Effects of human disturbance on five-lined skink, *Eumeces fasciatus*, abundance and distribution

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Abstract

We studied the effects of human disturbance on five-lined skinks at Point Pelee National Park, Canada. Surveys indicated low skink abundance and a lack of woody debris in areas heavily used by humans and a downward population trend concurrent with high disturbance levels. Skinks preferentially used large moderately decayed logs and boards for refuge sites. Human disturbance resulted in degradation and removal of debris. Degradation by fragmentation and accelerated decay resulted in decreased quality of available debris. To test the hypothesis that skink absence in human-use areas was caused by a lack of suitable debris, we placed artificial microhabitats in areas which previously lacked woody debris and skinks. Experimental debris were colonized quickly and heavily used despite high disturbance rates. Skinks are resilient to minor disturbances such as displacements, but not to removal or degradation of debris. Essential microhabitat features must be actively preserved as well as suitable habitat to ensure the conservation of target species. © 1998 Elsevier Science Ltd. All rights reserved.

*Keywords: Eumeces fasciatus; Human disturbance; Abundance; Distribution; Microhabitat restoration*

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1. Introduction

Disturbance can be a major factor affecting populations and modifying interactions among species in communities (Connell, 1978; Sousa, 1984; Pickett and White, 1985). Although natural disturbances such as treefalls, floods, and fires are normal events in many ecosystems, there is a growing interest in anthropogenic disturbance. Habitat loss, fragmentation, and degradation are considered to be the most important threats to biological diversity (Primack, 1993). Loss of even small areas of habitat containing source populations can lead to extinctions in metapopulations (Pulliam, 1988). Fragmentation creates functional habitat islands by imposing dispersal barriers and increasing isolation. Other negative effects include creating ‘islands’ that are too small for home range requirements of some species, and edge effects that may result in degraded habitats or increased predation (Lovejoy et al., 1986; Wilcove et al., 1986). Reduction of population size can negatively affect demographic and genetic structure which increases the probability of local extinction (Gilpin and Soulé, 1986). A common remedial action taken to reduce habitat loss and fragmentation is to establish parks or preserves, but even here human recreation may impact on the protected biota (Boyle and Samson, 1985; Pomerantz et al., 1988; Garber and Burger, 1995).

Little research has focused on either the effects of human disturbance or the management of reptiles (Boyle and Samson, 1985; Gibbons, 1988). Evidence suggests that reptiles can be affected by agricultural practices (Heatwole, 1966; Bowman et al., 1990; Bock et al., 1990), forestry (Ruthven, 1911; Szaro et al., 1988; Lunney et al., 1991; Greenberg et al., 1994), mining (Twigg and Fox, 1991), urbanization (Neill, 1950; Minton, 1968), or visitor numbers in protected areas (Bernardino and Dalyrmple, 1992; Garber and Burger, 1995). The impact of human disturbance is of contemporary interest in the fields of conservation biology (Primack, 1993) and wildlife management (Szaro et al., 1988).

The population ecology of the five-lined skink *Eumeces fasciatus* has been under continuous study at Point Pelee National Park, Ontario, Canada since 1989. Initially, the studies focused on population biology (Seburn, 1989; Heenan and M’Closkey, 1994). In these studies, we have documented that skinks are affected by human disturbance and that artificial microhabitats can be used by skinks in areas with degraded natural debris. In this study, we tested the hypothesis that skink absence in areas with high levels of human disturbance was caused by the lack of suitable debris.

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1990) and habitat selection (Heenar, 1991), but our observations suggested that human activities were affecting skinks. Evidence suggested that skink habitat was being degraded by humans in high-use areas and that large scale illegal collections had taken place.

The objective of this study was to determine the impact of human disturbance on the Point Pelee skink population. This population is important because of its insular nature, and its value as a gene pool.

2. Study system and methods

2.1. Study area

Point Pelee National Park, Ontario, Canada (42° 10' N, 82° 30' W) is a 16 km² sandspit foreland which extends 16 km into the western basin of Lake Erie. The peninsula was formed about 4000 BP as sand was deposited by water action (East, 1976). The west beach and associated dunes were formed within the last 1000 years (Trenhaile and Dumala, 1978). The peninsula is geomorphologically dynamic with net processes of deposition on the west beach and erosion on the east beach (East, 1976). The park has a humid cool temperate climate which is strongly moderated by Lake Erie. The park is within the Carolinian zone of the Eastern Deciduous Forest. Terrestrial habitats cover 6 km² and include beach, dry forest, swamp forest, and cedar-savannas. Marsh habitat covers 10 km² of the park. Point Pelee is a functional island since it is surrounded by water on 80% of its perimeter and by agricultural land on 20%. Point Pelee is a small heavily used national park with about a half million visitors annually. Numbers tend to show two annual peaks, one in May when birdwatching occurs, and in July when general beach use reaches a peak (park records).

2.2. Natural history

The five-lined skink is a small, secretive, insectivorous lizard found in the Eastern Deciduous Forest of North America (Conant, 1975). Five-lined skinks occur in open habitats, spend most of their time in refuges, and make short foraging forays from a heavily used core area (Fitch and von Achen, 1977). At Point Pelee skinks emerge from hibernation in early April and remain active until early to mid October. The peaks of human use and skink use coincide closely. In May skinks are searching for mates and breeding, and females are nesting in July. In the study area skinks are found under or within woody debris (driftwood, snags, woodpiles, boardwalks) in open habitats such as stabilized dune, open woods, or cedar-savanna (Patch, 1919, 1934; Seburn, 1990; Heenar, 1991). At Point Pelee, skinks show preferential use of larger moderately decayed woody debris which provides a relatively stable microclimate and which probably acts as an important refuge from predation (Heenar, 1991, 1994). Large logs are especially important for nest sites (Heenar, 1994). Skinks are prone to desiccation stress (Noble and Mason, 1932) and extreme temperatures (Fitch, 1954), which makes suitable woody debris an essential microhabitat. The amount of woody debris available for skink use in the most important habitat in the park (stabilized dune), is a balance between input as driftwood and removal through decay and human actions (Heenar, 1991). Because beach building and succession advances westward the amount of skink habitat has not been reduced.

Females remain at their nests brooding eggs for about four to six weeks. At this time it would be easy for humans to collect females or eggs, or destroy nests. Frequent disturbance may result in females abandoning nests (Fitch, 1954). Hasagawa (1985) found that skink egg mortality was 9% for attended clutches, but was 96% for nests without the female present. Skinks are social and tend to aggregate. Disturbance of a single microhabitat can affect more than single individuals, and aggregations make matters simpler for illegal collectors.

2.3. Initial surveys

We conducted an initial survey of the west beach in June 1990, to determine if the pattern of skink distribution and abundance suggested a role of human disturbance. We checked every piece of woody debris that was a prospective skink microhabitat within a 10 m wide transect extending the length of the west beach (c. 9.8 km). We considered a prospective skink microhabitat to be any piece of woody debris lying prone, with a minimum horizontal dimension of 9 cm (large enough to conceal a skink), and surrounded by some herb or grass cover. Debris on the open beach was never used by skinks.

To determine if skink numbers were reduced in human high-use areas, we examined skink distribution at six locations which are heavily used by humans (high disturbance) and at adjacent less heavily used locations (low disturbance) on the west beach: Sanctuary-N.W. Beach (S/NW), Dunes-Sleepy Hollow (D/SH), Pioneer-Black Willow (P/BW), White Pine (WP), West Beach (WB), and the Transit stop. These locations are heavily used beach access points for park patrons. All feature parking lots with wooden boardwalk or path access to the open beach. These areas pass through prime skink habitat (stabilized dune, open woods, cedar-savanna) on the west beach. If a human disturbance effect exists, lower skink numbers should occur in high disturbance plots compared to low disturbance plots.

Since we thought that human disturbance might involve removal of woody debris, and thus render the
boardwalks in the high disturbance plots especially important for skinks, we carried out a second survey. In each low disturbance plot (except Transit stop) we investigated whether there was less debris in the half sector lying adjacent to each high disturbance plot compared to the more distant sector. We counted all suitable debris in a 10 m wide transect across both sectors.

2.4. Population censuses

We conducted 60 population censuses during 1990–1995 at two sites on the west beach, Northwest Beach (NW) and Black Willow Beach (BW). These sites are skink ‘hot spots’ and have been under continuous study since 1989. Both the NW (2.85 ha) and BW (2.55 ha) sites consist of stabilized dune, savanna, and open forest extending 950 and 850 m (respectively) along the beach. Although skink habitat is continuous along the beach, the two sites are 1.7 km apart which is much more than the maximum annual skink movement (Seburn, 1993).

We measured activity density because the secretive nature of skink behaviour (Taylor, 1936; Fitch and von Achen, 1977; Stamps, 1977) makes true density difficult to assess, and the two measures are considered to be strongly correlated (Pimm et al., 1985; Abramsky and Pinshow, 1989; Mitchell et al., 1990).

On each census animals were counted only once in a site, and represented a minimum number known to be alive on that date. We also recorded sex of skinks where possible and noted the maximum number observed for each age class (hatchling, juvenile, or adult) to determine the approximate age structure of the population.

2.5. Debris availability and use

In 1990, we recorded the type and dimensions of each piece of debris (log or board) and devised a scoring system that reflected the increasing structural complexity associated with decay (Fig. 1). To each piece of debris, we affixed a numbered aluminum tag for identification of microsites. In comparing the patterns of skink use with available debris size or decay class, disproportionate use indicates preference. To determine if the distribution of available debris had changed since 1990, we resurveyed the NW and BW sites at the end of the 1995 activity season.

2.6. Microhabitat restoration experiment

To test the hypothesis that lack of woody debris in human high-use areas limits skink numbers, we placed weathered boards as artificial microhabitats in areas that lacked both woody debris and skinks. The boards (4×15×155 cm) were in the size range preferred by skinks (>1700 cm²; Hecnar, 1991). Following an initial pilot trial in July 1991, a full scale experiment was run from 1992 to 1995. Prior to skink emergence from hibernation in April 1992, we placed 45 boards, five to a cluster, in open areas adjacent to shrubs or herbs. We replicated each cluster of five boards three times in three different habitats, stabilized dune (SD), open woods (OW), and savanna (SA). The SD and OW board clusters were in human high- and medium-use areas which were previously devoid of woody debris and had no skink use. The SA board clusters were in savanna areas having the lowest human use, but also previously lacked debris and skink use.

To quantify disturbance in relation to skink activity and visitor numbers, we affixed numbered aluminum tags to each board and mapped their locations. We checked the boards bimonthly, recorded skinks present, and noted if boards had been disturbed. If boards were displaced, we returned them to their original positions and we replaced boards that were removed.

2.7. Statistical analyses

In the microhabitat restoration experiment, we used repeated measures ANOVA to determine if the number of boards disturbed, or skink activity differed among habitats or over time. In the ANOVAs, habitat was the grouping factor and year was the repeated measure. The experimental unit was the board cluster (five boards/cluster×three clusters×three habitats).

To investigate disturbance at the microhabitat level on a short time scale (bimonthly), we compared skink presence and absence with the condition of the board (disturbed, not disturbed) during the census in a 2×2 contingency table analysis.

To determine if disturbance affected skink activity at the habitat level on an annual time scale, we used
regression analysis assuming that activity measured on
different censuses was independent. This assumption
was likely violated since skinks were not individually
marked and some may have occurred in more than one
census. However, the analysis would be revealing if
increased disturbance affects the level of skink activity.
Because skink activity is highly seasonal (Fitch, 1954;
Seburn, 1990; Hecnar, 1991), we used the activity profile
from the population censuses (NW and BW) to control
for seasonality in the board experiment. The maximum
number of skinks observed in each year’s population
censuses represented 100% activity, and for each other
census we calculated the relative proportion of skinks
that were active. We derived an index that represented
the proportion of the subpopulation which was active
with respect to the number expected to be active on a
particular census date. If disturbance affects activity, it
would change the slope of the activity density regression
line from zero. Because the indices could not be nor-
malized by transformation we used Kendall’s Tau in
lieu of standard linear regression.

To investigate the long-term trend in skink numbers
we used linear regression on the maximum skink num-
bers of each year for NW and BW. Assuming indepen-
dence of years in the regression was justified because of
low recapture rates (Seburn, 1990). Where necessary we
used appropriate data transformations prior to analysis
(Sokal and Rohlf, 1981). We report descriptive statistics
as mean ± one standard error.

3. Results

3.1. Initial surveys

In the initial survey (June 1990), we observed sig-
ificantly fewer skinks in high disturbance plots than in
low disturbance plots (Table 1). The high disturbance
plots were virtually devoid of debris and stabilized dune

vegetation was conspicuously absent. Significantly less
debris occurred in the sectors adjacent to each high dis-
turbance plot compared to distant sectors (Table 2).
Skink numbers were not significantly lower in the adja-
cent sectors, but when debris availability was taken into
account, significantly more skinks than expected occurred
in adjacent plots compared to distant plots for three of
five sites. This apparent source effect must be inter-
preted with caution because in two of three locations,
expected frequencies are < 5 (Sokal and Rohlf, 1981).
However, when all five sites were pooled an overall source effect was still indicated ($G = 24.48$, 1 df, $p < 0.001$).

3.2. Population censuses

From 1990 to 1995 we observed 1352 skinks in the
population censuses (Table 3). Although skink activity
density showed seasonality, a significantly decreasing
trend in skink numbers existed at both NW (linear
regression; $F_{1,4} = 45.4$, $p = 0.003$, $r^2 = 0.94$) and BW
sites ($F_{1,4} = 15.7$, $p = 0.017$, $r^2 = 0.80$) (Fig. 2). From
1990 to 1995, the maximum annual activity density
decreased nearly three-fold (55 to 17 skinks) at NW,
and nearly five-fold at BW (37 to 8 skinks). The
decrease in skink numbers was not correlated with
either mean annual temperature ($r = 0.67$, $p = 0.142$,

Table 2
Debris availability and skink activity in low disturbance plots divided into sectors adjacent (A) and distant (D) to high disturbance sites, 1990

<table>
<thead>
<tr>
<th>Site</th>
<th>Debris available</th>
<th>Skinks observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>S/NW</td>
<td>88</td>
<td>322</td>
</tr>
<tr>
<td>D/SH</td>
<td>72</td>
<td>361</td>
</tr>
<tr>
<td>P/BW</td>
<td>78</td>
<td>153</td>
</tr>
<tr>
<td>WP</td>
<td>56</td>
<td>210</td>
</tr>
<tr>
<td>WB</td>
<td>45</td>
<td>118</td>
</tr>
<tr>
<td>Totals</td>
<td>339</td>
<td>1164</td>
</tr>
</tbody>
</table>

<sup>a</sup>p < 0.025 <sup>**</sup>p < 0.01 <sup>***</sup>p < 0.001; all tests 1 df.
<sup>a</sup>G-test, expected ratio 1:1.
<sup>b</sup>G-test, expected proportions based on debris availability.

Table 3
Numbers of skinks observed in the population censuses at Northwest Beach and Black Willow Beach from 1990 to 1995

<table>
<thead>
<tr>
<th>Year</th>
<th>Censuses</th>
<th>$\varnothing$</th>
<th>$$$$</th>
<th>A</th>
<th>J</th>
<th>H</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>4</td>
<td>108</td>
<td>52</td>
<td>16</td>
<td>121</td>
<td>3</td>
<td>300</td>
</tr>
<tr>
<td>1991</td>
<td>7</td>
<td>60</td>
<td>21</td>
<td>87</td>
<td>48</td>
<td>30</td>
<td>266</td>
</tr>
<tr>
<td>1992</td>
<td>13</td>
<td>107</td>
<td>20</td>
<td>47</td>
<td>56</td>
<td>43</td>
<td>273</td>
</tr>
<tr>
<td>1993</td>
<td>12</td>
<td>87</td>
<td>27</td>
<td>20</td>
<td>73</td>
<td>25</td>
<td>232</td>
</tr>
<tr>
<td>1994</td>
<td>12</td>
<td>65</td>
<td>18</td>
<td>12</td>
<td>30</td>
<td>32</td>
<td>157</td>
</tr>
<tr>
<td>1995</td>
<td>12</td>
<td>51</td>
<td>9</td>
<td>6</td>
<td>47</td>
<td>11</td>
<td>124</td>
</tr>
<tr>
<td>Totals</td>
<td>60</td>
<td>478</td>
<td>147</td>
<td>188</td>
<td>375</td>
<td>164</td>
<td>1352</td>
</tr>
</tbody>
</table>

<sup>A</sup>= adult (sex not determined), <sup>J</sup>= juvenile, <sup>H</sup>= hatchling.
$n = 6$) or total precipitation ($r = 0.69, p = 0.126, n = 6$). The annual pattern of activity density was similar among years and showed two peaks, one coinciding with breeding in May and the other with nesting in July.

The age structure of the population appeared to be adult-biased in all years (Fig. 3) which suggested that recruitment may be insufficient to maintain population size. There was also a declining trend in the number of nests that we observed from 1990 to 1995 ($n = 29, 42, 29, 5, 18, 12$), but the trend was not statistically significant (linear regression; $F_{1,4} = 4.3, p = 0.106, r^2 = 0.52$). These results are consistent with the long-term pattern of population decline we observed.

This decline was also apparently associated with several large scale disturbances of skink microsites which occurred during 1990 to 1995 at the NW and BW sites. Logs or boards were rolled over or broken and ID tags removed affecting 26.3% of debris at NW in June, 30.7% of BW debris in July, and 50.8% of NW in August of 1990. Disturbances affected 76.6% of NW and 53.5% of BW microsites in 1991, and a high level of disturbance persisted in 1992 and 1993. In June 1994 and August 1995 nearly all debris on the west beach were disturbed.

After these disturbances, we observed fewer gravid females and nests and few hatchlings were observed in the autumn when they should have formed the largest part of the population. Evidence indicated that these disturbances were not because of natural predation, but because of illegal organized collecting.

3.3. Debris availability and use

Woody debris at the NW and BW sites consisted of equal proportions of logs to boards in 1990 ($150:134$, $G = 0.90, 1 df, p > 0.1$), and skinks showed no preference for logs over boards ($G = 2.20, 1 df, p > 0.05$). By 1995, more debris was available, but the distribution had shifted to proportionately more logs than boards ($276:177$, $G = 21.79, 1 df, p < 0.001$). Although some new debris had entered the study area as driftwood, and some removal had occurred, the increase in total number of logs largely reflected fragmentation of logs that were present in 1990. In 1995, skinks showed proportionately more use of boards than logs ($G = 6.00, 1 df, p < 0.025$).

In 1990, skink use of logs compared to available logs, indicated a preference for moderate decay classes ($G = 41.63, 4 df, p < 0.001$; Fig. 4A). The same pattern of preference remained in 1995 ($G = 22.93, 3 df, p < 0.001$; Fig. 4A), but the availability had shifted towards more advanced decay classes ($G = 12.321, 4 df, p < 0.001$; Fig. 4A). Skink use of boards indicated no preference based on decay class in 1990 ($G = 1.93, 2 df, p > 0.1$; Fig. 4B), but preference for intact boards occurred in 1995 ($G = 6.06, 2 df, p < 0.05$; Fig. 4B). The distribution of available boards shifted towards more advanced decay classes from 1990 to 1995 ($G = 10.28, 2 df, p < 0.01$; Fig. 4B).

The pattern of log use by skinks in 1990 also indicated a preference for larger logs (Kolmogorov-Smirnov one-sample test, $D = 0.474, n = 65, p < 0.001$; Fig. 5A). By 1995, the available log distribution had shifted to significantly smaller sized pieces, away from the preferred range (Kolmogorov-Smirnov two-sample test, $D = 0.409; n = 148, 246; p < 0.0001$; Fig. 5A).

The pattern of board use by skinks in 1990 also indicated a preference for boards of greater area (Kolmogorov-Smirnov one-sample test, $D = 0.284, n = 44, p < 0.01$; Fig. 5B). By 1995, the available board distribution had shifted towards smaller area classes, away from the range of preferred use (Kolmogorov-Smirnov two-sample test, $D = 0.289; n = 134, 177; p < 0.0001$; Fig. 5B).
3.4. Microhabitat restoration experiment

High levels of skink activity and disturbance occurred throughout the microhabitat restoration experiment (Table 4). From 1992 to 1995, we observed a total of 228 skinks and 86-7% of the experimental boards had been used (Fig. 6). Annual board use was 57.8, 48.9, 51.1, and 46.7% for each year respectively. Proportionately more subadults than adults used the boards only in 1992 ($G = 14.21, 1 \, df, \, p < 0.001$). More adults than subadults used the boards in 1993 ($G = 19.27, 1 \, df, \, p < 0.001$) and 1994 ($G = 17.24, 1 \, df, \, p < 0.001$) but not in 1995 ($G = 3.13, 1 \, df, \, p > 0.05$).

Disturbance rates for individual board clusters (five boards) on each census ranged from 0 to 100%. By the end of the season for each year, respectively, 62.2, 82.2, 66.7, and 53.3% of all experimental boards were disturbed at least once.

Repeated measures ANOVA of the number of boards disturbed (Table 5A, Fig. 7A) revealed significant differences among habitats, over time, and there was a significant year X habitat interaction. Among habitats, the highest level of disturbance occurred in SD and the lowest in SA (3 of 4 years). Among years, 1993 had the

<table>
<thead>
<tr>
<th>Site</th>
<th>Displaced</th>
<th>Removed</th>
<th>Occupied</th>
<th>Skinks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>37</td>
<td>8</td>
<td>29</td>
<td>41</td>
</tr>
<tr>
<td>SD</td>
<td>31</td>
<td>3</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>OW</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>1993</td>
<td>69</td>
<td>1</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>SA</td>
<td>20</td>
<td>2</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>1994</td>
<td>10</td>
<td>0</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>SD</td>
<td>46</td>
<td>11</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>OW</td>
<td>4</td>
<td>1</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>SA</td>
<td>16</td>
<td>0</td>
<td>21</td>
<td>27</td>
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<tr>
<td>1995</td>
<td>19</td>
<td>3</td>
<td>22</td>
<td>18</td>
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<tr>
<td>SD</td>
<td>9</td>
<td>0</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>OW</td>
<td>6</td>
<td>0</td>
<td>13</td>
<td>15</td>
</tr>
</tbody>
</table>

SD, stabilized dune; OW, open woods; SA, savanna.

* Total for 12 surveys (15 boards/site) = 180 board observations.

* Total for 11 surveys (15 boards/site) = 165 board observations.

Fig. 4. Availability of logs (A) and boards (B) by decay class and skink use of debris in 1990 and 1995.

Fig. 5. Availability of woody debris by size (1990 and 1995) and skink use (1990) for logs (A) and boards (B). Units are log_{10} cm$^3$ for log volume and cm$^2$ for board area.
highest level of disturbance and 1995 had the lowest. The significant interaction reflected different trends in disturbance among habitats over time. A unimodal pattern of disturbance occurred in SD, whereas disturbance trends decreased over time in OW, and increased in SA (Fig. 7A).

Regressions analyses of the number of skinks observed (Table 5B, Fig. 7B) indicated that no significant differences existed among habitats or years, but a significant habitat X year interaction occurred. The significant interaction reflects the different patterns of skink use over time largely between SD and SA (Fig. 7B).

Regression analyses indicated that the disturbance rate at boards significantly affected skink activity at the habitat level only at the OW site in 1992 (Table 6). Disturbance rate did not affect skink activity at OW in 1992 or 1994, or at SD or SA sites in any year. At the microhabitat level, comparison of skink presence/absence to board condition (disturbed, not disturbed; Table 7) indicated that skink presence at boards on bimonthly censuses was independent of whether or not the board was disturbed in 1992 \( (G = 3.60, 1 \text{ df}, p > 0.05) \) and 1995 \( (G = 1.58, 1 \text{ df}, p > 0.05) \). However, skink presence was less likely at disturbed boards compared to undisturbed boards in both 1993 \( (G = 4.25, 1 \text{ df}, p < 0.05) \) and 1994 \( (G = 7.33, 1 \text{ df}, p < 0.01) \) (Table 7).

4. Discussion

Activity density of five-lined skinks at Point Pelee has drastically declined from 1990 to 1995. The decline was not weather related, and because of the process of beach building, dune formation and stabilization, the amount

Table 6
Correlation (Kendall’s Tau) of skink activity with disturbance rate at experimental boards

<table>
<thead>
<tr>
<th>Site</th>
<th>Year</th>
<th>n</th>
<th>( \tau )</th>
<th>( b_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD</td>
<td>1992</td>
<td>12</td>
<td>0.084</td>
<td>0.129</td>
</tr>
<tr>
<td>SD</td>
<td>1993</td>
<td>10</td>
<td>0.050</td>
<td>-0.167</td>
</tr>
<tr>
<td>SD</td>
<td>1994</td>
<td>11</td>
<td>-0.326</td>
<td>-0.294</td>
</tr>
<tr>
<td>SD</td>
<td>1995</td>
<td>11</td>
<td>0.184</td>
<td>0.331</td>
</tr>
<tr>
<td>SD</td>
<td>Pooled</td>
<td>44</td>
<td>0.006</td>
<td>-0.008</td>
</tr>
<tr>
<td>OW</td>
<td>1992</td>
<td>12</td>
<td>-0.504</td>
<td>-0.548*</td>
</tr>
<tr>
<td>OW</td>
<td>1993</td>
<td>10</td>
<td>-0.108</td>
<td>-0.102</td>
</tr>
<tr>
<td>OW</td>
<td>1994</td>
<td>11</td>
<td>0.449</td>
<td>0.113</td>
</tr>
<tr>
<td>OW</td>
<td>1995</td>
<td>11</td>
<td>0.258</td>
<td>0.220</td>
</tr>
<tr>
<td>OW</td>
<td>Pooled</td>
<td>44</td>
<td>-0.004</td>
<td>-0.065</td>
</tr>
<tr>
<td>SA</td>
<td>1992</td>
<td>12</td>
<td>†</td>
<td>†</td>
</tr>
<tr>
<td>SA</td>
<td>1993</td>
<td>10</td>
<td>-0.388</td>
<td>-0.409</td>
</tr>
<tr>
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<td>1994</td>
<td>11</td>
<td>-0.262</td>
<td>-0.231</td>
</tr>
<tr>
<td>SA</td>
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</tr>
<tr>
<td>SA</td>
<td>Pooled</td>
<td>44</td>
<td>-0.114</td>
<td>-0.233</td>
</tr>
</tbody>
</table>

\*p < 0.05, †no disturbance occurred in 1992.

a Raw skink numbers.
b Skink numbers corrected for seasonality.

Table 7
Skink presence and board condition based on pooled bimonthly censuses

<table>
<thead>
<tr>
<th>Board condition</th>
<th>Skinks 1992</th>
<th>Skinks 1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbed</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Not disturbed</td>
<td>4</td>
<td>75</td>
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<td></td>
<td>54</td>
<td>407</td>
</tr>
<tr>
<td></td>
<td>39</td>
<td>354</td>
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</table>

<table>
<thead>
<tr>
<th>Board condition</th>
<th>Skinks 1994</th>
<th>Skinks 1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbed</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Not disturbed</td>
<td>1</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>380</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>35</td>
</tr>
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</table>
of skink habitat has not decreased in the park. However, the decline was concurrent with high levels of human disturbance.

Our initial surveys clearly established two patterns. Low skink activity and less woody debris occurred in sites with high human disturbance compared to sites with lower disturbance. The boards in the microhabitat restoration experiment were colonized quickly and heavily used by skinks in areas which previously lacked both debris and skinks. In fact, skinks used 47 to 58% of the experimental boards annually, whereas only 37% of the naturally occurring debris was used (Hecnar, 1991). These results lead us to accept the hypothesis that lack of suitable microhabitat (woody debris) is responsible for the absence of skinks in areas heavily used by humans. The locations with heavy human use are virtually devoid of woody debris, a pattern which is caused by park patrons removing debris and by park staff in beach cleaning. At Pinery Provincial Park on Lake Huron (150 km N of Point Pelee) the beaches and dune areas are virtually devoid of woody debris, and five-lined skinks are found only in savanna and open woods habitats away from the beach (S. Hecnar, personal observation). The positive results of the microhabitat restoration experiment suggests the feasibility of placing suitable woody debris to enhance skink habitat. However, it is important to note that the experiment would not have had positive results if we had not replaced boards as they were removed, i.e. active management would be required to maintain habitat quality and skink use.

Another conspicuous pattern in the highly disturbed areas is the lack of stabilized dune vegetation. Open beach in these areas typically extends from the lakeshore to the forest edge. Damage to vegetation is the result of trampling by humans (Liddle, 1975; Bratton, 1985; Sutter et al., 1993) especially in fragile dune environments. Human traffic off paths can also affect skinks directly even in less heavily used areas of the park. On five occasions we found squashed skinks under debris that had been stepped on.

Evidence suggested that simple management practices can decrease disturbance to woody debris and trampling. In 1995, public access to the SD site was partly obstructed by a snow fence and a 'closed for regeneration' sign was placed on a trail that leads through the area. Mean disturbance rate subsequently dropped from 34 to 13% (Fig. 7A).

Although we observed few skinks in the high disturbance plots, we commonly observed skinks on the wooden boardwalks that traverse these areas. Point Pelee has 3.3 km of wooden boardwalks in these human high-use areas, and skink activity was greater than expected (based on available debris) adjacent to these sites. Boardwalks may therefore be important artificial microhabitats as important corridors linking patches of natural habitats. Artificially high densities of skinks can occur in anthropogenic habitats such as woodpiles (Fitch, 1954) and skink use of boardwalks has been noted elsewhere (Lovich and Jaworski, 1988). At Point Pelee, some wooden boardwalks have been replaced by either plastic lumber boardwalks or interlocking brick sidewalks in an effort to become more environmentally friendly. However, we have not observed skinks using these new materials and research on their suitability is warranted.

In addition to the negative impact of removal of woody debris, human action appears to be accelerating the degradation of debris. Skinks show preferential use of large moderately decayed logs and intact boards of greater surface area. As woody debris ages it becomes brittle (Hecnar, 1991) and repeated disturbance breaks fragile debris into portions too small for skink use. Large moderately decayed logs are required for nest sites (Hecnar, 1994), but these debris are becoming less available and this likely accounts for the decreasing number of nests we have encountered. The board debris distribution has also shifted to smaller sizes, apparently from removal of larger pieces.

Park patrons have removed woody debris for firewood, have taken driftwood for ornamental use, or

Fig. 7. Total number of boards disturbed (A) and total number of skinks observed (B) among habitats in the microhabitat restoration experiment. Bars represent mean ± 1 SE for board clusters in each habitat (n = 3/habitat).
removed salvageable boards as lumber. Park maintenance staff continue to remove woody debris to 'clean' beach areas for human use. A similar problem of microhabitat loss and degradation affects geckos in Australia where widespread collection of larger rocks for gardens occurs (Schlesinger and Shine, 1994).

Providing suitably sized boards for habitat restoration will increase skink activity, but may not provide all the refuge requirements for a viable sustaining population because of nest site requirements. For five-lined skinks, large moderately decayed logs should also be added. Such woody debris could also benefit other species that we commonly observed using woody debris in this site, including the fox snake Elaphe vulpina, eastern garter snake Thamnophis sirtalis, northern brown snake Storeria dekayi, American toad Bufo americanus, green frog Rana clamitans, white-footed mouse Peromyscus leucopus, meadow jumping mouse Zapus hudsonius, short-tailed shrew Blarina brevicauda, and many invertebrates.

Our results indicated that human disturbance can affect skink activity on short time scales. However, when we replaced boards, skink use resumed quickly. The general pattern of population decline is likely the result of a cumulative effect of human disturbance acting on microhabitat. We conclude that five-lined skinks are relatively resilient to short-term minor disturbances, but cannot tolerate loss or degradation of woody debris. A possible exception where even minor disturbances could be detrimental would be during the nesting period. Disturbing brooding females at nests can result in females abandoning their nests (Fitch, 1954) resulting in high egg mortality (Hasagawa, 1985).

The low proportion of subadults, and the decreasing numbers of nests that we observed throughout the study suggests that the population age structure is top heavy and that recruitment failure may be the ultimate cause of decline. Because of the five-lined skinks' secretive behaviour and seasonality, age structure must be interpreted cautiously (Fitch, 1954). However, hatchlings should have formed the largest proportion of observations in the late summer and autumn. Management practices to protect nests could be as simple as posting signs (e.g. closed for regeneration) or temporarily fencing sensitive areas while females are brooding. This measure would reduce disturbance caused by the average park patron, but may not likely stop illegal collectors.

The impact of illegal collection is difficult to quantify. In 1990, we made inquiries at four local pet shops and each was willing to fill orders at $10 per skink. An employee of one shop admitted collecting reptiles including skinks, in the park, and suggested that we could save money by collecting our own. The employee then gave us directions to one of our own study sites. Increased enforcement efforts in recent years have discovered several parties of illegal collectors, but the problem persists.

Problems related to tourism and illegal collection in parks are global in extent (Primack, 1993) and growing. Nature-related recreation activities are practiced by c. 121 million people annually in Canada and the United States, and generate an estimated $4.8 billion revenue (Fillon et al., 1985; Shaw and Mangun, 1984a,b). As more habitat is lost and parks and preserves are formed, problems related to human traffic may intensify even with non-consumptive activities (Garber and Burger, 1995). Five-lined skinks at Point Pelee are subjected to a high level of human disturbance in a small heavily used park. The skink population appears somewhat resilient to minor disturbances such as displacement of debris, but not to loss or degradation of debris, or large scale illegal collecting. An important implication of this study for wildlife management or reserve design is that general habitat preservation may not be enough to conserve target species. Essential microhabitat features for individual species must also be identified and preserved. Active management at the microhabitat scale may then be required to conserve target species faced with increasing levels of human disturbance.

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