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El Niño - events and the establishment of ground beetles in the Galápagos Archipelago

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Abstract

'El Niño' - events have increasingly been interpreted on a global scale, linking the occurrence of extreme drought in the Indo-Pacific region to unusually warm conditions with heavy rains on the normally arid western coast of tropical South America. Such events profoundly influence local conditions, e.g. by provoking humid years in the otherwise arid to very arid Galápagos Archipelago. These islands are situated in the middle of the eastwards shifting climatological anomalies.
For several years we have been studying the beetle and spider fauna of Galápagos. About 40 carabid species are known from these islands, 90 % of which appear to be real endemics. Our detailed field data suggest that two species have been introduced recently and unintentionally, presumably during the extreme 'El Niño' - event of 1982/1983. It is argued that such events are of utmost importance not only by increasing the number of possible colonization events (increased rafting of vegetation islets from Ecuador towards Galápagos), but especially by enabling a quick and firm establishment of newly arriving species in the otherwise harsh environments of Galápagos. In this way such events may well have been a primordial step in the evolution and adaptive radiation of many carabids (and possibly many other invertebrates) of the archipelago. Global changes in the frequency and amplitude of 'El Niño' - events, along with a recently much more increased human traffic to Galápagos, in this way are influencing or even disturbing the interesting fauna of these isolated islands.
Key-words: carabid beetles, Galápagos Islands, El Niño, evolution

Résumé

Les phénomènes 'El Niño' sont de plus en plus interpretés comme des événements s'oppérant à l'échelle mondiale, corrélant l'apparition d'extrêmes sécheresses dans la région Indo-Pacifique avec de fortes pluies dans le nord-ouest de l'Amérique du Sud, région normalement aride.
Ces phénomènes influencent profondémment les conditions locales, p.ex. en provoquant des années très humides dans l'archipel des Galápagos, région aride à très aride. Ces îles se trouvent en plein centre de la progression est orientale de ces anomalies climatologiques.
Nous étudions depuis plusieurs années la faune carabidologique et arachnologique des Galápagos. Près de 40 espèces de coléoptères carabiques sont connues dont 90% semblent être de vrais endémiques. Notre travail de terrain détaillé suggère que deux espèces ont récemment été introduites involontairement, et probablement durant l'extrême 'El Niño' de 1982-83. Il est argumenté que de tels événements sont de grande importance, non seulement en augmentant le nombre de colonisations possibles (augmentation du nombre d'îlots flottants se dirigeant de l'Equateur vers les Galápagos), mais également en assurant l'établissement ferme et rapide d'espèces nouvellement arrivées dans un environnement normalement extrêmement hostile. De ce fait, ces phénomènes peuvent avoir été un pas primordial dans l'évolution et la radiation adaptive de beaucoup de carabes (et possiblement de beaucoup d'autres invertébrés) de l'archipel.
Des changements globaux dans la fréquence et l'amplitude des phénomènes 'El Niño', ainsi qu'une augmentation du trafic humain vers les îles, influencent certainement et même perturbent la faune intéressante de ces îles isolées.
Mots-clés: Coléoptères Carabiques, Iles Galápagos, El Niño, évolution

Introduction: El Niño and the Galápagos Archipelago

'El Niño' - events have increasingly been interpreted on a global scale, linking the occurrence of extreme drought in the Indo-Pacific region to unusually warm conditions with heavy rains on the normally arid western coast of tropical South America. Such events occur irregularly and differ much in strength and amplitude.
The El Niño - phenomenon is the result of a series of interacting atmospherical and oceanic changes. Warming of the surface waters in the central and eastern Pacific tends to move atmospheric convections and associated rainfall away from their normal position in the western Pacific (Fig. 1, modified from HANSEN, 1990). As a result, the region with heavy rainfall, usually lying across the Indo-Pacific 'island continent' is displaced towards the central Pacific and sometimes even shifts further eastward to Ecuador and northern Peru. These changes in the pattern of atmospheric convections and rainfall are accompagnied by a change in the strength and direction of the normally westward blowing south-Pacific tradewinds which become eastward. This change in prevailing surface winds in its turn generates an eastward travelling equatorial Kelvin wave, which reaches – during strong events – Galápagos and the western coast of South America. In El Niño - circumstances this wave is

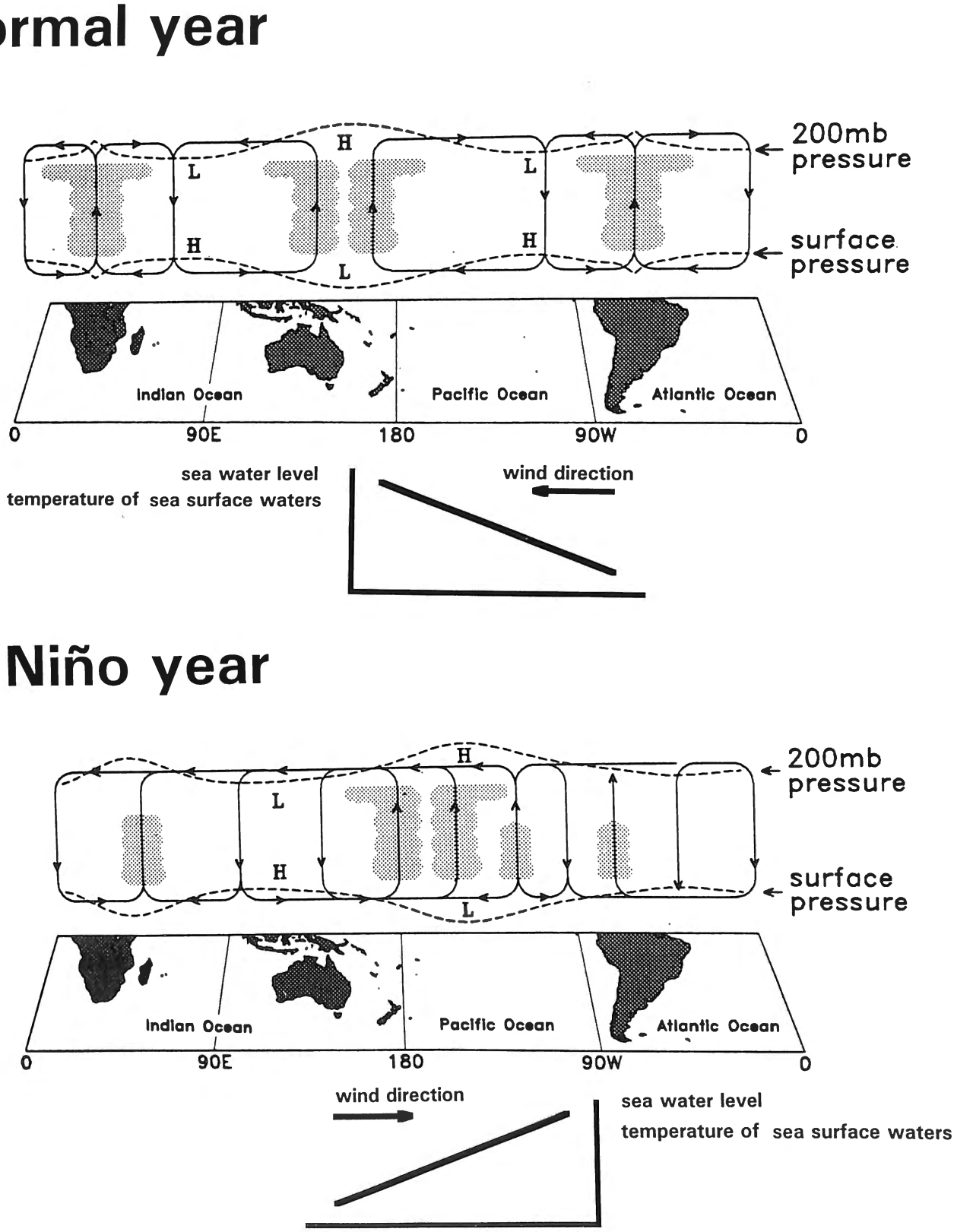

Fig. 1. – Schematic representation of regions of strong tropical rainfall during 'El Niño' years as compared to normal years (modified from HANSEN, 1990).

associated with an elevation of the sea water level up to 44 cm in Galápagos (due to the absence or even the reverse of normally westward blowing winds), with unusually warm sea surface waters and with extensive rains (HANSEN, 1990).
El Niño - events profoundly influence local conditions, e.g. by provoking humid years in the otherwise arid to very arid Galápagos Archipelago. These islands lie at the edge of the Central Pacific dry zone and are situated in the middle of the eastward shifting climatological anomalies during El Niño - events. Such events recur irregularly in Galápagos. During this century the El Niño - event with probably most impact upon the Galápagos took place during 1982/83. This extraordinary event has been described as 'the strongest oceanographic warming trend off the coast of South America this century' (HANSEN, 1990).
The Galápagos Archipelago lies astride the equator, roughly 1000 Km west of Ecuador. The islands are oceanic and strictly volcanic in origin, being the outpourings from the Galápagos hotspot, now situated near the western islands. In general the southeastern islands appear to be the oldest (near 3 million years old) whereas the northern and western islands appear to be the youngest (no rocks dated older than 0.7 million years) (SIMKIN, 1984).

Distribution types of carabid beetles in Galápagos

For several years we have been studying the beetle and spider fauna of Galápagos (cfr. DESENDER et al, 1992 for a recent account and for more information on the islands). One of our main interests is the evolutionary ecology of the carabid beetle species, studied by means of systematic, biogeographic, ecological and population genetic approaches.
Since our recent expeditions, carabids are now known from all major islands and even from several very small or satellite islands. About 40 species belonging to 11 genera are known to us from the islands; 90 % of these species appear to be real endemics, limited in their occurrence to one or several islands of the archipelago. Two species only are natives, also occurring on the South American mainland. Our detailed field data suggest that two more species, *Cicindela trifasciata* and *Pentagonica flavipes,* recently have established themselves in the archipelago. The arguments for this conclusion will now be elaborated. All our detailed data on these two species, new for the Galápagos fauna, will be compiled hereafter, as well as those on the endemic *Cicindela galapagoensis* (older data compiled by REICHARDT, 1976; completed with data from FRANZ, 1985 and all our recent data).

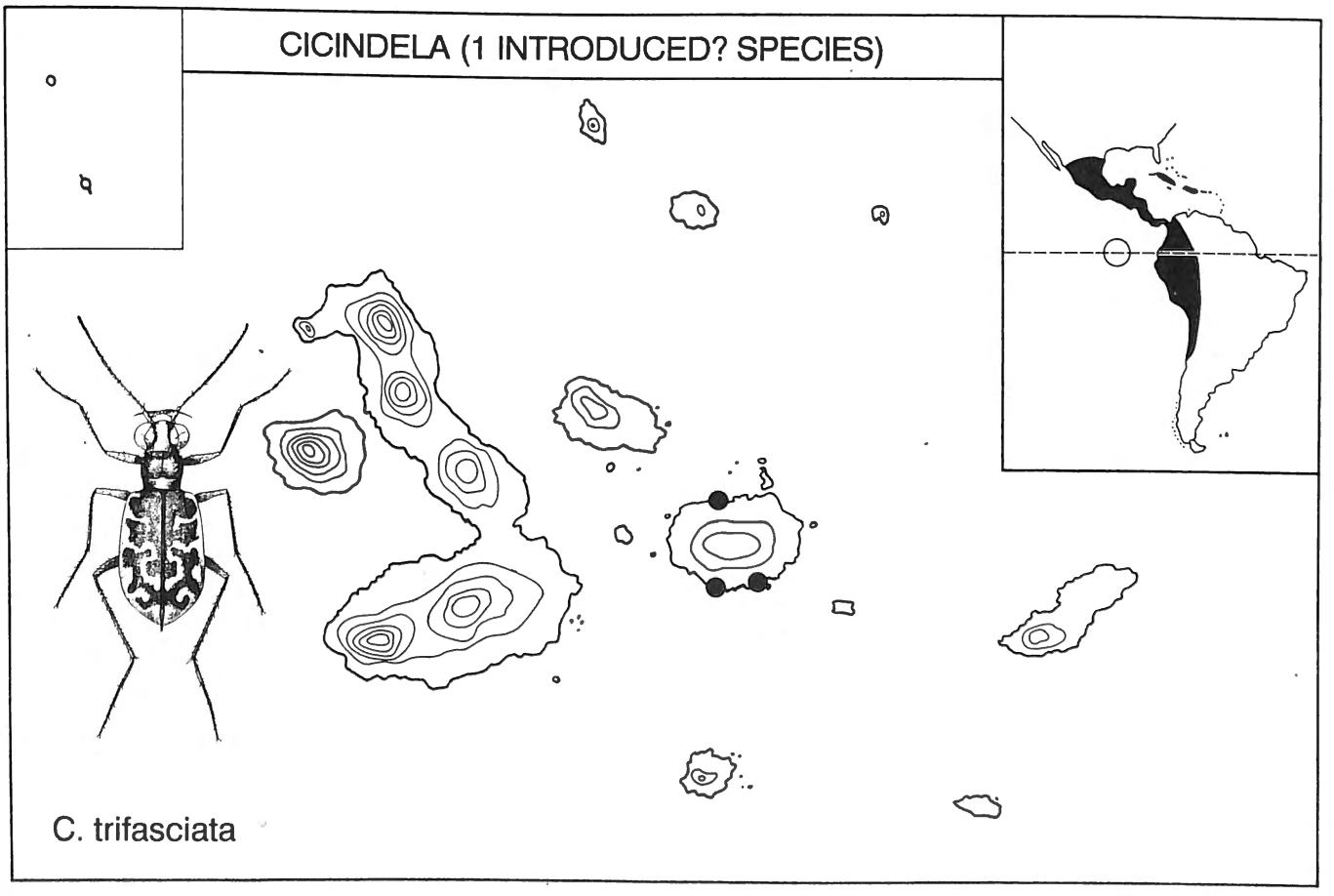

Fig. 2. – Geographical distribution of *Cicindela trifasciata* in the Galápagos Archipelago.

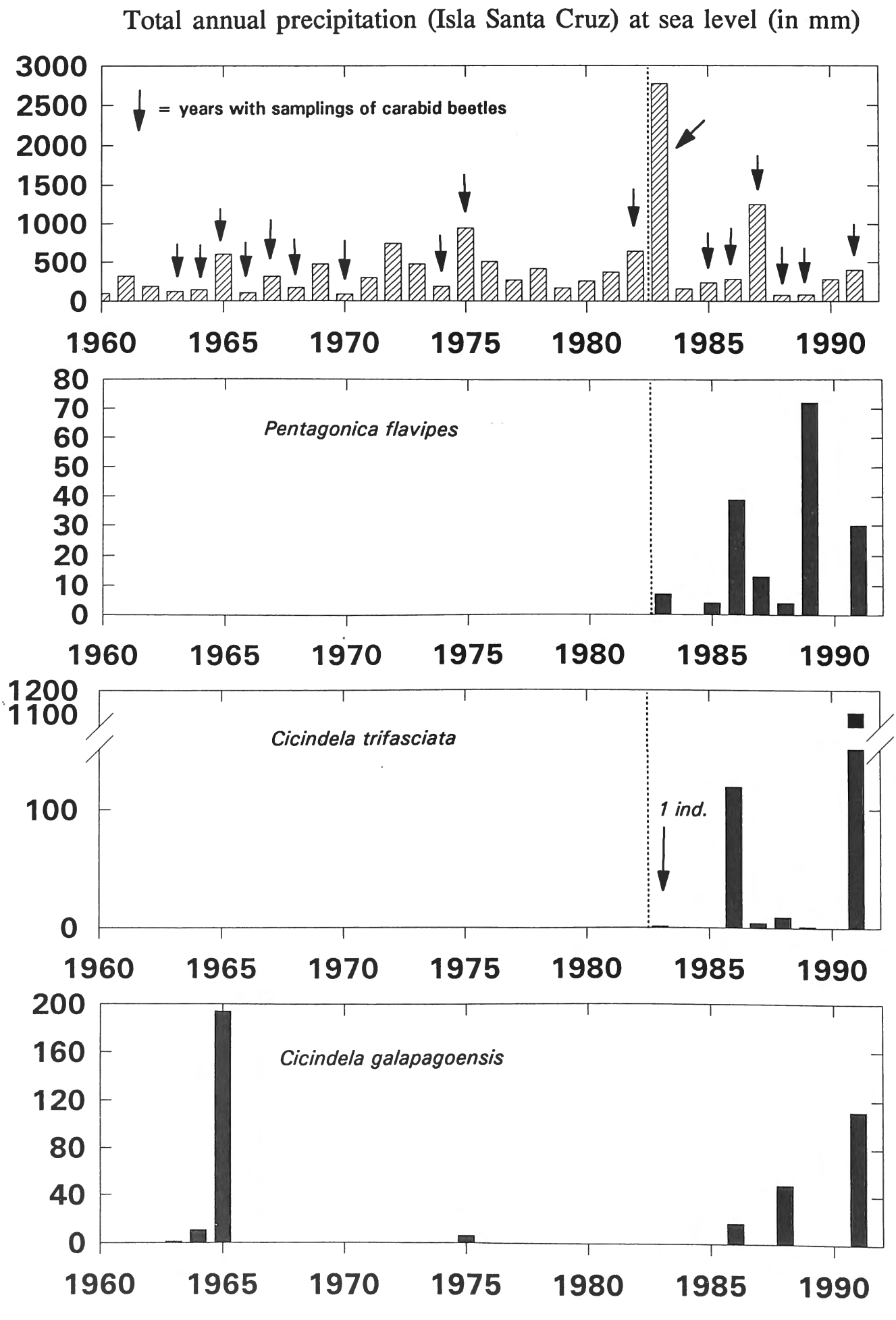
Total annual precipitation (Isla Santa Cruz) at sea level (in mm)
3000
2500
2000
1500
1000
500
0
= years with samplings of carabid beetles
1960
1965
1970
1975
1980
1985
1990
80
70
60
50
40
30
20
10
0
Pentagonica flavipes
1200
1100
100
0
Cicindela trifasciata
1 ind.
200
160
120
80
40
0
Cicindela galapagoensis

Table 1. Years when carabid beetles have been collected in Galápagos; number of collected individuals of two presumably introduced species from the South American mainland (*Cicindela trifasciata* and *Pentagonica flavipes*) along with the numbers of an endemic cicindelid species (*Cicindela galapagoensis*).

YEAR	extensive collection	*Cicindela galapagoensis*	*Cicindela trifasciata*	*Pentagonica flavipes*
1835				
1888				
1891				
1898				
1899				
1905				
1906	**	26		
1923				
1925				
1932				
1935		9		
1939				
1941				
1963		1		
1964	**	11		
1965	***	194		
1966				
1967				
1968				
1970	**			
1974	**			
1975	***	6		
1982				
1983			1	7
1985	**			4
1986	***	17	118	39
1987	***		4	13
1988	***	49	9	4
1989	***		1	72
1991	***	111	1108	30

Fig. 3. – Total annual precipitation on Isla Santa Cruz (in mm, at sea level; upper graph) as an indication of the strength of 'El Niño' events since 1960 together with a compilation of all known data (number of individuals) for the species *Pentagonica flavipes*, *Cicindela trifasciata* and *Cicindela galapagoensis* from Galápagos.

The establishment of *Cicindela trifasciata* and *Pentagonica flavipes* in Galápagos

C. trifasciata is known from the western part of Central and South America (BELL, 1985; Fig. 2). In Galápagos it only occurs in lagoon and salt marsh areas of the centrally located island Santa Cruz, together with the endemic *C. galapagoensis*, which occurs in the same habitat but also on many other islands of Galápagos (cfr. DESENDER et al., 1992). Both cicindelid species fly readily at night and are then collected at light traps.
Our data on *C. trifasciata* show that it has only been collected since 1983, although its habitat was prospected on many earlier occasions (cfr. Table 1 and Fig. 3). The first individual of *C. trifasciata* was collected at the end of the 1982/1983 El Niño - event (cfr. Table 1 and Fig. 3, where the amplitude of this El Niño - event is visualized by plotting the available annual precipitation data from Isla Santa Cruz).
The recent evolution of the relative abundance of *C. trifasciata* in the 'Bahiá Tortuga' lagoon area (cfr. Fig. 4, Isla Santa Cruz) compared to the endemic congeneric species *C. galapagoensis* shows it has become very abundant in a short time span. It is not yet clear whether the endemic species is actually interacting with and displaced by the newcomer; all we know at the moment is that in Galápagos *C. trifasciata* seems to have established itself in a restricted number of populations, now has reached a high abundance level there and always has been found in sympatric populations with *C. galapagoensis*.

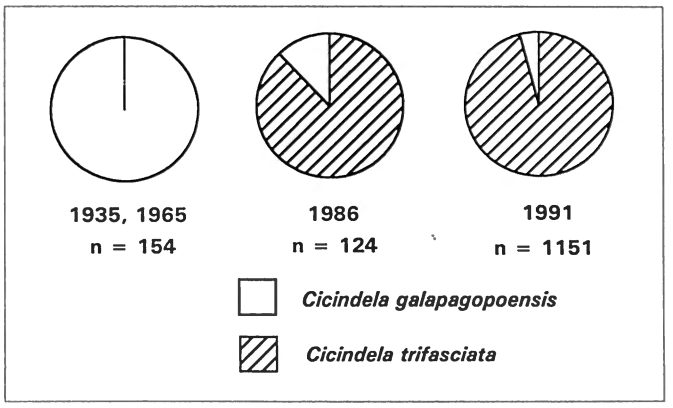

Fig. 4. – Relative abundance of *Cicindela trifasciata*, a presumably introduced species in Galápagos at the 'Bahía Tortuga' lagoon and salt marsh area (results from light trapping sessions) in comparison with the endemic *Cicindela galapagoensis*.

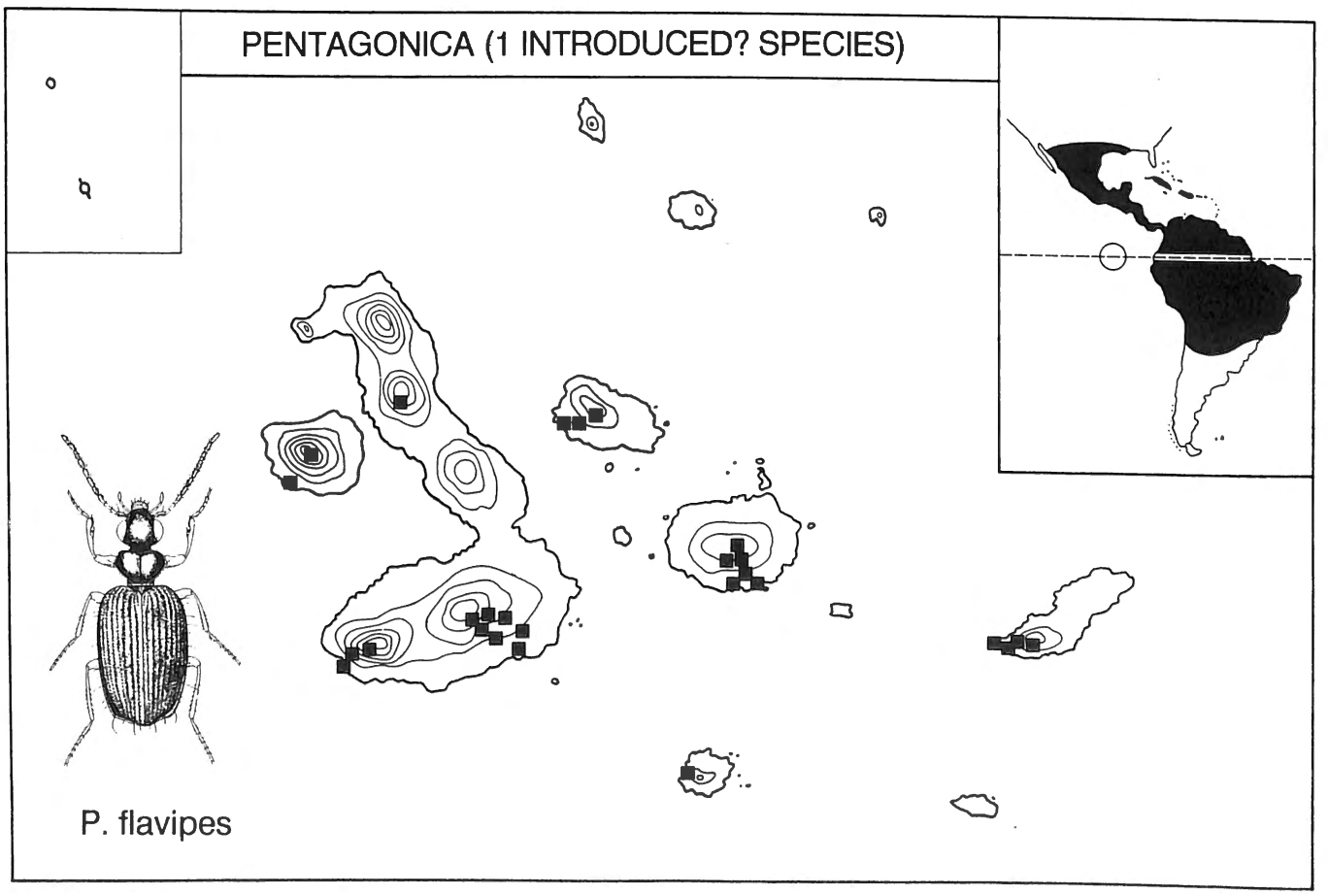

Fig. 5. – Geographical distribution of *Pentagonica flavipes* in the Galápagos Archipelago.

P. flavipes also is known from many parts of Central and South America (Fig. 5). The species is especially active during the day, regularly shows flight activity and also is caught, in small numbers, at light traps during the night.

In Galápagos it was also found for the first time during the 1982/1983 El Niño - event (cfr. Table 1, Fig. 3). Since early 1983 the number of data, different habitats and islands occupied by the species in Galápagos have augmented rapidly. By the end of the 1982/1983 El Niño the species had already been collected on three different islands of Galápagos. The species now occurs on at least 6 different islands (Fig. 5), in extremely different habitats such as mangroves, dunes and lagoon salt marshes, the lower dry arid zones with tree cacti, transition forests with a lot of epiphytes at intermediate elevation, the culture zone of Isla Santa Cruz with orchards and pastures until and including the more humid *Scalesia* zone (endemic composite trees) as well as the fern-sedge vegetation zones at higher altitude.

An altitudinal frequency distribution of all our pooled data shows the occurrence of the species at nearly each elevation along the Galápagos volcanic slopes (cfr. Fig. 6). Apparently the species mostly has been found in humid microhabitats and seems clearly hygrophilous; it has for example only been found in the dry arid zone during periods with a lot of rain, but these are exactly the periods during which invertebrate studies in Galápagos have been concentrated. For these different reasons it is very unlikely that the species' presence would have been overlooked earlier in Galápagos.

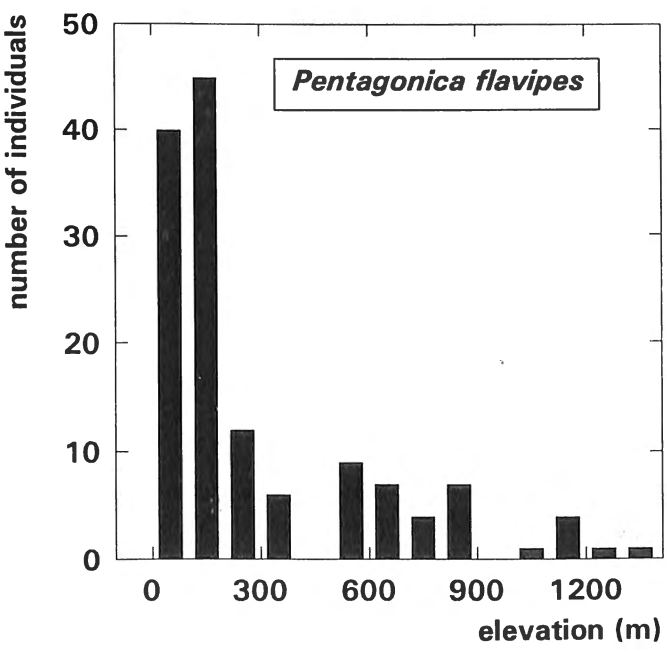

Fig. 6. – Altitudinal frequency distribution of *Pentagonica flavipes* on different islands of the Galápagos Archipelago (all data pooled).

Conclusion

We conclude that these species presumably have been introduced in the archipelago during the extreme El Niño - event of 1982/1983. According to meteorologists this was most probably the strongest El Niño of our century.

Whether the species arrived by natural means from the mainland (dispersal by flight or rafting on vegetation islets) or by 'public transport' is not yet clear, although the restricted occurrence of *C. trifasciata* on Isla Santa Cruz (the central island most involved in human transport for tourism and local inhabitants) points towards an introduction by man. These examples thus most probably have to be added to the growing list of recently introduced insect species in Galápagos, which are one of the major concerns for the conservation of the interesting endemic fauna.

Our data show that such extreme El Niño - events are of utmost importance not only, in the case of natural introductions, by increasing the number of possible colonization events (increased rafting of vegetation islets from Ecuador towards Galápagos due to increased inundations in the Ecuadorian lowlands), but especially by enabling a quick and firm establishment of newly arriving species in the otherwise harsh environments of Galápagos. In this way such events may well have been a primordial step in the evolution and adaptive radiation of many carabids (and possibly many other invertebrates) of the archipelago.

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