A New Formula for Calculating Species Dominance in the Case of Mosquitoes

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Abstract

Objective: To explore the calculation method of dominance degree from biomass, time scale and space scale, so as to provide a reference basis for more realistic reflection of species dominance degree. Methods: Excel was used for statistical analysis of mosquito monitoring data in Wuxi from 2012 to 2021, and t-test was used to test the variability of three calculation methods, namely Time-Space index, Berger Parker index and McNaughton index. Results: The three indices of Culex pipiens pallens and Aedes albopictus were basically consistent, and there was no significant difference between them; Time-Space index of Culex tritaeniorhynchus and Anopheles sinensis was significantly lower than Berger-Parker index (P<0.05), and was close to the significant level (P=0.0762, P=0.0621) lower than McNaughton index; The difference of coefficient of variation among the three calculated results was 4.63%, which was significantly lower than that of the other three mosquitoes (P<0.05). Conclusion: Time-Space index can significantly improve the resolution of species distribution heterogeneity, and better reflect the true state of relative dominance among species.

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Species dominance refers to the status and role of a species in a biological community, which is used to quantify the dominance of a seed set on the total abundance of a community [1]. Studying the species dominance of a community is helpful to determine the evenness of species distribution in the community and determine the dominant species. It is widely used in community ecology research and species diversity protection. Species dominance is mainly reflected in the individual number, biomass, volume, frequency and other aspects of the species. Due to the differences in living conditions, activity types and other characteristics, different species have different methods to calculate the dominance. Simpson [2], Lloyd[3], Austin [4], etc. calculate the species dominance based on the number of individuals and species in the community; McNaughton index is used to determine the dominant species of plankton according to the overall occurrence frequency and individual number of species, and it is also widely used at present [5]. From the perspective of material circulation and energy flow in the ecosystem, species dominance refers to the degree to which a species in the community has an impact on the material and energy flow of its niche relative to other species. This includes three latitudes, one is the proportion of the total amount of material and energy held by the species in the community, the other is the scale of the impact of the species on the niche on the time scale, and the third is the scale of the impact of the species on the niche on the spatial scale. Due to the spatial and temporal heterogeneity of species distribution, the species dominance can be better reflected only when these three influence latitudes are fully considered.

Mosquitoes are important medical insects. Different mosquitoes transmit different diseases, such as malaria transmitted by Anopheles mosquito, Zika virus disease transmitted by Aedes mosquito, dengue fever, Japanese encephalitis transmitted by Culex mosquito, etc. Generally, only when the vector mosquitoes are in the dominant species can the infectious diseases become widespread. Therefore, the assessment of mosquito dominance has a strong early warning effect on the assessment of the epidemic risk of potential mosquito borne infectious diseases within a certain niche. At present, when the above two mainstream calculation methods are used to evaluate the dominance of mosquitoes, the results are inconsistent with the reality [6]. This study will discuss the calculation method of dominance from the above three latitudes of biomass, time scale and space scale, and compare it with the current commonly used methods, so as to provide a reference basis for more realistic reflection of species dominance.

1.Materials and methods

1.1 data sources

The research data are mosquito monitoring data of Wuxi from 2012 to 2021. From 2012 to 2015, 5 points will be set for residential areas, parks and hospitals, 4 points for farmers and livestock sheds, 5 points for each habitat in 2016, and 4 points for each habitat from 2017 to 2021. Mosquito traps are used to conduct mosquito surveys twice from March to November per year, and the interval between surveys is more than 10 days. Classify and count the mosquitoes captured. In this study, urbanization rate was used to reflect the proportion of different mosquito habitat types in spatial scale. The urbanization rate from 2012 to 2020 is 72.5, 73.4, 74.6, 76.9, 78.1, 79.8, 80.4, 82.0, 82.8% and 82.9% respectively [7].

1.2 Dominance algorithm

$$D_i = \frac{b_i}{B} \times \frac{t_i}{T} \times \frac{s_i}{S}$$

Where:

D_i – relative dominance of species i

B – Total biomass of all species in the community

b_i – total biomass of species i

T – Total period of time

t_i – total time period of occurrence of species i

S –total space coverage

s_i – the total spatial coverage of species i

D_i is the relative dominance of species i, and the value range is (0,1]. When it is 1, it indicates that the material and energy flow in the target niche is 100% affected by a species in terms of biology. T is the total period of time. The length of the specific period is determined according to the time scale of the study. t_i represents the time frequency of species in the total period. S is the total spatial coverage. According to the total area of the niche, it is the total spatial coverage of the target area. s_i represents the total coverage of species in the area.

1.3 Statistical analysis

The proportion of individual number of each mosquito species in each year is calculated on an annual basis, which is expressed by $\frac{n_i}{N}$. The annual occurrence time ratio of each mosquito species is calculated according to the number of monitored time sections, which is expressed by $\frac{t_i}{T}$. The spatial coverage ratio is calculated based on the percentage of points where species occur, which is expressed by $\frac{s_i}{S}$. Excel is used for statistical analysis of data, and Adobe Illustrator is used for graphic layout. *T-test* was used to test the variability of different calculation methods.

Results

2.1 Population and distribution of mosquitos

From 2012 to 2021, the number of monitoring points set varies from 20 to 25, the number of time sections is 18 times a year, 27281 mosquitoes are captured, and the average mosquito density is 0.6 ind./(lamp.hour). Mosquitoes mainly include Culex pipiens pallens, Culex tritaeniorhynchus, Aedes albopictus and Anopheles sinensis. Mosquito monitoring results over the years are as follows.

Table1 Total number of individuals, number of occurrence points and number of occurrence time sections of different mosquito species in each year

Years		*Cx. pipiens pallens*	*Cx. tritaeniorhynchus*	*Aedes albopictus*	*Anopheles sinensis*	*Armigeres s*
2012	occurrences	23	20	14	15	6
	time sections	17	16	15	15	11
	mosquitoes	3402	1759	118	419	42
2013	occurrences	23	16	8	12	7
	time sections	18	17	14	14	12
	mosquitoes	4348	4211	108	1315	82
2014	occurrences	23	20	8	11	9
	time sections	18	14	11	10	12
	mosquitoes	1102	942	34	212	81
2015	occurrences	22	11	5	7	8
	time sections	17	12	8	12	11
	mosquitoes	741	242	20	44	44
2016	occurrences	23	13	11	8	6
	time sections	17	15	14	12	8
	mosquitoes	1026	504	99	74	32
2017	occurrences	20	12	9	6	6
	time sections	15	15	12	7	11
	mosquitoes	648	486	58	100	48
2018	occurrences	20	9	11	5	5
	time sections	15	10	12	8	5
	mosquitoes	953	600	63	76	47
2019	occurrences	20	10	10	5	3
	time sections	17	13	6	8	2
	mosquitoes	1075	688	42	66	7

2020	occurrences	19	5	14	6	1
	time sections	18	9	9	8	1
	mosquitoes	496	182	52	29	1
2021	occurrences	19	3	11	4	4
	time sections	18	5	13	7	5
	mosquitoes	410	53	83	22	6

2.2 Comparison of three dominance indices

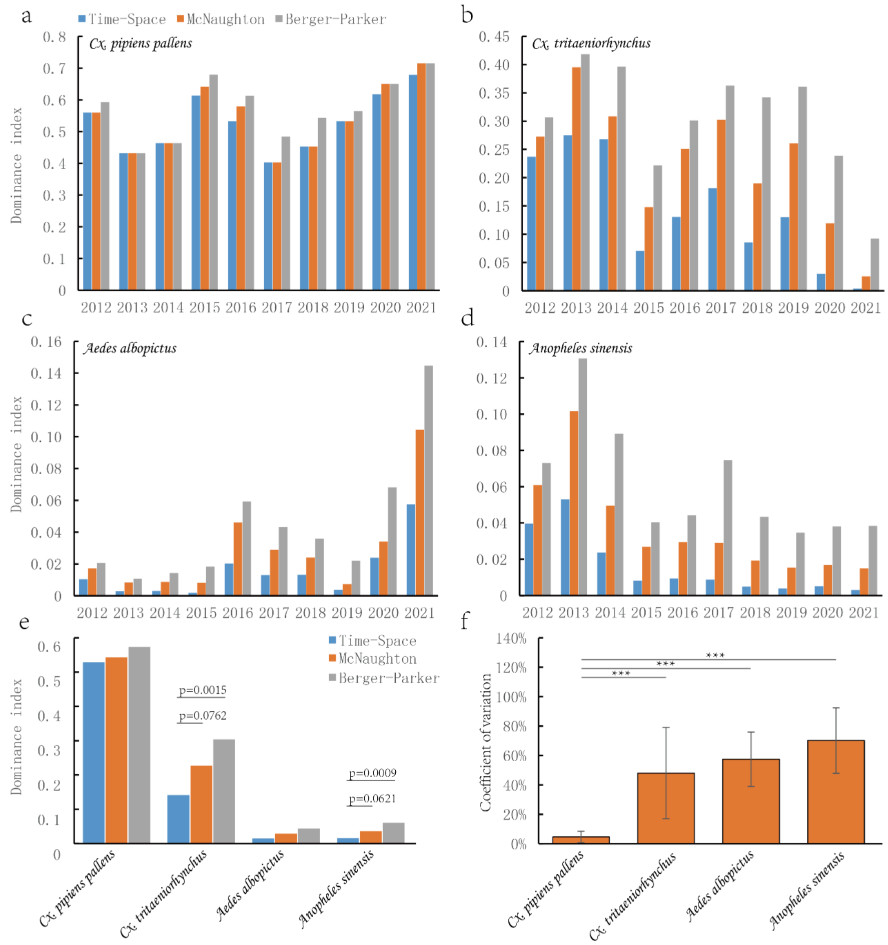

Figure 1 Comparison of three different dominance indices

Note: **a-d** represents the calculation results of three dominance indexes of four mosquitoes in each year. **e** is the difference comparison of three dominance indexes of each mosquito species.**f** represents the difference of coefficient of variation of three dominance indices among mosquito species from 2012 to 2021. * P¡0.05;** P¡0.01; *** P¡0.001.

The results of the three indexes showed that for Culex pipiens pallens and Aedes albopictus, which were widely distributed in space and time, the results of the three indexes were basically consistent, and there was no significant difference between the indexes. For Culex tritaeniorhynchus and Anopheles sinensis with high spatial and temporal distribution heterogeneity, the Time-Space index is significantly lower than Berger Parker index, which is close to the significance level and lower than McNaughton index (Figure 1e). The difference analysis of coefficient of variation showed that the three calculation results had the least impact on Culex pipiens pallens, and the coefficient of variation was 4.63%, significantly lower than the other three mosquitoes.

Discuss

There is no significant difference among the three calculation results of Culex pipiens pallens. The coefficient of variation is significantly lower than that of other mosquitoes, which may be due to the relatively uniform spatial and temporal distribution. The average spatial frequency ratio is 97.8%, and the temporal frequency ratio is 94.4% (Table 1). McNaughton index of Culex tritaeniorhynchus and Anopheles sinensis was lower than Berger Parker index, but the difference was not significant. The percentage of occurrence frequency introduced by McNaughton index failed to significantly distinguish the spatial and temporal heterogeneity of the distribution of Culex tritaeniorhynchus and Anopheles sinensis and Culex pipiens pallens respectively. This may be because McNaughton index uses the overall occurrence frequency. Although the distribution heterogeneity is considered, the resolution is not enough to distinguish. The Time-Space index is significantly lower than Berger Parker index, which may be because the resolution of distribution heterogeneity is improved after the spatio-temporal factors are separated. There are also some problems in the application of Time-Space. The balance of the survey point settings will affect the index results.

Conclusion

The Time-Space index has significantly improved the resolution of species distribution heterogeneity, and can better reflect the true state of relative dominance among species.

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Data Accessibility:

Monitoring points, mosquito species, quantity and other data:Dryad doi:10.5521/dryad.12311.

Data Availability:

The data that support the findings of this study are openly available in Dryad, Dataset, *https://doi.org/10.5061/dryad.rr4xgxdd5*

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