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Invertebrate research overview: 1. Terrestrial arthropods

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Despite greatly outnumbering the vertebrates, both in number of species and in population densities, the terrestrial invertebrates of Galápagos have never aroused the same interest and attention as that given to their vertebrate neighbours, which made the archipelago world-famous.

This situation changed significantly, however, during the 1980s when three independent, long-term study programmes were undertaken on the systematics and evolutionary ecology of the terrestrial arthropods of the archipelago. The teams carrying out these programmes have coordinated their research projects so that they now complement each other. They are as follows:

1) Since 1982, the Belgian team of the Royal Belgian Institute for Natural Sciences, in Brussels, focusing on arachnids (L. Baert, J-P. Maelfait), carabid (K. Desender) and chrysomelid (P. Verdyck) beetles, and isopods;
2) Since 1985, the Canadian team of Carleton University, Ottawa, comprising Professor Stewart Peck and several of his colleagues, focusing on several arthropod groups, especially beetles;
3) Since 1985, the Austrian team of the University of Innsbruck, comprising Heinrich and Irene Schatz, focusing on oribatoid mites and tenebrionid beetles.

The primary goal of these studies was to compile an inventory of the species of terrestrial arthropods living in the archipelago. To that end, for example, the Belgian team has sampled more than 500 different localities from the coastlines up to the top of all major islands and volcanoes. A database has been constructed containing the most important data usable in analyses and syntheses of ecological, biogeographical, and evolutionary patterns in the composition, structure, dynamics, distribution, and origins of the faunas.

Possible cases of parapatric speciation were found in sister species of carabid beetles and lycosid spiders with adjacent ranges but without obvious ecological or geographic barriers between them. This persuaded the Belgian team in 1996 to start molecular biological studies (allozyme electrophoresis and DNA-sequencing) to investigate the population genetics of these particular beetle and spider families. Interesting results have already been obtained on the *Hogna* lycosid spider, the *Calosoma* ground beetle, and the *Nesaecrepidia* chrysomelid beetle. It is worth noting that El Niño events may play an important role in this kind of speciation on Galápagos. In addition to its value in population genetics, the ecological and biological data that is being gathered can be of great use in formulating the management policies of the Galápagos National Park and for studies of faunal changes occurring due to human activities.

Biodiversity of the terrestrial arthropods of Galápagos

Before the Belgian team's studies started in 1982, only 70 spider species and less than 900 insect species were known. Thanks to the collecting efforts of the three teams mentioned above, aided by newly developed capture techniques such as pitfall, malaise, and flight interception traps, the number of terrestrial arthropod species has more than doubled (see Table 1).

A great many of the known arthropod species certainly colonized the archipelago by natural means, but it is obvious that a number have been introduced since man discovered and settled in the islands. It is, however, often difficult to determine whether a species that is not recognized as an endemic one has actually been introduced by man or not. (No doubts exist in the case of man-dependent immigrants or anthropogenic species.)

As a result of our work done in the 1980s we now know more or less the actual insect and spider fauna of Galápagos very well. In the course of each visit by the Belgian team to Galápagos they monitor on Santa Cruz Island, regardless of the duration of their stay, a north-south transect along the road to Baltra and a transect along the Bellavista-Cerro Crocker trail by means of pitfall trapping. This enables them to follow on a long-term basis the evolution of the populations of common species, and even detect new introductions, as is shown in the following overview.

Table 1 — Number of species of the most important terrestrial arthropod groups (from LINSLEY & USINGER, 1966; ROTH & CRAIG, 1970; LINSLEY, 1977; PECK, 1991; BAERT *et al.*, 1995; and PECK, 1996).

	1980	*1991*	*1997*	*Introduced species**
Insecta	883	1592	1748	212+
Scorpiones	2	2	2	
Pedipalpi		1	1	
Schizomida		1	1	1
Solifugae		1	1	
Pseudoscorpiones		16	18	
Opiliones		1	1	
Araneae	70	152	154	? (>1990:2)
Acari	38	192	248+	
Amphipoda		4	4	
Isopoda		17	17	7
Other Crustacea			17	
Chilopoda	10	13	13	5
Diplopoda	2	9	9	8
Symphyla		1	1	1
Onychophora			1	1
TOTAL	1005	2001	2236+	

* from PECK, 1996

Overview of recent arthropod introductions in the past ten years

1987. Introduction of the wasp *Polistes versicolor* in Floreana followed by its quick dispersal over most of the islands (ABEDRABBO, 1991).

1988. Wasmannia auropunctata (the little fire ant) is reported from Marchena (BAERT *et al.*, field trip report, unpublished, 1988).

1989. A spider, *Anyphaenoides octodentata*, is introduced in San Cristóbal. Our monitoring reveals its presence in Santa Cruz in 1990. This species probably competes with the endemic species *A. pacifica*. The black fly, *Simulium bipunctatum,* is introduced in San Cristóbal.

1992. Our monitoring of Santa Cruz reveals the presence of two new introductions in the agricultural zone: a nesticid spider, *Eidmanella pallida*, and a small brown cockroach *Anoplecta lateralis*. In the following years both species spread throughout the other vegetation zones. *Anyphaenoides octodentata* is found in Floreana.

1994. Introduction of the wasp, *Brachygastra lechuguana*, in Santa Cruz (Anonymous, 1994).

1996. Population explosion of the introduced cottony cushion scale, *Icerya purchasi* (first seen on San Cristóbal in 1982) which has invaded at least nine islands, where it attacks or kills more than 20 plant species. Also a population explosion of the introduced diplopod, *Asiomorpha coarctata*, at an altitude of between 350 and 600 metres (this species was first recorded in Academy Bay, Santa Cruz, in 1958). The spider, *E. pallida*, is found on San Cristóbal. *Anyphaenoides octodentata* is found on Sierra Negra volcano, Isabela Island.

1997. The black fly is found on Santiago.

1998. Population explosion of the cockroach *Anoplecta lateralis*, the diplopod *Asiomorpha coarctata,* and the little fire ant *Wasmannia auropunctata* on Santa Cruz. All are very common from the coast up to the pampa zone. *Asiomorpha coarctata* is found in the highlands of Santiago.

It seems clear that many introductions by humans are associated with transport of merchandise by boat and aircraft from the mainland of Ecuador. Food products such as fruit and vegetables are very likely to carry unwanted invertebrates. The nonchalant manner in which cargo is unloaded needs to be radically changed, with such activities subject to much tighter control and supervision. All goods should if necessary be treated so as to ensure that they are free of alien species. Until there is better control of the coming and going of merchandise the danger of potential new introductions will remain.

Tourism also has an adverse effect on the local fauna and flora. Travel between islands gives a helping hand to the spread of well established isolated populations of closely related taxa, thus causing "genetic pollution". The lights of tourist or other boats anchored in shallow bays close to the coast while spending the night between island visits can attract large numbers of flying insects including moths, ants, flies, etc. A recent study revealed

that flying insects were much less attracted to yellow neon light than white light. The use of such lighting should therefore be compulsory on every boat navigating in the waters of Galápagos.

I would like to emphasize the possible importance of El Niño events in the colonization processes. They may increase the number of possible colonization events, such as rafting of vegetation islets from mainland Ecuador towards Galápagos due to increased rainfall on the mainland, but also enable a quick and firm establishment of newly arrived species in the otherwise harsh environments of Galápagos. They can also trigger population explosions of already established introduced species, as seen above with the diplopod *Asiomorpha coarctata*. In this way such events may well have been the cause of primordial steps in the evolution and adaptive radiation of many invertebrates of the archipelago.

Current activities of the Charles Darwin Research Station with regard to terrestrial arthropods

The post of staff entomologist at the CDRS was only created in 1981. This was certainly due to the increasing problems caused by the fire ant *Wasmannia auropunctata*. Dr Yael Lubin, the entomologist working at that time in the islands, had to focus her research upon the bioeconomics of this pest species. Yael Lubin left the islands after the El Niño of 1983. From 1987 until 1993 the role of entomologist was taken over by Sandra Abedrabbo, who focused her research on *Wasmannia* and *Polistes*, on monitoring different vegetation zones of Santa Cruz, and in starting to organize the Museum.

At present [Spring 1998] two scientists in the Charles Darwin Research Station's Department of Terrestrial Plants, Invertebrates & Quarantine are concentrating on several projects which reflect the current priorities of the Entomology Section.

Dr Charlotte Causton from Great Britain is responsible for:

- The Quarantine programme, for establishing the system of monitoring the Agriculture Zone and other parts of the island of Santa Cruz in search of possible new introduced species.
- The Cottony Cushion Scale programme, including studying the ecology, distribution, and effects of the species in Galápagos; and preparing the ground for eventual biological control of this pest species by the introduction of a coccinelid beetle or "ladybird", *Rodalia cardinalis*. She has made an extensive literature study of biological control and is overseeing construction of the new hermetically-sealed laboratory for performing test experiments with the beetle.

Lic. Lázaro Roque from Ecuador is responsible for various eradication and monitoring programmes, such as:

- Monitoring programme for the introduced *Polistes* and *Brachygastra* wasps.
- Eradication programme for the fire ant *Wasmannia* on Marchena island.
- Monitoring programme for the black fly (Simulidae) on Santiago and San Cristóbal.
- Long-term monitoring of the Santa Cruz vegetation zones to observe eventual new introductions, and long-term monitoring of Volcán Alcedo in the framework of the goat eradication programme.
- Museum development.

But all these activities need finance for research equipment; personnel; technical aid in the monitoring programmes; and for curatorial work in the museum. It is obvious that all available energy is focused on those introduced arthropod species which by one means or another (e.g. stinging people, destroying valuable plants) make their presence clear to man. But what about the equally obvious but relatively inoffensive introduced spider species cited earlier, and the small diplopod and the cockroach?

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