Marine iguanas in

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The endemic marine iguanas of Galapagos are in severe danger of extinction on some islands. Predation by introduced cats, dogs, pigs and rats is one cause but the first findings of Andrew Laurie's three-year field study, which started in 1981, show that the situation is more complicated.

The marine iguana *Amblyrhynchus cristatus*, which occurs only on Galapagos, has recently disappeared from several areas, probably due to predation by introduced animals (Kruuk, 1979; Kruuk and Snell, 1981) to which it is particularly vulnerable because of its low breeding potential; females reach sexual maturity only after several years and lay only two to four eggs per year (Carpenter, 1966). Much has been discovered about this species's unique adaptations for feeding on marine algae in the cold waters of the Humboldt current, but little is known about population age structures or fluctuations in numbers. A three-year field study was started in January 1981 to provide information on which to base conservation strategies.

There are two main questions to be answered:

(1) What differences are there in population density and composition, mortality, reproductive success and social organisation between areas, and how are they related to environmental variables such as physiography, predation and marine flora?

(2) What differences are there in individual reproductive success according to size, age, and social and other variables?

To answer the first question, information is being collected during survey voyages with frequent short stops on each island, and during longer stays at three main study sites. The second is being tackled by intensive work at one of these three sites: Miedo, on Santa Fé.

The survey

Five survey voyages totalling 60 days were made in a 10-m long converted fishing boat with a maximum speed of 6·5 knots and a shallow draft which enabled us to travel close to the coast. All islands and islets on the map were circumnavigated; two small islands, Culpepper and Wenman, far to the north-west of the main archipelago, remain to be visited. Landings were made whenever possible to survey the coast on foot. We spent 127 hours travelling between the islands, 131 hours surveying from the boat, and 237 hours on land surveys.

Coastlines were classified according to physiography, exposure to the sea, and abundance and distribution of marine algae. The availability and nature of nesting sites were recorded and collections made of feral dog and cat faeces and hawk and owl pellets for analysis. Iguanas were counted along measured stretches of coastline using binoculars, accuracy depending upon distance from the shore when in the boat and how easily we could walk along the coast. Census techniques, developed earlier on Santa Cruz, allowed us to make adjustments for time of day and state of the tide. Population compositions were assessed by classifying samples of several hundred individuals at each landing place.

Differences in body size, head width and nuchal-crest development were used to determine the

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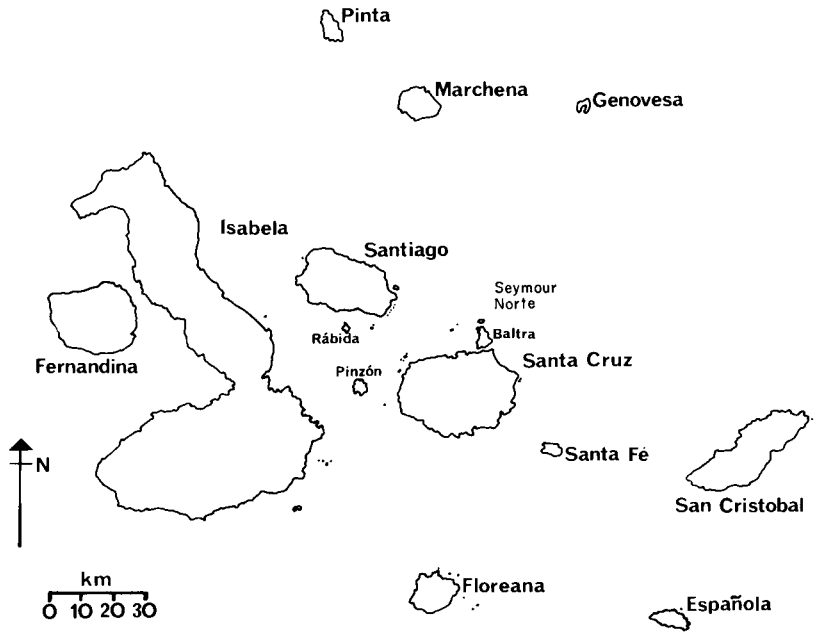

Figure 1. Map showing islands and islets visited during survey trips, with names of the main islands.

sex of adult animals. Prominent hemipenes were visible in some younger males when held in the hand, but sex determination was generally possible only for the older adults, and it was easier to be sure of a positive determination for males than females. Eleven different size classes were used, and with practice it became possible to estimate accurately the size class to which each individual belonged without capturing or disturbing the iguanas. The size classes are based on the snout to vent length which varied from less than 10 cm in hatchlings (class O) to nearly 60 cm (class X), with nine 5-cm classes in between.

All population compositions are given according to size, as the relationship between size and age is as yet insufficiently known. By measuring and marking a large sample of individuals of each size class and remeasuring them at intervals it is hoped to be able to convert at least some of the size classes to age classes. A total of 642 hatchlings and 700 older animals were captured, weighed, measured, and marked at Miedo. Numbers were branded on the chest, and the crests marked with the same number in a code of coloured glass beads on nylon lines. At the end of July 1981, 99·3 per cent of 150 brands checked were still readable by someone who had not been involved in the marking, and only 2·3 per cent of hatchlings and 0·1 per cent of older animals had lost their beads.

Results

As Figure 2 shows, iguanas are almost ubiquitous, but patchily distributed, with enormous concentrations in some areas and very low densities in others. Even in sheltered mangrove-lined bays one or two lone iguanas are found. Presumably constant dispersal by some individuals has enabled the species to colonise almost every suitable site in Galapagos. Population compositions also vary enormously. Figure 3 compares two extremes of population composition. There are considerable differences between islands in adult iguana size, so, to avoid confusing comparisons, Figure 4 shows the percentage of hatchlings and yearlings respectively in some of the major colonies.

Habitat preferences

Iguanas clearly prefer the exposed, southern as opposed to the sheltered, northern coastlines, and are most abundant where shallow reefs and extensive intertidal zones occur. Most live on low rocky coastlines with stretches of low cliffs (2–5 m), boulders or lava flows. Steep high cliffs are generally less favoured except where shallow reefs occur as a result of cliff erosion. Many coastlines, apparently suitable above sea level, are too sheltered, or lack intertidal rocks, and are only sparsely inhabited. Suitable nesting sites are also

important in determining the distribution of the major colonies, but females may travel considerable distances to nest. The results of coastline classification will be analysed after next season's survey work, during which a detailed investigation of the feeding behaviour and ecology of the iguanas will be made. In some cases the coast's inaccessibility protects iguanas from feral predators, for example on the cliffs of southern Floreana and Roca Vicente on northern Isabela.

Dogs, cats, rats and pigs

Introduced dogs, cats, rats and pigs all feed on marine iguanas or their eggs, and one or more of these predators occur on Isabela, Santiago, Pinzón, Baltra, Seymore Norte, Santa Cruz, Floreana, San Cristobál and some of the small islets. On all these islands balanced iguana populations are rarer and population densities lower than on islands without feral predators.

Figure 4 shows results for colonies where at least 100 iguanas could be accurately classified, but most sample sizes were of more than 500 (range 111 to 2322). In many areas, particularly Isabela, there is very little, if any, recruitment to the adult population. San Cristobál and Santa Cruz also have extremely imbalanced populations most of which are not dense enough to sample, but the large colonies of northern Isabela and Punta Espinosa on Fernandina were the most marked examples of imbalanced populations. Despite abundant and well-used nesting areas at both places, the populations include fewer than one per cent of animals of class II or lower, compared with up to 30 per cent in colonies on Santa Fé and Genovesa and more than 20 per cent in colonies on other parts of Fernandina.

The reasons for low densities and grossly imbalanced populations probably differ between regions, but imbalanced populations occur mainly on islands with introduced predators, and there is considerable evidence that these, particularly cats, are the culprits. In 1979 it was shown that dog predation on marine iguanas at Caleta Webb was much greater than the population could sustain (Kruuk and Snell, 1981) and where large dog populations occur in other parts of southern Isabela the marine iguanas are under threat. Dog faeces collected on Isabela by Bruce Barnett and myself showed that marine iguanas occurred in between 45 and 80 per cent of faeces according to location. However, there are relatively few coastal areas on Isabela with large feral dog populations—and none in northern Isabela or on any other island apart from Santa Cruz.

Cats are much more widespread than dogs on all islands. On Isabela fresh tracks and faeces were found at almost every place we landed. We collected 475 and 20 per cent of these contained the remains of young, mainly hatchling iguanas. Locally, at Muñeco, 65 per cent of 92 faeces samples contained hatchling remains.

Signs of cats were particularly abundant on nesting sites (e.g. at Caleta Negra, Roca Vicente and Muñeco) after the hatching season, and half-eaten remains of hatchlings were often found. At all these colonies, where obviously large numbers of eggs had been laid and hatchlings had emerged, only very few hatchlings were still surviving by mid-July, approximately 2½ months after emergence (Figure 4). On Santa Fé, where there are no cats, hatchlings still made up more than 10 per cent of the total population at the end of July, whereas at Muñeco and Caleta Negra

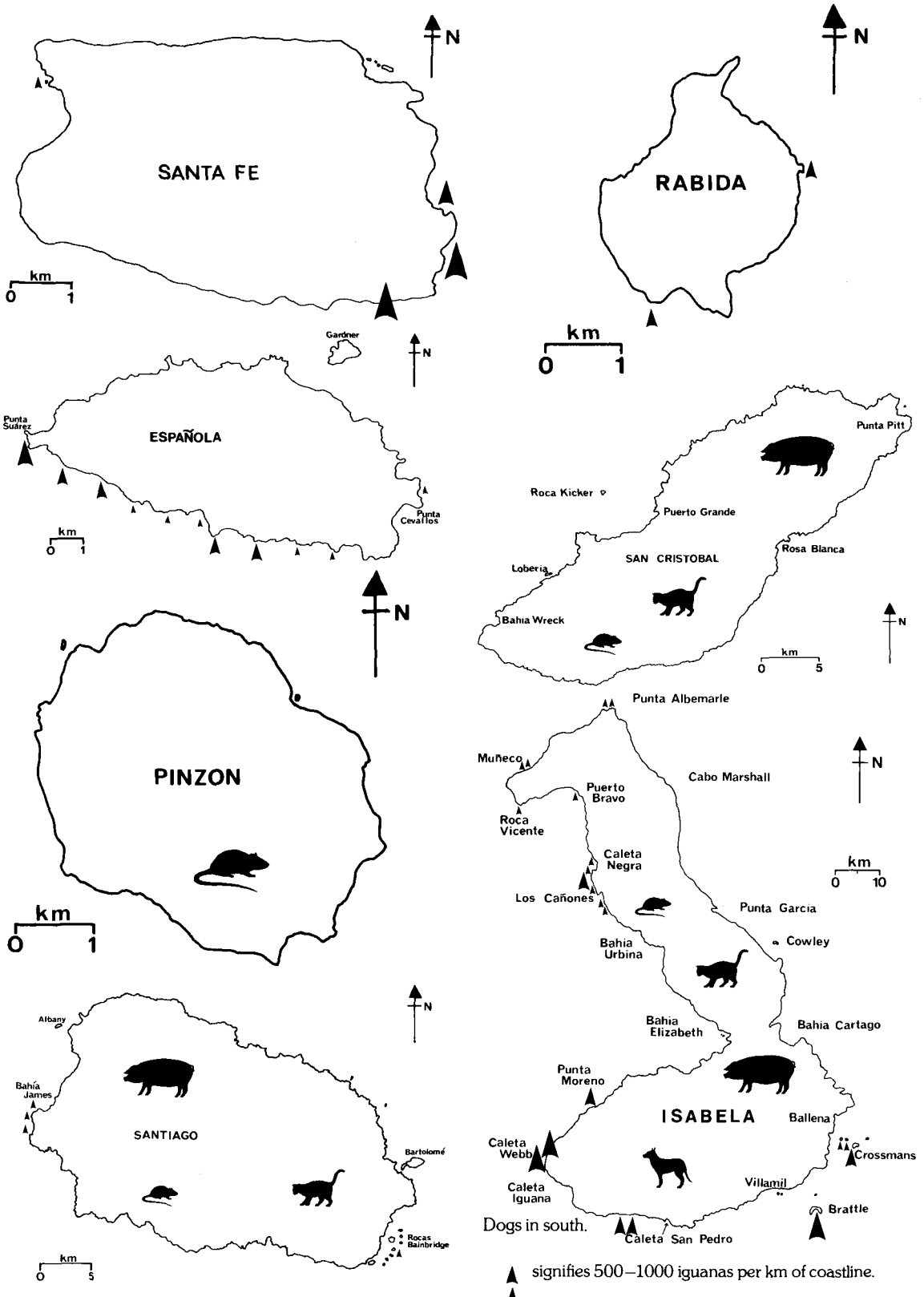

Figure 2. Maps showing distribution of feral predators on the main islands.

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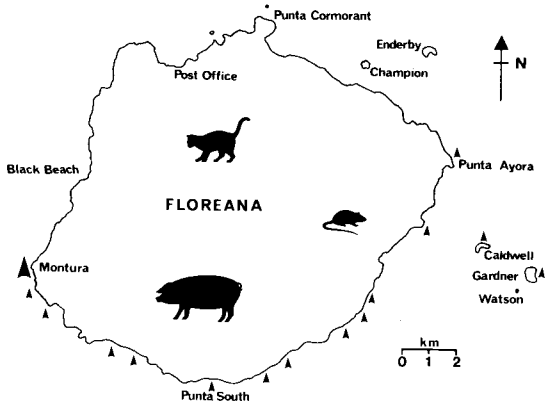
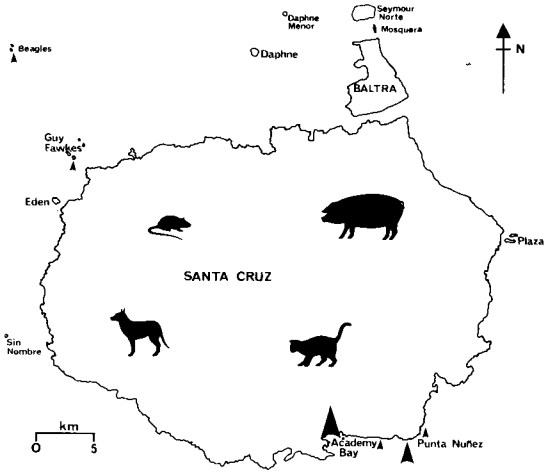
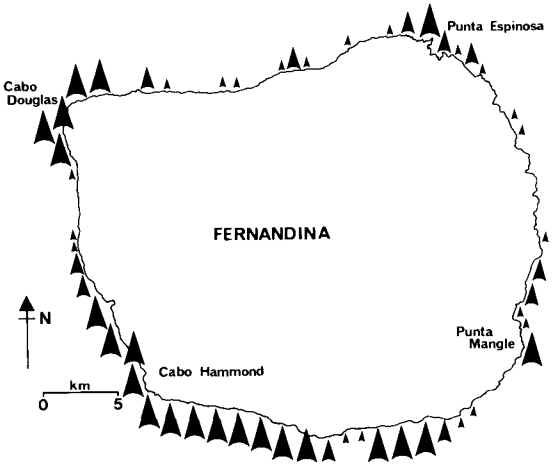
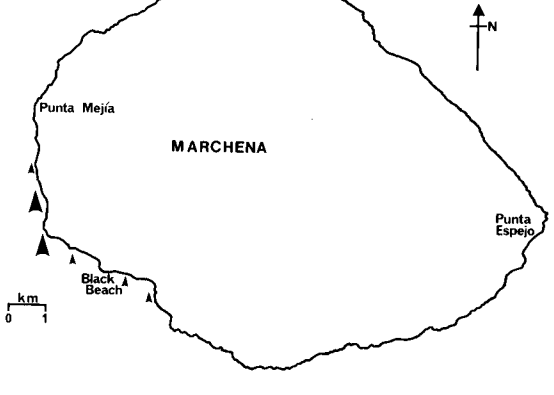
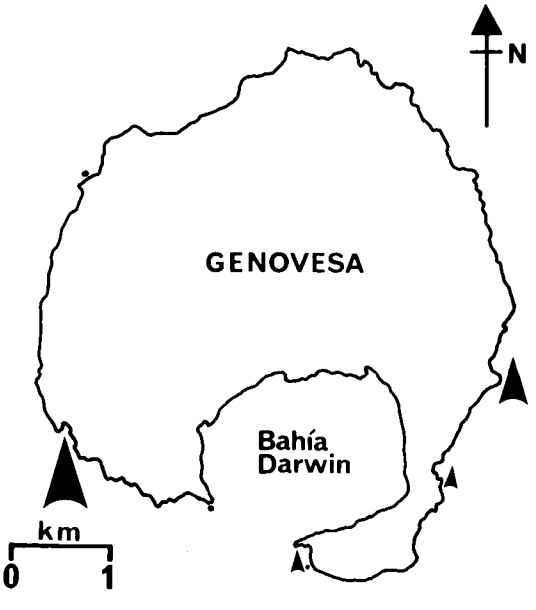




Santa Cruz and surrounding islands: rats on Eden, Seymore Norte and Baltra. Note: the large colony in Academy Bay is on the tiny islet Coamaño.







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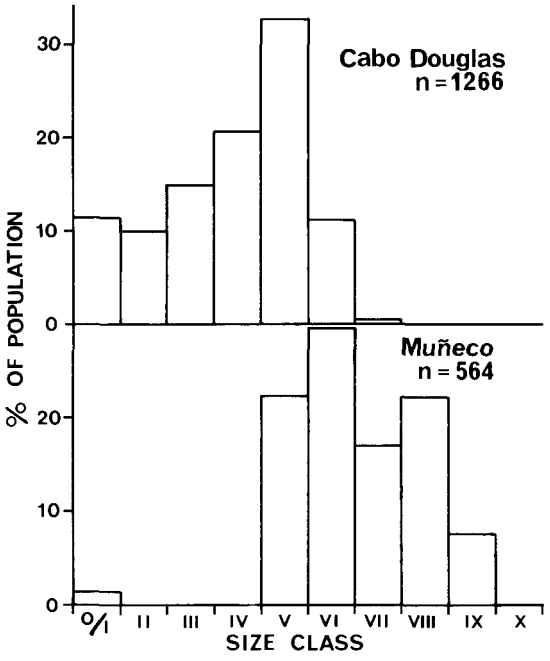

Figure 3. Comparison of the compositions of two marine iguana populations.

they made up less than one per cent with even fewer class I and class II individuals. Hatchlings and yearlings were much more common on steep cliffs (e.g. Ballena and Roca Vicente) and on offshore islands (e.g. Brattle and Crossmans) inaccessible to cats. In November 53 per cent of 650 hatchlings marked at emergence on Santa Fé were still surviving, whereas at Punta Nuñez on Santa Cruz, where cats occur, N. Rauch (pers. comm.) found fewer than one per cent survivors out of more than 1000 marked hatchlings. It appears that intensive seasonal predation by cats on newly emerged hatchlings could have caused the extremely skewed population compositions shown in Figure 3.

Punta Espinosa

Punta Espinosa is the exception to the general pattern that healthy, well-balanced iguana populations only occur on islands without introduced predators. There it appears that a low hatching rate, rather than a low hatchling survival rate, may have skewed the population. We excavated a number of nests two months after hatching and found that only five out of 49 eggs had successfully hatched. Higher hatching rates occurred in all other areas including other parts of Fernandina —Punta Mangle, Cabo Hammond and Cabo Douglas all have well-balanced populations. Punta Espinosa needs further investigation. Tourists trampling on the nesting areas (there are no tourist sites elsewhere on Fernandina) could be the cause, and the possibility of egg parasitism or predation by insects has also to be investigated. It has also been suggested that heron *Ardea herodias* predation on newly emerged hatchlings is particularly severe at Punta Espinosa, or that sea-level changes associated with volcanic activity have led to a deterioration of the nesting ground's incubatory properties.

Natural predation

On Santa Fé snakes *Dromicus* spp. and buzzards *Buteo galapagoensis* prey on newly emerged hatchlings; but once they reach the rocks at the coast both hatchlings and older animals appear to be safe from buzzards. Snakes take up to five days to digest a single hatchling, so could only take a very small proportion of the total. Hatchlings and young animals avoid swimming in the sea, where they are in danger from fish. Two of about 30 hawkfish *Cirrhitus rivulatus* we caught had eaten young iguanas of class I and class II. Sealions, although they did not appear to prey on iguanas, frequently played with swimming adults, pulling them by the tail, and possibly this was the reason for the large proportion of adult iguanas that were missing parts of their tails.

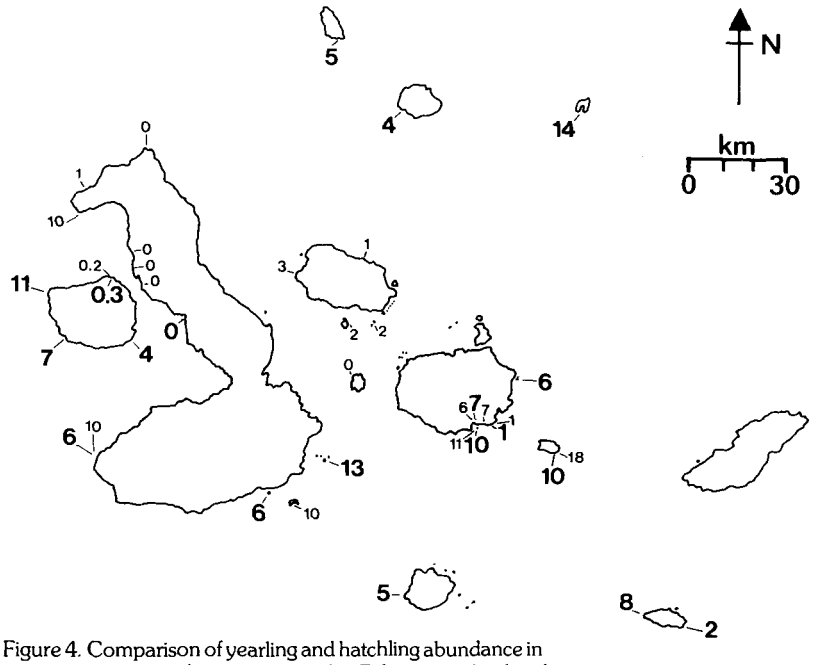

Figure 4. Comparison of yearling and hatchling abundance in marine iguana populations censused in February to April and June to July respectively.
Large figures indicate percentages of yearlings in the population (before 1981 hatching season).
Small figures indicate percentages of hatchlings in the population (after 1981 hatching season).

Conclusion

So far much of this is speculation, but there is no doubt that many of the Galapagos marine iguana populations, particularly those of Isabela, are in severe danger of extermination once the present adult populations die of old age. It could be that iguanas might only survive on offshore islets such as Crossmans, Brattle, Plazas and Coamaño (in Academy Bay) which at present have much healthier, more balanced populations than those on the adjacent mainland.

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