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

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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 22-24ºC, about 2-3º 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,

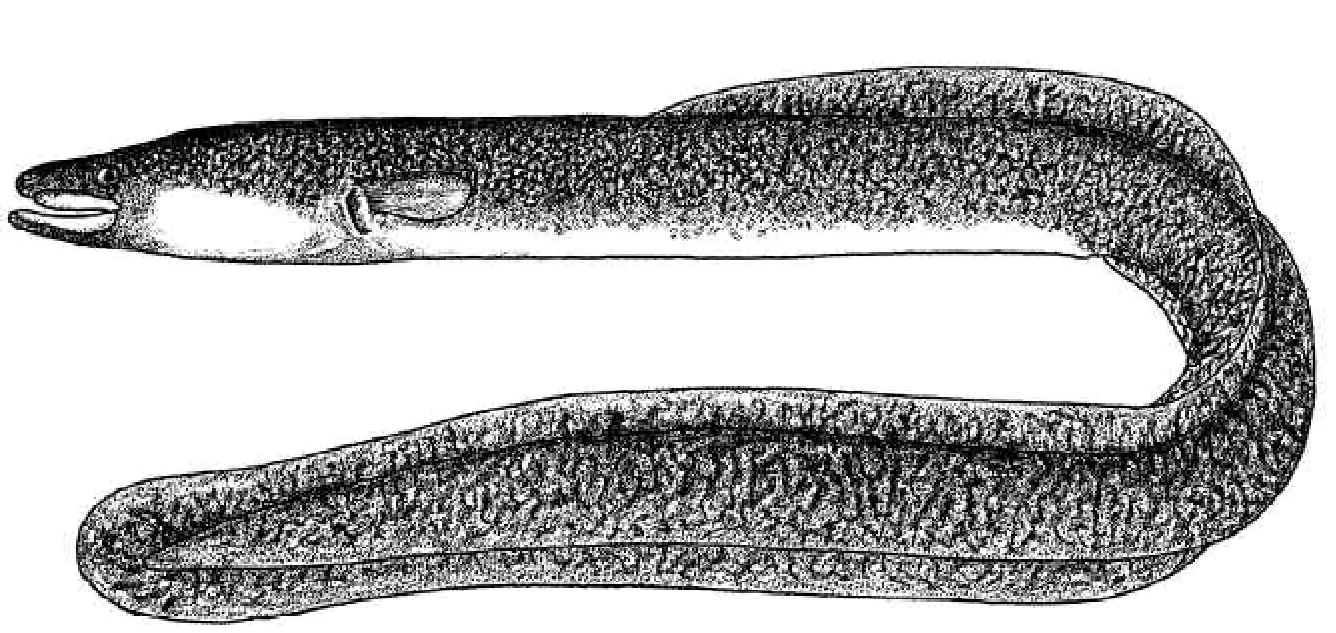

Figure 3. *Anguilla marmorata* Quoy and Gaimard, the Giant mottled freshwater eel.

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.

ACKNOWLEDGMENTS

We wish to thank many people for their assistance with this project, including but not limited to: Kleber Garcia for collecting *"El Monstruo"*; our colleagues Jerson Moreno, Carmen Chasiluisa, Fernando Rivera, and Robert Bensted-Smith at CDRS for their continuing support; Eliecer Cruz and Mario Piu at the Galápagos National Park Service for permission to perform research in the National Park and the Marine Reserve; Jacinto Gordillo and Julian Fitter for their advice and photographs; Dora Gruber Werder of Hotel Ballena Azúl for her advice and assistance; Michael Lamboeuf of FAO for permission to use Figure 3; the staff of the California Academy of Sciences Ichthyology Department for assistance with specimens; Mysi Hoang for assistance with illustrations; David G. Smith of the Smithsonian Institution and Joseph L. Reid and Richard H. Rosenblatt of the Scripps Institution of Oceanography for advice on our manuscript; and the David and Lucile Packard Foundation, the Pew Charitable Trust through its Pew Fellow Program in Marine Conservation to RHB, and the Fundación El Viejo for assistance with our Galápagos research and conservation projects.

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

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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.