# Species Diversity and Optimum Sampling Size of Auchenorrhyncha (Homoptera) in a Homogeneous Habitat*

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**Abstract**. Local species diversity of Auchenorrhyncha in Uminonakamichi Seaside Park, Fukuoka was surveyed by a sweeping method. A total of 16 species were collected. To estimate an optimum sampling size, collector's curves of accumulated number of species were illustrated. The mean optimum size was 724.7 times of sweeping. This size was significantly correlated with the number of rare species. The Lloyd's index of each species collected was usually more than 1 and their spatial distributions were concentrated. The Iwao's overlapping index between collected species was distinctly less than 1 in any combination of paired species and their spatial distributions did not overlap. To survey effectively, one should move another better site just after collecting a few species.

Key words: diversity, optimum sampling size, homogeneous habitat, transient, collector's curve, Homoptera, Auchenorrhyncha.

## Introduction

A species richness is one of the most important traits of biodiversity, because the number of species existing at a site is a quantitative measure of biodiversity and allows comparison with other sites (Harper and Hawksworth, 1996). To assess a true species richness, the determination of sampling size is very important, but a sufficient sampling size is different in taxa, study areas, etc. Therefore in this paper we discuss the optimum sampling size and factors affecting its size.

Auchenorrhyncha is a large sap-sucking taxon in Insecta and includes more than 35,000 species (Dolling, 1991). This taxon should be very available to understand a biodiversity, because diversity patterns vary widely with taxa. In addition the diversity patterns rely upon just a few '*indicator groups*', and therefore the patterns would not optimally preserve others (Colwell and Coddington, 1996).

Since most surveys have been performed in heterogeneous habitats (Ogata *et al.*, 1998), a complete species richness have never been evaluated. In contrast, a true rich-

* Contribution from Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka (Ser. 5, No. 35).

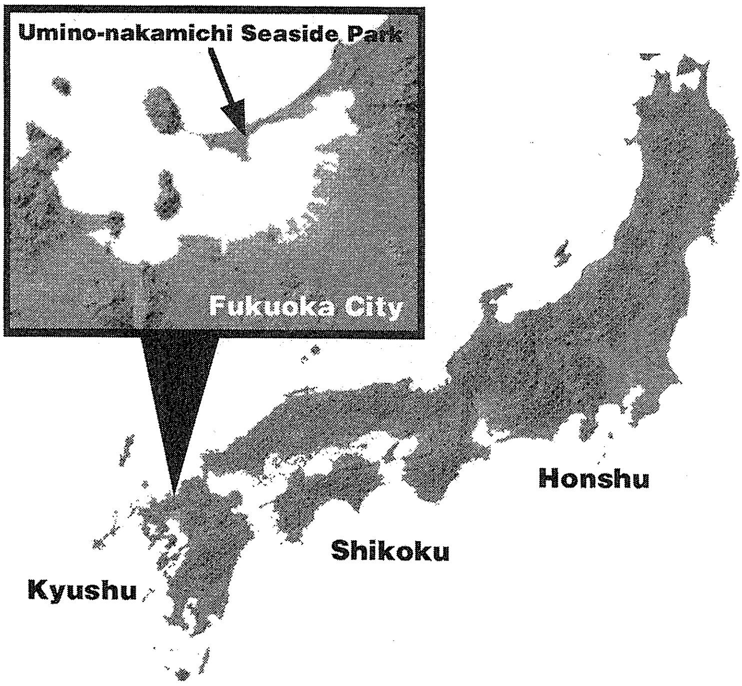


**Fig. 1.** Study site.

**Fig. 2.** Umino-nakamichi Seaside Park.

ness surveyed on a homogeneous habitat would lead more meaningful discussions (Novotny and Basset, 1998). Therefore, this study was performed in a homogeneous habitat, a lawn ground of *Cynodon dactylon* Linnaeus (Poaceae), to contribute to further discussion on the biodiversity. Furthermore, as *C. dactylon* is a very short grass, such a sampling loss as escaping of species and individuals can be minimized, and thus the lawn ground is a very suitable site for the purpose of this study.

Hosotsuji & Yoshida (1979) reported important pests infesting lawn. They listed the following 3 auchenorrhyncan species: Cicadellidae, *Nephotettix cincticeps* Uhler and *Psammotettix striatus* Linnaeus; Delphacidae, *Muirodelphax exiguus* Boheman. They explained that *N. cincticeps* is a transient from *Oryva sativa* Linnaeus (Poaceae). Thereafter, Kamitani (1992) added 15 species to the auchenorrhyncan fauna of lawn: Cicadellidae, *Batracomorphus diminutus* (Matsumura), *Cicadella viridis* (Linnaeus), *Empoascanara limbata* (Matsumura), *Hecalus prasinus* (Matsumura), *Orosius orientalis* (Matsumura), *Macrosteles striifrons* Anufriev, *Recilia* sp., *Aconurella grandis* (Matsumura), *Exitianus indicus* (Distant), *Exitianus nanus* (Distant); Delphacidae, *Tropidocephala brunneipennis* Signoret, *Delphacodes sp.*, *Nilaparvata lugens* (Stal), *Sogatella furcifera* (Horvath). *Muirodelphax exiguus* (Boheman) is a junior synonym of *Kosswigianella exigua*, and *Delphacodes* sp. listed by Kamitani (1992) is missidentification of *K. exigua.*

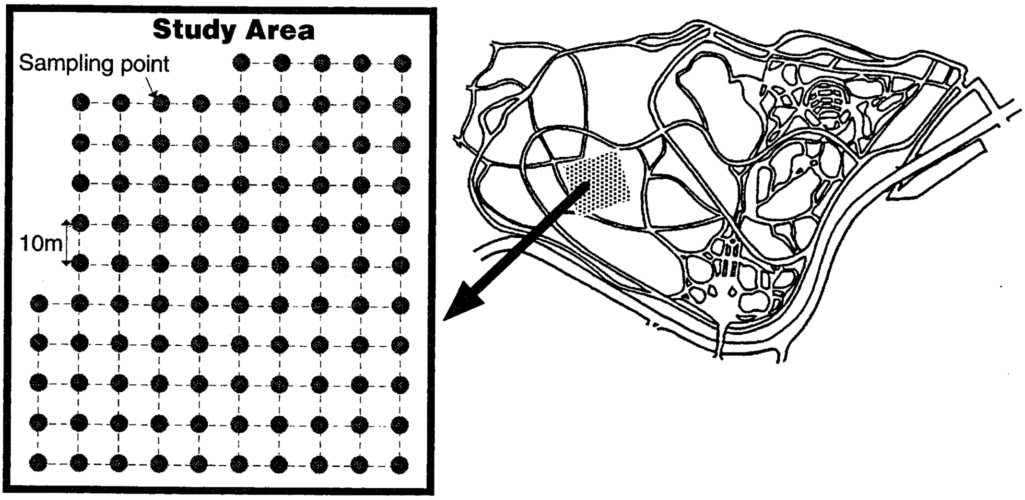


**Fig. 3.** Study area.

## Materials and Methods

*Field study*: The local species diversity of Auchenorrhyncha was surveyed at Umino-nakamichi Seaside Park (UNSP, hereafter), which is located in the northeastern part of Fukuoka City, Japan (Figs. 1-3). The park is about 53,930,000 $m^2$ in area and covered mostly by a lawn species of *Cynodon dactylon.* This survey was performed 19 times at 10-day intervals from March to September, 1990: 26 March, 6 April, 16 April, 24 April, 8 May, 16 May, 23 May, 3 June, 19 June, 30 June, 5 July, 17 July, 30 July, 4 August, 16 August, 26 August, 6 September, 16 September, and 26 September.

The auchenorrhynchan specimens were collected by sweeping the lawn area with an insect net at a constant sampling effort, 20 times of sweeping per 1 m walking distance. One sampling consists of 20 times of sweeping, which cover 0.5 $m^2$ (1 m of walking distance x 0.5 m of both sides of transect). One investigation consists of 100 samplings. These sampling points were arranged in a 10 m x 10 m grid covering 1 ha.

*Data analysis*: The shape of curves indicating the accumulated number of species varies with the order of accumulation, as well as with real heterogeneity among samplings (Colwell & Coddington, 1996). To eliminate such an arbitrariness, the accumulation order was randomized 100 times and the mean and standard deviation of the accumulated number of species ($S$) were computed for each value of the number of sweepings pooled ($N$). The curves show these mean values and their standard deviations.

The optimum sampling size was represented by the $N$ value at the time when $S$ was 90% of total species number at each investigation.

*Relationships*: To analyze the effect of factors determining the optimum sampling size, species collected were divided into 4 categories by combining the following 2 pairs of attributes: inhabitant and transient species; abundant and rare species. Inhabitants were distinguished from transients by the presence of nymphs. The threshold between abundant and rare species was defined as 0.1 individuals per 1 sampling, therefore rare species were those collected less than 10 individuals per 100 samplings.

## Results

*Field survey*: Table 1 shows a list of the species collected, the mean number of species per sampling, and the numbers of individuals, total species, inhabitants, transients, abundant species, and rare species. A total of 16 species were sampled: 3 species were found in March, 7 species in April, 9 species in May, 9 species in June, 10 species in July, 7 species in August, and 7 species in September. *Macropsis* sp., *Doratulina grandis* (Matsumura), and *Balclutha incisa* (Matsumura) were newly recorded from the lawn. On 5 July we collected 8 species, which was most abundant in this study. The mean number of species was 4.9 per investigation. Of 16 species, 10 were regarded as transient species: Cicadellidae, *Batracomorphus diminutus*, *Hecalus prasinus*, *Macrosteles striifrons*, *Exitianus indicus*, *Macropsis* sp., *Doratulina grandis*, *Balclutha incisa,* and *Nephotettix cincticeps*; Delphacidae, *Tropidocephala brunneipennis* and *Sogatella furcifera* (Table 1).

The mean number of species ranged from 0.59 to 2.94 per sampling. The highest value was also observed on 5 July as in the total species number. The correlationship between total species number and average species number was significant ($r = 0.639$, $p = 0.0032$).

The inhabitant species number was ranged from 3 to 6. The highest value was observed on 3 June. The transient species number ranged from 0 to 3. The highest value was observed early to mid June. The number of both inhabitant and transient species fluctuated similarly. The abundant species number ranged from 1 to 4, and the rare species number from 1 to 4. The highest values were observed occasionally in the year.

*Optimum sampling size*: Only 7 out of 19 collector's curves form March to September reached, before the 2,000th sweeping, to the equilibrium in the total accumulated number of species (Fig. 4). The equilibrium was observed in the data on 26 March, 6 April, 5 July, 4 August, 16 August, 26 August, and 26 September. The optimum sampling size of the 7 data ranged from 340 to 1,340 sweepings, and the mean was 725 sweepings (Table 1).

*Correlationship*: The correlation between the optimum sampling size and the various numbers mentioned in the first paragraph of results were not significant except the number of rare species (Table 2, Fig. 5).

**Table 1.** A summary of a list of species, individual number of each species, average species number per 1 sampling, total species number, inhabitant species number, transient species number, abundant species number, rare species number, and optimum sampling size.

| | | May | April | | | May | | | June | | | July | | | Aug. | | | Sep. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| species | type* | 26 | 6 | 16 | 24 | 8 | 16 | 23 | 3 | 19 | 30 | 5 | 17 | 30 | 4 | 16 | 26 | 6 | 16 | 26 |
| *Aconurella orientalis* | IN | 546 | 433 | 218 | 179 | 92 | | | 253 | 1 | | 422 | | | 223 | | | 464 | | 16 |
| *Balclutha incisa* | TR | | | | | | 1 | | | | | | | | | | | | | |
| *Batracomorphus diminutus* | TR | | | | | | | 1 | 1 | | | | | | | | | | | |
| *Doratulina grandis* | TR | | | | | | | | | | | | 1 | 1 | | | | | | |
| *Empoascanara limbata* | IN | | | | | | | 2 | 8 | 1 | | 28 | 12 | 4 | 3 | 3 | 3 | 7 | 1 | 7 |
| *Exitianus indicus* | TR | | | | 1 | | | | | | | | | | | | | | | |
| *Exitianus nanus* | IN | 133 | 203 | 86 | 111 | 33 | 302 | 143 | 302 | 330 | 292 | 560 | 1537 | 632 | 281 | 628 | 782 | 1344 | 987 | 1875 |
| *Hecalus prasinus* | TR | | | | | | | | | | | | 1 | | | | 1 | | | |
| *Macropsis sp.* | TR | | | | | | | | | | 1 | | | | | | | | | |
| *Macrosteles striifrons* | TR | | | | 1 | | 1 | | | | | | | | | | | | | |
| *Nephotettix cincticeps* | TR | | | | | 1 | | | | 1 | | 1 | | | | | 2 | 1 | 1 | |
| *Psammotettix striatus* | IN | | | 6 | 30 | 76 | | | 18 | | | | | | | | | 1 | | |
| *Recilia sp.* | IN | | | | 4 | 347 | 3 | 8 | 280 | 1 | | 1183 | | | 169 | | | 129 | | |
| *Muirodelphax exiguus* | IN | 4 | 8 | 2 | | | 2 | 6 | 23 | 1 | 3 | 30 | 18 | 3 | 10 | 10 | 8 | 28 | 20 | 10 |
| *Sogatella furcifera* | TR | | | | | | | | | | | 7 | | | | | | | | |
| *Tropidocephala brunneipennis* | TR | | | | | | | | | | | 3 | 1 | | | | | | | |
| Total sp. No. | | 3 | 3 | 4 | 6 | 5 | 5 | 5 | 7 | 6 | 3 | 8 | 6 | 4 | 5 | 3 | 5 | 7 | 4 | 4 |
| Mean sp. No. | | 1.22 | 1.46 | 1.07 | 1.24 | 1.58 | 0.59 | 0.68 | 2.44 | 0.75 | 0.73 | 2.94 | 1.00 | 0.82 | 1.79 | 0.94 | 0.98 | 2.34 | 1.15 | 1.14 |
| Inhabitant sp. No. | | 3 | 3 | 4 | 4 | 4 | 3 | 4 | 6 | 5 | 2 | 5 | 3 | 3 | 5 | 3 | 3 | 6 | 3 | 4 |
| Transient sp. No. | | | | | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | | | 2 | 1 | 1 | |
| Abundant sp. No. | | 2 | 2 | 2 | 3 | 4 | 1 | 1 | 4 | 1 | 1 | 5 | 3 | 1 | 4 | 2 | 1 | 4 | 2 | 3 |
| Rare sp. No. | | 1 | 1 | 2 | 3 | 1 | 4 | 4 | 3 | 5 | 2 | 3 | 3 | 3 | 1 | 1 | 4 | 3 | 2 | 1 |
| Optimum sampling size | | 860 | 340 | 1,240 | 1,430 | 870 | 1,540 | 1,210 | 710 | 1,750 | 1,144 | 960 | 1,560 | 1,296 | 500 | 633 | 1,340 | 1,370 | 1,550 | 440 |

*: IN, Inhabitanr species; TR, transient species.

**Table 2.** A summary of correlation between the optimum sampling size and the various numbers; total species number, Mean species number per sampling, inhabitant species number, transient species number, abundant species number, and rare species number.

| | Total sp. No. | Mean sp. No. | Inhabitant sp. No. | Transient sp. No. | Abundant sp. No. | Rare sp. No. |
|---|---|---|---|---|---|---|
| r | 0.438 | 0.058 | 0.131 | 0.733 | 0.221 | **0.877** |
| *p* | 0.3258 | 0.9025 | 0.7787 | 0.0609 | 0.6335 | **0.0096** |

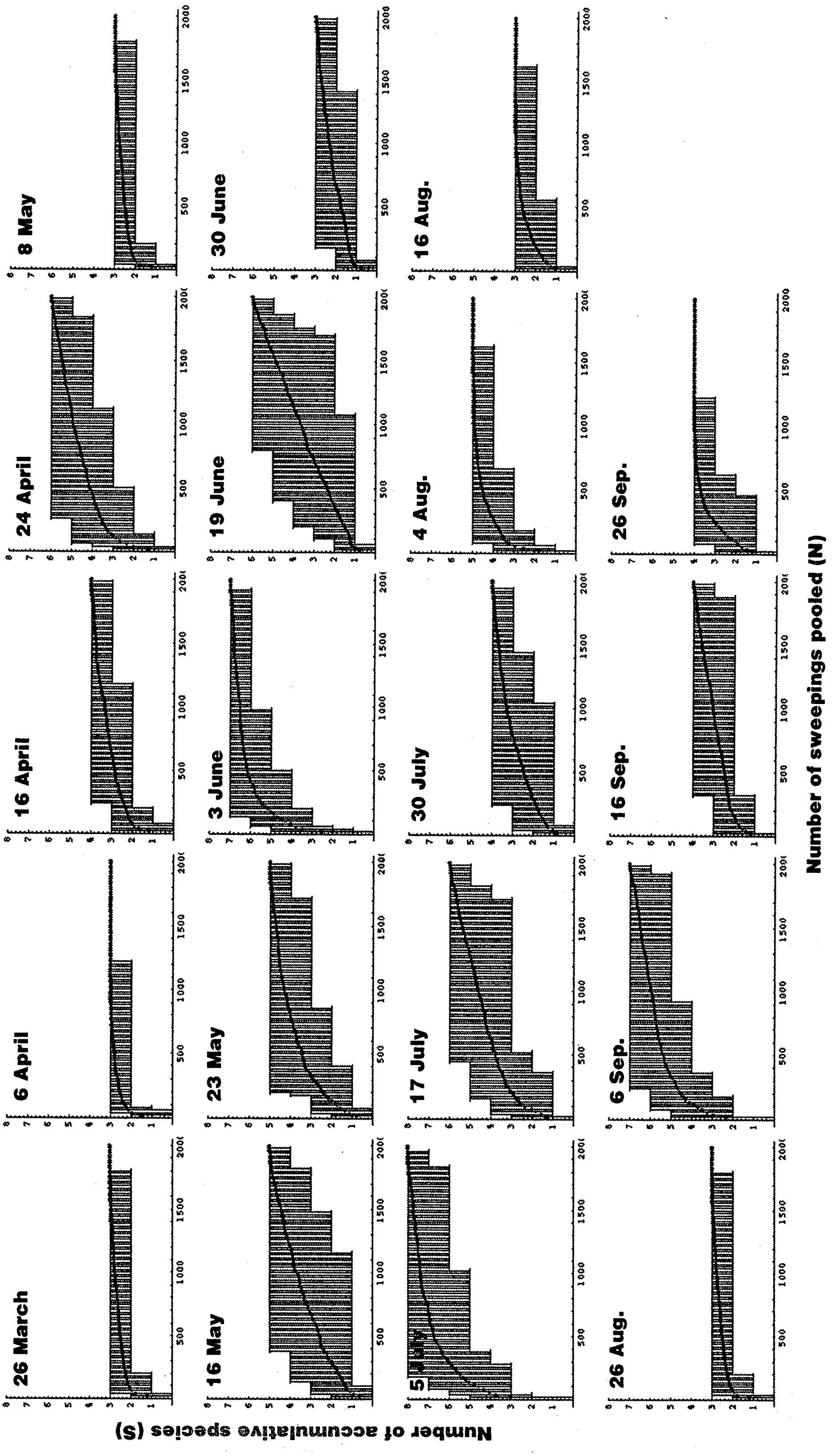


**Fig. 4.** Collector's curves from March to September. The mean values in each sweepings pooled show as points, their maximum and minimum accumulated number of species as bars.

## Discussion

The optimum sampling size in the aforementioned 7 data with the equilibrium was not significantly correlated with the total species number. This is explained by the facts that (1) the optimum sampling size was strongly correlated with the rare species number, (2) All transient species were rare species, and (3) about 60% of the rare species were the transient species.

To reduce the optimum size, it is necessary to use more effective sampling methods are required. *Nephotettix cincticeps* exhibited a strongly concentrated spatial distribution pattern in a homogeneous rice field (Kuno, 1968). Similar distribution patterns were observed, for example in the data on 5 July, for the following 3 most abundant cicadellid leafhoppers: 2.3 (Llyod's index, m*/m) in *Exitianus nanus*, 2.7 in *Recilia* sp., and 1.3 in *Aconurella orientalis*. The index of a rare species, *Tropidocephala brunneipennis*, was also more than 1 on 5 July (m*/m = 22.22).

The distributional overlapping (Iwao, 1977) between respective species was very low: the overlapping indices in the data on 5 July between *E. nanus* and *Recilia* sp., and *Tropidocephala brunneipennis* and *Sogatella furcifera* were 0.004 and 0.169, respectively.

These data indicate that in order to survey more efficiently we should move to another better site just after collecting a few species. Thus, we will be able to clarify a true species richness efficiently if we pay attention to the optimum sampling size and the ecological nature, especially about spatial distribution patterns of target insects.

Since the present study was performed in a homogeneous habitat and during a limited time of the year, detailed studies in heterogeneous habitats and during whole seasons of the year are required for further understandings of auchenorrhynchan biodiversity.

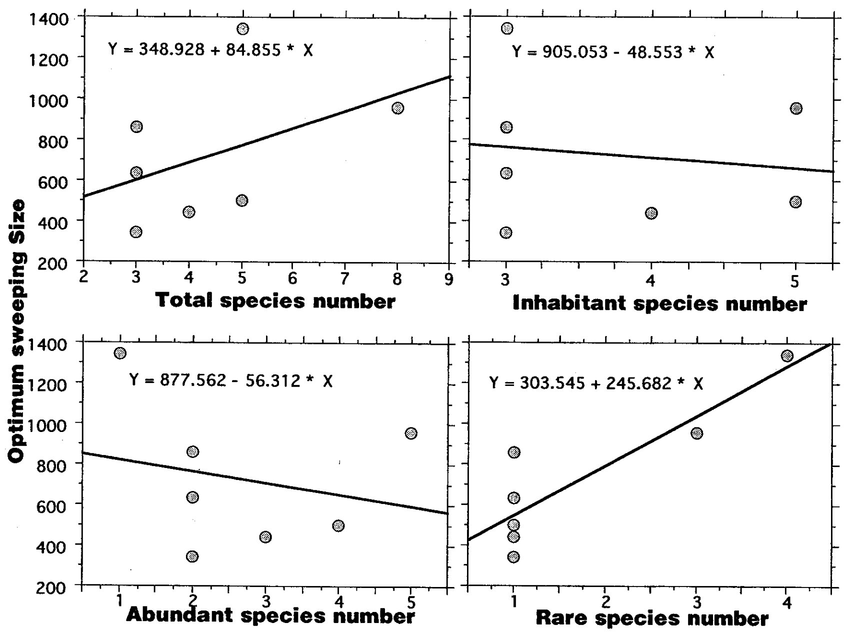


**Fig. 5.** Correlation with the optimum sweeping size and the various numbers; total species number, inhabitant species number, abundant species number, and rare species number.

## Acknowledgments

We wish to express our sincere gratitude to Prof. J. Yukawa and Assoc. Prof. O. Tadauchi (Entomological Laboratory, Kyushu University) for his directions. Our cordial thanks are due to Assoc. Prof. K. Ogata (Institute of Tropical Agriculture, Kyushu Univ.) for his valuable suggestions.


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