



# Sand-swimming behaviour reduces ectoparasitism in an iguanian lizard

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## Abstract

Sand swimming behaviour occurs in several lizard clades. Known ecological advantages of sand swimming include reduced predation risk and enhanced thermoregulation. We addressed whether, by way of sand abrasion, sand-swimming reduces ectoparasitism in the lizard *Microlophus occipitalis*, whose natural habitat includes sandy substrates (beach) and firm soil (dry forest). We hypothesised that, aside from habitat differences in infestation probability, ectoparasite prevalence and load would be lower in the beach than in the forest because of ectoparasite removal caused by sand-swimming. In an experiment with lizards confined in boxes with substrate from both habitats, lizards in beach boxes showed a greater decrease in ectoparasite load compared with lizards in forest boxes. Ectoparasite prevalence and load were much higher in the forest than in the beach across seasons. Larger lizards showed higher ectoparasite loads, and there were no sex differences in ectoparasite infestation. We provide evidence that sand swimming may confer another ecological advantage to lizards: reduced ectoparasitism.

**Keywords** Sand-swimming · Lizards · Ectoparasites · *Microlophus*

## Introduction

Lizards are a significant component of vertebrate diversity in arid ecosystems and exhibit morphological, physiological and behavioural adaptations to desert life (Pough 1980). Several desert-dwelling lizards show sand swimming, a locomotor behaviour involving axial oscillations of the tail and trunk that allows burying and moving efficiently in loose sand (Arnold 1994, 1995). Sand swimmers typically have small heads, wedge-shaped snouts, countersunk lower jaws, and external

structures (eyelids, flaps, scales) that prevent sand from entering the body (Mosauer 1932).

Sand swimming is an evolutionary derived behaviour present in at least eight lizard clades (Arnold 1994). Known ecological advantages of sand-swimming that might have contributed to its evolution include reduced predation risk and enhanced thermoregulation (Arnold 1995). However, other ecological factors might be involved. Researchers working in xeric scrubs reported that a sand skink species had the lowest ectoparasite prevalence among three lizard species, discussing that the sand-swimming behaviour of the sand skink could have facilitated the removal of attached parasites through sand abrasion (McCoy et al. 2012). This hypothesis awaits experimental verification. Ectoparasitism is common in lizards, can decrease host fitness (Sorci and Clobert 1995), and may vary with habitat conditions (Apperson et al. 1993; Tälleklint-Eisen and Eisen 1999) and lizard size and sex (Bauwens et al. 1983).

We addressed whether sand swimming reduces ectoparasitism in the iguanian lizard *Microlophus occipitalis* (Tropiduridae), whose natural habitat includes both sandy substrates and firm soil. By studying a single species that uses different substrates, we avoided a bias of phylogenetic origin on the association between sand swimming and ectoparasitism. We have observed that in the sandy habitat (beach), *M.*

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*occipitalis* exhibits sand swimming behaviour, while in the compact soil habitat (forest), this behaviour is not performed (Florián and Gonzáles, personal observations). We hypothesised that, aside from likely habitat differences in infestation probability, ectoparasite prevalence and load would be lower in the beach than in the forest because of ectoparasite removal caused by sand swimming. The latter was experimentally tested in controlled conditions. To get a better understanding of ectoparasitism in this system, we also evaluated the association between ectoparasite prevalence/load and habitat (forest vs beach), season (summer and winter), sex, and size.

## Materials and methods

### Species

*Microlophus occipitalis* is a small iguanian lizard (snout-vent length, SVL: 45–80 mm) distributed in and around the dry forest in SW Ecuador and NW Peru (Dixon and Wright 1975). It is found on rocks, fallen logs, shrubs, and trees (Dixon and Wright 1975; Jordán and Pérez 2012), and is also observed in sandy beaches adjacent to the forest (Florián and Gonzáles, personal observations). *M. occipitalis* shows sexual dimorphism: males are bigger and have an orange dorsal crest, while females have a smaller crest and less conspicuous colouration (Watkins 1996).

### Sampling

The study area is located in NW Peru, near Huacura beach (Tumbes, 3° 45' 7.3" S; 80° 47' 14.2" W). Two adjacent habitats are distinguished along the coast: sandy beach with scattered small vegetation patches, and dry forest with scrub vegetation (Venegas 2005).

Sampling was conducted in summer 2014, summer 2015, and winter 2015. The two habitats were sampled in summer 2014 (forest: 23 females, 16 males; beach: 25 females, 15 males) and winter 2015 (forest: 10 females, 20 males; beach: 12 females, 18 males). In summer 2015, due to logistical problems, sampling was only done in the forest (29 females, 17 males). Lizards were captured by noosing or by hand (sampling hours: 8:00–16:00). Sex was determined from the morphological traits that characterise sexual dimorphism in this species (Watkins 1996). SVL was measured with a digital calliper.

We recorded ectoparasite prevalence (% individuals with parasites) and load (number of parasites per individual). We removed ectoparasites using alcohol-soaked cotton swabs and stored them (96% alcohol) until identification in the Laboratory of Animal Parasitology (Universidad Cayetano Heredia).

## Experiment

We considered only lizards from the forest and with loads > 10 before ectoparasite removal (lizards from the beach had few ectoparasites or none). To evaluate whether sand swimming reduced ectoparasite infestation, six plastic boxes (90 × 30 × 30 cm) were used to represent the beach and forest substrates (three boxes per habitat). The beach boxes had only sand, while the forest boxes contained forest soil, twigs, and pebbles (≈ 5 cm depth in both cases); materials were obtained from the original habitats. All boxes were put outdoors at the collection site, so lizards were exposed to natural conditions of temperature and daylength.

Before starting the experiment, we recorded sex, SVL, and ectoparasite load. Ten pairs of lizards with similar ectoparasite loads were systematically distributed in the two treatments, three or four individuals sharing the same box. Lizards were identified with coloured rubber bands tied to the abdomen. After the start of the experiment, an observer supervised the boxes hourly from 7:00 AM to 18:00 PM. After 48 h, we removed lizards from the boxes and counted ectoparasites again to calculate the reduction in ectoparasite load. The remaining ectoparasites were removed and lizards were released afterwards.

## Analyses

A generalized linear model (GLM) was used to determine the effects of season, size and sex on ectoparasite load; only data from the forest were considered because lizards from the beach were almost devoid of ectoparasites. The same variables were tested for their association with ectoparasite prevalence using a GLM of binomial family. A *t* test was used to compare ectoparasite removal (%) between lizards in beach and forest boxes.

## Results

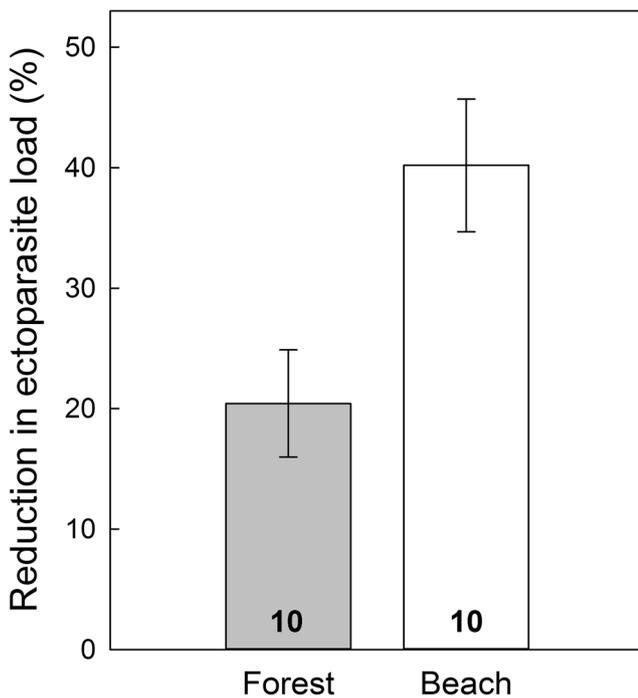
Lizards inside the boxes became active between 08:00 and 09:00 AM. Around 12:00 PM the lizards looked for shelter (forest boxes) or buried themselves in the sand (beach boxes). Lizards became active again starting at 15:00 PM until no later than 16:30 PM. This was the last period of activity in the day after which the lizards hid in shelters or buried themselves until the morning. There was a reduction in ectoparasite load in both groups after 48 h; however, lizards in beach boxes showed a significantly greater decrease in ectoparasite load compared with lizards in forest boxes ( $t_{18} = 2.784$ ,  $P = 0.012$ ; Fig. 1).

Ectoparasite prevalence and load were much higher in the forest than in the beach across seasons (Fig. 2). In the forest habitat, only season affected ectoparasite prevalence, while

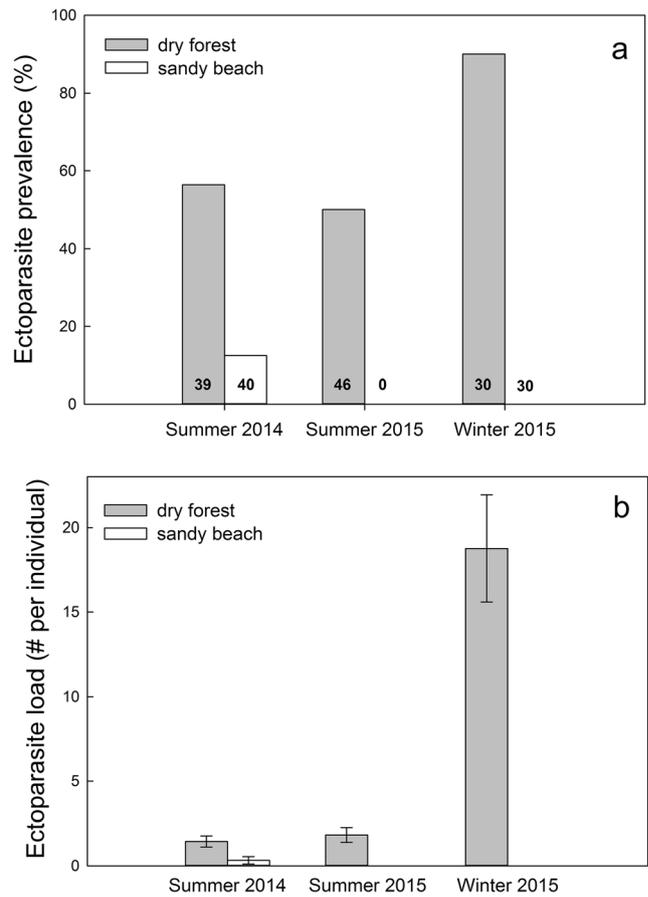
both season and size influenced ectoparasite load (Table 1). A regression analysis showed a positive relationship between size and ectoparasite load ( $r = 0.36$ ,  $F_{1,113} = 17.7$ ,  $P < 0.0001$ ). Sex was not associated with ectoparasitism (Table 1). Almost all ectoparasites (~95%) were *Ophionyssus* mites (Acari:Macronyssidae). Another mite taxon was present but could not be identified.

### Discussion

*Microlophus occipitalis* individuals from the dry forest were much more likely to be infested with mites than those from the beach. Earlier work reported similar patterns for *Sceloporus occidentalis* (Tälleklint-Eisen and Eisen 1999) and *Eumeces inexpectatus* (Apperson et al. 1993), with higher tick infestation rates in lizards from forested habitats as compared to open areas. This might be because ectoparasites are more prone to desiccation in open habitats (Tälleklint-Eisen and Eisen 1999). Although mites may survive off-host across broad environmental ranges (Schöler et al. 2006), ectoparasite performance is often higher in mild environments (Needham and Teel 1991). *Ophionyssus* parasites are particularly sensitive to temperature, as shown for the development of their different life stages (Wozniak and DeNardo 2000). Moreover, adults of *O. natricis* were found to be more active at higher temperatures, although a combination of heat and humidity has a



**Fig. 1** Reduction in ectoparasite load (%; mean ± SE) on the lizard *Microlophus occipitalis* after 48 h in experimental boxes with substrates from a sandy beach (white bar) and a dry forest (grey bar). Sample size appears within bars



**Fig. 2** Ectoparasitism in the lizard *Microlophus occipitalis* across seasons in two adjacent habitats: a sandy beach\* (white bars) and a dry forest (grey bars). **a.** Ectoparasite prevalence: percentage of individuals with parasites (sample size appears within bars). **b.** Ectoparasite load: number of parasites per individual (mean ± SE). \*Not sampled in summer 2015

negative effect on them (Schroeder 1934). This apparent environmental influence on ectoparasite performance may be inferred from field data. If the analysis focuses on the forest habitat (where most mite-bearing lizards were found), ectoparasite prevalence and load were higher in winter compared with summer, when air and substrate temperatures may reach 40 °C (Jordán and Pérez 2012). This evidence supports the environmental control hypothesis. However, if the high

**Table 1** Generalized linear models of factors influencing ectoparasite prevalence and load in *Microlophus occipitalis* lizards

	df	X <sup>2</sup>	P
<b>Prevalence</b>			
Season	2	14.07	0.009
Sex	1	1.77	0.183
Size	1	0.63	0.427
<b>Load</b>			
Season	2	599.09	< 0.0001
Sex	1	1.05	0.306
Size	1	32.26	< 0.0001

temperatures in the beach habitat are responsible for the reduced ectoparasite performance, it is paradoxical that the few parasitized lizards detected in the beach were found exclusively during summer. Therefore, environmental conditions alone hardly explain the contrasting patterns of ectoparasite abundance in lizards from the two habitats.

Regardless of the environmental influence on ectoparasite performance, we consider that sand-swimming contributes significantly to explain the lower ectoparasite prevalence and load observed in the beach compared to the forest. The experiment showed that mites were removed from lizard skin to a greater extent when lizards were kept in boxes with beach substrate compared to boxes with forest substrate. Since *Ophionyssus* mites are susceptible to physical disturbance when attached to their hosts (Schroeder 1934), they were likely removed by sand abrasion during lizard locomotion (Baumgartner et al. 2007). Sand-swimming can only take place in loose substrates, so the rather compact forest soil did not allow this behaviour.

We found that larger lizards carried more ectoparasites, but no differences were found between sexes. Previous studies have suggested that larger individuals often have bigger home ranges, thus increasing the likelihood of infestation (Bauwens et al. 1983; Schall et al. 2000). Similarly, studies finding higher infestation levels in males related this pattern to territoriality and mate-searching behaviour (Bauwens et al. 1983; Tälleklint-Eisen and Eisen 1999). Given its sexual dimorphism and territorial behaviour (Watkins 1996), *M. occipitalis* was expected to show greater ectoparasite prevalence and/or load in males. However, our results suggest that factors related to size rather than sex influence ectoparasite infestation in *M. occipitalis*, as shown for other species (McCoy et al. 2012).

We provide correlational and experimental evidence that sand-swimming may confer lizards an ecological advantage by reducing ectoparasitism. This previously largely neglected effect adds to the advantages of predator avoidance and thermoregulation (Arnold 1995). Given that ectoparasites may decrease lizard fitness (Sorci and Clobert 1995), this finding may contribute to a better understanding of the ecology and evolution of sand-swimming in lizards.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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