Estimation of True Species Richness of Leafhopper (Homoptera: Cicadellidae)

Kamitani, Satoshi

Matsunaga, Akimichi

https://doi.org/10.5109/2672

出版情報：ESAKIA. 43, pp.43-49, 2003-03-31. Entomological Laboratory, Faculty of Agriculture, Kyushu University

ESAKIA, (43): 43 - 49. March 31, 2003

Estimation of True Species Richness of Leafhopper (Homoptera: Cicadellidae)*

Satoshi KAMITANI

Entomological Laboratory, Faculty of Agriculture, Kyushu University,
Fukuoka, 812-8581 Japan

and

Akimichi MATSUNAGA

Entomological Laboratory, Graduate School of Bioresource and Bioenvironmental Sciences,
Kyushu University, Fukuoka, 812-8581 Japan

Abstract. Species richness is one of the most important indices of biodiversity, but assessing true species richness is no easy task. In this study, we tried to determine the best estimator among seven estimators: ACE, ICE, Chao1, Chao2, Jack1, Jack2, and Bootstrap methods. A total of 7,579 samplings in two census fields, Motooka and Ino, were performed during 2000 - 2002. We established eight survey sites. Sixty-one and 56 leafhopper species were collected at Motoola and Ino, respectively. Because the standard deviations of penultimate observed species richness were zero at the six sites, such observed species richness was regarded as true species richness. Although most of the estimators were not consistent with the true species richness, ICE was the most appropriate method to estimate the true species richness. Correlation between the true species richness of leafhoppers and the observed species richness of tree species or tree + grass species was highly significant.

Key words: biodiversity, ICE, ACE, floral data, trees.

Introduction

Species richness is one of the most important indices of biodiversity (Harin and Hawksworth, 1996), but assessing true species richness (*Strue*, hereafter) is no easy task because extraordinarily intensive field surveys are needed. Therefore, we must find

---

* Contribution from the Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka (Ser. 5, No. 97).

measures to estimate the *Strue* from insufficient field data.

One of the most effective methods to estimate the *Strue* is *K* value, carrying capacity, of logistic function curve that is usually applied to the estimation of population size. However, this function curve does not fit well with the practical accumulated species richness curve, because the former curve is S-shaped, while the latter is not. Therefore, some other methods have been proposed instead of *K* value. They are ACE, ICE, Chao1, Chao2, Jack1, Jack2, and Bootstrap methods. ACE (Chao & Lee, 1992; Chao, Ma, & Yang, 1993) and Chao1 (Chao, 1984) are abundance-based coverage estimators of species richness. ICE (Lee & Chao 1994), Chao2 (Chao, 1987), Jack1 (Burnham & Overton, 1978, 1979; Heltshe & Forrester, 1983), Jack2 (Smith & van Belle, 1984), and Bootstrap (Smith & van Belle, 1984) are incidence-based coverage estimators of species richness.

To evaluate relative exactitude of seven estimators to the *Strue* is very important, because the observed species richness (*Sobs*, hereafter) is usually quite different from the *Strue*. In this study, we tried to determine the best estimator among the aforementioned seven to estimate the *Strue* for leafhoppers (Homoptera: Cicadellidae).

All of leafhoppers are phytophagous and their occurrence strongly depends on the existence of their host plants. Therefore, theoretically, we could estimate the *Strue* of leafhoppers using floral data without using the aforementioned estimators. We discuss whether or not we can estimate the *Strue* of leafhoppers based on floral data.

We wish to express gratitude to Prof. J. Yukawa and Assoc. Prof. O. Tadauchi (Entomological Laboratory, Kyushu University) for reading through an early draft. Our thanks are due to Miss. A. Saito for her assistance in our surveys.

Materials and methods

Field survey:

Local species diversity of leafhoppers was surveyed at two census fields, Motooka (Fukuoka City) and Ino (Hisayama Town), Fukuoka Prefecture, Kyushu, Japan. Both census fields are largely covered with secondary forests dominated by an evergreen tree species, *Quercus glauca* Thunb. ex. Murray (Fagaceae). For field surveys, we established six survey sites (M1 - M6) at Motooka and two sites (I1 and I2) at Ino. Sites M1 - M3 were surveyed once a month from May to August and from October to November in 2000, from March to October in 2001, and from April to October in 2002. Sites M4 - M6 were surveyed once a month from March to October in 2001 and from April to October in 2002. Sites I1 and I2 were surveyed once a month from May to October in 2000, from March to October in 2001, and from April to October in 2002. At every site, we collected leafhoppers along an about 0.5 km trail by the quantitative sweeping method (Kamitani & Saito, 2001) and floral species diversity was surveyed at September 2001 along the same trail.

We must note that the 2000 field data were not enough to estimate the *Strue* due to the lack of May 2000 data. As shown in Kamitani (2002), field surveys through May to September are required to estimate the *Strue* for leafhoppers. Therefore, the 2000 data were not used for the calculation with the seven estimators, although the data was included in the calculation of the *Strue* for whole survey period from 2000 to 2002. In addition, we reduced the intensity of 2002 field survey down to 60% of 2001 field survey intensity in order to evaluate the influence of inadequate sampling data on the *eStrue*.

Data analysis:

The mean values of observed *Sobs* and its standard deviation were computed with the 50 fold randomized sample order. When the standard deviation of penultimate *Sobs* reached zero, the curves were considered to have reached equilibrium and the *Sobs* was regarded as the *Strue*. The seven species richness estimators, ACE, ICE, Chao1, Chao2, Jack1, Jack2, and Bootstrap, were calculated with a computer application, EstimateS 6.01b1 (Colwell, 1997), for M1 - M6, MA (all sites of Motooka are taken together), I1 - I2, and IA (all sites of Ino are taken together).

Indices to evaluate relative exactitude of seven estimators to the *Strue* were calculated by the following equation; index of exactitude = mean (| *Strue* - *eStrue* |). The equation in the parenthesis means the absolute value of difference between two parameters, *Strue* and *eStrue,* of which the latter shows the estimated *Strue* value of each estimator.

To estimate the *Strue* of leafhoppers with floral parameters, we calculated correlation between the *Strue* and three floral parameters, such as the numbers of tree species, grass species, and tree and grass species taken together.

Results and Discussion

A total of 5,215 samplings at Motooka and 2,364 at Ino were accumulated during 2000 - 2002 (Table 1). A total of 61 and 56 species of leafhoppers were collected at MA in 2000-2002 and at IA in 2000-2002, respectively. The similarity in the number of leafhopper species between the two census fields is referable to the similarity of habitat represented by an evergreen secondary forest. Forty-three species were common at MA both in 2001 and in 2002, and 29.5 % of *Strue* was not common between the two years. The rate of common species was low also at other sites; 44.7% at M1, 59.5% at M2, 45.9% at M3, 58.3% at M4, 51.4% at M5, 47.5% at M6, 37.5% at IA, 50.0% at I1, and 60.0% at I2. Inadequate sampling data in 2002 were considered to have caused such a low percentage of common species, as has been demonstrated in Kamitani &

Table 1. Summary of true species richness (*Strue*), number of samplings, observed species richness (*Sobs*), estimated species richness calculated by seven estimators, and index of exactitude.

Field	Site	*Strue*	Surveyed year	Sampling	*Sobs*	ACE	ICE	Chao1	Chao2	Jack1	Jack2	Bootstrap
Motooka	MA	61	2001	2907	56	56.0	56.0	56.0	56.0	56.0	50.0	57.2
			2002	1686	48	57.2	56.7	64.2	68.0	58.0	66.0	52.3
	M1	47	2001	722	38	53.0	49.8	52.3	49.1	48.0	54.0	42.4
			2002	457	35	38.9	38.9	38.6	40.1	41.0	44.0	37.9
	M2	42	2001	475	34	51.1	50.8	51.3	54.6	46.0	54.9	38.9
			2002	276	25	30.6	28.3	30.1	30.1	31.0	34.0	27.8
	M3	37	2001	464	31	33.8	37.8	36.0	36.8	39.0	42.0	34.7
			2002	400	26	28.4	28.1	29.2	29.2	30.0	32.0	27.9
	M4	36	2001	300	30	34.5	34.2	32.8	31.7	35.0	33.0	32.9
			2002	188	21	25.5	26.5	24.6	25.0	27.0	29.0	23.8
	M5	35	2001	455	33	38.6	37.3	57.5	49.3	40.0	46.0	36.1
			2002	138	19	23.9	30.7	22.6	46.0	27.9	35.8	22.6
	M6	40	2001	491	38	41.4	41.6	41.3	43.4	45.0	48.0	41.4
			2002	227	23	34.7	32.5	35.8	28.8	31.0	34.0	26.7
Ino	IA	56	2001	1135	52	56.8	57.9	59.4	61.1	62.0	67.0	56.7
			2002	832	39	49.3	55.1	59.0	55.0	51.0	59.0	44.1
	I1	50	2001	734	45	50.2	51.2	54.0	56.1	55.0	61.0	49.6
			2002	492	30	39.5	42.2	35.8	36.2	39.0	42.0	34.2
	I2	45	2001	401	35	45.0	43.1	44.0	49.3	45.0	52.0	39.3
			2002	340	28	28.9	29.8	28.3	28.5	31.0	26.0	30.4
		Index of exactitude				0.13	0.10	0.19	0.17	0.13	0.15	0.16

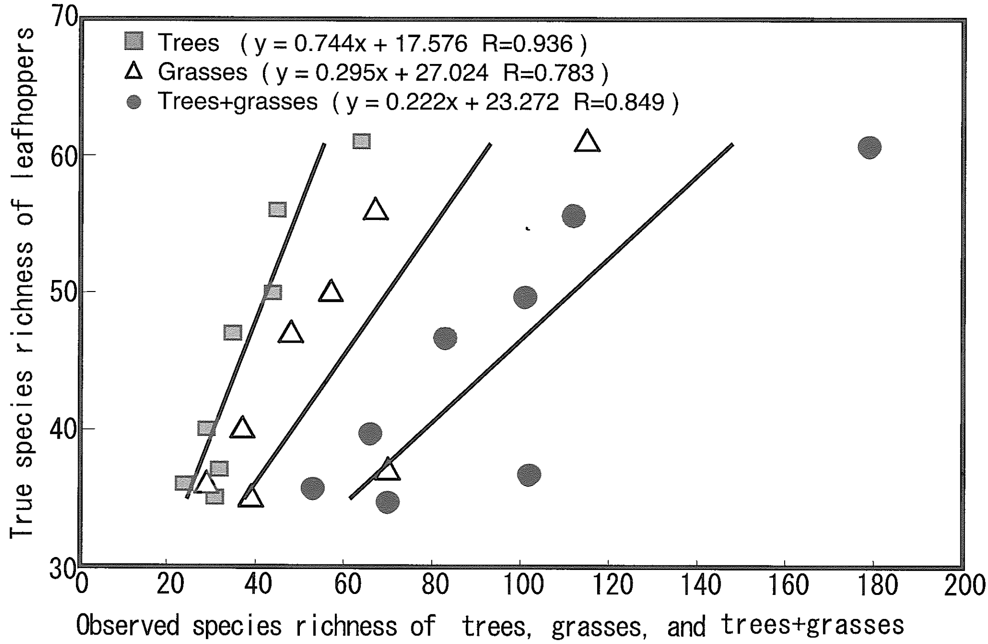

Fig.1. Correlation between true species richness of leafhoppers and observed species richness of trees, grasses, and trees+grasses.

Saito(2001).

Accumulate species richness curves reached equilibrium at six of the 10 sites; at MA in 2000-2002, at M3 in 2000 - 2002, at M4 in 2001 - 2002, at M5 in 2001 - 2002, at IA in 2000 - 2002, and at I1 in 2000 - 2002. These data indicate that the species richness of leafhoppers can be regarded as *Strue* and the *eStrue* at MA, M3, M4, M5, IA, and I1 were used for analysis. The differences in *Sobs* among different years of survey at the same site were large at all sites. The differences in *eStrue* of seven estimators were also large at almost all sites except MA and IA: *eStrue* of ACE were 56.0 at MA in 2001 and 57.2 at MA in 2002; *eStrue* of ICE were 56.0 at MA in 2001 and 56.7 at MA in 2002; *eStrue* of Jack1 were 56.0 at MA in 2001 and 58.0 at MA in 2002; *eStrue* of ICE were 57.9 at IA in 2001 55.1 at IA in 2002; *eStrue* of Chao1 were 59.4 at IA in 2001 and 59.0 at IA in2002. No *eStrue* were consistent with their *Strue*. The following 29 *eStrue* values exceeded the respective *Strue* values: *eStrue* values of ACE at M5 in 2001 and at IA in 2001; *eStrue* values of ICE at M3 in 2001, at M5 in 2001, at IA in 2001, and at I1 in 2001; *eStrue* values of Chao1 at MA in 2002, at M5 in 2001, at IA in 2001, at IA in 2002, and at I1 in 2001; *eStrue* values of Chao2 at MA in 2002, at M5 in 2001, at M5 in 2002, at IA in 2001, and at I1 in 2001; *eStrue* values of Jack1 at M3 in

2001, at M5 in 2001, at IA in 2001, and at I1 in 2001; *eStrue* values of Jack2 at MA in 2002, at M3 in 2001, at M5 in 2001, at M5 in 2002, at IA in 2001, at IA in 2002, and at I1 in 2001; *eStrue* values of Bootstrap at M5 in 2001 and at IA in 2001. The values of *Strue* were underestimated by ACE, ICE, Jack1, and Bootstrap methods at most sites, while overestimated by Jack2 at most sites.

Indices to evaluate relative exactitude of seven estimators to the *Strue* were 0.13 in ACE, 0.10 in ICE, 0.19 in Chao1, 0.17 in Chao2, 0.13 in Jack1, 0.15 in Jack2, and 0.25 in Bootstrap. Because the index of ICE was smallest, ICE was considered to be the most suitable estimator for the *Strue* of leafhoppers.

Correlations between *Strue* of leafhoppers and *Sobs* of trees and trees + grasses were significant (Fig.1; p=0.006, R=0.936 for trees; p=0.032, R=0.849 for trees + grasses) but the correlation between the *Strue* of leafhoppers and the *Sobs* of grasses was not significant (Fig.1; p=0.066, R=0.783). Therefore, we can estimate, without field surveys, the *Strue* of leafhoppers based on the *Sobs* of trees or tree + grasses. This is the first report for Cicadellidae and the conclusion supports well the plant species richness hypothesis, by which galling arthropod species richness has been explained (Docters van Leeuwen-Reijnvaan & Docters van Leeuwen, 1926; Wright & Samways, 1998; Yukawa *et al.*, 2000; 2001a; Yukawa *et al.*, 2001b).

To assess the natural environment, it is very important to determine the *Strue*. Therefore, we should evaluate the *Strue* more accurately based on the *eStrue* values calculated by ICE method and on the *Sobs* of trees or trees + grasses.

References

Burnham, K.P. & W. S. Overton, 1978. Estimation of the size of a closed population when capture probabilities vary among animals. *Biometrika*, **65**: 623-633.

Burnham, K.P. & W. S. Overton (1979) Robust estimation of population size when capture probabilities vary among animals. *Ecology*, **60**: 927-936.

Chao, A., 1984. Non-parametric estimation of the number of classes in a population. *Scand. J. Stat.*, **11**: 265-270.

Chao, A., 1987. Estimating the population size for capture-recapture data with unequal catchability. *Biometrics*, **43**: 783-791.

Chao, A. & S-m. Lee, 1992. Estimating the number of classes via sample coverage. *J Amer. Stat. Assoc.*, **87**: 210-217.

Chao, A., M-c. Ma, & M. C. K. Yang, 1993. Stopping rules and estimation for recapture debugging with unequal failure rates. *Biometrika*, **80**: 193-201.

Colwell, R. K., 1997. EstimateS: Statistical estimation of species richness and shared species from samples. Version 5. User's Guide and application published at:

http://viceroy.eeb.uconn.edu/estimates.

Docters van Leeuwen-Reijnvaan J. & W. M. Docters van Leeuwen, 1926. *The Zoocecidia of the Netherlands East Indies*. 601pp.Batavia-Drukkerij de Unie.

Harin, J. L. & D. L. Hawksworth, 1996. Preface. Pp. 5-12. In Hawksworth, D. L. (ed.) *Biodiversity: Measurement and estimation*. Chapman & Hall, London.

Heltshe, J. & N. E. Forrester, 1983. Estimating species richness using the jackknife procedure. *Biometrics*, **39**: 1-11.

Kamitani, S., 2002. Optimal number of field surveys in a year to assess the diversity of leafhopper and butterfly. *Esakia*, (42): 33-39.

Kamitani, S. & A. Saito, 2001. Which cicadellid species (Homoptera) are difficult to find in a heterogeneous habitat? *Esakia*, (41): 27-36.

Lee, S-m., & A. Chao, 1994. Estimating population size via sample coverage for closed capture-recapture models. *Biometrics*, **50**: 88-97.

Smith, E. P. & van G. Belle, 1984. Nonparametric estimation of species richness. *Biometrics*, **40**: 119-129.

Wright, M. G. & M. J. Samways, 1998. Insect species richness tracking plant species richness in a diverse flora: galling-insects in the Cape Floristic Region, South Africa. *Oecologia*, **115**: 427-433.

Yukawa, J., K. Ogata, S. Kamitani, T. Ueno, T. Partomihardjo, S. Kahono & P. O. Ngakan, 2000. A preliminary report of the field survey in 1999 on Sulawesi Island, Indonesia. *Bull. Inst. Trop. Agr., Kyushu Univ.*, **22**:51-57.

Yukawa, J., K. Ogata, O. Yata, O. Tadauchi, S. Kamitani, S. Helwint, T. Partomihardjo, S. Kahono, P. O. Ngakan & D. Yamaguchi, 2001a. An Interim Report of the 2000 Survey of Entomofauna on Lombok Island, Bali Island, the Krakatau Islands, and in Ujung Kulon, Indonesia. *Esakia,* (41): 1-10.

Yukawa, J., M. Tokuda, N. Uechi & S. Sato, 2001b. Species richness of galling arthropods in Manus, Amazon and the surroundings of the Iguassu falls. *Esakia*, (41): 11-15.