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An hypothesis of historical dispersion concerning nematode parasites in Spanish populations of *Psammodromus* (Reptilia, Lacertidae, Gallotiinae)

Una hipótesis de dispersión histórica referente a nematodos parásitos en poblaciones españolas de *Psammodromus* (Reptilia, Lacertidae, Gallotiinae)

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Resumen

Psammodromus algirus y *Psammodromus edwardsianus* (Reptilia: Lacertidae) son hospedadores en España de nematodos pertenecientes al género *Parapharyngodon* (Nematoda: Oxyuridomorpha, Pharyngodonidae). Una atenta observación de los rangos de distribución, tanto de parásitos como de hospedadores, sugiere que los primeros pudieron haber llegado accidentalmente a España desde el Nuevo Mundo en barcos de la "Carrera de Indias".

Abstract

Psammodromus algirus and *Psammodromus edwardsianus* (Reptilia: Lacertidae) are host to nematodes in the genus *Parapharyngodon* (Nematoda: Oxyuridomorpha, Pharyngodonidae) in Spain. Investigation into the mutual distribution of parasite and host suggests that *Parapharyngodon* may have accidently arrived in Spain from the New World on ships belonging to the "*Carrera de Indias"*.

1. Introduction

Roca, Lluch, & Navarro (1986) reported the examination of 63 *Psammodromus algirus* and 66 *Psammodromus hispanicus* (recently re-classified as P. *edwardsianus* (Fitze, 2014) for helminth parasites (classification follows De Ley & Blaxter, 2002 2004) from 12 localities in an approximate area of 7523 km^2 extending south from Santa Magdalena de Pulpis (Fig. 1, a; Castellón Province, N40.356287, E0.303178) to Arenales del Sol (Fig. 1, c; Alicante Province, ~N38.253056N, W0.521389), and generally no more than 40 km west (Fig. 1, b; Valencia Province, N39.382140, W0.787204) along the Mediterranean Sea coast. Their survey identified *Parapharyngodon echinatus* (Nematoda, Pharyngodonidae) from four *Psammodromus algirus* and two *P. edwardsianus*, all from coastal localities (Fig. 1, d; Canet d'en Berenguer [Almeria Province, N39.680544, W0.219253], El Saler [Fig. 1, e; Valencia Province, N39.366844, W0.328443], and Benitaxel [Fig. 1, f; Alicante Province, N38.731342, E0.143576]).

Roca and Lluch (1986) also described *Parapharyngodon psammodromi* (Nematoda, Pharyngodonidae) from intestines of two (1 male, 1 female) *Psammodromus edwardsianus* also found at El Saler, establishing a degree of sympatric distribution between transmission agents of both *Parapharyngodon echinatus* and *P. psammodromi.*

During internal examination of *Psammodromus algirus*, SDB salvaged presumably unreported nematodes (Salvador, 2014:308) from the population inhabiting the vicinity of La Barca de la Florida, Cádiz

Province (Fig. 1, g; N36.63536, W5.88744, 76 m). Specimen CM 53045.D, Carnegie Museum of Natural History, an adult male measuring 61.0 mm snout-vent length (SVL), collected 26 April 1970, was parasitized by *Abbreviata abbreviata* (Spiruromorpha, Physalopteroidea, Physalopteridae; H. W. Manter Laboratory of Parasitology [HWML] 64801, University of Nebraska). CM 51332, an adult female, SVL 56.0 mm, collected 17 August 1969, and CM 53139, adult male, 59.5 mm SVL, collected 13 April 1970, were parasitized by *Skrjabinelazia taurica* (Ascaridomorpha, Seuratoidea, Seuratidae; HWML 64803).

In addition, *Psammodromus algirus*, CM 53247, an adult female (54.1 mm SVL) collected 16 May 1970, and CM 54874, an adult male (67.1 mm SVL) collected 18 June 1971, from the population at La Algaida, Cádiz Province (Fig. 1, h; ~N36.862136 W6.302683, 11 m) harboured *Parapharyngodon psammodromi* (HWML 64802).

The two reported localities now known for *Parapharyngodon psammodromi* (La Algaida, Cádiz, and El Saler, Valencia), suggest that further examination into habitats and Spanish naval history is warranted.

2. Host habitats

La Algaida and La Barca de la Florida sites are separated by 45 (airline) kilometers (Fig. 1, h & g) and each is influenced by proximity to the Atlantic Ocean. Data compiled between 1955 and 1964 (Instituto Naciónal de Investigaciones Agronomicas, 1971) indicate average annual temperatures at La Algaida were only slightly cooler than those at La Barca (16.9°C versus 17.2°C), but average precipitation (51.9 cm vs. 106.4 cm) and humidity coefficients (1.97 vs. 16.9) were considerably lower. Thornthwaite Aridity and Humidity for La Algaida were 51.8 and -19.2, respectively, and the Lang Index was 30.7 during this period, classifying it as an arid zone. La Barca values for Thornthwaite Aridity and Humidity were 45.0 and 35.4, respectively, and the Lang Index was 61.8, classifying it as a wet area with few trees (Lang, 1920; Thornthwaite, 1948). Values from Fleet Weather Central at the *Base Naval de Rota* suggest little change from these characterizations for the period 1969-1971 (SDB, unpublished transcription).

Both La Algaida (Fig. 2, a) and La Barca (Fig. 2, b) sites are flat (*llanura verdadera*), with drainage gradients of <3%, and with soil (entisols; weakly-developed, recent origin) on each classified as quarzipsamments (parent material mainly quartz, particle size 0.02 mm to 2.0 mm) occurring on late-Pleistocene and older surfaces (Huang & Sumner, 2011). The substrate at La Algaida is *Arenoso*, a diluvial soil that covers approximately 8,593 ha (1.2%) of Cádiz Province; the alluvial soil at the La Barca site is *Franco-Arcillo-Arenoso*, a soil covering approximately 15,932 ha (2.2%) of Cádiz Province (Instituto Naciónal de Investigaciones Agronomicas, 1971). Neither site was being used for agricultural purposes at the time of the 1969-1971 survey.

The *Pinus pinea* woodland on top of the sand dune area known as La Algaida, in a sense, is artificial habitat, ceded to the Duke of Medina Sidonia by King Don Juan I in 1445. Firewood production and hunting on the property has been managed by Sanlúcar de Barrameda since the city joined the Kingdom of Spain in 1645. In 1846 La Algaida was characterized as "dead shifting sand… wind formed hills and valleys…[with] planted … pine trees…trimmed bushes and scrubland… medicinal and aromatic herbs... mastic, myrtle, oleander and wild vine [as] dominant shrubs…. ferruginous mineral waters…small houses [for a guard and two subordinates] in the center... and [grazing] herds of cattle…[abounding] with fur and feather game" (Madoz, 1846). Re-forested following economic downturns in 1803, La Algaida currently serves, in part, as the recreation area "Pinar de la Algaida", part of the Doñana Natural Park system (Fielden & Hidalgo, 2010; Junta de Andalucía, 2015). The La Barca site was cleared and burned in 1972 and was plowed over during a 2013 visit (SDB, personal observations).

During the period of study both La Algaida and La Barca de la Florida sites supported populations of *Pistacia lentiscus* L. (Anacardiaceae); *Halimium halimiifolium* (L.) and *Cistus crispus* L. (Cistaceae); *Chamaerops humilis* L. (Arecaceae); *Erica scoparia* L. (Ericaceae), and *Myrtus communis* L. (Myrtaceae). La Algaida is primarily forested with *Pinus pinea L.*, and dropped needles mix with the sandy soil to form much of the substrate. La Algaida also supported *Juniperus phoenicea* L. (Cupressaceae); *Corema album* (L.) D. Don. (Ericaceae); *Juncus acutus* L. (Juncaceae); and *Cistus salviifolius* L. (Cistaceae), plants not found at La Barca de la Florida.

The northern border of the La Barca de la Florida site was bordered by Cádiz provincial road CA-203 (currently CA-2003), and trees were present only along its perimeter. One *Pinus halepensis* Mill. recently had been planted along the eastern border, several *Quercus suber* L. (Fagaceae) lined the southern border, and a recent planting of *Eucalyptus globulus* Labill (Myrtaceae) formed the western border. This site was more heavily vegetated than La Algaida, and also contained *Allium* sp. (Amaryllidaceae), *Pulicaria arabica* (L.) Cass (Compositae), *Quercus coccifera* L. (Fagaceae), *Centaurium erythraea* Rafn. (Gentianaceae), *Lavandula stoechas* L. (Lamiaceae), *Phillyrea angustifolia* L. (Oleaceae), *Genista triacanthos* Brot. (Leguminosae), and *Ulex parviflorus* Pourr (Leguminosae). An analysis (July, 1969; Department of Agronomy, Cornell University, Ithaca, New York) determined the soil to have a pH of 6.8, and to contain (parts/

million in extract solution [ppm]) NO_3 at 1 ppm, Ca at 100 ppm, and K at 5 ppm, along with trace amounts of P and soluble salts.

Psammodromus algirus was common at both sites, but *Psammodromus edwardsianus* was not found at either site.

3. Historical summary

By 1570, Sanlúcar de Barrameda, located at the mouth of the Guadalquivir River, was serving as the most important anteport to the city of Sevilla. It was the first port of entry into Spain after the merchant fleet (*Carrera de Indias*) returned from New World ports of call. Transportation by large vessel from the Atlantic to Sevilla, however, was often complicated a few kilometres up river by "… aquella barra ingrate que tantas barras de plata le a tirado al hondo centro. Aquella infernal cuadrilla de peñascos que atrabiesa el agua de orilla a orilla…." (a dreadful bar that has thrown so many ingots of silver into the depths. That infernal quadrille of congealed mud and sand [use of *peñascos* is considered poetic license] that breaks through the water from shore to shore; Beltrán, 1612:26-27). Transport past Bonanza (~ 2 km up river from Sanlúcar de Barrameda, ~ 9 km south of La Algaida) became difficult between June and August when the Guadalquivir River's water level was low and goods were transferred to ground at this point. By the early 1680s, Cádiz had assumed the de facto role as hub for the *Carrera de Indias*, and by 1717 the *Casa de Contratación* (1503) had formally transferred the hub from Sevilla to Cádiz and allowed off-loading of goods from the Americas. Between 1717 and 1765, 82% of all return sailings from the Americas off-loaded all but gold at Sanlúcar de Barrameda, El Puerto de Santa María, and other ports lining the shores of the Bahía de Cadiz. By 1796 all imports from the colonies entered Spain through the port of Cádiz (O'flanagan, 2008).

4. An hypothesis

Utilizing mtDNA data, Jones *et al.* (2012) determined that the house mouse (*Mus musculus*) arrived on the North American continental island of Greenland via Viking ships in the tenth century and, according to Bern (2003; Boursot *et al.*, 1993), the house mouse was carried aboard ships of Spanish explorers to the Americas in the early sixteenth century. A substantial portion of the state of California's flora was derived from plantings carried (through Mexico) by missionaries from Spain (Baldwin, *et al.*, 2012). Organisms transferred from Europe and elsewhere to the New World by explorers during very early periods of exploration remain well-established and survive today, as do more-recent migrants, both accidental and deliberate.

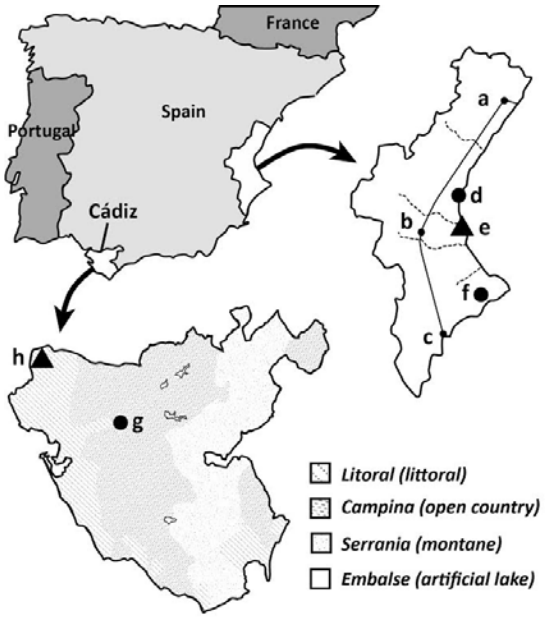

Figure 1. Distribution of the nematodes *Parapharyngodon echinatus* (circles) and *Parapharyngodon psammodromi* (triangles) in lizards of the genus *Psammodromus* in Spain.

— Distribución de los nematodos *Parapharyngodon echinatus* (círculos) y *Parapharyngodon psammodromi* (triángulos) en lagartos del género *Psammodromus* en España.

Roca, Lluch, & Navarro (1986: Fig. 1) discovered no *Parapharyngodon* species from non-coastal areas in their survey of *Psammodromus algirus* and *P. edwardsianus* along Spain's north-central, eastern coast, and no representatives of the genus *Parapharyngodon* were found in the more humid, more heavily vegetated (Fig. 2, b) non-coastal population of *Psammodromus algirus* from La Barca de la Florida. While *Psammodromus algirus* and *P. edwardsianus* are widely-distributed throughout various habitats in Spain (Fitze, 2014; Salvador, 2014), Iberian peninsular localities currently shared by *Psammodromus* and nematodes in the genus *Parapharyngodon* (Fig. 1, d, e, f & h) are coastal.

The more recently described *Parapharyngodon psammodromi* (Roca & Lluch, 1986) is currently known only from areas in direct proximity to localities historically served by ships of Spain's merchant fleet (Fig. 1, triangles). As the genus *Parapharyngodon* appears well-represented in helminth assemblages along coastal areas and on islands within the Mediterranean Sea (Roca, 1995; Roca *et al.*, 2006) and, coupled with its predominantly New World distribution (22 of 50 [44%] recognized species, (Velarde-Aguilar *et al*., 2015), appears to have its "center"

Figure 2. La Algaida (a), and La Barca de la Florida (b), study sites, 1970.
— La Algaida (a), y La Barca de la Florida (b), sitios de estudio, 1970.

of diversification in New World areas historically served by Spanish merchant fleets, consideration of human-assisted transport seems appropriate. While molecular data for this nematode genus is currently unavailable, future phylogenetic analysis would serve to validate or reject this hypothesis.

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