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Shrinking forest shrinks skink: morphological change in response to rainforest fragmentation in the prickly forest skink (*Gnypetoscincus queenslandiae*)

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Abstract

Large-scale fragmentation of rainforest occurred on the Atherton Tableland in the Australian Wet Tropics from 50 to 100 years ago, leaving numerous fragments of varying sizes. Eleven fragments (from <1 to 75 ha in area) and eight continuous-forest sites were studied to assess the effects of fragmentation on the morphology and demography of the rainforest-endemic prickly forest skink (*Gnypetoscincus queenslandiae*). Skink abundance (number of individuals captured per hour of search effort) was significantly greater in continuous forest than in forest fragments. Moreover, both skink abundance and the availability of decaying logs, which provide key habitat for this species, increased with fragment area. Fragments contained a smaller proportion of adults, and individuals in fragments were smaller on average for all measured morphological features, than those in continuous forest. Thus, although prickly forest skinks appear to be maintaining populations in rainforest remnants, they are nonetheless being affected by fragmentation. These demographic and morphological changes may be caused by alterations in habitat and prey availability and/or by microclimatic changes associated with edge effects. © 1999 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Tropical forests are the planet's most biologically diverse ecosystems (Lewin, 1986), but are being cleared and fragmented at unprecedented rates. In fragmented populations, genetic drift and inbreeding can lead to an erosion of genetic variation (Frankel and Soule, 1981), reducing the ability of individuals to respond both to novel environmental changes and to more common perturbations, such as parasites and diseases. Fragmentation (or isolation of island populations) has been shown to increase inbreeding and genetic drift in rodents (Leung et al., 1993; Campbell, 1995) and reptiles (Sarre, 1994; Cunningham and Moritz, 1997; Madsen et al., 1997), and can increase fluctuating asymmetry in centipedes (Weishampel et al., 1997) and reptiles (Soule, 1967; Sarre and Dearn, 1991; Sarre et al., 1994).

Fragmentation may also cause morphological changes in populations, potentially by altering selection regimes. For forest species, altered radiation, wind, water, and nutrient regimes in fragments may create unusual stresses (Laurance and Yensen, 1991; Saunders et al., 1991; Turton and Freiburger, 1997). Forest microclimate can be altered up to 60 m from fragment edges (Kapos, 1989), while increased tree mortality in fragments can alter forest dynamics and structure (Laurance, 1997; Laurance et al., 1998). Although there is currently little direct evidence of fragmentation-induced changes in animal morphology (Sarre, 1995), such changes are possible. For example, Smith et al. (1997) found that differences in vegetation structure between African rainforest and the rainforest-savanna ecotone led to different selection regimes, causing morphological changes in rainforest birds. Brown et al. (1992) suggested that populations of cyprinid fish isolated by habitat degradation showed morphological divergence among populations, although these changes could conceivably have occurred prior to fragmentation.

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Forests have been extensively fragmented in the wet tropics of north Queensland, especially in the coastal lowland (<300 m elevation) and in upland areas like the Atherton Tableland. Clearing of the Tableland's rainforests began in 1909 (Laurance, 1994) and proceeded rapidly over the next 20 years. By 1983, the destruction of large areas of forest (>77,000 ha) created hundreds of forest fragments, mostly surrounded by dairy cattle pastures, with larger tracts of unfragmented forest persisting only on hillsides surrounding the Tableland (Winter et al., 1987).

Most studies of fragmentation in north Queensland rainforests have focused on birds and mammals, often at the community level. In general, these studies suggest that species diversity increases with habitat area, but that individual species vary greatly in their response to fragmentation (Pahl et al., 1988; Crome et al., 1994; Laurance and Laurance, 1995; Warburton, 1997). Extinction proneness of species is best predicted by their relative abundance in the surrounding matrix, not by their initial rarity in unfragmented forest or other life-history features (Laurance, 1990, 1991a, 1994; Warburton, 1997). There is some evidence of reduced genetic variation in fragmented populations of rodents (Leung et al., 1993; Campbell, 1995), although comparisons between fragmented and continuous sites can be confounded by underlying historical effects (Cunningham and Moritz, 1997). The response of reptiles to fragmentation has received limited attention, both in north Queensland (Andrews, 1990; Cunningham and Moritz, 1997) and elsewhere (How and Dell, 1994; Sarre, 1994, 1995, 1996; Sarre et al., 1995; Smith et al., 1996; Madsen et al., 1997; Luiselli and Capizzi, 1997; Tiebout and Anderson, 1997).

Lizards can adapt quickly to environmental change, especially in island systems. For example, *Anolis* lizards exhibit morphological changes in response to strong selection pressures within 10–14 years after colonizing an island (Losos et al., 1997), and directional selection on morphotypes can occur in as little as two months (Malhotra and Thorpe, 1991; Thorpe and Malhotra, 1992). The speed at which lizards can adapt to local conditions makes them ideal candidates for the present study, which focuses on morphological and demographic responses of populations to anthropogenic fragmentation. This study is concerned with determining whether such changes occur, although without additional experiments it is not possible to determine whether morphological changes are genetic responses to altered selection regimes or the result of phenotypic plasticity.

The prickly forest skink (*Gnypetoscincus queenslandiae*) represents a monotypic genus endemic to north Queensland rainforests. They are live-bearing, giving birth to 1–5 young in the late wet season (January–March) (Cunningham, 1993), and are habitat

specialists, restricted to rainforests and living under and within rotting logs (Naylor, 1980; Cogger, 1992). Individuals show strong site-fidelity (Sumner and Moritz, unpublished data). Earlier studies revealed that prickly skink populations north and south of a historical disjunction in north Queensland rainforest, the Black Mountain Barrier, exhibit large genetic differences (Moritz et al., 1993; Joseph et al., 1995; Cunningham and Moritz, 1997). Morphological comparisons of these populations, however, showed consistent differences only in minor scale characters, despite the fact that they had been isolated for an extended period (Schneider and Moritz, 1998). Morphological differences have been recorded over smaller areas, however, especially among populations at different elevations (Cunningham, 1993).

To investigate the effects of fragmentation on prickly skink populations, we compared the relative abundance, habitat availability, and differences in size and shape of individuals, among populations in fragments and nearby sites within continuous forest. In concert with earlier studies, our results provide insights into the effects of fragmentation on this rainforest-endemic lizard.

2. Methods

2.1. Field study

We surveyed sites on the Atherton Tableland twice in the late dry season (November 1995 and 1996) and twice in the late wet season (April 1996, February 1997). On each trip we surveyed 11 rainforest fragments and eight sites within nearby continuous forest (Fig. 1). Two additional surveys were made in November 1997 and February 1998, during which one continuous-forest site (Massey Creek) was revisited.

The fragments and continuous-forest sites encompassed a similar geographic area, and to avoid confounding fragmentation effects with long-term processes, all sites were chosen within the same historical area, as defined by their mtDNA haplotype (Cunningham and Moritz, 1997). Six of the fragments were among those included in previous studies of fragmentation effects on mammals (Laurance, 1990; 1991a,b; 1994; Campbell, 1995) and birds (Warburton, 1997). The fragments ranged from <1 to 75 ha, and were surrounded by pastures, which we believe prickly skinks are unlikely to traverse. All sites consisted of primary, complex notophyll vine-forest (Tracey, 1982), although most had undergone some logging during the past century, and parts of some fragments were prone to trampling by cattle. At each site we searched opportunistically for skinks for ca. 12 person-hours, except for sites of ≤ 1 ha, which were searched until the entire fragment had been covered. All captured animals were

weighed, measured, and allocated to a sex if possible, then released at the point of capture.

At most study sites, logs (>5 cm diameter) were counted along two 10×50 m strip transects in November 1996 to estimate log availability in fragments and to assess the relationship between log availability and skink abundance. There was space for only one transect at four sites. For each log, measurements of length, diameter, and decomposition (0 = none apparent, 1 = slight, 2 = moderate, 3 = advanced), were recorded.

2.2. Analyses

Skink abundance was estimated as the number of captures per hour of search effort. Lizard abundances and variables measured along log transects were compared between fragmented and continuous forests using *t*-tests, after testing that data conformed to assumptions of homoscedasticity using Bartlett's tests. Linear regression analyses were used to test for relationships between lizard abundance and log density, mean length, mean width, and mean decomposition. Regressions were generated for all sites, and for fragmented and

continuous forests separately. For the fragments, fragment area (log transformed) was included as a predictor. If an outlier (± 2 SD) was detected, variables were log-transformed, then if the outlier was still present, it was removed from the analysis.

Seven morphological characters were measured for each skink: snout-vent length (SVL), total length (TL), inter-limb length (ILL), weight (WT), head length (HL), head-width (HW), and jaw length (JL). A two-factor MANOVA was used to analyze sexual size dimorphism within four populations from continuous forest, while a two-factor MANCOVA was used to assess body-shape differences among populations, with snout-vent length the covariate for TL, ILL, WT and HL, and head length the covariate for HW and JL. Due to significant site effects, a nested ANOVA was used to test for effects of fragmentation on skink size; eight sites were nested within the fragmented forest treatment and eight sites nested within the continuous forest treatment. A nested ANCOVA (with eight sites nested within both fragmented and continuous forest treatments) was used to investigate body-shape differences, with snout-vent length and head length used as covariates. Three of the small fragments were excluded from these analyses due to small sample sizes (Woolward 1, Woolward 2, and Carmichael; Table 1). Chi-square tests and *t*-tests were

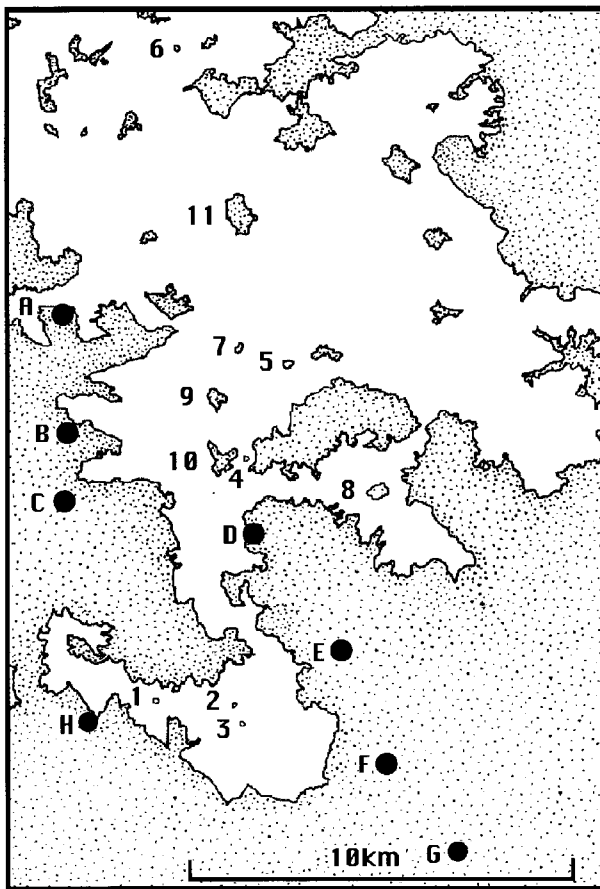


Fig. 1. Sampling sites for fragments (1–11) and continuous-forest sites (A–H) on the Atherton Tableland in tropical Queensland, Australia (adapted from Cunningham and Moritz, 1997).

Table 1

Location of sampling sites and number of prickly forest skinks captured at each site in North Queensland

Site	Size (ha)	Latitude	Longitude	N ^c	Search (h)	N/H
<i>Fragments</i>						
(1) Woolward 1	0.25	145.36	17.37	2	3.83	0.52
(2) Woolward 2	0.25	145.36	17.37	1	2.5	0.4
(3) Carmichael	0.5	145.39	17.34	0	3.65	0
(4) Maalan Road	0.5	145.34	17.435	51	11.5	4.43
(5) McInnes	6	145.35	17.27	15	12	1.25
(6) Pat Daley Park	6	145.37	17.32	21	15.5	1.35
(7) Waltham	7	145.37	17.33	34	18	1.89
(8) Souita Falls	13	145.39	17.34	15	15	1
(9) Nose Ring (Trantor)	21	145.37	17.33	21	17	1.23
(10) Whiteing Road	43	145.36	17.34	66	15.5	4.26
(11) Millaa Millaa Falls	75	145.37	17.3	70	14	5
<i>Continuous forest</i>						
(A) Millaa Millaa Lookout		145.34	17.31	23	14.4	1.59
(B) Reynolds		145.34	17.33	57	13	4.38
(C) Brotherton		145.34	17.34	62	10.75	5.77
(D) Pepina Falls		145.37	17.34	25	18	1.39
(E) Mount Father Clancy		145.38	17.36	108	16.3	6.63
(F) Sutties Gap Road 1		145.38	17.4	22	13	1.69
(G) Sutties Gap Road 2		145.39	17.42	19	3 ^a	6.33
(H) Massey Creek		145.34	17.37	345	86.75 ^b	3.98

^a Single visit only.

^b Massey Creek is the site of a mark-release-recapture experiment, hence the larger search effort.

^c N = number of prickly forest skinks captured. All "continuous forest" sites are within a continuous stretch of forest that is approximately 100,000 ha.

used to examine sex-ratios and the proportion of lizards with original vs. regenerated tails. All analyses were conducted using STATISTICA 4.1 (Anon., 1994).

3. Results

3.1. Skink abundance and sex ratios

We captured 1052 individual skinks, of which 743 were from continuous forest and 309 from fragments (Table 1). Males were identified by eversion of the hemipenes. Females mature at ca. 55 mm SVL and males at ca. 50 mm SVL (Cunningham, 1993), but hemipenes could be everted only on males of ≥ 65 mm SVL. Therefore, analyses on 'adults' included only individuals of ≥ 65 mm SVL. A total of 239 females, 160 males, and 653 individuals with SVL of < 65 mm were captured.

Skink abundance was significantly lower in fragments (1.94 ± 1.77 SD) than in continuous forest (3.97 ± 2.18 ; $t = -2.23$, d.f. = 17, $P = 0.039$; Table 1). There were significantly more logs in fragments (18.95 ± 4.21) than continuous forest (14.86 ± 2.37 ; $t = 2.33$, d.f. = 16, $P = 0.033$), but other log parameters (length, diameter, decomposition) did not differ significantly. When analyses were restricted to fragments, linear regressions revealed that log number ($r^2 = 0.47$, $F_{1,9} = 7.98$, $P = 0.020$; Fig. 2A) and fragment size ($r^2 = 0.72$, $F_{1,8} = 20.48$, $P = 0.002$; Fig. 2B) were both significant and positive predictors of skink abundance. There was also a weak, positive relationship between skink abundance and log condition ($r^2 = 0.31$, $F_{1,9} = 4.11$, $P = 0.073$). The density of logs was strongly and positively related to fragment size ($r^2 = 0.52$, $F_{1,8} = 5.54$, $P = 0.019$; Fig. 2C). These predictors were non-significant, however, when both fragmented and continuous sites, or only continuous sites, were included in the model.

Among identified adults, the sex ratio was significantly biased toward females (1 male: 1.49 females), based on the entire sample of individuals ($\chi^2 = 15.64$, d.f. = 1, $P < 0.001$). There was no significant difference in sex ratio between continuous and fragmented sites ($\chi^2 = 0.70$, d.f. = 1, $P = 0.40$).

3.2. Sexual dimorphism

To evaluate the extent of sexual dimorphism in prickly skinks, individuals were analyzed from four continuous-forest sites (Massey Creek, Reynolds, Thorrel, and Mt. Father Clancy), using only adults over 65 mm SVL. A two-factor MANOVA revealed a significant effect of both sex (Wilk's Lambda (λ) = 0.720; d.f. = 21, 761; $P < 0.001$) and site ($\lambda = 0.872$; d.f. = 7, 265; $P < 0.001$), with a non-significant interaction term

($\lambda = 0.932$; d.f. = 21, 761; $P = 0.59$). There were sex-related differences in four of the seven morphological characters: males were significantly larger for all head characters (HL: $F = 5.21$; d.f. = 1271; $P = 0.023$; HW: $F = 9.00$; d.f. = 1, 271; $P = 0.003$; JL: $F = 5.63$; d.f. = 1, 271; $P = 0.018$), while females had significantly longer interlimb lengths ($F = 7.29$; d.f. = 1271; $P = 0.007$).

A two-factor MANCOVA was used to investigate shape differences in adult prickly skinks. When SVL was the covariate, both sex and site were found to contribute significantly to shape differences (sex: $\lambda = 0.904$;

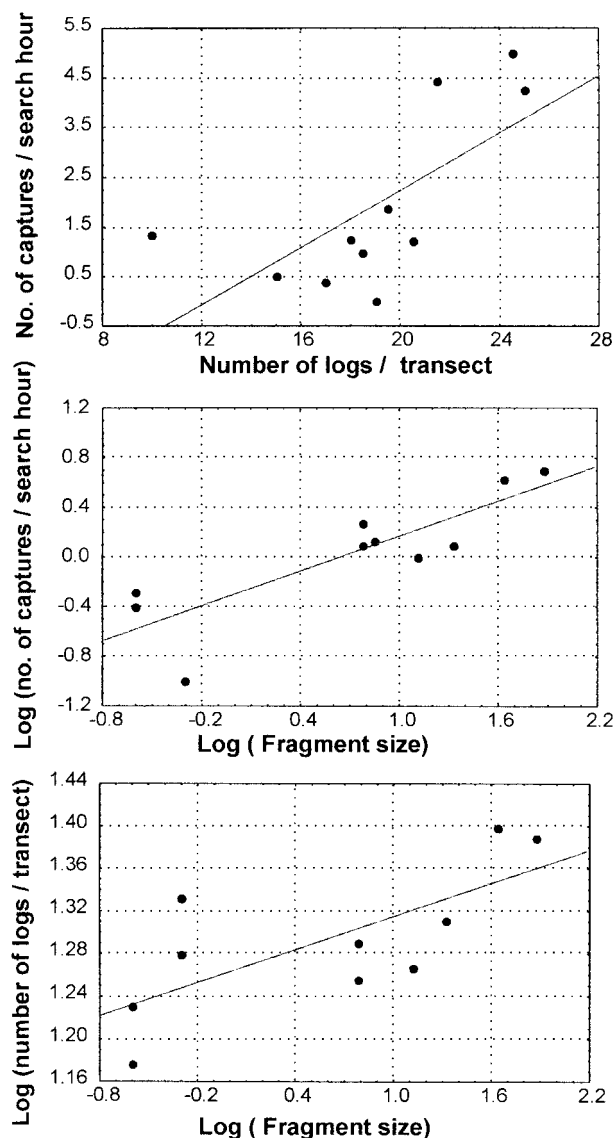


Fig. 2. (A). Relationship between the number of logs per transect and skink abundance in rainforest fragments (captures per search hour = $-3.522 + 0.288$ logs). (B). Relationship between fragment size and skink abundance in rainforest fragments. (log [captures per search hour] = $-0.298 + 0.471 * \log$ [fragment size in ha]). (C). Relationship between fragment size and the number of logs per transect in rainforest fragments (log [no. of logs] = $1.263 + 0.052 * \log$ [fragment size in ha]).

d.f. = 12, 709; $P=0.007$; site: $\lambda=0.899$; d.f. = 4, 268; $P<0.001$), with a non-significant interaction term ($\lambda=0.965$; d.f. = 12, 709; $P=0.655$). When using head length as the covariate, however, there were sex differences but no site differences (sex: $\lambda=0.843$; d.f. = 6, 542; $P<0.001$; site: $\lambda=0.982$; d.f. = 2, 271; $P=0.081$; interaction term: $\lambda=0.969$; d.f. = 6, 542; $P=0.20$). Univariate tests revealed that female and male skinks differed significantly in the relationship between snout-vent length and interlimb length ($F=6.21$; d.f. = 1, 271; $P=0.013$), head length ($F=7.16.11$; d.f. = 1, 271; $P<0.001$), and weight ($F=6.61$ d.f. = 1, 271; $P=0.011$), and between head length and head width ($F=4.86$; d.f. = 1, 272; $P=0.028$; Table 2).

3.3. Size, shape, and tail-break differences between fragmented and continuous forest

Significant differences in skink size were found between fragments and continuous for sites for all characters (Table 3), with skinks in fragments being smaller on average than those in continuous forest (SVL: $F=5.89$; d.f. = 1, 14; $P=0.029$; TL: $F=5.029$; d.f. = 1, 14; $P=0.042$; ILL: $F=5.48$; d.f. = 1, 14; $P=0.035$; HEADL $F=7.23$; d.f. = 1, 14; $P=0.018$; HW: $F=8.24$; d.f. = 1, 14; $P=0.012$; JL: $F=7.24$; d.f. = 1, 14; $P=0.018$; WT: $F=5.95$; d.f. = 1, 14; $P=0.029$; Fig. 3).

Analysis of shape characters (corrected for either SVL or HL as appropriate) indicated no significant difference

Table 2

Mean values of morphological characters for female and male prickly forest skinks of > 65 mm snout-vent length from four continuous-forest sites

Site	Sex	Snout-vent length	Total length	Interlimb length	Head length	Head width	Jaw length	Weight (log)	N
Massey Ck.	F	74.72	158.36	40.23	16.86	11.35	9.41	0.95	119
Massey Ck.	M	74.09	158.84	38.76	17.42	11.71	9.69	0.96	74
Reynolds	F	75.60	163.90	40.90	16.90	11.16	9.73	0.95	10
Reynolds	M	73.15	153.62	38.31	16.92	11.62	9.82	0.93	13
Thorrel	F	71.67	148.00	38.80	15.41	10.02	8.77	0.88	15
Thorrel	M	70.10	153.40	37.90	16.26	10.91	9.60	0.89	10
Mt Father Clancy	F	72.63	157.44	39.04	16.21	10.63	9.64	0.91	27
Mt Father Clancy	M	72.09	159.64	36.82	16.79	11.24	10.65	0.90	11

Table 3

Mean values of morphological characters of prickly forest skinks from each site as used for the nested MANOVA comparing size-differences between skinks caught in fragments and continuous forest

Site	Snout-vent length	Total length	Inter-limb length	Head length	Head width	Jaw length	Weight (log)	N
<i>Fragments</i>								
Maalan Rd.	54.32	125.44	27.80	12.51	7.92	7.05	0.50	41
McInnes	54.45	128.36	27.64	12.78	7.97	7.04	0.45	11
Pat Daley Park	52.45	123.86	27.36	12.84	8.08	7.75	0.43	11
Waltham	47.27	108.50	23.53	11.59	7.32	6.98	0.27	26
Souita Falls	43.43	98.21	21.43	10.83	6.97	6.35	0.15	14
Nose Ring	40.92	92.78	19.85	10.52	6.42	6.37	0.04	13
Whiteing Rd.	46.74	106.68	23.23	11.59	7.51	6.75	0.27	31
Millaa Millaa Falls	46.10	106.00	23.14	11.83	7.38	7.10	0.23	28
Site means	48.21	111.14	24.25	11.81	7.44	6.92	0.29	
<i>Continuous forest</i>								
Millaa Millaa Lookout	53.91	125.82	27.55	12.98	8.29	7.38	0.46	11
Reynolds	54.52	125.64	28.40	12.74	8.01	7.21	0.47	25
Thorrel	53.38	124.38	27.76	12.51	7.92	7.00	0.45	21
Pepina Falls	48.44	111.00	24.13	11.90	7.55	7.24	0.32	16
Mt. Father Clancy	52.17	119.13	26.55	12.59	8.00	7.45	0.41	60
Sutties Gap Rd. 1	52.14	120.71	26.29	12.51	8.11	7.56	0.47	7
Sutties Gap Rd. 2	59.83	137.83	30.33	14.32	9.82	8.53	0.63	6
Massey Creek	53.76	123.13	27.54	13.07	8.44	7.22	0.48	214
Site means	53.52	123.46	27.32	12.83	8.27	7.45	0.46	
All groups	51.82	119.01	26.39	12.55	8.02	7.17	0.41	535

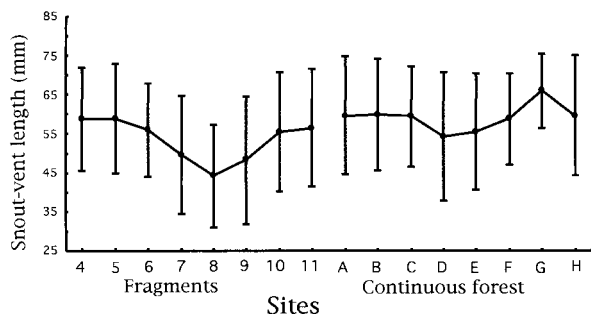


Fig. 3. Snout-vent length and its standard deviation for prickly skinks in fragmented and continuous forest. Sites are numbered according to Table 1.

between individuals in fragmented and continuous forest. Skinks in fragments did tend to be somewhat thinner, however, being generally lighter for their SVL ($F=3.887$; d.f. = 1, 14; $P=0.069$).

Comparisons of animals with regenerated tails (indicating a past tail break) indicated that significantly more animals had past tail breaks in continuous forest (45.1%) than fragmented sites (37.9%; $t=1.98$; d.f. = 1; $P=0.047$).

4. Discussion

4.1. Skink abundances and sex ratios

Our study reveals that habitat fragmentation has altered the abundance, population structure, and morphology of prickly forest skinks. Forest fragments supported lower skink abundances, and smaller individuals, than comparable areas in nearby unfragmented forest. There was also some tendency for skinks in fragments to be thinner than their counterparts in continuous forest.

Previous studies suggest that different reptile species vary greatly in their responses to habitat fragmentation (Sarre et al., 1995). For example, How and Dell (1994) reported that responses differed among taxonomic groups and that no group varied significantly with remnant size. Smith et al. (1996) found that three species were significantly influenced by the availability of cover and shelter in remnants of gimlet woodland, a result similar to that encountered in this study, while three others showed no such relationship. Sarre (1995), in his study of *Oedura reticulata* in woodland remnants, found that population sizes varied greatly among remnants but, unlike our study, population sizes were not significantly correlated with remnant size and the number of habitat trees in remnants.

The sex ratio of prickly forest skinks in our field study (1:1.49) is very similar to that found in museum collections of this species (1:1.47; Cunningham, 1993). Prickly skinks born in captivity had an approximately equal sex ratio (12 males: 14 females; J. Sumner, unpubl. data),

however, suggesting that the differences in the sex ratio of captured skinks could be due to increased mortality or lower catchability of males.

Prickly skinks appear to be more abundant in larger forest areas (as demonstrated by their significantly higher abundance in continuous forest than fragments, and the positive correlation between skink abundance and fragment size). The density of logs was higher in fragments than continuous forest, which may be the result of elevated wind shear or microclimatic changes near forest edges, which commonly leads to increased tree mortality in fragments (Kapos et al., 1997; Laurance, 1997; Laurance et al., 1998). In addition, lower humidity near edges (Turton and Freiburger, 1997) may reduce decomposition rates in fragments. This could conceivably cause heavily decayed logs to be a more-limiting resource in fragments, which in turn could have a negative effect on prickly forest skinks, which appear to favor heavily decayed logs. Edge effects do not, however, explain the pattern of increasing log density in larger fragments which, with their smaller edge-to-core ratios, would be expected to have fewer logs.

Assuming our abundance estimates are an accurate index of population density, the lower abundances of skinks in fragments would likely compound the effects of population isolation, by also decreasing population size. Small populations are more prone to stochastic extinction events, and, given the low vagility of this species, their lower density could increase the probability of an individual mating with close relatives, raising the risk of inbreeding (Lande, 1993). These processes are likely to reduce effective population size, increasing genetic drift and demographic instability within fragmented populations (Mills and Smouse, 1994).

4.2. Body size

Prickly skinks in fragments were smaller on average than those in continuous forest, which may reflect differences in growth rate, survivorship, or both. Variation in growth rates of reptiles has been attributed to food and other environmental factors (Sorci et al., 1996), genetic differences among populations (Niewiarowski, 1995), and within-population differences due to a combination of environmental factors (e.g. nest site selection) and maternal effects (Shine and Harlow, 1993; Shine et al., 1997a,b).

Food availability affects growth rate in many lizard species. In Amazonian forest fragments, edge effects alter both the abundance and community structure of invertebrates (Klein, 1989; Didham, 1997; Carvalho and Vasconcelos, 1999). Although the density changes reported in these studies were variable among different invertebrate taxa, the fact that species composition was altered near edges suggests that the preferred prey of

prickly skinks might be reduced in small fragments. Such a reduction might lower growth rates of the lizards, leading to the comparatively smaller size of adults. The fact that prickly skinks tended to be thinner (lower weight for a given snout-vent length) in fragments is consistent with this hypothesis.

Environmental factors can also affect phenotypically plastic traits in skinks (Vleck, 1988). Shine and Harlow (1993) found that maternal basking regimes in a viviparous skink significantly affected the body shape of its neonates: increased thermal variance during pregnancy caused a decrease in offspring snout-vent length and an increase in relative mass (Shine et al., 1997b). The tendency for treefall gaps to increase near fragment edges (Laurance, 1997) could cause increased temperature variability in the forest understory (Williams-Linera, 1990). This could potentially affect skink gestation, leading to smaller sizes of individuals in fragments. Further study and manipulative experiments (e.g. Shine and Harlow, 1993) will be needed to determine whether microclimatic or other habitat factors cause the observed morphological changes.

An alternative explanation is that differences in survivorship underlay size differences between populations in fragmented and continuous forest. Changes in the size of individuals may result from differences in selection pressure in an altered habitat. Predation pressure has been postulated to drive morphological changes in rainforest-savanna birds (Smith et al., 1997). Changes in habitat structure due to increased treefalls, for example, in conjunction with reduced cover (rotting logs), might lead to increased susceptibility to predation and a related decline in mean body size. The lower frequency of tail breaks in continuous forest appears inconsistent with this hypothesis, but is inconclusive because tail breaks can be caused by either interspecific or intraspecific interactions.

4.3. Conclusions

The changes wrought by habitat fragmentation on species can be highly varied. This study identifies differences in the abundance and morphology of one species, the prickly forest skink, between fragmented and continuous forests, and suggests possible reasons for those changes. The decrease in available habitat (decaying logs) for skinks in fragments may have led to a reduction in shelter from predators. However, the tendency for skinks to be thinner in fragments, as well as smaller and less abundant, suggests that increased susceptibility to predators alone can not account for these differences. Edge effects and a possible scarcity of heavily decayed logs in fragments may have reduced prey availability. Fragmentation might also have indirect effects on skink populations, possibly by altering thermal regimes, which in turn modify embryonic development. Further

study will be needed to identify the mechanisms underlying the morphological and demographic changes revealed by our study, and to determine whether forest fragments can maintain viable populations of this rainforest-specialized skink into the future.

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