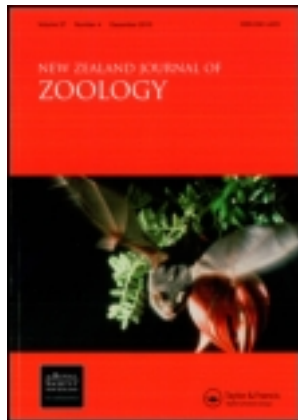


This article was downloaded by: [University of Auckland Library]

On: 08 February 2012, At: 20:12

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



New Zealand Journal of Zoology

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/tnzz20>

Population structure and habitat use by the spider *Latrodectus katipo* along the Manawatu-Wanganui coastline

Jessica. A Costall^a & Russell. G Death^a

^a Institute of Natural Resources. Ecology Group, Massey University, Private Bag 11222, Palmerston North, 4442, New Zealand

Available online: 10 Nov 2010

To cite this article: Jessica. A Costall & Russell. G Death (2009): Population structure and habitat use by the spider *Latrodectus katipo* along the Manawatu-Wanganui coastline, *New Zealand Journal of Zoology*, 36:4, 407-415

To link to this article: <http://dx.doi.org/10.1080/03014223.2009.9651473>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.tandfonline.com/page/terms-and-conditions>

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Population structure and habitat use by the spider *Latrodectus katipo* along the Manawatu-Wanganui coastline

JESSICA A. COSTALL*

RUSSELL G. DEATH

Institute of Natural Resources—Ecology Group
Massey University
Private Bag 11222
Palmerston North 4442, New Zealand

*Corresponding author: jesscostall@gmail.com

Abstract A survey of habitats likely to support the widow spider, *Latrodectus katipo* (Theridiidae), endemic to New Zealand, was carried out at seven locations along the Manawatu-Wanganui coastline. Altogether, 151 juvenile, 74 female and 14 male katipo were found, with considerable differences in population structure between sites. The lack of juveniles at some sites suggests there is low reproductive output, but continued monitoring will be needed to confirm this. Most individuals were found on driftwood. Fewer were found occupying debris and vegetation. There is substantial overlap between the sizes of driftwood refuges occupied by katipo and by *Steatoda capensis*, an introduced theridiid spider from South Africa. We conclude that katipo populations along the Manawatu-Wanganui coastline are threatened by a range of human activities, and that management action may be required to prevent local extinctions of this charismatic invertebrate.

Keywords *Ammophila arenaria*; arachnid; Araneae; coastal dunes; *Latrodectus katipo*; *Steatoda capensis*; Theridiidae

INTRODUCTION

The katipo, *Latrodectus katipo* Powell, 1871 (Theridiidae), is an endangered species of widow spider endemic to New Zealand coastal sand dunes (Vink et al. 2008). Katipo populations have declined over the

last 30 years, predominantly as a result of habitat loss and degradation (Patrick 2002). An introduced South African spider species, *Steatoda capensis* Hann 1990, also a member of the family Theridiidae, is well-established nationwide and may compete with katipo, as the two species have similar ecological niches (Hann 1990, but see Griffiths 2001, Patrick 2002). *Steatoda capensis* occupies a wide range of habitats, but in sand dunes is found predominantly living on driftwood (Hann 1990), where it may meet katipo. *Steatoda capensis* is highly abundant along the Manawatu-Wanganui coastline (Ward 1998; JAC pers. obs.).

The Manawatu dunes form the largest transgressive dune field in New Zealand, although 80% of the original active area has been lost since the 1950s (Hilton et al. 2000), largely replaced by pasture or exotic forest (Muckersie & Shepherd 1995). The remaining dune lands have been degraded through a variety of disturbances including vehicle use, rubbish dumping, grazing by introduced mammals, and the introduction of exotic plants (Hilton et al. 2000; Griffiths 2001).

Ammophila arenaria (L.) Link (marram), deliberately planted in dune systems nationwide in an attempt to stabilise sand movement, has had a large impact on dune systems as it displaces native sand-binding plants (Partridge 1995), and alters the shape and mobility of dunes (Hesp 2002). Katipo are rarely found living in dense marram (Griffiths 2001; Patrick 2002; JAC pers. obs.). Griffiths (2001) and Patrick (2002) attributed this avoidance to marram's dense growth form, as it provides insufficient open space for katipo to build their prey-catching web. Smith (1971) found higher proportions of katipo living in sparse and medium-density marram than in dense marram clumps at South Brighton Beach, Christchurch. Yet katipo will also avoid constructing webs in sparse marram clumps if native sand-binding plants are present (Costall 2006).

Katipo populations along the Manawatu-Wanganui coastline were last surveyed by Ward (1998) and Patrick (2002). The Department of Conservation has also performed annual checks of katipo habitat

in this region (DoC unpubl.), and is currently trialing a monitoring programme using artificial cover objects (ACOs) (Lorraine Cook pers. comm.). Ward (1998) found a total of 47 katipo at 21 sites along the Manawatu coastline (including the seven sites of this study), comprising 21 females, 16 males, and 10 juveniles. However, she found only two katipo at Moana Roa, six katipo at Koitiata, and no katipo at Foxton, Himatangi, Tangimoana, Castlecliff or Wanganui South. Patrick (2002) completed a nationwide survey of *L. katipo* populations, and found three female katipo at each of Moana Roa, Himatangi and Foxton, but no katipo at Tangimoana or Koitiata within a standardised searching time of 30 min. Patrick's survey did not include male or juvenile katipo as they "being so small, are difficult to locate" (Patrick 2002, p. 12).

The purpose of this survey was to update existing distribution information for *L. katipo* along the Manawatu-Wanganui coastline. In contrast to Patrick's study (2002), this survey included male and juvenile katipo as well as females, in order to compare population structure at each site. We also examined habitat use by katipo, and compared driftwood usage by *L. katipo* and *S. capensis*.

METHODS

Field methods

The seven sites were all surveyed between January and April 2005, the time of year when male and juvenile katipo are most abundant (Costall 2006). Foxton, Tangimoana, and Himatangi Beach were visited on more than one occasion, as they comprise the largest areas of potentially suitable katipo habitat. At each site searches were completed within the established foredunes, excluding the seaward side of the foremost dune. The surveys were conducted by two or three searchers. Global positioning system (GPS) coordinates were taken at the start and end points, and later used to calculate the area of dune searched. The total area searched varied between sites, due to differences in terrain, vegetation, dune extent, and the number of visits made.

Vegetation was searched by parting plant bases by hand, and examined for webbing between plant gaps. If webbing was found, it was followed until the spider's retreat was located. Katipo retreats are tubular structures constructed of densely woven silk, which can incorporate sand, shell fragments, prey exoskeletons and dead plant material (Costall 2006),

and katipo typically conceal themselves within their retreat during the day. Pieces of driftwood and other debris were searched by carefully turning them over and inspecting the surface for retreats. Spiders that were concealed within crevices and holes in the driftwood were coaxed out where possible, so that species identity could be confirmed.

Individuals were recorded as male, female or juvenile, as katipo cannot be readily sexed until they have reached at least the third or fourth instar (Griffiths 2001). Additional information including the surface area of the occupied driftwood or the density of occupied vegetation, the distance to nearest vegetation (for driftwood-dwelling spiders), the slope at the immediate vicinity of the spider's retreat, the GPS position of the spider, and whether the individual was living closely with conspecifics or *Steatoda capensis*, was also recorded. If an individual had webbing that extended through more than one plant species, or incorporated more than one piece of driftwood, only the individual plant or piece of driftwood that contained the spider's retreat was used for subsequent analysis. At Himatangi and Foxton, the surface area of driftwood occupied by *Steatoda capensis* was also recorded, to compare driftwood usage by juveniles and females of the two species.

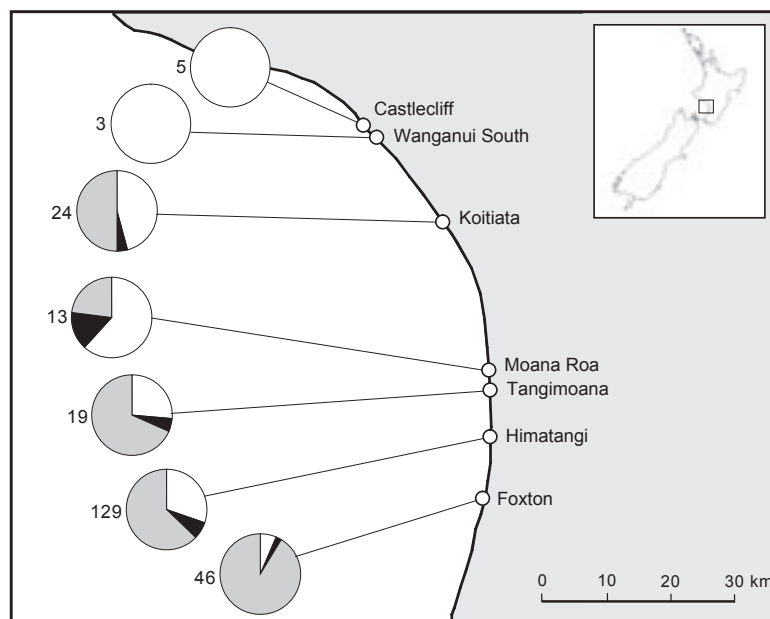
Data analysis

Global positioning system (GPS) coordinates were used to calculate the distances between individual *L. katipo*, and then averaged for each site to give the mean nearest neighbour distance. The nearest neighbour index (Rn) was calculated using the formula:

$$Rn = \frac{\bar{D}}{0.5\sqrt{\frac{a}{n}}}$$

where \bar{D} = the mean nearest neighbour distance, a = the area searched, and n = the number of individuals found (Clark & Evans 1954). Populations that have a clumped distribution have Rn values close to 0, whereas an Rn value of 1 suggests a random distribution pattern, and values close to the maximum of 2.15 indicate that individuals are regularly spaced (Clark & Evans 1954). A Kruskal-Wallis non-parametric analysis of variance was performed in SAS version 9.1 to compare the distribution of nearest neighbour distances between spiders at five of the sites (Wanganui South and Castlecliff were excluded from this analysis because of low sample size).

Fig. 1 Katipo population structure at the seven survey locations along the Manawatu-Wanganui coastline, 2005. The total number of individuals found at each site is presented alongside each pie graph showing the proportion of males (black), females (white) and juveniles (grey) found.



Kruskall-Wallis non-parametric tests were performed in SAS version 9.1 to compare the distribution of driftwood or debris sizes occupied by juvenile and female *L. katipo* and *S. capensis*. Driftwood usage by male spiders was not compared, as few male *L. katipo* and *S. capensis* were found on driftwood (13 and three individuals respectively). Males typically abandon their own webs upon maturity (Griffiths 2001), and are commonly found with females. The degree of niche overlap in driftwood usage was calculated using Ecosim version 7 (Gotelli & Entsminger 2001), assuming that driftwood in different size classes (250 cm² intervals, with all driftwood over 5000 cm² lumped into one class) were equiprobable, as these data were not collected. However, as this is unlikely to be the case, the test will tend to overestimate the degree of overlap (Gotelli & Entsminger 2001).

A chi-square test was performed in SPSS 16.0 to compare population structure (i.e., the number of males, females and juveniles) between sites. As 11 out of 21 table cells had expected frequencies less than five, yet the data set was too large to compute Fisher's exact test, a Monte Carlo estimate of exact significance (10 000 permutations, 99% confidence interval) was calculated. Chi-square tests with Monte Carlo estimates of exact significance were also used, firstly to see if the proportions of male, female and

juvenile katipo found on driftwood versus vegetation differed, and secondly to compare the proportion of mature and juvenile katipo occupying different plant species.

RESULTS

Two-hundred-and thirty-nine katipo were found along the 4.7 km of coastline surveyed, of which 31% were female, 6% male and 63% juvenile. Population structure varied significantly between locations ($\chi^2 = 45.80$, d.f. = 12, $P \leq 0.001$; Fig. 1). Himatangi and Foxton had proportionally more juveniles, whereas no juveniles were found at Wanganui South or Castlecliff. The mean nearest neighbour distances between individual katipo varied between locations ($\chi^2 = 24.05$, d.f. = 4, $P \leq 0.001$), with *L. katipo* being highly clumped at Koitiata, Himatangi, Tangimoana and Foxton and more randomly spaced at Moana Roa (Table 1).

Most of the searched area consisted of vegetation-sparse blowouts, with 79% (189) of the spiders found on driftwood or other debris, while the remainder (50 individuals; 21%) were found on vegetation. The proportions of male, female and juvenile katipo found on plants were not significantly different to those found on driftwood ($\chi^2 = 2.84$, d.f. = 2, $P = 0.24$).

Table 1 List of survey locations, total area searched, and number of spiders found at each location. Estimated population densities are expressed as number of individuals found per hectare searched. Nearest neighbour distances were calculated using GPS coordinates taken at each individual spider's location, and then averaged for each site. The nearest neighbour index (Clark & Evans 1954) indicates the basic spatial distribution of individuals, with values of $Rn \approx 0$ representing highly clumped distributions, ≈ 1 representing random spacing, and Rn values approaching the maximum value of 2.15 representing regular spacing of individuals. Asterisk denotes sites with insufficient sample size to calculate Rn .

Site	Grid reference	Dates surveyed	Length of coastline surveyed (km)	Area surveyed (ha)	No. of katipo found			Estimated density (per ha)	Mean nearest neighbour distance (m)	Rn	
					Female	Male	Juvenile				Total
Himatangi	40°22'12"S, 175°13'46"E	10/1/05, 21/1/05, 27/1/05, 20/2/05, 24/3/05	2.05	22.5	39	9	81	129	5.73	3.5	0.17
Tangimoana	40°18'49"S, 175°13'51"E	16/1/05, 5/2/05	0.49	3.9	5	1	13	19	4.87	3.4	0.15
Foxton	40°27'56"S, 175°12'93"E	14/1/05, 18/1/05, 7/2/05, 8/2/05	0.81	16.2	3	1	42	46	2.84	7.6	0.25
Moana Roa	40°16'71"S, 175°13'34"E	5/04/2005	0.36	4	8	2	3	13	3.25	17.4	0.63
Koititua	40°04'57"S, 175°08'16"E	8/04/2005	0.21	1.1	11	1	12	24	21.82	1.3	0.12
Wanganui South	39°57'77"S, 175°00'77"E	5/03/2005	0.5	2.5	3	0	0	3	1.20	18.0	*
Castleclyff	39°56'58"S, 174°58'63"E	25/02/2005	0.29	1.5	5	0	0	5	3.33	20.0	*
Total			4.71	49.7	74	14	151	239			

Katipo webs were found on four native plant species, *Spinifex sericeus* R.Br. (spinifex or silvery sand grass), *Desmoschoenus spiralis* (A. Rich.) Hook. f. (pingao), *Calystegia soldanella* (L.) R.Br. (shore bindweed), and the grass *Lachnagrostis billardieryi* (R.Br.) Trin., and on four exotic plant species, *A. arenaria* (L.) Link (marram), *Senecio elegans* L. (purple groundsel), *Carpobrotus edulis* L. (iceplant), and *Leontodon taraxacoides* (Villars) (hawkbit). Although katipo webbing was sometimes found attached to *C. soldanella* plants, the spider's retreat and the bulk of the catching web were always constructed in an adjacent, larger plant species, therefore *C. soldanella* was not included in any analysis. Of the juvenile katipo found in vegetation, 73% were living within marram, 16% were found in spinifex, and the remainder were living in other plant species. Two juvenile katipo were found occupying hawkbit, a small plant that would probably not provide enough space for mature female katipo to construct webs. In contrast, only 28% of mature female katipo were found in marram, with 56% in spinifex (Fig. 2). The species of plants used by juvenile and mature katipo were significantly different ($\chi^2 = 3.23$, d.f. = 14, $P \leq 0.001$).

Driftwood tends to be concentrated within the flat basins of blowouts, so most katipo living on driftwood were found on flat or near-flat ground, whereas the vegetation occupied by katipo grew on a range of slopes, up to 70° (data not presented). Despite there being many isolated pieces of driftwood present, no driftwood-occupying katipo were found living more than 10 m away from vegetation, and 56% (106 individuals) were found within 1 m. There was no significant relationship between the size of occupied driftwood, and the distance to the nearest vegetation ($r = -0.39$, $P = 0.60$).

It was common to find several *L. katipo* individuals occupying the same piece of driftwood, or living in vegetation in very close proximity (i.e., within 30 cm) with conspecifics or the introduced *S. capensis* (Table 2). Although male *S. capensis* were seen during the survey, they were never

found together with *L. katipo* individuals. The most common type of “sharing”, recorded 16 times, was one juvenile *L. katipo* living closely with one juvenile *S. capensis*. The second most common types of sharing (nine records each) was 1 female and 1 male *L. katipo* found together, and 1 female and 1 juvenile *L. katipo* together. The highest number of individuals found sharing was eight, at Moana Roa Beach, where 3 female, 2 male, and 1 juvenile *L. katipo* were found with 1 female and 1 juvenile *S. capensis*, on a piece of driftwood with a surface area of 1250 cm².

Shared pieces of driftwood were not necessarily larger than driftwood occupied by individual katipo. On four occasions, multiple *L. katipo* were found not only sharing driftwood or vegetation, but living in contiguous retreats, although with separate openings, and surrounded by seemingly continuous catching webs.

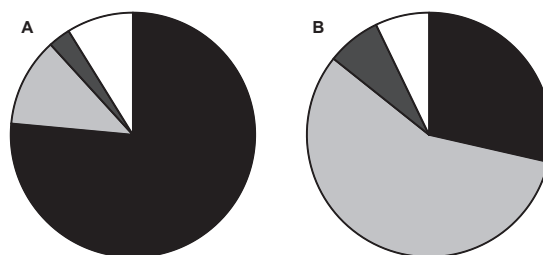


Fig. 2 Plant species occupied by **A**, juvenile ($N = 34$) and **B**, mature katipo ($N = 28$); black segments represent marram, light grey is spinifex, dark grey is pingao and all other plant species combined are represented by white segments.

Table 2 Combinations of *Latrodectus katipo* and *Steatoda capensis* occupying the same piece of driftwood, and the frequency at which they occurred. Each row represents one type of combination. Note that in the two instances where numerous *S. capensis* juveniles were recorded (marked with asterisks), the individuals were from newly hatched egg sacs.

<i>L. katipo</i>			<i>S. capensis</i>		Frequency
Female	Male	Juvenile	Female	Juvenile	
		1		1	16
1	1				9
1		1			9
1				1	7
		2			4
1				2	3
2					3
1		1		1	3
1	1	1			2
1	1			1	2
1			2	1	2
2				1	2
1			2	1	1
1			1		1
2	1				1
1		1		2	1
2	2				1
2	1	1			1
	1			1	1
	1		1		1
	1	1			1
		1	1	25+*	1
		1		10+*	1
3	2	1	1	1	1

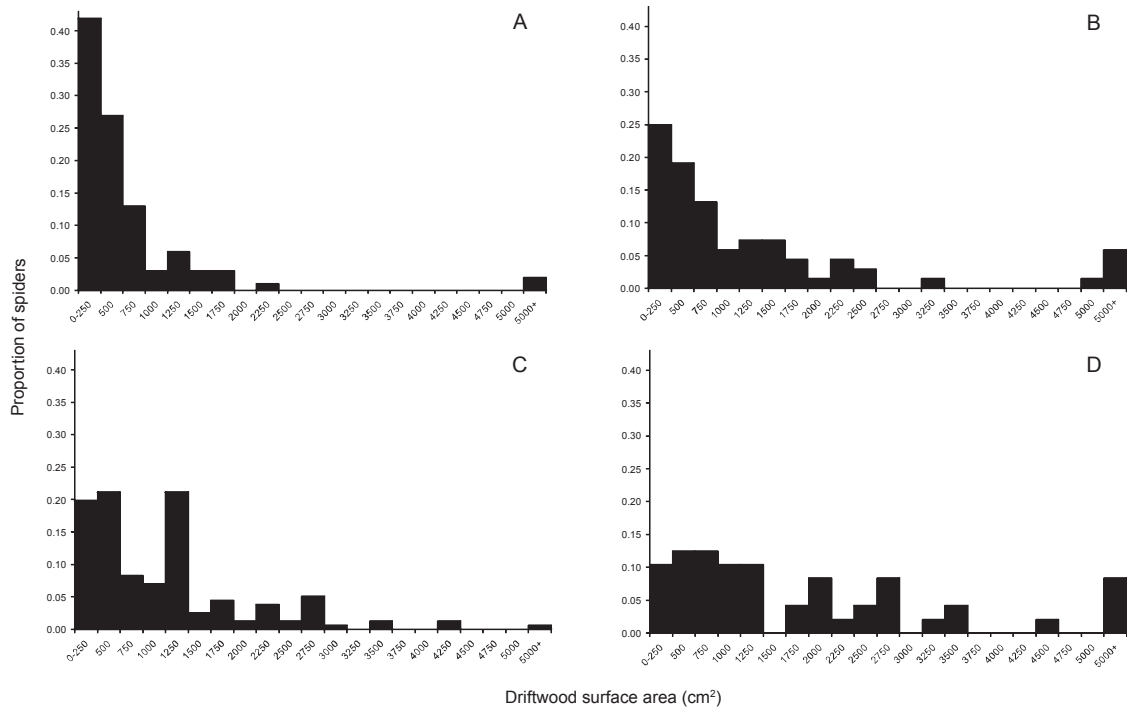


Fig. 3 Comparison of the surface area of driftwood or other debris occupied by mature female and juvenile *Steatoda capensis* and *Latrodectus katipo*. **A**, Juvenile *L. katipo* ($N = 100$, mean = 610.21 cm², SE = 145.33); **B**, Female *L. katipo* ($N = 69$, mean = 1667.03 cm², SE = 442.90); **C**, juvenile *S. capensis* ($N = 156$, mean = 968.40 cm², SE = 80.57); **D**, female *S. capensis* ($N = 48$, mean = 1682.40 cm², SE = 238.09). Male *L. katipo* data not depicted ($N = 13$, mean = 2593.46 cm², SE = 1672.47).

Table 3 Pianka's (1973) index of niche overlap, calculated for surface area of occupied pieces of driftwood. Index values range between 0 and 1, with a value of 1 representing complete overlap.

	<i>L. katipo</i> juveniles	<i>S. capensis</i> females	<i>S. capensis</i> juveniles
<i>Latrodectus katipo</i> females	0.952	0.799	0.909
<i>L. katipo</i> juveniles		0.629	0.840
<i>Steatoda capensis</i> females			0.832

There were age- and species-specific differences in the surface area of driftwood and other debris occupied by *L. katipo* and *S. capensis* (Fig. 3). A higher proportion of juvenile *L. katipo* was found on small (i.e., <500 cm²) pieces of driftwood compared with female *L. katipo* ($H = 14.62$, d.f. = 1, $P < 0.0001$). Likewise, juvenile *S. capensis* were found on smaller pieces of driftwood than female *S. capensis* ($H = 14.62$, d.f. = 1, $P = 0.0001$). Juvenile *S. capensis* were found on larger pieces of driftwood than juvenile *L. katipo* ($H = 27.20$, d.f. = 1, $P < 0.0001$). Female *L. katipo* were more often found on smaller pieces of driftwood than female *S. capensis*

($H = 6.03$, d.f. = 1, $P = 0.01$). When individuals of all ages were considered together for each species, *L. katipo* was still found to occupy smaller pieces of driftwood than *S. capensis* ($H = 20.33$, d.f. = 1, $P < 0.0001$). The largest objects occupied by *L. katipo* were; a large log (12 500 cm²), a discarded car bonnet (22 500 cm²), and a sheet of corrugated iron (17 500 cm²).

Pianka's index of niche overlap applied to driftwood sizes was 0.86 between *S. capensis* and *L. katipo* overall, with all of the simulations having lower overlap than the observed value. When age and sex was taken into account, it showed that overlap in

driftwood use was greatest between juvenile and female katipo, and lowest between juvenile *L. katipo* and female *S. capensis*, though still substantial (Table 3).

DISCUSSION

More katipo were found during this survey than in previous studies (Ward 1998; Patrick 2002). The female-biased sex ratio has been reported elsewhere (e.g., Smith 1971). It is unlikely that males' smaller size (compared with females) explains why fewer were located, as males are larger than juveniles which were still found in high numbers. Male katipo abandon their webs upon maturity to search for females (Griffiths 2001). Although we recognise that they may be more difficult to find during this wandering phase, mature male katipo are often found in conspicuous positions in close proximity to females. We do not believe that this behaviour is the sole explanation for the low numbers of males found. Instead, the female-biased sex ratio is likely a reflection of the differential life expectancies of the two sexes; males live for an average of 77 days past their final moult (Costall 2006), whereas females can live for over 2 years (Forster & Kingsford 1983).

The population density estimates produced will be lower than actual population densities, as detection probability must have been less than 100%. We kept search effort as constant as possible by minimising changes to search personnel, and by searching in a systematic fashion. Hence, although variation in terrain and vegetation density affected the total area searched, we believe that detection probability was fairly constant across sites. Therefore, the population density estimates will be useful in comparing the status of katipo at different sites. The population density estimates suggest that Koitiata had the highest *L. katipo* density at the time of our survey, however, only a comparatively small area was surveyed at this site, and the area of foredune is much smaller compared with other areas such as the continuous dune system that incorporates Tangimoana, Himatangi and Foxton beaches.

It is more difficult to locate katipo within vegetation than on driftwood. In addition, much of the area searched in this survey consisted of large vegetation-sparse blowouts typically containing large amounts of driftwood, so it is not surprising that the majority of katipo were found on driftwood. In other areas of the country, such as along the Canterbury coastline, driftwood tends to be scarce within the dunes, so

katipo are more likely to be found in vegetation (Griffiths 2001). Choice experiments indicated no evidence that katipo prefer to construct webs on driftwood over native vegetation, or vice versa (Costall 2006).

Vegetation still seems to be an important determinant of web site, as all of the spiders found on driftwood were within 10 m of vegetation, and most within 1 m. A possible explanation for this is that katipo are selecting web sites based on prey availability. Pitfall-trapping conducted at three sites at Himatangi Beach indicated that sand dune invertebrates tend to be more abundant in areas with high plant cover (J. A. Costall unpubl.).

There were differences in habitat usage between katipo of different ages. For example, proportionally more juvenile katipo occupied marram than mature female *L. katipo*. In addition, some juvenile katipo were found occupying very small pieces of driftwood, or living in small hawkbit plants. Juvenile katipo probably require a smaller area over which to construct their platform-like catching web, which might explain why they can be found in habitat that is apparently unsuitable for mature katipo (Griffiths 2001; Patrick 2002). It is unclear whether juvenile katipo living in such locations later relocate their web site, or if survival rates for such individuals are low.

At some sites katipo had a strongly clumped distribution, and it was common to find multiple katipo on the same piece of driftwood, an observation also made by Ward (1998). Artificial cover objects (ACOs) used as monitoring tools are often occupied by more than one katipo at a time (Costall 2006; Letink & Patrick 2006; Lorraine Cook pers. comm.). Not only were katipo found living very closely with conspecifics, but sometimes they were even found in communal webs. This is perhaps surprising, given that Forster & Kingsford (1983) found that katipo reared together in a laboratory engage in aggressive competition for prey items and often cannibalise one another. In the four cases of communal katipo webs we found, it was not clear how closely related the spiders were (although individuals were of varying ages), how the catching webs were partitioned, or if the spiders cooperated in prey capture. Communal webs have also been observed in *Latrodectus hesperus* Chamberlin & Ivie, 1935 (Kaston 1968).

Latrodectus katipo was often found sharing driftwood with *S. capensis*, although their webs were always separate. Patrick (2002) also noted katipo and *S. capensis* sharing driftwood in his nationwide survey. This indicates that katipo can successfully

coexist with *S. capensis*, although *S. capensis* densities at Himatangi sometimes exceeded twice that of *L. katipo* (Costall 2006). As there is substantial overlap in the size of driftwood used by *L. katipo* and *S. capensis*, direct competition for web sites could occur if they became limiting, perhaps if *S. capensis* population densities increase further. *Steatoda capensis* certainly appears to have the potential to indirectly out-compete katipo, due to its wider habitat tolerance, and ability to reproduce year-round (Hann 1990).

Griffiths (2001) found that katipo showed a preference for slopes of 1–30°, although aspect and vegetation were more important determinants of web site, whereas Smith (1971) reported that katipo were more likely to be found at slopes of 30–45°. This survey revealed that katipo living in vegetation chose a range of slopes below 70°, with no apparent preference for any slope within that range. The large proportion of driftwood-dwelling katipo found at slopes <10° is a reflection of the way driftwood was concentrated within the flat-bottomed blowouts.

Katipo were found living on both exotic and native plants. Although no katipo were found occupying other native coastal dune plant species such as *Coprosma acerosa* A. Cunn. and *Pimelea arenaria* A. Cunn. during this survey, this is probably a reflection of the comparative scarcity of these plants, and the patchy distribution of katipo, because later searches at Himatangi did find katipo living within these species (J. A. Costall pers. obs.).

This survey showed that katipo populations are persisting at a number of sites along the Manawatu-Wanganui coastline. However, the differences in population structure and overall abundance of katipo at each of the locations suggests that there is substantial variation in the viability of these populations. For example, the large proportion of juvenile *L. katipo* at sites like Himatangi and Foxton shows that reproductive output is comparatively high at these sites. The overall low number of individuals found at Castlecliff and Wanganui South beaches, and the apparent absence of juveniles, is a cause for concern. The seemingly low reproductive output at these two sites could be due to Allee effects, whereby the very low population density makes it hard for male katipo to locate mates. These results suggest that katipo populations at some sites like Wanganui South and Castlecliff have been more severely affected than at other sites. The reasons for this are unclear, although displacement by *S. capensis* is unlikely to be the

cause, as densities of this introduced spider appeared to be relatively lower at these two sites, compared to Himatangi and Foxton.

The katipo populations at all of the sites covered by this survey remain under threat through further degradation of the dune system, a problem faced by katipo populations nationwide (Patrick 2002). Populations at all sites will need to be monitored in order to assess if current levels of reproduction are sufficient to maintain or increase current population levels. Translocations of katipo into dune systems at sites such as Wanganui South and Castlecliff may be necessary to prevent local extinctions. More important, however, will be the reduction and reversal of damage that is currently being inflicted upon the dune systems, from vehicle use, rubbish dumping, grazing by hares and the spread of exotic plants that exhibit dense growth.

ACKNOWLEDGMENTS

Thanks to Viv McGlynn and Kate Steffens from the Palmerston North Department of Conservation Office for advice and assistance with the initial stages of this study. Staff and postgraduate students of the Ecology Group at Massey University provided assistance and advice, in particular Emily Atkinson, Shaun Nielsen, Richard Carter, and Kiryn Curnow provided assistance in the field, and Jill Rapson helped with plant species identification. Two anonymous reviewers provided helpful feedback on an earlier version of this manuscript.

REFERENCES

- Clark PJ, Evans FC 1954. Distance to nearest neighbour as a measure of spatial relationships in populations. *Ecology* 35: 445–453.
- Costall JA 2006. The ecology and conservation of *Latrodectus katipo*, New Zealand's endangered widow spider. Unpublished MSc thesis, Massey University, Palmerston North, New Zealand.
- Forster L, Kingsford S 1983. A preliminary study of development in two *Latrodectus* species (Araneae: Theridiidae). *New Zealand Entomologist* 7: 431–439.
- Gotelli NJ, Entsminger GL 2001. EcoSim: null models software for ecology. Version 7.0. Acquired Intelligence Inc. & Kesey-Bear. <http://homepages.together.net/~gentsmin/ecosim.htm>. (date accessed 23 June 2009).

- Griffiths JW 2001. Web site characteristics, dispersal and species status of New Zealand's katipo spiders, *Latrodectus katipo* and *L. atritus*. Unpublished PhD thesis, Lincoln University, New Zealand. 91 p.
- Hann SW 1990. Evidence for the displacement of an endemic New Zealand spider, *Latrodectus katipo* Powell by the South African species *Steatoda capensis* Hann (Araneae, Theridiidae). New Zealand Journal of Zoology 17: 295–307.
- Hesp P 2002. Foredunes and blowouts: initiation, geomorphology and dynamics. Geomorphology 48: 245–268.
- Hilton M, Macauley U, Henderson R 2000. Inventory of New Zealand's active dunelands. Science for Conservation 157. 30 p.
- Kaston BJ 1968. Remarks on black widow spiders, with an account of some anomalies. Entomological News 79: 113–124.
- Lettink M, Patrick BH 2006. Use of artificial cover objects for detecting red katipo, *Latrodectus katipo* Powell (Araneae: Theridiidae). New Zealand Entomologist 29: 99–102.
- Muckersie C, Shepherd MJ 1995. Dune phases as time-transgressive phenomena, Manawatu, New Zealand. Quaternary International 26: 61–67.
- Patrick B 2002. Conservation status of the New Zealand red katipo spider (*Latrodectus katipo* Powell, 1871). Science for Conservation 194: 33 p.
- Partridge TR 1995. Interaction between pingao and marram on sand dunes: completion of permanent plot studies. Science for Conservation 3: 1173–2946.
- Smith DJ 1971. The habitat and distribution of the katipo spider at South Brighton Beach, Christchurch, New Zealand. New Zealand Entomologist 5: 96–100.
- Vink CJ, Sirvid PJ, Malumbres-Olarte J, Griffiths JW, Paquin P, Paterson AM 2008. Species status and conservation issues of New Zealand's endemic *Latrodectus* spider species (Araneae: Theridiidae). Invertebrate Systematics 22: 589–604.
- Ward M 1998. Conservation status, distribution and habitat description of the endemic katipo spider *Latrodectus katipo*. Unpublished report for the Department of Conservation, Palmerston North, New Zealand.