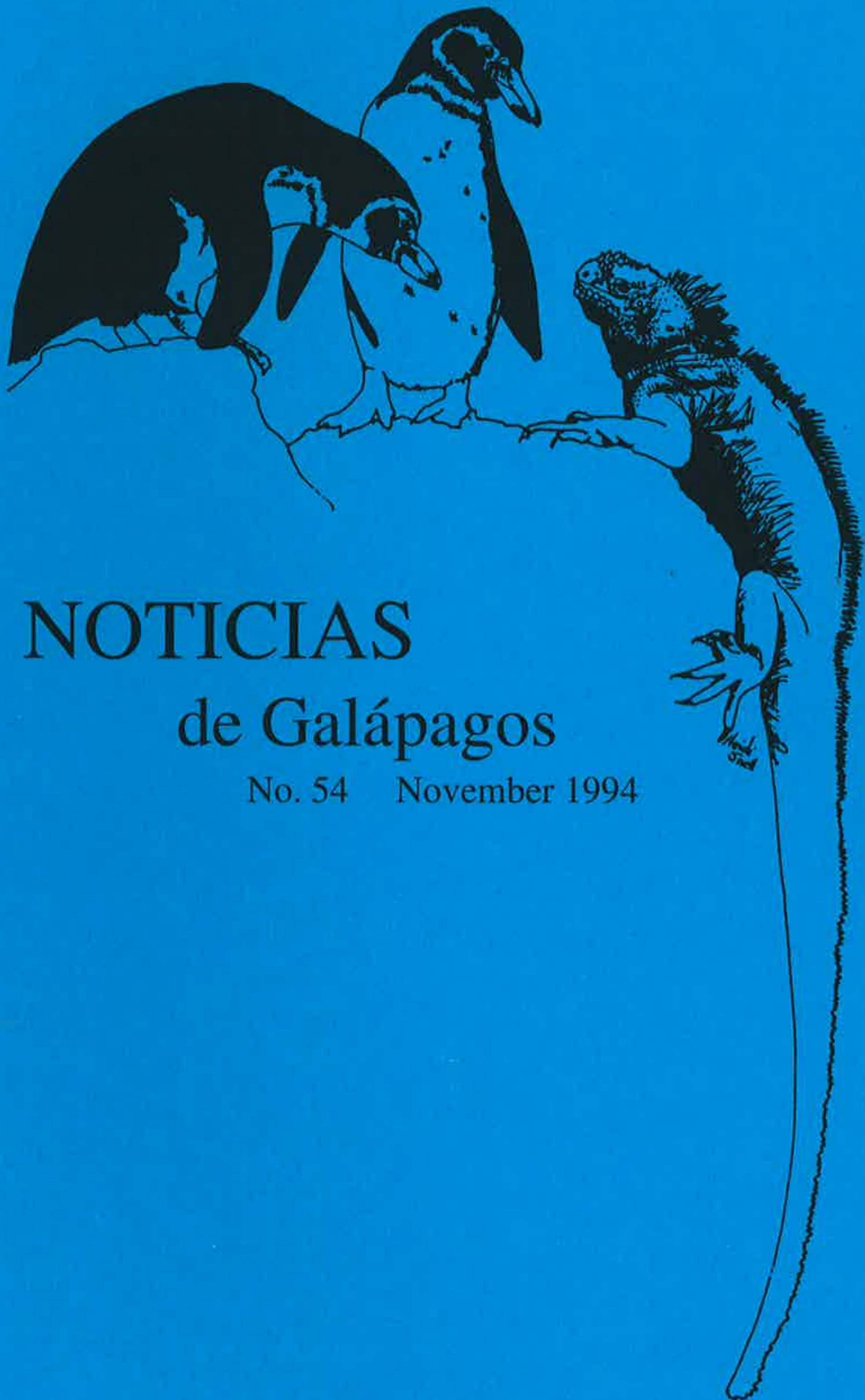

NOTICIAS

de Galápagos

No. 54 November 1994

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RECENT INCREASE IN KILLING OF GIANT TORTOISES ON ISABELA ISLAND

By: Linda J. Cayot and Ed Lewis

INTRODUCTION

Several populations of giant tortoises (*Geochelone elephantopus*) on Isabela Island are once again endangered, this time due to poaching by local inhabitants. During 1994, the level of killing has increased alarmingly and may cause irreparable damage.

The distribution of the five subspecies of giant tortoises on Isabela is determined by the five large volcanoes and the natural barriers among them (Fig. 1). Each of the three major northern volcanoes has its own subspecies, while the distribution of the two southern Isabela subspecies, *G. e. vicina* and *G. e. guntheri*, is not clear. Various authors differ on the classification and distribution of these tortoises (Van Denburgh, 1914; MacFarland et al., 1974; Fritts, 1984). Nevertheless, a study of morphology indicates that the only site in which tortoises of the subspecies *guntheri* remain is Cinco Cerros (Fritts, 1984). The absence of *G. e. guntheri* in other areas increases the importance of this population and its vulnerability to extinction.

The populations in greatest danger due to poaching are those of Cazuela, Cerro Paloma, and Roca Unión on Volcán Sierra Negra; Cinco Cerros on Cerro Azul; and Piedras Blancas and Puerto Bravo on Volcán Wolf (Fig. 1). Although the other populations are considered in good condition, they are at risk due to problems with introduced animals.

In general, the populations on the volcanoes Wolf, Darwin, Alcedo, and Cerro Azul have greater numbers of individuals and are in better condition than the populations on Sierra Negra. Historically, a considerable tortoise population, possibly the largest in the Archipelago, lived on the southern slopes of Sierra Negra. Over-exploitation during the last two centuries has nearly exterminated this population, leaving small groups of tortoises only in Cerro Paloma and Cazuela. The population of Cerro Paloma, currently estimated at fewer than 25 tortoises, is the smallest in the Archipelago (aside from Pinta Island represented by only one known individual). The next smallest is the population of Cazuela, which had large numbers as recently as 15 years ago, before poaching decimated it and left mostly juveniles.

Although various populations on Isabela have suffered from poaching for many years, the recent increase in tortoise killings severely threatens their survival. Stronger action must be taken immediately to ensure that these populations of tortoises, the symbol of Galápagos, do not disappear.

TORTOISE KILLING

Illegal killing of tortoises has occurred in some populations of tortoises on Isabela since the establishment of the Galápagos National Park in 1959. The data presented in this report are the result of a review of field-trip reports of personnel of the Galápagos National Park Service (GNPS) and the Charles Darwin Research Station (CDRS), as well as those of visiting scientists, contained in CDRS files (Table 1). Between 1970-79, only three tortoises were reported killed on Isabela; these were on Volcán Alcedo and were considered to have been slaughtered in the 1960s.

Between 1980 and 1994, tortoises killed by humans were reported in Cazuela, Cerro Paloma, and Roca Unión on Sierra Negra; Cinco Cerros on Cerro Azul, and Piedras Blancas and Puerto Bravo on Volcán Wolf (Table 2). In September 1994, a tortoise was found killed by humans at Caleta Iguana, approximately 1/2 hour walk from the coast (K. Mills, pers. comm.). In addition, a tour guide reported a tortoise killed in 1994 at Urbina Bay on Volcán Darwin (this information is not presented in the table, as there is no written report). There are no reports of slaughtered tortoises during this same period in Las Tablas, Los Gavilanes, Los Crateres, and Cabo Rosa on Cerro

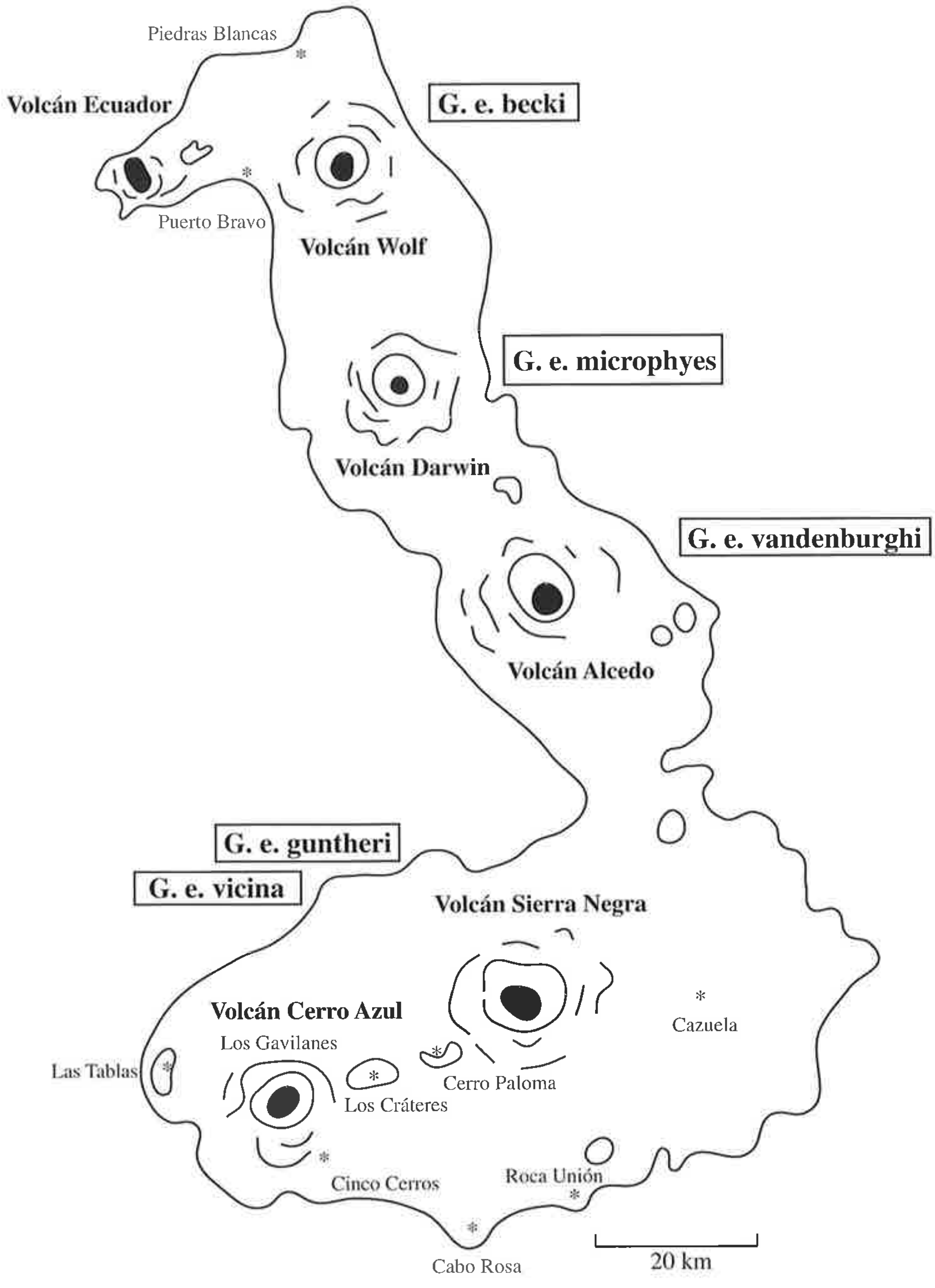

Figure 1. Distribution of the five subspecies of giant tortoise (*Geochelone elephantopus*) on Isabela Island.

Azul; Volcán Alcedo; and Volcán Darwin (except the report from Urbina Bay). However, no recent trip has been made to Cabo Rosa; given its location between Cinco Cerros and Roca Unión, it is imperative to undertake a search there as soon as possible.

Poaching of tortoises has increased significantly within the last year (Table 3). Of all tortoises killed by humans on Isabela since 1980, 40.1% were found

Table 1. List of reports of tortoise poaching (VS = Visiting Scientist). * = no report, only a few field notes.

Authors	Date	Location of Poaching	Type of Report
Cartagena P.	1988 (Dec)	Cazuela	GNPS
Cartagena P.	1992 (March)	Cazuela	GNPS
Cartagena P.	1992 (July)	Roca Unión	GNPS
Cartagena P.	1992 (Nov)	Roca Unión	GNPS
Cartagena P.	1993 (May)	Cinco Cerros	GNPS
Cocha J.	1980 (Sept)	Cazuela	GNPS
Cocha J.	1981 (Dec)	Cazuela	GNPS
Cocha J.	1984 (Nov)	Cazuela	GNPS
Garcia W., P. Cartagena	1985 (Oct)	Roca Unión	GNPS
Garcia W., P. Cartagena	1986 (June)	Cazuela	GNPS
Gil L., F. Yepez, P. Cartagena	1988 (March)	Cazuela	GNPS
Gordillo J.	1994 (June)	Cazuela	CDRS
Llerena F.	1994 (Aug)	Piedras Blancas, Pto. Bravo	GNPS
Louis E.	1994 (July/Aug)	Cerro Paloma, Roca Unión, Cinco Cerros, Pto. Bravo, Piedras Blancas	VS
Márquez C.	1986 (April)	Piedras Blancas, Pto. Bravo	CDRS
Márquez C.	1994 (April/May)	Cerro Paloma, Roca Unión	CDRS
Márquez C.	1994 (Aug)	Cinco Cerros	CDRS
Márquez C., P. Cartagena	1985 (June)	Cerro Paloma	CDRS/GNPS
Morillo G.	1991 (Sept)	Cazuela	CDRS
Morillo G., E. Muñoz	1991 (April/May)	Roca Unión	CDRS
Mosquera A., J. Gil	1994 (June)	Cazuela	GNPS
Mosquera A., M. Mendoza, A. Jaime	1994 (July)	Roca Unión	GNPS
Naranjo, S.	1989 (Nov)	Cazuela	GNPS
Fritts, T. , C. Márquez, S. Naranjo	1986 (Aug)	Piedras Blancas, Pto. Bravo	CDRS/GNPS
Park Wardens	1980 (Oct)	Piedras Blancas	GNPS*
Pinargote J., P. Cartagena	1985 (Nov/Dec)	Roca Unión	GNPS
Serrano H., A. Toro, J. Miranda	1986	Piedras Blancas, Pto. Bravo	GNPS
Snell H.	1988 (July)	Cerro Paloma	VS
Tupiza A.	1994 (Aug)	Cinco Cerros	CDRS
Tupiza A., M. Mendoza, J. Gil	1994 (April)	Cazuela	GNPS
Yepez F., F. Franco	1994 (June/July)	Cazuela	GNPS
Zuniga T.	1982 (Jan)	Piedras Blancas	GNPS
Zuniga T.	1991 (July)	Pto. Bravo	GNPS
Zuniga T.	1994 (Feb)	Cazuela	GNPS

in the first eight months of 1994. The threat is even more obvious if the data from Volcán Wolf are excluded. There the greatest exploitation of tortoises was reported in 1980 and was probably by non-local fishermen. On southern Isabela alone, of all tortoises recorded as killed by humans during the last 15 years (135), 54.4% (73) were found between January and August of this year.

The population of Cazuela (southeastern Sierra Negra) has suffered the greatest amount of poaching during the last 15 years. Where previously a good reproductive population was found, currently only juveniles and very few adults remain. Of the 56 tortoises of this population transferred recently to the Breeding Center in Puerto Villamil, 15 are adults (three males and 12 females) and 41 are juveniles or subadults. The reproductive group, therefore, is of the same size and sex ratio as that of the Española Island tortoises when they were brought into the breeding program.

The population of Cerro Paloma was seriously diminished by humans many years ago. In 1984, only 10 individuals were found. In 1994, 10 tortoises (four males, one female, and five juveniles) were transferred from Cerro Paloma to the Breeding Center. At least five more adult males exist in the wild. The lack of adult females is alarming.

The impact of poaching is probably lowest on the Roca Unión population. However, killing of tortoises in this population is relatively recent and may increase as a result of the diminution of tortoises in other zones, principally in Cazuela. In addition, the tortoises live close to the coast, which makes them more vulnerable.

Poaching of tortoises in Cinco Cerros is the most alarming of all, due to the presence there of the last individuals of the *guntheri* type, the majority of which are old adults. Tortoise poaching has been recorded in this zone only since 1993. The killing of more adults could result in the extinction of the *guntheri* subspecies.

There are additional reasons for concern over the survival of the Volcán Wolf tortoises. These populations are rarely visited by scientists or Park personnel.

Table 2. Numbers of field trips to the different tortoise areas on Isabela Island during 1970 to 1979 (first row), 1980 to 1989 (second row) and 1990 to August 1994 (third row), based on reports in CDRS files. Total numbers of trips for the respective groups of years are 95, 158 and 44. LT = Las Tablas, LG = Los Gavilanes, LC = Los Crateres, CC = Cinco Cerros, CR = Cabo Rosa, RU = Roca Unión, CP = Cerro Paloma, C = Cazuela, VA = Volcán Alcedo, VD = Volcán Darwin, PiB = Piedras Blancas, PuB = Puerto Bravo.

	LT	LG	LC	CC	CR	RU	CP	C	VA	VD	PiB	PuB
1970 - 1979	23	0	0	23	10	0	2	10	11	6	5	5
1980 - 1989	26	5	4	30	28	20	3	17	11	2	7	5
1990 - 1994	2	1	1	6	5	9	2	14	0	1	1	2
Total	51	6	5	59	43	29	7	41	22	9	13	12

Table 3. Number of tortoises killed by humans on Isabela Island between 1980 and August 1994. Data are based on reports in CDRS files which are believed to contain the majority of existing reports. nr = no reports.* = considered killed by fishermen from the continent or foreigners. ** = includes tortoises killed some years ago, probably many from 1980. *** = includes duplicated data (see 1980 and 1986). C = Cazuela, CP = Cerro Paloma, RU = Roca Unión, CC = Cinco Cerros, PiB = Piedras Blancas, PuB = Puerto Bravo.

YEAR	C	CP	RU	CC	PiB	PuB	TOTAL
1980	1	nr	0	0	27*	nr	28
1981	2	nr	0	0	0	0	2
1982	0	nr	0	0	1	0	1
1983	0	nr	0	0	nr	nr	0
1984	2	nr	0	0	0	0	2
1985	2	2	3	0	nr	nr	7
1986	1	nr	nr	nr	21**	5	27**
1987	0	0	nr	0	nr	nr	0
1988	10	3	0	0	nr	nr	13
1989	4	nr	0	0	nr	nr	4
1990	nr	nr	0	0	nr	nr	0
1991	15	nr	1	0	nr	5	21
1992	6	nr	9	0	nr	nr	15
1993	0	nr	0	1	nr	nr	1
1994	44	0	18	11	3	5	81
Total	87	5	31	12	52***	15	202***

There are field trip reports from only six of the last 15 years for both Piedras Blancas and Puerto Bravo. Nevertheless, killing of tortoises was recorded in four of the six years at Piedras Blancas and three of the six (the three most recent) at Puerto Bravo (Table 3). Both populations migrate toward the coast, where fishermen make illegal camps. The tortoise nesting zones are nearby, and there is imminent danger of losing the majority of the females during the nesting seasons. Finally, these populations, together with those of Volcán Darwin, are the least studied in the Archipelago. Volcán Wolf has two morphotypes (saddleback and domed), and the relationship between them is not known. Continued killing of tortoises on Volcán Wolf could result in the loss of a subspecies or two before they are even known.

RECOMMENDATIONS AND MANAGEMENT ACTIONS

1) Maintain captive reproductive groups of the populations of Cazuela, Cerro Paloma, and Cinco Cerros (*guntheri* type), ensuring as far as possible that examples of these populations exist both in the wild and in captivity. The Breeding and Rearing Center for tortoises of Isabela, planned for Puerto Villamil since the fire of 1985, was finally finished in 1994. Currently, it holds tortoises from Cazuela and Cerro Paloma. Additional corrals will need to be built to house tortoises from Cinco Cerros. Once the incubation systems are in operation, various experiments will need to be carried out to determine optimum conditions for domed tortoises.

2) Immediately conduct a study of the status of the population of Cinco Cerros, prior to its inclusion in the Captive Breeding Program. Various proposals have been written to look for funds for this study, however the funding and personnel are not yet available.
3) Undertake a trip to the area of Cabo Rosa as soon as possible, to search for signs of tortoise poaching.
4) Improve the patrolling systems in all the indicated zones. Following the discovery of over 30 tortoises killed in Cazuela in February of this year, the GNPS intensified its patrol in that area. Further efforts must be directed at the other sites, especially Cinco Cerros and the two sites on Volcán Wolf.
5) Take effective legal action against poachers. Although upon the first report of slaughtered tortoises in Cazuela in February the GNPS initiated legal actions, a lack of informers in Isabela inhibits their success.
6) Strengthen existing laws and impose harsher sanctions. INEFAN (the parent institution of the GNPS) is currently developing a project to reform the Law of Forestry and the Conservation of Natural Areas and Wildlife, which includes a strengthening of sanctions.
7) Drastically intensify the efforts of Environmental Education on Isabela; captive breeding cannot be effective if the young tortoises are repatriated to sites where poaching still occurs. There has been some increase in the amount of environmental education in Isabela; this must be intensified tremendously and strategically to effect changes in behavior on a broad scale.
8) Undertake, as soon as possible, an intensive study (for at least two years) of the tortoises of Volcán Wolf, including natural history, seasonal distribution, interrelationships between the two morphotypes, current status, and an evaluation of the threats. Proposals for funding are being developed; as of yet, the funding and personnel are not available.
9) Maintain more and higher levels of CDRS and GNPS personnel in Puerto Villamil, Isabela. In 1994, the GNPS has increased its personnel in Isabela. Soon to arrive are two upper level staff, the Head of the Technical Office of Isabela and an Official of Protection.

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Linda J. Cayot, Head of the Area of Protection, Charles Darwin Research Station, Galápagos, Ecuador. Ed Lewis, Animal Genetics, Kleberg Center, Texas A&M University, College Station, Texas 77843-2471, USA.

K. Thalia East

THE FIRE OF 1994 AND HERPETOFAUNA OF SOUTHERN ISABELA

By: Cruz Márquez, Jacinto Gordillo and Arnaldo Tupiza
(Translated by K. Thalia East)

Between February and June 1994, Isabela Island experienced its fourth wild fire this century. Approximately 3,500 to 4,500 ha on the southwestern slopes of Sierra Negra Volcano were burned. From conversations with various inhabitants of Isabela it is known that the fire was started on 12 April by hunters who forgot to extinguish their cooking fires. Winds then spread the flames.

The tragic event alarmed biologists, ecologists and natural resource managers from national and international institutions alike. Through mass efforts by personnel of the Galápagos National Park Service (GNPS), the National Institute of Galápagos (INGALA), the Ecuadorian Forestry Institute of Natural Areas and Wildlife (INEFAN), the Municipality of Isabela, the Ecuadorian Army, the Charles Darwin Research Station (CDRS), and the Civil Defense, and in part, due to an increase in precipitation, the fire was finally put out on 7 June.

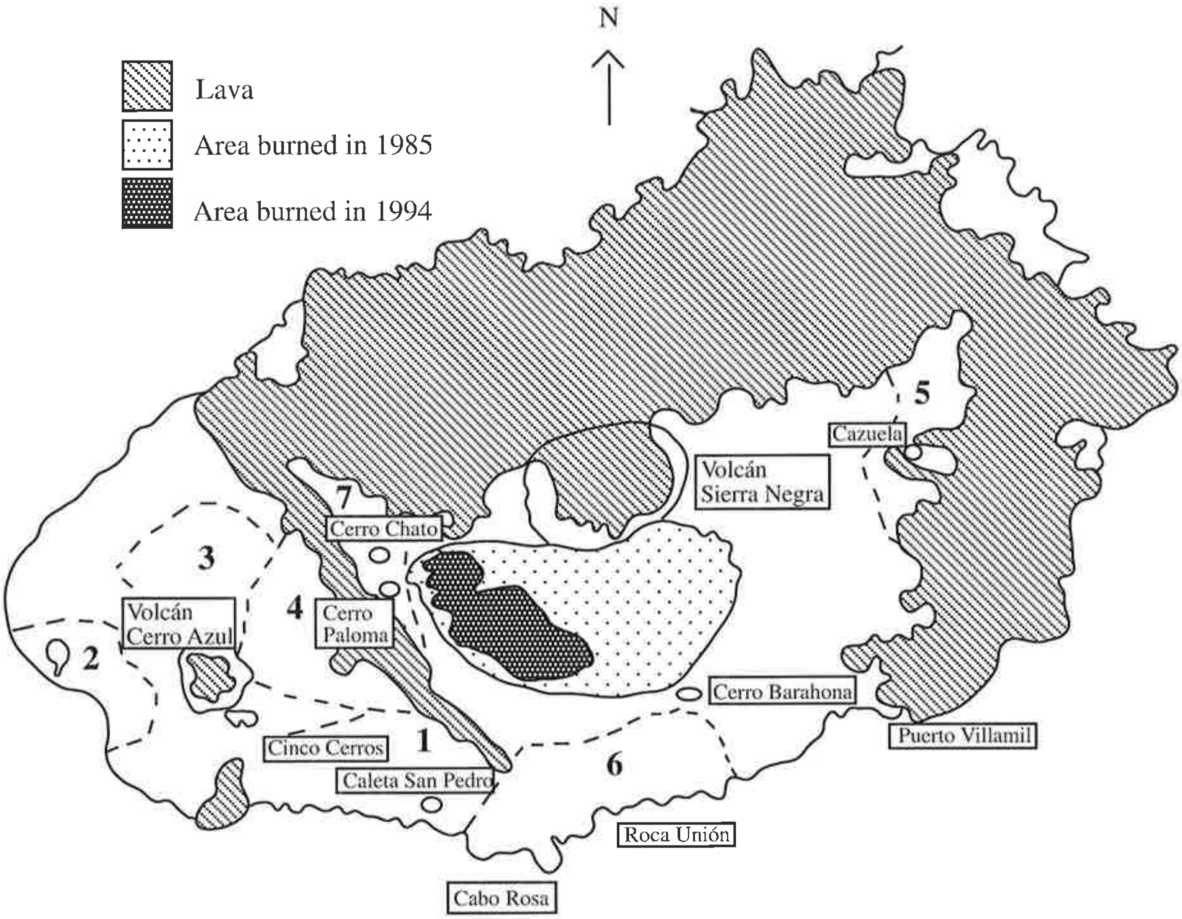
Fortunately the fire was only about one fifth the strength of Isabela's last wild fire which occurred in 1985. That fire burned 20,000 ha in the same area, in the same months, and under similar climatic conditions (Márquez, 1987). While in 1985 the fire never endangered the tortoises of Cerro Paloma and Roca Unión, due to the potential threat, preventative measures were taken and some individuals were evacuated to enclosures constructed at Roca Unión and Caleta San Pedro.

THE REPTILES

In the past, the herpetofauna of southern Isabela and particularly that of Sierra Negra has continuously been decimated by introduced feral mammals such as pigs, dogs and cats and even by humans themselves, but never by any of the known wild fires. During the 16th to 19th centuries Galápagos was a refuge for buccaneers and whalers (Slevin, 1931; Townsend, 1925). They decimated tortoise populations for food throughout the archipelago and in particular on southern Isabela. However, the intermediate-sized tortoise, *Geochelone guntheri,* remained abundant in the grasslands of Sierra Negra up until the first decades of this century (Slevin, 1959; Van Denburgh, 1914; Beck, 1903). Human population growth in Isabela, beginning about 1897, drastically diminished the tortoise population until the defenseless animals became virtually extinct. A few individuals survived in the lower, semi-arid zones of Sierra Negra and a small colony survived in sympatry with a population of its relative, *G. vicina,* in Cinco Cerros on Cerro Azul (Fig. 1). However, even today colonists continue to threaten the survival of the populations in Cerro Paloma, Cerro Cazuela, Cabo Rosa-Roca Unión and Cincos Cerros, by killing and eating the tortoises.

On 23 April, while the fire burned, we visited the tortoises of Roca Unión. We found that while the fire did not threaten the tortoises in this zone, humans continued to endanger them. We found eight tortoise carapaces, whose plastron had been separated from the carapace with a machete; the limbs were dismembered and missing. The animals had been sacrificed for their meat.

Between 28 April and 2 May we visited the tortoises of Cerro Paloma to look for and evacuate tortoises to the Breeding Center in Puerto Villamil. We did not find any evidence of recent poaching, only the carapaces of tortoises killed in 1988 (Snell, 1988). However we did see the same type of machete cuts on the cacti along the tortoise trails as those we had observed along the trails in Roca Unión. This suggests that the same group of men that were eating tortoise meat on Roca Unión may also have been searching for tortoises at Cerro Paloma.



Tortoise Zones

Cerro Azul
1. Cinco Cerros
2. Las Tablas
3. Los Gavilanes
4. Los Cráteres

Sierra Negra
5. Cerro Cazuela
6. Cabo Rosa and Roca Unión
7. Cerro Paloma

Figure 1. Map of southern Isabela Island showing locations of tortoise populations (Zones 1-7) and the areas burned in 1985 and 1994.

EVACUATION STRATEGIES

During the 1994 fire, the staff of GNPS, CDRS, the Civil Defense and the Ecuadorian Military surveyed the burned area on foot and by air. No charred remains of lava lizards (*Microlophus =Tropidurus albemarlensis*), geckos (*Phyllodactylus galapagoensis*), snakes (*Phylodryas* or *Alsophis* sp.), land iguanas (*Conolophus subcristatus*) or giant tortoises (*Geochelone guntheri* or *G. vicina*) were found. Nonetheless, the absence of copses and bones does not prove that reptiles were not killed in the fire. Furthermore, uncontrollable fires on Isabela had previously destroyed tortoise habitat at both Cerro Paloma and Roca Unión. Given the potential danger of the 1994 fire to tortoise populations, the following strategies for evacuating tortoises from the two critical areas were developed:

Tortoises at Roca Unión and San Pedro

1) The tortoises would be evacuated if the fire advanced to about 1 km either from Cerro Barahona or the southern most extremity of the lava flow.
2) The tortoises would be transferred to the two evacuation enclosures constructed in 1985, one at 0.5 km from the coast at Roca Unión and the other only 8 m from the coast at Caleta San Pedro.
3) The tortoises nearest to the enclosures would be chosen for transfer.
4) Park wardens would be stationed at the enclosures to feed and care for the tortoises.
5) Prior to transferring the tortoises, they would be marked with white paint on the fourth dorsal plate with the initials of the sector from which they were taken.

Tortoises at Cerro Paloma

1) Tortoises would be evacuated if the fire advanced towards Cerro Chato.
2) Tortoises would be moved directly to the Breeding Center in Puerto Villamil; the smaller individuals would be transported by burro and the larger by helicopter.

EVACUATION OF THE TORTOISES IN 1994

Considering the real threat of poaching and the potential threat of the forest fire on the tortoises, the transfer of individuals to the Breeding Center was considered the only way to recover the populations of tortoises at Cerro Paloma and Cerro Cazuela (a tortoise area far from the fire but with a high level of poaching). Due to the fire fighting activities, two helicopters of the Ecuadorian Army were available to evacuate the larger adult tortoises.

In the first week of May, after four days of searching for tortoises around Cerro Paloma, five individuals were captured. Of these, two (a juvenile and a male) were transported out by burro, and the other three (two males and a juvenile) were evacuated by helicopter. In the weeks that followed, five more tortoises were evacuated (a male, a female and three juveniles). These tortoises will be kept in the Breeding Center in hopes of establishing a reproductive group and producing young tortoises to repopulate the slopes of Sierra Negra. These initial efforts must be continued so that the survival of the tortoise populations of southern Isabela will be assured.

ACKNOWLEDGMENTS

We thank Santiago Matheus, President of the Permanent Commission of Galápagos, Mario Salzmann, representing PNUD, the Ecuadorian Army, GNPS, INEFAN, the Municipality of Isabela, INGALA and CDRS for their efforts in putting out the fire and evacuating the tortoises. We also thank TAME for providing reduced airfare for flights between the continent and Galápagos.

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RECENT ACTIVITY IN ALCEDO VOLCANO, ISABELA ISLAND

By: Jonathan R. Green

During November and December 1993 and January 1994, there were several reports of increases in activity levels and other changes inside the crater of Alcedo Volcano (Fig.1). These included:

1) Seismic events, i.e. tremors of varying magnitude.
2) Explosions and subterranean "noises".
3) Vapor and gases visible from various locations at sea level, indicating an increase in fumarole activity.

During a visit to Alcedo Volcano and its crater floor from 16 to 18 February 1994, I made the following observations. While no explosions were heard or tremors felt, on arrival at the rim it was possible to see that there had been extensive changes in fumarole activity in the crater. Previously, there had been only one main fumarole releasing vapor and gases produced by phreatic activity (contact between ground water and magma heat). This fumarole now had a double exit; a second vent had opened up three meters above the first. There had been a considerable increase in pressure in the fumarole resulting in a greater output of vapor and gases.

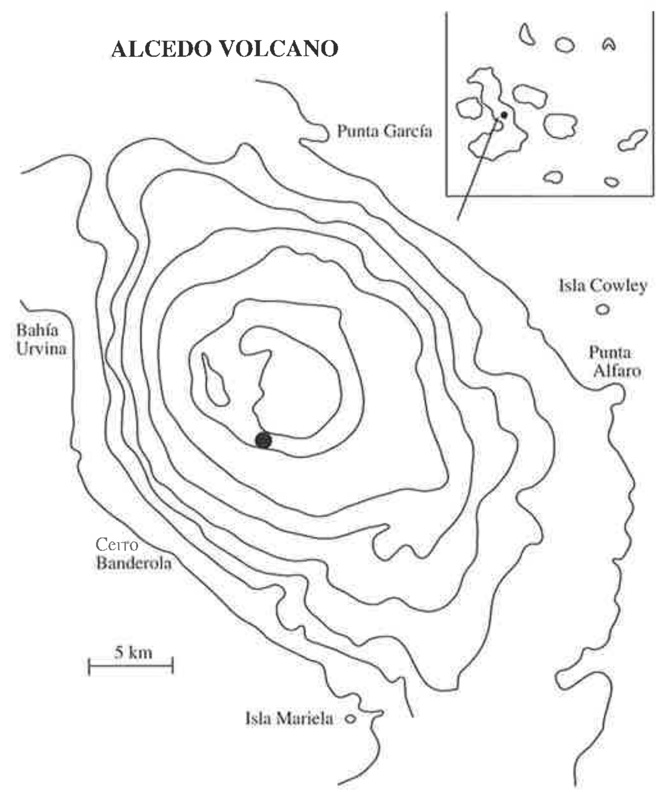


Figure 1. Location of fumarole activity on Alcedo Volcano, Isabela Island.

Two entirely new vents had opened up on the southwestern flank of the volcano, apparently due to explosive phreatic activity (Fig. 2). The smaller of the two vents (approximately 5 x 5 m) did not have much ash surrounding it but the larger one (approximately 75 x 100 m), situated at the same altitude but about 100 yards further west, was surrounded by considerable ash deposits. The ash was mixed with mud, and coated large pieces of debris which were presumably ejected by the same explosive event.

The ash deposits also covered rubble from a landslide originating from the flank of the crater. The landslide, however, had occured well before the formation of the fumarole. The vegetation surrounding and to the west of the large vent was dead, probably due to fumigation by sulfurous gases and contact with ash.

Pressure in the new fumaroles was much greater than that in the primary fumarole. A greater expanse of steaming ground, with more vapor and gas output, was visible from sea-level.

Information gathered from conversations with other tourist guides indicates that the two new fumaroles were formed between mid November and late December 1993. The following are two possible causes for this volcanic activity:

1) Magma rising towards the surface encountered phreatic waters and produced a minor phreatomagmatic eruption.
2) Percolating phreatic waters descended to a magma source and produced a minor eruption.

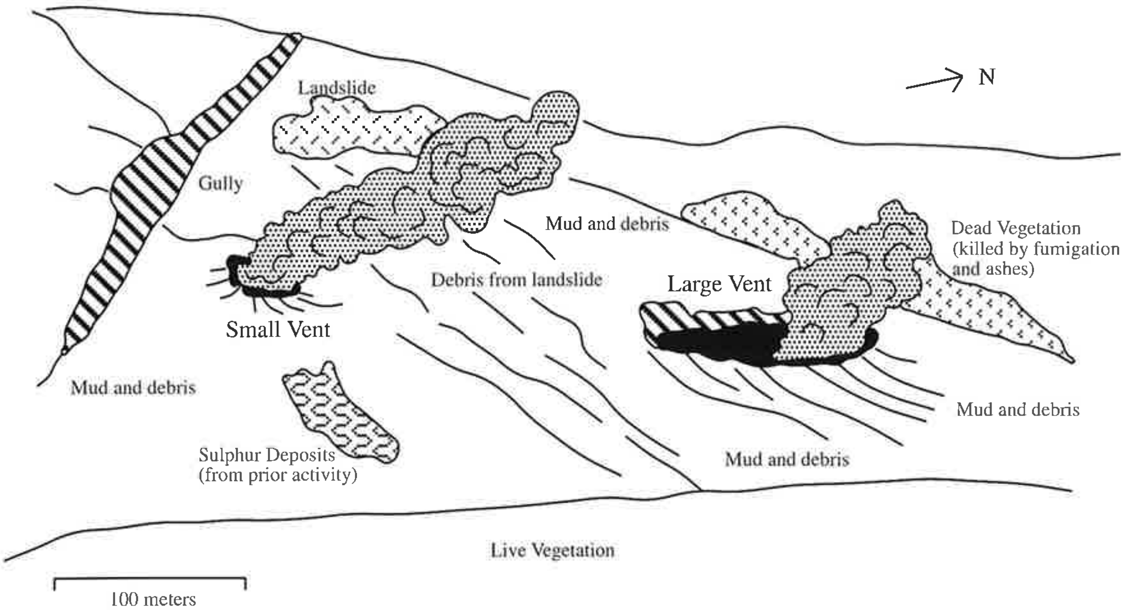


Figure 2. Area of recent activity on Alcedo Volcano. Redrawn by K. Thalia East from original illustration by Jonathan Green.

As there is no evidence of external lava and activity seems to be decreasing, the second explanation is the more likely. Further work, including gas sampling, is needed to confirm this hypothesis. It should be noted that this type of hydrothermal activity is typical of Alcedo and in no way indicates that the volcano is on the verge of a major eruption.

ADDITIONAL OBSERVATIONS

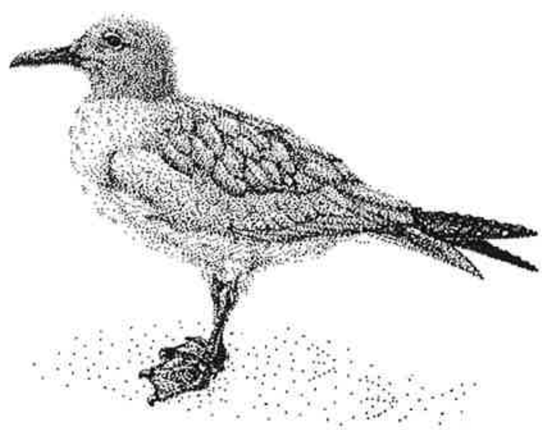
The carcass of an adult female tortoise was found at a distance of 300 m from the area of greatest activity, but whether its demise was due to Volcánic activity or other causes was impossible to determine. From its state of decomposition, death was determined to have been in December 1993 or January 1994.

Only one hawk, a juvenile, was sighted during the visit. Usually 75 to 100 hawks are seen in this area during the same amount of time. Reasons for the absence of hawks remain unknown.

ACKNOWLEDGMENTS

Thanks are extended to Salvador Cazar, Luis Rodriguez, Luis Die, Bolivar Sanchez and Fabio Peñafiel for providing information about the Volcánic activity on Alcedo.

Jonathan Green, Casilla 17-07-9329, Quito, Ecuador.



K. Thalia East

VISITORS FROM THE WEST

By: Godfrey Merlen

The arrival and establishment of organisms in the Galápagos Islands has been a subject of great interest. Evidence indicates that the islands have had more influence from Central America and the west coast of South America than from anywhere else. The predominant westerly direction of the currents and winds and the relative closeness of the South American continent facilitate organismal arrivals from the east. In contrast, the huge extent of the Pacific Ocean to the west of the archipelago defies organisms to reach Galápagos from that direction. Because the Pacific Ocean forms an ecological gulf, separating the fauna and flora of the east from the west, this expanse has been termed the 'East Pacific Barrier'. The paucity of identified arrivals from the central Pacific indicates that it is a highly effective barrier.

Although the Marquesan Archipelago is the nearest land west of Galápagos (3015 nautical miles away), one might suspect that any arrivals from this direction are more likely to come from a more equatorial location such as the Line Islands (including Christmas Island, found at 2° N, 4024 nautical miles from Galápagos), due to the eastward movement of the Equatorial Countercurrent. In addition, weak winds around the meteorological equator might facilitate the easterly movement of birds and other flying or wind-born organisms. The Marquesas Islands lie in the southern hemisphere trade wind belt (10°S latitude), where both currents and winds have a strong westerly flow likely to hinder any eastward movement of organisms.

Thus, the oceanic barrier is a formidable obstacle, yet not impassable. Arrivals from the west are occasionally recorded in the Galápagos, particularly after significant meteorological events such as El Niño Southern Oscillations. Even under more normal conditions, nature pushes travellers towards Galápagos. Sometimes they make it, as did two visitors from the west which I observed in May and August of 1994.

On May 24, while diving near a fur seal colony on the southeast corner of Wenman Island, I noticed a small, bright reef fish moving about just above some large rocks on the sea floor. Although the water was shallow (15-20 feet), the swell made an approach difficult, and I soon lost sight of the animal. However, further search revealed it again and I was able to make a sketch and take a few photographs. Even from my sketch, there was no doubt about its later identification. It was a terminal phase red-shouldered wrasse, *Stethojulis bandanensis* (Fig. 1). This fish is unknown from the Americas, but is common in the central tropical Pacific and the Line Islands (Myers, 1989). Its point of departure, probably as a planktonic larva, could well have been from these

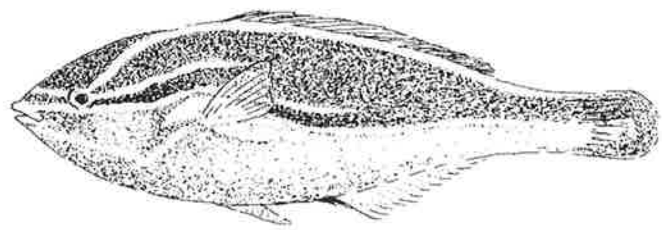


Figure 1. Sketch of a red-shouldered wrasse (*Stethojulis bandanensis*) by G. Merlen.

islands. The closely related belted wrasse, *S. balteata*, is found to the north in the Hawaiian Archipelago, and another related species, *S. albovittata,* occurs in the Indian Ocean (Randall, 1985). Not only do I find it fascinating that such an animal could survive the journey to Galápagos, but the fact that it was in terminal phase, recognized by its scarlet shoulder patch surrounded by bright yellow and bright blue lines radiating from around the eye, suggests that it had survived for some time in its new habitat. The possibility that it arrived in the Galápagos Islands as an adult seems remote since this species, wherever found, is closely associated with reefs. Since I did not see any other members of this species, either in terminal or initial phase, I wonder if the develop-

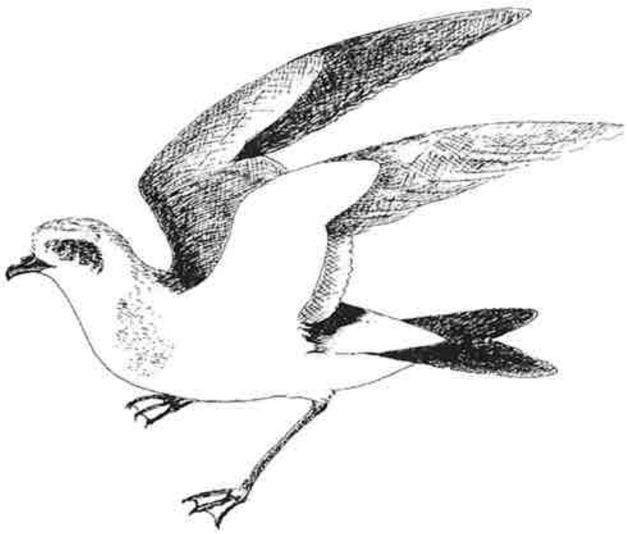


Figure 2. Sketch of a white-faced storm petrel (*Pelagodroma marina*) by G. Merlen.

ment of terminal phase characteristics is independent of the presence of other individuals.

The second visitor from the west was observed on the night of August 7, two miles to the north of Cape Berkeley, Isabela Island. I went to the stern of the boat with Fábian Ramírez to adjust the sail, and saw, by lantern light, a small form fluttering on the deck. Fábian caught the small bird and was about to release it overboard when I suggested that we examine it further, for its aspect was unusual. Under the bright light of the wheelhouse I realized that the tiny bird, which was as light as tissue paper, was a species unknown to me. Again I sketched it and took a few photographs. After keeping it in the dark for 15 minutes to allow it to recover from the bright lights, we released it back into the night. Later identification proved to be simple. Peter Harrison's book 'Seabirds' (1983) clearly showed it to be a white-faced storm petrel, *Pelagodroma marina maoriana*, which is completely different in coloration from any storm petrel occurring regularly in Galápagos (Fig. 2). In the past, sightings of *P. marina* have been recorded near Galápagos and between Galápagos and Peru, but never within the archipelago itself (Harris and de Vries, 1968; Harrison, 1983). What is truly incredible is that New Zealand is the nearest breeding area for this species, where it lays its eggs during the last ten days of October (Murphy, 1936). This means that an individual visiting Galápagos and then returning to New Zealand would cover a minimum distance of 10,717 nautical miles. According to Harrison (1983), Galápagos seems to be the limit of its migration, although it is commonly seen in the central Pacific.

I salute these long-distance visitors and hope there will always be room at the inn for such travellers.

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K. Thalia East

NOTES ON THE STATUS OF TERRESTRIAL ARTHROPODS IN GALÁPAGOS

By: Léon Baert
(Translation assisted by Heidi Snell and K. Thalia East)

Despite far outnumbering the terrestrial vertebrates in species diversity and population numbers, comparatively little is known about the terrestrial invertebrates of the Galápagos Archipelago. Most publications about Galápagos fauna deal with the systematics, phylogeny, physiology, ecology, ethology and preservation of native vertebrates for which the islands are famous. Much work has also been conducted on introduced birds and mammals. In contrast, terrestrial arthropods have been given little attention.

In 1982, Friedman Köster, then director of the Charles Darwin Research Station (CDRS), asked in an annual report , 'How many species of introduced insects and invading invertebrates are there in the islands?'. At that time even the number of native invertebrates in Galápagos was unknown. This realization prompted some important changes. Three long-term studies on the systematics and evolutionary ecology of terrestrial arthropods in the archipelago were initiated. In 1982, K. Desender, J.P. Maelfait and I, from the Royal Belgian Institute of Natural Sciences in Brussels, began a study of Arachnids, Carabid beetles and Isopods. In 1985, Stewart Peck and several of his colleagues from Carleton University, Canada, started a study of several arthropod groups, especially beetles. Also in 1985, Heinrich and Irene Schatz of the University of Innsbruck, Austria, commenced a study of Oribatoid mites and Tenebrionid beetles. All three projects continue to this day and while the groups work independently, they have coordinated their projects to complement one another.

Before any serious ecological work on a arthropod group could be conducted in Galápagos it was necessary to have an understanding of the diversity and population numbers of all species inhabiting the islands. This required extensive taxonomic research to identify and describe the existing invertebrate fauna. Such information is also of interest to the Galápagos National Park Service (GNPS) and to CDRS for developing and implementing management policies and for studies of faunal changes occuring due to the ever increasing human population within the islands.

Linsley and Usinger (1966) compiled the first insect species list for Galápagos, enumerating some 618 species, treated in about 190 publications. The list was derived from results of collecting campaigns of 21 multidisciplinary expeditions ever since Charles Darwins visit in 1835. In a later supplement, Linsley (1977) added another 265 species, treated in 118 publications. These additions were principally the result of collecting efforts of the Galápagos International Scientific Program of the Californian Academy of Sciences in 1963-64 and the collecting campaign of Leleup (1965) in 1964-65.

With this initial list, the first task of the Belgian, Canadian and Austrian research groups was to compile summaries of known data on terrestrial invertebrates in Galápagos. A data base was constructed, containing the following types of information:

1) Literature citations for all invertebrate species of the archipelago.
2) Distribution information of each species within and between islands as well as on the continent.
3) Whether each species is introduced, native or "endemic".
4) Ecological data for each species, such as habitat preference, seasonality, elevational zonation, dispersal power, diet and host specificity.

All major islands and volcanoes have been at least roughly sampled by the scientists. Due to improved arthropod capturing techniques such as pitfall, malaise, flying interception and bait traps the teams were able to almost double the arthropod species list during the 1980s (see Table 1). Even now a collection

Table 1. Growing number of species for the most important terrestrial arthropod groups.

	1966	1980	1991
Insecta	618	883	1592
Scorpions	2	0	2
Pedipalpi	0	0	1
Solifugae	0	0	1
Pseudoscorpiones	0	0	16
Opiliones	0	0	1
Araneae	70	81	152
Acari	38	0	192
Amphipoda	0	0	4
Isopoda	0	0	17
Chilopoda	10	0	13
Diplopoda	2	0	9
Symphyla	0	0	1

made on any island or volcano can add a new species to the list. Table 2 provides a detailed example of how the total number of spider (Araneae) species recorded in Galápagos has increased after each collecting trip.

Due to the efforts of the teams, we have a fairly good idea of the composition of some of the arthropod groups in the archipelago and have been able to conduct ecological analyses of the data. For example, we have been able to compare spider communities among the different vegetation zones of Santa Cruz Island (Baert et al., 1991) and of the five volcanoes on Isabela Island (Baert et al., 1990). We have concluded that species composition of spiders is correlated primarily with the altitudinal gradient and thus the vegetation zones. On Isabela spider communities are also influenced by the age of the volcanos as well as by the presence or absence of human settlements and agriculture.

K. Desender has been investigating distribution patterns of Carabid beetles (Desender et al.,1992a). He has shown that the Carabid beetles have a wide variety of distribution and speciation patterns including small and large scale allopatry, parapatry, allopatry with secondary contact of sister species, and allo-parapatry. The same is true for spiders (e.g. Maelfait & Baert, 1986) and may be intrinsic to small arthropods.

Another important group of invertebrates in Galápagos is the cave dwelling Cryptozoa. Other than some fossil remnants of a probably endemic rat, the only animals found in caves are invertebrate representatives of Crustacea, Arachnida, Chilopoda, Diplopoda and Insecta. Leleup (1965) pioneered a study of cave animals in Galápagos which is now being followed up by S. Peck and his team (see Hernandez Pacheco et al.,1992). Cryptozoic arthropods are of special interest in studying the principals and historical processess of animal geography. They are often considered archaic or relictual and as having an exceedingly slow dispersal potential. Some Cryptozoans have adapted to an extreme and can be morphologically characterized by reduced or absent eyes, a reduction of body pigmentation, often a thinning of body cuticle, flightlessness in normally winged groups and an increased physiological sensitivity to

Table 2. Growing number of spider species.

Year	Number of Species Added	Total Number of Species	Collecting Expedition
1877	6	6	
1889	5	11	
1902	17	38	Hopkins-Stanford 1898-1899
1924	5	43	Williams 1923
1930	6	49	Norwegian Zoological 1925
1970	21	70	Cal. Acad. Sci. and Leleup ('64-'65)
1982	11	81	Various publications
1982	29	110	Baert and Maelfait
1985	2	112	H.and I. Schatz (1991)
1985	3	115	Peck et al.
1986	7	122	Baert, Maelfait and Desender (1989)
1988	4	126	Baert, Desender and Maelfait (1991)
1989	8	134	Peck et al. (1991)
1991	11	145	Baert, Desender and Maelfait (1991)
1991	4	149	Peck and Heraty
1992	3	152	Abedrabbo

dehydration. Peck (1990) lists 56 species of eyeless and reduced-eyed arthropods, of which 40 are native or endemic and 16 have become well established since their probably inadvertent introduction by man.

INTRODUCED ARTHROPODS

While a large proportion of arthropod species in Galápagos certainly colonized the islands naturally, it is obvious that a number have been introduced since the islands were discovered and inhabited by humans. Kramer (1984) stated that the problem of introduced invertebrates, many of which may be man-dependent immigrants, had not yet been and needed to be tackled. Part of the problem was that it is often difficult to know whether a non-endemic species was introduced by man or immigrated naturally. No doubts exist in the case of man-dependent immigrants, examples of which are the spiders *Heteropoda venatoria*, which inhabits almost every house in Galápagos, the long-legged *Scytodes longipes*, and all the beautiful jumping spiders around Puerto Ayora, Santa Cruz, such as *Hasarius adansonii*, *Menemerus bivittatus* and *Plexippus paykulli* (Fig. 1). *Theridion rufipes,* which lives both indoors and out and is often found under the plank beds of tourist boats, tends to be carried from island to island. *Latrodectus geometricus* which I have only found under wooden seats at the Canal de Itabaca (Santa Cruz Island) and in the town of Puerto Baquerizo Moreno (San Cristóbal Island) is another example of an introduced man-dependent spider.

The true number of introduced species is difficult to assess because few extensive studies of arthropod groups in Galápagos have been published. However, it is known that 13 out of 18 cockroach species (Peck and Roth, 1992), 7 out of 8 Diplopod species (Shear and Peck, 1987) and 10 out of 13 Chilopod species (Shear and Peck, 1992) have been introduced to the islands by man.

Introduced species can negatively affect existing

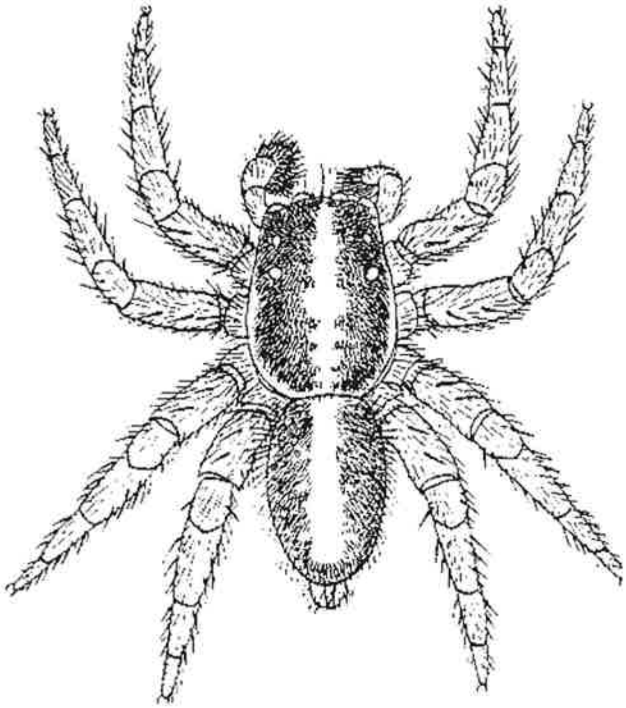

Figure 1. Sketch of an introduced jumping spider, *Plexippus paykulli* (Salticidae), by L. Baert.

ecosystems. Arthropods can be as devastating to plant and animal communities as can vertebrates such as goats, pigs and rats. However, their influence on the natural community also depends on the achieved equilibrium state of the natural community. For example, species which can fill an empty niche or which are able to adapt to harsh conditions of a specific microhabitat not occupied by a native species, can evolve to play a benign or even a beneficial role in the ecosystem. On the other hand, in Galápagos, difficulties of natural colonization in the islands have resulted in simpler arthropod assemblages than those found on the continent. This in turn may have made them more vulnerable to human-assisted introduction of aggressive species.

In 1972, at the Galápagos Science Conference held in Washington DC, the continuation of "alpha level" systematics for the diverse but still poorly known invertebrate fauna in Galápagos was recommended. However, it was only in 1981 that the position of a staff entomologist at the Charles Darwin Research Station (CDRS) was established and that Dr. Yale Lubin was hired to study, among other things, the rapid spread of the introduced fire ant *Wasmannia auropunctata* (Lubin, 1984; 1985).

W. auropunctata was probably introduced to inhabited islands of Galápagos during the 1930s. In 1975, it was discovered on an uninhabited island at a camping area used by scientists. *W. auropunctata* is a tiny ant which lives in small colonies containing several queens and has a high level of swarming activity by which it disperses easily over large areas. The ants are highly aggressive and do not tolerate other invertebrates in their immediate vicinity. Areas infested by them undergo the loss of many endemic and native invertebrate species. This is especially true in the transition zone on Santa Cruz where they are most abundant. However, since there was never a complete inventory of invertebrate species before the *W. auropunctata* invasion, the extent of their impact cannot be quantified. Few spider species are able to coexist with *W. auropunctata*. In parts of the transition zone not heavily infested with the ants we encountered 16 spider species, whereas in strongly infested areas of the zone we found only two tiny oonopid spiders and one ochyroceratid spider, all of which were possibly introduced with the ants.

By the time people realized what kind of damage was being caused by *W. auropunctata*, it was too late; whole areas were literally covered with the ants and it is likely that we will never be able to eradicate the species without inflicting serious damage to other native invertebrates.

Introduced invertebrates are in general extremely difficult to eradicate once they have established themselves. Generally they are small, they hide in tiny cracks and holes and are thus easily overlooked. They can easily be transported from one island to another by means of cargo ship or tourist or fishing boat. Once on land they can as easily been transported by man over the whole island. Many also have the ability to fly and can colonize nearby islands on their own. Only one gravid female is needed to start an entire population, for invertebrates can breed at high rates and inbreeding does not seem to effect population quality.

Introduced invertebrates tend to be extremely difficult to eradicate in part because they are hard to trace; they are noiseless (or their sounds resemble that of the native species and it takes an expert to tell the difference), they don't leave footprints, they tend to disappear into places difficult to penetrate by man and they are not always very visible when flying. By the time they become a nuisance they usually have reached high population densities and are beginning to disperse. By then it is too late to intervene without drastic methods that may cause even more harm to the native invertebrate fauna.

So, what eradication methods can be used? Each group or species requires a different eradication method. One possibility is biological control. For this, a biological enemy is needed to control or eradicate the pest species without becoming a nuisance species itself. This method opens new perspectives but needs a thorough initial study of the ecology of both the pest species and the biological control species which is, of course, yet another introduced species and therefore a potential problem species.

An example of a recent introduction is the *Polistes versicolor* wasp. This introduction apparently occurred in 1988 during a shipment of bananas and other fruit from mainland Ecuador to Floreana Island. The wasp has since spread over all of the archipelago. Not only is the sting very painful and sometimes causes fever, but *P. versicolor* may be having a significant negative impact on the Galápagos ecosystem by competing with native fauna. From an unpublished report prepared by Jhon Heraty at al., the major prey item of *P. versicolor* might be caterpillars, a major dietary item of many birds and reptiles and of *Calosoma* beetles. The danger exists that a severe disruption of caterpillars might have disastrous effects on these various populations.

Polistes wasps are not regarded on the mainland as pest animals in normal numbers, but as an introduced species on the remote islands of Galápagos things may be different. For this reason the wasps are being observed closely and anxiously by entomologists at CDRS under the supervision of Sandra Abedrabbo, and eradication possibilities are being discused. For example, *Polistes* have many parasites (over 40 species are known) and one of them may possibly be useful as a biological control agent.

Other recent introductions of exotic invertebrates have not illicited much attention because unlike *W. auropunctata* and *P. versicolor*, they do not sting and have not come directly into contact with humans. Only scientists working in Galápagos generally encounter them. But with these "hidden" introductions too, native or endemic species may be adversely affected. There are now two Cicindelid beetles living in sympatry in lagoons and salt marshes along the coast of Santa Cruz (Desender et al.,1992b). One species, *Cicindela galapagoensis*, is endemic and well spread over the archipelago. The second species, *Cicindela trifasciata*, is known from the western part of Central and South America. Our data on *C. trifasciata* show that it has only been collected since 1983, even though the habitat it occupies on Santa Cruz has been searched on many earlier occasions. The first individual was collected at the end of the 1982/1983 El Niño event. The recent population growth and relative abundance of *C. trifasciata* in the Bahia Tortuga lagoon area compared to that of the endemic *C. galapagoensis* shows it has become very abundant in a short time span. The introduced species may be displacing the endemic species. The restricted occurrence of *C. trifasciata* on Santa Cruz suggests that it was introduced by man. However, the importance of the El Niño events must be emphasized in this particular colonization. El Niño events may increase the number of possible colonizations, primarily by an increase in vegetation rafts from the mainland forming and reaching Galápagos due to increased rainfall on the mainland, but also because climatic conditions are more favorable for establishment of newly arrived species in the usually harsh environments of Galápagos. Such events may well have helped during the first steps in the adaptive radiation and evolution of many invertebrates of the archipelago.

A second hidden introduction involves the spider Any*phaenoides octodentata*. *A. pacifica* is widespread over the Galápagos archipelago, from the pampa down to the littoral zone. The vicinity around CDRS is always emphasized during each collecting campaign. The second to last collection done in this area in 1989 by Peck revealed the presence of only the native species *A. pacifica*. Our last collections (by Peck and myself) in 1991 revealed the sudden presence of a second congeneric species, *A. octodentata* (11 specimens) living sympatrically with the former species. This species has a wide continental distribution from Venezuela to Perú.

An interesting note about the species is that it was discovered for the first time in 1971 in the German seaport of Hamburg in a load of Ecuadorian bananas. Has this species been accidentally introduced to Galápagos in a shipment of bananas or other fruit or vegetables from the mainland? It certainly appears so, as *A. octodentata* appeared suddenly in the vicinity of Puerto Ayora where most of the goods shipped from the mainland to Santa Cruz are unloaded. A specimen was also found at Puerto Baquerizo Moreno, the shipping port for San Cristóbal.

It seems clear that introductions are occurring through transport of goods by boat and by plane from mainland Ecuador. Food products are especially likely to carry unwanted invertebrates. The nonchalance with which the unloading of merchandise is conducted indicates a need for more controlled supervision of docking activities. All goods should be carefully controlled and if necessary treated in an adequate way to insure that no living animals are transported along with them. As long as there is no better control of the the import goods to the islands there remains the very real danger of continuing to introduce potentially harmful plants and animals to the islands.

Tourism also plays a negative role in affects on the local fauna and flora. Boats travelling between islands increases the risk of genetic pollution between the well established isolated populations of closely related taxa. Insects are frequently attracted to the lights of tourist and fishing boats anchored near shore at night. Boats often travel between islands at night or in the predawn hours carrying these insects to a new location. A recent study revealed that flying insects are much less attracted to yellow light than white light. The use of yellow lights should be obligatory on every boat navigating in the Galápagos waters.

Finally, man is not only affecting the faunal composition of the islands by introducing animals by design or accident, but also by altering the natural landscape. One example is the exploitation of the most fertile zone of Santa Cruz, the *Scalesia* zone, for agricultural activities and livestock. To end this article I give a specific example of the impact of human-introduced arthropods on the native fauna with a synopsis of a comparative study on the spider community of different vegetation zones on Santa Cruz (Baert et al., 1991). Our data reveal 22 species for the agricultural zone (outside Park boundaries) and 20 species for the remaining *Scalesia* area near Los Gemelos. The transformation of the original *Scalesia* zone into the agricultural zone resulted in a slight quantitative enrichment (with only two additional species), but also in a qualitative impoverishment of the original *Scalesia* fauna. For instance, seven endemic species and two native species disappeared and were replaced by three endemic species originating from the lower arid zones, by one native species, four man-dependent species and by two introduced species, the man-dependent and introduced species obviously having a lower value for nature conservation and the maintenance of biological diversity in Galápagos.

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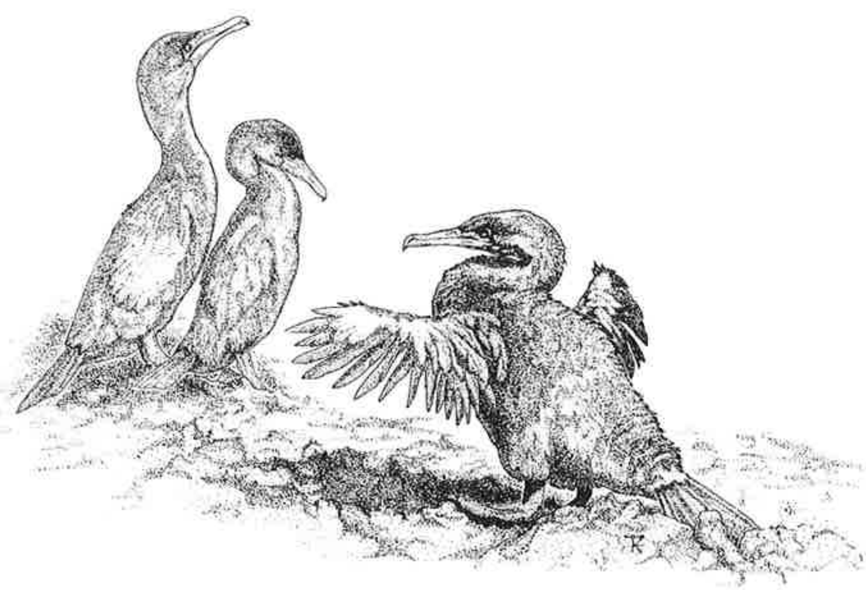

K. Thalia East

POLLINATOR AVAILABILITY: A POSSIBLE EXPLANATION OF INTER-ISLAND FLORAL VARIATION IN *JUSTICIA GALAPAGANA* (ACANTHACEAE)

By: Conley K. McMullen

INTRODUCTION

Floristic studies in Galápagos have had an admirable history, and have culminated in works such as 'Flora of the Galápagos Islands' (Wiggins and Porter, 1971) and 'An updated and annotated check list of the vascular plants of the Galápagos Islands' (Lawesson et al., 1987). However, an understanding of the relationships that exist between the members of this unique flora and their insect coinhabitants is still in its infancy.

Stewart (1911), after visiting the Galápagos Islands as part of the California Academy of Sciences expedition in 1905-6, made one of the earliest references to this subject when he noted that most of the endemic angiosperms had small flowers and suggested that this was due to the scarcity of insects in the archipelago. The inference was that large showy corollas had little selective value since there were so few insects present to attract as pollinators.

Studies on the pollination biology of various Galápagos angiosperms have followed (Aide, 1986; Elisens, 1989; Grant and Grant, 1981; Linsley et al., 1966; McMullen, 1987; Rick, 1963, 1966). Results suggest that the endemic carpenter bee, *Xylocopa darwini* Cockerell (Hymenoptera: Apidae), is a major pollinator on the islands it inhabits. In total, 73 angiosperm taxa (70 species) have been recorded as visited by this bee. Non-endemic plants appear to be favored as only 24 of these taxa are restricted to the Galápagos Islands. Linsley et al. (1966) suggested that *X. darwini* was probably more important for the establishment of the native and introduced elements of the Galápagos flora than for the older endemic members. Reports of other insect visitors are limited (Grant and Grant, 1981; Linsley, 1966; McMullen, 1986). Plant breeding studies have also been conducted, resulting in 53 angiosperms being classified as self-compatible, with 50 of these capable of autogamy (Aide, 1986; Elisens, 1989; McMullen, 1990; Rick, 1966). Only one species has been classified as self-incompatible (Grant and Grant, 1981).

Based on the results of these breeding studies and the fact that there are relatively few potential pollinators in the Galápagos, it has been hypothesized that the first angiosperms to colonize the islands were those that possessed upon arrival, or developed soon after, the ability to reproduce autogamously (Aide, 1986; McMullen, 1987, 1990; Rick, 1966). The initial scarcity of pollinating insects, including *X. darwini*, could also explain the small flower size and drab color of the majority of endemics. Without faithful pollinators there would be little or no apparent selective advantage for large attractive corollas. The small amount of pollen produced by most flowers further supports this scenario (Colinvaux and Schofield, 1976; McMullen and Close, 1993).

The objective of this study was to investigate the relationship between pollinator availability and plant reproduction by comparing these variables on Pinta Island and Santa Cruz Island. *Xylocopa darwini* is common on Santa Cruz, but has never been found on Pinta. These studies would help determine whether or not the carpenter bee, since its arrival, has influenced the development of floral characters and pollination strategies of selected plants on the islands it inhabits.

Hypothetically, the presence of *X. darwini* on Santa Cruz will have promoted more attractive floral displays than those found in the resident flora of Pinta. This attractiveness might be expressed in characters such as inflorescence and flower sizes. Moreover, a characteristic such as larger flowers might mean that the plants inhabiting Santa Cruz rely less on autogamy.

METHODS

Fieldwork for the first phase of this research was performed on Pinta Island from 23 June to 26 July 1990. Four angiosperm species that inhabit both Pinta and Santa Cruz had sufficient flowers for testing at this time (McMullen, 1993). However, only *Justicia galapagana* Lindau (Acanthaceae) is reported here since it alone was known from previous studies to be regularly visited and pollinated by *X. darwini* on Santa Cruz (Linsley et al., 1966; McMullen, 1985; Rick, 1966).

This plant is an endemic herb that may reach 1 m in height. It produces axillary inflorescences that typically have only a few flowers. The corollas are purple to lavender or white in color, and the former often have white markings in the throat. No noticeable fragrance is present. The fruit is a capsule that may produce up to four seeds.

The study site was located at 580 m altitude on the southeastern slope of Pinta. Breeding experiments were conducted to determine if the species was capable of autogamy. Fruit and seed yields were compared between inflorescences completely isolated from insects (bagged) and others that were exposed to potential pollinators before being covered (open-pollinated). The actual number of individuals studied was impossible to determine without destroying the plants due to their close spacing and vegetative growth by runners.

Other studies were performed while awaiting the results of the breeding experiments. First, a variety of inflorescence and floral characters were measured using vernier calipers. Second, 26 hours of observations were conducted over four days to determine what insects were flower visitors and might act as pollinators. Information such as how many visits were made and how long each visit lasted was obtained. An LED stopwatch was used to make these measurements.

Similar studies were undertaken on Santa Cruz Island from 31 July to 10 August 1990. Two sites near the craters known as Los Gemelos (ca. 630 m altitude) were used. No breeding experiments were conducted as this information was available from previous studies performed in 1983-84 (McMullen, 1987). All other measurements and observations were performed as on Pinta. However, only five hours over two days were spent observing insect visitors on this island. Once again, this was due to the fact that research had previously been conducted on Santa Cruz.

RESULTS

Breeding studies indicate that *J. galapagana* is at least facultatively autogamous (Table 1). This species showed a higher percentage of autogamous fruit and seed set on Pinta than on Santa Cruz. Open-

Table 1. Breeding experiment results. Those for Santa Cruz are based on studies conducted in 1983-84 (McMullen, 1987).

	# Flowers Tested	% Fruit Set	% Seed Set
Bagged			
Pinta	80	43.8	31.3
Santa Cruz	68	32.4	18.0
Open-Pollinated			
Pinta	92	29.3	19.6
Santa Cruz	125	14.4	10.8

pollination on both islands produced a lower fruit and seed set than bagged flowers. Once again, however, a higher percentage was found on Pinta than on Santa Cruz.

Table 2 shows the results of the measurements of the inflorescences and flowers. Significant differences in all characters except number of open flowers per inflorescence and corolla lip width are found between Pinta and Santa Cruz. The mean values of all characters except corolla tube width are higher for Santa Cruz.

A single insect was observed visiting *J. galapagana* on Pinta (Table 3). This was a damsel bug nymph (Hemiptera: Nabidae), which visited only one flower for a total of 95 seconds. Three insect species visited this plant on Santa Cruz during the timed observations. These were *Toxomerus crockeri* Curran (Diptera: Syrphidae), *Urbanus dorantes galapagensis* Williams (Lepidoptera: Hesperiidae), and a short-horned grasshopper nymph (Orthoptera: Acrididae). *Toxomerus crockeri* was most frequently observed (44 visits, 3,810 seconds). One untimed visit was made by *Phoebis sennae* L. (Lepidoptera: Pieridae).

Xylocopa darwini was not observed at the flowers of *J. galapagana* during these studies. This was probably because of the weather. The highlands were often wet due to rain and the seasonal mist known as garua. It must be remembered, however, that previ-

Table 2. Inflorescence and flower measurements (mm). Significant differences: ***= P<.001; *= P<.05. (Independent samples t-test).

	Mean	SD	N
Inflorescence Length***			
Pinta	33.09	16.76	50
Santa Cruz	44.75	18.70	97
Flowers Open / Inflorescence			
Pinta	1.00	0.00	50
Santa Cruz	1.03	0.17	97
Entire Corolla Length***			
Pinta	9.52	0.53	50
Santa Cruz	10.07	0.68	100
Corolla Tube Length*			
Pinta	5.24	0.54	50
Santa Cruz	5.45	0.51	100
Corolla Tube Width***			
Pinta	2.36	0.27	50
Santa Cruz	2.17	0.21	100
Corolla Lip Width			
Pinta	7.87	1.24	50
Santa Cruz	8.27	1.67	100

Table 3. Insect visitors. Visitation times are in seconds. Total refers to the times of all visits combined. N refers to the number of visits.

	Total	Mean	SD	N
Pinta				
Damsel Bug nymph				
(Hemiptera: Nabidae)	95	-	-	1
Santa Cruz				
Toxomerus crockeri				
(Diptera: Syrphidae)	3,810	86.59	122.50	44
Urbanus dorantes galapagensis				
(Lepidoptera: Hesperiidae)	300	-	-	1
Short-Horned Grasshopper nymph				
(Orthoptera: Acrididae)	6	2.00	0.00	3
Phoebis sennae				
(Lepidoptera: Pieridae)	Not Timed			1

ous studies have shown that this plant's flowers are frequently visited on Santa Cruz by *X. darwini*. In addition, *Leptotes parrhasioides* Wallengren (Lepidoptera: Lycaenidae) and *Wasmannia auropunctata* Roger (Hymenoptera: Formicidae) are visitors to its flowers (Linsley et al., 1966; McMullen, 1986, 1990; Rick, 1966).

DISCUSSION

Justicia galapagana exhibited a higher level of autogamy and generally smaller floral characters on Pinta than on Santa Cruz. These results may be explained by the scarcity of insect visitors to this plant on Pinta. Although the damsel bug nymph had pollen adhering to its body, it was seen only once. A return visit to Pinta by myself in 1993 confirmed this absence of faithful pollinators. Although no timed observations were made, it was apparent that these flowers were of little interest to the local insects. *Leptotes parrhasioides* was commonly seen flying about the plants. Only rarely did they land on a flower, and then just for an instant. These butterflies did not appear to come into contact with the anthers during their brief visits.

Toxomerus crockeri was the most common visitor to *J. galapagana* on Santa Cruz during this study. Individuals were often seen pushing their way into the corolla throats. This movement caused the insect's abdomen, and more often its dorsal surface, to rub against the flower's anthers and stigmas. This appears to be an ideal movement for pollination. The butterflies and grasshopper nymphs that visited *J. galapagana* during this study appear to be unimportant as pollinators. *Leptotes parrhasioides* and *W. auropunctata* as well are unlikely pollinators of this species (McMullen, 1986). Although not observed in 1990, *X. darwini* remains an important pollinator of this plant.

Open-pollinated flowers produced fewer fruits and seeds than those that were bagged. With so few pollinators, one might not expect open-pollinated flowers to produce a higher yield. This is especially true since wind pollination is thought to be of no consequence to this plant (McMullen and Close, 1993). These results suggest that reproduction in this species is pollen-limited on both islands. In other words, more fruit could be set if more pollen vectors were available. However, an explanation for fewer open-pollinated fruits and seeds is more difficult to come by. Perhaps some of the flowers were damaged by birds or insects before being bagged.

The results of this study support the hypothesis that autogamous angiosperms were favored in the initial colonization of the Galápagos Islands. The presence of *X. darwini* on Santa Cruz, along with other insects such as *T. crockeri*, may have since selected for flowers and inflorescences better able to vie for the attention of potential pollinators than those of the same plant species on Pinta. This could also explain why *J. galapagana* had a lower level of autogamous fruit set on Santa Cruz.

Although differences were observed between these islands, two explanations might be offered for why they weren't more obvious. First, although there is no evidence of this, it is possible that *X. darwini* inhabited Pinta in the past. Several tree species that this bee uses for nesting on Santa Cruz are also found on Pinta. Second, perhaps *X. darwini* has not been in the archipelago long enough to have had more of an effect. This may be true since it would have needed several food and nesting plants present on the islands before it could survive and reproduce (Linsley et al., 1966). In addition, the fact that the bees themselves do not differ between islands would seem to indicate a recent arrival in the archipelago. This is another area in which work is needed.

One final question should be explored. What other explanations might account for the inter-island floral variation encountered? Perhaps this is simply an example intraspecific variation among island populations. In other words, the smaller flowers of Pinta might be exhibiting a founder effect. The distance between Pinta and Santa Cruz would serve as a strict enforcer of reproductive isolation between these island populations. Rick (1983) and Elisens (1989) have demonstrated such inter-island variation in the morphological and allozymic characters of *Lycopersicon cheesmanii* Riley (Solanaceae) and *Galvezia leucantha* Wiggins (Scrophulariaceae).

Perhaps the observed morphological variation is due to differing environmental regimes on Pinta and Santa Cruz. An obvious next step would be to raise individuals from both islands in the uniform environment of a greenhouse, and then make the same flower and inflorescence measurements. If the differences are still present, then this would eliminate environmental factors as an explanation. Unfortunately, implementing such research is often much more difficult than formulating the idea. The logistics of obtaining the necessary seeds, returning with them, and raising the plants to reproductive maturity have yet to be overcome.

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Justicia galapagana. Photograph by C. McMullen.

REPORT OF TWO ORCA ATTACKS ON CETACEANS IN GALÁPAGOS

By: Bernard Brennan and Patricia Rodriguez

The Research Vessel *Odyssey* studied sperm whales (*Physeter macrocephalus*) and other cetaceans in the Galápagos Archipelago from February 1993 to April 1994. During the tenth cruise around the islands, from 17 October to 6 November 1993, orcas (killer whales, *Orcinus orca*) were observed attacking Bryde's whales (*Balaenoptera edeni*) and sperm whales on two consecutive days.

Orcas are regularly seen in the Galápagos Archipelago (Day, 1994). However, only one orca attack on another cetacean (sperm whales) in Galápagos has been reported (Arnbom et al., 1987). Two other unpublished incidents have been noted by local naturalists: one involving bottlenose dolphins (*Tursiops truncatus*) and the other, common dolphins (*Delphinus delphis*).

THE ATTACKS

At 0830 h on 25 October 1993, a group of at least five Bryde's whales was observed being pursued by ten orcas in Banks Bay, north of Fernandina Island (initial sighting: 0°08.8S, 91°32.8W). The orcas were spread out in small groups of one to three individuals, following and flanking the Bryde's whales. Half the orcas soon disappeared from sight leaving two males, a mother and calf, and another female. Individuals were distinguished by size, dorsal fin shape and behavior. While being pursued, the Bryde's whales traveled as a closely knit group, made mostly short dives and increased their blow rate. One individual breached twice. On several occasions, the two male orcas converged from opposite sides of a Bryde's whale and then the three animals submerged, preventing further observations of any interactions. No physical contact, open flesh wounds or carcasses were seen. However, blood was observed at the surface and the orcas were seen feeding on pieces of flesh and intestines. Therefore, we believe that a Bryde's whale may have been killed. No sounds were heard on our hydrophones other than an orca squeal and some clicks on two occasions. The interaction between the two species was observed for two and a half hours until the Bryde's whales left the area.

The second attack occurred the following day at 1530 h while the *Odyssey* was following a dispersed group of 12 sperm whales, 8.5 miles southwest of Fernandina (0°28.9S, 91°45.5W). An orca was observed to porpoise out of the water and bite a sperm whale behind the dorsal fin. Two more orcas were seen immediately behind the attacked sperm whale before all the animals submerged. A large expanse of blood subsequently formed at the surface. Several minutes later a group of five orcas (a large male, a mother and calf, and two females or immature males) were sighted. They circled the expanse of blood at high speed, then left the area. The interactions lasted less than seven minutes. Meanwhile, the remaining sperm whales tightened their group at the surface and made frequent direction changes. They ceased making deep or long dives and were mostly silent. This behavior was observed until nightfall (1835 h) when it became impossible to follow the whales. As far as it could be determined, only one sperm whale was attacked.

The proximity of these two attacks in space and time, and the similar composition of the two orca groups, suggested that some of the orcas were involved in both incidents. However, analysis of photographs of the dorsal fins and white "saddle" markings of each individual has revealed that the two groups were distinct.

The Bryde's and sperm whales demonstrated marked behavioral responses to the presence of orcas. Both species formed tighter groups than normal, made frequent directional changes as a group and ceased making long dives. These responses and particularly the breaching of one of the Bryde's whales and the prolonged silence of the sperm whales, differ from anything that has been observed in Galápagos during the past years' work on board the *Odyssey.*

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NOTES ON THE CUVIER'S BEAKED WHALE (*ZIPHIUS CAVIROSTRIS*), WITH OBSERVATIONS OF A DEAD SPECIMEN

By: Daniel M. Palacios, Patricia Rodriguez, Bernard Brennan and Kim Marshall

The Cuvier's beaked whale (*Ziphius cavirostris*) is a poorly known member of the cetaceans found in Galápagos. During research cruises aboard the R/V Odyssey in 1993 and 1994 we only saw this species about 15 times during 13 months. However, we were lucky to find a dead individual which prompted the writing of this note. Our observations on this individual follow a brief description of Cuvier's beaked whales paraphrased from Leatherwood et al. s (1988) identification guide to whales.

The Cuvier's beaked whale, or goose beaked whale, belongs to an interesting and diverse, but poorly known, group of odontocete cetaceans, the family Ziphiidae. Most of what is known about this group comes from individuals stranded on shore. Since Ziphiids tend to be shy and relatively inconspicuous at the surface, they are infrequently seen at sea.

Cuvier's beaked whales grow to about 7 m, becoming sexually mature at about 5.4 m. Length at birth is 2 to 3 m. The head is relatively small and the beak is short and poorly demarcated. The profile of the head and jaw appears similar to a goose's beak. A single pair of conical teeth is located under the gum, at the tip of the lower jaw. These teeth emerge only in males and visibly protrude from the closed mouth. The throat has two long, anteriorly convergent creases. The dorsal fin, located well behind the central dorsal region, tends to vary in size and shape. Unlike in other cetaceans, the flukes of Cuvier's beaked whale are usually not divided by a distinct notch and their trailing edge is somewhat concave.

Coloration appears to be related to both age and sex. Calves and juveniles are tan or light brown. As they age, they becomes marred with scratches and white or cream-colored oval blotches, especially on the abdomen. In older animals the head becomes distinctively lighter than the rest of the body. Old males may appear all white.

Cuvier's beaked whales are probably deep divers since they prey mostly on squid and deepwater fish.

Occasionally groups of individuals will surface unexpectedly near a vessel and seem startled by its presence. After a series of respirations between shallow dives, the pod will sound, disappear below the waves and not be seen again.

This species appears to be a year-round inhabitant of at least portion of its geographic range in the eastern North Pacific. It is known to occur in the Galápagos Archipelago (Leatherwood et al., 1988; Day, 1994), where it was first reported in 1975 (MacFarland, 1977). However, it is rarely seen perhaps because its preferred habitat, deep off-shore water, is not often visited by local boats.

In 1983 six live animals were stranded on Baltra Island (Robinson et al., 1983). Two of these animals died, and their skulls were placed in the Charles Darwin Research Station museum reference collection. Over the years, local residents of the islands have found additional remnants of at least four dead animals washed up on beaches (D.M. Palacios, unpublished data). These observations suggest that Cuvier's beaked whales may be more common in Galápagos waters than previously thought.

OBSERVATIONS OF A DEAD SPECIMEN

It is rare to find corpses of whales. As aquatic animals their bodies decompose rapidly, sink to the ocean floor or are eaten by scavengers soon after death. Occasionally bodies are washed ashore but they are usually in poor condition to study.

On 4 March 1994, during a research cruise aboard the *R/V Odyssey*, we found a recently dead Cuvier's beaked whale floating in the open sea. We encountered the whale approximately 28 miles WNW of Cabo Berkeley, Isabela Island (0°10.7'N; 92°02.0'W), while watching a pod of 10 to 15 killer whales (*Orcinus orca*). After retrieving the body, we organized a complete necropsy using standardized protocols for dissecting small cetaceans (e.g. Hohn et al. 1986). The carcass was affixed to the side of the vessel while two of us collected samples of various tissues.

The specimen was a young female, 4.2 m in length. Her ovaries were visually inspected for the presence of corpus albicans (scars from previous ovulations which indicate sexual maturity), but none were observed. From the small body size and absence of corpus albicans on the ovaries we concluded that this was an immature animal.

The stomach was full and contained mostly undigested squid beaks and shrimp exoskeletons. These prey items remain to be identified to species.

Approximately 40 sessile barnacles, probably *Xenobalanus globicipitis*, were attached to the trailing edge of the flukes. These barnacles form a relationship with cetaceans known as phoresia, i.e. the carrying of one organism by another without parasitism. This relationship has been recorded on at least 19 species of cetaceans, including the Cuvier's beaked whale, from temperate, warm-temperate, and tropical waters (Rajaguru and Shanta, 1992).

An impressive 56 cm long wound, severing two ribs, was found on the right side of the animal. Parallel teeth rakes emanated from the wound and extended 1 m posteriorly. These wounds appear to have been caused by killer whales. Killer whales have been observed feeding on fur seals (Trillmich, 1987), sperm whales (Arnbom et al., 1987), dolphins, and Bryde's whales (see Report of Two Orca Attacks on Large Cetaceans in the Galápagos Islands, this issue) in Galápagos. It is likely that this Cuvier's beaked whale was the victim of one of such attack, perhaps by the pod of killer whales that we had originally been observing.

Interestingly, Robinson et al. (1983) suggests that the pod of Cuvier's beaked whales that was stranded on Baltra in 1983 may have entered the shallow waters of the port while trying to escape from killer whales. One of the two animals that died, a large male, had sessile barnacles attached to the teeth on the lower jaw. Since *X. globicipitis* has only been found attached to skin (Rajaguru and Shanta, 1992), these barnacles may have been a different species, probably *Conchoderma auritum*.

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BOOK REVIEW: CLINKER ISLANDS: A COMPLETE HISTORY OF THE GALÁPAGOS ARCHIPELAGO

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It seems that every book on Galápagos flora and fauna begins with an obligatory historical chapter, in which the adventures of every visitor since Tomas de Berlanga are recounted. Such accounts are often brief, since the author's expertise lies elsewhere, usually in natural rather than human history. It is no bad thing for such introductory chapters to end quickly, for the author cannot do justice to the enchanting human history of the islands in one chapter. Thus, the history of human occupation in Galápagos rarely gets the serious attention it deserves.

Does Lillian Otterman's book 'Clinker Islands: A Complete History of the Galápagos Archipelago' finally put matters right? Her publisher describes the book as "The most complete single-volume history of the Galápagos Islands ever written", and the author has clearly done her homework. The last half of the book is the best, with a complete timetable of ship traffic in Galápagos from the days of Allan Hancock and *Velero III* to the visit of Irving Johnson's *Yankee* in 1964. Although this edition of 'Clinker Islands' was published in late 1993, it only covers the history of Galápagos up until her own visit to the islands in December, 1964. Other than a few brief paragraphs on the status of Galápagos tourism in 1975, the past 30 years are neglected. We learn of the mysterious disappearance of Sarah [sic, actually Saydee] Reiser early in 1964, but not of the discovery of her remains some fifteen years later.

Notwithstanding the missing time period, Ms. Otterman's description of the 30 odd years before 1964 will no doubt prove to be valuable for those who want a convenient reference to this interesting period in Galápagos history. These chapters alone earn Clinker Islands a worthy place in the complete Galápagos library.

Unfortunately, Otterman's treatment of the first three centuries of Galápagos human history is not as commendable. She repeats several errors introduced into the Galápagos history by modern "authorities", and inserts a few new ones of her own. Some of these falsities are illustrated below. We read erroneously that William Dampier ".. concluded that the discoursing of Women at Sea was very unlucky and occasioned the Storm". Actually, it was another William (William Ambrosia Cowley) who reached that conclusion as he rounded the Horn on the way to Galápagos and points west. Otterman writes of Cowley as "disregarding all Spanish names which the islands may have had" and of dubbing some islands as Guy Fawkes. If indeed the islands had spanish names in 1684, there is no known record to suggest that Cowley or anyone else knew about them, nor that he named any of the islands Guy Fawkes. The name Guy Fawkes did not show up on Galápagos charts till much later. Otterman also states that Charles Island was renamed as Floreana in 1892 to honor President Flores of Ecuador. In fact, the island was christened Floreana by Ignacio Hernandez in 1832, and was renamed as Santa Maria in 1892.

Surprisingly enough, James Colnett is credited as setting up the first post office barrel in 1749, which happens to be about five years before he was born. During his actual visit to Galápagos some 50 years later, Colnett was unable to land at Charles (Floreana), and his westward cruise took him around the southern end of the island, well away from what is now known as Post Office Bay. He mentions neither the barrel nor the bay in his book.

Later, Otterman describes the visit of Captain David Porter aboard a former British whaler, captured and renamed "*U.S.S. Essex*". This was actually the *U.S.* (not *U.S.S.*) frigate *Essex*, built in Salem and manned by Americans until its later capture by the British. She reports that Porter was reprimanded by Congress for exceeding his orders in rounding the Horn and was consequently suspended for six months. In fact, Porter returned home a hero, dined with the President and was given a new command. Some 10 years later, a court inquiry (not Congress) suspended him for actions entirely unrelated to his command of the *Essex*.

Finally, Otterman recalls a remark by Mr. Lawson, the vice-Governor of the islands, who informed Charles Darwin "..that the tortoises differed from the different islands, and that he could with certainty tell from which island any one was brought". She then tells us that

> "This remark prompted Darwin to label the tortoises, as well as other specimens, as to the islands on which they were found. Had he commingled the species, the all-important evidence of variation would have been lost in later classification of the finds. Even Dampier, as far back as 150 years before, had noticed four different species of tortoises on four separate islands."

In actuality Darwin had confessed "I did not for some time pay sufficient attention to this statement, and I had already partially mingled together the collections from two of the islands". As for Dampier, he did indeed notice four different species of tortoises, but that was in the West Indies. In Galápagos, he noticed only one type, individuals of which were "..like the Hecatee, except that they are much bigger and have very long small Necks and little Heads".

'Clinker Islands: A Complete History of the Galápagos Archipelago' offers the reader an interesting, though not always accurate, armchair voyage through Galápagos during the first half of this century. One interesting discovery that I made while reading the book is that Otterman's late husband was apparently a frequent visitor to Galápagos. He appears at several points in the narrative, but only as "Captain Otterman". The connection between the skipper and his lady comes only at the end when the author mentions how, on her second visit, "Captain Otterman skillfully maneuvered the vessel". A bit more about the Ottermans in Galápagos would have made this book an even more intriguing resource about the history of humans in Galápagos.

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