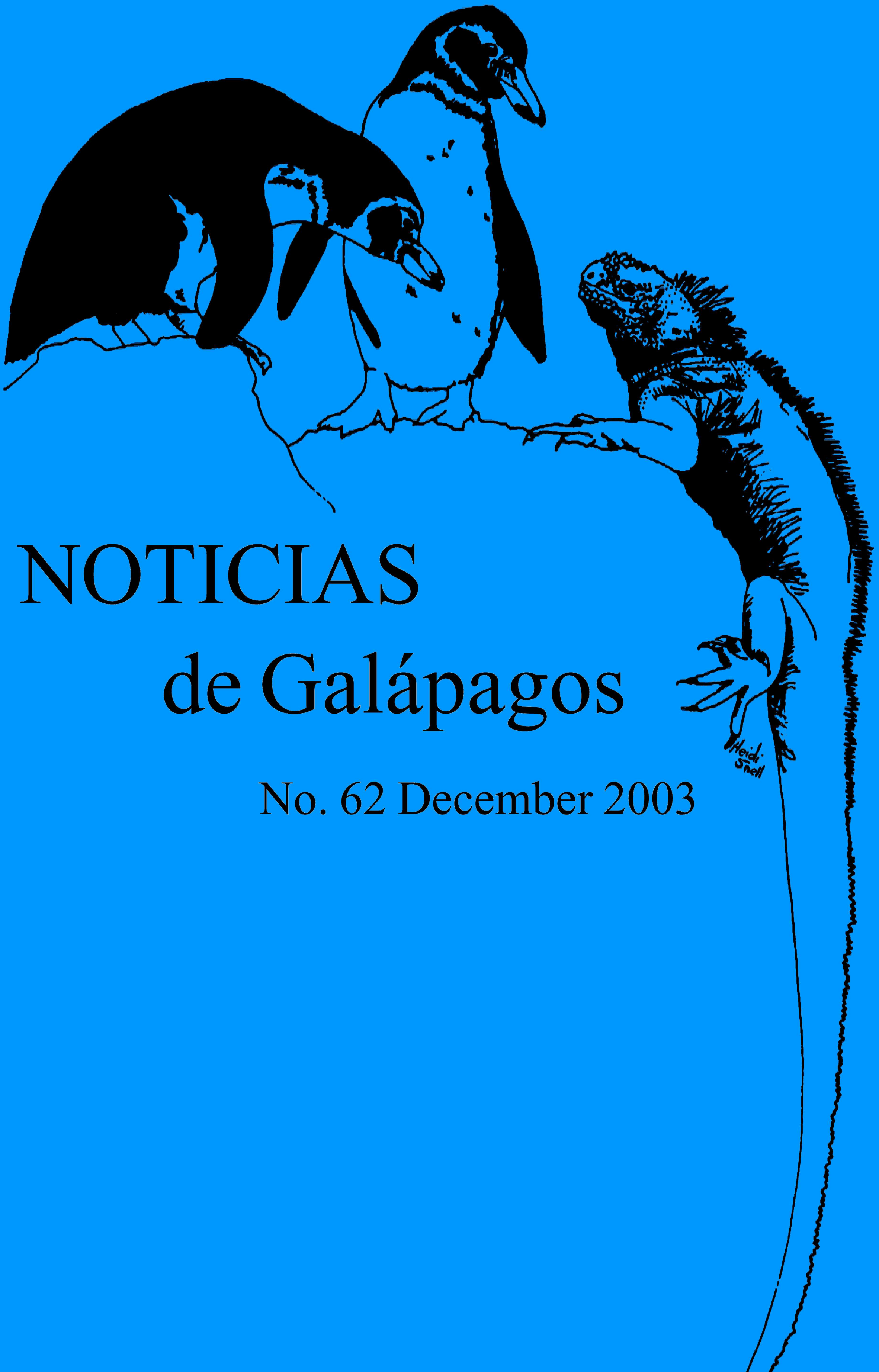

NOTICIAS
de Galápagos

No. 62 December 2003

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NOTICIAS DE GALÁPAGOS

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the Galápagos National Park Service, and the Charles Darwin Foundation

No. 62 August 2003

Contents

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THE FRESHWATER EEL, *ANGUILLA MARMORATA*, DISCOVERED IN GALÁPAGOS

By: John E. McCosker, Rodrigo H. Bustamante, and Gerard M. Wellington

INTRODUCTION

Residents and visitors to Isla Isabela have told tales of mysterious and monstrous eels for several decades. Not unlike the Loch Ness Monster, these elusive and slippery fish were known only from local stories and legends, blurry photographs, and vague memories of their attributes and taste. A blurry photograph taken in October 1996 of a dark eel swimming rapidly in a brackish pool about 200 meters inland from the coast at Punta Moreno (SW Isabela) was sent by Julian Fitter to the senior author for identification. Julian explained that

> "around nine in the morning we ... were ... commenting on the very low level of water compared to normal. Out of a fissure at one end of the pool, an eel-like creature emerged and swam towards (us). During the course of its journey, it had to slither over a dry patch of weed, and then it disappeared into the reeds. We all agreed to a meter and a half long as a fair estimation of its size ... the colour was black all over with definite eel-like swimming characteristics, moving in a snake-like manner. Its face was that of a fish with distinctive mullet-like lips suggestive of being a mud feeder. The actual body tapered quickly to the final part of the tail, but its dorsal and anal fins continued to the end and then tapered abruptly. This creature also had distinctive pectoral fins. The eyes were also obvious."

On the basis of his description (the photograph was not conclusive), it seemed possible that it might be a freshwater eel; however, lacking a specimen its identification was unsure. Subsequently, two photographs (Figures 1 and 2) of a mysterious eel captured in June 1997 at Laguna las Diablas, Puerto Villamil, were sent by Jacinto Gordillo to Rodrigo Bustamante at the Charles Darwin Research Station (CDRS). The brown, mottled specimen was approximately 1.5 m in length, and the photograph allowed it to be clearly identified as an adult *Anguilla*. The specimen was ultimately consumed by the fishers that had caught it while netting mullets. We subsequently interviewed Dora Gruber Werder, the proprietress of Hostel Ballena Azúl in Puerto Villamil, who advised that such eels were occasionally seen in the brackish pools in the vicinity of Puerto Villamil, and that she had observed them over the years and had even fed small pieces of fish to eels with which she was personally familiar. She also advised us that Antonio Constante, the co-proprietor of Hotel Ballena Azúl, had "regularly" seen freshwater eels in the brackish pools and lagoons of Puerto Villamil since the 1960s. Similarly, Don Bernardo Gutierrez, the captain of the CDRS vessel *Beagle*, reported to us that he and his brother had seen such eels for at least 20-30 years, including sightings at Roca Unión (southwest of Puerto Villamil, Isabela Island). And one of us (GMW) recalls observing an eel in 1974, presumably an *Anguilla*, along the east side of the bay at Villamil about 10 m from the shoreline in a mangrove area in a shallow water pool that issued from a lava crack. It was neither photographed nor collected.

RESULTS AND DISCUSSION

We advised residents of Villamil to inform the CDRS if such an eel was captured, and finally, an adult female

Figure 1. Mysterious eel captured in June 1997 at Laguna las Diablas, Puerto Villamil, Isabela Island.

was captured on 15 October 1998 by Kleber Garcia and Jerson Moreno, the former a CDRS volunteer native to Galápagos, and the latter a resident CDRS scientist on Isabela. They mentioned that such eels had been seen around Villamil. It was captured at the brackish lagoon known as "Poza de la Anguilla." The lagoon was small, 5 m x 2 m x 2 m deep, but associated with a large system of interconnected lava tubes, sink holes and cracks that drain water from the highlands. As a result of the significant 1997/1998 El Niño event at that time, the water was much fresher and more abundant than normal. The water temperature was 22-24°C, about 2-3° cooler than the coastal seawater, and the salinity ranged from nearly fresh during that El Niño event at 5-8 ppm (after a heavy rainfall) to 16-18 ppm during the La Niña periods. Lacking adequate formaldehyde, the specimen deteriorated somewhat, but it was ultimately preserved and is now being studied at the California Academy of Sciences (CAS) in San Francisco, CA, USA.

With specimen in hand, we are now confident that *"El Monstruo de Villamil"* is a species of *Anguilla*, which we cautiously (our caution is explained below) identify as *A. marmorata* Quoy and Gaimard, the Giant mottled freshwater eel (Figure 3). The accepted common name for this species in Spanish is "Anguilla moteada gigante" (Smith 1999). The measurements (in mm) and counts of the Galápagos specimen are as follows: total length 863; head 113; head + trunk 378; tail 485; caudal fin extension 23; dorsal fin origin 288; pectoral fin 45.5; pectoral fin base 18.3; jaw 30; lower jaw extension 2.3; snout 22; eye diameter 9.4; gill opening 19; interorbital width 23.3; isthmus ~41; body depth at gill opening ~50; body width at gill opening ~50; total vertebrae 109; predorsal vertebrae 28; preanal vertebra 39. It possesses large ovaries with developing but immature ova. The coloration (in ethanol preservative) of the specimen's chin, cheeks, throat and ventral surface is yellowish tan, overlain with a darker mottling at mid-body, becoming entirely dark along the dorsal surface and the posterior third of the tail region. All of its fins are dark.

Figure 2. Same eel as Figure 1, captured while netting mullet in the lagoon near town.

The discovery of an *Anguilla* in Galápagos represents a family (Anguillidae) previously unrecorded from Galápagos or elsewhere in the eastern Pacific. It is clearly not an Atlantic species (the two Atlantic species are distinctly different), and its likely provenance is the central Pacific. *Anguilla marmorata* is widely distributed in the tropical Indo-west Pacific from east Africa to the Society Islands and north to southern Japan (Tsukamoto and Aoyama 1998). It reaches a length of 2 m and a maximum weight of 21 kg (Castle 1984), making it one of the larger species within the genus. Freshwater eels are slow-growing and long-lived. The European *A. anguilla* can reach an age of 50 years or more (Moriarty 1978) and the New Zealand Longfin eel (*A. dieffenbachii*) is estimated to reach at least 60 years (Burnet 1969). The maximum age of *A. marmorata* has not been established. Adult *A. marmorata* in the central Pacific are known to inhabit deep, rocky estuarine and freshwater pools where they actively feed, usually at night, on a wide range of prey, including crabs, frogs and fish. Freshwater eels differ from all other true eels in a combination of characters including the projecting lower jaw, large pectoral fins, bands of minute teeth, and the presence of small scales on the body.

The approximately 15-16 species of freshwater eels, family Anguillidae, were heretofore known only from the tropical and temperate Atlantic, central and western Pacific and Indian oceans (Smith 1989, 1999, Tsukamoto and Aoyama 1998, Arai *et al*. 2001). They are catadromous, whereby the juveniles and adults live in estuaries and freshwater and the semelparous adults return to oceanic gyres to spawn and die. Their larvae, called leptocephali, return via surface currents to the estuaries, transform into juvenile elvers, and then enter freshwater habitats as adults (Moriarty 1978). Absent the deep, saline gyres necessary to anguillid reproduction in the eastern Pacific Ocean, it has long been assumed that anguillid eels do not maintain reproducing populations in the eastern Pacific or its outlying islands (Smith 1989,

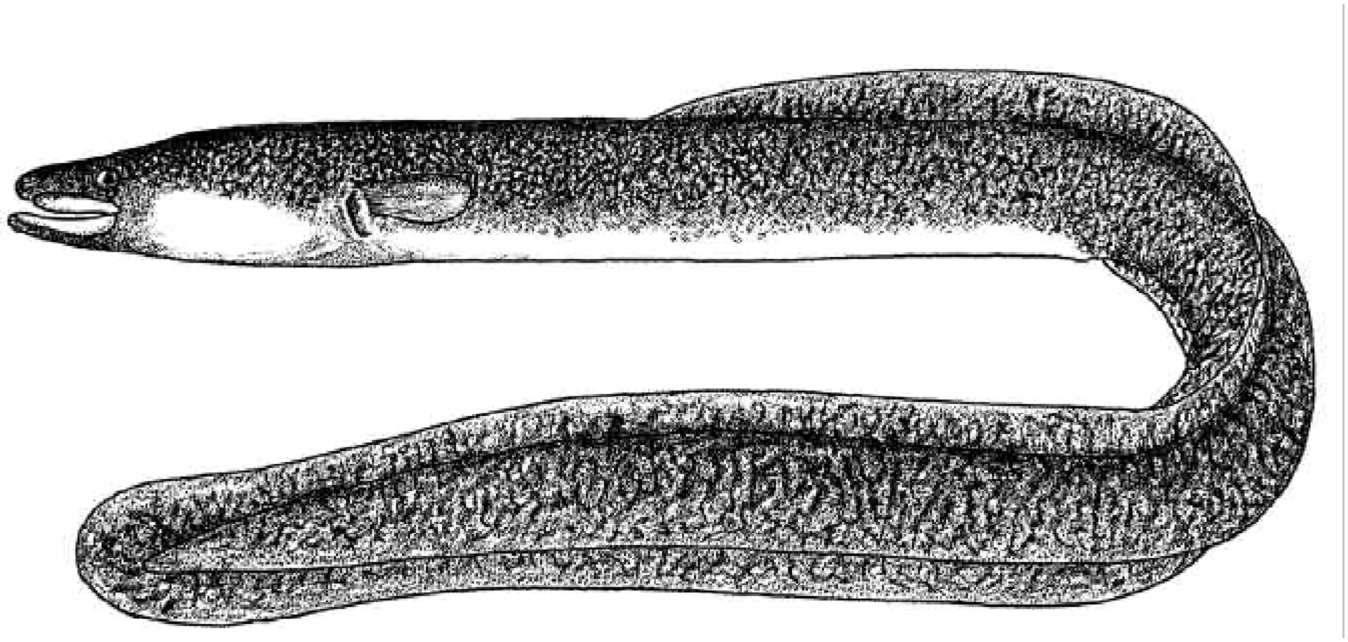

Figure 3. *Anguilla marmorata* Quoy and Gaimard, the Giant mottled freshwater eel.

Williamson and Tabeta 1991). Adult and juvenile specimens of *Anguilla* spp. previously found in western North America were the result of accidental or intentional release of larvae in order to harvest the grown individuals (McCosker 1989). We find it highly unlikely that the Galápagos specimens would have been released by humans, particularly because they have been observed long before opportunities such as airfreight transportation would have allowed the transport and release of juveniles by humans to Galápagos. We assume that the presence of *Anguilla* in Galápagos represents the sporadic arrival of their larvae and fortuitous events that allowed their settlement at SW Isabela. Recent studies have demonstrated that extreme El Niño events can increase the likelihood of Indo-Pacific larval transport to Galápagos (Richmond 1990, Grove 1989, Glynn and Ault 2000). Other recent studies indicate that spawning sites for *A. marmorata* may occur within the North Equatorial Current west of the Marianas Islands and a southern population may be associated with the South Equatorial Current (Arai *et al.* 2001). During El Niño/Southern Oscillation (ENSO) events, it is likely that larvae could be transported in an easterly direction either by the Northern or the Southern Equatorial Counter Currents (Wyrtki 1967, 1985, Delcroix *et al.* 1987, Johnson and McPhaden 2000). Arai *et al.* (2002) found the average duration of the leptocephalus stage of *A. marmorata* to be 116-132 days and the age at recruitment to range between 145-159 days. Accelerated North Equatorial Counter Current flow between the Line Islands and the Galápagos during ENSO events can reduce the transit time from 160 to 50-80 days (Richmond 1990, Grigg and Hey 1992), easily allowing the surface transport of *A. marmorata* larvae. As well, the deeper-flowing (50-300 m) Equatorial Undercurrent (Wyrtki 1967) could provide transport from the Line Islands to Galápagos within the larval duration of *A. marmorata*. The precise origin of the Galápagos individuals will best be identified with the aid of genetic markers.

An alternative hypothesis would favor a vicariance explanation, such that the Galápagos *Anguilla* were derived from a pan-Tethyan, western Atlantic species that was distributed across the shallow Central American seaway. Such an explanation suffices to explain the curious presence of the Blackspot porgy (*Archosargus pourtalesii*), a Galápagos endemic that lacks a Pacific congener but whose closest relatives are from the Caribbean (McCosker and Rosenblatt 1984). However, we find a vicariance hypothesis extremely unlikely in the case of the Galápagos *Anguilla* in that there is no evidence that a reproducing population of *Anguilla* exists at Galápagos, and its Atlantic congeners differ considerably from it. We therefore consider the Galápagos specimens to be periodic waifs from the west.

Approximately 16% of the Galápagos shorefish fauna is shared with and originated from the Indo-Pacific region (McCosker and Rosenblatt 1984, McCosker, unpublished data). However many of those species have not established reproducing populations at Galápagos are known from but a single or few specimens, such as the scorpionfish *Taenianotus triacanthus*; the puffers *Canthigaster amboinensis*, *C. janthinoptera*, and *C. valentini*; the butterflyfishes *Chaetodon auriga*, *C. kleini*, *C. lunula*, and *C. meyeri*; and the moray eels *Enchelycore lichenosa*, *Gymnothorax flavimarginata*, *G. meleagris*, and *G. pictus* (McCosker and Humann 1996, McCosker 1998). An otolith (left sagitta) was removed from the *Anguilla* specimen and appears to be about five years old (the obscure condition of the otolith did not allow for a planktonic larval duration count to be made). Although *Anguilla* otoliths may show more than one opaque ring in a year (Deelder 1976), the size of the specimen would validate an age of approximately five years. If the eel were that old, then it would suggest that it arrived at Galápagos in 1993 during a Niña, not a Niño, event, which is contrary to our expectation.

CONCLUSIONS

As mentioned above, we are cautious in the specific identification of the Galápagos specimen of *Anguilla* in that it is in a poor state of preservation and because its dorsal fin arises at a location quite atypical of that of *A. marmorata*. Normally, the dorsal fin of *A. marmorata* arises at a location much closer to the gill opening or pectoral fin base than to the anus (Ege 1939, Smith 1999). Examination by the senior author of 27 specimens of *A. marmorata* from Palau, Laos, the Marquesas, and Papua New Guinea showed all to be "normal" in their dorsal fin locations; single specimens of *A. marmorata* in the CAS collection from India (CAS 82736) and Myanmar (CAS 96562) had their dorsal fin location comparable to that of the Galápagos specimen (much closer to the anus than to the pectoral fin base), but agreed in coloration, dentition, and total vertebrae (both they and the Galápagos specimens have 109, the extreme condition of *A. marmorata*) to that of other *A. marmorata*. Ege's (1939) examination of 116 specimens of *A. marmorata* from Madagascar to the Caroline Islands found a range of 103-110 vertebrae. Further analysis of other Galápagos specimens and other extralimital specimens may serve to explain these differences. If an anguillid leptocephalus is captured in the vicinity of Galápagos, it can be identified using Jespersen's (1942) extensive treatise.

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FERAL ROCK DOVES IN THE GALÁPAGOS ISLANDS: BIOLOGICAL AND ECONOMIC THREATS

By: R. Brand Phillips, Howard L. Snell, and Hernan Vargas

INTRODUCTION

Rock doves (*Columba livia*) have been introduced worldwide and are found in most major cities (Reinke 1959, Simms 1979, Robbins 1995). They inhabit urban, suburban, and rural environments (Jobin *et al.* 1996, Henderson *et al.* 2000). In many areas, rock doves roost and nest in natural areas, but make daily flights of several kilometers to forage in cities and agricultural zones (Earle and Little 1993, Baldaccini *et al.* 2000). Rock doves often cause problems, such as fouling structures, contaminating food, and transmitting diseases (Haag 1995, Weber 1979). Behavioral traits related to the domestication of this species permit rock doves to exist at unnaturally high population densities in these environments (Haag 1995). This ability to tolerate high population densities is a major factor contributing to the social and environmental impacts of rock doves.

In the Galápagos, little is known about rock dove populations. The entire population of rock doves in the Galápagos is reported to be the descendents of four captive rock doves introduced to the islands in 1972 or 1973 (Harmon *et al.* 1987); however, previous introductions probably occurred. By the early 1980s, rock doves occurred on four of the five Galápagos islands with resident human populations (Santa Cruz, Isabela, San Cristóbal, and Floreana; Baltra appears to have escaped introduction or invasion of rock doves). In the mid-1980s, the owner of the Floreana birds abandoned his flock, which presumably then died off or emigrated. In 1985, the entire population of rock doves for Galápagos was estimated at approximately 200 (Harmon *et al.* 1987). The majority of the birds were kept in lofts in the towns of Puerto Baquerizo Moreno, San Cristóbal (112), Puerto Ayora, Santa Cruz (30), and Villamil, Isabela (50). A flock of 20 feral rock doves was observed using a gorge near Puerto Ayora.

During 2000 and 2001, preliminary surveys for rock doves on San Cristóbal, Santa Cruz, and Isabela yielded population estimates of 220, 200, and 130, respectively (Phillips and Snell in preparation). The rock dove populations were still concentrated in and around the 3 principal towns; however, in contrast to the mid-1980s, the majority of rock doves are now feral. In addition, captive flocks were present in the rural areas of the highlands on San Cristóbal and Santa Cruz. On Santa Cruz, the majority of the population nests, and roosts, in Galápagos National Park lands bordering Puerto Ayora.

The data from the recent surveys and those from the 1980s, indicate that rock dove populations are increasing rapidly (annual rate of approximately 5 to 10%), despite human consumption and occasional control programs by the Galápagos National Park Service (GNPS). If the rock dove population continues to increase at the present rate, urban and suburban habitat will soon become filled.

Thus, we can expect further expansion of the rock dove's distribution into parklands and the agricultural zone, as well as to other islands. With an expanding distribution will come greater chances for interaction between rock doves and the native fauna.

Feral rock doves have not been linked to impacts on human health or the native fauna in the Galápagos. However, rock doves harbor a wide range of human and avian pathogens (Weber 1979, Shivaprasad 2001), with the potential to infect and impact Galápagos's human residents and avifauana. To prevent impacts to and extinctions of the Galápagos's native fauna, the Charles Darwin Research Station (CDRS), in cooperation with the GNPS, has initiated a pro-active campaign to eradicate rock doves from the islands. An essential first step in this campaign is to educate and inform the local public of the negative aspects associated with rock doves. Fostering public support for this project will not only facilitate eradication efforts, but more importantly, it should reduce the chance of subsequent intentional reintroductions of rock doves after eradication is completed. The objective of this paper is to provide information on the potential impacts of rock doves for use in educational programs.

In addition to the education and eradication campaigns, the CDRS began a cooperative project with the GNPS, the University of Missouri, and the Saint Louis Zoo aimed at studying the diseases of native and introduced birds. Feral rock doves and chickens from Santa Cruz and San Cristóbal were necropsied and samples of tissues, saliva and blood for detection and diagnosis of several avian diseases. Results from this preliminary survey are expected within one year and additional sampling will be conducted on Isabela next year.

NEGATIVE ASPECTS OF FERAL ROCK DOVES

Human Health Effects

For the general public in Galápagos and elsewhere, feral rock dove populations present serious concerns for human health. Rock doves are reservoirs and vectors for over 40 human pathogenic bacteria, viruses, fungi, and parasites (Weber 1979, Long 1981, Haag and Gurdan 1990, Shivaprasad 2001, Dautel *et al.* 1991). Human infection can occur from consuming contaminated food or water (Alexander *et al.* 1997, Ricca and Cooney 1998, AVMA 2001). Human dwellings in close proximity to rock doves, their perch sites, and nests facilitate transmission of diseases by inhalation of aerosolized dried feces and the transfer of arthropod parasites (Dautel *et al.* 1991).

Most of the diseases transmitted to humans by rock doves have only minor health effects. For example, *Salmonella* spp. poisoning normally causes cramping and diarrhea in the 2 million persons infected yearly in the U.S.; however, even normally mild diseases can have serious effects (CDC 2001). Approximately 1000 persons die each year in the U.S. from salmonellosis, and rock doves are known to transmit this disease to man (Weber 1979). Toxoplasmosis, an infection caused by the parasitic protozoan (*Toxoplasma gondii*), is another very common disease transmitted by rock doves (Weber 1979). It occurs world-wide and infects more than 60 million people in the U.S. Normally, toxoplasmosis only causes flu-like symptoms, but permanent brain and eye damage can result in immuno-compromised individuals, and infected fetuses can be born retarded or with other serious mental or physical problems.

Psittacosis is another serious disease caused by the bacterium (*Chlamydia psittaci*; Martinov *et al.* 1997). Rock doves are linked to the transmission of *C. psittaci* to humans (Williams 1989, Gherman *et al.* 1995, Martinov *et al.* 1997). In 1025 cases of psittacosis reported to the Center for Disease Control from 1975 to 1984, 70% occurred in pet shop employees and bird owners, including those of rock doves (Williams 1989). In untreated cases, mortality from psittacosis can be as high as 20%. Mortality for persons treated with antibiotics is <1%, but serious complications can still occur, including pneumonia, hepatitis, arthritis, encephalitis, and fetal death.

Histoplasmosis and cryptococcosis are two fungal diseases found in many parts of the world, including South America (Ricca and Cooney 1998, Mattsson *et al.* 1999). The reservoir for the disease-causing agent is soil contaminated with bird feces (primarily rock dove). In areas where the histoplasmosis is endemic, 80% of the people test positive to skin tests. Most people who contract histoplasmosis only develop flu-like symptoms, but chronic lung damage can occur. For the general population, the risk of contracting cryptococcosis is low (<1/100,000), but 12% of all cases are fatal.

Several ectoparasites, such as ticks, fleas, and mites, infest rock doves and their nests, causing health problems for humans (Dautel *et al.* 1991). The soft tick (*Argas reflexus*) occurs in active and abandoned nesting sites of rock doves in West Berlin. Several people bitten by the tick suffered severe symptoms, including urticaria, bronchial obstruction, and loss of consciousness.

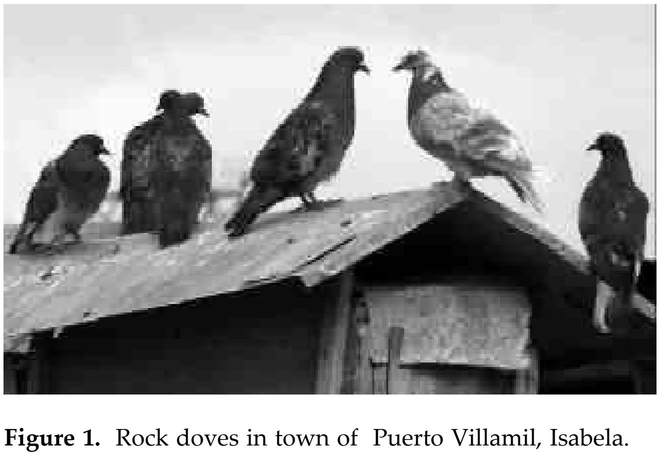

Figure 1. Rock doves in town of Puerto Villamil, Isabela.

Although we do not have medical records to document it, the risk of rock doves transmitting diseases to people is probably higher in the Galápagos than elsewhere due to several social and environmental factors. It is a common practice to collect rainwater from roofs for drinking. In many locations rock doves roost and defecate on these roofs. Rock doves harbor dozens of endoparasites (Ritchie *et al.* 1991), with many occurring in the feces. These parasites would be deposited in the cisterns and subsequently ingested. Many dove owners in the Galápagos feed their birds by broadcasting seed in their yards, which are generally dirt and shared by children, pets, and poultry. In this environment, many pathogens could easily become airborne and transmitted to humans, as well as to pets and livestock (Ritchie *et al.* 1999). Moreover, houses in Galápagos are often poorly constructed, lacking windows or well-sealing doors, thus increasing exposure to pathogenic organisms. Finally, the high humidity and mild temperatures of the islands provide favorable conditions year-round for pathogens.

There are additional health concerns associated with rock doves aside from disease transmission. We have encountered people that consume rock doves in Puerto Ayora and Villamil. Rock doves accumulate large quantities of toxic metals, such as lead, cadmium, and zinc in their tissues (Hutton 1980, Hutton and Goodman 1980, Garcia *et al.* 1988). In fact, rock doves are being considered as monitors of manganese pollution in urban environments (Loranger *et al.* 1994).

Economic and Social Impacts

In addition to direct impacts on human health, rock doves can cause significant agricultural loss. Rock doves serve as a reservoirs and vectors for several avian bacterial, viral, fungal, and parasitic pathogens (Shivaprasad 2001). More than 20 diseases in domestic poultry (chicken and turkey) are also found in rock doves (Macpherson *et al.* 1983, Saif *et al.* 1997, Shivaprasad 2001). This commonality of diseases between rock doves and poultry is considered a disease transmission threat (Johnston and Key 1992). During 1991 to 1994, rock doves were responsible for epizootic outbreaks of Newcastle disease, an avian paramyxovirus, in domestic chickens in the European Union (Alexander *et al.* 1997). Newcastle disease is the principal factor limiting chicken production in many developing countries (Alexander 1991, Spradbrow 1988), where mortality from Newcastle disease can be as high as 100% in unprotected flocks.

Rock doves foraging on stored grain are considered a causative factor in the transmission of diseases to livestock. This behavior also results in contaminated food stores and associated economic losses (Long 1981, Smith 1992, Little 1994, Alexander *et al.* 1997). Municipalities and private individuals incur monetary costs from rock doves. Their feces foul and damage buildings, statues, and cars, requiring cleanup and repair (Haag 1995). In United States cities, they are considered the most serious pest bird, causing an estimated $1.1 billion damage per year in urban areas (Pimentel *et al.* 1999).

The principal economic threat to the Galápagos from rock doves may be the potential decrease in revenues resulting from a decline or extinction of native avifauna (see Ecological Concerns). Tourism is a key component of the Galápagos economy, with the majority of the local workforce employed in tourism and commerce (Anonymous 2001). In 1999, tourism accounted for $78 million in the local economy (Anonymous 2000). In comparison, fisheries contributed only $6.4 million (J. C. Murillo, CDRS, Marine Biology, pers. comm.). The Galápagos are noted for several species of wildlife, such as tortoises (*Geochelone* spp.) and marine iguanas (*Amblyrhynchus cristatus*). Famous as well are several endemic species of birds, including finches (Fringillidae), penguins (*Spheniscus mendiculus*), and cormorants (*Nannopterum harrisi*). Several tourist sites are specifically visited for the avifauna (*e.g.*, Española and Genovesa). The extinction of one or more species of endemic avifauna could have devastating economic consequences.

Ecological Concerns

As conservation and natural resource management organizations, the CDRS and the GNPS are concerned about the potential ecological impacts of rock doves, with transmission of diseases to endemic avifauna the principal threat. Rock doves often forage in mixed avian species flocks. In Cape Town, South Africa, feral rock doves fly, nest, and roost with native rock pigeons (*C. guinea*; Earle and Little 1993, Little 1994). In the Galápagos, rock doves are frequently seen feeding with finches in Puerto Ayora and Puerto Baquerizo Moreno. Finches and warblers (*Dendrocia petechia*) have been observed sharing artificial water sources.

The tendency of rock doves to associate with other avian species, in combination with their gregarious behavior, facilitates inter-specific disease transmission. Rock doves have apparently introduced the avian pathogen, *Trichomonas gallinae*, into wild bird populations wherever they have been introduced (Stabler 1954, Honigberg 1978). Because of the relatively close phylogenetic relationship between native doves and rock doves, the chance of disease transmission is even more likely (Stabler 1954). In South Africa, feral rock doves and native rock pigeons were found to share three blood parasites (Earle and Little 1993). Harmon *et al.* (1987) identified *T. gallinae* in the Galápagos dove (*Zenaida galapagoensis*), an endemic species with several populations that appear to be declining sharply, and rock doves are suspected of transmitting the pathogen.

The threat of disease transmission from rock doves is not only limited to members of the Columbidae. Newcastle disease, which was recently documented in the Galápagos's rock dove population (unpublished data), caused widespread death in double-crested cormorants (*Phalacrocorx auritus*) in Canada and the U.S. (Kuiken *et al.* 1999). Juvenile mortality in cormorants infected with Newcastle disease is as high as 64% (Kuiken *et al.* 1998). Newcastle disease has also been isolated from Adelie penguins (*Pygocelis adeliae*) and falcons (Austin and Webster 1993, Wernery *et al.* 1992). The presence of feral rock doves infected with Newcastle disease is cause for concern considering the Galápagos has endemic species of cormorants, penguins, and raptors. The threat to Galápagos's cormorant and penguin populations is especially heightened because of their small, restricted populations.

In addition to Newcastle disease, rock doves are reservoirs for more than 20 wild avian pathogens, which infect taxa including, seabirds, penguins, raptors, and passerines (Shivaprasad 2001). The Galápagos harbor endemic species in each of these avian groups. Among this suite of pathogens found in rock doves is the protozoan responsible for causing avian malaria. Avian malaria has yet to be detected in the Galápagos, but *Culex quinquefasciatus* mosquitoes, the vector responsible for transmitting the disease, now occur in the Galápagos (Peck *et al.* 1998).

Avian malaria (and similar diseases) may be one of the most potentially serious threats facing the Galápagos's avifauna. The introduction of avian malaria to the Hawaiian islands, in conjunction with habitat destruction and introduced predators, is attributed with the extinction or decline of >75% of Hawaii's native avifauna (Atkinson *et al.* 1995). The impact of avian malaria on Hawaii's native avifauna, is such that, many species of birds now survive only in the mosquito-free high altitude zones (Atkinson *et al.* 2000).

CONCLUSION

Clearly feral rock dove populations in Galápagos have the potential to influence human health and impact the economic livelihood of citizens. Equally important is the serious risk of disease transmission from rock doves to Galápagos avifauna. Rock dove eradication is the only long-term solution to these problems. In most areas worldwide, eradication of rock doves is not an option; the Galápagos situation is different. In the Galápagos, rock dove populations exist in localized areas, and because it is an island ecosystem, the chances of reintroduction are greatly reduced and more easily managed. The latter aspect is aided by the recent passage of the Special Law of Galápagos, which makes it illegal to import alien species into the Galápagos. From a technological standpoint, rock doves are a relatively easy species to eradicate; the social and political obstacles to eradication pose difficult challenges. Despite the challenges, the eradication of rock doves is desirable to safeguard the health and economic viability of the local populace and to protect Galápagos's unique avifauna.

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Opuntia echios echios, Isla Plaza Sur.

EVIDENCE FOR LOW GENETIC DIVERGENCE AMONG GALÁPAGOS *OPUNTIA* CACTUS SPECIES

By: Robert A. Browne, David J. Anderson, Mark D. White and Michele A. Johnson

INTRODUCTION

Islands are often showplaces of dramatic examples of evolutionary divergence and adaptive radiation. A combination of factors, including reproductive isolation from mainland populations, founder effect, limited competition, and freedom from predation can result in rapid evolution. Among the best-known examples of morphological divergence in the Galápagos are tortoises, finches, and prickly pear cacti (*Opuntia*) with markedly different forms on different islands.

Cacti are a prominent, and often dominant, component of the Galápagos flora. During the driest period of the year in the lowlands, they are virtually the only green vegetation to be found. Of the three cactus genera in the islands, *Brachycereus* and *Jasminocereus* are each represented by a single species (Dawson 1962a, 1962b). In contrast, prickly pear (*Opuntia*) are both widespread and highly diverse, growing on all of the major islands and most islets. Six species are currently recognized, with three of these further divided into varieties, yielding a total of fourteen taxa (Anderson and Walkington 1971). A long-standing debate has revolved around how many taxa deserve species status versus recognition as subspecies or varieties. Pronounced morphological variation in such traits as degree of spines, seed size, and height are the basis for taxonomic designation. *Opuntia* in the Galapagos can occur as large arboreal (tree-like) forms up to 12 m in height and as low-growing, shrubby forms. This variation could result from various genetic factors such as genetic drift and selection, but could also be due to environmental influences.

The origins of *Opuntia* in the Galápagos are not well understood. Two methods of colonization have been proposed. One theory suggests that parts of cacti may have rafted to the islands on the Humboldt Current which flows northward along the west coast of South America, turning west as it nears the equator, and proceeding to the Galápagos Islands (Dawson 1962b). Alternatively, cactus seeds may have been carried by birds flying across the ocean from the mainland (Porter 1983).

Cacti are an important resource in the Galápagos because of the extensive use of pads, flowers, and fleshy fruits as a food source by reptiles, birds, and insects. Tortoises on some islands appear to be highly dependent upon *Opuntia* during the dry season for both food and water. This resource may be in jeopardy since populations of *Opuntia* have been greatly reduced or eliminated on a number of islands. Photographs from the early twentieth century show areas occupied by numerous large cacti where none exist today. The most apparent reason for this reduction is damage inflicted upon the cacti by goats which were introduced to the islands (Grant and Grant 1989). Goat populations have been eradicated or reduced on several islands, hopefully allowing for the recovery of *Opuntia* populations, but are at high densities and even expanding on other islands. It appears that even in areas with large numbers of fruits and seeds, germination frequency is low, perhaps due in part to the low density or absence of tortoises. Tortoises may aid seed germination by dissolving some of the tough seed coat in their digestive track, thereby helping to disperse and speed germination of the seeds. However, it is important to note that *Opuntia* occur on several islands and islets where no tortoises occurred historically.

Galápagos *Opuntia* have been hypothesized to be an outstanding example of the evolutionary divergence for which these islands are well known (Dawson 1962a, 1962b, Anderson and Walkington 1971). However, in contrast to some other Galápagos organisms, such as finches, the evolutionary and genetic relationships of the cacti have not been studied. This study utilizes allozyme electrophoresis 1) to assess levels of genetic variability and to characterize the population genetic structure of Galápagos *Opuntia;* and 2) to estimate the degree of genetic divergence between Galápagos *Opuntia* and the two species of *Opuntia* found in coastal Ecuador which could possibly be ancestral species. This knowledge will help illuminate the evolutionary processes at work in the islands and the genetic implications for insular populations. It could also aid in the conservation of *Opuntia* since the genetic data may clarify taxonomic status and help set resource priorities and management decisions.

MATERIALS AND METHODS

Cactus tissue samples were collected from 15 islands and islets of the Galápagos Islands from 1995-1998 (Appendix1). Wherever possible, 25 samples were collected at each location. In order to minimize the possibility of collecting individuals from only a single clone, the samples were collected along a 1000 m transect if space and cactus distribution allowed. A single cladode (pad) was collected from the five cacti closest to each of five "sites" along the transect (0 m, 250 m, 500 m, 750 m, and 1000 m). Plants consisting of only a single cladode were excluded.

All cladodes were taken to the Charles Darwin Research Station (CDRS), and within seven days, sections of approximately 20 cc were cut out of each cladode and placed in individual plastic vials or bags. Within three days, samples were transported at ambient temperature to the Department of Biology at Wake Forest University. Upon arrival, samples were placed in storage at –70°C. Remnants of the cladodes were destroyed by burning.

In July 2000, 26 *O. melanosperma* samples were collected from a 30 km section of the Ecuadorian coast centered on the Puerto Lopez area. In addition, 30 *O. macbridei* samples were collected from a single location (~ 1 km in diameter) 1.5 km west of Huayaquilles, Ecuador, located ~ 2 km north of the Peruvian border. In December 2000, five individuals of *Opuntia dillenii* were collected from Isla Monito, Puerto Rico (18° 3.8′N, 67° 51.7W) and were analyzed for comparative purposes.

Enzymes were extracted from the tissue samples by grinding 0.5 g of frozen tissue in 1 ml of chilled "moderate" extraction buffer modified from Wendel and Weeden (1989). Horizontal starch gel electrophoresis was conducted using standard techniques as described in Murphy *et al.* (1996). Resolution of thirty different enzymes was attempted repeatedly on as many as ten different buffer systems. Buffer and stain recipes were taken from Wendel and Weeden (1989), Soltis and Soltis (1989) and Hillis *et al.* (1996). The remainder of all tissue samples and extracts are stored at –70°C at Wake Forest University.

RESULTS

The majority of buffer/stain combinations did not produce enzyme activity and/or scorable loci, a problem encountered in other cactus studies (Parker and Hamrick 1992). Eight presumptive loci were identified which were consistently expressed and scorable; all were resolved using Poulik's buffer: Malate Dehydrogenase (MDH), EC 1.1.1.37; Phosphogluconate Dehydrogenase (PGDH), EC 1.1.1.44; Glutamate Dehydrogenase (GTDH), EC 1.4.1.2; Glycerol-3-Phosphate Dehydrogenase (G3PDH), EC 1.1.1.8; Phosphoglucomutase (PGM), EC 5.4.2.2; Glucose-6-Phosphate Dehydrogenase (G6PDH), EC 1.1.1.49; Glucose-6-Phosphate Isomerase (GPI), EC 5.3.1.9; Superoxide Dismutase (SOD), EC 1.15.1.1.

Allele frequencies, percent of loci polymorphic, and average individual heterozygosity for the populations are listed in Table 1. All eight loci were found to show no detectable variability across all 240 individuals from the Galápagos and hence the listing in Table 1 is a single entry "*Opuntia* sp. Galápagos n=240". G6PDH, G3PDH, PGDH, PGM and SOD were nonvariable among all 301 samples. While no variability occurred within *O. melanosperma* or within *O. macbridei,* these species were distinguishable from the Galápagos *Opuntia* by the fixed difference in alleles at the GPI locus. Puerto Rican *Opuntia* differed from Galápagos and coastal Ecuadorian *Opuntia* at GTDH, MDH, and GPI loci. Only the Puerto Rican population exhibited heterozygosity. Genetic distance values (Nei 1972) are 0.134 between Galapagos *Opuntia* and both *O. melanosperma* and *O, macbridei* and 0.470 between Puerto Rican *Opuntia* and *O. melanosperma, O. macbridei* and Galapagos *Opuntia*.

DISCUSSION

The low number of scorable loci limits confidence in data interpretation within ecological and evolutionary contexts. Nevertheless, the complete absence of genetic variabity among the 240 samples from 15 islands/islets of the Galápagos archipelago, as well as the lack of variability in the two *Opuntia* species from coastal Ecuador, is notable.

There are several explanations for the lack of genetic variability for these species. The first is sampling error of the loci used to estimate genetic diversity. Due to the difficulty of obtaining metabolically active and scorable allozymes from *Opuntia*, data are available from only eight loci, much less than 20+ loci constituting the basis

Table 1. Allele frequencies at eight loci for *Opuntia* species from coastal Ecuador, Galápagos Islands, and Puerto Rico. Percent polymorphism (%P) and average individual heterozygosity values (H) are listed for each population.

Enzyme	**Allele**	***O. melanosperma*** **N. coast Ecuador N=26**	***O. macbridei*** **S. coast Ecuador N=30**	***Opuntia sp.*** **Galápagos N=240**	***Opuntia dillenii*** **Puerto Rico N=5**
PGDH	100	1.00	1.00	1.00	1.00
G3PDH	100	1.00	1.00	1.00	1.00
SOD	100	1.00	1.00	1.00	1.00
GTDH	95	-	-	-	1.00
	100	1.00	1.00	1.00	-
G6PDH	100	1.00	1.00	1.00	1.00
MDH	95	-	-	-	1.00
	100	1.00	1.00	1.00	-
PGM	100	1.00	1.00	1.00	1.00
GPI	93	1.00	1.00	-	-
	95	-	-	1.00	-
	98	-	-	-	0.90
	100	-	-	-	0.10
%P		0	0	0	12.5
H		0	0	0	0.025

for most allozymic studies. However, since the percent of loci polymorphic averages 26% across plant species (Nevo 1978), the complete absence of polymorphism is markedly different from the two to three loci expected. The fact that the Puerto Rican population of *Opuntia*, even with a sample size of five, was found to be allozymically variable, and that other cactus species are genetically variable (Parker and Hamrick 1992, Dougherty 1996, Austin *et al.* 1999), suggests that monomorphism documented in this study generally reflects low genetic variability of the Galápagos and coastal Ecuadorian species.

Low genetic variability has been reported for other Galápagos organisms. No heterozygosity and low polymorphism were found in populations of the Galápagos tomato, *Lycopersicon cheesmani* (Rick and Forbes 1975, Rick 1983). Galápagos petrels (*Pterodoma*) also have no detectable allozymic variability among populations occurring on three islands in the Galápagos, although petrels from Galápagos are allozymically distinguishable from those in Hawaii (Browne *et al.* 1997). Limited genetic differentiation has been reported for populations of marine iguanas (Rassman 1996) and tortoises (Marlow and Patton 1981, J. Palmer, pers. comm.) which have pronounced morphological differentiation.

This study may have bearing on the taxonomic status of Galápagos *Opuntia* which is currently based on morphological traits. The allozymic data suggest that minimal genetic differences exist among the six Galápagos *Opuntia* species. However, a number of authors (Wiggins and Focht 1967a, 1967b, Racine and Downhower 1974, Nobel 1981, Hicks and Mauchamp 2000) have suggested that environmental factors such as rainfall, herbivory, and vegetative/sexual reproduction may profoundly shape *Opuntia* morphology, especially height. Nearly eighty years ago, Britten and Rose (1923) noted that arborescent cactus occur throughout the western hemisphere and that wide variation in height occurs within a species. Anderson and Walkington (1971) noted that both arborescent and sprawling individuals of *O. melanosperma* occurred in coastal Ecuador. Furthermore, Arp (1971) made the observation that in the Galápagos *Opuntia* reach the height of surrounding vegetation of each island, suggesting that competition for light (and perhaps moisture) is a major determinant of *Opuntia* growth form. Alternatively, low genetic variability does not necessarily mean that morphological differences are environmentally determined since changes in only a few regulatory genes, which may not be detected in molecular investigations (Turelli *et al.* 2001), could result in potentially dramatic differences in selected morphological traits such as height. The classical approach for investigating genetic and environmental influences on plant growth and morphology is the "common garden experiment" whereby different taxa are raised from seeds in a common environment. However, this is difficult with *Opuntia* due to the length of time required for them to reach maturity.

This study offers preliminary evidence that few genetic differences exist among the *Opuntia* species or subspecies of the Galápagos, and from a conservation viewpoint, local extinctions would not necessarily lead to loss of unique genes. However, morphological and functional variation among Galápagos *Opuntia* taxa is extensive. Given what appears to be the long-lived nature of the *Opuntia*, the extensive reliance upon them by large components of the coastal zone communities, and the fact that we are still relatively ignorant of the forces that shape *Opuntia* morphology, it would be prudent to maintain as much taxonomic and morphological variability as possible. As we have stressed, the current study, while strongly suggestive of low genetic variability, is based on a relatively small number of loci. Peter Verdyck and Hilde Dhuyvetter (University of Antwerp and RBINS Belgium) and Alan Tye (Charles Darwin Research Station) have conducted DNA sequence analysis of *Opuntia* from a few islands and have detected little variability (P. Verdyck, pers. com.). An expanded study using DNA sequence and microsatellite analyses of the samples we collected should further help resolve the question of how much genetic divergence has occurred in Galápagos.

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Appendix 1. Location, taxonomic designation, and sample sizes for *Opuntia* used in allozymic analyses.

Galápagos Islands
Opuntia echios echios: Daphne, 2; Baltra, 2;
O. e. barringtonensis; Santa Fé, 2;
O. e. gigantea; Santa Cruz, 25;
O. e. zacana; Seymour, 25;

O. helleri; Genovesa, 22;

O. insularis; Isabela, 25;

O. galapageia galapageia; Bartolomé, 25; Santiago , 25;
O. g. macrocarpa; Pinzón, 25;
O. g. profusa; Rábida, 25;

O. megasperma megasperma; Floreana, 2; Gardner (by Floreana), 2;
O. m. mesophytica; San Cristóbal, 25;
O. m. orientalis; Española, 2;

Mainland Ecuador
O. melanosperma; Central Coast 26;
O. macbridei; South Coast, 30;

U.S.A.
O.dillenii; Puerto Rico, 5

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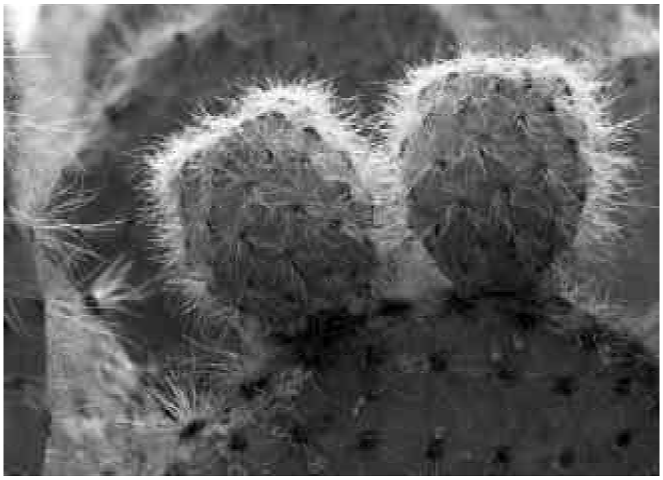

Opuntia megasperma orientalis, Isla Española.

PRESENCE OF *STENOMA CATENIFER* WALSINGHAM (LEPIDOPTERA, ELACHISTIDAE, STENOMATINAE), THE AVOCADO SEED MOTH, IN THE GALÁPAGOS

By: Bernard Landry and Lazaro Roque-Albelo

In September 2000, inspectors of the recently established Quarantine and Inspection Program on Baltra Island found caterpillars on a damaged avocado fruit (*Persea americana* Mill., Lauraceae) which had come from mainland Ecuador by plane. The caterpillars were reared by entomologists at the Charles Darwin Research Station (CDRS) on Santa Cruz Island, where a male moth emerged successfully. Subsequently, Lazaro Roque-Albelo (LR) collected other seeds of avocados 2 km west of Bella Vista on Santa Cruz Island and reared three female moths of the same species. Finally, using a mercury vapor light, LR collected a male specimen at CDRS on February 19, 2001, at the location called "Barranco".

A picture of the moth was taken (Fig. 1) and sent to Bernard Landry (BL) for identification. A tentative determination was made, and the picture was sent to colleagues in the United States and Brazil for confirmation. The species proved to be *Stenoma catenifer* Walsingham, a member of the Gelechioid family Elachistidae (subfamily Stenomatinae) *sensu* Hodges (1999). Although several species of *Stenoma* have a similar wing pattern, all *Stenoma* specimens reared from avocado fruits so far seen by Dr. Vitor Becker have been *S. catenifer*, the avocado seed moth, or worm (pers. comm. to BL).

The avocado seed moth occurs from Mexico, south to Brazil, Argentina and Peru (Artigas 1994). Caterpillars can attack fruits at various stages of maturation (Arellano Cruz 1998). The presence of caterpillars in larger fruits can be detected by the appearance of white, chalky looking spots and by accumulations of frass at the hole by which the larva entered the fruit. Infested fruits fall prematurely. Newly emerged caterpillars bore through the crust of the fruit to start eating the pulp, and later the seed itself. Mature larvae are about 16 mm long and generally whitish in color with a black head; they have a slight greenish tinge that turns to greyish-green in the prepupal stage, and transverse pale pink bands dorsally (Artigas 1994). Cervantes Peredo *et al.* (1999) provide illustrations

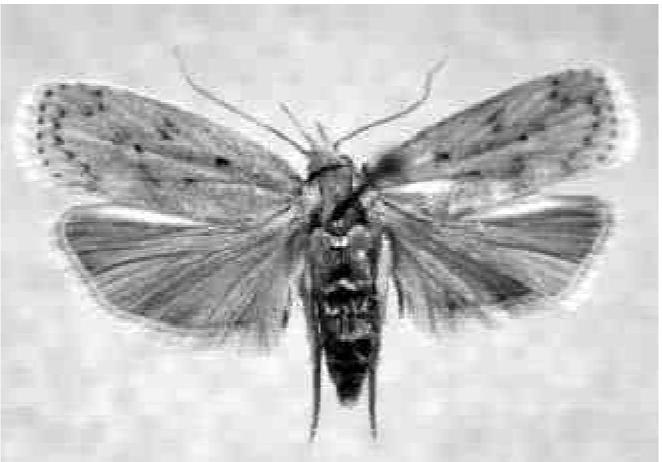

Figure 1. *Stenoma catenifer*, the avocado seed moth, or worm.

of the life stages. The larva generally leaves the fruit to pupate on the ground. The complete life cycle of the moth took between 31 and 63 days in Venezuela (Boscán de Martínez and Godoy 1984), the larvae taking between 16 and 33 days to go though their five stages. Moths reach a wingspan of 13-15 mm. They are nocturnal, live less than a week, and fly only short distances (Garcia *et al.* 1967). The eggs can be laid anywhere on the surface of fruits (Boscán de Martínez and Godoy 1984). Different avocado varieties suffer different levels of attack (0-100%) by *S. catenifer* (Arellano Cruz 1998, Hohmann and Meneguim 1993, Ventura *et al.* 1999). At least seven species of Hymenoptera and Diptera parasitoids are known to control the populations of *S. catenifer*, and levels of control reached an average of 70.37% in a study published by Arellano Cruz (1998). Another species of Lauraceae, *Chlorocardium rodiei* (Schomb.) Rohwer, Richter and van der Werff, an economically important Guyanese endemic tree, is also affected by *S. catenifer* (Cervantes Peredo *et al.* 1999). However, measured levels of infestations on this species have been less than 10%, in contrast to the higher levels on avocado.

The introduction of *S. catenifer* to the Galápagos should not cause any threat to endemic plant taxa because this species appears to be restricted to Lauraceae, and the avocado tree is the only member of this plant family on the Galápagos (Lawesson *et al.* 1987). However, it may cause problems for avocado growers, although avocados are grown on a small scale and are not exported from the archipelago. Since avocados are grown on Isabela, San Cristóbal, Santiago, and Floreana, as well as Santa Cruz (Lawesson *et al.* 1987), *Stenoma catenifer* should ultimately be expected on all those islands. This is the first species of Stenomatinae recorded from the Galápagos. This is in striking contrast with the very rich fauna of Stenomatinae in the Neotropical region, some 1,100 species, including 352 of the genus *Stenoma* (Becker 1984).

Note: Thanks to Liliana Guaman, we know that *Stenoma catenifer* is now established on San Cristóbal.

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A NEW RECORD OF ANEMONE BARRENS IN THE GALÁPAGOS

By: Thomas. A. Okey, Scoresby. A. Shepherd, and Priscilla C. Martínez

Continuous carpets of the anemone *Aiptasia* sp. were recorded on vast areas of shallow reef platforms along the eastern shore of Fernandina Island in December 2000 and March 2001. The *Aiptasia* sp. carpets have replaced diverse assemblages of algae, invertebrates, and fishes that once characterized these platforms. Virtually the only other mega-invertebrate that persists in these areas is the pencil urchin *Eucidaris thouarsii.* Patches of the alga *Padina* sp. are occasionally present, although somewhat covered with *Aiptasia* sp. anemones. Fishes are very low in abundance and diversity. Hence, we describe the anemone-dominated habitat as anemone barrens—the term barrens has been applied previously in many parts of the world to habitats of similarly reduced diversity created by high densities of grazing sea urchins. We define anemone 'barrens' as areas of considerably reduced diversity (of species, or biogenic structure, or both) caused by the unchecked spread of a single species or guild, or by an exotic agent of disturbance, or both. Like urchins in urchin barrens, a carpet of anemones might have a high biomass. Anemone barrens might also have moderate levels of primary production due to symbiotic zooxanthellae in *Aiptasia* anemones (Muller-Parker 1984). Extending the comparison, urchin barrens also have moderate levels of primary production due to algal turfs and microphytobenthos.

The upper depth limit of the anemone zone was about 1.5 m, and the greatest depth was 15 m where rock gave way to sand. At Punta Espinosa on the northeastern corner of Fernandina, two of the authors (SAS and TAO) noted that the anemones covered most of the inner part of the bay at depths from 2 to 10 m. While being towed from west to east toward Punta Espinosa and using a diver's benthic sled to maintain a depth of 5 to 7 m, we observed that the upper depth limit of the barrens deepened as exposure to oceanic swell increased, and that the anemone carpet stopped abruptly about 250 m from Punta Espinosa. Wellington's (1975) transect B, located about 300 m from Punta Espinosa, was now entirely carpeted with the anemones where previously a macro-algal community of *Ulva, Amphiroa,* and *Codium* had covered almost 100% of the reef platform to 10 m depth (Wellington 1975). Surviving specimens of the alga *Padina* within the barrens were smothered by anemones. The food supply of the large population of marine iguanas on the sheltered side of the peninsula now appears to be limited to a narrow zone of *Ulva lobata* shallower than 2 m.

When did the anemone barrens first appear? Wellington (1975) did not record them in his detailed study of the bottom communities at Punta Espinosa, and he believes that, if present, they must have been rare (G.M. Wellington, pers. comm.). Jaime Peñaherrera recalls first seeing anemone patches there in 1995, although he had dived in the area two years previous to that. One of the authors (PCM) has surveyed Punta Mangle and Punta Espinosa annually for sea cucumbers since 1993. She noted in August 1997 that crustose and erect coralline algae had replaced the once dominant *Ulva* and foliose red algal turf soon after commencement of the El Niño. The once common brown algae, *Padina* and *Hydroclathrus,* however, still persisted in smaller patches. The formerly common ophiuroids were uncommon in 1997.

In June 1998, Fernando Rivera (pers. comm.) first observed patches of presumably the same anemone at Punta Mangle (at the southeast corner of Fernandina). By February 1999, the anemones were much more conspicuous along that coast and were also observed in Puerto Priscilla (also called Punta Gavilán) between Punta Mangle and Punta Espinosa.

In November 1999, PCM recorded that the anemone had spread throughout sheltered areas of Punta Mangle, Puerto Priscilla, and Punta Espinosa and covered much of the bottom from about 1.5 to 10 m depth. She also observed that the amount of loose sediment had also apparently increased at that time. Fernando Rivera (pers. comm.) noted that the anemone had covered some areas that had once contained the algal turfs of the territorial herbivorous damsel fishes *Stegastes leucorus beebei* and *S. arcifrons.*

On 2 June 1999, Dr. Cleveland Hickman (pers. comm.) found the anemone in great abundance at Punta Espinosa and collected specimens for identification (Fig.1). Dr.

Figure 1. *Aiptasia* sp. (photo taken by Dr. Cleveland Hickman of a specimen taken at Punta Espinosa 1999).

Daphne Fautin (University of Kansas) then provisionally placed the specimens in the genus *Aiptasia.*

These anemones have since been observed in other locations in the Galápagos Islands. In February 2001, Dr. Koichi Fujiwara (pers. comm.) observed anemones in abundance at Cabo Douglas at the northwest extremity of Fernandina. In January 2001, SAS recorded the same anemone under rocks at about 1 m depth in the lagoon at Playa Mansa (near Bahia Tortuga) and in Academy Bay, Santa Cruz Island. In March 2001, we observed the anemone in small patches on the western coast of Isabela at 5 to 10 m depth. Both sites are near mangroves, and this may be a preferred habitat throughout the archipelago. When we overturned rocks exposing the anemones, the damselfish, *Stegastes arcifrons*, quickly attacked them.

Anemones can reproduce sexually and asexually. The latter method, termed cloning, most commonly occurs by longitudinal fission, inverse budding or marginal budding, but pedal laceration is the method used by *Aiptasia* (Muller-Parker, pers. comm.) Cloning is common in some anemone species and results in extensive patches of clones on reef bottoms. Cloning is considered to be adaptive in the colonization of space because clones inherit high fitness from the adjacent parent (Shick 1991, Ayre and Grosberg 1995) and because budded clones can colonize space rapidly (G. Muller-Parker, pers. comm.). Pedal laceration in *Aiptasia* entails very low reproductive effort (Hunter 1984), and this process also ensures that symbiotic zooxanthellae are contained in the propagules (Muller-Parker and D'Elia 1997). The presence of zooxanthellae in the tissues of *Aiptasia* enhances the growth of asexually reproducing colonies when food is scarce (Clayton and Lasker 1985), and this would engender a particular advantage in bright environments such as the Galápagos reefs that are currently carpeted with *Aiptasia*. The ecological advantages provided by low reproductive effort and the contributions of reduced carbon from zooxanthellae are compatible and likely contribute to the recent success of *Aiptasia* on these shallow reefs (see Hunter 1984, Clayton and Lasker 1985, Muller-Parker and D'Elia 1997).

There are other examples around the world of clones spreading over small to large areas, usually in sheltered reef habitats. In Europe and on the west coast of North America, the anemone *Metridium senile* grows over large areas in the shallow subtidal (Purcell and Kitting 1982, Anthony and Svane 1995). *Metridium* responds to disturbance by increasing the rate of pedal lacerates and longitudinal fission. *Anthopleura elegantissima* proliferates at sheltered intertidal sites on the North American west coast (Ayre and Grosberg 1995). At Moorea, Society Islands, the anemone *Heteractis magnifica* covered very large areas of reef until cyclones broke up the anemone fields into small patches (D. Fautin, pers. comm.). Similarly, on a fringing coral reef at Eilat in the northern Red Sea, the corallimorpharian anemone *Rhodactis rhodostoma* covered up to 69% of the inner reef flat after a catastrophic low tide in 1970 partially caused by consecutive days of strong wind from the north (Chadwick-Furman and Spiegel 2000). They suggested that this species has become an alternative dominant species replacing stony corals in that system.

One explanatory hypothesis for the recent spread of the *Aiptasia* anemone in the Galápagos is that the biological assemblages on the shallow reef flats of Fernandina were particularly vulnerable to the higher temperatures (and other conditions) associated with the 1990s El Niño events (El Niño is a cyclical warming of central and eastern Pacific surface waters centered along the equator). The ensuing mass mortality of the existing assemblage led to the availability of space for colonization by the opportunistic anemone species *Aiptasia* sp. In theory, colonial anemones can pre-empt space and exclude recolonization of competitors by consuming any propagules that would otherwise recruit to the area. Similar interspecific adult-larval interactions are known to shape some infaunal communities dominated by polychaetes (Woodin 1974a, 1974b). Such a positive feedback might stabilize a resulting alternative community state, *i.e.*, the anemone barrens, over time if no predatory or physical limiting mechanisms intervene.

The two species of territorial damselfishes mentioned above, *Stegastes leucorus beebei* and *S. arcifrons*, are known predators of the *Aiptasia* anemone in the Galápagos (Grove and Lavenberg 1997, and SAS personal observations). The damselfishes do not stray far from small to medium boulder habitats or other crevice refuges, and are thus not common on the open areas of platform reefs such as those we observed to be covered with *Aiptasia*. In cases where damselfish turf areas were usurped by anemones as mentioned previously, El Niño conditions likely dispersed the damselfishes by decreasing preferred foods, thus providing opportunities for anemones to invade areas that were previously tended by damselfishes (F. Rivera, pers. comm.). If *Aiptasia* enjoys a size refuge from damselfish predation, then established anemone mats could persist even when damselfishes reinvade old territories.

The holothurian *Stichopus fuscus* is a suspected predator of *Aiptasia* in the Galápagos because Bermeo-Sarmiento (1995) found 'cnidarian polyps' in this benthic-feeder's gut. Holothurians like *Stichopus fuscus* are more likely to inhabit open habitats because of their chemical and other defenses, but a very intense sea cucumber fishery (Okey *et al.* 2002) has considerably reduced this species throughout the Galápagos concurrently with the appearance of the anemone barrens.

The nudibranch *Burghia major* preys on *Aiptasia pulchella* in Hawaii, as do the puffer fish *Arothron meleagris* and the butterfly fishes *Chaetodon auriga* and *Chaetodon unimaculatus* (Muller-Parker 1984). The puffer fish *A. meleagris* has been recorded in the Galápagos (Anon 2001), but it is uncommon (TAO personal observations); the butterfly fish *C. auriga* has been reported as rare in the Galápagos and only at the northern islands of Darwin and Wolf (Humann, 1993) and *C. unimaculatus* has not been recorded in the

Galápagos. However, two other *Chaetodon* species are somewhat common in some locations. Ates (1989) found that more than 50 fish species around the world prey on anemones, and 13 species include anemones as a large portion of their diets. He predicted anemone consumption would be revealed in many more fishes.

Hawksbill turtles, *Eretmochelys imbricata*, are known to eat anemones (Den Hartog 1980). Mayor *et al.* (1998) found that the anemone-like zoanthid *Zoanthus sociatus* made up the bulk of hawksbill diets at St. Croix, U.S. Virgin Islands, and Leon (2000) found that the anemone-like corallimorpharian made up a major proportion of hawksbill diets in the Dominican Republic. Loggerhead sea turtles, *Caretta caretta*, eat sessile benthic cnidarians including anemones (Plotkin *et al.* 1993), and other sea turtle species might eat anemones when available. Neither species of these sea turtles is conspicuous in Galápagos. Sea turtles in general probably consume benthic invertebrates in some proportion to the abundance or availability of the prey (see Carr and Stancyk 1975). Turtles such as the hawksbill were considerably more abundant in other areas in the past than they are today (NRC 1990, Bjorndal *et al.* 1993), and such turtles might have effectively controlled their prey populations and strongly shaped shallow reef ecosystems (Jackson 1997, Bjorndal et al. 2000, Jackson 2001). The relative absence of these predators in Galápagos might further enable the spread of prey such as anemones. Elsewhere, anemones are also consumed by bearded seals, *Erignathus barbatus,* (Finley and Evans 1983) and a number of bird species around the world (Ates 1991).

It appears that predators of *Aiptasia* in the vicinity of the Galápagos anemone barrens have not controlled the spread of this species on these platform reefs. More information is needed on the identities, histories, and abundances of the predators of *Aiptasia* in the Galápagos.

Several studies (Chadwick-Furman and Spiegel 2000, Anthony and Svane 1995, Shick 1991) lend support to the general hypothesis that catastrophic disturbances can lead to barrens dominated by anemones. The extreme low tide in the northern Red Sea was presumably a natural, albeit rare, event. In the Red Sea example, it is possible that the anemone-coral assemblages have adapted to that rare disturbance, albeit on a broad temporal scale. Similarly, did the Galápagos fauna on these shallow reef platforms ever adapt to the apparent deleterious effects of El Niño events that are as severe as those recently observed? Observed increases in the frequency and intensity of El Niño events corresponding with sudden shifts in community states would lend weight to the notion that exotic disturbances or natural disturbances with exotic (new) characteristics may have led to an alternative community state that can persist for several years.

It would not be surprising if the severe 1997-98 El Niño event was the proximate cause of the expansion of an anemone, probably already present in low abundance in the archipelago, but this would not rule out the possibility that a concurrent decline or loss of predators of *Aiptasia* was a key reason for the appearance of the anemone barrens. Distinguishing the relative roles of these two general explanations is the task of our continuing investigation of the anemone barrens phenomenon.

Notwithstanding the cause of the appearance of the barrens, their persistence raises many other urgent or interesting questions. What impact might these barrens have on the marine iguana population that is already stressed from reduced algal food during El Niño events? Are the barrens a stable alternative community state, or are they an ephemeral phenomenon that will give way to the previously diverse invertebrate, algal, and fish community? At present, we cannot answer these questions as too little is known of the biology or ecology of this anemone in the Galápagos.

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NEW RECORDS OF FISH-PARASITIC ISOPODS (CYMOTHOIDAE) IN THE EASTERN PACIFIC (GALÁPAGOS AND COSTA RICA)

By: Ernest H. Williams, Jr. and Lucy Bunkley-Williams

Brusca (1981) published a monograph of the fish-parasitic isopods (Cymothoidae) of eastern pacific fishes. We have observed and collected additional samples of cymothoid isopods from this region. *Anilocra meridionalis* Richardson is tentatively synonomized with *Anilocra gigantea* (Herklots), and the latter species is reported in the eastern Pacific for the first time. Three new host records and two new family records for *Nerocila californica* Schioedte and Meinert from the Galápagos Islands, and two new host records for *Cymothoa exigua* Schioedte and Meinert from Costa Rica are noted.

Fish hosts and their associated isopods in the Galápagos Islands were observed underwater; those in Costa Rica were collected with fish traps. Isopod specimens were preserved in 70% ethanol individually in vials for each host specimen. All isopod specimens collected were deposited in the U.S. National Parasite Collection (USNPC), Beltsville, Maryland, USA.

ANILOCRA GIGANTEA (HERKLOTS, 1870)

This isopod is one of the largest, if not the largest, cymothoid isopod with females reaching 10 cm in length. Little is known about the biology of this parasite that infects deep slope snappers and groupers. It has been found on the Ruby Snapper, *Etelis carbunculus* Cuvier in New Caledonia (Trilles 1972); the Golden Eye Jobfish, *Pristipomoides flavipinnis* Shinohara; and on an unidentified grouper, *Epinephalus* sp. (Bruce and Harrison-Nelson 1988) in Fiji in the southwestern Pacific. We previously found it on *E. carbunculus* in Hawaii in the northern Pacific, which extended the known range approximately 5000 km (Bunkley-Williams and Williams 1996, 1998).

Anilocra meridionalis was described in Galápagos waters from a single, distorted, immature female specimen in the process of molting (Richardson 1914). Two additional juvenile specimens caught in a mid-water trawl of unknown depth between the Hawaiian and Clipperton Islands were identified as *A. meridionalis* by Brusca (1981). Species of *Anilocra* are difficult to identify using distorted immature females and impossible using juveniles, but *A. meridionalis* appears to be the same as *A. gigantea*, and hence should be synonymized. This identification would extend the known range of *A. gigantea* from Hawaii halfway to the Clipperton Islands (approximately 2400 km) and then to the Galápagos Islands (approximately 7700 km total). This isopod is apparently a pan-Pacific species parasitizing deep-sea snappers and groupers.

NEROCILA CALIFORNICA SCHIOEDTE AND MEINERT, 1881

This isopod is found from off Los Angeles in southern California south to Peru, and in the Las Tres Marias, Galápagos, and Hawaiian Islands. It parasitizes a wide variety of fish hosts in two classes, 10 orders, 20 families, and 39 species in the eastern Pacific. This parasite tolerates a broad range of salinities and habitats from offshore oceanic to coastal fresh waters (Williams and Bunkley-Williams 1999). It has been reported from a few offshore pelagic species, but more commonly infects shallow water, near-shore species. It attaches on the external body surface and fins of fishes. Females are 14.0-25.0 mm long and 7.0-13.0 mm in maximum width; males are 10.0-20.0 and 3.0-10.0 mm (Brusca 1978, 1981).

We found *N. californica* on three new host species representing two new host families in the Galápagos Islands (Table 1). A female was attached to the caudal fin of an approximately 46 cm total length (TL) Ballonfish, *Diodon holocanthus* Linnaeus, at 4 m depth. In a group of four 10-13 cm TL adult White-tail Damselfish, *Stegastes leucorus* (Gilbert) Pomacentridae, a new host family for this species, at 2.5-3.0 m depth, each specimen had one female *N. californica* attached to its fins (upper caudal fin lobe of two fish, and pectoral fin of two fish). Scale and tissue erosion occurred around all of the isopods, and the caudal fin of one fish was eroded and split. Algal growth was present on the telson (posterior shield) and pleon (abdomen) of one isopod. In another group of four *S. leucorus* 11-13 cm LT, at 3 m depth, each had one female isopod on the upper caudal fin. An Azure Parrotfish, *Scarus compressus* (Osburn and Nichols) Scaridae, a new host family for this species, approximately 46 cm in TL, and at approximately 5.5 m depth, had a female *N. californica* on the left side of the dorsal fin approximately 4 cm from the fin insertion.

CYMOTHOA EXIGUA SCHIOEDTE AND MEINERT, 1884

This isopod is of interest because it is shipped all over the world in commercial catches of snappers from the eastern Pacific. It was the subject of a lawsuit in Puerto Rico brought against a leading supermarket chain. The customer in the lawsuit claimed to have been poisoned by eating an isopod cooked inside a fish. Isopods are not known to be poisonous to humans, and some isopods are routinely consumed as human food. Thus, testimony was given stating that the isopod could not have been the source of the illness. This parasite has a Panamic distribution extending from the Gulf of California south to just north of the Gulf of Guayaquil, Ecuador. Contrary to statements by Brusca (1981), Williams and Williams (1978) refuted Comeaux's (1942) record of this isopod from Louisiana. It has been collected from waters 2 m to almost 60 m in depth. This isopod is known to parasitize eight species in two orders and four families of fishes [7 species of Perciformes, 3 snappers (Lutjanidae), 1 grunt (Haemulidae), 3 drums (Sciaenidae), and 1 Antheriniformes grunion (Atherinidae)]. The female occurs on the tongue and the male on the gill arches beneath and behind the female. Females are 8.0-29.0 mm long and 4.0-14.0 mm in maximum width; males are 7.5-15.0 and 3.0-7.0 mm (Brusca 1981).

Females of this isopod occurred in the mouths of three species of snappers Perciformes: Lutjanidae (Table 1). A 23 cm TL Colorado Snapper, *Lutjanus colorado* Jordan and Gilbert, and a 24 cm TL Jordan's Snapper, *L. jordani* (Gilbert), both from Costa Rican Pacific waters, are new hosts for this isopod. Five 22-25 cm TL Pacific Red Snapper, *L. peru* Nichols and Murphy, have previously been noted as hosts for this isopod. We have been unable to determine the identity of "*Lutjanus maculatus*" listed as a host for this isopod by Brusca (1981) and Brusca and Iverson (1985). "*Lutjanus maculatus*" was listed in Froese and Pauly (2001) as a junior synonym of the Saddle Grunt, *Pomadasys maculatus* (Bloch 1793), which does not occur in the eastern Pacific. Brusca (pers. comm.) could provide no additional details to help correctly identify this host species. This species is not listed by Allen (1985), and the record could be for one of the new host species we list.

Information about these three isopod species is important because each infects and reduces the productivity of commercially important species of fishes. *Anilocra gigantea* was originally thought to have a rather limited distribution, but now appears to damage deep-slope snappers and groupers throughout the Pacific. *Nerocila californica* is controversial in the sense that Brusca (1981) synonomized it with the temperate Atlantic *N. acuminata* Schioedte and Meinert, 1881, while we chose, for various reasons, to consider them separate species (Bunkley-Williams and Williams 1999, Williams and Bunkley-Williams 1999). However, we consider *N. acuminata* to be a junior synonym of *N. lanceolata* (Say 1818). More information may be needed to resolve this question. *Cymothoa exigua* parasitizes a number of commercially important hosts, but the extent of the damage to the eastern Pacific snapper fishery, or even the exact species parasitized (*e.g.*, "*L. maculatus*"), remains unknown.

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Table 1. Isopods from some marine fishes from the Galápagos and Costa Rica

Isopod Species Host Species	**Location On Host**	**Date**	**Geographic Locality**	**# Hosts/ # Parasites**	**Museum Number**
***Anilocra gigantea* (Herklots)**					
no host recorded	unkown	—	off Galápagos Islands	-/1I	USNM 46400[1]
no host recorded	unkown	—	between Clipperton & Hawaiian Islands	-/2J	AHF[2]
***Nerocila californica* Schioedte and Meinert**					
Diodon holocanthus [3]	tail	7 May 1996	Gardner Bay, Hood Island, Galápagos	1/1F	—
Stegastes leucorus [3,4]	fins	11 May 1996	Puerto Egas, James Island, Galápagos	8/8F	—
Scarus compressus [3,4]	fin	11 May 1996	Puerto Egas, James Island, Galápagos	1/1F	—
***Cymothoa exigua* Schioedte and Meinert**					
Lutjanus colorado [3]	Mouth	16 Mar 1990	Pacific coast, Costa Rica	1/1F	USNPC 87849[5]
Lutjanus jordani [3]	Mouth	17 Aug 1990	Pacific coast, Costa Rica	1/1F	USNPC 87850[5]
Lutjanus peru	Mouth	16 Mar 1990	Pacific coast, Costa Rica	3/3F	—
Lutjanus peru	Mouth	17 Aug 1990	Pacific coast, Costa Rica	2/2F	—

[1]U.S. National Museum, [2]Allan Hancock Foundation, University of Southern California, [3]New Host Record,
[4]New Family Record, [5]U.S. National Parasite Collection;
F = female, I = immature female, J = juvenile

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Support can come in all shapes and sizes. The Charles Darwin Foundation and its cooperating Friends of Galapagos Organizations would be happy to discuss gifts and (taking the appropriate tax laws into consideration) trusts, bequests, life insurance assignments, and pooled income funds—all instruments of deferred giving plans. There are many opportunities and options for giving to the CDF: naming a Research Chair, creating a scholarship fund, or funding a specific scientific research program for several years, to mention but a few.

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This is your opportunity to continue your Galápagos involvement by supporting the unique wonders of Galápagos for today and the future. Through your financial support, you can be part of the magic…the magic of these Enchanted Islands of Ecuador. Your consideration, time and input are appreciated.

THE FISHERY FOR ENDEMIC CHITONS IN THE GALAPAGOS ISLANDS

By: Adelaida Herrera, R. H. Bustamante and S. A. Shepherd

SUMMARY

A local or cottage fishery, principally for the endemic chiton *Chiton goodalli,* persists in the Galápagos Islands despite declining numbers of chitons. Restaurant consumption has also declined in recent years. The size structure of animals in past and recent catches was estimated from examination of shell middens on the coast near Puerto Ayora, Santa Cruz Island. The number of chitons sold annually in restaurants was estimated from questionnaire responses received from restaurant owners in Puerto Ayora. Sampling at study sites from 1996-2000 showed that densities of chitons on exposed coasts have declined, consistent with overfishing of localized populations. Recruitment to a size that can be conveniently sampled was variable between sites and between years, but occurred mainly between March and November. We propose a legal minimum harvest size to encourage conservation of local populations and to prevent growth overfishing (excessive fishing that removes all adults locally).

INTRODUCTION

Chitons, or coat-of-mail shells, are a group of mollusks having eight interlocking plates dorsally as protection instead of the one or two shells that most other mollusks have. Like gastropods, they use the muscular foot for adhesion to the rock surface to which they are attached.

Coastal inhabitants have traditionally eaten chitons found in the intertidal zones. Aborigines in the western Kimberleys of northwest Australia harvest *Acanthopleura spinosa*. Native Alaskans take *Katharina tunicata*. Indians of Puget Sound favor *Cryptochiton stelleri,* and islanders in the Bermudas and Lesser Antilles have harvested chitons as well (Beesley *et al.* 1998).

In the Galápagos Islands, chitons, locally known as "canchalaguas", have been a popular food item and harvested since the earliest days of human habitation (Ferreira and Ferreira 1977). Most recently, the fishery has existed mainly on the inhabited islands of Santa Cruz, San Cristóbal,Floreana and Isabela, but harvest is known to occur to a lesser extent on the uninhabited islands of Gardner por Española, Santiago and Genovesa, and has probably occurred on others in the central and southern parts of the archipelago.

Chitons are typically cryptic by day, hiding in narrow crevices in the rocky intertidal zone, but emerge at night to graze on micro-algae. Thus, fishers walking in this zone, preferably during a full moon, can prise the chitons from the rocks with a knife or other sharp object. Once harvested, the chitons are processed by excising the foot and gonads and discarding the shells and viscera in middens on the upper shore.

In recent years, this fishery has grown from a traditional subsistence level to a small-scale commercial activity. Local markets in Santa Cruz and San Cristóbal sell chitons, and restaurants offer chiton as a typical "ceviche de canchalagua" (raw, chopped seafood marinated with lemon and spices) on their menus.

Thirteen species of chitons are recorded intertidally in the Galápagos Islands (Finet 1994), and six of them are endemic. Two of these endemic species, *Chiton goodalli* (Broderip 1832) and *Chiton sulcatus* (Wood 1815) grow to a large size (80-150 mm total length) and are abundant compared with the other species. While both species are found in the archipelago (Bullock 1988) , *C. goodalli* is much more abundant on exposed coasts where most harvesting occurs.

The only previous studies on these chitons are by Salguero and Carvajal (1989) and Tirado (1996), but neither considers the reproductive biology, ecology or population biology of the species. As there are clear signs of local depletion of chiton populations, there is a need for basic biological information about the species in order to manage the fishery and conserve the species.

This paper describes the size structure, density and recruitment patterns of lightly and heavily fished populations of *C. goodalli* on the southern coast of Santa Cruz Island. Shell collections from middens yielded information on the size structure of animals in past catches. The magnitude of the commercial catch in recent years was estimated from questionnaire responses by local restaurateurs in the town of Puerto Ayora, Santa Cruz (Fig. 1).

METHODS

Samples of 20 - 30 *C. goodalli* were taken monthly from Punta Estrada and/or Barranco, with infrequent samples from Academy Bay, Punta Núñez and the Caamaño Islet, from 1995- 2000 (Fig. 1). Following a standardized sampling protocol at selected sites, we searched systematically under boulders and in crevices for *C. goodalli* for one hour per visit and measured the shell length (SL) of every accessible chiton to the nearest 0.1mm. Morphometric data on shell length (SL), total weight, foot weight, gonad weight, sex, species, and length and width of the cephalic plate were obtained from a sub-sample. By least squares regression analysis, equations were derived expressing the relationship between various morphometric measures of interest. Individuals <20 mm SL were rarely found, so the size class 20-50 mm SL was used as an index of recruitment of *C. goodalli* to the population.

Fixed quadrats were placed in the low- to mid-intertidal zone at four sites between the dock of the Charles Darwin Research Station (CDRS) in Academy Bay (AB 0, 1, and 2) and Punta Núñez (Fig. 1). At each site 6-8 permanent quadrats of $1m^2$ were demarcated with patches (each 1 cm^2) of white epoxy glue fixed to the rock at the corners of each quadrat.

Once or twice monthly, the sites were monitored for the presence of chitons during a low tide. Shell length of accessible animals was recorded as well as habitat characteristics, including wave swell, rock type, and other intertidal sedentary fauna present. At all sites except Punta Nuñez, the substratum is of large heterogeneous blocks of black volcanic "aa" lava. At Punta Núñez the substratum is predominantly sand, "pahoehoe" rope lava, and small boulders 5-30 cm diameter (Walsh 1993).

The mid-intertidal is typically carpeted with a green algal mat of *Ulva lobata* on horizontal surfaces and a *Gelidium* sp. turf on vertical surfaces. Common mollusks indicative of mid-tidal levels include: *Purpura pansa*, *P. columellaris*, *Hoffmannola lesliei*, *Acanthochina hirudiniformis* and the barnacle *Tetraclita stalactifera*. Other common fauna include the sally lightfoot crab *Grapsus grapsus*, the small anemone *Isoactinia* sp. and the herbivorous marine iguana *Amblyrhynchus cristatus*.

Field surveys of chiton shell middens left by fishers were carried out along the southern coast of Santa Cruz Island from August 1994 to August 1999. In each midden, shell fragments were collected and the width of all cephalic plates of *C. goodalli* was measured to the nearest 0.1mm. From the relationship between cephalic width and total length, the distribution of shell lengths of chitons taken by fishers was predicted from the cephalic plate measurements. The midden sites were revisited during the period of the study to determine the extent of subsequent fishing. Shells of chitons killed between visits retained their dried integument and were easily distinguishable from older, weathered shells.

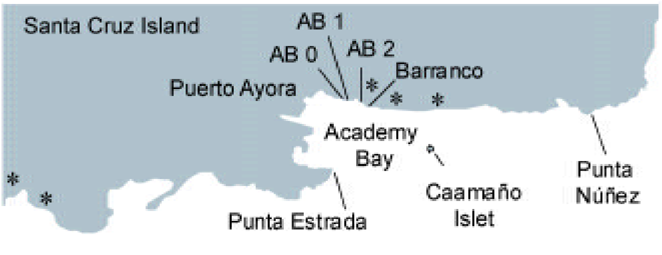

Figure 1. Map showing sites on the coast of Santa Cruz Island near Puerto Ayora where chitons (*Chiton goodalli* or *Chiton sulcatus*) are taken by fishers. The five sampling sites named in the text are: Academy Bay (AB 0, 1, and 2), Barranco, Caamaño Islet, Punta Nuñez, and Punta Estrada. Fixed quadrats were monitored from 1994-1999. Asterisks (*) indicate the presence of shell middens.

In order to estimate the size of the commercial fishery for chitons, a questionnaire was prepared and distributed to local restaurateurs in 1995 and again in 2000.

RESULTS

Chiton goodalli and *C. sulcatus* have been recorded from all the larger islands (Santa Cruz, San Cristóbal, Isabela, Fernandina and Floreana) and a few smaller islands of the archipelago (Santiago, Española and Santa Fé). The habitat of *C. goodalli* is deep within narrow crevices formed by large boulders and blocks of lava in the mid-to-low intertidal where rocks are exposed to strong wave action.

Morphometrics

A total of 1391 *C. goodalli* were taken intertidally from Santa Cruz.

The relationship between total weight (TW g) and shell length (SL mm) is given by the equation:

$$TW = 7E - 0.5\ SL^{2.948} \quad (R^2=0.88,\ N = 1372)$$

The relationship between the width of the cephalic plate (C) and SL is given by the equation:

$$SL = 4.94 + 2.585\ C \quad (R^2=0.94)\ (N= 144)$$

Densities, Size Structure and Recruitment

Densities of *C. goodalli* in the fixed quadrats in Academy Bay declined significantly from 1994 to 1999 at four sites (2- tailed Kolmogorov-Smirnov, P= 0.082), but increased slightly at the eastern end of Academy Bay during the same period (Fig. 2). Length frequency distributions for all samples combined from Santa Cruz and for all midden shells derived from cephalic plate measurements (Fig. 3) show that while fishers obviously selected for

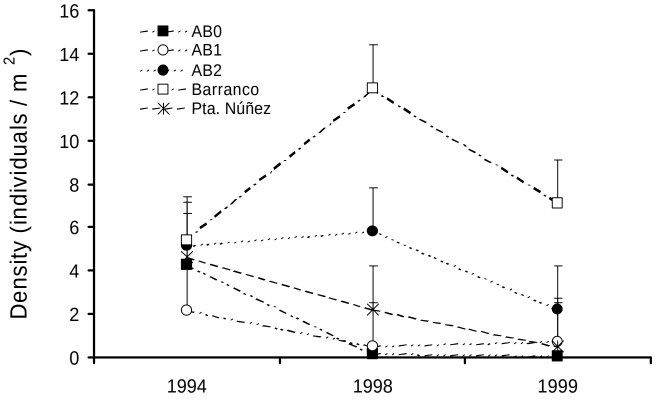

Figure 2. Change in density of *Chiton goodalli* over time at four fixed sites in Academy Bay and one at Punta Núñez, Santa Cruz. Vertical bars are plus one standard error.

larger shells, they still took substantial numbers of shells < 85 mm SL. The modal size of midden shells (100.0 mm SL; s.e 16.8 mm) is significantly larger than that for the wild population (80.0 mm SL; s.e. 24.7 mm) (X^2= 366.563, df = 1, P<0.05). Similarly, the maximum size of midden shells was 165 mm, compared with 145 mm for the wild population. At Caamaño Islet, which is seldom visited by fishers, the modal size of shells (110.5 mm) is significantly greater than on Santa Cruz (82.20 mm) (X^2=28.855, df = 1, P<0.05).

Recruitment strength, as estimated from the numbers of individuals in the 20-50 mm size class, varied between and within years (Fig. 4). At Punta Estrada, recruitment was recorded mainly from February to July and was high in 1996, 1999 and 2000, whereas at Barranco, recruitment was highest variously from March to November in 1997 and 1998.

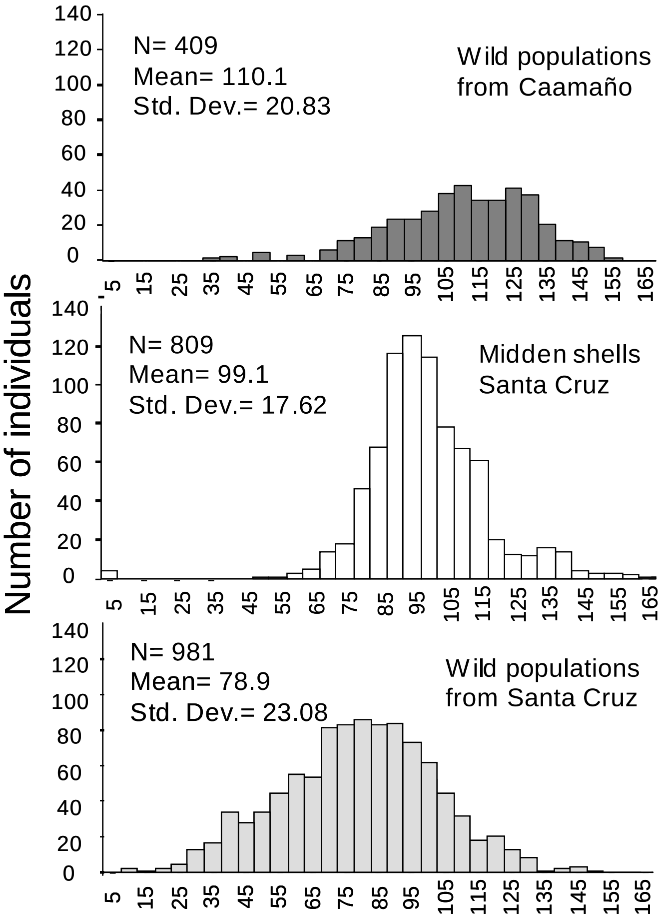

Figure 3. Length frequency distributions of shell lengths (SL) of *Chiton goodalli* in wild populations from Caamaño (top), from midden shells on Santa Cruz (middle) and from wild populations on Santa Cruz (bottom). Data for wild populations were obtained by researchers' direct sampling; data for middens were estimated with morphometric equations applied to shells and shell fragments left by fishers.

Chiton Harvests

Between Academy Bay and Punta Núñez, nine middens with 4,146 shells (cephalic plates) were found from August 1994–98. At Punta Núñez alone, the middens were conservatively estimated to contain about 2,200 shells.

Seven restaurateurs completed the questionnaire in March 1995. The total amount of chiton meat then purchased by the 10 restaurants was about 22 kg (meat weight) per month. Assuming that the midden data reflected the sizes of chitons sold to restaurants, we calculated that about 1,100 chitons were sold per month to restaurants, in addition to those taken for home consumption.

A subsequent questionnaire administered to 30 hoteliers and restaurateurs in January 2000 in Puerto Ayora indicated that consumption in hotels was negligible and very low in restaurants, equivalent to only about 130 chitons per month. Data from these surveys showed that local residents (63%) consumed more chitons than national visitors (36.36%) or foreign visitors (0%).

Fishers customarily collected from the intertidal zone and sold their catches once or twice per month. The catch was mainly chitons but also included some sally lightfoot crabs, *Grapsus grapsus*, and gastropods in the genera *Nerita* and *Purpura.*

DISCUSSION

This is the first general report on the chiton fishery in the Galápagos, but interpretation of the data is still hampered by lack of information on the biology of the species. Ongoing studies by the first author (unpublished data) show that the spawning cycle of *C. goodalli* is year round although spawning peaks may occur in March and October. The average size at onset of sexual maturity is about 90 mm. The data show that recruitment to the population at two sites is irregular over time and not obviously related to the El Niño phenomenon.

The data suggest that the intensity of chiton harvest declines with increasing distance from Puerto Ayora. Since 1995, densities of *C. goodalli* have declined more conspicuously closest to Puerto Ayora. The ready accessibility of Pta. Núñez by boat explains the high intensity of fishing there. Mean sizes of chitons on the offshore island of Caamaño are probably larger due to the low fishing pressure. The decline in chiton densities can almost certainly be attributed to human harvesting rather than the natural mortality or recruitment failures by considering both the midden evidence and the estimated aggregate human consumption of chitons.

Many parts of the coast of Santa Cruz such as the cliffs at El Barranco are difficult to access by local chiton fishers, and so may have virtually pristine densities of *C. goodalli.* Unless recruitment is largely restricted to very localized parental stocks, it is difficult to believe that even intense

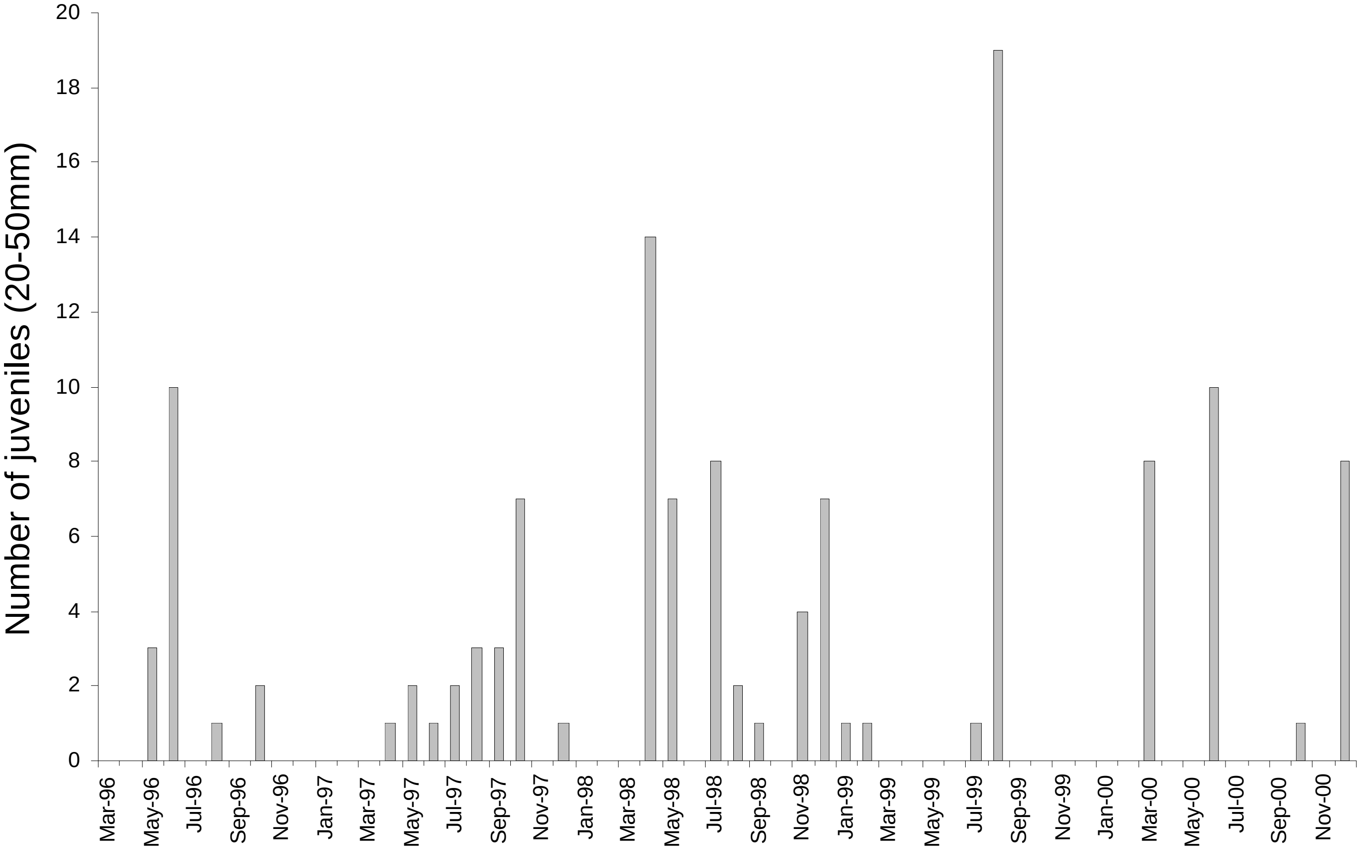

Figure 4. Recruitment in numbers of juveniles (20-50mm SL) of *Chiton goodalli* per hour searching time at Punta Estrada and El Barranco during monthly sampling from 1996 to 2000.

local harvesting will seriously affect recruitment to local populations. Hence, although growth overfishing (excessive fishing that removes all adults locally) may well have occurred on parts of the coast of Santa Cruz near Puerto Ayora as indicated by the substantial numbers of sexually immature chitons caught, recruitment overfishing (overfishing of spawning stock that causes recruitment failure) has not been established. Very small *C. goodalli* of about 1mm SL have been observed in the intertidal *Gelidium* and *Ulva* mats in Academy Bay, and it is possible that this is the habitat in which the larval settlement of this chiton occurs. Questions of recruitment variability and stock-recruitment relationships may best be examined by the use of artificial collectors placed in the intertidal zone.

It is clear from the midden data that many chitons are harvested at a suboptimal size. We recommend that a minimum size of capture be imposed in this fishery. The appropriate minimum size limit should be determined after taking into account size of sexual maturity and intensity of harvesting. This would eliminate the problem of growth overfishing and would encourage fishers to conserve stocks.

The estimated 88% decline in consumption of chitons in restaurants and hotels between 1995 and 2000 is consistent with the local depletion of chitons in Academy Bay. However, from the number of chitons still found in local middens, it is likely that many more chitons are taken for domestic consumption than are accounted for by sales in restaurants in Puerto Ayora. As yet, the total catch of chitons is still speculative.

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PHENOTYPIC VARIATION IN *CALANDRINIA GALAPAGOSA* (PORTULACACEAE)

By: Patricia Jaramillo

ABSTRACT

Calandrinia galapagosa St. John is found only on San Cristóbal Island in the Galápagos archipelago, where it is severely threatened by feral goats. A population at Cerro Colorado is protected by an exclosure constructed for this purpose in 1993. Individuals of this population have white or pinkish white flowers with a green stem, whereas the population at La Galapaguera, has pinkish white flowers with a purple stem.

INTRODUCTION

There are 60 species of the genus *Calandrinia* (family Portulacaceae) in Australia and 40 species in the Americas. Some are cultivated as ornamental plants because of their fleshy leaves and attractive flowers. Polymorphic species are found in the subgenera *Baitaria, Cistanthe*, and *Rumicastrum* (Mabberley 1997). In Galápagos, Stewart (1911) reported a *Calandrinia* for the first time from Sappho Cove, on the central north coast of San Cristóbal Island.

Later, St. John (1937) noted differences between Stewart's collection and other species of *Calandrinia*, specifically *C. splendens* from Chile. He established that the sepals, the number of stamens, and the seeds were different, and he described it as a new species, *C. galapagosa*, endemic to Galápagos. Later, Eliasson (1968) reported 20 bushes, which were non-reproductive and severely grazed by feral goats, surviving only on inaccessible cliffs. In 1977, H. Adsersen (pers. comm.) found some plants on lava at Bahía Rosa Blanca (non-reproductive specimens, Charles Darwin Research Station Herbarium).

In 1993, Jacinto Gordillo (pers. comm.) reported a population on Cerro Colorado at an altitude of 150 m on a red clay soil. Ortiz (1994) noted the danger of extinction of this species, mainly due to pressure by feral goats. This site was therefore protected by a 300 m barbed wire fence built in 1993. This fence was never entirely adequate and deteriorated over the years, permitting access by goats once more. It was therefore replaced by a chain-link fence built in 1999 by the Charles Darwin Research Station and Galápagos National Park Service. This exclosure protects not only the largest *Calandrinia* population, but also a large population of the threatened San Cristóbal endemic *Lecocarpus darwinii.*

Arsiniegas (1996) reported a new *Calandrinia* population in four small cones to the southwest of the cone "Media Luna" and in two larger cones located southeast of the cones "Calzoncillo" and "Pan de Azúcar" in the eastern part of the island in the section called La Galapaguera. These individuals are protected from the donkeys and feral goats that exist in the area due to their location on the vertical walls of the cones. In 1999, Alan Tye and Patricia Jaramillo (pers. obs.) found three individuals of this species at a new location at Bahía Rosa Blanca.

In this study I report differences in the color of the leaves and flowers between individuals found at Cerro Colorado and La Galapaguera.

MORPHOLOGY

Most observers have reported pink-white flowers and green leaves (Stewart 1911, St. John 1937, Eliasson 1968, Wiggins & Porter 1971). More recently, variably colored leaves (Arsiniegas 1996) or slightly purple leaves, or white flowers (Jaramillo 1998) have also been noted.

At Cerro Colorado, Jaramillo (1998) found plants with white flowers that were otherwise identical to the pink flowered plants at the same site, thus confirming that variation exists at this site. J. Sotomayor collected some seeds of this species from Cerro Colorado and M. Arsiniegas from La Galapaguera. Sotomayor germinated them at the Charles Darwin Research Station facility in San Cristóbal. The seeds were germinated with the same substrate at an altitude of 20 m above sea level. The color of the flowers and leaves was different in the two cases: flowers from La Galapaguera were purple and leaves were slightly purplish, whereas flowers from Cerro Colorado were white and the leaves were green. Presumably samples from plants with pink flowers from this site would have produced pink flowers.

Different populations of C*alandrinia galapagosa* thus seem to differ phenotypically, and there is also variation within the Cerro Colorado population. More studies are necessary in order to explain the taxonomic and genetic status of the different forms.

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I want to express my deep gratitude to Jorge Sotomayor for his help and information and to Mark Gardener, Alan Tye, Lázaro Roque and Washington Tapia for checking the article; to Adolfo Verdugo for the field work. I gratefully acknowledge Gayle Davis for her help in the bibliography and text review.

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C*alandrinia galapagosa* San Cristóbal Island.

DID GALÁPAGOS EXPERIENCE AN EL NIÑO IN 1878?

By: Matthew J. James

The biological consequences of the warm water produced by the El Niño phenomenon in the eastern Pacific Ocean are felt early in the Galápagos Islands, and the impacts can be severe, both on the islands themselves and in the near shore waters surrounding the islands. Recent experience by Galápagos scientists has shown that sea surface temperatures near the Charles Darwin Research Station exceeded 28°C (83°F) during both the 1982-83 and 1997-98 El Niño events (Snell & Rea 2002, data for March 1983 and March 1998). Documenting the frequency and magnitude of even earlier El Niño events in this area could assist in better understanding the impact of the phenomenon on Galápagos organisms.

In the summer of 2000, I visited the National Archives in Washington, DC, to find information about a United States Coast Survey vessel that would ultimately figure prominently in Galápagos history. Serendipitously, air and sea temperature information from this ship's log eventually led me to believe that an El Niño occurred in 1878 when the ship passed 200 miles to the west of the Galápagos Islands. Kiladis and Diaz (1986) recognized evidence for an El Niño event in 1877-1878. My research confirms both the existence and severity of that event.

Figure 1. The schooner *Earnest* (later renamed *Academy)* when she was on the rocks on Yerba Buena Island in San Francisco Bay in March 1904. (U.S. Naval Historic Center, Wash., D.C.).

In the year 1875, the 89-foot composite-hulled gaff-rigged schooner *Earnest* was launched in Baltimore by the William E. Woodall Company, a well-known shipbuilder (Figure 1). Following some brief coastal surveying work in Florida, the *Earnest* sailed north on assignment to Maine where she was badly damaged and sank in shallow water off Isle Au Haut in an October 1876 storm. The schooner was re-floated, returned to Baltimore for repairs, and was then dispatched to Puget Sound on the opposite coast, by way of Cape Horn.

Under the command of Sailing Master P. G. Letournau, the *Earnest* departed Baltimore in the fall of 1877. While rounding the Horn, the vessel's most southerly position was 59° 8′ 24′′ S and 65° 7′ 12′′ W before turning north towards the equator.

My specific interest in this voyage of the *Earnest* was to learn if the ship had stopped at the Galápagos Islands en route to Puget Sound. I examined several of the 35 logbooks covering the period from 1875 to 1898 housed in the National Archives. If the *Earnest* had visited Galápagos, it would have presaged another, more famous, trip by the same vessel some 28 years later. The logbooks revealed that the *Earnest*'s sailing track carried her nearly 200 miles to the west of the Galápagos. But as I tracked the vessel's northward progress on page after page of the logbook, I

Table 1. – Geographic and ocean temperature data obtained by the U.S. Coast Survey schooner *Earnest* in 1878, approx. 200 miles west of the Galápagos Islands (Source: National Archives 1878).

1878 April	Sea Surface Temp.	Latitude	Longitude	Rainfall Weather
10	82-83°F (27.8-28.3°C)	8°41′24′′S.	104°4′48′′W.	Light squalls & rain
11	83°F (28.3°C)	7°9′00′′S.	105°9′36′′W.	Light squalls
12	83°F (28.3°C)	4°32′24′′S.	106°25′12′′W.	Fine & clear
13	83°F (28.3°C)	2°25′ 2′′S.	107°4′48′′W.	Fine clear weather
14	82-83°F (27.8-28.3°C)	0°33′00′′S.	109°1′12′′W.	Fine clear weather
15	83-84°F (28.3-28.9°C)	On Equator	109°19′12′′W.	Fine clear weather
16	83-84°F (28.3-28.9°C)	1°28′48′′N.	109°24′00′W.	N/A
17	84° F(28.9°C)	3°7′12′′N.	109°7′12′′W.	Much rain
18	83-84°F (28.3-28.9°C)	4°6′00′′N.	110°21′00′′W.	Much rain
19	84°F (28.9°C)	5°6′36′′N.	112°15′00′′W.	Fine weather

stumbled onto what is perhaps an equally interesting historical observation.

On a nearly daily basis while en route from Baltimore to Puget Sound, Letournau and his crew took the air and sea surface temperature readings mentioned previously. These data, along with daily general weather observations and latitude and longitude readings, were consistently recorded in one of the *Earnest*'s logs. Data for ten days as the *Earnest* approached and departed the equator (Table 1) indicate a mass of extremely warm water in the eastern Pacific.

The maximum sea surface temperature recorded between April 15 and 19, 1878, was 28.9°C (84°F) from the time when the schooner had just crossed the equator and continuing at least until 5° north of the equator. Since these readings fall in the upper range of temperatures for an El Niño event and are higher than those of non-El Niño years, it appears that the *Earnest* sailed right through an El Niño on its way from Cape Horn to Puget Sound.

How strong was the El Niño event that the schooner *Earnest* sailed through in 1878? Quinn and Neal (1995) analyzed the intensities of 115 separate El Niño events between 1525 and 1987. On an intensity scale of 1 to 5, they assigned a value of 5 to both the 1877-78 and 1982-83 events. Their highest ranking of "Very Strong" was also given to both the 1877-78 and 1982-83 events, a ranking that was only given to nine out of the 115 events documented since 1525. According to Kiladis and Diaz (1986), the 1877-1878 El Niño was an extreme event comparable to the 1982-83 event, and these two events are most likely the strongest such occurrences that can be documented with reliable data. Many of the same extreme worldwide weather anomalies observed in 1982-83 were also observed in 1877-78.

After reaching San Francisco in May 1878, and spending two weeks there, the schooner continued north to spend the next 20 years in Coast Survey work in Puget Sound, the San Juan Islands, and on several trips to Alaska. By the end of the 19th century, the now-tired and well-used schooner was "of no further use" to the U.S. Coast and Geodetic Survey. In February 1898, the *Earnest* was "condemned as a hulk" and turned over to the U.S. Navy at the Puget Sound Naval Station in Bremerton, Washington "to be used as a target or for any other purpose." Despite two offers to purchase the schooner in 1898, the Chief of the Navy's Bureau of Navigation informed the Secretary of the Navy that: "The schooner "Earnest" is worth far more than three hundred dollars to this Bureau for target practice, and was turned over to the Navy Department for that purpose – not to be sold." (National Archives 1898).

Ships, like people, sometimes get a second (or third or fourth) chance. In September 1898, a reprieve of the scuttling sentence came when the Commandant of the Puget Sound Naval Station wrote to the Secretary of the Navy in Washington, D.C., requesting that the *Earnest* be converted for use as a lighter at the Naval Station. Permission was granted.

On March 9th, 1904, the *Earnest* was anchored near Yerba Buena Island in central San Francisco Bay, now playing a new role as a naval training vessel. During the night, a violent southeast gale parted both a heavy wire rope and a sturdy hawser causing the *Earnest* to be tossed above the high tide mark on the island. Her advanced age, intense Coast Survey use in the 1880's and 1890's, and newly acquired storm damage resulted in the Navy putting the schooner up for public sale (the documents authorizing the sale were signed by President Theodore Roosevelt; National Archives 1898).

In May 1905, the California Academy of Sciences purchased the schooner from the Navy in a sealed-bid auction for $1000. As the West Coast's largest and oldest museum, the Academy was eager to purchase a suitable vessel for a scientific expedition. They changed her name to the *Academy* and again made her seaworthy. Her eager new owners soon dispatched her on a yearlong voyage of scientific collecting and exploration to the Galápagos Islands. The expedition departed San Francisco on June 28, 1905.

In late September 1905, almost 70 years to the day after Charles Darwin first approached the Galápagos archipelago aboard HMS *Beagle*, and approximately 28 years after having rounded Cape Horn and passing westward of the archipelago, this sturdy schooner would approach Hood Island from the north, 89 days out of San Francisco. While following in Darwin's footsteps, the *Academy* and her crew of eight young men who served as sailor-scientists assembled an unrivaled collection of scientific specimens, including tortoises, birds, plants, insects, mollusks, fossils, and other organisms. Notable scientific events during the 17-month expedition included the documentation of tool-use by the woodpecker finch, and the collection of the only known tortoise specimen from Isla Fernandina. The schooner herself was honored in perpetuity when the bay on southern Santa Cruz Island was named Academy Bay on November 5, 1905. The schooner and her expedition members remained in Galápagos waters for a year and a day before returning to San Francisco in late November 1906.

Joseph R. Slevin's 1931 *Log of the Schooner "Academy"* and other works published after the voyage provide much useful information for Galápagos researchers. In this short article, I have added another link between this special boat and science in the islands by highlighting the careful and useful records by the crew of the U.S. Coast Survey vessel *Earnest* in 1878.

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THE CHARLES DARWIN RESEARCH STATION HERBARIUM: IMPROVEMENTS OF THE LAST SIX YEARS

By: Patricia Jaramillo and Alan Tye

INTRODUCTION

An herbarium is an indispensable tool for all botanical research since plant studies depend on reliable identifications. For many difficult taxonomic groups, well-prepared specimens are essential for identification. Herbarium collections also provide material for traditional (morphological) and modern (genetic) research in plant systematics, evolution, and ecology.

Until 1963, all plant collections made in Galápagos had been sent to herbaria located outside the Galápagos Islands (Mauchamp and Aldaz 1997). Large or important collections from Galápagos are deposited at: the Royal Botanic Garden, Kew, UK; Cambridge University, UK (including most of Darwin's collections); and the California Academy of Sciences, San Francisco, USA (Wiggins and Porter 1971, Mauchamp and Aldaz 1997). In 1964, the Charles Darwin Research Station (CDRS) created its own herbarium to preserve important collections locally and to facilitate botanical investigation in the islands. The majority of the first collections were made in 1963–64 by David Snow, Director of the CDRS at that time. An important contribution was made by I. L. Wiggins in 1966, who left duplicates of the specimens collected for the preparation of the modern flora of the islands (Wiggins and Porter 1971). The herbarium received international recognition in 1975 with its inclusion on the World Index Herbariorum with the institutional identifier acronym of CDS.

Until 1994, herbarium maintenance was sporadic and often not up to international standards, resulting in many specimens still being deposited in other institutions (Mauchamp and Aldaz 1997). In March 1994, the collections were moved to a new dehumidified, and since 1995, air-conditioned room with custom-built storage cabinets (Mauchamp and Aldaz 1997). The collection data were entered into a computerized database which now forms the core of the CDRS Database of the Galápagos Flora. In 1995, an agreement was signed with the National Herbarium in Quito, Ecuador, (QCNE), providing for identification assistance from mainland researchers (especially for introduced species) and for the deposit of duplicate specimens in Quito. The present paper reports activities since 1996.

THE COLLECTIONS

The botanical collections have increased greatly in recent years, growing from 7,000 specimens in 1996 (Mauchamp and Aldaz 1997) to more than 14,000 in 2003, a growth of nearly 1,000 specimens per year (Figure 1). This near doubling of the collection in six years has necessitated continued expansion of the herbarium facilities. The collections currently represent approximately 85% of vascular plant taxa known from the islands, 70% of algal taxa, 40% of lichens, and a collection of bryophytes which is not yet fully catalogued. The collections include

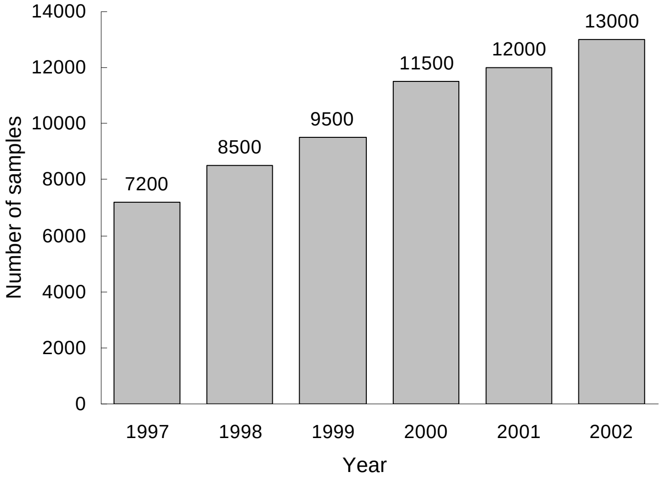

Figure 1. Increase of specimen numbers at the CDRS Herbarium.

isotype specimens (specimens from the plant originally used to describe the taxon) of three endemic taxa.

The principal collection is of pressed and dried specimens mounted on standard herbarium sheets, but several auxiliary collections are also maintained. Large dried specimens of fruit, wood, bark, roots, tubers, etc., are curated separately because of their size and shape. These are stored at present on open shelving until more suitable storage cabinets can be obtained.

Most seeds that accompany standard specimens are mounted in envelopes on the relevant specimen sheet, but an auxiliary collection of additional or oversized material is also maintained. These are mostly dry, in sealed jars, or in plastic bags. A large addition to the seed and fruit collection was made during 1999–2001 by Ana Mireya Guerrero.

For a few plant groups (*e.g.* algae, succulents), as well as for certain plant parts (*e.g.* soft fruit, flowers of Orchidaceae, Asteraceae and Papilionaceae), wet preservation is used. For these, Copenhagen Mixture, which is 70% ethanol, 29% water, and 1% glycerol (Bridson and Forman 1998), is currently used. The glycerol helps maintain natural color and prevents complete drying should evaporation occur from the specimen containers. Some earlier collections were preserved in formalin but have since been transferred to alcohol. Wet collections are kept in wall-mounted cabinets separate from the dry collections. The wet collections currently include about 260 specimens of which the great majority (240) are algae.

A pollen collection was begun in 2001, using mostly pollen taken from flowers on existing herbarium samples, but with additional specimens prepared from supplementary material collected in the field. The pollen collection now includes specimens of 40 taxa representing some 20% of Galápagos endemic species. The accumulation of more specimens, including pollen from non-endemic natives and introduced species, will facilitate studies of floral history and pollination biology (Figure 2).

A collection of representative photographs of plant specimens is being accumulated and will be linked to the database for assistance in identifications.

HERBARIUM MANAGEMENT

Regular management procedures are detailed below.

Climate Control

In tropical regions, the high temperatures and humidity promote rapid growth of herbarium pests (Bridson and Forman 1998). The herbarium has therefore been air-conditioned and dehumidified since 1995, with some sporadic, but unavoidable interruptions due to breakdown of the machinery. Temperature and humidity are monitored to ensure that the temperature is maintained below 24° and the humidity below 60% (normal ranges are 20–22° and 50–55%).

Monitoring and Treatment of Pests

Collections are continuously monitored for pests, and treatment for infestations is undertaken as needed. Seals at key points restrict insect access. The entrance door is protected by a sticky trap, and other openings (such as the emergency door and air-conditioner mount) are sealed with silicone. Pest control within the herbarium formerly (1994–1999) involved quarterly fumigation with Gastion (active ingredient aluminium phosphide, which releases phosphine [PH_3] gas), but this technique was discontin-

Figure 2. Part of the pollen collection, comprising slide mounts and electron micrographs.

ued in 2000, due to the high toxicity of phosphine. Pest control at present involves freezing the specimens in rotation every six months and spraying the room and storage cabinets with pyrethrin insecticide every three months, and at intervening periods as found necessary. Sticky traps (Insect Monitor™) are used to attract and detect pests; all invertebrates trapped are identified and assessed for risk to specimens (Figure 3). Traps are replaced every three months. This procedure permits the identification of pests which favor particular types of specimens, taxonomic groups of plants, or the mounting materials themselves, *e.g.*, paper, gum, etc. (Bridson and Forman 1998).

Decontamination

Before new dried specimens are added to the collections, they are decontaminated by freezing in a domestic chest freezer for at least 48 hours. Larger specimens such as wood samples require freezing for a longer period which is minimally 4 days. Similarly, all collections that have been temporarily removed from the herbarium room are frozen before being returned to the room.

Specimen Preparation

For most dried specimens, standard herbarium sheets are prepared by gluing the specimen to the sheet. Mounting procedures were considerably improved in1999, with more frequent use of seed and fragment envelopes and enhanced protection for delicate flowers. Certain specimens or plant groups require special treatment. Succulents, especially Cactaceae, are either dried whole or with part of the internal flesh extracted through cuts. Specimen labels are usually printed from the original collector's information, which is previously entered into the CDRS Flora Database. Most of the routine curation and preparation of specimens is carried out by Ecuadorian student volunteers gaining work experience.

For the pollen collection, microscope slide mounts are prepared of both fresh and acetolysed pollen, whenever possible. For fresh mounts, pollen is simply mounted in glycerine containing methyl green in order to stain the exine (external coat) of the grains. For acetolysed mounts, the acetolysis is carried out by boiling the pollen in a mixture of sulphuric and acetic acids at 1:9 (Erdtman 1950, Reitsma 1959). The specimens are then fixed in acetic acid, washed twice with distilled water, and dehydrated in alcohol, grading through 50, 70, 96 and 100% solutions. They are then mounted in unstained glycerine since the acetolysis itself colors the lignin of the exine. To prepare samples for scanning electron micrography, they are acetolysed, and after dehydration, mounted on metal grids, allowed to dry, and coated with gold by high-vacuum ion-sputtering. Electron micrographs to date have been prepared at the University of Málaga, Spain. The micrographs are kept together with fragments of the sample used for preparation of the mounts.

Database Maintenance

The CDRS Database of the Galápagos Flora includes data for all herbarium specimens. It was redesigned with additional data fields in 1997, and its design is being continuously improved. The data accompanying each specimen are entered into the database before the specimen is formally added to the collection, and specimen labels are printed from the database.

In addition to routine curation activities, the following projects have been carried out since 1995.

Auxiliary Collections

Recent activities have included cataloguing of the algae (1998, Lucy Buxton) and lichens (2000, Olivia Le Dee), initiation of the pollen collection (2001, Patricia Jaramillo), and verifying the registration and curation of seeds and wood samples.

Specimen Identification

Checking the identification of specimens, particularly of difficult groups, is undertaken by staff as time and specific expertise and interests permit. Revision of all endemic vascular taxa (Alan Tye) and all ferns and grasses (Heinke Jäger and Simon Laegaard) has recently been completed, although some difficult cases remain unresolved. Work in the near future will focus on introduced species.

Figure 3. Invertebrate pest monitoring trap.

Herbarium Expansion

The herbarium is a single room, which was enlarged twice during the last four years (1999 and 2001). Walls were removed so that two small storage rooms were incorporated into the main room. This has provided space for two additional cabinets as well as an increase to the preparation area and an area for the database and GIS computers.

Training

Patricia Jaramillo received training in herbarium management at the Royal Botanic Garden, Kew, UK, in 1999, and in pollen collection management at the University of Málaga, Spain, in 2001. This experience has enabled us to improve our management standards significantly as well as to establish new special collections.

Communication

As part of the new Charles Darwin Foundation web site, the Herbarium established its own web page in 2000 (http://www.darwinfoundation.org/terrest/Botany/herbar.html).

PROBLEMS AND THE FUTURE

A major problem for the herbarium has always been funding. Current annual costs of maintenance of the collections are approximately US $35,000, including the curator's salary, volunteer support, materials, storage cabinets, and equipment replacement. Funds available within the Charles Darwin Foundation (CDF) have never been adequate for herbarium maintenance, which has therefore always had to be funded in part from research projects. The herbarium is an essential tool for all botanical research in the islands, and a current high priority for the Charles Darwin Foundation is to secure stable funds for the maintenance of such essential services. The lack of dedicated and stable funding places the maintenance of the collections at risk and subject to annual fluctuations in Botany Department finances. The failure of an air-conditioner or the exhaustion of mounting materials at a time when funds are otherwise committed can mean that collections remain susceptible to intermittent deterioration and processing delays. We envision a need for US $35,000 per year for the foreseeable future to meet current and future herbarium functions.

However, if secure funding can be found, the future looks promising with botanical and related ecological studies being better served by ever-growing collections amassed by an active research department. Plans are being drawn for a new, larger specimen storage room with better climate control and a larger, custom-designed research area with a separate specimen preparation room. Activities for the near future include linking the database to a geographic information system, revising the list of introduced species documented from Galápagos, and completing the collections for missing taxa. Hopefully, five years from now, we may be able to report on more improvements and a flourishing herbarium that plays an enhanced role in Galápagos research for resident and visiting scientists alike.

Editor's Note: If you wish to receive information on the needs of the herbarium or Botany Program or ways to give funds, equipment, or expertise please contact the CDF's Institutional Development Area, Ms. Paola Diaz (pdiaz@fcdarwin.org.ec) or any of the Friends of Galapagos Organizations listed in the inside front cover of this edition of Noticias de Galapagos.

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ESTIMATING THE ABUNDANCE OF CLUSTERED AND CRYPTIC MARINE MACRO-INVERTEBRATES IN THE GALÁPAGOS WITH PARTICULAR REFERENCE TO SEA CUCUMBERS

By: S. A. Shepherd, V. Toral-Granda, and G. J. Edgar

SUMMARY

Estimating the abundance of marine macro-invertebrates is complicated by a variety of factors: 1) human factors, such as diver efficiency and diver error; and 2) biological factors, such as aggregation of organisms, crypsis, and nocturnal emergence behavior. Diver efficiency varied according to the detectability of an organism causing under-estimation of density by up to 50% in some species. All common species were aggregated at scales from 10-50 m. Transects need to be long enough to transcend the scale of patchiness to improve accuracy. Some species of sea urchins and sea cucumbers (pepinos) which are cryptic by day emerged at night so that daytime censuses underestimated their abundance by up to 10 times. In the sea cucumber fishery, estimates of abundance need to be made at the scale of the population, *i.e.* at hundreds of km. A strategy for this is proposed.

INTRODUCTION

Surveys of fish and marine macro-invertebrates on rocky bottoms are used in landscape ecology to identify bioregions and their subunits. In the Galápagos Islands, surveys are in progress to help classify bioregions for the purpose of zoning the islands according to the types of use permitted. Survey data are also employed to estimate the abundance of the sea cucumber, *Stichopus fuscus,* for the purpose of fixing quotas in the sea cucumber fishery.

The data collected on reef surveys are subject to numerous sources of error. The spatial dispersion of an organism affects the accuracy of a census and the efficiency of a diver. Conversely, the detectability of an organism varies according to visibility, swell, and the organism's behavior, as well as the diver's ability.

Not surprisingly, the appropriateness of specific sampling techniques has been much disputed among biologists. This preliminary note describes the pattern of dispersion of some common marine macro-invertebrates recently surveyed in the Galápagos archipelago and recommends appropriate survey methods. The special case of the sea cucumber, a commercially valuable species, for which abundance estimates are needed at the population scale, *i.e.* hundreds of km rather than the finer scale appropriate for bio-regional assessment, is also considered.

METHODS

Two survey methods were used: (a) employing a circular quadrat, a diver counted all organisms within a circle determined by a line 5.64 m long fixed at a central point; and (b) using the more traditional line transect, a diver swam along a 50 m or 100 m line and counted all organisms within a meter of one or both sides of the line. The former method covers 100 m^2 and has been used in sea cucumber surveys in the Galápagos; the latter covers 100 m^2, or 200 m^2 if both sides of the line are surveyed, and is used for macro-invertebrate surveys.

A comparison of the two methods was made for surveys at seven sites near western Isabela and Fernandina Islands. The sites near Isabela were: Caleta Iguana, Bahía Elizabeth, Playa Negra and Punta Vicente Roca. Those near Fernandina Island were: Punta Espinosa and Punta Mangle Sur and Norte. At each site, 2-4 (mean 2.3) circular quadrats and 1-5 (mean 3.1) line transects covering 100 m^2 at the same depth were sampled.

Other surveys with 100 m transect lines were done by one of the authors (SAS) at Cabo Douglas, Fernandina Island, El Muñeco, Poza de las Azules (2 depths), Puerto Bravo (2 depths), Piedra Blanca (2 depths) and Caleta Iguana (2 depths) on Isabela Island. All macro-invertebrates were counted in 10 m segments over a total of 200 m^2 in some transects and on 100 m^2 on others. The resultant abundance data for 9 common species were analyzed by a simple test for randomness, the variance-mean ratio (s^2/n, where n is the mean density) [see Sokal and Rohlf 1973] which was calculated for 10 m and 50 m segments for the subset of data available.

To estimate diver efficiency when sighting sea cucumbers, the diver swam in one direction along the line and removed all the individuals encountered. Then he swam back slowly in the opposite direction recording those animals which were missed in the first count. To estimate efficiency at sighting sea-urchins, the diver counted organisms within a square meter. He then removed larger animals which hid other organisms from view and did a recount. To examine the effect of an organism's nocturnal behavior on counts, a transect was delimited in the day and censused soon thereafter. The transect census was repeated several hours later at night. These day-night comparisons were at Punta Moreno (2 sites) and Piedra Blanca on Isabela Island, Las Cuevas and Punta Cormorant on Floreana Island, Site 2 San Cristóbal Island, Bahía Gardner, Española and Isla Bartolomé, near Santiago. The surveys and experiments were done during the period December 2000 to March 2001.

RESULTS

Spatial Dispersion

The results (Table 1) show that all abundant species, with a few exceptions, were aggregated at a spatial scale of 10 m and when data were combined over 50 m segments, aggregation persisted at the larger scale. In the case of *Eucidaris*, s^2/n approached a random distribution at only two sites out of 17. In the case of the sea cucumber, *Stichopus fuscus*, this occurred at one site out of four at a scale of 50 m, and at no sites at a scale of 10 m.

A comparison of density estimates for sea cucumbers at seven sites where both circular quadrats and line transects were done showed that the two methods produced well correlated ($r=0.8$; $P<0.05$) density values. However, the circular quadrat estimates of density were on average 64% higher than the line transect estimates.

Diver Efficiency

Efficiency was estimated for the sea cucumber, *S. fuscus*, at Cabo Douglas on Fernandina, and at Los Cañones, Playa Negra, Punta Moreno and El Muñeco on Isabela along a line transect of 100 m covering an area of 100 m^2. Mean diver efficiency for the five sites was 0.75 (s.e. 0.02) at a mean apparent sea cucumber density of 0.11 (s.e. 0.01) m^{-2}. At all sites, the habitat varied from irregular boulders to blocks, 0.5-3 m diameter.

Efficiency at counting the sea-urchin, *Lytechinus*, was estimated at Poza de los Azules, Isabela Island, where clusters of *Lytechinus* were obscured between groups of *Eucidaris* and boulders to 1 m diameter. In five 1m^2 quadrats randomly placed on the bottom, diver efficiency was estimated to be 0.55 (s.e. 0.07) where the mean apparent density of *Lytechinus* was 6.8 (s.e. 0.9) m^{-2}.

Lastly, diver efficiency at counting *Eucidaris* was estimated at Bahía Elizabeth, Isabela, where the habitat is heterogeneous and where numerous overhangs reduce detectability of organisms. Efficiency in five 1 m^2 quadrats randomly placed on the bottom was 0.57 (s.e. 0.01) at a mean apparent density of 5.2 (s.e. 0.8) m^{-2}.

Nocturnal Behavior

Day-night comparisons of density of macro-invertebrates are given in Table 2. Three species of sea-urchin, *Eucidaris*, *Lytechinus* and *Tripneustes*, showed major changes in density from day to night but with no consistent trend. A fourth species, *Diadema*, showed a large increase at night at two sites. *Stichopus* generally increased in density at night, whereas *Nidorellia* decreased sharply at night. The gastropod, *Hexaplex*, always in low density, showed no consistent trend. For less common species data are too few to show any trend.

DISCUSSION

The pattern of spatial dispersion of a species may be related to the heterogeneity of the habitat or to the behavior of the species. The sea-urchin, *Lytechinus*, a detrital

Table 1. Variance-mean ratios calculated for common macro-invertebrates counted during surveys. N is the number of sites for which data are available. s^2/n is the variance-to-mean ratio, and where s^2/n is close to unity, data are shown separately.

Species	N	Density Range (Nos/10m^2)	s^2/n for 10 m Segments	N	Density Range (Nos/50m^2)	s^2/n for 50 m Segments
Eucidaris thouarsii	16	2.6-112	2.7-26.4	9	13.0-486	2.1-26.8
	2	12.3-28.1	1.3			
Lytechinus semituberculatus	14	2.9-340	2.7-178	6	48.3-162.8	24.9-289
Tripneustes depressus	5	2.8-19.2	2.9-9.4	4	13.8-95.8	6.8-13.3
Nidorellia armata	4	2.4-10.2	3.2-7.0	6	1.8-51.2	1.8-8.1
Stichopus fuscus	7	0.8-7.9	1.5-5.7	3	2.1-6.0	2.1-23.0
				1	7.25	1.3
Stichopus horrens	1	11.8	5.8			
Holothuria atra	1	1.5	4.2			
Holothuria kefersteinii	1	2.9	4.1			
Holothuria fuscocineria	1	0.8	0.95			
Diadema mexicana	1	1.0	8.0-17.5			
Hexaplex princeps	5	0.6-3.8	2.1-7.4	4	3.0-19.0	2.1-5.9

Table 2. Day-night comparisons in density (numbers.10 m^{-2}) at eight sites in the Galápagos. The sites are: 3 on Isla Isabela: PMoreno1; PMoreno2; PBlanca; 2 on Isla Floreana: LCuevas; Cormorant; and at the islands: Española; Cristóbal; Bartolomé. Only significant results ($P<0.05$) are shown as decreases or increases. Density values are shown for each site. Where no change was noted, the two values are listed.

Species	Site	Increase Night	Decrease Night	No Change
Eucidaris	LCuevas	6 - 25		
	Cristóbal	28 - 58		
	Española	3 - 40		
	Bartolomé	113 - 171		
	Cormorant		20 - 16	
	PMoreno1			5, 3
	PBlanca			12, 15
Lytechinus	Moreno1	0.9 - 28		
	LCuevas	0 - 0.4		
	Española	2.9 - 19.5		
	Bartolomé	4.7 - 9.0		
	PMoreno2		13 - 3	
	Cormorant		30 - 22	
	PBlanca			118, 103
Tripneustes	PMoreno2	15 - 19		
	PMoreno1		7 - 1	
	Bartolomé			6, 4.6
Diadema	Cormorant	0 - 0.3		
	LCuevas	1 - 11		
	Bartolomé			5.7, 3.3
Nidorellia	PMoreno1		2.4 - 0.1	
	PMoreno2		0.6 - 0	
	PBlanca		2.4 - 0	
Stichopus fuscus	PMoreno1	8 - 16		
	PBlanca	2 - 22		
	LCuevas	0.6 - 1.3		
	Cormorant	0 - 0.7		
	PMoreno2		12 - 6	
Stichopus horrens	Bartolomé	0.1 - 11.8		
Holothuria fuscocinerea	Bartolomé	0 - 0.8		
Hexaplex princeps	PMoreno1	0 - 2		
	LCuevas	0.4 - 1.4		
	Cormorant		0.7 - 0	
	Bartolomé			0.8, 1.0

feeder (Wellington 1975), and the sea-cucumbers, *Holothuria* spp., tend to occur in or near sandy patches. Hence, the uneven distribution of sand among rock will cause patchiness in their distribution. The sea-urchins, *Eucidaris* and *Diadema*, are both largely crevice-dependent, although at very high densities *Eucidaris* may be less so, while *Tripneustes* prefers exposed resting sites on open rock. The dispersion pattern of these species is most likely influenced by habitat. The sea-star *Nidorellia* feeds on filamentous algae and sessile invertebrates (Hickman 1997); the sea cucumber *Stichopus* feeds on diatoms and other microphytoplankton, and possibly sessile invertebrates (Aguilar *et al.* 1993); and the gastropod *Hexaplex* preys on barnacles and oysters (Hickman 1997). In all these cases, habitat features affect prey or algal distribution and hence distribution of the predator. However, all of these species except *Hexaplex* are broadcast spawners and aggregate for spawning. Thus spawning behavior may be important as a cause of aggregation.

Estimating the abundance of such species accurately requires understanding of their dispersion pattern. A useful operational rule is that the length of transect chosen for sampling should exceed the scale at which aggregation occurs. Since the majority of these invertebrates are aggregated at a scale of at least 50 m, the minimum length of transect lines should be twice that or about 100 m. Hence, circular quadrats and short transect lines cannot be expected to yield accurate estimates of abundance without a large number of randomized replicates. In the comparison between circular quadrats and 100 m line transects, the correlation was evident, but circular quadrats substantially over-estimated the abundance of *S. fuscus*. The consistently higher values in circular quadrats may be due to the aggregated dispersion of this sea cucumber and the possible bias of researchers toward sea cucumber habitat, or alternatively, avoidance of inferior habitat chosen for placement of the quadrat. This bias is much less likely in the placement of 100 m transect lines. While measures could be taken to avoid bias in the selection of quadrat locations, from a logistical point of view it is probably easier to lay out line transects in an unbiased manner than circular quadrats.

The nocturnal behavior of species which may be cryptic by day can also cause variation in abundance estimates. In the case of the four sea-urchin species described, all are active at night apparently for feeding or for spawning (Wellington 1975). Of these, *Tripneustes* and *Lytechinus* were often seen to crowd together on elevated rocks at night, suggestive of spawning clusters. Hence, it must be expected that day-night differences in density could show large changes in both directions depending on where the transect line lies in relation to elevations where aggregation occurs. *Stichopus fuscus* is also partially cryptic by day, emerging in the late afternoon and evening to feed. Hence, nocturnal counts may be higher, depending on the species' degree of crypsis by day. *Stichopus horrens*, on the other hand, is always cryptic by day and normally seen only at night.

Lastly, there are variations caused by diver experience, diver efficiency, and diver error. In these surveys, we used experienced divers, but inexperienced divers should rapidly gain the experience necessary to recognize the relatively few species involved. However, diver efficiency may vary between habitats. On a few surveys, different divers did the day-night comparisons of transects, so it is possible that some of the differences in observations are due to differences between divers. Meter distances were marked on the transect line, but in all surveys, divers estimated the meter distance from the transect line; this provided another opportunity for diver error. In the current baseline surveys, the accepted protocol was to estimate abundance with minimal disturbance to the habitat. Hence, efficiency values of 0.55-0.75 as recorded here for some echinoderms are inevitable depending on the heterogeneity of the habitat, crowding, or other factors obscuring detection. To meet this source of error, evaluation of efficiency in specific habitats can easily be incorporated into the monitoring protocol.

Estimating the Abundance of Sea Cucumbers

Surveys of sea cucumbers have specific problems because population size estimates are needed at a metapopulation scale in order to fix quotas. This requires a different strategy from that used for other invertebrates for bioregional mapping at a smaller scale. In the Galápagos, *Stichopus* occurs both on rock platforms in shallow bays and on steeply sloping shores. A stratified sampling strategy first used by Bermeo-Sarmiento (1995) in the Galápagos for bays and for steeply sloping coasts has clear advantages. For irregular bottom habitat in bays, the use of long transect lines placed systematically throughout the area under study seems optimal. For similar habitat in Torres Strait, Uthicke (1996) recommended 200´4 m transects with appropriate replication. However, for steeply sloping bottom, the method used in southeast Alaskan fjord habitats is more appropriate. There, transects are set normal to the shore from the intertidal to the lower depth limit. A diver swims down the slope with a meter stick, returning upward at a specified distance from the first transect. From these data, the density of sea cucumbers per km of coast can be calculated. In Alaska, transects are placed on average every 8.5 km over 4000 km of shoreline during surveys extending over three years (Woodby and Larson 1997). Such data, after standardizing for diver efficiency and emergence of sea cucumbers at night, can provide robust biomass estimates for the purpose of setting quotas and estimating parental stock size.

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EFFECTS OF THE 1997–98 EL NIÑO ON POPULATION SIZE AND DIET OF THE GALÁPAGOS SEA LION (*ZALOPHUS WOLLEBAEKI*)

By: S. Salazar P. and R. H. Bustamante

SUMMARY

The multi-annual climatic event, El Niño Southern Oscillation (ENSO) is an important factor in the population dynamics of coastal marine species in the Galápagos. The Galápagos sea lion, *Zalophus wollebaeki*, suffered an apparent population decline of about 50%, considering both mortality and movements away from study sites during the 1997-98 El Niño. This change was in part due to changes in the availability of sardines of the Family Clupeidae, its main prey. These declines resulted partly from elevated mortality (35%) in sea lion colonies, particularly among pups, juveniles (< 1 year old), and dominant males and as a result of movements of adults elsewhere (15%), presumably where there were alternative prey and better environmental conditions.

INTRODUCTION

The climatic phenomenon, El Niño Southern Oscillation, has severe effects on the Galápagos marine ecosystem. Sea temperatures increase some 2– 5°C above average as the subtropical convergence moves south, and the high rainfall reduces coastal salinity (Feldman 1986), causing significant changes in the relative abundances of fishes.

The 1982-83 ENSO reduced populations of the fur sea lion *Arctocephalus galapagoensis* Townsend 1934 and the Galápagos sea lion *Zalophus wollebaeki* Silvertsen 1953. During this ENSO event, both species suffered high pup mortality. Fur sea lions were reduced in numbers by 50 – 70% and the survivors lost weight, while the Galápagos sea lion numbers declined by about 30% (Trillmich and Limberger 1985, Trillmich and Dellinger 1991).

In light of the likely serious impact of ENSO events on marine organisms, a long-term study of the population size and diet of vulnerable species like the Galápagos sea lion began in 1997. The purpose of this study was to monitor changes in local populations of this sea lion using periodic censuses, to determine the causes of mortality wherever possible, and to quantify the composition of the diet during and after periods of environmental stress such as ENSO events. We hypothesized that such events would affect the distribution and abundance of prey fish populations and that changes in the sea lion's diet would reveal behavioral adaptations to available food resources, as suggested by Dellinger (1987).

METHODS

In all, 289 censuses were carried out in twelve Galápagos sea lion colonies in the central and southern part of the archipelago (Figure 1). Direct visual counts were made between April 1997 and December 2000 including data of K. Reid from 1997 (Reid and Prothero-Thomas 1997). Most of the colonies were visited regularly by one person (S. Salazar) at 2-4 month intervals and during daylight hours. In each census, individual sea lions were classified in four categories: males, females, pups, and indeterminates (Carlozzi 1997). In addition, during the 1997-98 El Niño period, any freshly dead animals (*i.e.*, decomposing animals and carcasses which still had skin over the bones) were included in the counts classified in the above categories.

A total of 439 fecal samples (scats) were collected from colonies on 7 islands of the central and southern Galápagos Islands (Figure 1) during two sampling periods: 1) April to November 1997, and 2) January to July 1998. All scat samples were washed carefully with water and detergent, and visually examined to recover fish eyes, otoliths, and other biological remains such as cephalopod beaks, exoskeletons of crustaceans, mollusks and plant material. Otoliths are small pieces of aragonite which are located in the internal fish ear. The function of these ear

Figure 1. The central Galágapos archipelago, showing the sea lion colonies monitored.

bones is related to balance, orientation, and hearing. Each bony fish has six pairs of otoliths in the neurocraneal cavity. The most useful for taxonomic purposes is the largest, the *Sagitta*.

The analysis of scats is a method widely used in marine mammal dietary studies, in particular Phocidae and Otariidae (Gales and Pemberton 1994, Reid 1996, Antonelis *et al*. 1997, Merrick *et al*. 1997, McMahon *et al*. 1999, Childerhouse *et al*. 2001, Orr and Harvey 2001).

The otoliths were identified mostly to family level with descriptive catalogs (Miranda 1982, Hecht 1987, García–Godos 1996, Reid 1996) and using comparative material in the first author's reference collection. Identification was based on the shape and texture of the otolith (Reid 1996).

RESULTS

Population Size

During the 1997–98 El Niño, population numbers of the Galápagos sea lion declined by 50% in the monitored colonies of which 35% was direct natural mortality and 15% was presumed migration or movement away from the study sites (Figure 2; Table 1). The age–classes most affected were pups born during the 1997 reproductive season and adult males dominant during the same period. The presumed cause of death was lack of food.

Despite the high variability of the numbers of observed sea lions (Figure 2), the census data on total sea lion abundances show a weak downward trend in numbers during the 1997–98 El Niño (with warm water conditions) and a weak upward trend during the succeeding La Niña (a cooling trend) through December 2000. The maximum numbers detected at the onset of the 1997-98 ENSO fluctuated between 800 and 1,700 sea lions, while these numbers never exceeded 600 sea lions per colony from the end of the 1997-98 ENSO conditions in November 1998 and until December 2000 (Figure 2). In addition, during this El Niño event, the sea lions were judged to be thin, weak, and in generally poor condition. However, as La Niña conditions became established from about November 1998 onwards (Figure 2), the numbers of sea lions present in their colonies increased, and the condition of the sea lions improved.

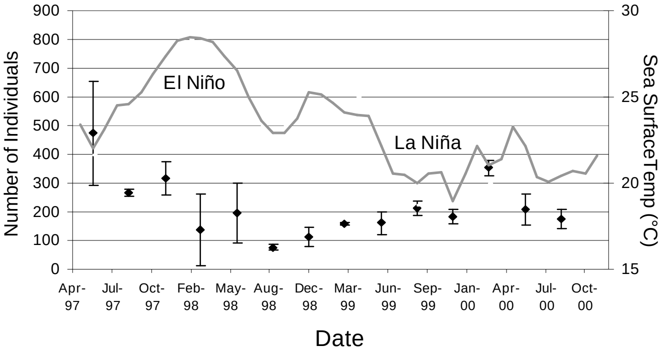

Figure 2. The total numbers of individuals averaged for three-month intervals (depicted as diamonds) in twelve colonies during the monitoring period from April 1997 to December 2000 and corresponding standard error estimates (vertical bars). The continuous line is the Sea Surface Temperature (ºC). The El Niño (ENSO) conditions in the Galápagos Islands started in December 1997 and ended in about June 1998. La Niña (LN) conditions started in June 1999 and continued until January 2000.

Table 1. Population reductions for monitored islands and sites.

Island	Site	Max. Total 1997	Max. Total 1998	% Reduction
Española	Punta Cevallos	51	6	88.24
San Cristóbal	La Lobería	201	35	82.58
San Cristóbal	Isla Lobos	330	90	72.72
North Seymour	North Seymour	310	86	72.26
Santa Cruz	Caamaño	474	211	55.48
Española	Gardner Bay	313	147	53.04
Floreana	Champion	286	175	38.81
Santa Cruz	South Plaza	827	685	17.17
Santa Fe	Santa Fe Bay	203	183	9.85
Mosquera	Mosquera	1691	1553	8.16
Total		**4686**	**3171**	**498.31**
% reducción				49.831

The census data for Mosquera (Figure 3a) showed a sharp decline in the maximum numbers from about 1,600 in April 1998 to 160 sea lions in November 1998 (Figure 3a). From that date, a steady recovery was found thereafter to about 660 animals (300 adults and 360 juveniles and pups) through late 2000 (Figure 3a). The most consistent and frequent censuses were conducted at the Caamaño Islet because it is close to the Charles Darwin Research Station (CDRS) on Santa Cruz Island (Figure 1), and thus the population could be regularly monitored. Here, as in Mosquera (Figure 3b), the numbers of sea lions declined steeply from 474 in April 1997 to only 29 adults in July 1998, but by late 2000 had recovered to 256 individuals, of which 130 were adults and 126 were juveniles and pups (Figure 3b).

At the onset of the 1997-98 ENSO and during the sea lion breeding season (June to December), the mean number of newborn pups per colony was highest (82.6; Figure 4), but about 90% of them died. In the 1998-99 breeding season, the lowest number of newborns (14) was recorded. As conditions improved in the next two breeding seasons, (1999-2000 and 2000-2001) numbers of newborns increased rapidly to an average of 42 pups per colony, but

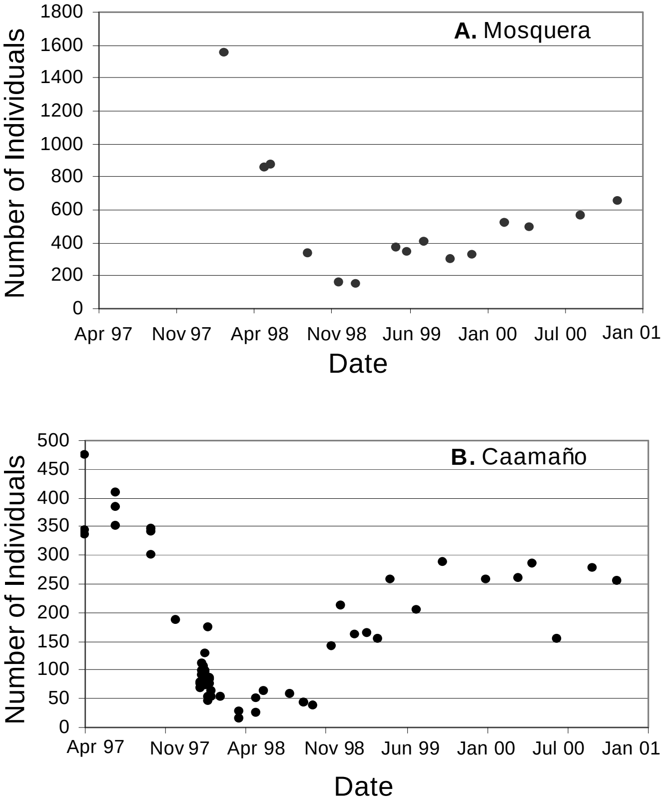

Figure 3. Maximum daily count of sea lions in Mosquera (A) and Caamaño (B) colonies.

still nearly 50% lower than the 1997-1998 breeding season (Figure 4).

Diet

During the 1997 and 1998 sampling periods, the main prey items evident in the feces were fish (97%), followed by cephalopods (2.9%) and crustaceans (< 1%).

The families of fishes represented in the Galápagos sea lion diet are given in Table 2 with positively identified species, and tentative prey species within the respective families. Changes in percentage of each item before 1997 and during the 1997–98 El Niño are evident in Figure 5. In 1997, the most common items identified were clearly dominated by otoliths from the family Clupeidae, that includes sardines, pilchards and anchovies (32.5%), followed by otoliths of the family Myctophidae or lantern fishes (20.8%) and Serranidae that include many species of jacks and pompanos (about 12%) with a progressive decline in the other families (Figure 5). In 1998 however, the compositional change was drastic and more than 79.0% of the identified remains were otoliths from the family Myctophidae (32.8%), and the family Serranidae, (32.3%). In 1998, the other dominant prey group, family Clupeidae, accounted for only 12% of the identified remains in sea lions scats (Figure 5).

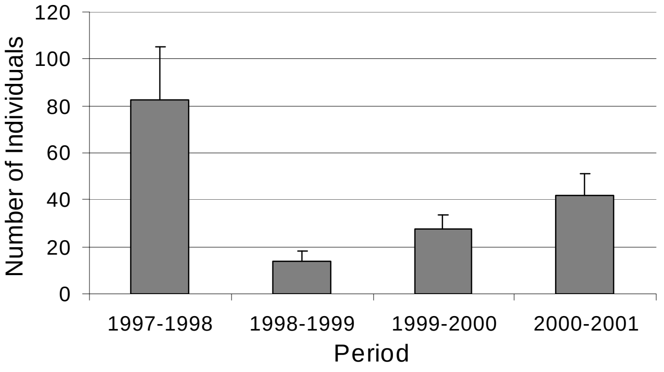

Figure 4. Mean number of newborn pups in four breeding periods: 1997 - 1998 (83 ±22.7), 1998 – 1999 (14 ±4.3), 1999 – 2000 (28 ±6.3), and 2000 – 2001 (42 ±9.6).

Discussion

The decline in overall abundance of sea lions in south central Galápagos during the 1997–98 El Niño (50%) was greater than the approximately 30% recorded by Trillmich and Limberger (1985) during the 1982–83 El Niño (Trillmich and Dellinger 1991, Dellinger and Trillmich 1999), although one of the causes of death in 1983 was a viral disease called "pox," which affected various colonies in the central and southern parts of the Archipelago (Limberger 1985, Trillmich and Limberger 1985, Trillmich and Dellinger 1991). In 1998, the principal cause of death was an apparent lack of food, and only five isolated cases were recorded of individuals possibly infected with "pox".

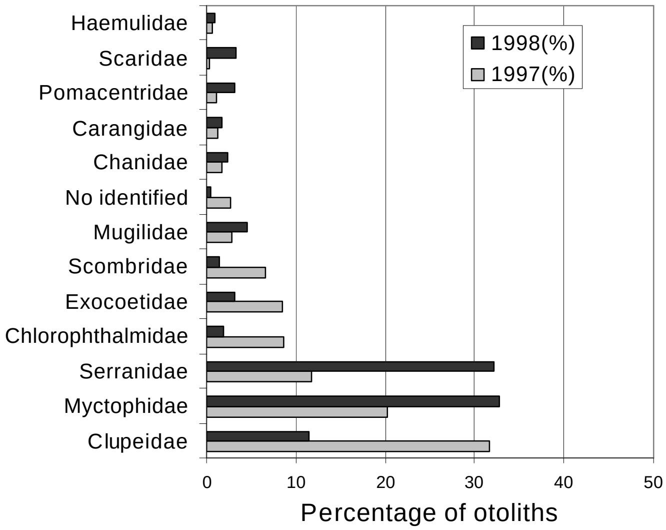

Figure 5. Frequency of food items in 1997 and 1998 sampling periods expressed as percentage of fish otoliths found in annual sample.

The population declines resulted largely from mortality, movement between islands, and potentially migration from the archipelago. The migration of sea lions from the Galápagos is not yet well established (Trillmich 1979), although individuals of the Galápagos sea lion have occasionally been reported on the coasts of continental Ecuador (Ortiz 1980, Haase 1991, Felix 1991, Chiluiza 1995), and particularly on Isla de la Plata (Carvajal 1996), and Costa Rica (Angel Herrera, pers. comm.).

The most vulnerable individuals in the colonies were pups (28% of the corpses counted) which died after being abandoned by their mothers during the suckling period in December to March 1998 (Trillmich and Limberger 1985). Further, during the 1997–98 El Niño, an elevated mortality in dominant males compared with other individuals was recorded in almost all the colonies. During the breeding season, these animals can spend up to 32 days guarding their territories without feeding (Trillmich 1987), but afterwards must ingest large quantities of food to regain a fit condition. During El Niño conditions when food is scarce or of poor nutritional quality, these males begin to weaken and show signs of malnutrition, which subsequently can lead to death. A consequence of the death of dominant males was that formerly subordinate "submissive" males occupied free territories in the three breeding seasons following the 1997–98 El Niño (namely 1998–1999, 1999–2000, and 2000–2001). In some cases, these territories were divided into several territories each guarded by individual males, thereby introducing more genetic diversity into the colony relative to previous circumstances.

The dietary analyses confirm that the principal sources of food of Galápagos sea lions are pelagic fishes, with some cephalopods and crustaceans. However, the proportion of cephalopod remains in the feces could underestimate the true consumption, since various authors (Spalding 1964, Frost and Lowry 1980, Pitcher 1980, Fiscus 1982, Nascimento *et al.* 1985) have suggested that, in general, pinnipeds regurgitate the mandibles (also known as "beaks") of cephalopods. In addition, recent studies have shown that analyses of scat and feces can be biased when used to determine absolute prey abundances due to high digestion rates, otolith breakage, and differential gut passage times, generally underestimating the overall diet of sea lions (Bodley *et al*. 1999, Orr and Harvey 2001). The results presented here are of value in that they describe the compositional diet of sea lions in relation to climatic variation and are not intended to assess the actual abundance and prey selection of sea lions in Galápagos.

It appears that the availability of schooling pelagic species like sardines, pichards, and anchovies declines during El Niño events. Perhaps normal development is impeded or distributions are affected by the warm, nutrient-poor, tropical waters in the archipelago. These schooling species are well known to thrive in cool ocean conditions and are dominant pelagic schooling species in upwelling ecosystems (Cury *et al*. 2000, Caddy and

Table 2. Identified and likely prey–species of *Z.wollebaeki.* Likely prey–species were determined according to their abundance and distribution in the archipelago (Wisner1974, Human 1993, Grove and Lavenberg 1997). (*)Species identified by their otoliths.

Family	Common name	Species
Myctophidae	Lantern fish	_Diogenichthys laternatus_ _Loweina laurae_ _Triphoturus oculeus_
Serranidae	Creole fish and bacalaos	_Paranthias colonus_ *_Paralabrax albomaculatus_ *_Mycteroperca olfax_
S2	_Lapillus_ possible	_Myctophidae?_
Clupeidae	Sardines	_Sardinops sagax sagax_ _Opisthonema berlangai_ _Opisthonema libertate_
Exocoetidae	Flyingfishes	*_Fodiator acutus_ *_Cheilopogon spp_
Mugilidae	Mullets	_Mugil cephalus_ _Mugil galapagensis_
Scombridae	Tunas	*_Scomber japonicus_ *_Sarda orientalis_
Pomacentridae	Damselfish	_Stegastes leucorus_ _Stegastes arcifrons_ _Microspathodon bairdii_
Scaridae	Parrotfish	_Scarus spp._ _Calotomus spunidens_ _Nicholsina denticulata_
Chanidae	Milkfish	*_Chanos chanos_
Carangidae	Pompanos and jacks	*_Caranx lugubris_ _Caranx caballus_ _Trachinotus stilbe_
Haemulidae	Grunt	*_Anisotremus interruptus_ *_Haemulon scudderi_ *_Orthopristis forbesi_
Sciaenidae	Drums	_Umbrina galapagorum_ _Cilus gilberti_ _Corvula macrops_
Sparidae	Porgies	_Archo sargus pourtalesii_
Branchiosteginae	No species reported for Galápagos	
Kyphosidae	Chub	_Kyphosus analogus_ _Kyphosus elegans_ _Sectator ocyurus_
Centropomidae	Róbalos	_Centropomus viridis_
Gerreidae	Mojarras	_Eucinostomus argentus_
Labridae	Wrasses	_Bodianus especies._

Garibaldi 2000). Hence, secondary consumers such as sea lions at upper trophic levels are affected by food shortages lower in the food web.

Population and ecological studies of pinnipeds are important for two reasons. Pinnipeds are sensitive to bottom-up forces induced by inter-annual, oceanographic climatic and habitat shifts, and they also cause top-down effects on fish populations at intermediate trophic levels which can cascade down to lower levels in pelagic and coastal reef ecosystems (Colinvaux 1993, Pinnegar *et al.* 2000).

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Galápagos sea lion, *Zalophus wollebaeki* on Española Island.

GAYLE DAVIS-MERLEN

7 FEBRUARY 1948 – 27 MAY 2001

There are people who become defined with a place, who represent it in ways that others cannot, who carry that place in their heart and mind, and who constantly and diligently work for the betterment of their world. These people are not always the most outspoken or conspicuous to the casual observer, but to those who know and love the place, they are part of the rock that forms its foundation. Gayle Davis-Merlen was such a person for the Galápagos Islands.

Gayle was a true resource person, giving more than she received. Scientists, students, naturalist guides, Galápagos National Park personnel, and many Charles Darwin Research Station (CDRS) Directors and their staff depended on Gayle. She was a living historical source, a vital library search system, a catalyst for excellence in publications, a help to all who asked, and a loyal friend to so many. Gayle's death affects each and every one of us who call, or have called, Galápagos home at some time in our lives. She will be greatly missed.

Gayle Davis-Merlen was born in Chicago, 7 February 1948. In the 1970s, while completing her degree in zoology at the University of Wisconsin in Madison, she met the people who provided her with a bridge to Galápagos - Bill Reeder, Craig MacFarland, and Elizabeth Pillaert. She crossed that bridge in 1976 and never looked back.

From 1976 to 1979, Gayle worked in the Galápagos Islands, first as a Peace Corps volunteer and later funded by World Wildlife Fund, to design and develop the original exhibitions in the Van Straelen Visitor Center of the CDRS and the Galápagos National Park Service (GNPS). During these years, she fell in love with the islands, their flora and fauna, and determined to remain. She also met and fell in love with the British naturalist and Galápagos resident, Godfrey Merlen, who she married in 1986.

With the completion of the Van Straelen exhibits, Gayle began work as a naturalist guide and continued her involvement with the CDRS through volunteer work. She helped develop and manage the Naturalist Guides Course conducted jointly by the GNPS and the CDRS. For many years, until computers took over, she kept a detailed log of observations on the flora, fauna, and other important sightings provided by naturalist guides during their cruises throughout the Galápagos Archipelago.

From 1983 to 1987, while Gayle worked at the Hotel Delfin, she continued her volunteer work, including her involvement in the annual Guides Course. She also offered her assistance to visiting scientists whenever possible. I had the good fortune to have Gayle join me on both Santa Cruz and Pinzón during my study of giant tortoises. Many other scientists were also lucky to have Gayle as a field assistant.

In 1987, Gayle returned to the CDRS as Head Librarian and Head of Publications. She remained dedicated to these areas until her untimely death in May 2001.

During her years at the CDRS, Gayle touched the lives and work of nearly everyone who passed through the Station. As Head Librarian, she was a resource for all who sought information. Rather than looking in a card catalogue, many people simply asked Gayle for the best references on whatever subject they were working. Her historical knowledge of the Islands also resulted in an ability to identify misinformation in the literature, which was sometimes as important as finding the correct information. She worked to increase the photographic slide collection which frequently served as an aid for presentations by staff and visitors alike. She cheerfully helped the library's clientele, whether scientists, students, naturalist guides, or the occasional tourist who had a deep interest in the Islands.

As Head of Publications, Gayle was responsible for the finished product of Annual Reports, the Director's Reports, the Annual Operative Plans, and many more institutional documents. She collected, edited, and translated articles for *Noticias de Galápagos* and served as its editor during 1999 and 2000.

At its 40th anniversary celebration in 1999, the Charles Darwin Foundation recognized Gayle, along with several others, with an award for dedication and steadfast work for Galápagos.

Her love and concern for Galápagos was obvious in everything she did. Her house was an asylum for wounded birds – blue-footed boobies, a shearwater, and Fred, the swallow-tailed gull. Sounds of well-fed finches filled her front patio. At different times in the Station history, she led the Green Team, fighting to get everyone to reduce, reuse, and recycle.

Her anger and frustration at the destruction and exploitation that increased during the 1990s, related to the problems with Galápagos fisheries, was only surpassed by her increased dedication to the protection of the Islands. Throughout the decade, her off-and-on battle with lymphoma went side-by-side with her continued struggle for the conservation of Galápagos. Her dedication to Galápagos was paramount, and she often sacrificed her well being for its protection.

There are so many memories of times shared with Gayle. One that symbolizes her desire to know Galápagos in all its seasons occurred during the El Niño of 1983. Although Gayle spent most of her time in the library, she loved to be out in nature. Gayle, Godfrey, and I wanted to experience the rivers of Santa Cruz in all their glory. We watched the skies day after day, waiting for one of the big storms. When it finally came, we hiked up to Media Luna, where we sat for an hour or more in the pouring rain, to be sure the rivers would be at their fullest. Gayle's tongue turned blue with the number of *Miconia* berries she ate. Heading back down to Bellavista, we took the "river" route – a by-pass for the water that had been bulldozed behind the town. We walked in the river, passed by waterfalls, and became one with the water. It was an experience impossible to repeat, and it gave us greater insight into the reality that is Galápagos.

Our memories of Gayle will always be tied to Galápagos, her love for the Islands, and her dedication to their preservation. Galápagos, and we, thank you, Gayle. We miss you.

Linda J. Cayot

FROM BEHIND THE TORTOISE

OBSERVATIONS FROM THE PRESIDENT OF THE CHARLES DARWIN FOUNDATION.

The tortoise logo of the Charles Darwin Foundation (CDF) prompts the title of this brief update on recent events within the Foundation from the viewpoint of the Foundation's President. Personally, I always enjoyed the commentaries entitled "The View from the Castle" which were written by the former Secretary of the Smithsonian, S. Dillon Ripley, and printed regularly in the Smithsonian Magazine. It is appropriate to note that Mr. Ripley, who passed away on 12 March 2001, was one of the Charles Darwin Foundation's original founders and long time supporters. Mr. Ripley had full rights to the title of Dr. (with a PhD in ornithology from Harvard) but preferred the Mr. as a more convenient title in the diverse circles in which he moved. His approach to supporting the Charles Darwin Foundation and its conservation programs showed similar diversity and humility. He was not only willing to lend his name and contacts for the conservation cause, but also to serve in less conspicuous ways by providing staff support, meeting venues, and closed door arm twisting when necessary. Mr. Ripley had a long and fruitful career as a scientist, chief administrator of the Smithsonian's cadre of facilities, a builder of institutions, and as a servant of many good causes, including conservation of the Galápagos. He was a leader whose efforts on behalf of CDF were innumerable and much appreciated. For details on Ripley's life and accomplishments, see the article entitled *S. Dillon Ripley 1913-2001* in the May 2001 Smithsonian Magazine.

It is one of the unfortunate consequences of the Charles Darwin Foundation being formed more than 42 years ago that we must endure the aging and occasional loss of some of our founders. Another loss was the death on 8 August 2001 of Prof. Jean Dorst, noted French zoologist, conservationist, and Director of the Natural History Museum of Paris. Jean Dorst played an important role in the formation of the Charles Darwin Foundation and took on additional leadership roles as the first Secretary General of the Foundation (1959-1964) and as Foundation President (1964-1974). Like Dillon Ripley, Jean Dorst was a busy man, but one who realized the value of the conservation of Galápagos and accordingly placed his personal energies, professional influence, and creativity into actions in serving the conservation of the Islands through the Charles Darwin Foundation. For further details on Dorst's life and accomplishments, consult the article entitled *Jean Dorst (1924-2001)* in *Ibis* 144:370-371.

On a brighter note, I had the pleasure in April 2002, at the semi-annual meeting of the Charles Darwin Foundation and later in July when I visited his laboratory, of spending time with Professor Irenäus Eibl-Eibesfeldt whose interest, vigor, and academic involvement in Galápagos continue with his anticipating the 50th anniversary of his initial visit to Galápagos in 1954. The energetic and accomplished zoologist's reaction to seeing growing problems in Galápagos in that early visit was to return to Europe and immediately begin raising the awareness of Galápagos among scientific leaders and the Government of Ecuador. Through the organization that would eventually be known as the International Union for Conservation of Nature (IUCN), UNESCO, and a few other key organizations, funds were raised to send Professor Eibl-Eibesfeldt, Dr. Robert Bowman, a San Francisco ornithologist, and other expedition members back to Galápagos to inventory the situation and biological problems. Dr. Bowman had visited Galápagos as part of his PhD research even before Eibl-Eibesfeldt's trip, but they independently developed a shared a mutual sense of commitment to protecting Galápagos. The results of their trip in 1957 were summarized and brought before an International Congress of Zoology in 1958, giving the problem visibility and resulting in a small but important band of prominent people formally organizing the Charles Darwin Foundation for the Galápagos Isles through its incorporation in Brussels 23 July 1959. Professor Eibl-Eibesfeldt is a widely honored scientist and formerly headed his own research institute of human ethnology within the Max Planck Institute (Andechs), but although now retired, he still regularly finds time to continue his prolific writings, attend meetings of CDF, search for financial support, and visit Galápagos.

Dr. Robert I. Bowman, noted ornithologist who conducted exhaustive early field studies of Darwin's Finches beginning in 1952 and participated in that initial pre-foundation Galápagos Expedition in 1957, was a strong voice in sounding serious concerns for the future of the Islands' biota. Hence, he too springs to mind as one of our enduring friends and collaborators. Robert Bowman, now retired from San Francisco State University and residing in Berkeley, California, suffered a threat to his health in recent years but is reported to be recovering with reduced activities. He was not only instrumental in fostering early work in Galápagos by a broad spectrum of investigators, but also through his own pivotal analyses of Darwin's Finches in the Islands, contributed to critical discussions of evolutionary theory. He has remained involved in Galápagos, serving as ornithological mentor, organizing meetings, and assisting in a plethora of other ways while residing in the San Francisco area. He was the recent recipient (2001) of the Fellow's Medal of the California Academy of Sciences, an Institution with a long and pivotal role in Galápagos science. Those who would like to probe the details of Eibl-Eibesfeldt's and Bowman's respective and intertwined roles in the Foundation's and Park's origins are referred to E. J. Larson's book, *Evolution's Workshop, God and Science on the Galápagos Islands,* published by Basic Books (2001) and the diverse sources mentioned therein, as well as to G. T. Corley Smith's history of the Charles Darwin Foundation 1959-1988 (*Noticias de Galápagos* No. 49, 1990). While space limitations prevent me from mentioning many others who have played pivotal roles in the early days of the Foundation, it should be obvious that the long-term involvement and commitment of many prominent and busy individuals committed to this unique set of ecosystems have been and continue to be important in the successful activities of the Charles Darwin Foundation.

Acknowledging the "silver-backed veterans" of the Charles Darwin Foundation prompts me to pass on information on younger generations that have worked with the Charles Darwin Foundation. A recent compilation estimated that approximately 2,000 students, volunteers, and young scientists have received valuable research training and indelible professional experiences through contact with both science and applied management in real world situations in the scientific and educational programs of the Charles Darwin Foundation. These people and the many scientists who came for independent investigations constitute an invaluable resource for Ecuador, other Latin American countries, and the rest of the world at the same time as they made invaluable contributions to conservation in Galápagos.

RE-ORGANIZATION OF THE CHARLES DARWIN FOUNDATION

Like any successful institution spanning decades of activity, the CDF has seen changes in its capabilities, opportunities, and challenges. In keeping with a desire to continue its service to the conservation of the Galápagos Islands, changes were considered, planned, and accomplished in recent years. In brief, after a major institutional re-examination and strategic planning process, a set of changes involving a streamlined executive leadership structure, modification of by-laws, and strengthening of key support in the form of an Executive leadership team for the Foundation were approved by the Foundation's membership in 1998 and placed in motion through the Foundation's Board in 1999. The new leadership structure called for the naming of an Executive Director who would oversee all Foundation activities with the assistance of an executive leadership team comprised of senior people in the areas of: 1) Financial Administration; 2) Institutional Development; 3) Communications, Education and Participation; 4) Science; and 5) National and International Affairs. Oversight of Foundation affairs was also planned with the election of nine board members from and by the Foundation's General Assembly membership while ensuring that one slot each was specifically delegated for representatives from Belgium (where the CDF is officially incorporated) and the Government of Ecuador (whose strong support and involvement are so essential to Foundation programs). The new Board will elect its President from the group of nine members rather than the President being elected by the general membership. The new Board structure in intended to promote active involvement, facilitate decision-making, and foster responsiveness in an increasingly complex Charles Darwin Foundation. Much progress has been made and the Charles Darwin Foundation is constantly changing to better address its mission in Galapagos science and conservation working with the Galapagos National Park, other entities of the Ecuadorian government and a broad array of international organizations and scientific authorities.

NOTABLE LOSSES FROM THE GALÁPAGOS FAMILY

It was with considerable sadness that the CDF learned of the deaths of two long-term members of the CDF family in 2001. Gayle Davis-Merlen was one of a core group of CDF employees present when I first worked at the Research Station in 1976. She had come that year with responsibilities to design and build public exhibits and to deliver the educational messages of the CDF's activities to Station visitors. She certainly developed an unwavering allegiance to Galápagos, and from her arrival until her death on 27 May 2001 following a long illness, Gayle held a variety of responsibilities and posts in Galápagos which utilized her communication, editorial, and educational skills. Linda Cayot has prepared a tribute to Gayle's involvement in Galápagos, included in this issue of *Noticias*.

Fernando Ortiz-Crespo, a professor at the Catholic University in Quito, was one of my first contacts within the Quito scholarly community when I began biological research in Ecuador in 1969. He helped orient and guide this naïve and young biologist in planning trips to remote Andean and Amazonian regions and provided logistical support; we were later to come in frequent contact when I began work in Galápagos. As a young man, Fernando participated in the Galápagos International Science Expedition in 1964 and hence, was present at the inauguration of the Foundation's incipient Research Station. While primarily involved in mainland teaching, administration, and research, over the years Fernando retained an interest and involvement in Galápagos and the Charles Darwin Foundation. He served as a Foundation member, headed up the Ecuadorian government's Galápagos Institute for several years, and just as importantly, supported programs and students in Galápagos both as a university professor and as an executive of Ecuador's Science and Technology Foundation. Fernando Ortiz-Crespo died in an unfortunate boating accident on Lake Mica in Antisana, Ecuador, on 13 September 2001. For details of Fernando's career, the reader is referred to an obituary entitled *Fernando I. Ortiz-Crespo (1942-2001)* published in *Ibis* 144:371-372 which was written by CDF board member Tjitte de Vries.

INTERNATIONAL RECOGNITION OF THE CDF

On 27 November 2001, the World Wildlife Fund announced its award of the J. Paul Getty Wildlife Conservation Prize to the Charles Darwin Foundation in recognition of its outstanding contributions to conservation in Galápagos. The award was conveyed in a special ceremony involving several Charles Darwin Foundation representatives and distinguished guests in Quito, Ecuador.

The Society for Conservation Biology presented a Distinguished Service Award to the Charles Darwin Foundation, accepted by the Foundation President, at its annual meeting in Canterbury, England, on 18 July 2002. This award was given in recognition of exemplary work for the conservation of the Galápagos Islands.

On 8 July 2002 , the Expo '90 Foundation in Japan announced the award of the International Cosmos Prize to the CDF. This prize is awarded annually to an individual or organization for research contributing to significant understanding of relationships among living organisms, the interdependence of life, and the global environment. The prize was accepted by the Executive Director of CDF at a special ceremony and series of commemorative lectures in Japan in October 2002.

These awards signify a widespread recognition and appreciation of the accomplishments and goals of the Charles Darwin Foundation. Credit for achievements must go to the entire staff of the Charles Darwin Foundation , its officers, members, the Charles Darwin Foundation's constant partners in conservation the Galapagos National Park, other collaborators, and financial supporters; each and everyone is important to the advancement of conservation work in Galápagos.

Thomas H. Fritts E-mail: frittstom@cs.com

FUNDACION CHARLES DARWIN PARA LAS ISLAS GALÁPAGOS
CHARLES DARWIN FOUNDATION FOR THE GALAPAGOS ISLANDS
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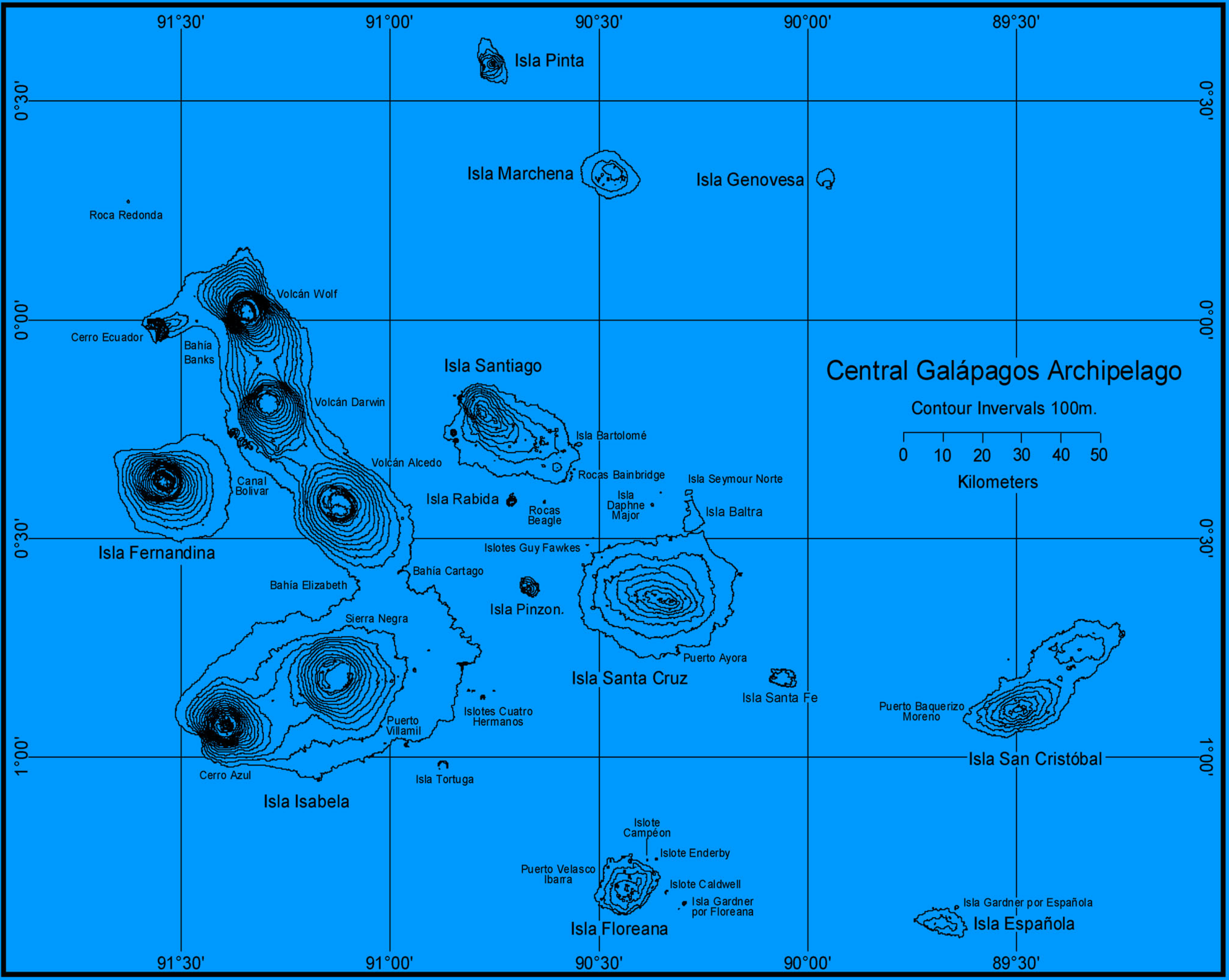
Charles Darwin Foundation for the Galapagos Islands (www.darwinfoundation.org), P.O. Box: 17 01- 3891, Quito, Ecuador

Central Galápagos Archipelago
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