The Komodo Dragon

On a few small islands in the Indonesian archipelago, the world's largest lizard reigns supreme.

A deer nimbly picks its way down a path meandering through tall savanna grasses. It is an adult male of its species, *Cervus timorensis*, weighing some 90 kilograms (about 200 pounds). Also known as a Rusa deer, the animal knows this route well; many deer use it frequently as they move about in search of food. This Rusa's home is the Indonesian island of Komodo, a small link in a chain of islands separating the Flores Sea from the Indian Ocean [see illustration]. Most wildlife find survival a struggle, but for the deer on Komodo, and on a few of the nearby islands, nature is indeed quite red in tooth and claw. This deer is about to encounter a dragon.

The Komodo dragon, as befits any creature evoking a mythological beast, has many names. It is also the Komodo monitor, being a member of the monitor lizard family, *Varanidae*, which today has but one genus, *Varanus*. Residents of the island of Komodo may call it the ora. Among some on Komodo and the islands of Rinca and Flores, it is buaja darat (land crocodile), a name that is descriptive but inaccurate; monitors are not crocodilians. Others call it biawak raksasa (giant monitor), which is quite correct; it ranks as the largest of the monitor lizards, a necessary logical consequence of its standing as the biggest lizard of any kind now living on the earth. (A monitor of New Guinea, *Varanus salvadorii*, also known as the Papua monitor, may be longer than the lengthiest Komodo dragons. The former's lithe body and lengthy tail, however, leave it short of the thickset, powerful dragon in any reasonable assessment of size.) Within the scientific community, the dragon is *Varanus komodoensis*. And most everyone also calls it simply the Komodo.

The Komodo's Way of Life

The deer has wandered within a few meters of a robust male Komodo, about 2.5 meters (eight feet) long and weighing 45 kilograms. The first question usually asked about Komodos is, how big do they get? The largest verified specimen reached a length of 3.13 meters and was purported to weigh 166 kilograms, which may have included a substantial amount of undigested food. More typical weights for the largest wild dragons are about 70 kilograms; captives are often overfed. Although the Komodo can run briefly at speeds up to 20 kilometers per hour, its hunting strategy is based on stealth and power. It has spent hours in this spot, waiting for a deer, boar, goat or anything sizable and nutritious.

Monitors can see objects as far away as 300 meters, so vision does play a role in hunting, especially as their eyes are better at picking up movement than at discerning stationary objects. Their retinas possess only cones, so they may be able to distinguish color but have poor vision in dim light. Today the tall grass obscures the deer.

Should the deer make enough noise the Komodo may hear it, despite a mention in the scientific paper first reporting its existence that dragons appeared to be deaf. Later research revealed this belief to be false, although the animal does hear only in a restricted range, probably between about 400 and 2,000 hertz. (Humans hear frequencies between 20 and 20,000 hertz.) This limitation stems from varanids having but a single bone, the stapes, for transferring vibrations from the tympanic membrane to the cochlea, the structure responsible for sound perception in the inner ear. Mammals have two other bones working with the stapes to amplify sound and transmit vibrations accurately. In addition, the varanid cochlea, though the most advanced among lizards, contains far fewer receptor cells than the mammalian version. The result is an animal that is insentient to such sounds as a low-pitched voice or a high-pitched scream.

Image: George Mason University

KOMODO DRAGON flicks his foot-long, yellow forked tongue to taste the air.

Vision and hearing are useful, but the Komodo's sense of smell is its primary food detector. Its long, yellow forked tongue samples the air, after which the two tongue tips retreat to the roof of the mouth, where they make contact with the Jacobson's organs. These chemical analyzers "smell" the deer by recognizing airborne molecules. The concentration present on the left tongue tip is higher than that sampled from the right, telling the Komodo that the deer is approaching from the left. This system, along with an undulatory walk in which the head swings from side to side, helps the dragon sense the existence and direction of odoriferous carrion from as far away as four kilometers, when the wind is right.

The Komodo makes its presence known when it is about one meter from its intended victim. The quick movement of its feet sounds like a "muffled machine gun," according to Walter Auffenberg, who has contributed more to our knowledge of Komodos than any other researcher. Auffenberg, a herpetologist at the University of Florida, lived in the field for almost a year starting in 1969 and returned for briefer study periods in 1971 and again in 1972. He summed up the bold, bloody and resolute nature of the Komodo assault by saying, "When these animals decide to attack, there's nothing that can stop them." That is, there is nothing that can stop them from their attempt--most predator attacks worldwide are unsuccessful. The difficulties in observing large predators in dense vegetation turn some quantitative records into best estimates, but it is informative that one Komodo followed by Auffenberg for 81 days had only two verified kills, with no evidence for the number of unsuccessful attempts.

For the sake of instructive exposition, the Komodo that has ambushed the deer reaches its target. It attacks the feet first, knocking the deer off balance. When dealing with smaller prey, it may lunge straight for the neck. The basic strategy is simple: try to smash the quarry to the ground and tear it to pieces. Strong muscles driving powerful claws accomplish some of this, but the Komodo's teeth are its most dangerous weapon. They are large, curved and serrated and tear flesh with the efficiency of a plow parting soil.

Its tooth serrations harbor bits of meat from the Komodo's last meal, either fresh prey or carrion. This protein-rich residue supports large numbers of bacteria, which are currently being investigated by Putra Sastrawan, once Auffenberg's student, and his colleagues at the Udayana University in Bali and by Don Gillespie of the El Paso Zoo in Texas. They have found some 50 different bacterial strains, at least seven of which are highly septic, in the saliva.

Image: American Museum of Natural History

KOMODOS FEAST on a pig. Their curved, serrated teeth easily tear through flesh. Meat caught in the serrations supports the growth of septic bacteria.

If the deer somehow maneuvers away and escapes death at this point, chances are that its victory, and it, will nonetheless be short-lived. The infections it incurs from the Komodo bite will probably kill it within one week; its attacker, or more likely other Komodos, will then consume it. The Komodo bite is not deadly to another Komodo, however. Dragons wounded in battle with their comrades appear to be unaffected by these otherwise deadly bacteria. Gillespie is searching for antibodies in Komodo blood that may be responsible for saving them from the fate of the infected deer.

Should the deer fail to escape immediately, the Komodo will continue to rip it apart. Once convinced that its prey is incapacitated, the dragon may break off its offensive for a brief rest. Its victim is now badly injured and in shock. The Komodo suddenly launches the coup de grâce, a belly attack. The deer quickly bleeds to death, and the Komodo begins to feed.

The muscles of the Komodo's jaws and throat allow it to swallow huge chunks of meat with astonishing rapidity: Auffenberg once observed a female who weighed no more than 50 kilograms consume a 31-kilogram boar in 17 minutes. Several movable joints, such as the intramandibular hinge that opens the lower jaw unusually wide, help in the bolting. The stomach expands easily, enabling an adult to consume up to 80 percent of its own body weight in a single meal, which most likely explains some exaggerated claims for immense weights in captured individuals.

Large mammalian carnivores, such as lions, tend to leave 25 to 30 percent of their kill unconsumed, declining the intestines, hide, skeleton and hooves. Komodos eat much more efficiently, forsaking only about 12 percent of the prey. They eat bones, hooves and swaths of hide. They also eat intestines, but only after swinging them vigorously to scatter their contents. This behavior removes feces from the meal. Because large Komodos cannibalize young ones, the latter often roll in fecal material, thereby assuming a scent that their bigger brethren are programmed to avoid consuming.

More Komodos, attracted by the aromas, arrive and join in the feeding. Although males tend to grow larger and bulkier than females, no obvious morphological differences mark the sexes. One subtle clue does exist: a slight difference in the arrangement of scales just in front of the cloaca, the cavity housing the genitalia in both sexes. Sexing Komodos remains a challenge to researchers; the dragons themselves appear to have little trouble figuring out who is who. With a group assembled around the carrion, the opportunity for courtship arrives.

Most mating occurs between May and August. Dominant males can become embroiled in ritual combat in their quest for females. Using their tails for support, they wrestle in upright postures, grabbing each other with their forelegs as they attempt to throw the opponent to the ground. Blood is usually drawn, and the loser either runs or remains prone and motionless.

The victorious wrestler initiates courtship by flicking his tongue on a female's snout and then over her body. The temple and the fold between the torso and the rear leg are favorite spots. Stimulation is both tactile and chemical, through skin gland secretions. Before copulation can occur, the male must evert a pair of hemipenes located within his cloaca, at the base of the tail. The male then crawls on the back of his partner and inserts one of the two hemipenes, depending on his position relative to the female's tail, into her cloaca.

The female Komodo will lay her eggs in September. The delay in laying may serve to help the clutch avoid the brutally hot months of the dry season. In addition, unfertilized eggs may have a second chance with a subsequent mating. The female lays in depressions dug on hill slopes or within the pilfered nests of Megapode birds. These chicken-size land dwellers make heaps of earth mixed with twigs that may reach a meter in height and three meters across. While the eggs are incubating, females may lie on the nests, protecting their future offspring. No evidence exists, however, for parental care of newly hatched Komodos.

The hatchlings weigh less than 100 grams and average only 40 centimeters in length. Their early years are precarious, and they often fall victim to predators, including their fellow Komodos. They feed on a diverse diet of insects, small lizards, snakes and birds. Should they live five years, they can weigh 25 kilograms and stretch two meters long. By this time, they have moved on to bigger prey, such as rodents, monkeys, goats, wild boars and the most popular Komodo food, deer. Slow growth continues throughout their lives, which may last more than 30 years. The largest Komodos, three meters and 70 kilograms of bone, teeth and sinew, rule their tiny island kingdoms.

The Komodo's Past

Komodos, as members of the class Reptilia, do have a relationship with dinosaurs, but they are not descended from them, as is sometimes believed. Rather Komodos and dinosaurs share a common ancestor. Both monitor lizards and dinosaurs belong to the subclass Diapsida, or "two- arched reptiles," characterized by the presence of two openings in the temporal region of the skull. The earliest fossils from this group date back to the late Carboniferous period, some 300 million years ago.

Two distinct lineages arose from those early representatives. One is Archosauria, which included dinosaurs. The ancestor of monitor lizards, in contrast, stemmed from primitive Lepidosauria at the end of the Paleozoic era, about 250 million years ago. Whereas some dinosaurs evolved upright stances, the monitor lineage retained a sprawling posture and developed powerful forelimbs for locomotion. During the Cretaceous, and starting 100 million years ago, species related to present-day varanids appeared in central Asia. Some of these were large marine lizards that vanished with the dinosaurs, about 65 million years ago. Others were terrestrial forms, up to three meters in length, that preyed on smaller animals and probably raided dinosaur nests. About 50 million years ago, during the Eocene, these species dispersed throughout Europe and south Asia and even into North America.

Wolfgang Böhme of the museum of natural history in Bonn has contributed much to

our understanding of the rise and evolution of the Varanus genus, based on morphological data. Dennis King of the Western Australian Museum and Peter Baverstock and his colleagues at Southern Cross University are continuing research into the evolutionary history of the genus through comparisons of DNA sequences and chromosomal structure of varanid species and related families. They have concluded that the genus originated between 40 and 25 million years ago in Asia.

Varanids reached Australia by about 15 million years ago, thanks to a collision between the Australian landmass and southeast Asia [see illustration]. Numerous small varanid species, known as pygmy monitors, quickly colonized Australia, filling multiple ecological niches. More than two million years later a second lineage differentiated and spread throughout Australia and the Indonesian archipelago, which was at the time far closer to Australia than it is today, because much of the continental shelf was above water. *V. komodoensis* is a member of that lineage, having differentiated from it about four million years ago.

The Indo-Australian varanids could take advantage of their unique faunal environment. Islands simply have fewer resources than large landmasses do. Because reptilian predators can subsist on much lower total energy requirements than mammals can, a reptile will have the advantage in the race for top predator status under these conditions.

In such a setting, reptiles can also evolve to huge size, an advantage for hunting. A varanid called *Megalania prisca*, extinct for around 25,000 years, may have reached a length of six meters and a weight of 600 kilograms; the late extinction date means that humans may have encountered this monster. Komodos adopted a more moderate giantism. Reasons for the Komodo's current restricted home range--the smallest of any large predator--are the subject of debate and study. Various researchers subscribe to alternative routes that the dragons' ancestors may have taken to their present locale of Komodo, Flores, Rinca, Gili Motang and Gili Dasami.

Komodo has a different paleogeography from its neighbors. According to worldwide sea-level changes over the past 80,000 years and bathymetric data of the study area, Flores and Rinca were joined until 10,000 years ago. Gili Motang was connected several times to their combined landmass. Komodo was long isolated but appears to have joined its eastern neighbors about 20,000 years ago, during the last glacial maximum. That association may have lasted 4,000 years. (This scenario is based on my calculations of the effect of sea-level variations of about 130 meters during the last Pleistocene glaciation, combined with available bathymetric data for the area.)

Tantalizing fossil evidence supports the notion that today's Komodo populations are relics of a larger distribution that once reached Timor, to the east of Flores. Fossils of two identical forms of a now extinct pygmy elephant, Stegodon, about 1.5 meters at the shoulder, on both Timor and Flores suggest that those two islands might have been sufficiently close in the Pleistocene to allow migration.

The limited resources of an island could have driven the evolution of the pygmy elephants, because smaller individuals, with lower food requirements, would have been selected for. In contrast, today's Komodo dragon may have evolved from a less bulky ancestor; the availability of the relatively small elephants as prey may have been a driving force in the selection of largeness that resulted in the modern three-meter Komodo. (A large reptile still needs far less food than a mammal of similar size.) Auffenberg suggests that the Komodo could once "have been a highly specialized pygmy stegodont predator," although prey species similar to modern

deer and boars may also have been present before the arrival of modern humans within the past 40,000 years.

Further attempts to reconstruct the Komodo's evolutionary history require more comprehensive fossil finds and accurate dating of the islands that harbor extant populations. The work of King and Baverstock, as well as the integration of paleogeographic data and genome analysis, should shed more light on the origin of the species.

The World Discovers a Dragon

The West was unaware of the Komodo until 1910, when Lieutenant van Steyn van Hensbroek of the Dutch colonial administration heard local stories about a "land crocodile." Members of a Dutch pearling fleet also told him yarns about creatures six or even seven meters long. Van Hensbroek eventually found and killed a Komodo measuring a more realistic 2.1 meters and sent a photograph and the skin to Peter A. Ouwens, director of the Zoological Museum and Botanical Gardens at Bogor, Java.

Ouwens recruited a collector, who killed two Komodos, supposedly measuring 3.1 and 2.35 meters, and captured two young, each just under one meter. On examination of these specimens, Ouwens realized that the Komodo was in fact a monitor lizard. In the 1912 paper in which Ouwens introduced the Komodo to the rest of the world, he wrote simply that van Hensbroek "had received information ... [that] on the island of Komodo occurred a Varanus species of an unusual size." Ouwens ended the paper by suggesting the creature be given the name V. komodoensis.

Understanding the Komodo to be rare and magnificent, local rulers and the Dutch colonial government instituted protection plans as early as 1915. After World War I, a Berlin Zoological Museum expedition roused worldwide interest in the animal. In 1926 W. Douglas Burden of the American Museum of Natural History undertook a well-equipped outing to Komodo, capturing 27 dragons and describing anatomical features based on examinations of some 70 individuals.

The Komodo's Future

More than 15 expeditions followed Burden's, but it was Auffenberg who performed the most comprehensive field study, looking at everything from behavior and diet to demographics and the botanical features of their territory. Auffenberg determined that the Komodo is, in fact, rare. Recent estimates suggest that fewer than 3,500 dragons live within the boundaries of Komodo Island National Park, which consists of the islands of Komodo (1,700 individuals), Rinca (1,300), Gili Motang (100) and Padar (none since the late 1970s), and some 30 other islets. A census on Gili Dasami has never been done. About another 2,000 Komodos may live in regions of the island of Flores. The Komodo is now officially considered a "vulnerable" species, according to the World Conservation Union; it is also protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

The Komodo dragon has faced major challenges during the past 20 years that threaten its survival in part of the national park and on Flores. The disappearance of dragons on Padar probably stems from poaching of their primary prey, deer. Policing this rugged and sometimes inaccessible habitat is difficult; two days after I finished a census of the island in 1997, 10 deer were poached. Nevertheless, a trend toward less poaching overall on Padar has moved officials to discuss a

reintroduction program.

Padar covers an area of only about 20 square kilometers and supports no more than 600 deer, in turn limiting the number of Komodos. Consequently, genetic diversity, as insurance against inbreeding, would be highly desirable among a new, small Komodo population.

Image: Steve Mirsky

KRAKEN, born at the National Zoo in Washington, D.C., on September 13, 1992, was the first Komodo hatched in captivity outside of Indonesia. She still lives there and is now 87 centimeters from her snout to the base of her tail and weighs 22 kilograms. Another 54 dragons eventually were hatched at the zoo, from eggs produced by Kraken's mother, a gift from Indonesia in 1988. Those dragons are now in zoos across the U.S. and in Japan, Germany, the Netherlands and Singapore.

To assist this plan, I started a genetic study of the remaining Komodo populations in 1994 to determine the degree of genetic similarity within and between the existing groups. I am currently analyzing DNA from blood samples of 117 dragons drawn in 1994 and 1997 [see sidebar]. The findings should eventually allow the authorities to choose the most appropriate source populations for restocking Padar, based on genetic diversity. Sex ratio and age structure will also be factors in the choice of individuals.

Komodos on Flores face the twin threats of prey depletion and habitat encroachment by humans. New settlers slash and burn the monsoon forest, and Komodo dragons are among the first species to disappear. In 1997 I set up a biotelemetric study to look at movement and home-range size of adult dragons in areas with differing degrees of human presence, both inside and outside the national park. A data collection covering a number of consecutive years can show conclusively whether human interference drives Komodos simply to migrate to different areas or to extinction.

I also initiated a long-term survey to obtain information on the distribution and level of threat to Komodo populations throughout Flores. The survey relies on traps set in localities chosen on the basis of habitat and on sighting reports by local people. Over the past 20 years, habitat loss has caused the species to vanish from an area stretching for 150 kilometers along Flores's northwest coast. Populations on the north and west coasts are also threatened by deforestation and indirectly through deer hunting.

The fortunes of the Komodo dragon are inexorably linked with those of numerous other species of fauna and flora, and measures to protect this giant lizard must take into account the entirety of its natural habitat. For example, although central Flores is inhospitable to dragons, the southern and eastern regions of the island may harbor scattered populations, still unknown to researchers, that could act as "umbrellas" to protect the ecosystem as a whole. The charismatic dragon already draws some 18,000 visitors a year to the area, and patches of forest containing Komodos could be the cornerstone of an economically viable protection plan for the entire habitat, based on ecotourism.

In addition, I hope to save the extant populations of Komodos by altering the current usage patterns of natural resources, in a transition to sustainable land use. Local officials have already expressed interest in such a plan. For example, slash-and-burn agriculture could be superseded by the cultivation of plant species that do not require clearing of the canopy to be economically useful. A technique as simple as instruction in the manufacture and laying of brick could save hardwood now harvested for house construction.

The fate of the world's few thousand Komodos, living out their lives in a tiny corner of the earth, is probably now in human hands. Policy decisions, as in so many wildlife conservation issues, will be as much aesthetic as scientific or economic. We can choose to create a homogeneous world of stultifying sameness. Or we can choose to maintain a remnant of the mystery that provoked medieval cartographers to mark the unexplored territories of their maps with the exhilarating warning, "Here there be dragons."

Further Information:

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Related Links:

A lecture by Walter Auffenberg (RealAudio)

Komodo Dragon: Earthwatch Program

Varanus komodoensis: The Animal Diversity Web

Komodo Dragon: The American Museum of Natural History

The Author

CLAUDIO CIOFI received his undergraduate education at the University of Florence. In 1998 he completed his Ph.D. at the Durrell Institute of Conservation and Ecology at the University of Kent at Canterbury in England. He is now based at the Zoological Society of London. Ciofi has worked in collaboration with the University of Gadjah Mada in Java and with Udayana University in Bali. His Komodo project, originating as a population genetic study, has broadened to include

behavioral ecology and demography and the consequent protection of habitat and involvement of indigenous people. His research has been supported by the Zoological Society of London, the Wildlife Conservation Society, the Smithsonian Institution, Earthwatch Institute and British Airways.

From Grad Student to Dragon Wrangler

I became interested in Komodos as a graduate student at the University of Kent at Canterbury in England. My doctoral thesis, in conservation biology, required me to perform field research on a rare or endangered species. I wished to work with reptiles, and I wanted to combine fieldwork with state-of-the-art molecular biological techniques, which are useful in determining genetic relationships and divergences between populations. Such studies require collecting blood from a study specimen. Based on these parameters, the creatures that would have most benefited from study were limited to two species.

The first was a tortoise, Testudo hermanni, that is distributed throughout southern Europe. I instead chose the Komodo both for the challenge and because it is still one of the world's least studied large predators. I would discover many of the reasons for this continuing ignorance. All the materials needed for fieldwork must be shipped in or created from scratch; building Komodo dragon traps is arduous and time- consuming; while rare, attacks by Komodos on humans are not unheard of; and then there is the smell.

I wanted mobile traps and immobilized Komodos. I therefore built devices along the lines of humane mousetraps, only my mice might reach lengths of three meters. I made the devices with local timber and iron-mesh fencing material. Each trap measured three meters by a half meter by a half meter and had a closable door. Goat served as both bait and as rations for me and a local ranger assistant. Komodos would force themselves into the trap as far as they could to get to the meat at the other end. Once they touched the bait, which was connected to a trigger mechanism, the entrance to the trap closed.

At this point, we would hang the entire trap on a balance, thus determining the weight of the captured individual. Then we would open the door at the tail end and pull the Komodo out. Komodos smell quite intense to begin with, what with their oral bacterial factories and their frequent association with carrion. The rotting goat meat adds to the aroma, and punctuating the olfactory experience is the habit of the threatened Komodo to immediately vomit and defecate, in preparation for fight or flight. Once the rear legs were free, we would tie them together. We would then continue to pull the Komodo from the trap until the front legs appeared, and we tied those. Finally, we would tape the mouth shut, allowing us to do a quick physical examination and take blood. We went through this routine on animals smaller than about 2.5 meters in length. When we happened to trap any of the largest individuals, we contented ourselves with drawing blood while the Komodo remained ensnared. Using these techniques, I was able to get blood samples from 117 Komodos over five months in 1994 and 1997, and I am currently analyzing them. Also in 1997 I attached transmitters to eight Komodos to obtain information about movement and home-range size.

--*C.C.*

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Komodos Feast

... on a pig. Their curved, serrated teeth easily tear through flesh. Meat caught in the serrations supports the growth of septic bacteria.

Image: American Museum of Natural History

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Komodo Island

Komodo Island has an area of about 340 square kilometers (130 square miles) and is clearly hilly. The highest points are about 735 meters above sea level. Komodo dragons tend to stay below 500 meters but are found at all elevations. The creatures live only on a few Indonesian islands. As shown on the map, Australia is 900 kilometers southeast, with Java some 500 kilometers to the west and New Guinea 1,500 kilometers to the northeast.

Image: Laurie Grace

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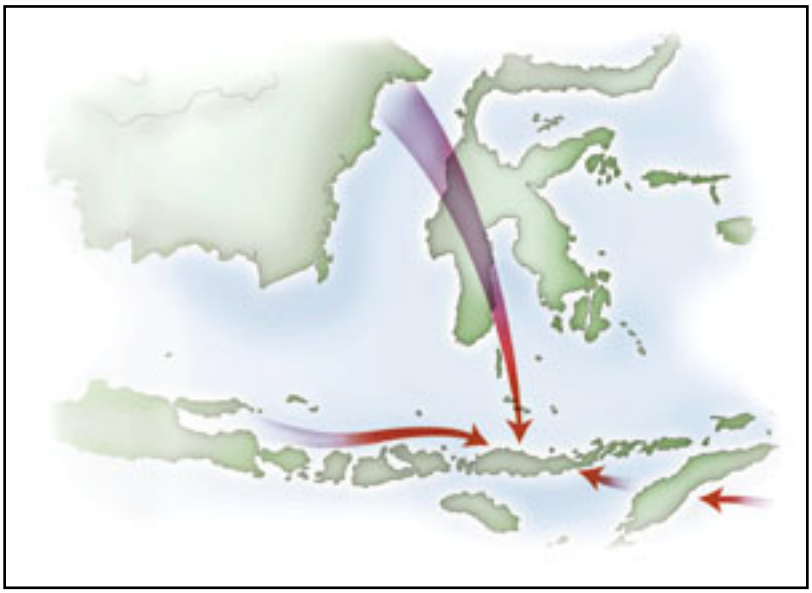
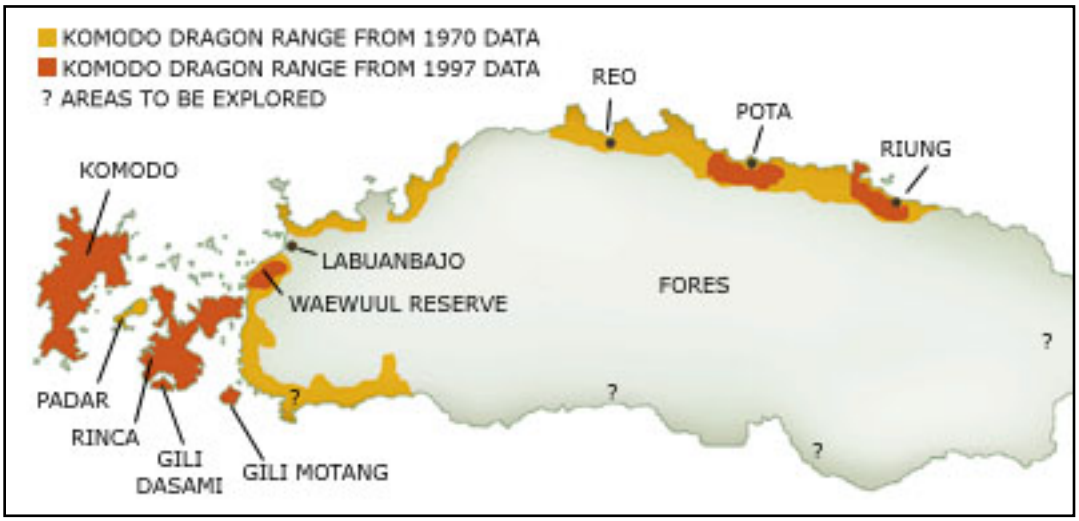
Possible Routes

Possible Routes (right) by which Komodo ancestors traveled to their current island habitat are still the subject of debate. Whether they came from Asia directly or through Java or Australia first is not clear. Certainly the lower sea levels of the past made more routes possible than are obvious today. The more recent research in the region has updated the decades-old knowledge that we had of the Komodo's current territory (below).





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