

Population monitoring of the endangered New Zealand spider, *Latrodectus katipo*, with artificial cover objects

Jessica A. Costall* and Russell G. Death

Ecology Group, Institute of Natural Resources, Massey University, Private Bag 11 222, Manawatu Mail Centre, Palmerston North 4442, New Zealand

*Author for correspondence (Email: jesscostall@gmail.com)

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Abstract: The endangered New Zealand widow spider, *Latrodectus katipo*, is believed to have undergone marked population decline over the last 30 years, but as monitoring methods are time- and labour-intensive, and require observers to have a high level of experience, the current status of many populations is unknown. We investigated the use of artificial cover objects (ACOs) as an alternative monitoring tool for *L. katipo* at three sites at Himatangi Beach, Manawatu, New Zealand, from late 2004 through to mid-2005. Occupancy rates of the ACOs were compared to population densities obtained from habitat searches, to assess their efficacy as a monitoring tool. Numbers of the introduced spider, *Steatoda capensis*, which may be a competitor of *L. katipo*, were also recorded during habitat searches. ACOs were reliable monitoring tools, with occupancy rates higher at the site with the highest *L. katipo* population density. *Latrodectus katipo* populations were found to have highly female biased sex-ratios, with a longer breeding season at Himatangi than reported previously at other sites. *Steatoda capensis* exists at much higher population densities than *L. katipo* at Himatangi. However, fluctuations in the populations of the two species appear to be unrelated. ACOs could be used as a non-destructive monitoring tool for many other invertebrate species.

Keywords: Araneae, coastal dunes, *Steatoda capensis*, Theridiidae

Introduction

The katipo spider, *Latrodectus katipo* Powell 1871 (Family Theridiidae), is an endangered species that is endemic to New Zealand (Patrick 2002). Although closely related to the Australian redback, *Latrodectus hasseltii* Thorell 1870 (Garb et al. 2004; Griffiths et al. 2005), *L. katipo* is distinct in terms of morphology, habitat, and behaviour (specific differences between the two species are outlined in Forster (1992) and Forster & Forster (1999)). Species in the genus *Latrodectus* contain the vertebrate-specific neurotoxin α -latrotoxin in their venom (Vetter & Isbister 2008), but there have been no human fatalities resulting from *L. katipo* bites since the 1800s (Griffiths 2001).

Latrodectus katipo spiders are specialised to coastal dune habitats, and construct their webs in the bases of vegetation, or under driftwood and other debris. A marked decline in the abundance and range of this species has occurred over the last 30 years, and it is listed as in 'Serious Decline' in the Department of Conservation's Threat Classification System (Hitchmough et al. 2007). The decline in *L. katipo* is largely attributed to habitat loss and degradation (Patrick 2002). Competitive pressure from the introduced species *Steatoda capensis* Hann 1990 may also be important (Hann 1990). *Steatoda capensis* is very abundant in many coastal dune areas (Hann 1990; pers. obs.), but the impact, if any, on *L. katipo* populations is unclear (Griffiths 2001; Patrick 2002). The black katipo, *Latrodectus atritus* Urquhart 1890, now recognised as a junior synonym of *L. katipo* (Vink et al. 2008), is believed to have undergone a similar decline (Griffiths 2001).

It is unknown whether *L. katipo* populations are still in decline. Patrick (2002) completed a nationwide survey of *L. katipo* populations, and recommended further monitoring. This has occurred at only a few locations, for example at Kaitorete Spit, Canterbury, New Zealand (Troup 2004 in Lettink & Patrick 2006). This lack of monitoring can in part be attributed to the time- and labour-intensive nature of current monitoring methods, principally transect and quadrat searches.

The cryptic nature of *L. katipo* webs makes detection difficult unless searchers receive adequate training and practice (Lettink & Patrick 2006). In addition, many *L. katipo* surveys have not included males or juveniles, probably because of their small size, different abdominal markings, and less obvious webs. Male *L. katipo* abandon

their webs upon maturity and search for mates, but can often be found in the webs of females (Patrick 2002; pers. obs.). A 2004–2005 survey of seven sites along the Manawatu coastline found that males and juveniles made up 69% of the total *L. katipo* population, with the proportion of juveniles varying considerably between sites (Costall & Death 2009). This may reflect differential reproductive output and thus provide an indication of population viability. This survey also revealed that *L. katipo* tend to occur in scattered clumps (Costall & Death 2009), so that transect or quadrat searches would have a high probability of missing *L. katipo* altogether.

These problems have highlighted a need for a monitoring technique that is quick and easy to perform, incorporates juvenile and mature *L. katipo* of both sexes, and can be applied nationwide. The use of artificial cover objects (ACOs) is a potential solution to the *L. katipo* monitoring problem. ACOs are man-made objects that are designed to imitate microhabitats already utilised by the focal species. They are placed within natural habitat, and are checked on a regular basis for occupancy. ACOs are easily replicable, standardised units, provided the ACO design remains unchanged (Wakelin et al. 2003). ACOs can be checked more quickly than transect searches can be performed; therefore a much larger area can be covered. Checking ACOs also tends to be less disruptive to the study animal than manual habitat searches (Houze & Chandler 2002; Wakelin et al. 2003), and should minimise damage to webs. Although *L. katipo* are not usually aggressive (Ward 1998, unpubl. report), the use of ACOs may also reduce the risk of searchers receiving venomous bites as a result of accidental provocation.

Previously ACOs have mostly been used for monitoring herpetofauna (e.g. Smith & Petranksa 2000; Houze & Chandler 2002). In New Zealand, ACOs are used to monitor native weta (Orthoptera: Anostomatidae and Rhabdophoridae) (Sherley 1998; Trewick & Morgan-Richards 2000; Bowie et al. 2006), and lizards (Lettink & Patrick 2006). ACOs have also been used for arachnids. Hodge et al. (2007) used tree-mounted artificial shelters to study arboreal spider communities, and Bowie and Frampton (2004) found that spiders, mites and harvestmen occupied ACOs designed to assess ground invertebrate assemblages.

The use of ACOs as *L. katipo* monitoring tools was first considered when ACOs intended for lizards were coincidentally occupied by *L. katipo* at Kaitorete Spit, Canterbury (Lettink & Patrick 2006).

Although this study demonstrated that *L. katipo* will readily use ACOs, Lettink and Patrick (2006) recognised the need for occupancy rates of ACOs to be compared with population estimates obtained from habitat searches, in order to ‘calibrate abundance estimates’.

Potential drawbacks of ACOs are that, depending on shelter design, population estimates may be biased if *L. katipo* avoid or are overly attracted to the shelters. There is also the concern that ACOs may artificially boost population numbers by increasing available habitat (Wakelin et al. 2003). However, as many of New Zealand’s coastal dune systems have declined in habitat quality due to vegetation changes and driftwood removal (Patrick 2002), this could be a positive potential side-effect, similar to the use of nest boxes that improve nest site availability for birds.

The aim of this study was to examine the effectiveness of ACOs as a monitoring tool for *L. katipo*, and to use background habitat searches in two ways; firstly as an investigation into the population dynamics of this species, and secondly as a comparison with ACO occupancy rates. This study tracked *L. katipo* populations at three sites at Himatangi Beach, Manawatu, between December 2004 and July 2005. Numbers of the introduced species *Steatoda capensis* and all other spiders were also recorded.

Methods

Study site

Himatangi Beach (40°22’12” S, 175°13’46” E) is located 30 km west of Palmerston North, on the west coast of the North Island of New Zealand. The beach is part of the Manawatu dunefields, the largest transgressive dune fields in New Zealand (Muckersie & Shepherd 1995). Much of the Manawatu dunefields have been stabilised and afforested, and the remaining dunes have been modified through the planting of exotic sand-binding plants such as marram, *Ammophila arenaria* (L.), and the use of off-road vehicles. Similar modification has occurred in virtually all of New Zealand’s coastal dune ecosystems (Hilton et al. 2000).

The foredunes at Himatangi consist of large dunes that run parallel to the coastline, punctuated at intervals by large depressions or ‘blowouts’, which have formed after dune collapse. These blowouts are characterised by having only sparse vegetation, and often contain large amounts of driftwood, which is occupied by comparatively high numbers of *L. katipo* and *S. capensis* (M. Ward 1998, unpubl. data). Three of these blowouts were selected as study sites, all south of the main beach entrance. Sites A and B were about 100 m apart, approximately 5 km south of the main beach entrance, whereas Site C was a further 600 m south, adjacent to a small stream. The three blowouts were 900, 3390, and 300 m² respectively, with the sides of the blowouts designated as the borders of each study area.

ACO design

The ACOs used in this study (Fig. 1) were designed as analogues to driftwood commonly occupied by *L. katipo*. They had a concave undersurface, and linear grooves for the spiders to build retreats, as female *L. katipo* in particular are often found within crevices and holes on driftwood. They were constructed from non-treated timber and galvanised nails, in contrast to the Onduline covers used by Lettink and Patrick (2006) and L. Cook (2009, unpubl. data).

Field methods

The ACOs were first placed at Sites A and B in December, 2004, and Site C in January, 2005. Initially six ACOs were placed at Site A, and 10 each at Sites B and C. The ACOs were spread evenly throughout each of the blowouts and positioned close to existing vegetation and driftwood, as *L. katipo* do not occupy isolated pieces of driftwood (Costall & Death 2009). However, the actual number of shelters varied slightly over time due to occasional vandalism at sites A and B. Although damaged or missing ACOs were replaced at each sampling occasion, this still meant there were effectively five ACOs operating at Site A for four sampling occasions, and the number of ACOs at Site B was reduced to seven on one occasion, and nine on two other occasions. The three sites were surveyed approximately once every 4 weeks between January and July, 2005. Searches were only completed during reasonably fine weather, because of reduced detection during wet and windy conditions. The mean number of individuals per ACO is hereafter referred to as the ACO occupancy rate.

In addition to checking all ACOs, a count was made of all *L. katipo*, *S. capensis* and other spiders occupying driftwood within the blowouts. Vegetation was not searched as it was sparse within the basin of the blowouts. Individuals were classified as either mature or juvenile, and sex was recorded for mature individuals. Counts were then divided by the area searched, to be used as an estimate of population density. The ACO counts were included in this population density estimate to avoid recording an apparent drop in population density when spiders had simply moved from driftwood to ACOs. Spearman rank correlations were calculated in SPSS 16.0 to test for a relationship between ACO occupancy rates and population density estimates. Egg sacs were not counted, as they were often stored deep within a female’s silk retreat, making it difficult to distinguish between hatched and unhatched egg sacs without causing substantial damage to the web. However, a note was made if any unhatched egg sacs were visible.

There is substantial variation in abdominal markings between *L. katipo* individuals (pers. obs.). Thus if a retreat on an ACO was occupied on consecutive sampling periods we could determine whether it was the same individual with some confidence, supported by notes and photographs. The mean site fidelity on ACOs was calculated for female and juvenile *L. katipo*.

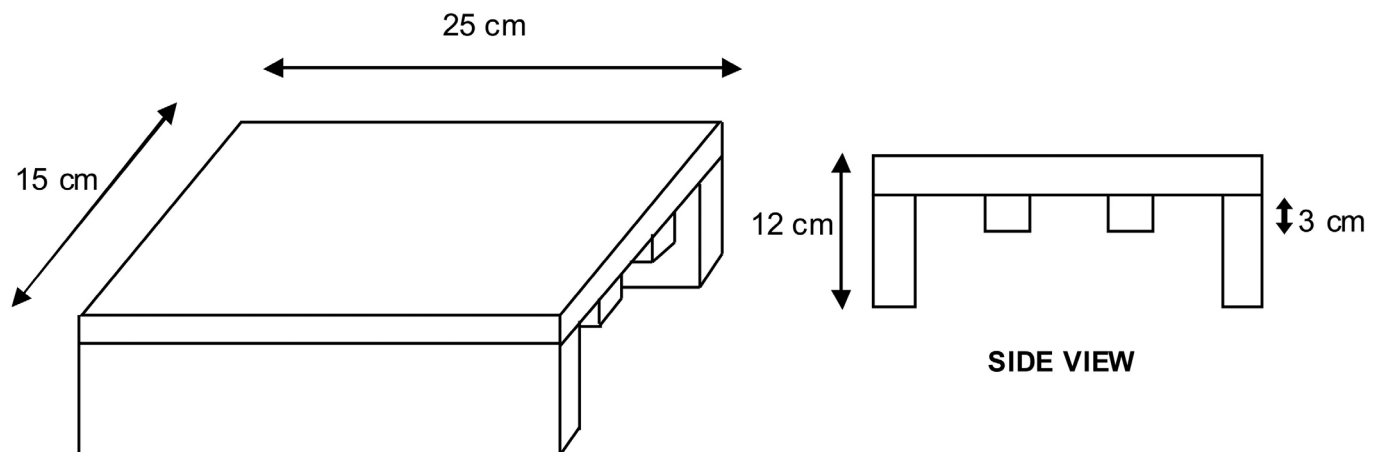


Figure 1. Design of artificial cover objects (ACO) used to sample *Latrodectus katipo*.

Once monitoring had been completed, the ACOs were left out in the dunes, and checked once during the following summer (2006) to see if they were used as sites for egg sac construction.

Results

Driftwood counts

The population density estimates based on driftwood counts showed similar patterns at all three sites (Fig. 2a–c). The three *L. katipo* populations had strongly biased sex-ratios. Males only comprised 3.5% of all *L. katipo* individuals recorded across the three sites, compared with 55.8% and 40.7% for juvenile and female *L. katipo*

respectively. Males therefore comprised 8% of all sexed individuals. The maximum number of males recorded at any site during a single sampling occasion was four, which occurred in February and March at Site B, and in March at Site C. Females and juveniles were located in the field throughout the study period, but only two males were seen over the last three sampling occasions. The number of juvenile *L. katipo* peaked at different times at each of the three sites: in June at Site A, March at Site B, and during April at Site C. Site C had a higher *L. katipo* population density than the other two sites. Newly constructed egg sacs were found at all three sites until June.

Figure 3a–c compares the population density of *L. katipo* to that of *S. capensis* and other spiders, at each of the three sites. More *S. capensis* than *L. katipo* were found at Site A, whereas at Sites B

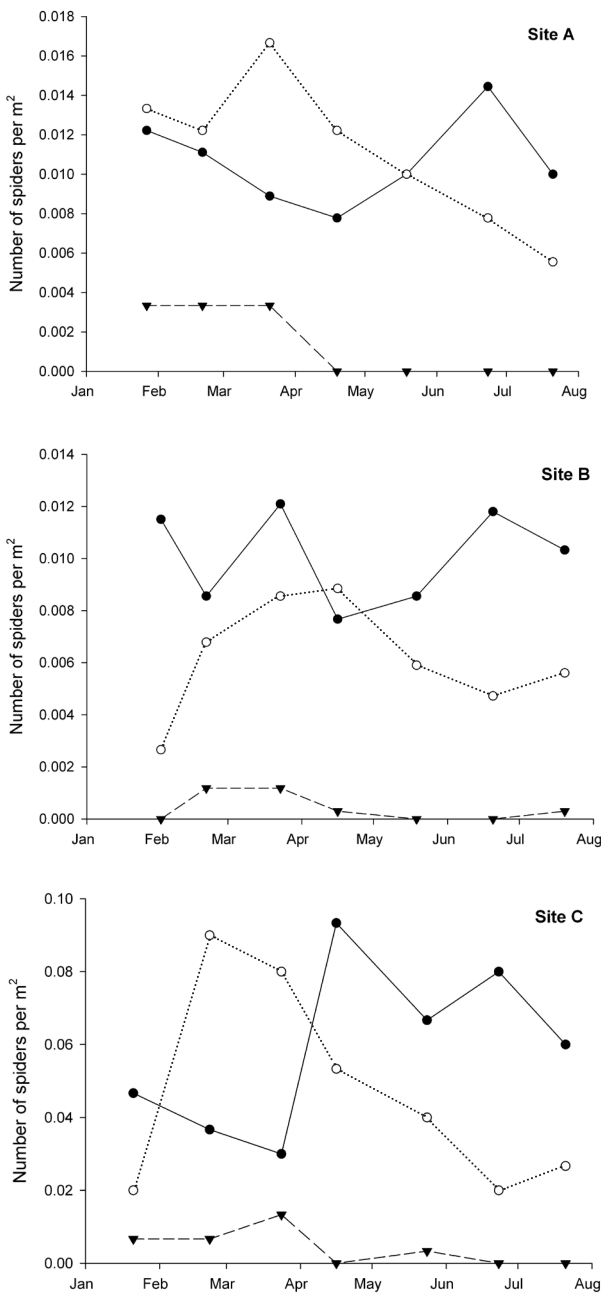


Figure 2. Seasonal changes in number of *Latrodectus katipo* counted on driftwood at Himatangi Beach, January–July 2005. Open circles = mature females, closed circles = juvenile spiders, closed triangles = mature males.

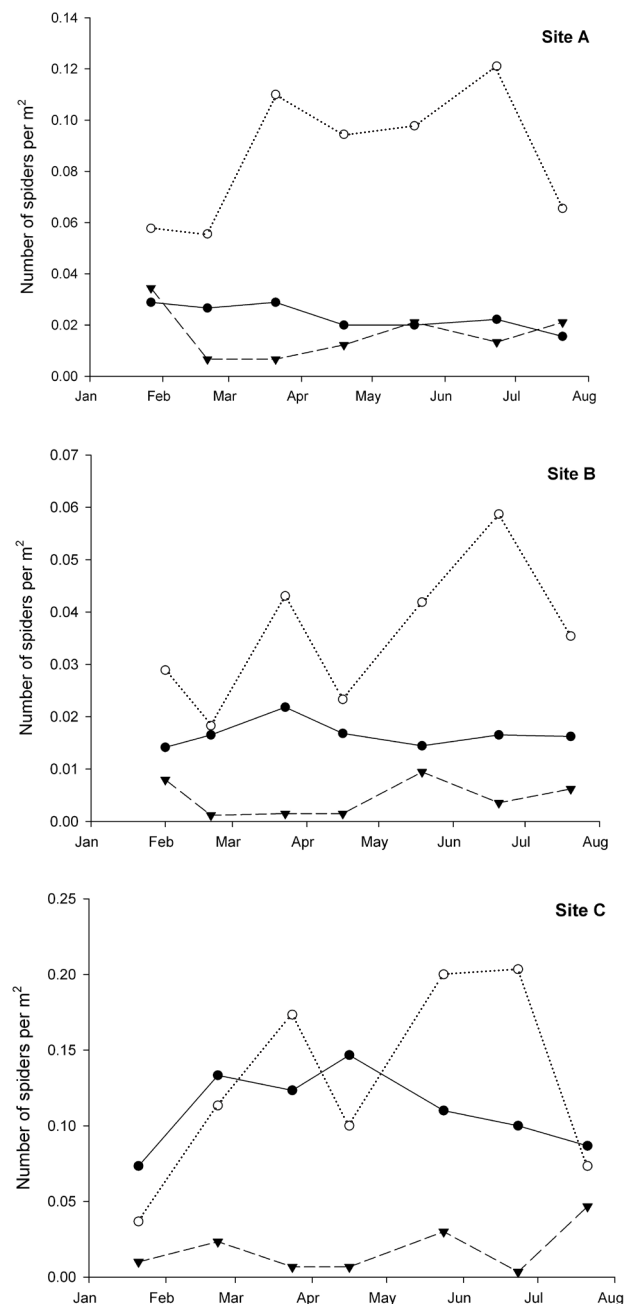


Figure 3. Seasonal changes in numbers of *Latrodectus katipo*, *Steatoda capensis* and other spiders counted on driftwood at Himatangi Beach, January–July 2005. Open circles = *S. capensis*, closed circles = *L. katipo*, closed triangles = all other spiders.

and C, *L. katipo* and *S. capensis* had similar densities until May, when numbers of *S. capensis* increased greatly. *Steatoda capensis* populations also fluctuated markedly throughout the sampling period, mostly because of large pulses of newly hatched juveniles. There was no significant relationship between the population density of *L. katipo* and that of *S. capensis* at any of the three sites (Site A: $\rho = 0.38$, $P = 0.40$; Site B: $\rho = 0.11$, $P = 0.82$; Site C: $\rho = -0.14$, $P = 0.79$).

The counts of all other driftwood-dwelling spiders remained low relative to that of *L. katipo* or *S. capensis* throughout the sampling period. These were mostly free-living spiders from the families Salticidae and Lycosidae, with small numbers of unidentified spiders from other families.

ACOs

The ACOs were quickly colonised. At the site with the highest *L. katipo* density (Site C), all of the ACOs were occupied within 4 weeks of being placed. At Sites A and B some of the ACOs were not colonised until the fourth sampling period. Over the 6-month sampling period, 73% of the ACOs were occupied by *L. katipo* at least once, whereas 54% of the ACOs were occupied by *S. capensis* at least once. Only two of the 26 ACO locations were not occupied by either species during the sampling period. The ACOs were also occasionally occupied by other invertebrates, including spiders (families Salticidae and Lycosidae), pseudoscorpions, beetles (family Oedemeridae), ants, and cicada nymphs.

Male, female and juvenile *L. katipo* used the ACOs. Often more than one individual would occupy the same ACO, resulting in occupancy exceeding 100% on one occasion at Site C. The ACOs also provided some data on the site tenacity of *L. katipo*. Out of a maximum occupancy of 6 months, female *L. katipo* occupied ACOs for an average of 2.17 months (SD = 1.63), whereas juveniles had an average occupancy of 1.68 months (SD = 0.95). Male *L. katipo* never occupied the same ACO over consecutive sampling occasions.

Figure 4 compares the occupancy rate of the ACOs with the *L. katipo* population densities calculated from the driftwood counts. Occupancy was highest at Site C, which also had the highest population density. Occupancy was positively correlated with population density across all sites ($\rho = 0.70$, $P = 0.001$; Fig. 5), but this relationship did not hold when sites were considered separately. At Sites A and B there was no statistically significant relationship between population density and ACO occupancy (A: $\rho = -0.15$, $P = 0.75$; B: $\rho = 0.16$, $P = 0.74$), whereas at Site C occupancy rates were negatively correlated with population density ($\rho = -0.82$, $P = 0.046$). This, however, occurred over a small range of population density values.

Steatoda capensis occupied the ACOs less frequently than *L. katipo*. The mean occupancy across all sites was 0.20 *S. capensis* per ACO, compared with 0.42 for *L. katipo*. There was also no relationship between *S. capensis* population density and ACO occupancy rate, when sites were considered separately (A: $\rho = 0.19$, $P = 0.69$; B: $\rho = 0.34$, $P = 0.46$; C: $\rho = -0.06$, $P = 0.91$), or combined ($\rho = 0.32$, $P = 0.17$).

After one year in the field the ACOs were still intact, and had been only slightly degraded by sand abrasion. Four of the ACOs at Site C were used by female *L. katipo* as sites for egg sac production during the summer following the monitoring period.

Discussion

The strongly biased sex-ratio of *L. katipo* populations was also recorded by Parrott (1948), Smith (1971) and Lettink and Patrick (2006), and is typical of *L. katipo* populations along the Manawatu-Wanganui coastline (Costall & Death 2009). This can be explained by the differing life expectancies of the two sexes, as the sex ratio of *L. katipo* egg sacs appears to be 1:1 (Kavale 1986). Male *L. katipo* do not live much beyond one breeding season, whereas females can live for more than 2 years (Forster & Kingsford 1983; Costall 2006). As male *L. katipo* are similar in size or larger than juveniles, the low number of males found appears to be an accurate reflection of population structure, unless sex-based behavioural differences, such as increased mobility of males, influenced detection probability. However, as *L. katipo* are nocturnal (Ward 1998, unpubl. report; Griffiths 2001), individuals were probably stationary during the day when searches occurred.

According to Griffiths (2001), male *L. katipo* typically reach maturity in spring and early summer, and die within a few weeks. A similar short lifespan is also reported by Kavale (1986), who raised *L. katipo* spiders at elevated temperatures in laboratory conditions. However, Forster and Kingsford (1983) report an average male lifespan of 72 days past their final moult, and similarly male *L. katipo* raised in ambient laboratory conditions lived for an average of 77 days (SD = 28.3) past reaching maturity (Costall 2006), suggesting that male *L. katipo* may have a longer life expectancy than previously thought.

Forster and Forster (1999) and Griffiths (2001) found that *L. katipo* produce egg sacs during November and December in the South Island of New Zealand. At Himatangi, male *L. katipo* can be found in the field year-round (pers. obs.), although the driftwood

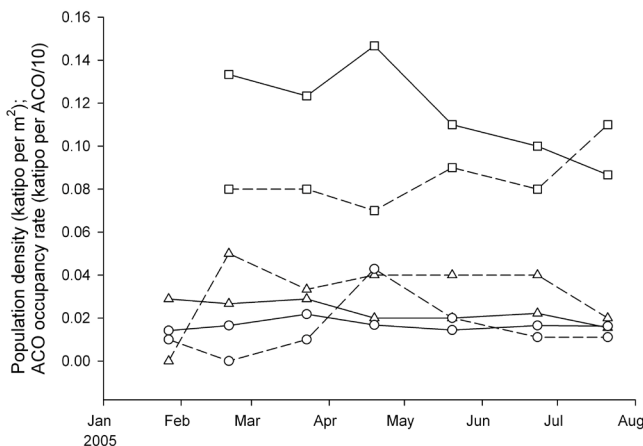


Figure 4. Comparison of occupancy rates of ACOs (dashed lines), with population densities obtained from driftwood counts (solid lines-). Circles = Site A, triangles = Site B and squares = Site C. Occupancy is expressed as the mean number of *Latrodectus katipo* on an ACO, divided by a constant value of 10 (so that occupancy and population density are on a comparable scale).

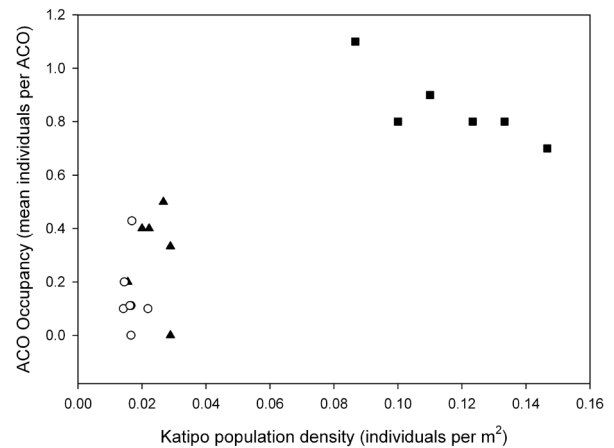


Figure 5. Occupancy (expressed as the mean number of *Latrodectus katipo* per ACO) plotted against population density estimates. Points are coded by site; squares = Site A, triangles = Site B, circles = Site C.

counts indicate that male numbers peak in late summer and autumn. As both male and female *L. katipo* can mate more than once (Kavale 1986), egg sacs can theoretically be produced until much later than suggested by Forster and Forster (1999) and Griffiths (2001), and indeed unhatched egg sacs and newly hatched (2nd instar) juveniles were found at Himatangi up until June. The number of juvenile *L. katipo* did not peak until spring, presumably once the majority of the season's egg sacs had hatched. The longer male life expectancy, coupled with the length of time that males, unhatched egg sacs and 2nd instar juveniles can be found in the field, suggests a longer breeding season at Himatangi than reported elsewhere. Colder temperatures may limit the length of the breeding season at sites closer to the southern limit of *L. katipo* distribution.

The density of *L. katipo* was much higher at Site C than at Sites A and B. This could be attributed to a number of factors. Site C was adjacent to a stream, and had higher plant cover and diversity, and thus may have had higher prey abundance. It also has lower levels of human activity, being further down the beach from the main vehicle access point (Himatangi Beach is a public road). The highest population density of 0.15 *L. katipo* per square metre recorded at Site C was still substantially lower than historical records. For example, Smith (1971) recorded 1.1 *L. katipo* per square metre at South Brighton Beach, Christchurch.

There was no evidence of a negative relationship between *L. katipo* and *S. capensis* living on driftwood. According to Patrick (2002), *L. katipo* populations fluctuate dramatically, yet in this study *L. katipo* populations were remarkably constant, especially compared with *S. capensis*. The marked fluctuations in the abundance of *S. capensis* were due to large influxes of juveniles. Unlike *L. katipo*, *S. capensis* reproduces year-round (Hann 1990). Despite *S. capensis* being largely discounted as a competitor with *L. katipo* (Griffiths 2001; Patrick 2002), the high densities of this introduced species merit concern. Although only low numbers of other spiders were recorded, these were predominantly free-living spiders from the families Lycosidae and Salticidae, and habitat searches may not accurately reflect their abundance.

A high proportion of the ACOs were occupied by *L. katipo* during the sampling period. The location of each ACO may have influenced the probability of occupancy, as *L. katipo* can show preferences for certain web sites, such as those with warmer temperatures and adequate ground cover (Griffiths 2001). ACOs that were placed in areas with higher vegetation and driftwood cover seemed to have higher occupancy rates, but this was not explicitly examined. In contrast, Lettink and Patrick (2006) recorded higher occupancy rates for ACOs placed in areas with low natural cover.

The ACOs were often occupied by mature female *L. katipo*, indicating they are more mobile than suggested by Griffiths (2001) and Forster and Forster (1999), who believed that female *L. katipo* rarely relocate their webs upon maturity. Furthermore, the short length of occupation also suggests that female *L. katipo* are more mobile than previously thought. Females also occasionally abandoned webs constructed on driftwood, although specific occupancy lengths on driftwood were not recorded.

It was common for more than one *L. katipo* to occupy the same ACO simultaneously, often sharing the same groove, a result also noted by Lettink and Patrick (2006). On two occasions female *L. katipo* were found to have constructed adjoining retreats on an ACO, with one continuous catching web. This was unexpected, as *L. katipo* have very high rates of cannibalism when held in captivity (Forster & Kingsford 1983; Ward 1998 unpubl. report), although other examples of extended peer tolerance do exist both for *L. katipo* (Lettink & Patrick 2006) and other *Latrodectus* species (Kaston 1968). Communal *L. katipo* webs have also been found under driftwood at Himatangi and other beaches along the Manawatu-Wanganui coastline (Costall & Death 2009).

There was a correlation between *L. katipo* occupancy rates and population density across all sites, although this relationship did not hold at individual sites. However, the population densities at each site did not vary considerably over the sampling period, and it is likely that ACOs would be able to detect large fluctuations in population

density if they occurred. Alternative monitoring methods such as transect or quadrat searches are highly time-consuming, and produce variable results, even by experienced observers (Patrick 2002). It is encouraging that ACOs were able to detect *L. katipo* populations with very low densities. As *S. capensis* had lower affinity for the ACOs than *L. katipo*, ACOs could potentially provide additional habitat for *L. katipo* in areas where *S. capensis* reaches extremely high densities.

The occasional vandalism of the ACOs was unfortunate, but not entirely unexpected given the high rate of human activity at Sites A and B. The effect of this vandalism would have been greatest at Site A due to the lower number of ACOs that were initially deployed. We are hopeful that future vandalism can be minimised through appropriate signage and public education.

After one year the ACOs were still intact, but due to the gradual effects of sandblasting they would require occasional repair and maintenance if used on a long-term basis. Unlike Onduline covers, the wooden ACOs we used were not blown away in strong winds, a problem identified by L. Cook (2009, unpubl. data).

No egg sacs were constructed on the ACOs during the monitoring period, but this was probably because ACOs were placed out in the dunes late in the breeding season. Lettink and Patrick (2006) noted four egg sacs during their study, and many of the ACOs in this study were used by female *L. katipo* as a site for constructing egg sacs in the following summer (pers. obs.) ACOs allow for easier inspection of egg sacs compared with those in webs constructed on driftwood or vegetation.

The potential applications for ACOs are not limited to population monitoring; Samu et al. (1996) used a variety of artificial web sites to assess web site selection, site tenacity, and tolerance of conspecifics in the Linyphiid spider *Tenuiphantes tenuis* (Blackwall 1852), whereas Bowie and Frampton (2004) and Hodge et al. (2007) suggest the use of ACOs in conservation translocations of spiders and other invertebrates. In New Zealand, artificial shelters have also been used for advocacy purposes, by allowing nature reserve visitors close examination of normally cryptic invertebrates such as weta.

A trial of ACO monitoring for *L. katipo* is currently underway at five beaches along the Manawatu-Wanganui coastline, and early results show that ACO occupancy rates are higher at Moana Roa than at Himatangi or Foxton beaches (L. Cook 2009, unpubl. data), in agreement with population density estimates derived for these sites the last time they were intensively surveyed, in 2005 (Costall & Death 2009). Given these results we believe the use of ACOs would be preferable for a nationwide *L. katipo* monitoring programme. At the very least, ACOs could be easily established in areas that are not currently monitored because of time and labour constraints.

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Editorial board member: Jacqueline Beggs

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