. That slaughter began when toads arrived in 1935, and the wave of death is moving faster and faster. Nobody paid attention to the carnage in the first few decades after toads began to spread. Most of the Cane Toad's victims were animals that people disliked (like crocodiles and snakes) or that were a threat to poultry (like large lizards and predatory marsupials). But as environmental awareness grew, and unreasoning hatred of reptiles receded, the terrible truth became clear. In 1975, two biologists at the Queensland Museum published a landmark paper drawing attention to the catastrophic mortality of wildlife caused by the Cane Toad invasion.

A TOAD IS A TYPE OF FROG, BUT NOT VICE VERSA

All of the 6,000-plus species of modern frogs and toads are closely related. They form the Anura, one of three main lineages of amphibians (the others are salamanders and the limbless burrowers and swimmers called "caecilians"). All the Anura are called "frogs"—and some of those frogs are toads.

Today's anurans evolved from an ancestor that lived 250 million years ago. Some of its descendants live in the trees—slender-waisted, long-limbed, elfin creatures with big eyes and large toe-pads. Others live in water, with webbed feet that aid their swimming. Most of the ones that live on land are brown (and thus are well camouflaged), with feet better suited to hopping or digging than to clinging. Several evolutionary lineages of frogs have opted for the ground-frog lifestyle, and they all look similar. Trying to identify a small brown ground-frog in the forest at night, with mosquitoes buzzing in your ears and a dim flashlight for illumination, is one of the most frustrating experiences in tropical fieldwork.

But toads are easy to identify; they stand out among the fifty major families of frogs. Toads are toads—in shape, posture, and behavior. Evolution worked out a good design 50 million years ago, and most of the five hundred living species of toads have retained that design. These so-called "true toads" (Family Bufonidae) are a very old group in geological terms, but they haven't changed much. The species from 40 million years ago would be easily recognizable as toads if they came back to life and hopped across your backyard.

The Bufonidae also include some weird creatures that deviate from that prototype, but most modern toads have opted for conservatism in their ecological niche as well as their body shape. Regardless of whether you find them in the rainforests of Brazil or the suburbs of London, these Universal Toads are short, fat, slow-moving ground-dwellers that live around water bodies, eat anything that moves, and protect themselves with a toxic cocktail of chemicals in glands on their shoulders.

Lacking the athletic ability of active mega-leapers like the aptly named "rocket frogs," the climbing ability of the tree frogs, or the underwater acrobatics of aquatic frogs, toads make do by sitting in moist spots and grabbing unlucky insects that come too close. Their sex lives are also staid. Many other types of frogs have complicated reproductive strategies, laying their eggs on land or even incubating the babies inside the father's vocal sac or the mother's uterus or stomach. But the Universal Toad eschews such new-fangled frippery. It lays its eggs—and lots of them—in strings in the nearest pond, and these hatch into small tadpoles that emerge from the water as tiny toadlets—miniature versions of their parents.

The Cane Toad is one of the largest and most toxic amphibians in the world. Photo by Matt Greenlees.

It took another three decades before detailed studies were conducted to measure the impact of Cane Toads on wildlife. In site after site across tropical Australia, that research showed that within a few months of Cane Toads arriving in an area, more than 90 percent of the "top predators" were dead. The rotting bodies of Freshwater Crocodiles floated downstream. The corpses of giant varanid lizards ("goannas") dotted the floodplain. Species once common, like the Northern Quoll and the massive Bluetongue Lizard, could no longer be found. These are apex predators—critically important for ecosystem function. They control the numbers of smaller species. Take the top predators away and everything changes. In North America, the near eradication of Wolves and Mountain Lions was followed by an explosion in deer abundance and massive overbrowsing of vegetation. The ecosystem changed. It is changing in tropical Australia as well, as Cane Toads mow down the top predators, and we still don't know where it will all end.

How could this happen? How could an animal that evolved in the Amazon—in a warm, wet world—survive and flourish in the harsh Australian outback?

From the perspective of its victims, the Cane Toad was the wrong animal in the wrong place at the wrong time.

To explain the toad's success in Australia, we have to go back to its origins in South America. Cane Toads belong to a pioneering group of amphibians—the bufonids—whose transcontinental invasions make Genghis Khan and his Mongol hordes look like introverted homebodies. Toads thrive in most parts of the world because they are ecological generalists. Thirty-five million years ago, ancestral toads embarked on a circumglobal journey that would end with world domination. Beginning in South America, these humble, squat little creatures achieved an extraordinary diaspora from Acapulco to Zanzibar.

Not all toads are created equal. Some kinds of toads were better than others at marching across continents and floating on driftwood over oceans. Across millions of years and the entire circumference of the globe, the pioneering toads were those with land-dwelling adults (so they could move from one pond to the next), large poison glands (that kept them safe from predators), fat-storage organs (to survive the bad times, when food was scarce), opportunistic breeding (so they could make babies whenever the chance arose), and a large number of offspring in every clutch (so at least a few babies survived). Once they had evolved that set of characteristics, the South American toads took off to North America, Africa, Europe, and Asia.

So, toads were Great Invaders long before a supersized species evolved 20 million years ago in the Amazon Basin, at the margins of the great rainforests. This giant species—the Cane Toad—was destined to become the ultimate world traveler, eclipsing all of its relatives. Nonetheless, it was just building on a long family tradition, established eons before prehumans evolved in the African savannas 2 million years ago. And the final missing element in the Bufonidae's global conquest fell into place in 1935, when thirty-three-year-old Reg Mungomery collected 101 Cane Toads in Hawaii and brought them back to Australia. Reg brought toads to the only toad-habitable continent that they hadn't reached on their own.

The sugarcane growers who invited the Cane Toad to Australia wanted an animal that would eat as many insect pests as possible. And they succeeded: given the opportunity, Cane Toads eat hundreds of prey items in a single night. When you pick up a well-fed Cane Toad, it crackles in your hand from insect exoskeletons rubbing together in the toad's stomach. The cane farmers didn't realize that they had also chosen an awesome invader. Cane Toads inherited a capacity for long-distance dispersal, powerful toxins, a flexible