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A PRELIMINARY STUDY OF THE INVASION AND DISPERSAL OF *DIGITONTHOPHAGUS GAZELLA* (FABRICIUS, 1787) IN MEXICO (COLEOPTERA: SCARABAEIDAE: SCARABAEINAE)

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RESUMEN

Los escarabajos coprófagos han sido usados recientemente para el control del estiércol en pastizales. Dentro de esta tónica el escarabajo afroasiático *Digitonthophagus gazella* fue introducido a Texas en 1972 por primera vez en el Continente Americano. Fue posteriormente liberado en otras partes de la Unión Americana. En 1981 se registró la primera captura en territorio mexicano. La dispersión de este organismo se ha dado a partir de dos centros de introducción en los Estados Unidos (Texas y California) y siguiendo tres frentes de penetración principal (Llanuras del Golfo de México, Altiplano Mexicano y Llanuras del Pacífico); y hasta este momento un frente de penetración secundaria, la Depresión del Balsas. Su tasa de dispersión ha sido variable, aunque en general muy alta, de tal forma que en aproximadamente 7 años ha logrado cruzar el país sobre la Vertiente Atlántica, hasta penetrar en el Petén, Guatemala, en 1987.
Palabras Clave: Scarabaeinae, Mexico, dispersión, fauna introducida.

ABSTRACT

Dung beetles have recently been used for controlling dung in pastures. Based on this fact the Afro-Asian beetle, *Digitonthophagus gazella* was introduced in Texas in 1972 for the first time in the American Continent. It was subsequently released in other parts of the U.S.A. It was recorded for the first time in 1981 in Mexico. The dispersal of this species in Mexico has radiated from two introduction sites in the U.S.A. (Texas and California) and has followed three main dispersal routes (Plains of the Gulf of Mexico, the Mexican High Plateau and the Plains of the Pacific); and up to now a secondary dispersal route, the Balsas River Depression. Its dispersal rate has been variable, although very high in general, so that in seven years it has crossed the country from one end to another along the Atlantic slope, and has invaded the Petén, Guatemala, in 1987.
Key Words: Scarabaeinae, Mexico, dispersal, introduced fauna.

INTRODUCTION

Invasions of species in a new territory are always interesting and a spectacular phenomenon. Most times, the spread process is rather fast. However, the effects these processes have on the ecological structure of native communities is a rather

poorly understood subject. Another very interesting and little analyzed process is the genetic dynamics of such a rapid spread.

Hengeveld (1989) has indicated that highly dynamic processes can have stable outcomes and as such invasions can be conceived as "temporary disturbances leading to spatial dynamism". Hengeveld (1989) suggests that invasions are then normal features of general range dynamics. Therefore, the study of these range dynamics can shed light on the ecology and biogeography of invasions and dispersal.

A very good opportunity for analyzing these geographic processes is given by the example of the beetle *Digitonthophagus gazella* (Fabricius 1787). *D. gazella* - formerly included in the genus *Onthophagus* Latreille 1802, subgenus *Digitonthophagus* Balthasar 1959, raised to generic rank by Zunino (1981) - is an Afro-Asian species that has been introduced to tropical, subtropical, arid and semi-arid regions of the world for controlling excess dung generated by cattle raising activities.

The species was first introduced in America in 1972 in Victoria and Kleber Counties, Texas, and later into other regions of Texas (Blume and Aga, 1978). They were subsequently released in southeastern California (Anderson and Loomis, 1978) in the Coachella Valley area (Indio and Indian Wells) in 1975 (Legner, 1986; Legner and Warkentin, 1991), with subsequent releases (Fig. 1) during the 1975-1977 period in the Ojai Valley, San Diego, Escondido, Valley Center, Santa Isabel, Sun City, Palm Springs, Blythe (along the Colorado River), El Centro, El Dorado, Santa María, San Fernando Valley, and at Misión Viejo Ranch (Anderson, Legner and Moon, *in litt.*), as well as in other places of the southeast in the U.S.A. where it has spread at a high rate (Fincher *et al.*, 1983). *D. gazella* has been subsequently released in other regions of the American Continent, the island of Grenada, Uruguay, Brazil and Chile (Fincher, *in litt.*)

The species expanded its range very rapidly and started invading northeastern Mexico in 1981. Since then, it has invaded the rest of Mexico at an astounding pace and has even penetrated into Guatemala. The objectives of this study were to register the advance of *D. gazella* in Mexico and to elucidate ecological and biogeographical aspects of this process.

MATERIALS AND METHODS

The recorded species localities have been obtained by personal collections and many others by personal or written communications. All records are supported by specimens deposited in several collections, with the sole exception of a 1982 record for the species at Palma Sola, Veracruz.

THE SPREAD OF *D. GAZELLA* INTO MEXICO
(Figure 1)

D. gazella was first recorded in Mexico in 1981 in the states of Nuevo León (Monterrey) and Tamaulipas (San Fernando, Carboneras, Punto Piedras, La Pesca, Lago República Española) by Lago *et al.* (1984), and in Piedras Negras, Coahuila, by Fincher *et al.* (1983). By 1982 it had been recorded in Monclova and Saltillo, state of Coahuila (L. Delgado-Castillo, *pers. comm.*). By 1984 the species had already spread to La Mesa, Chihuahua (Instituto de Biología, Univ. Nal. Autón. de México, IBUNAM); San Ignacio, Durango (Zunino & Halffter, 1988) and Palma Sola, Veracruz (Kohlmann, *unpubl.*). Regarding this last locality, Palma Sola, an anonymous reviewer indicates that the species had already been collected at this same locality in 1982. However, the fate of this material is unknown. This record could considerably alter our dispersal estimates. Until this material is found again the dispersal rate will be estimated on the basis of the 1984 collection.

The first record on the Pacific slope occurred in 1983 in Manzanillo, Colima (Bezark, *in litt.*). The same anonymous reviewer called my attention to the fact that there is another record for the same year in Michoacán. Unfortunately, he did not specify the precise locality in his review. An interesting record in the Pacific Ocean pertains to the Islas Marías, Nayarit, where *D. gazella* was recorded on the Isla María Madre and on the Isla María Magdalena in 1986 (IBUNAM).

Further important advances were recorded in 1987 along the Pacific coast in Zihuatanejo, Guerrero (L. Delgado-Castillo, *pers. comm.*) and towards the Mexican Plateau in San Luis Potosí, San Luis Potosí (J. Blackaller, *pers. comm.*). The same year, *D. gazella* was recorded from Sayaxché, Petén, in Guatemala (W. Warner, *pers. comm.*), apparently having crossed all Mexico along the Atlantic slope in approximately seven years.

During 1989, the species was recorded along the Pacific in Puerto Angel, Oaxaca (C. Deloya, *pers. comm.*) and somewhat belatedly in relation to the Petén record the following two localities: "Los Tuxtlas Biological Station", and San Andrés Tuxtla, Veracruz (IBUNAM) and Palenque, Chiapas (Barbero and López-Guerrero, 1992). Interestingly in 1991, *D. gazella* was recorded in Naranjas Road, in the Cabos Region of Baja California (R. Cunningham, *in litt.*).

The previous records follow a north to south axis. There are also records that indicate an inland spread from the Pacific and Atlantic regions. Along the Atlantic Coast, there was a record in 1990 in Tuzamapán, in the Coatepec Region, Veracruz (Barbero and López-Guerrero, 1992), that exemplifies an inroad towards the Sierra Madre Oriental. Further south on the same Atlantic slope there was a record in 1990 on Km 116, on the Tuxtepec-Palomar Highway, Oaxaca (IBUNAM).

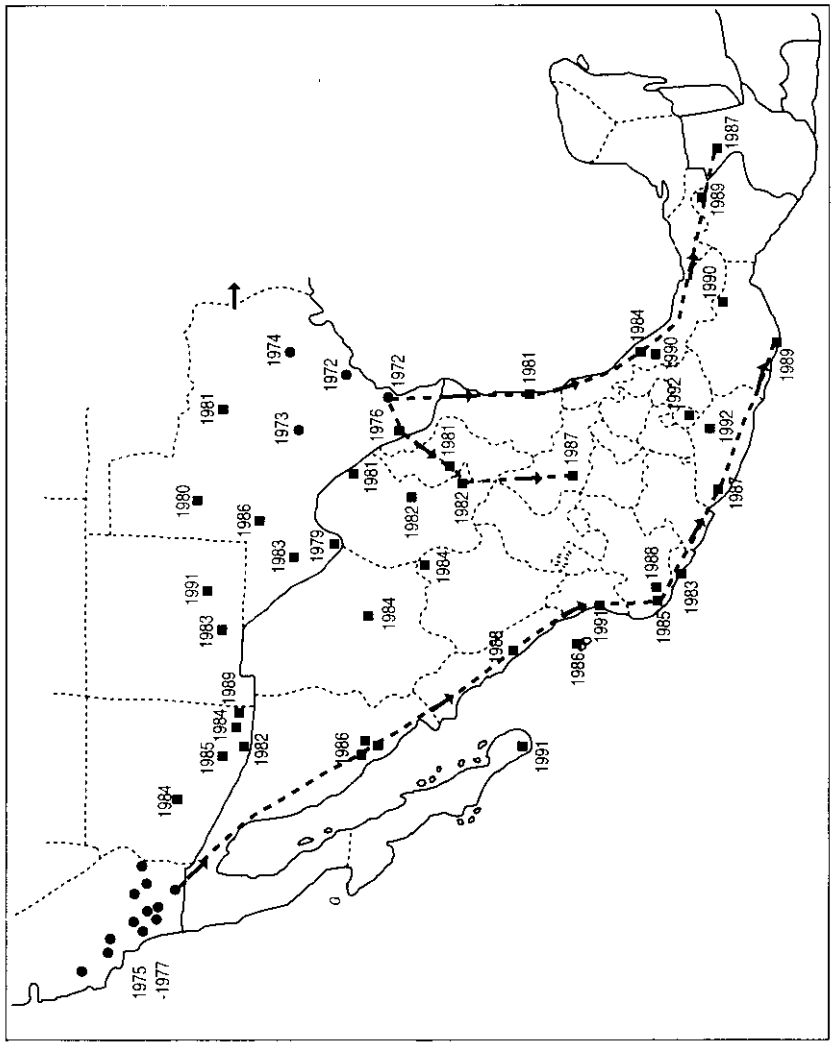


Figure 1

Introduction and dispersal of *D. gazella* in North America. Original introduction sites are indicates by dots. Subsequent collecting sites are marked by squares. Corresponding introduction and collecting years are indicated to one side. The arrow pointing to the East along the Texas/Louisiana border indicates the spread of this species to Southeastern U.S.A. The three dash/arrow lines indicate three presumed dispersal routes of *D. gazella* from the U.S.A. into Mexico that are further specified in Table I. Starting from east to west, the lines represent the Atlantic, the Mexican High Plateau and the Pacific dispersal routes. Points along the lines represent maximum fronts of advance, whereby the years correspond to the localities indicated in Table 1.

In the Pacific region there were several records for 1985 in Chamela and the near-by locality of José María Morelos, Jalisco (Morón *et al.*, 1988); and for the 1988-1990 period in Zenzontla, La Calera, Autlán, El Grullo and El Limón (Rivera-Cervantes and García-Real, 1991). The highest elevation recorded for *D. gazella* in Jalisco occurred in Autlán (1,150 m). Another record occurred in San Blas, Nayarit, in 1991 (IBUNAM). The species seems to be invading the Balsas River Depression as well, since it was collected in 1992, about 6 Km. south of Xochipala, Guerrero (J. Blackaller, *pers. comm.*), and as far inland as Jojutla, Morelos (C. Deloya, *pers. comm.*).

It is worthwhile mentioning that the species was also recorded in some out of chronological sequence localities. The species was recorded in the Alvaro Obregón Dam, Ruiz Cortines Dam and Navojoa, Sonora in 1986 (IBUNAM); and in Mazatlán, Sinaloa in 1988 (R. Cunningham, *in litt.*).

DISCUSSION

The invasion of *D. gazella* into Mexico originated from two main point sources, Texas and California, contrary to the sole Texan source implied by former studies (Rivera-Cervantes and García-Real, 1991; Barbero and López-Guerrero, 1992).

The invasion of Mexico has apparently been taking place along three main fronts. One front occurs along the Atlantic Slope following the Gulf of Mexico Plains, a second front moves along the Mexican High Plateau, and a third front occurs along the Pacific Slope.

Starting on the Atlantic Coast, *D. gazella* has dispersed from its southernmost Texan release point in Kleberg County in 1972 to Sayaxché in the Petén in 1987. The species has dispersed approximately, 1550 km in 15 years, a mean dispersal rate of 103 km/year, approximately. However, data presented in Table 1 show evidence that *D. gazella* has been spreading faster during the last 6 years than it did during the first 9 years, as Barbero and López-Guerrero (1992) had indicated. This process, however, could not be verified for the other two proposed invasion routes. The inland spread from the Atlantic Coast to the states of Veracruz and Oaxaca has been rather more slowly (Fig. 1). The Sierra Madre Oriental, has without doubt, represented an important barrier, most probably due to cooler temperatures at higher elevations.

Judging from the distribution records and dates (Fig. 1), the spread along the Pacific Coast seems to originate almost certainly from the California releases. The spread has apparently been much faster here (mean dispersal rate of 220 km/year, approximately) than anywhere else in Mexico (Table 1), most probably because the climatic conditions are better suited. It is unknown if the species is already present

Table 1
Rates and main routes of dispersal of *Digitonthophagus gazella* from the release sites in U.S.A. into Mexico.

Sites	Time (years)	Distances (km)	Dispersal rate (km/year)
		Spread along the Atlantic Slope	
Kleberg County, Texas, 1972- La Pesca, Tamaulipas, 1981	9	385	42.77
La Pesca, Tamaulipas, 1981- Palma Sola, Veracruz, 1984	3	475	158.33
Palma Sola, Veracruz, 1984- Sayaxché, Petén, 1987	3	690	230.00
		Rounded Mean: 103	
		Spread along the Mexican High Plateau	
Kleberg County, Texas, 1972- Monterrey, Nuevo León, 1981	9	310	34.44
Monterrey, Nuevo León, 1981- Saltillo, Coahuila, 1982	1	75	75.00
Saltillo, Coahuila, 1982- San Luis Potosí, San Luis Potosí, 1987	5	350	70.00
		Rounded Mean: 49	
		Spread along the Pacific Slope	
El Centro, California, 1976- Manzanillo, Colima 1983	7	2000	285.71
Manzanillo, Colima, 1983- Zihuatanejo, Guerrero 1987	4	310	77.50
Zihuatanejo, Guerrero 1987- Puerto Angel, Oaxaca, 1989	2	560	280.00
		Rounded Mean: 220	

in the Pacific slopes of Chiapas, but collecting on the Pacific Coast of Guatemala has not yet yielded any confirmed reports of the presence of *D. gazella* up to the year of 1993 (E. Cano and J. Monzón, *pers. comm.*). It is unclear how did this species spread to Baja California, if it did along the peninsula or across the sea from nearby Sinaloa. The same can be said of the Islas Marías record. Did the species fly or arrive as a stowaway in a ship? The inland penetration has met with variable success. *D. gazella* had spread from the Pacific Coast up to 88 km at El Limón, Jalisco, in 1990 (Rivera-Cervantes and García-Real, 1991); whereas it had advanced up to 210 km from the coast to Jojutla, Morelos, in 1992. Again, the mountain barrier effect seems to be hindering the inland penetration.

According to the distribution data, the spread of *D. gazella* into the greater part of the Mexican High Plateau and eastern New Mexico seems to have originated from the Texan releases. The distribution in Arizona and western New Mexico originated most probably from the Californian releases. It is possible that the Sacramento Mountains might function as barriers for both release sources in New Mexico. One cannot rule out the possibility that the spread of the species into the northwestern part of the Mexican Plateau originated from Californian and Texan releases. An analysis of genetic material from specimens of this area would be most illustrative for clarifying this point. The species now occurs in all of Texas, except in the northern portion of the panhandle, and most probably it would not be able to live in northern Arizona or northern New Mexico (G.T. Fincher, *in litt.*). The spread in this area seems to be the slowest one, 49 km/year, approximately

We can observe that *D. gazella* has been invading Mexico along three main fronts, the Atlantic slope, the Pacific slope and the Mexican High Plateau. Although the dispersal rates have been variable (49-220 km/year), they have always been high. According to distribution records, the preferred climates have been warm/humid and warm/dry. Inland spread along mountains has been rather slow in comparison, suggesting that cooler temperatures in temperate climates represent a climatic barrier. At least, along the Pacific Coast an elevation of 1,150m seems to represent the upper distributional limit. In general, the species has shown a preference for open vegetation, although in some occassions it has been found singly in tropical forest. It is probable that the species will not invade areas of temperate and alpine vegetation. One can expect the species to continue spreading along both coasts, and it is not improbable that they will eventually reach northern South America along these routes.

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