# Effect of urbanization on the population density of aak weevil

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**Urbanization can lead to the emergence of discontinuities in the preferred habitat of a plant resource, which might affect the populations of its consumers via bottom-up effects. Decline in the population density of aak weevil (*Paramecops farinosus*), a specialized herbivore on *Calotropis procera*, was related to urbanization-induced decrease in canopy cover and density of its host plant. Lower number of weevil-infested host plants in the urban matrix might be due to limited active dispersal capability of the weevil. Passive dispersal of buoyant cocoons might assist the weevil to disperse to relatively distant patches. The study suggests that decline in *C. procera* population might have serious implications for the associated fauna.**

**Keywords:** *Calotropis procera*, dispersal capability, habitat fragmentation, *Paramecops farinosus*, urbanization.

HABITAT loss and fragmentation currently threaten ecosystems worldwide. Habitat fragmentation leads to patch isolation, edge effects, biodiversity changes[1–3] and increased entropy in ecosystems[4]. Besides geological processes, habitat fragmentation is caused by human activity such as agriculture and growth of the urban matrix[5]. An immediate effect of urbanization is on the magnitude and quality of vegetation. Loss of vegetation, particularly key host plant species, may in turn affect consumer diversity and abundance. Proper interpretation of fragmentation effects requires consideration of habitat fragments and conditions in the matrix, and the use of both by the organisms targetted for investigation.

*Calotropis procera* (Ait.) R.Br. (Asclepiadaceae) is an iteroparous perennial plant inhabiting degraded ecosystems. Although the plant flowers almost all round the year, abundant flowering/fruiting occurs from March to May. A field study in 1984 revealed *C. procera* to occur in patches of relatively higher density superimposed on a low-density dispersion in urban parts of Ujjain and the adjoining rural area[6]. A preliminary follow-up survey carried out in 2003 showed only a modest change in the dispersion pattern of *C. procera* in the rural area. On the other hand, the high-density patches had nearly disappeared giving way to a relatively sparse plant population in most urban parts. Notably, there was about 20-fold increase in human population density per sq. km during 1981–2001 in urban Ujjain compared to the adjoining rural area[7].

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*C. procera* is known to attract/support about 80 animal species[8] which range from casual visitors to those dependent on the plant for completion of their life cycle. The most adapted and specialized insect occurring on *C. procera* is *Paramecops farinosus* Wied. (Coleoptera:Curculionidae), the aak weevil[9]. It is a small (8–10 mm long), cryptic, monophagous herbivore that feeds nocturnally on the leaves and flowers of *C. procera*[10,11]. The weevil is seldom observed on *Calotropis gigantea*, the other potential host plant species which is either grown as a sacred plant or sometimes occurs as a garden escape. In addition to using *C. procera* for shelter and food (Figure 1 *a*), the weevil uses its fruits as an oviposition site and applies the plant latex to seal oviposition punctures (Figure 1 *b* and *c*), presumably to protect eggs/larvae from desiccation and natural enemies. Moreover, larvae of the aak weevil are predispersal seed predators, which pupate at the end of the last instar in pupal cases made from seed silk (Figure 1 *d*). Because altered dispersion pattern and decreased abundance/loss of key host-plant species are known to cause a far-reaching impact on the associated animal life, it was of interest to study the response of the aak weevil population to urbanization-induced change in the density/cover and dispersion of *C. procera*.

The study was conducted at two experimental sites in Ujjain (23°18′N, 75°77′E). One of the two sites was located in the rural area about 20 km northwest of Ujjain Railway Station (henceforth, rural site) and was characterized by extended stretches of agriculture fields mixed with patches of degraded land. The other site was located near the University Campus and had typical urban physical structures such as buildings, roads and industrial complex (henceforth, urban site). The rural site had a high-density patch of *C. procera* superimposed on a low-density dispersion and covered 0.5 sq. km. The urban site had punctuated low-density plant dispersion and covered 3 sq. km, allowing to work with plant numbers comparable to that at the rural site. A census of all the plants ≥100 cm crown diameter was carried out to determine plant density at both the sites every year in March from 2004 to 2006. Crown cover of fifty randomly selected plants was determined at each site in the first year of study by the crown–diameter method, according to Mueller-Dombois and Ellenberg[12]. Rootstock perimeter of the selected plants was determined using a measuring tape. In addition, the number of rootstock ramets and basal-branch ramets per plant was also recorded. During daytime, the aak weevils are generally sedentary and gregarious, usually remain in the upper half of the host plant occurring either on the lower side of the sessile leaves at the base or within the inflorescence, and do not crawl or fly away readily. Hence, the number of adult insects was recorded during the daytime by direct counting at both the sites in all the plants having crown diameter ≥100 cm. The census was carried out once prior to the onset of fruiting (early March) and then after peak fruit dehiscence (late May) every year from 2004 to 2006. Dispersal

**Figure 1.** ***a***, Aak weevil feeding on leaf (left) and flower bud (right). ***b***, Female weevil ovipositing in the fruit pericarp. ***c***, Female weevil spreading plant latex on the oviposition scar (Inset) Latex seal indicated by arrow. ***d***, Last instar larva (bottom left), pupa (bottom right) inside the cocoon (above) composed of seed silk.

of the weevils was studied in 2006, first in April coincident with peak fruiting and then in June following fruit dispersal using the mark–release–recapture technique[13]. Because markers such as acrylic paint, ink, typewriter correction fluid, etc. were not retained for more than a month in preliminary experiments due to secretion of a white mealy efflorescent substance from the weevil's body[10], only a month-long study was conducted using acrylic paint. Twenty weevil-infested plants were randomly selected at each site. Weevils ($n$ = 100) were marked with acrylic paint using a colour and placement combination code unique to each plant with a fine-haired brush[14–16] and released in the place where they were captured. The male and female weevils were not treated separately because it was not possible to distinguish between the sexes correctly and quickly in the field (R. Oberprieler, pers. commun.). Surveys were carried out on day 3 and day 30 after marking to record the net displacement of weevils within each experimental site.

Population density of *C. procera* was about five-times greater at the rural site compared to the urban site (Table 1). Notably, greater population density of adult weevils at the rural site was coincident with the higher density of host plants, regardless of the month or year of study (Figure 2). The results thus seem to concur with the resource concentration hypothesis by Root[17], which states that herbivores are more likely to find and remain on hosts that are growing in dense patches and that the most specialized herbivore species frequently attain higher relative densities in such environment. However, a number of studies[15,18–22] have since shown that the hypothesis cannot explain the wider range of density–area relationships in the responses of herbivores to spatial heterogeneity of the habitat. Indeed, Bender *et al.*[18] reported that the sign of the relationship was positive in 72 and negative in 62 studies used by them for meta-analysis. Moreover, it was also observed[23] that specialist herbivores were no more abundant on high density patches of *Asclepias syriaca* (Asclepiadaceae) than they were on low-density patches. Similarly, in a related but separate study, it was found that the aak weevil density was only moderately greater in a high-density patch of *C. procera* compared with a low density patch occupying the same agricultural matrix (unpublished work of the authors). It is thus possible that some other plant attribute(s), in addition to host plant density, might be associated with the significantly lower density of the aak weevil at the urban site.

Notably, cover gives a better measure of plant biomass than does the number of individuals[12]. The amount and characteristics of the plant biomass are of paramount importance to herbivores associated with vegetation, because it is the plant biomass that provides their shelter and food. In contrast to the six-fold higher host plant density (per sq. km) at the rural site compared to the urban site, the canopy cover (sq. m/sq. km; average host plant density × canopy cover per plant) was nearly nine-fold greater at

**Table 1.** Density, cover and a few other characters of *Calotropis procera*

| Character | Rural site | | | Urban site | | |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | 2006 | 2004 | 2005 | 2006 |
| Number of plants at the study site | 139 | 141 | 144 | 141 | 162 | 154 |
| Density (per sq. km | 278 | 282 | 288 | 47 | 54 | 51 |
| Canopy cover (sq. m/sq. km) | 1465.9 | – | – | 171.36 | – | – |
| Canopy diameter (cm) | 257 ± 15 | – | – | 207 ± 17 | – | – |
| Rootstock perimeter (cm) | 52 ± 3 | – | – | 47 ± 4 | – | – |
| Number of rootstock ramets | 11.9 ± 0.87 | – | – | 10 ± 1.57 | – | – |
| Number of basal-branch ramets | 20.4 ± 1.59 | – | – | 4.9 ± 0.67 | – | – |

–, Not recorded/calculated.

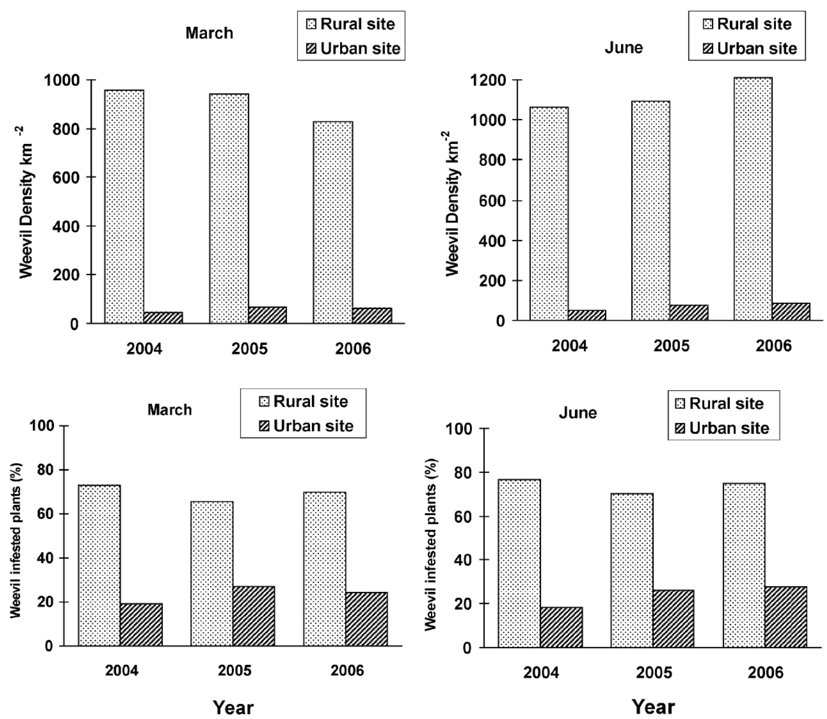


**Figure 2.** Aak weevil density and per cent weevil-infested plants.

the rural site (Table 1). Hence, significantly lower weevil density at the urban site (Figure 2) could also be attributed to the markedly lower host canopy cover. It is arguable that the difference in the host canopy cover between the two sites might be either due to a difference in the chronological age of the plants or due to some factor(s) causing reduction in the canopy cover, or both. Plants at the rural and urban sites differed little in rootstock perimeter (Table 1), which is a reasonably reliable indicator of plant age. Apparently, the difference observed between the two sites in canopy cover could hardly be attributed to the difference in the age of the plants. It is noteworthy in this context that the positive correlation observed between the rootstock perimeter and canopy cover per plant at the urban site was of somewhat lower degree ($r = 0.683$, $P < 0.01$; d$f = 98$) compared to the rural site ($r = 0.889$, $P < 0.01$; d$f = 98$). More importantly, the ratio of the number of rootstock ramets to basal-branch ramets was 0.6 : 1 at the rural site and 2 : 1 at the urban site (Table 1). Both the observations corroborated well with the practice of cutting of the aboveground plant parts as fuel by the urban poor. In other words, frequent removal of the aboveground plant parts, besides disturbing the relationship between the canopy cover and the rootstock perimeter, might have altered the ratio of the number of rootstock ramets to basal-branch ramets by adversely affecting the development and growth of basal branches at the urban site. It thus appears that the markedly lower canopy cover (plant biomass) and

**Table 2.** Net displacement of aak weevils

| Displacement (m) | Day 3 Rural site | Day 3 Urban site | Day 30 Rural site | Day 30 Urban site |
|---|---|---|---|---|
| | Recapture (%) | | | |
| <3 | 91 | 96 | 68 | 84 |
| 3–50 | 9 | 4 | 19 | 7 |
| 51–100 | 0 | 0 | 9 | 9 |
| 101–200 | 0 | 0 | 4 | 0 |

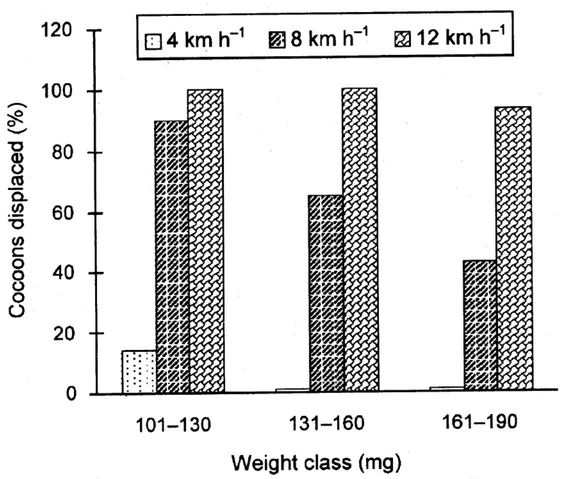


**Figure 3.** Effect of wind velocity on displacement of aak weevil cocoons in different weight classes. *F* values for the wind velocity and weight classes significant at $P < 0.01$.

density of *C. procera* might be related to remarkably lower population density of aak weevil at the urban site. Indeed, the resource is known to significantly affect the population of its consumer via bottom-up effects[24].

Yet another observation of particular interest was that in contrast to 65–75% host plant infestation at the rural site, only about 20–25% host plants were found infested at the urban site (Figure 2). In other words, the weevil appeared to lose habitat occupancy much more rapidly than its host plant. Notably, dispersal capabilities of organisms are critical in determining the landscape population structure of species as well as their likelihood of survival in fragmented landscapes[25]. The dispersal abilities of herbivorous insects vary widely from sedentary (dispersing <1 km) to moderately (5–20 km) or highly mobile (>20 km)[26]. Similar to *Paramecops stapeliae*[27], the aak weevil (*P. farinosus*) is reluctant to fly and can cover only a short distance in a single flight. Furthermore, the weevil also tended to settle on the first object encountered in the field in almost all test flights conducted irrespective of whether it was a host plant, another vegetation or a physical structure. Data relevant to the above observations are presented in Table 2. Net displacement of adult weevils was somewhat lower in March than in June, presumably due to higher mating/oviposition activity in the former month and greater mobility of newly emerged adults in the latter month. However, because there was little difference in the trend of weevil movement between the two months, displacement values are given for June only. At both the sites, about 90% of the recaptured weevils had moved <3 m on day 3. Although net displacement of weevils on day 30 was relatively greater at the rural site compared to the urban one, at neither site more than 5% weevils had moved >100 m. Indeed, weevils as a group are known to be sedentary[25,28,29], rarely dispersing >1000 m. Thus, greater proportion in the uncolonized host population in the urban site, which had sparsely dispersed host plants, might be attributed to weak active dispersal capability and lack of a precise host-plant detection mechanism in the aak weevil. Notably, lower densities of host plant species make it impossible for herbivores with a hit-and-miss host location strategy to survive in tropical regions[30], where predation rates are frequently much higher[31].

However, it should not be forgotten that the agricultural matrix – preferred habitat of the aak weevil – is also characterized by discontinuities, albeit less pronounced compared to the urban one. Apparently, the weevil must deploy additional dispersal strategies to colonize fresh plants/patches. As mentioned before, the pupae of the weevil develop inside the cocoons made from seed silk, which is known to be unusually buoyant[32]. Interestingly, the cocoons are sometimes seen dispersed at distances >1 km from the nearest host plant during summer. An experiment was therefore set-up to determine the wind velocity required to displace cocoons from the soil surface. A pedestal fan was used to obtain different wind velocities that were measured with an anemometer (Filotecnica, Milan, Italy) at the level of cocoons set for the experiment. Wind drafts were simulated by vertically moving up a wooden board with a mechanical device was placed between the cocoons and the pedestal fan. The cocoons were collected from the soil underneath the host plants, brought to the laboratory, weighed and categorized into three weight classes. In each weight class, cocoons ($n = 10$) in three replicates were placed one at a time at a fixed position on about 2-cm thick layer of field soil spread on a level platform and their displacement by wind drafts of different velocities was recorded. Wind drafts ≤4 km per h failed to displace cocoons effectively in all the weight classes, whereas wind at 8 km per h could displace 90, 65 and 43% cocoons in the lower, intermediate and upper weight classes respectively (Figure 3). Wind drafts at 12 km per h could displace all the cocoons regardless of the weight class. Notably, the cocoons generally drop down on the soil underneath the host plants during the summer season when the prevailing wind velocity is relatively high and wind drafts exceeding 10 per km h are not uncommon in the region (data courtesy: Jiwaji Government Observatory, Ujjain); not to speak of the whorl-winds that are frequent during noontime. Evidently thus, besides conferring protection from potential natural enemies such as ants or trampling by large grazing/browsing herbivores, pupation inside the cocoons composed of buoyant seed silk might allow the aak weevil to disperse passively to relatively distant patches and also to avoid sibling competition in agricultural as well as urban matrix.

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ACKNOWLEDGEMENTS. We thank Prof. H. R. Burke, Texas A&M University, USA; Dr R. Oberprieler, CSIRO Entomology, Australia and Dr V. V. Ramamurthy, IARI, New Delhi for technical assistance. Financial support from UGC, New Delhi under the SAP–DRS programme is acknowledged.

Received 10 November 2006; revised accepted 8 August 2007