# Walkway on coastal dunes negatively affects mobility of the spiny–footed lizard *Acanthodactylus erythrurus*

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**Abstract**

*Walkway on coastal dunes negatively affects mobility of the spiny–footed lizard* Acanthodactylus erythrurus.— Dune systems are the most degraded ecosystems of the entire European coast, and human activity on the Mediterranean coast of Spain has caused dramatic transformation. In Torredembarra (Tarragona, Spain), a population of spiny–footed lizards *Acanthodactylus erythrurus* inhabits the few remaining natural dunes and vegetation patches where wildlife coexists with intensive tourism activities. Our aim was to know whether walkways installed across the dunes were affecting the mobility of the spiny–footed lizard. We compared the mobility of marked lizards in two areas with a similar habitat, one with and one without a walkway. We found that the walkway reduced the distances between consecutive resightings, affecting juveniles more than adults. We conclude that the walkway may affect social interactions in the species.

Key words: Dune systems, Habitat fragmentation, Mobility of reptiles, Wooden walkways

**Resumen**

*Las pasarelas en las dunas costeras perjudican la movilidad de la lagartija colirroja* Acanthodactylus erythrurus.— Los sistemas dunares son los ecosistemas más degradados de toda la costa europea y la actividad humana ha causado una profunda transformación en la costa mediterránea de España. En Torredembarra (Tarragona, España) habita una población de lagartija colirroja *Acanthodactylus erythrurus* en algunas de las dunas naturales y parches de vegetación que aún existen, donde la fauna silvestre coexiste con unas intensas actividades turísticas. Nuestro objetivo fue conocer si las pasarelas instaladas sobre las dunas estaban afectando a la movilidad de la lagartija colirroja. Se comparó la movilidad de lagartijas marcadas entre dos zonas con hábitat similar, pero una con pasarelas y otra sin. Se observó que las pasarelas acortaron las distancias entre reavistamientos consecutivos y que afectaban más a los juveniles de lagartija colirroja que a los adultos. Llegamos a la conclusión de que la pasarela puede estar afectando a las interacciones sociales naturales de la especie.

Palabras clave: Sistemas de dunas, Fragmentación del hábitat, Movilidad de los reptiles, Pasarelas de madera

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## Introduction

Human activity can have a major impact on wildlife through habitat loss, fragmentation and degradation. Habitat loss is the main cause of endangerment for many of the world's threatened reptile species (Webb & Shine, 2000). For this reason, taxa such as reptiles that rely on specific components of the habitat for survival are at particular risk because of their low dispersal ability, morphological specialisation on substrate type, relatively small home–range sizes, and thermoregulatory constraints (McAlpine et al., 2015).

Dune systems are the most degraded ecosystems of the entire European coast (Buffa et al., 2012). The Mediterranean coast of Spain has been deeply transformed by human activity —particularly industry, agriculture and tourism— and dune systems are the most severely affected (De Ambrosio et al., 2002); there remain only a few small sandy islands where some natural vegetation patches persists (Carretero, 1999). The construction of barriers such as roads and walkways adversely affects the dynamics of the dune and consequently the flora and fauna that it houses (Gómez–Zotano et al., 2016). For example, Vega et al. (2000) showed the effects that the building of a road on some coastal dunes in Argentina had on two lizard species. They concluded that the human impact on the habitat structure of the lizards changed the relative abundance of these species and the proportional use of their favourite microhabitats; one of the two species in the area almost disappeared. The construction of wooden walkways can also enable opportunistic species of fauna and flora to penetrate the area (Carretero, 1999). Several studies (Barrows & Allen, 2007; Kacoliris et al., 2010; Stellatelli et al., 2013a, 2013b) show the negative effect of exotic plants and vegetation changes on the habitat of different lizard species.

The impact of tourism poses a significant threat to wildlife (Anthony & Psuty, 2014). Tourists often leave rubbish and organic waste that produce the appearance of ruderal plants or noise (GEPEC–EdC, 2008). These factors may affect the population of the spiny–footed lizard, a species that shows a clear preference for open habitats, with sparse vegetation, gentle relief and uncompressed soils (typical of coastal dunes), but that never inhabits urban areas (Belliure, 2015). Walkways over the dunes can therefore be a barrier to lizards but data on the subject are scarce. The main objective of this work was to determine the effect of a walkway on the mobility of the spiny–footed lizard. We hypothesized that the walkway reduces the spiny–footed lizard's mobility. To test our hypothesis, we compared the mobility of marked lizards in two areas with a similar habitat, one with and one without a walkway.

## Material and methods

### Study area

The study area was the dunes of Torredembarra (UTM 31TCF6857), Tarragona (Spain), where a few natural dunes and vegetation patches remain. This natural beach, called 'Els Salats i Muntanyans', has 75 hectares and one third of these are dunes (Carretero, 1999). Tourism in the area is intense. In 1993, 35 hectares of the natural beach in Torredembarra (2.2 km of beach) were declared Area of Natural Interest. Three lizard species coexist on this natural habitat: the large psammodromus *Psammodromus algirus*, the Catalonian wall lizard *Podarcis liolepis*, and the most isolated and northernmost population of the Mediterranean coast of the spiny–footed lizard (Carretero et al., 1999), which is in a vulnerable state of conservation. The conservations status of the other two species of lizards is currently not of concern.

In 1997 two boardwalks made from railway sleepers were built parallel to the beach. These boardwalks could affect the dunes and their natural ecosystem in a negative way because they were designed to let the people walk through the dunes rather than to link the inner zone with the beach. In 2002 the northern boardwalk was removed and thanks to the Annual Census (GEPEC–EdC, 'Grup d'Estudi i Protecció dels Ecosistemes Catalans') the population of spiny–footed lizard in this area increased (Carretero et al., 2007). In 2008 the railway sleepers of the southern boardwalk were replaced by another wooden walkway of 341 m long and 1.20 m width, raised about 21 cm above the sand level, although the '*Manual de restauración de dunas costeras*' (Coastal dunes restoration manual; Ley Vega de Seoane et al., 2007) recommends that the minimum distance between the sand and the boardwalk base should be 1m high to avoid negatively affecting dune dynamics.

Regarding the vegetation in the area, it is important to note that this changes depending on the dune morphology: in Els Muntanyans of Torredembarra in the dunes nearest the sea we find *Agropyterum mediterraneum;* on the fixed dunes we find *Ammophiletum arundinaceae;* in the backdunes we find *Crucianelletum maritimae* subassociation *thymelaeetosum hirsutae;* and in the saline depression we find *Eriantho–Holoschoenetum australis* (Figuerola, 1996).

### Study design

Field work was carried out in 2014. We selected two zig–zag transects each of 311 m, covering the study area. The first transect (1.2 ha) was located in the area with the walkway (from here on referred to as the 'with–walkway area') and the second transect (1.7 ha) was made in a nearby area (from here on referred to as the 'without–walkway area') (fig. 1). Both areas were the same length and had a surface of optimal habitat for the spiny–footed lizard.

### Sampling

We captured the lizards with a noose on the end of a fishing pole (also used by Guillén–Salazar et al., 2007), marked them with safe paint (Bennett, 1999; Mellor et al., 2004; Guillén–Salazar et al., 2007) and released them at the same site of capture. In September we marked 57 lizards: 30 in the with–walkway area and 27 in the without–walkway area. We deter-

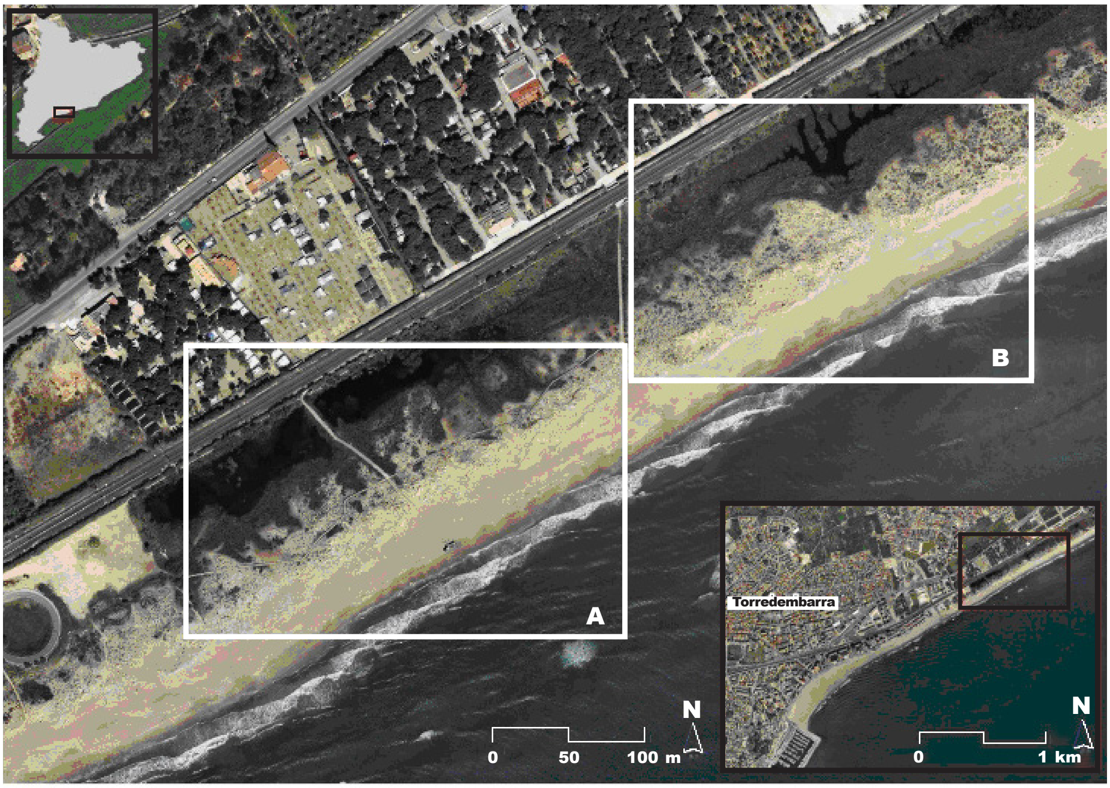


Fig. 1. Photograph **of** the two study areas: A. With–alkway area; B. Without–walkway area.

*Fig. 1. Fotografía de las dos zonas de estudio: A. Zona con pasarela; B. Zona sin pasarela.*

mined their maturity status (adult or juvenile) and sex (adults only), and took photographs of each animal before and after the marking. Body length of all adults exceeded 55/56 mm respectively for males/females. The remaining animals were considered immature (Carretero & Llorente, 1993). The marks were temporary and consisted of one to three coloured stripes on the back. They were different for each lizard to allow individual identification (Guillén–Salazar et al., 2007) (Yves Rocher Company). The markings were made with different colour nail polish (using colours other than red to avoid effects on behaviour or detectability, Fresnillo et al., 2015a, 2015b) depending on the area and on the side of the walkway they were captured.

Lizards were later resighted but not captured. Observations were made daily (except on rainy days) to locate marked lizards, and the time elapsed between sightings was taken into account. We made the sightings from the dunes, walking over the area in zigzag, thus covering a distance of 311 m/transect. The sightings were obtained in September, between 10.00 h and 14.30 h (Carretero, 1993).

### Statistical analysis

We measured the distances travelled between consecutive sightings of each specimen using Google Earth's distance measurement tool. We used these data to calculate the response variable used in the statistical analysis. The response variable was the average distance between sightings that is the average distance travelled between two consecutive sightings per day. Time elapsed between sightings was taken into account.

We created a generalized linear model (GzLM) that included the variable average distance between sightings/days as the response variable. We included age/sex (three levels: distinguishing between juveniles, males, and females) and the capture area (two levels: the with–walkway and the without–walkway) as explanatory variables in this model. We also included the interaction between age/sex and capture area. We used Gamma distribution with a log–link function. We performed all statistical analyses using InfoStat software with $\alpha = 0.05$.

## Results

During the study period we marked 57 individuals and had 113 resightings. The standard error of the mean (SE) number of re–sights for individuals that were observed at least once after capture was 2.43 ± 0.27, with a range of 1 to 7 resightings. We found more juveniles than males or females in both areas. We captured and resighted more adults in the without–walkway area than in the with–walkway area. We only resighted two females in the walkway area. The percentage of resightings was nearly 70% in both areas (table 1).

Our results show that the capture area and the interactions age/sex * capture area strongly affected the average distance travelled per day (table 2). In respect to the capture area, we found that the walkway significantly affected the distance between two consecutive re–sightings. Lizards living in the without–walkway area moved about more than those living in the with-walkway area. In addition, the interaction between age/sex and capture area showed that the effect of the walkway varied according to sex and age (fig. 2); average distances covered in the walkway area were lowest for juveniles.

Table 1. Number of individuals (from each age/sex category) captured in each area, and number of re–sightings in each area: J. Juveniles; M. Males; F. Females.

*Tabla 1. Número de individuos (de cada categoría de edad y sexo) que fueron capturados en cada zona y número de reavistamientos (de cada categoría de edad y sexo) en cada zona: J. Juveniles; M. Machos; F. Hembras.*

| Zone | J | M | F |
|---|---|---|---|
| With–alkway | | | |
| Marked | 25 | 3 | 2 |
| Resighted | 52 | 9 | 6 |
| Without–walkway | | | |
| Marked | 16 | 9 | 2 |
| Resighted | 30 | 11 | 5 |

## Discussion

Our results indicated that the walkway affected the mobility of the spiny–footed lizard because they moved shorter distances in this area than in the without–walkway zone. This could be due to the walkway itself or to some related factor related. The walkways may have a barrier effect on the spiny–footed lizard, limiting the distance the travel. Other explanations, however, cannot be overlooked. The walkway, for example, might attract insects or make insect capture easier for lizards, or it might provide refuge or shade. Greater availability of such resources might decrease the need to disperse long distances.

Barrows & Allen (2007) observed that the variables that affected the occurrence of the endangered lizard *Uma inornata* and its persistence in habitat fragments include patch size and the distance between additional habitat patches, the number of habitat patches, and habitat quality.

Vegetation of the dune ecosystem is strongly affected by substrate characteristics such as particle size and compactness (Seva & Escarre, 1980), factors that are affected by the presence of walkways. Muñoz–Vallés & Cambrollé (2014) observed how the building of a new walkway decreased the conservation status of the vegetation on the upper beach and foredune. The type of vegetation is an essential element for lizards inhabiting the dune systems (Vega et al., 2000), providing hunting sites (Kacoliris et al., 2010), thermal refuge, protection from predators, nesting sites, and visibility to conspecifics (Vega et al., 2000; Amat & Roig, 2001; Kacoliris et al., 2010). Several studies have found similar results and conclude that vegetation structure and cover are two of the main factors that affect habitat preferences of lizards (Seva & Escarre, 1980; Carretero, 1993; Carretero

Table 2. Z and p–values, df, and coefficients of the variables included in the model (n = 54 individuals) to explain the average distance between sightings per day. The coefficients for the level of fixed factors were calculated using the reference values of 'juveniles' in the 'age/sex' variable, 'with–walkway' in the 'capture area'.

*Tabla 2. Valores de z y p, grados de libertad y coeficientes de las variables incluidas en el modelo (n = 54 individuos) para explicar la distancia media entre avistamientos por día. Los coeficientes relativos al nivel de los factores fijos se calcularon utilizando los valores de referencia de "juveniles" en la variable "edad y sexo" y "con pasarela" en la variable "zona de captura".*

| Variables | z–value | df | p–value | Coefficients ± SE |
|---|---|---|---|---|
| Age/sex | 1.66 | 2 | n.s. | Males = 1.18 ± 0.35 |
| | | | | Females = –0.35 ± 0.05 |
| Capture area | 4.98 | 1 | < 0.01 | Without–walkway = 0.91 ± 0.24 |
| Age/sex * capture area | 3.44 | 2 | < 0.01 | |

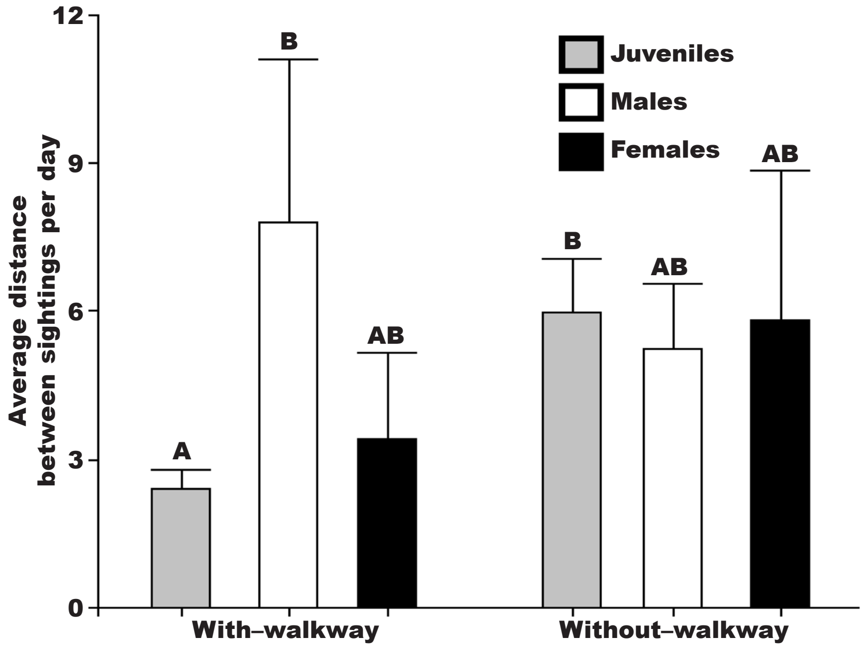


Fig. 2. Predicted mean values (± SE) of average distance between sightings per day (m/day) as a function of the interaction between class age/sex (juvenile, male, and female) and capture area (with and without walkway). Small case letters indicate significant differences ($P$ = 0.05) between groups according to Fisher LSD tests.

*Fig. 2. Valores medios predichos (± DE) de la distancia media entre avistamientos por día (m/día) como función de la interacción entre las diferentes clases de edad y sexo (juvenil, macho y hembra) y la zona de captura (con y sin pasarela). Las letras versales indican que existen diferencias significativas (*P* = 0,05) entre los grupos según los test LSD de Fisher.*

& Llorente, 1997). Amat & Roig (2001) stated that the spiny–footed lizard is highly sensitive to habitat features and that its distribution on the coastal dune ecosystems is a good indicator of the state of the dunes. The species also inhabits non–sandy areas in other parts of its distribution, however, suggesting its ecological requirements stretch beyond substrate (Seva & Escarre, 1980).

The spiny–footed lizard is the dominant species in sandy areas of southern Iberia (Busack & Jaksic, 1982; Carretero, 1993). Busack & Jaksic (1982) report it is not a territorial species (they observed only one agonistic encounter and it was with a specimen of *Psammodromus algirus*). Adult male lizards defend a larger territory than females (Seva, 1981) and our results support this as the distances between re–sightings were larger for males than for females or juveniles, in the walkway area (fig. 2). In the without–walkway area, nevertheless, we found no significant differences in sex/age groups. We therefore conclude that the walkway may affect social interactions among the species as juveniles, males and females are affected differently by the restrictions imposed by the walkway, with juveniles dispersing shorter distances in the walkway area. Findings from future research may help to design walkways that not only protect dune systems but that also take the home range of species such as the spiny–footed lizard into consideration.

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