J Insect Conserv
DOI 10.1007/s10841-014-9648-2

ORIGINAL PAPER

Abundance of *Latrodectus katipo* Powell, 1871 is affected by vegetation type and season

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Received: 5 October 2013 / Accepted: 16 June 2014

Abstract The seasonal abundance of *Latrodectus katipo* Powell, 1871, a declining spider species endemic to coastal dunes in New Zealand, was observed in two different plant communities: an endemic sedge, *Ficinia spiralis* A. Rich. and an exotic grass, *Ammophila arenaria* (L.) Link. Using artificial cover objects (ACOs), presence/absence data was collected for *L. katipo* in the two plant communities. ACOs were positioned at Kaitorete Spit, which supports a healthy population of *L. katipo*, adjacent to *F. spiralis* or *A. arenaria*. ACOs were checked over four seasons. *L. katipo* were found significantly more often in ACOs placed next to *F. spiralis* as opposed to *A. arenaria* and its presence was highest in summer. Conserving *L. katipo* will involve reducing the amount of *A. arenaria* in New Zealand's sand dunes. Studies monitoring *L. katipo* population dynamics should do so in summer when they are most abundant.

Keywords Presence/absence · Marram · Pingao · Dunes

Introduction

Extinction of species across the globe is mainly attributed to habitat loss and degradation (Pimm and Raven 2000; Seabloom et al. 2002; Hoekstra et al. 2005), which threatens entire ecosystems. Understanding relationships between populations and their habitats is crucial to conservation. Population monitoring can identify factors contributing to the decline of a species, such as loss of preferred habitat. For example, a major threat to the weevil *Hadramphus tuberculatus* Pascoe, 1877 is the destruction of its only host plant by fire and introduced mammals (Fountain et al. 2013). In order to conserve *H. tuberculatus*, the host plant must also be conserved. While vertebrate declines are often well-studied, and can sometimes be partially mitigated by captive breeding and wildlife corridors, invertebrate declines may go unnoticed, due to the number of species involved, their cryptic nature and lack of public interest in conserving invertebrates. Spiders are particularly unpopular among the general public, perhaps due to the high prevalence of arachnophobia (Davey 1991). However, spiders play a crucial part in the functioning and maintenance of ecosystems, being almost purely carnivorous (unlike most arthropods) and able to take on a variety of prey. In addition, spiders are ubiquitous in almost every type of terrestrial environment, even moving into aquatic habitat (Wise 1993). Spiders can be sensitive to habitat loss and degradation (Greenstone 1984; Malumbres-Olarte et al. 2013). A growing number of studies report the importance of habitat type to spider diversity, with some species of spider preferring particular types of vegetation as habitat (Blamires et al. 2007; Downie et al. 1995; Fourie et al. 2013; Hore and Uniyal 2008; Romero and Vasconcellos-Neto 2005; Wheater et al. 2000).

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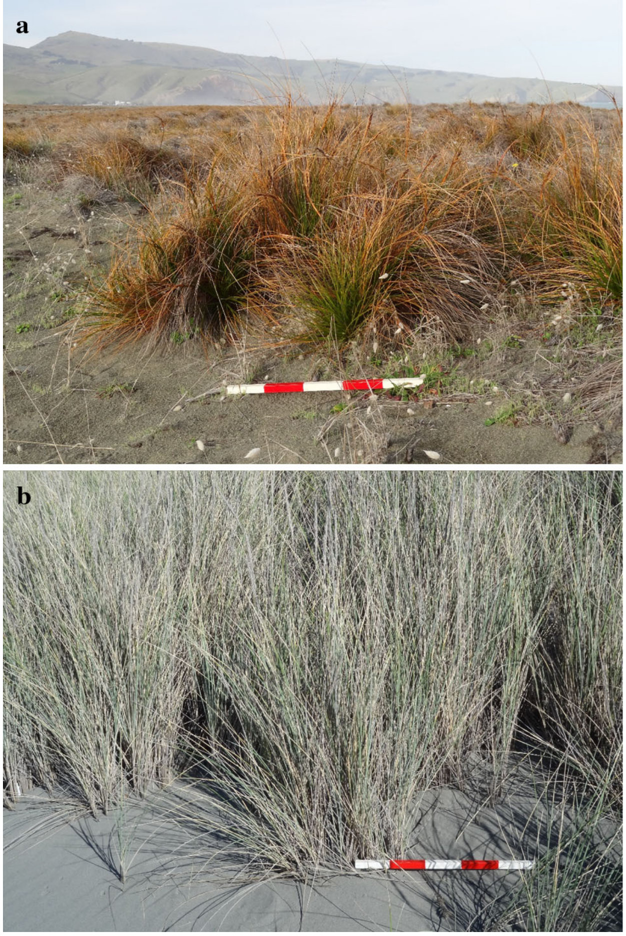

Fig. 1 Comparison between the open structure of both populations and individuals of *F. spiralis* (**a**), and the dense structure of both populations and individuals of *A. arenaria* (**b**). The scale stick is 50 cm long

Coastal sand dunes in New Zealand are inhabited by the endemic katipo spider *Latrodectus katipo* Powell, 1871 (Theridiidae). *L. katipo* are listed as “declining” by New Zealand’s Department of Conservation (Sirvid et al. 2012) and the leading cause may be the deliberate introduction, and subsequent colonisation, of an exotic marram grass [*Ammophila arenaria* (L.) (Poaceae)] into sand dunes inhabited by *L. katipo* (Griffiths 2001; Patrick 2002). In 2010, *L. katipo* was given full protection under the New Zealand Wildlife Act (New Zealand Government 1953).

Habitat reduction is already known to contribute towards the decline of *L. katipo;* their sand dune habitat declined in area from 1,294 km^2 in 1950 to 390 km^2 in 2000 (Hilton et al. 2000). The introduction of *A. arenaria* appears to be the main cause of native dune area reduction; *A. arenaria* stabilises sand more intensely than native dune plants such as pīngao [*Ficinia spiralis* A. Rich (Cyperaceae)] and spinifex [*Spinifex sericeus* R.Br. (Poaceae)], modifying dune structure. The resulting sand stabilisation builds dunes so quickly that native dune plants are often buried (Hilton et al. 2005). Stabilisation can also lead to afforestation (Hilton et al. 2000). Previous deliberate planting of *A. arenaria* aided the establishment of forestry and agriculture on the coast, contributing immensely to the degradation of native dune habitat (Hilton 2006). Illicit human use of recreational vehicles on sand dunes also threatens their structure and disturbs *L. katipo* habitat (Walls 1998; Hankin 2009).

Latrodectus katipo webs are of a typical theridiid structure consisting of a sock-shaped retreat, a platform, and gum-footed threads attached to the substrate (Court 1971). *L. katipo* webs have been found in native plants on the coast, including *F. spiralis*, *S. sericeus* and sand coprosma [*Coprosma acerosa* A. Cunn. (Rubiaceae)] (Griffiths 2001; Costall 2006). *L. katipo* webs seem less common in *A. arenaria* (Griffiths 2001, Patrick 2002). Unlike *F. spiralis*, which provides an open-structured habitat for *L. katipo* (Fig. 1a), *A. arenaria* forms large, dense clumps (Fig. 1b) (Griffiths 2001).

Latrodectus katipo appears to choose driftwood and native plants, such as *F. spiralis*, over *A. arenaria* in captive choice experiments (Costall 2006). The structure of *A. arenaria* may be less able to support a *L. katipo* web; in open-structured plants, such as *F. spiralis*, the platform area of the web in the foliage overhangs the gum-footed threads attached to the substrate, while in *A. arenaria* the vertical foliage structure prevents the platform from being positioned above the substrate (Costall 2006). The upright structure of *A. arenaria* might also provide less shelter than the curved leaves of *F. spiralis*. Unpublished reports indicate *L. katipo* to be more abundant in *F. spiralis* than in *A. arenaria* in the wild; however, previous studies (Smith 1971; Costall and Death 2010) offer contrasting evidence regarding *L. katipo* habitat preferences; Smith (1971) concluded that *L. katipo* were thriving in *A. arenaria* habitat, while Costall and Death (2010) suggest that juvenile *L. katipo* do well in *A. arenaria*, but adults do not. Driftwood and beach debris also provide good habitat for *L. katipo* (Griffiths 2001); corrugated iron in particular is often occupied by *L. katipo* (pers. obs.). Artificial cover objects (ACOs) resemble beach debris such as corrugated iron and driftwood, possibly contributing to their success as monitoring tools for *L. katipo*.

Although ACOs have been used in several *L. katipo* studies, there is no information comparing occupancy rates over different seasons. *L. katipo* are most active in the warmer seasons of spring and summer (Griffiths 2001). Therefore, occupancy of ACOs by *L. katipo* is likely to vary with season. Seasonal variation in *L. katipo* activity would have to be taken into account when monitoring their population size; the difference in seasonal activity would require the ACOs to be checked in the same season every

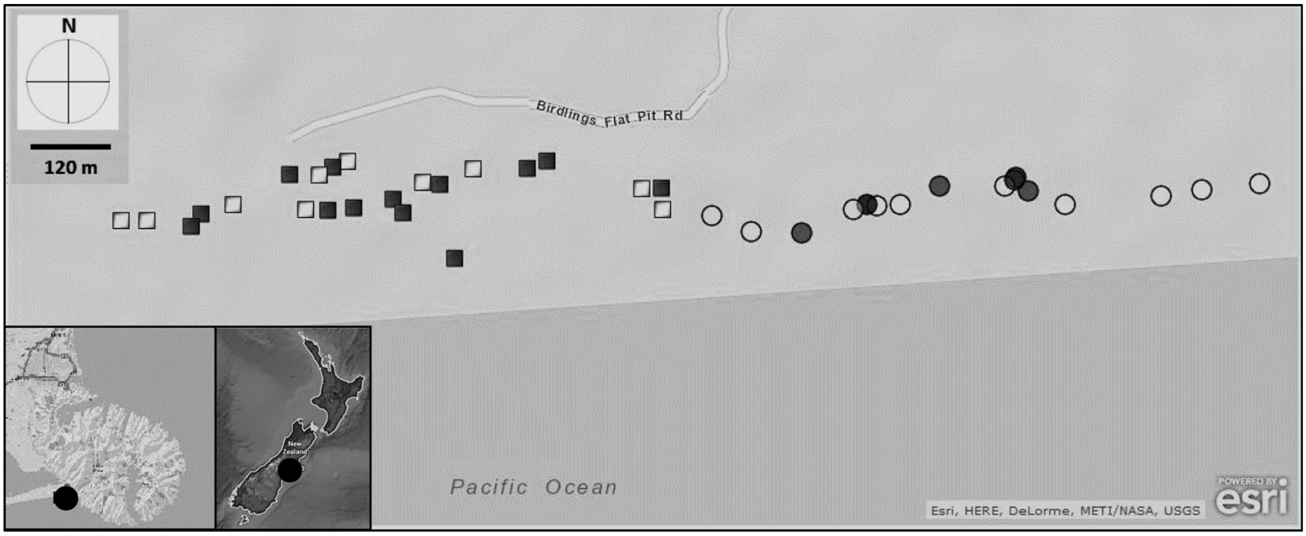

Fig. 2 Positions of individual ACO sites at Kaitorete Spit, Canterbury. Each field season, 20 of these sites were selected at random for study. Only sites that were selected for the study from the total 60 sites are shown. *Black* markers show sites where *A. arenaria* was present; *white* markers show sites where *A. arenaria* was not present. *Square* markers are in the undisturbed area and *circular* markers are in the disturbed area

year to avoid counts being confounded by seasonal changes in occupancy rate.

Juvenile *L. katipo* were found in dense *A. arenaria* by Costall and Death (2009), but fewer adult females were found, suggesting that different life stages of *L. katipo* may vary in their preference of *A. arenaria* habitat, or that *L. katipo* detectability changes as they age. Alternatively, juveniles may balloon away from their mother's web, land by chance in *A. arenaria*, have difficulty building a suitable web and then die or search elsewhere for more suitable habitat; juvenile *Latrodectus* spp. have been shown to translocate web sites more frequently than adults (Lubin et al. 1993). We hypothesise that, while more *L. katipo* will be found near *F. spiralis* than near *A. arenaria*, the difference in probability of finding *L. katipo* in either plant type will vary depending on season, due to differences in abundance of different *L. katipo* life stages within the population. In the present study, we investigate how *L. katipo* abundance varies depending on the vegetation species in an area, and hypothesise that *L. katipo* are more likely to be present in ACOs adjacent to *F. spiralis* than *A. arenaria*. The information gathered in the current study will enable recommendations to be made regarding the future monitoring and conservation of *L. katipo* populations.

Materials and methods

Study locations

Kaitorete Spit is a 28 km long barrier beach separating Lake Ellesmere from the Pacific Ocean (Fig. 2). At the north-eastern end of the barrier is a large and continuous population of *F. spiralis.* Although *A. arenaria* is beginning to invade the area, Kaitorete Spit remains populated by a high-density population of *L. katipo* that can be found all year round (Griffiths 2001).

The portion of Kaitorete Spit used in this study consists of a large 1,220 m tract of relatively undisturbed land (43°49′40.36″S, 172°40′25.87″E) and a smaller 800 m tract of more disturbed land (43°49′39.99″S, 172°40′35.55″E). Behind the dunes, and separated from them by a fence, is a sheep farm. From sea to fence, the less disturbed tract of land is approximately 300 m wide while the more disturbed sampling area is 270 m wide. The more disturbed tract of land is frequented by off-road vehicles and dogs (seen regularly every season) and contains paths that have formed through the dunes as a result (pers. obs.). There are no such visible paths in the undisturbed area, and only once during this study were recreational vehicles observed within this area. By examining a map provided by Environment Canterbury using ArcGIS software (Esri 2012), we determined that the more and less disturbed tracts of land do not greatly differ in soil composition, plant types or groundwater features.

Artificial cover objects

Artificial cover objects were suggested as a method of monitoring *L. katipo* populations after *L. katipo* were found frequently inhabiting ACOs used to monitor native lizards (Lettink and Patrick 2006). The most successful ACO design used to attract *L. katipo* (Lettink and Patrick 2006; Costall and Death 2010) consists of two pieces of

Fig. 3 A typical ACO placement at the base of some *F. spiralis* at Kaitorete Spit

Onduline® corrugated roof cladding, a tough black material made from ceramic fibres embedded in bitumen. Sheets of cladding were placed one on top of the other, separated by short lengths of dowel glued onto the underside of the top piece. Two sizes of Onduline have been used to monitor *L. katipo* numbers, depending on availability: small ACOs are 385 mm by 325 mm and large ACOs are 385 mm by 600 mm.

Samples

Twenty sites (10 *A. arenaria* and 10 *F. spiralis*) were selected randomly from a total of 60 potential 10 m^2 sites. Potential sites were selected mainly based on the plant species present, with *F. spiralis* or *A. arenaria* as the dominant species. Also taken into consideration was the suitability of the site for ACO placement, flat sites being preferred to minimise the risk of ACOs sliding or being blown down slopes. At each site, an ACO was placed next to the base of an individual *A. arenaria* or *F. spiralis*, and weighted down with rocks before a GPS location was taken (Fig. 3). The percentage cover of *F. spiralis* and *A. arenaria* was visually estimated for each site. Individual study sites were at least 20 m apart to minimise the chance that individuals would move between them (Griffiths 2001). During the winter season, small (385 mm by 325 mm) ACOs were used. Due to the use of the small ACOs in a different experiment, large (385 mm by 600 mm) ACOs were used for the spring, summer and autumn field seasons. The smaller ACOs could conceivably be less attractive to prospecting *L. katipo*, as they provide less shelter. However, both sizes of ACO are many times the size of an individual *L. katipo*. ACO size difference is unlikely to affect the results of the present study.

Artificial cover objects were checked once every 15 days for 60 days during all four seasons between July 2011 and June 2012 (July until September was the winter field season, October until December was the spring field season, January until March was the winter field season, and April until June was the summer field season). The 60 day period for each season began approximately halfway through a season. The number of spiders in each of the four age–sex classes was recorded (adult female (AF), subadult female (SF), male (M) or juvenile (J)) (Fig. 4). In spring, ACOs were deployed on the ninth of October and taken in on the eighth of December. At the end of each season, any *L. katipo* occupying ACOs were released onto the sand near vegetation. Taking the ACOs in at the end of the season and deploying them at the beginning of the next season meant that, in addition to comparing occupancy rates for ACOs next to *A. arenaria* versus *F. spiralis* plants, occupancy rates in different seasons could be compared given that they had to be recolonised every season by *L. katipo*. Again, sites for the spring, summer and autumn seasons were selected randomly from a sample of the 60 potential sites; some sites were used more than once. When an ACO was deployed in a previously used site, the site was located to within a 10 m radius of the original site

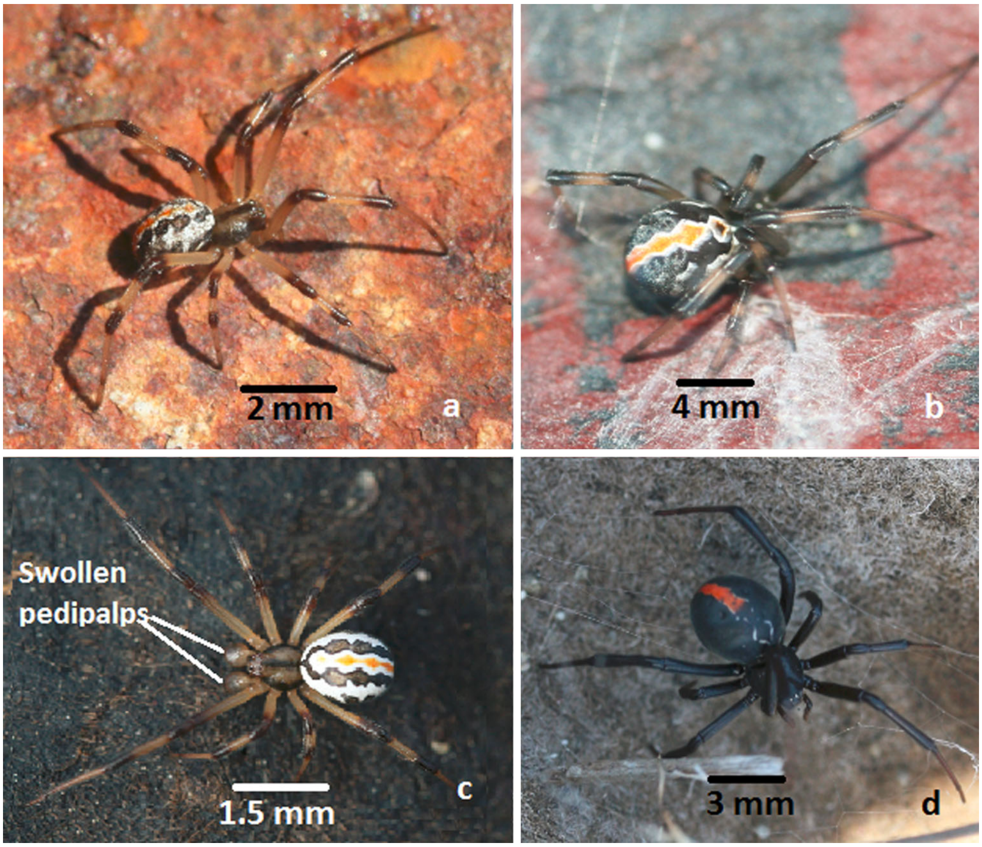

Fig. 4 The four age–sex classes of *L. katipo*, as distinguished for the present study. **a** Juvenile *L. katipo* have an equal or larger amount of white on the abdomen than black, and dark and light striped brown legs. They vary in size depending on the instar, but are smaller than sub-adult or adult females. **b** Sub-adult female *L. katipo* are mostly black on the abdomen but there are still white lateral abdominal markings in addition to the white outline of the dorsal stripe. There are also obvious stripes on the legs. **c** Adult male *L. katipo* resemble juveniles, but they possess *swollen pedipalps*. The difference in pedipalp size between juveniles and adult males is quite clear. Note that males also have striped legs. **d** Adult female *L. katipo* are black with a red dorsal stripe and black legs which do not show an obvious striping pattern. There is often a small amount of white on the abdomen, usually connected to the dorsal stripe

using GPS, and the ACO was deployed using the original protocol.

Data collection

Disturbance was minimised at each site when obtaining spider counts. Each Onduline® sheet was lifted carefully and placed upside–down on the substrate before being scrutinised. Adult and subadult female *L. katipo* are more conspicuous than males and juveniles, which are much smaller and mostly white in colour with black spots (Fig. 4) (Forster and Forster 1999). All demographic groups are easily visible against the dark background of the Onduline® sheets.

Statistical analysis

Generalised linear mixed models (GLMM) were fitted to the data [Genstat Version 13 (VSN International 2011)]. The distribution of the number of *L. katipo* found in each ACO was zero-inflated, particularly for sites positioned within the more disturbed area; the data from the four age-sex classes were thus pooled and treated as a presence/absence binary response variable. Presence/absence data were analysed using a binomial error distribution with a logit link function in which the denominator was the total number of ACO checks performed. Site number and visit number (the number of ACO checks conducted in the season so far) were treated as random effects to account for any temporal autocorrelation for multiple checks within each season. The fixed effects were dominant vegetation type and the four seasons.

Fixed effects were added individually to the null model and the minimum adequate model was chosen by assessing the significance of the fixed effects, using Wald tests for significant reductions in the deviance ($p < 0.05$).

Results

Ammophila arenaria has yet to dominate over *F. spiralis* at Kaitorete Spit. In each season, 10 sites contained *A.*

Table 1 Numbers and age classes of *L. katipo* found in ACOs

Season	Vegetation type	Total number of occupied ACOs	Number of live *L. katipo* found from each demographic group					Total individuals
			Juvenile	Sub-adult female	Adult male	Adult female	Egg sac	
Winter	*A. arenaria*	3	1	2	0	0	0	3
	F. spiralis	7	4	3	0	0	0	7
Spring	*A. arenaria*	4	0	0	0	4	2	6
	F. spiralis	9	0	0	0	10	4	14
Summer	*A. arenaria*	8	2	1	0	6	0	9
	F. spiralis	23	33	3	8	12	0	56
Autumn	*A. arenaria*	0	0	0	0	0	0	0
	F. spiralis	15	17	1	3	5	0	26
	Total individuals	69	57	10	11	37	6	121

Numbers reported are seasonal totals

arenaria, but, on average, only three sites per season contained more *A. arenaria* than *F. spiralis*. Sixty ACO sites (some pseudoreplicated due to random allocation) from Kaitorete Spit were included in the final GLMM presence/absence analysis. On three occasions an ACO could not be found, and in summer ACOs were left out for an extra 15 days before being taken in.

In total, 115 *L. katipo* and six egg cases were found under ACOs (Table 1). Sixteen *L. katipo* and two egg sacs were found adjacent to *A. arenaria* ACOs, while 99 *L. katipo* and four egg sacs were found next to *F. spiralis* ACOs. Ten *L. katipo* were found in winter, 20 in spring, 60 in summer and 26 in autumn. Egg sacs were only found in summer. 34 % more adult females were found than adult males (Table 1), perhaps due to their greater longevity and presence in the winter and spring (Griffiths 2001).

The GLMM output showed a significantly higher probability of detecting *L. katipo* adjacent to *F. spiralis* compared to *A. arenaria* ($x^2 = 17$, DF = 6, $p < 0.001$). There was also a significant interaction between the vegetation type and season ($x^2 = 13.22$, DF = 6, $p = 0.042$), with a greater difference in occupancy rate of *L. katipo* in *F. spiralis* versus *A. arenaria* in the summer and autumn than in winter and spring (Fig. 5).

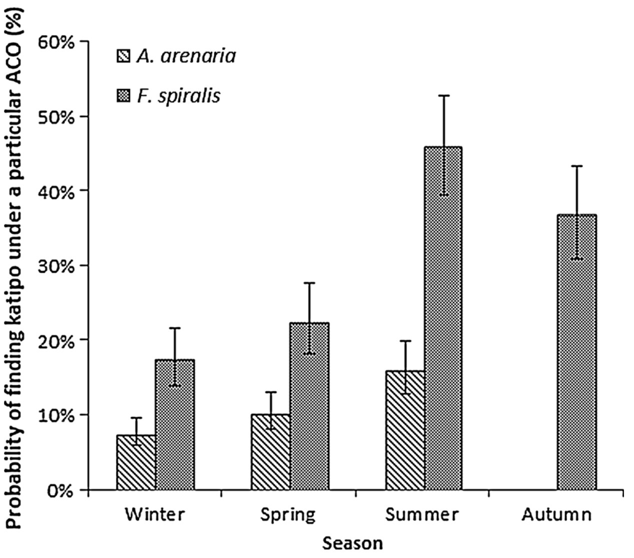

Fig. 5 Seasonal variation in ACO occupancy probabilities in *A. arenaria* and *F. spiralis* plots. Error bars show SEM, back-transformed from the logit scale

Other variables

The counts of *L. katipo* found per ACO over the entire year followed a poisson distribution. In the less disturbed area, 80 % of ACO checks yielded no *L. katipo*; 11 % showed 1 *L. katipo*; 9 % showed more than 1 *L. katipo* (maximum = 8). In the disturbed area, 19 % of ACO checks showed one or two *L. katipo*, but 81 % yielded no *L. katipo*. In total there were 24 *L. katipo* found in the disturbed area (mean 0.21 per ACO check), and 93 *L. katipo* found in the less disturbed area (mean 0.41 per ACO check). Due to the high zero-inflation, formal analysis between the two areas was not possible. Vegetation type did not significantly differ between the disturbed and undisturbed areas ($p = 0.4$). The zero-inflated nature of the data also meant that we were, therefore, unable to formally analyse the effects of season and vegetation on the distribution of age-sex classes of *L. katipo* found under the ACOs. Lizards were only present on 10 occasions (on three occasions they were cohabiting ACOs with katipo), so the effect of lizard presence on *L. katipo* presence could also not be formally analysed.

Discussion

A. arenaria *versus* F. spiralis

The probability of finding *L. katipo* in ACOs placed next to *A. arenaria* plants was significantly lower than the probability of finding them in ACOs placed next to *F. spiralis*. This difference confirms previous unpublished research showing *L. katipo* to be less likely to be found in *A. arenaria* than *F. spiralis* when conducting hand searches along a transect (Griffiths 2001). Even in spring and summer, when juveniles hatch, *F. spiralis* provides more suitable *L. katipo* habitat than *A. arenaria*, despite previous indications that juveniles often inhabit *A. arenaria* (Costall and Death 2009). Juvenile *L. katipo* in Manawatu are probably more likely to land in *A. arenaria*, as it is the dominant species in the Manawatu dunes, which may explain why Costall and Death (2009) found plenty of juvenile *L. katipo* in *A. arenaria*. This study also suggests that the difference between *L. katipo* occupation rates in *F. spiralis* and *A. arenaria* is greatest in the summer and autumn. The elongated summer field season (15 extra days of ACO monitoring) may have caused an increase in probability of katipo presence during summer, but not in autumn. A possible explanation for higher occupancy rates in summer and autumn is a delayed breeding season due to the lower than average summer temperatures in 2011–2012 (Griffiths and Tait 2012). The absence of males inhabiting the ACOs in winter and spring implies that the breeding season did not begin in earnest until the summer. Therefore, the difference in preference between *F. spiralis* and *A. arenaria* is most pronounced during the breeding season. Due to the low numbers of different age–sex classes in the current study, and the colder than average summer, further long-term studies are required to see whether this effect is consistent with a peak in the number of males.

Seasonal variation in occupancy

An increase in ACO occupancy, starting with a low presence rate in winter and peaking in summer, was demonstrated for ACOs placed in both *F. spiralis* and *A. arenaria* (Fig. 5). The low occupancy in winter is consistent with current knowledge on the biology of *L. katipo* (Griffiths 2001; Patrick 2002). It is unclear as to why no *L. katipo* were found in ACOs placed next to *A. arenaria* during the autumn when three *L. katipo* were found in *A. arenaria* ACOs in the winter. The microclimate present in *A. arenaria* may not be sufficient to shelter *L. katipo* from the drop in mean temperature between summer and autumn, leading to the deaths of spiders inhabiting *A. arenaria*. Alternatively, seasonal fluctuations in prey availability due to mortality and changes in invertebrate activity may cause *L. katipo* to leave their webs and search for more prey-rich habitat. Once spiders living in *F. spiralis* plants have adjusted to the colder temperatures, they may begin to search for new territory as prey becomes scarce and this might explain the winter rise in the number of *L. katipo* found in *A. arenaria* ACOs. Prey availability does not appear to influence *L. revivensis*, a desert species; Lubin et al. (1993) found that travelling *L. revivensis* tended to be juveniles moving to larger shrubs after moulting in the spring. However, *L. katipo* live in a temperate environment and may be limited more by prey than *L. revivensis*; additionally, exposure and dehydration may contribute towards the mortality rate of moving *L. revivensis*, reducing their propensity to move, whereas New Zealand sand dunes are not so dry or exposed.

Artificial cover objects as a monitoring technique

Although all demographic groups of *L. katipo* were found inhabiting ACOs (Table 1), and even small juveniles were visible during checks, there may be a discrepancy between the proportions of different demographic groups present in the environment, and those inhabiting the ACOs. Comparing the demographics of *L. katipo* found in ACOs with those present in the immediate environment, perhaps in a captive setting, would be a useful experiment to see how representative *L. katipo* found in ACOs are of the local population.

If *A. arenaria* was a more attractive habitat to *L. katipo* than ACOs, the number of *L. katipo* found in ACOs would not reflect local abundance. Alternatively, population abundance may be overestimated by surveys using ACOs if they are more attractive to the target species than the surrounding habitat (Wakelin et al. 2003). However, Costall and Death (2010) compared ACO occupancy rates to hand searches, and found that ACOs were reliable estimates of *L. katipo* population density. Presence/absence data acquired in studies using ACOs could therefore be considered as an index of abundance.

Based on the results of the current study, we suggest that any long-term *L. katipo* monitoring using ACOs also takes into account the increased activity levels of *L. katipo* in the summer. If ACOs are to be checked annually, they should be checked during the summer to maximise the probability of finding *L. katipo* in ACOs and increase the ability of the study to detect changes in population size.

Artificial cover objects have been used worldwide to monitor many different taxa, including salamanders (Caudata) (e.g. Riedel et al. 2012), weta (Orthoptera) (Bowie et al. 2013), and lizards (Squamata) (O'Donnell and Hoare 2012). Our study demonstrates how ACOs can also be used to examine the habitat preferences of invertebrates. Placing ACOs in different habitats will show variation in insect abundance between habitats. Corrugated covers, such as those used in our study, may be suitable for collecting presence/absence data on terrestrial insects such as Coleoptera and Thysanura. Since ACOs detect animals without killing them, researchers of endangered invertebrates should consider using ACOs rather than lethal trapping methods. Long-term studies of habitat use may also benefit from employing ACOs rather than lethal trapping methods, as trapped individuals are returned to the population rather than being removed from it. However, the survival rate of invertebrates that have been released after occupying ACOs is unknown.

Recommendations for conservation

Ammophila arenaria has been thought to be an aggressive weed for over two decades (Johnson 1982). The ability of *A. arenaria* to out-compete *F. spiralis* is well-documented (Johnson 1982; Partridge 1995; Gadgill 2006) and the subsequent detrimental effect on *L. katipo* populations has been discussed (Forster and Forster 1999, Hankin 2009) and studied at length (Court 1971; Griffiths 2001; Patrick 2002; Lettink and Patrick 2006). Habitat loss due to the invasion of *A. arenaria* may be the leading cause of decline in the *L. katipo* species. 1,208 of New Zealand's terrestrial invertebrate species are classified as "Data Deficient" under the New Zealand Threat Classification System (Stringer and Hitchmough 2012). Many of the "Data Deficient" species inhabit sand dunes, and may also be impacted by *A. arenaria* invasion; the full extent of the threat posed by habitat loss in New Zealand is currently not known. We recommend that *A. arenaria* removal programs be conducted to counter the spread of *A. arenaria* where it has already established and there are remnant *L. katipo* populations. Native sand-binding plants should be planted to restore native habitat and dune structure.

Ammophila arenaria's deeper roots enable it to grow in drier environments than *F. spiralis* (Partridge 1995). The roots also remove moisture from the sediment, causing nearby shallow-rooted plants such as pingao to desiccate (Partridge 1995). *A. arenaria* out-competes *F. spiralis*, dominating sand dunes and changing their structure. The stabilisation of sand dunes by the deep roots of *A. arenaria* is detrimental to native coastal species, which have adapted to live in the constantly shifting conditions promoted by native sand-binding plants (Partridge 1995; Gadgill 2006).

The current population size and rate of decline for *L. katipo* are not known (Sirvid et al. 2012), however Patrick (2002) searched habitat where *L. katipo* were historically found; only 46 % of sites were still inhabited by *L. katipo*, indicating a decline in range size. Long-term studies using ACOs can be implemented with minimal expertise. Seasonal placement and checking of ACOs will help to map *L. katipo* distribution and rate of decline. Local communities can become involved in checking the ACOs, linking communities with their local conservation issues and educating local people about the wildlife inhabiting sand dunes.

Acknowledgments Many thanks to Emily Fountain, Ben Wiseman, Hamish Patrick, Andrew Pugh and Jamie Cooper for help with fieldwork and editing previous versions of the manuscript. We are grateful to Roman Biek and David Bailey for comments on the manuscript. This project was undertaken as part of the University of Glasgow's MSci Work Placement scheme. The work placement was carried out by VRS at Lincoln University.

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