# Improving search strategies for the cryptic New Zealand striped skink (*Oligosoma striatum*) through behavioural contrasts with the brown skink (*Oligosoma zelandicum*).

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**Abstract:** The striped skink (*Oligosoma striatum*) is a poorly known New Zealand endemic species rarely seen in the wild despite ongoing efforts to locate specimens. It is uncertain whether its threatened status is due to low numbers, or to unusual habitat use and activity patterns that make it difficult to detect. Anecdotal reports indicate the species may be partly arboreal. We carried out captive-based behavioural comparisons between striped skinks and the common terrestrial brown skink (*Oligosoma zelandicum*). Brown skinks are of similar mass to striped skinks and overlap in geographic range and habitat, but are easily captured by hand and pitfall trapping in the wild. They were therefore a suitable comparison from which to assess activity levels and arboreal tendencies in striped skinks, with the aim of improving survey methods. Point samples and total frequencies of behaviours were collected using time-lapse video recordings taken concurrently of individuals of each species occupying identical enclosures. Striped skinks had significantly higher levels of diurnal activity than brown skinks. They also showed periods of nocturnal activity associated with high moisture levels. When active, the types of behaviours carried out by each species were very similar, as were the proportions of active time spent carrying out each behaviour. Striped skinks spent significantly longer periods at greater heights within the enclosure than brown skinks, indicating stronger arboreal tendencies. High levels of arboreal activity and in particular nocturnal activity may make striped skinks more vulnerable to introduced predators such as rodents and possums. In order to accurately assess the status and carry out long-term monitoring of the striped skink, new survey and capture techniques will be required. Arboreal traps, visual canopy surveys and surveying felled trees are recommended.

**Keywords:** arboreal; behaviour; *Oligosoma*; search methods; striped skink.

## Introduction

New Zealand's lizard fauna comprises at least 60 species (Towns and Daugherty, 1994; Towns *et al.*, 2001). Although recent advances in predator control and island restoration have increased the prospects for several reptile species in New Zealand, nearly 40% of the lizard fauna are still considered threatened or requiring conservation action (Towns *et al.*, 2001). One such species in need of attention is the striped skink (*Oligosoma striatum*). Since first described (Buller, 1871) fewer than 120 individuals have been reported from about 40 scattered mainland North Island locations, between Taranaki, Rotorua, Te Aroha and Kaipara (Whitaker, 1998; J. Heaphy, *pers. comm.*, Department of Conservation, Tauranga; Fig. 1). One individual has been found on each of Great Barrier and Little Barrier islands (Newman and Towns, 1985; Whitaker, 1998), the only known island locations for the species. Consequently striped skinks are listed as threatened by the International Union for Conservation of Nature (IUCN, 2002), although it is uncertain whether this ranking is warranted. They have recently been ranked nationally as 'data deficient' (Hitchmough, 2002).

Unlike many of New Zealand's threatened skink species, the striped skink is poorly known and almost impossible to find in the wild (Whitaker, 1998). Despite continued efforts to trap or manually catch individuals, not a single animal has been found during surveys since 1995. The skinks may be benefiting from an increasing number of North Island sites that undergo intensive predator management. Yet threats to the species and its current status are impossible to quantify

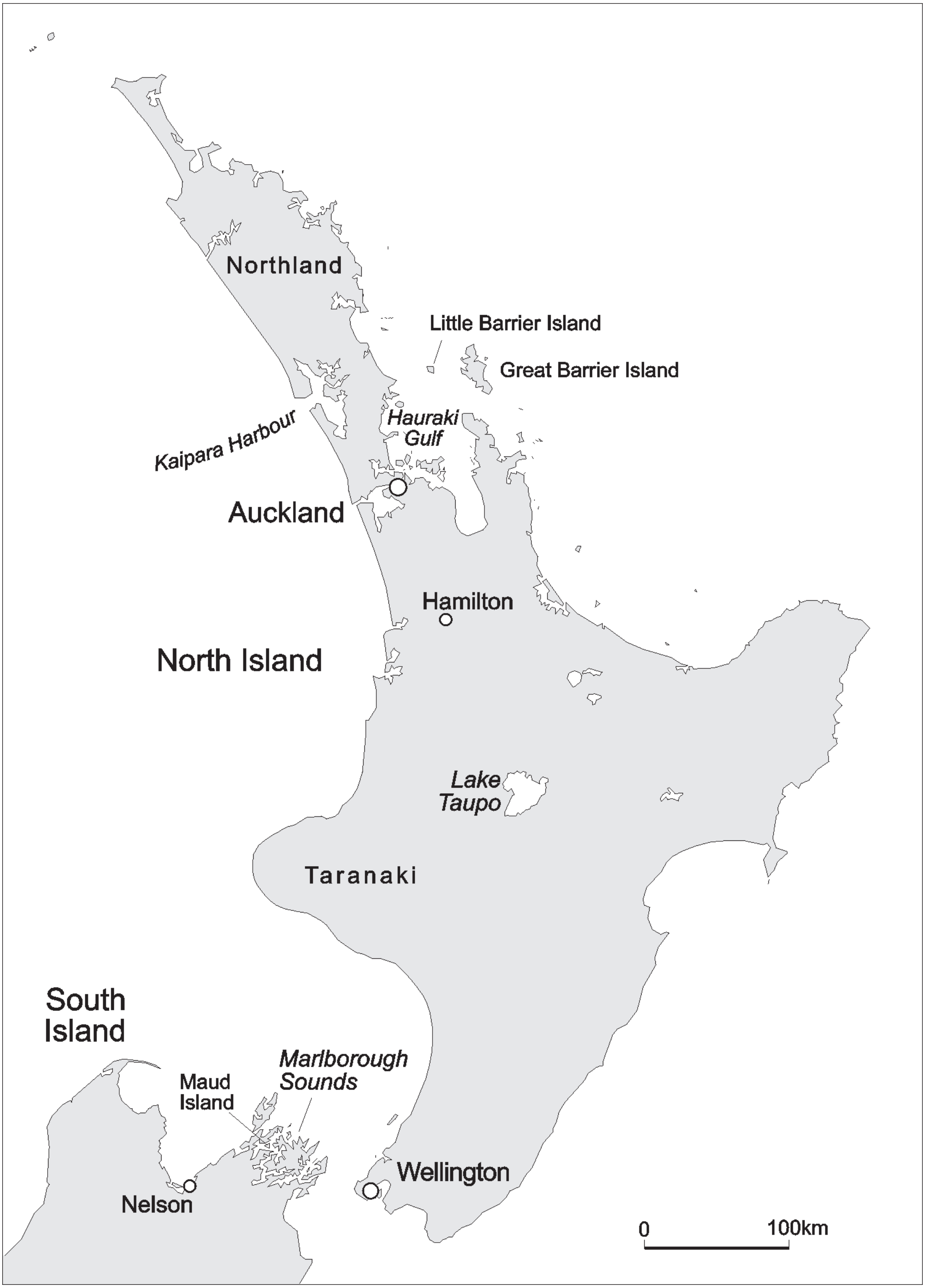


**Figure 1.** Map of the North Island and northern South Island, New Zealand, indicating locations mentioned in the text.

without a better knowledge of habitat preferences and reliable survey techniques.

Reports of striped skinks have come from a range of microhabitats, ranging from rotting logs in pastures and forests (Robb, 1980), epiphytes in forest canopies (Whitaker, 1998) to cowshed pits (Dean Caskey, *pers. comm.*, Department of Conservation, Stratford). All known localities are either in lowland podocarp/ hardwood forests or were covered by such forest in the recent past (Whitaker, 1998). Recent research indicates that habitat use is likely to be restricted by a susceptibility to high rates of evaporative water loss (Neilson, 2002). It has long been considered that striped skinks are agile climbers (Whitaker, 1998) and may be at least partly arboreal (Towns *et al*., 2002), with one author even referring to them as the "tree skink" (Melgren, 1980). However, this reputation has been based mainly on anecdotal reports. Whitaker (*pers. comm.*, 1993) notes that striped skinks entirely lack the specialised features, such as highly modified lamellae, sometimes found in arboreal lizards (McCoy and Fox, 1996).

Assessing the arboreal tendencies and activity patterns has been identified as a priority for improving survey methods for striped skinks (Towns *et al*., 2002). Some studies on reptiles have used captive animals in situations where behavioural observations on wild animals are problematic, and have extrapolated from these to predict wild behaviour. Meek (1999) examined captive thermoregulation and activity in the water dragon *Physignathus cocincinus* where the behaviour and densely vegetated habitat of the animals made wild observations difficult. In New Zealand Duncan (1999) used captive observations on the behaviour, activity and ability to escape traps of speckled skinks (*O. infrapunctatum*) and spotted skinks (*O. lineoocellatum*) to predict why the latter species is harder to trap in the wild.

Brown skinks (*Oligosoma zelandicum*) are similar in size to striped skinks but are among the more common lizards found in New Zealand. The species ranges from the central North Island south to Nelson and is abundant on several islands in the Marlborough Sounds (Pickard and Towns, 1988; Robb, 1980; Fig. 1). They prefer shaded, damp environments (Robb, 1980) and are considered terrestrial (Gill, 1976). Brown skinks are easily captured in pitfall traps (Towns and Elliot, 1996) and by hand (Gill, 1976), and are often observed basking in the wild (East *et al*., 1995).

Because of their terrestrial nature, brown skinks act as a suitable benchmark from which arboreal behaviour in striped skinks can be gauged. Both species are found in damp, forested habitats, they are partially sympatric and both are considered diurnal. However, there is a distinct difference in the observability and catchability of these two species at sites where they are known to occur. Comparing the behaviour of these two species could identify differences that may help us understand why striped skinks are so elusive in the wild, and assist with the development of efficient surveying methods.

We formulated two specific hypotheses: 1) Striped skinks spend considerable periods of time off the ground and thus should exhibit significantly more climbing activity in captivity than the congeneric terrestrial brown skinks. This outcome would help explain the lack of success in pitfall trapping and ground-based surveying techniques; 2) Striped skinks spend significantly less time active during a 24-hour period than brown skinks. As a result they may be only rarely observed in visual surveys and less likely to encounter traps than more active species. If one or both of these hypotheses were accepted, it would suggest that innovative surveying techniques need to be developed to accurately assess the distribution and status of striped skinks. Rejecting both hypotheses would further raise concerns about the current status of wild striped skink populations.

# Methods

### Study animals

Striped skinks were either found in the wild ($n = 8$; six males and two females) or born in captivity ($n = 4$; all sub-adults of unknown sex) from specimens collected from Taranaki (Fig. 1). Wild animals came from a range of habitat types and had been gathered over a period of two years as a result of public appeals for reports of striped skinks. These skinks remained in captivity at the conclusion of the work. Brown skinks ($n = 12$; two males, six females of which four were gravid, and four sub-adults) were hand captured on Maud Island in the Marlborough Sounds. They came from a mixture of modified and forested sites and were found by searching artificial seabird burrows and under logs. They were released back into the wild at the conclusion of the research. Sub-adult striped skinks were captive-born in 1999 and were therefore known to be immature animals. Brown skinks with a snout-to-vent length less than 58 mm were classified as sub-adult. This was the length at which sex could not be determined by cloacal examination (East *et al*., 1995).

For 30 days during October and November 2000, all animals were housed outdoors at the Reptile Research Centre in Nelson to acclimatise to identical conditions. Skinks were kept in same-species, same-sex pairs in enclosures (320 mm × 450 mm × 300 mm high) containing soil, leaf litter, a water dish and a piece of bark. The striped skinks are normally maintained in same-sex pairs at their captive facility and were thus kept this way throughout the experiment.

### Test enclosures and materials

A “test enclosure” (800 mm × 1600 mm × 1500 mm high) was built and then placed in an existing outdoor aviary-like facility at the Reptile Research Centre. The test enclosure was constructed of a mild galvanised steel frame, glass doors, fine mesh aluminium netting and Corflute™ plastic sheeting. The top of the enclosure remained uncovered except for a small Corflute overhang around the perimeter. The floor of the enclosure was an aluminium tray. The enclosure was divided in half across its width by a Corflute-covered steel frame preventing visual contact between the two compartments; each compartment was treated as a separate enclosure. The compartments were mirror images of one another and furnished with one treefern (*Dicksonia squarrosa*) log, 1200 mm in height, attached to the wall at the back of the enclosure. The top of the trunk was scooped out and soil lightly packed onto an impenetrable base. A small spider plant (*Chlorophytum comosum*) was planted in this soil. One slab from the outer part of a pine tree (*Pinus radiata*) including the bark, 1200 mm in height, was also attached to the back of the enclosure. A small wooden tray (250 mm × 250 mm × 16 mm high) was fixed to this at a height of 600 mm. This was filled with potting mix, sand and shredded bark. A piece of bark was placed over the tray to provide cover. An identical tray was fixed to the top of this structure. One large piece of bark (200 mm × 200 mm × 15 mm) was positioned on the enclosure floor. One small pile of wood (200 mm × 400 mm × 75 mm) constructed from pine slabs and held together with screws creating crevices and several retreats, was placed on the enclosure floor. One water dish and one food dish were placed on the enclosure floor. A substrate base consisting of an equal mix of potting mix, finely shredded pine bark and yellow quartz sand was used. To ensure free drainage, 30 mm of this substrate was placed onto a 20-mm layer of pebbles.

The treefern and pine logs were chosen to represent two different tree types that would be commonly available to striped and brown skinks in forested habitats. The bark and pine slabs mimicked the type of retreats that would typically be available on the forest floor, and the spider plant and wooden trays with bark imitated small epiphytes and loose bark on branches at arboreal retreats.

Two video cameras were placed above the enclosure division. A Panasonic™ (WV BL 204) video camera fitted with a focal-length lens of 2.8 mm was set to record ground activity in both divisions. A Panasonic™ (WV-BP 104) camera fitted with a focal-length lens of 4.5 mm was set to record above-ground activity in both divisions. Vaisala Humitter® 50U/50Y(X) temperature and relative humidity data logger probes were placed 1300 mm aboveground near the top of the enclosure.

A Yates Plassay™ Microjet Mist Spray nozzle was placed in the outside back corner of each compartment. This was turned on for one minute every third day at 0100 hours. Two Dennard™ infra-red illuminators (Type 880) were used from 1730 to 0800 hours to allow night-time recording.

The enclosure faced west so that the sun rose behind the back wall and set in front. Both compartments were covered with shade cloth to prevent very high temperatures and to better mimic a forest floor environment. One 50 W, 12 V, 24$^{o}$ halogen spotlight was fitted near the top of the two compartments at a height of 1400 mm. These lights gave additional daytime illumination to the ground area and up to a height of about 500 mm. The lights operated from 0800 to 1830 h and suitably compensated for the ever- changing, patchy natural light conditions, thus ensuring a relatively even quality of video recordings.

### Pilot study

A pilot study was carried out for two weeks during November 2000. One male of each species was placed in each compartment of the enclosure for a period of three days. During this time all activity was videoed by both cameras. These individuals were removed from the enclosure and the procedure repeated with a pair of females and then a pair of sub-adults. Activity of each individual was continuously recorded using two Panasonic™ AG-6040 time-lapse video recorders. The recordings were made in the 72-h mode, at one frame per 0.5 s. The data loggers in the enclosure divisions recorded climatic conditions. Tapes were examined and key behaviours identified (Table 1). Commonly occurring behaviours were categorised as “instantaneous”. These were behaviours that would be recorded using point samples at 5-min intervals during the main part of the study. Less frequently occurring behaviours were categorised as “all occurrence”. These were behaviours such as drinking and feeding that may not have been detected during point sampling, but were of interest to us in terms of the biology of the skinks. In the main study, the total frequency of occurrence of these was recorded. The behaviour “climb” was included in both categories because although it was a common behaviour, we wanted detailed information on its frequency in both species.

### Experimental protocol

All animals individually spent a minimum two-day acclimatisation period in one of the enclosure compartments prior to the research. Behavioural observations were carried out over the New Zealand summer between 30 December 2000 and 11 March 2001. The research was divided into 24 runs, with each animal being involved in two runs. All individuals, with the exception of sub-adults, were sexed prior to the start of the research. They were then assigned to interspecific same-sex pairs and randomly allocated a position in an experimental run order, using one skink in each enclosure compartment. This was designed so that (1) all pairs had completed a run before any had their second, (2) as many skinks as possible visited both compartments, and (3) at least one skink from each species-sex combination was preceded in its compartment by a skink of every species-sex combination including its own. This was done to allow investigation of any effect that preceding animal-type may have had on behaviour. Subsequently it was discovered that three brown skinks and one striped skink were incorrectly sexed, so investigation of carryover was abandoned. The positioning of enclosure floor furniture was also randomly allocated for each pair using three different 4×4 latin squares. However, we retained the mirror image arrangement. This was done to reduce any effect of furniture positioning on skink behaviour.

Each run was carried out over a 3-day period and skink behaviour was taped continuously using the 48-h mode of the video recorders, giving one frame per 0.34 s. For each run, only behaviours recorded on the second and third days were used for data analyses; the animals had one day to "settle" into the enclosure.

At the start of each run, animals were provided with fresh water and sufficient live mealworms (*Tenebrio molitor*) to last several days, but were left undisturbed during the subsequent three days.

## Data collection

Videotapes were analysed and behaviours recorded in three ways: (1) The 5-min interval point samples of behaviour were recorded as being either one of the "instantaneous" behaviours identified in the pilot study (Table 1) or as "other". (2) A record was kept of whether the skink had been active in the previous five minutes. (3) A total was kept of the frequency of the "all occurrence" behaviours. The number of times the skink carried out this behaviour in each 5-min period was recorded.

Location and height of the skink in the compartment were recorded at the same 5-min intervals as point samples. Categories for location were: pine tree, treefern, bark pile, wood pile, soil and other. Categories for height were: ground level (0 cm), low level (1–40 cm), medium level (41–80 cm), and high level (81–120 cm).

As each skink was run through the experiment twice, and two days per run were used for data collection, there was a total of 96 h of recording from each skink. This equated to 1154 five minute sampling periods per skink.

Climatic data was recorded every 15 min throughout runs. Each 5-min behaviour record was allocated the climatic recordings of the nearest 15-min record.

## Data analysis

As most of the skink activity occurred between 0600 and 2100 h, data from this period was summarised in hourly intervals giving a total of 15 intervals. All behaviour occurring between 2100 and 0600 h was combined into a sixteenth category labelled "sleep" (due to the relative inactivity). Data were summarised in this way for each of the four days of recording for each skink.

As so few activities occurred during the "sleep" period, statistical analysis was restricted to observations

**Table 1.** Activity categories for striped and brown skinks. Activities in the "instantaneous" category were recorded at 5-min intervals. Less frequent activities were listed in the "all occurrence" category and were recorded as counts over time.

| Category | Behaviour | Description |
|---|---|---|
| Instantaneous | Bask | Sitting still with entire (or part of) body in sun. |
| | Climb | Walking up, down or horizontally on a vertical surface. |
| | Crawl | Walking along the ground or on another horizontal surface. |
| | Explore | Attempting to climb an unusable surface, hanging body over the edge of a horizontal surface or pushing against a solid surface with snout. |
| | Peer | Inactive but with head partially or fully emerged from cover (therefore potentially visible in surveys). |
| | Retreat | Body completely underneath cover. |
| | Sit | Body completely emerged from cover, but not in the sun. |
| All occurrence | Climb | As above |
| | Drink | Taking water from dish. |
| | Feed | Taking food from dish or capturing live food from around the enclosure. |
| | Jump | Leaping from a vertical object to the ground, a lower object or another vertical object. |
| | Upside down | Hanging from or crawling upside down under a suspended object. |

in the 15 hours from 0600 to 2100 h, and data were analysed on a whole-day basis. Between-observation correlation, inherent to repeated measures data, was modelled by fitting error strata using the residual maximum likelihood procedure (REML) in Genstat 5 (VSN International, Herts, U.K). Error terms for date, skink, skink × Run (1st v. 2nd) and skink × Day (2nd v. 3rd) were retained if the variance component was positive, regardless of statistical significance. Average fixed effects for species, sex, species × sex, gravidity, Run, Day, and compartment were retained throughout the analysis. The effects of 15-hour average temperature and relative humidity were examined as covariates, and retained if statistically significant at the 1% level for at least one component of a complementary set. All first-order interactions other than species × sex were tested and rejected at the 5% level. Statistical significance for any fixed effect was tested by calculating an *F*-ratio from the Wald statistic, using the degrees of freedom from the relevant error stratum.

Totals for "instantaneous" data were expressed as percentage of all observations or (for activity behaviours) as percentage of observations recorded as active. To allow for the heteroscedasticity of the percentage scale, analysis was performed after applying the binomial data empirical logit transformation with inverse variance weighting. The variate analysed was:

$\log\ [(P + 0.5)/(N - P + 1.0)]$, weighted by $(N + 1.0)/[(P + 0.5)\times(N - P + 0.5)]$,

where $P$ is the number of times an activity, location or height is observed, and $N$ is the total number of observations in a set. Estimated means are back-transformed from the analysis and rescaled to centre on the observed overall mean percentage while retaining the odds-ratios estimated in the analysis. Standard errors of difference are values calculated to reproduce the '*t*-ratios' from the transformed scale. Standard errors for means are the average change in percentage resulting from the addition and subtraction of standard errors on the transformed scale.

"All occurrence'' data were similarly analysed, but as Poisson-distributed 15-h totals using the log-transformation and REML methods within the generalised linear mixed model (GLMM) procedure. The means presented (Table 2) are back-transformed and rescaled to the observed overall mean retaining the relative ratios estimated in the analysis.

# Results

## Activity periods and behaviour patterns

The daily activity periods for both skink species were unimodal; however; striped skinks were on average more active than brown skinks between 0600 h and 1200 h (Fig. 2). All striped skinks displayed some activity every hour from 0600 h until 2100 h during the four days they were recorded. In contrast, three of 12

**Table 2.** Mean percentage of intervals spent active, proportion of active intervals spent performing each activity, and mean frequency of daily occurrence of all occurrence behaviours in captive striped skinks and brown skinks. Mean differences refer to species differences. S.E.D = standard error of difference, NS = $P > 0.10$

| | Striped skink | | | | | Brown skink | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male *n* = 6 | Female *n* = 2 | Sub-adult *n* = 4 | Species mean | Species S.E. | Male *n* = 2 | Female *n* = 2 | Gravid *n* = 4 | Sub-adult *n* = 4 | Species mean | Species S.E. | Mean difference | S.E.D | *P* |
| **Activity** | | | | | | | | | | | | | | |
| Active | 59.8 | 69.5 | 63.8 | 64.6 | 3.6 | 30.1 | 59.2 | 51.9 | 47.8 | 45.5 | 4.7 | 19.1 | 6.0 | 0.004 |
| Non-retreat | 59.9 | 72.0 | 66.4 | 66.3 | 4.1 | 29.8 | 61.3 | 58.1 | 49.8 | 46.7 | 5.4 | 19.6 | 6.9 | 0.008 |
| Retreat | 40.1 | 28.0 | 33.6 | 33.7 | 4.1 | 70.2 | 38.7 | 41.9 | 50.2 | 53.3 | 5.4 | -19.6 | 6.9 | 0.008 |
| **% time active** | | | | | | | | | | | | | | |
| Sit | 38.6 | 47.7 | 34.6 | 40.4 | 3.0 | 29.7 | 42.5 | 42.7 | 48.7 | 40.2 | 4.0 | 0.2 | 5.0 | NS |
| Peer | 30.6 | 14.6 | 31.8 | 25.5 | 3.7 | 43.0 | 24.5 | 33.4 | 23.1 | 30.4 | 5.0 | -4.9 | 6.2 | NS |
| Crawl | 20.6 | 17.9 | 17.1 | 18.5 | 2.1 | 19.1 | 19.4 | 11.1 | 18.6 | 19.1 | 2.6 | -0.5 | 3.3 | NS |
| Explore | 5.1 | 10.0 | 4.8 | 6.6 | 1.3 | 3.3 | 2.7 | 1.8 | 1.9 | 2.7 | 0.7 | 3.9 | 1.4 | 0.018 |
| Climb | 3.3 | 3.6 | 4.7 | 3.9 | 0.5 | 3.2 | 3.1 | 1.0 | 3.0 | 3.1 | 0.5 | 0.7 | 0.7 | NS |
| Bask | 2.1 | 3.7 | 2.6 | 2.7 | 0.8 | 6.1 | 6.2 | 10.2 | 8.7 | 7.0 | 2.2 | -4.3 | 1.9 | 0.031 |
| **All occurrence** | | | | | | | | | | | | | | |
| Climb | 18.5 | 20.2 | 26.3 | 22.9 | 4.2 | 6.1 | 25.3 | 4.7 | 14.8 | 14.2 | 3.2 | 8.8 | 5.3 | 0.091 |
| Jump | 7.8 | 9.6 | 7.8 | 9.6 | 3.3 | 1.3 | 11.5 | 1.2 | 2.6 | 3.9 | 1.7 | 5.7 | 3.4 | 0.087 |
| Drink | 1.4 | 2.9 | 2.4 | 2.4 | 0.6 | 0.1 | 0.3 | 1.2 | 0.8 | 0.3 | 0.2 | 2.1 | 0.8 | 0.015 |

brown skinks were never active between 0600 h and 0700 h and four of 12 were never active between 0700 h and 0800 h. Between 1300 h and 2100 h the average level of activity was very similar for both species (Fig. 2). Between 2100 h and 0600 h striped skinks were on average more than 2.5-times more active than brown skinks. Striped skink night-time activity appeared to be correlated with the use of the enclosure mist sprayers. Seven of 12 striped skinks were active on at least one night during the hour after the mist sprayers were turned on. Two were active on both nights after mist sprayers were turned on. On the nights mist sprayers were not used, just two striped skinks were active during the same hourly period. Only one brown skink was active on one occasion in the hour after mist sprayer use.

The *F*-tests from the Wald statistics in the REML analysis showed that activity was positively associated with temperature ($P < 0.001$; Table 3) and retreat negatively associated with both temperature ($P < 0.001$) and relative humidity ($P = 0.046$).

Striped skinks were significantly more active than brown skinks (19.1 ± 6.0%, $P = 0.004$; Table 2). On average striped skinks were active during 64.6 ± 3.6 % of observation periods between 0600 h and 2100 h. Brown skinks were active during 45.5 ± 4.7 % of these periods. Striped skinks also spent significantly more time out of their retreats than brown skinks (19.6 ± 6.9%, $P = 0.008$), regardless of activity.

The most common behaviour for both species from 0600 h to 2100 h was to retreat (Table 2). Striped skinks spent an average of 33.7 ± 4.1% of that period retreated, and brown skinks 53.3 ± 5.4%. For striped

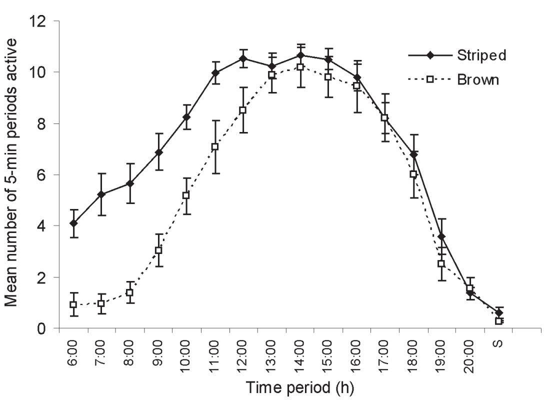


**Figure 2.** Mean number of 5-min periods active for captive striped skinks ($n = 12$) and brown skinks ($n = 12$) during four days of time-lapse video recording per animal (2 days × 2 runs). Time period refers to the hour following that indicated. Period S refers to the nine hours between 2100 h and 0600 h. The mean over that nine hour period is given. Error bars represent S.E. of the mean.

skinks this was followed by sitting (28.2 ± 3.3%), peering (16.1 ± 2.0%) and crawling (12.5 ± 1.2%). The same order was observed for brown skinks.

In order to investigate whether the two species were behaving differently when they were active, data were re-analysed as proportions of time spent active (Table 2). Crawling was positively, and peering negatively, associated with temperature, effectively balancing out on the percentage scale (Table 3). There was no significant species difference in the proportions of active time spent climbing, crawling, peering or sitting (Table 2). However, brown skinks spent a greater proportion of active time basking and a lesser proportion exploring than did striped skinks (Table 2).

Of the three all occurrence behaviours analysed, climbing was more variable than expected for a Poisson variate. This was accommodated by including an extra Poisson variation of 2.2 in the GLMM analysis. All three behaviours were positively associated with temperature (Table 3), and means adjusted accordingly.

Gravidity significantly reduced climbing behaviour in female brown skinks ($F_{1,10} = 10.75$; $P = 0.008$). On average, striped skinks climbed half as often again as brown skinks — 22.9 ± 4.2 compared with 14.2 ± 3.2 per day — but this was not statistically significant ($P = 0.091$, Table 2).

There was no significant difference in the frequency of jumping behaviour between species (Table 2). However we observed differences in the way the animals jumped. Striped skink jumps were very deliberate and targeted. They would usually balance on their hind legs and overhang from the top of the pine or treefern before pushing off and jumping out. They appeared to be trying to land on the Corflute division between compartments. In one instance a striped skink landed on the vertical surface and clung by a claw to a tiny hole in the plastic. Striped skinks also jumped out and landed at least 40 cm from the base of the trees they were on, and were also able to jump up and cling to the data logger placed above the top of the trees. Brown skinks always jumped straight down from the trees and landed at the tree base, and never jumped out or up. Upside-down climbing did not occur often enough for analysis.

Striped skinks drank (2.4 ± 0.6 times per day), significantly more frequently than brown skinks (0.3 ± 0.2 times per day) (Table 2). No individuals of either species were seen feeding during the observation periods, although they may have fed on mealworms under the retreats.

## Locations

Use of the woodpile was negatively associated with temperature ($P = 0.003$; Table 3) and time on bare soil positively associated with temperature ($P < 0.001$). As these did not balance out as percentage changes, use of

**Table 3.** Relationship between climatic variables and activity, behaviour, location and enclosure height of captive striped and brown skinks. NS = $P > 0.10$, b = change in % or number of occurrences per 1°C or 5% relative humidity at the average level observed.

| | Temperature | | | | Relative humidity | | | |
|---|---|---|---|---|---|---|---|---|
| | *F* | f2 | *P* | b | *F* | f2 | *P* | b |
| **Activity** | | | | | | | | |
| Active | 52.35 | 25 | < 0.001 | 6.53 | 1.87 | 24 | NS | 1.26 |
| Retreat | 26.34 | 46 | < 0.001 | -5.29 | 4.20 | 46 | 0.046 | -2.25 |
| **% time active** | | | | | | | | |
| Sit | 0.06 | 49 | NS | -0.23 | 0.11 | 49 | NS | -0.30 |
| Peer | 6.52 | 50 | 0.014 | -2.42 | 2.10 | 49 | NS | 1.49 |
| Crawl | 14.76 | 50 | < 0.001 | 1.67 | 1.44 | 49 | NS | -0.54 |
| Explore | 0.07 | 11 | NS | 0.07 | 6.10 | 11 | 0.031 | -0.68 |
| Climb | 0.39 | 36 | NS | 0.08 | 6.66 | 36 | 0.014 | -0.31 |
| Bask | 0.03 | 7 | NS | 0.08 | 0.12 | 7 | NS | 0.16 |
| **All occurrence** | | | | | | | | |
| Climb | 28.08 | 7 | 0.001 | 4.10 | 1.29 | 6 | NS | -0.17 |
| Jump | 22.32 | 19 | < 0.001 | 1.84 | 0.60 | 18 | NS | 0.06 |
| Drink | 7.92 | 19 | 0.011 | 0.34 | 0.26 | 18 | NS | -0.01 |
| **Location** | | | | | | | | |
| Pine tree | 0.70 | 18 | NS | 1.38 | 0.04 | 17 | NS | 0.35 |
| Woodpile | 10.75 | 21 | 0.004 | -6.05 | 2.24 | 20 | NS | 3.00 |
| Treefern | 1.27 | 36 | NS | 1.06 | 1.92 | 35 | NS | -1.27 |
| Soil | 13.71 | 32 | 0.001 | 1.26 | 0.45 | 31 | NS | 0.24 |
| Bark | 3.01 | 12 | NS | 0.44 | 0.00 | 11 | NS | 0.02 |
| **Height** | | | | | | | | |
| High | 0.17 | 19 | NS | 0.73 | 1.81 | 19 | NS | -2.47 |
| Medium | 1.33 | 7 | NS | 1.34 | 0.32 | 7 | NS | 0.63 |
| Low | 6.75 | 7 | 0.036 | 0.19 | 0.49 | 7 | NS | 0.05 |
| Ground | 2.17 | 18 | NS | -2.79 | 0.26 | 18 | NS | 1.06 |

pine tree, treefern and bark are also adjusted for temperature although their positive correlations with temperature were not significant ($P > 0.10$).

On average, striped skinks spent 57.4 % of the day either on the pine tree or the treefern. The majority of the remainder of their time was spent in or on the woodpile (31.7 ± 5.7%; Table 4). There was no significant difference between species in the percentage daily use of the pine tree or woodpile (Table 4). However, striped skinks used the treefern significantly more than did brown skinks. In particular, female striped skinks favoured the treefern, spending 39.9 ± 11.2% of observations at that location. Brown skinks spent significantly more time on or under the bark than did striped skinks (Table 4).

### Enclosure height

No adjustments for temperature or humidity were required for this analysis (Table 3). Striped skinks spent significantly more time during the day in the "high" portion of the enclosure (49.5 ± 4.7% ) than did brown skinks (31.3 ± 6.9%, $P = 0.001$; Table 4). After "high", "ground" and "medium" were the next favoured enclosure heights. The most favoured level of the enclosure for brown skinks was the ground (Table 4).

## Discussion

Determining the status of the striped skink is a prerequisite for assessing the need for conservation measures and establishing recovery actions. Whether the species even requires management to ensure its survival needs to be clarified (Whitaker, 1998). To achieve this, information on the behaviour and habitat preferences of the species is required to assist in the development of improved capture and survey methods.

Our results support our first hypothesis that striped skinks have more arboreal tendencies than the terrestrial brown skink. Although both species spent a similarly small proportion of their active time climbing, striped skinks spent significantly greater periods at high locations in the experimental enclosure. This suggests that although both species explored all parts of the enclosure, striped skinks were more inclined to stay for long periods at greater heights. They often attempted

**Table 4.** Mean percentage of intervals spent at each location and at each height in the enclosure by captive striped skinks and brown skinks. Mean differences refer to species differences. S.E.D = standard error of difference, NS = $P > 0.10$

| | Striped skink | | | | | Brown skink | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male $n = 6$ | Female $n = 2$ | Sub adult $n = 4$ | Species mean | Species S.E | Male $n = 2$ | Female $n = 2$ | Gravid $n = 4$ | Sub adult $n = 4$ | Species mean | Species S.E. | Mean difference | S.E.D | *P* |
| **Location** | | | | | | | | | | | | | | |
| Pine tree | 34.3 | 28.3 | 33.1 | 32.6 | 4.1 | 17.7 | 42.8 | 29.6 | 46.6 | 35.0 | 5.9 | -2.4 | 7.0 | NS |
| Woodpile | 33.8 | 16.3 | 44.2 | 31.7 | 5.7 | 71.4 | 15.0 | 54.1 | 36.6 | 40.7 | 7.3 | -9.0 | 8.9 | NS |
| Treefern | 22.3 | 39.9 | 12.6 | 24.8 | 4.1 | 5.2 | 12.2 | 4.8 | 5.9 | 7.9 | 2.3 | 16.9 | 4.8 | 0.004 |
| Soil | 5.8 | 7.3 | 8.8 | 7.4 | 0.9 | 7.0 | 12.4 | 15.4 | 9.6 | 9.6 | 1.3 | -2.3 | 1.5 | NS |
| Bark | 1.3 | 1.4 | 1.4 | 1.4 | 0.4 | 3.3 | 6.5 | 3.6 | 2.6 | 4.0 | 1.3 | -2.3 | 1.0 | 0.048 |
| **Height** | | | | | | | | | | | | | | |
| High | 53.5 | 63.4 | 30.8 | 49.5 | 4.7 | 12.7 | 24.0 | 24.8 | 18.4 | 18.2 | 4.2 | 31.3 | 6.9 | 0.001 |
| Medium | 9.5 | 8.5 | 11.5 | 10.3 | 2.3 | 9.3 | 25.8 | 16.5 | 24.5 | 19.4 | 4.8 | -9.0 | 4.8 | 0.086 |
| Low | 1.6 | 1.6 | 2.3 | 1.8 | 0.3 | 0.9 | 1.3 | 0.7 | 0.8 | 1.0 | 0.2 | 0.8 | 0.4 | 0.037 |
| Ground | 38.0 | 27.0 | 56.3 | 39.8 | 4.5 | 75.6 | 44.0 | 65.9 | 51.0 | 57.6 | 5.9 | -17.8 | 7.3 | 0.099 |

to climb the smooth surface above the highest level in the enclosure and hung their bodies out over the edge of the high platform, apparently looking for other structures. Striped skinks appeared to be more agile climbers than brown skinks, often jumping up or out from trees to other structures.

Our second hypothesis of reduced activity in striped skinks compared with brown skinks is not supported by our research. Striped skinks were at least as active, and often more active, than brown skinks through all periods of the day and night. Caution has to be applied in the interpretation of this result, as the enclosure was kept quite moist throughout the period of the research. This probably resulted in less variation in behaviour due to climatic conditions than would be found in the wild. Enclosures were kept moist as both species are considered to prefer damp habitats (Towns *et al*., 2002), and striped skinks are known to have high rates of evaporative water loss (Neilson, 2002). The significantly higher drinking rates and lower frequency of basking of striped skinks in the current work, and the night time activity associated with mist sprayer use are consistent with high rates of water loss in this species. It is therefore possible, that had the enclosures been kept drier, striped skink activity may have been reduced. However, such conditions may also have reduced brown skink activity. In any case, results indicate that activity of striped skinks is significantly higher than that of brown skinks during summer and when substrate is moist.

As expected, activity was positively associated and retreat negatively associated with temperature. Therefore, based on current knowledge, warm and damp conditions are likely to provide the best opportunity for capturing active wild striped skinks. During favourable conditions, inactivity should not be a reason for failure to catch individuals of this species.

Observations from the wild indicate that striped skinks can be found on the ground, even when in forested habitats (Whitaker, 1998). In our research, striped skinks spent on average just under half their time on the ground, although the range of habitats available at all levels was clearly limited. Pitfall trapping has been regularly carried out in at least four known striped skink locations over the past ten years, with only two individuals ever being captured in a trap (A.H. Whitaker, *unpubl. data*, Whitaker Consultants Limited, Motueka; H. Speed, *pers. comm.*, Department of Conservation, Auckland; D. Caskey, *pers. comm.*). Tests on the ability of striped skinks to escape from round four-litre tin and plastic pitfall traps indicate that they can not do so over a 24 hour period (K. Neilson, *unpubl. data*). If striped skinks spent half their time on the ground in the wild, more animals might have been expected to be captured over that period, particularly given the apparent high levels of daily activity. Alternatively, striped skinks may be very trap-wary, or occur in very low numbers.

In the genus *Oligosoma*, the most highly threatened species tend to be those that are large. With a maximum snout to vent length of 76 mm, striped skinks are an average size for the genus, and most similarly sized diurnal species are not considered endangered (Gill and Whitaker, 1996). It is difficult to understand why striped skinks would be more susceptible than other small congeners. They certainly would have been affected by deforestation in large parts of their range (Taylor *et al*., 1997). However at least 600 000 ha of lowland podocarp/hardwood forests remain within the range of striped skinks and at least 360 000 ha of this is on public conservation land (D. Brown, *pers. comm.*, Department of Conservation, Christchurch). Like some other New Zealand reptiles, a low annual reproductive output may be contributing to a decline (Cree, 1994), although captive striped skinks are observed to breed annually, and litter sizes of four to six are common (Whitaker, 1998). A higher level of activity could be detrimental to striped skinks if mortality risk is higher for active lizards than for less active ones (e.g. Adolph and Porter, 1993). Inactivity in a protected retreat may be advantageous due to energy conservation and predator avoidance (Rose, 1981). In particular, occasional nocturnal activity by striped skinks may make them more susceptible to predators such as rodents and possums (*Trichosurus vulpecula*), whose nocturnal activity is not thought to be substantially altered by short periods of light rain (Ward, 1978; C. Gillies, *pers. comm.*, Department of Conservation, Hamilton).

Given our results combined with anecdotal data (Whitaker, 1998), it is appropriate to explore potential survey and capture methods for striped skinks in arboreal habitats. A variety of techniques have been employed to locate, survey for and monitor arboreal lizards elsewhere, including visual surveys (Cooper, 1993; Perry and Buden, 1999), observations using binoculars (Mori *et al.*, 1995), catching animals on the ground following tree felling (Brown and Fehlmann, 1958), noosing (Blair, 1960) and trapping (Blair, 1960; Zani and Vitt, 1995). Lizards have also been found incidentally during canopy fogging for invertebrates (Das, 2004, *in press*). However, in many cases arboreal lizards can still be very difficult to find. Approximately 50% of species in the arboreal lizard genus *Abronia* have been discovered in the last 20 years (Campbell *et al.*, 1998). Brown and Fehlmann (1958) reported that the species *Lipinia leptosoma* was only exposed and captured by felling trees and observing the skinks in the crown or removing them from the axils of the leaves. They report that the species was never seen on the trunks or leaves by an observer on the ground, nor on a bank overlooking the crown of the tree.

Given the elusiveness of striped skinks, it would seem that ground-based visual surveys and associated capture methods are unlikely to be the best means for locating individual striped skinks in forested habitats. Visual surveys using binoculars from elevated positions may be useful for locating skinks that are active in the canopy. There are at least two existing canopy towers within the range of striped skinks that could be used for this purpose. Our results indicate that surveys carried out between about 1100 to 1700 h are most likely to coincide with peak activity periods over summer.

Conservation managers in the North Island of New Zealand have been encouraged to investigate opportunities to examine epiphytes in recently felled native trees within the range of striped skinks (A.H. Whitaker, *pers. comm.*). The recent find of juvenile striped skinks in a newly fallen tree following a storm (J. Heaphy, *pers. comm.*), combined with the results of our research indicates that opportunities for examining felled native trees should not be missed. They may provide the best opportunity for identifying striped skink populations for longer term studies on status.

We also recommend trialling of traps targeting arboreal lizards at known striped skink locations. A range of arboreal traps have been tried outside of New Zealand including glue traps (Bauer and Sadlier, 1992), and wire-mesh minnow traps set over tree holes (Zani and Vitt, 1995) and along canopy drift fences (Vogt, 1987). Blair (1960) used a ground-based trapping method consisting of wire traps and drift fences set around the base of trees. A similar technique was also used on tree trunks. This was designed to target lizards moving onto the ground or up and down trunks. As striped skinks appear to spend time both on and off the ground, this method, along with traps set in trees and along canopy drift fences, should be investigated. Trials on captive individuals will be required to test whether the animals are willing to enter the traps, and are unable to escape from them. Captive trials of baits and lures are also recommended.

Radiotracking of reptiles can provide valuable information on habitat use and assist in conservation management decisions (Webb and Shine, 1997), but has not been widely employed in New Zealand. Now that transmitters small enough for use on striped skinks are available, radiotracking could be used to confirm their degree of arboreal habit once wild individuals are captured.

Given that captive striped skinks are at least as active as brown skinks, appear to carry out similar types of behaviour during daily activity periods, and spend at least part of their lives on the ground, determined efforts using new trap designs at known locations, visual canopy surveys and surveying felled native trees should prove fruitful in locating more lizards. If this is not successful, we should have real concerns about the status of striped skinks in the wild.

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