Research article

Spatial Analysis of Ecosystem Disservice via Disamenity of Mosquitoes – A Case Study in Nagoya City, Japan

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Abstract Nature provides many benefits to human society, known as ecosystem services (ESs), and also has negative impacts on human society, known as ecosystem disservices (EDSs). Mosquitoes contribute to EDSs, such as the risk of disease, the disamenity of mosquito bites. The purpose of this study was to understand the factors of EDSs caused by mosquitoes, employing a case study in Nagoya City, Japan. Mosquitoes were collected by CDC (Center for Disease Control) CO_2-baited traps. Also a questionnaire survey of Nagoya citizens was conducted to assess the disamenity level of mosquitoes. Many variables, such as land use type, were developed by geographical information system (GIS). Statistical analyses were conducted to identify the main factors of mosquito abundance and disamenity. Important factors were identified for both mosquito abundance and its disamenity. Further studies, including multi-point trap surveys and more detailed spatial studies, are required to elucidate these aspects.

Keywords ecosystem service, ecosystem disservice, mosquito, biodiversity, GIS

INTRODUCTION

Nature provides many benefits to human society, known as ecosystem services (ESs), which include carbon absorption, water regulation, timber supply, and water cycling, among others (Millennium Ecosystem Assessment, 2005). Nature also has negative impacts on human society, known as ecosystem disservices (EDSs), which include agricultural pests and vectors of diseases, etc. (Lyytimäki and Sipilä, 2009; Escobedo et al., 2011). The use of the concept of EDSs is relatively limited (Ango et al., 2014). Mosquitoes (MQs) are considered an EDS because they are disease vectors and also because of their disamenity effect. Numerous studies have already been conducted on MQs as a public health issue (Eshita and Kurihara, 1978; Kobayashi et al., 2002; Tsuda et al., 2006; Tsuda 2011, 2013). According to Tsuda (2011), the main purpose of MQ studies in Japan was to establish the distribution status of MQ species to assess the risk of diseases caused by them, as opposed to developing counter measures for potential diseases. Kamimura (1968) reported that *Aedes albopictus* (Skuse) was one of main MQ species appearing in residential areas in Japan. In Nagoya City, the third largest city in Japan, the most abundant MQ species were *Culex pipiens* group and *Ae. albopictus* (Sugiyama, 2007; Yokoi, et al., 2014; Nagoya City, 2015). To date, many studies, especially from a public health perspective, have been conducted on *Ae. albopictus* (Takagi et al., 1995; Tsuda et al., 2003; Tsuda and Kim, 2012). With the technological advancement in the geographical information system (GIS) and remote sensing, studies on the relationship between land use and MQ distribution is an emerging area of research

(Johnson et al., 2008; Yonejima et al., 2011; Landau and van Leeuwen, 2012). However, there are limited studies on the EDSs of MQs, e.g., the level of disamenity, because disamenity depends on the citizens' subjective assessment. The GIS studies and factor analyses of MQ's EDSs, especially *Ae. albopictus* have been limited to urban areas in Japan.

OBJECTIVE

The aim of this study was to understand the main factors of EDSs, focusing on the disamenity of MQs (especially for, *Aedes albopictus* (Skuse)), using MQ traps and a questionnaire survey of the subjective assessment by citizens in Nagoya City, Japan.

METHODOLOGY

Nagoya City (the city hall: 35.181°N, 136.906°E) is located in the central part of Japan (Fig.1 (a)). The average annual temperature in 2014 was 16.1°C, and the average precipitation was 1506 mm (Japan Meteorological Agency, 2015: http://www.data.jma.go.jp/obd/stats/etrn/index.php). The city has an area of about 326 km^2 and a population of 2.3 million as of April 1, 2014 (Nagoya City, 2015: http://www.city.nagoya.jp/shisei/category/67-5-0-0-0-0-0-0-0-0.html). The study area for the trap survey was the east part of the city, including an urban residential area, universities, and a forest park (Fig.1 (b)).

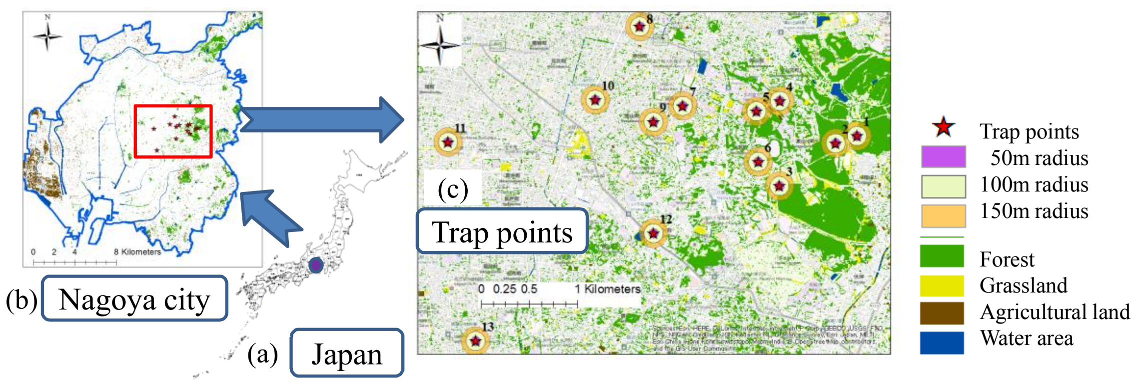

Fig. 1 Maps of the study area: (a) Japan with Nagoya City circled, (b) Nagoya City outlined in blue, with trap points indicated by star symbols, (c) trap points in east-Nagoya

Source: Land use map was developed by Nagoya City (2010)

A two-step approach was employed to assess the disamenity of MQs in the urban area. In the first step, MQs were collected by CDC (Center for Disease Control) CO_2-baited traps (Inokuchi-Tekko, Nagasaki, Japan) in Nagoya City, Japan. The traps were set at approximately 1.5 m height under tree branches or equivalent height of structures. The traps were equipped with a small, battery-driven fan, and 1 kg of dry ice wrapped with newspaper in a styrofoam cooling box, was set at approximately 10–15 cm above the fan. In total, 13 traps were set within an area of approximately 9 km^2. Traps were set in a relatively large secondary forest located on the east hill of the city, on the edges of forests, and in residential areas in flat locations for five nights from July to September of 2013 (Fig. 1 (c)). The candidate trap points were decided after conducting a pre-survey in 2012. These sites were selected to study the relationship between land use type and MQ abundance. The elevations of the sites were between around 15 m and 70 m. The traps were set between 12:15PM and 16:40PM on the first day of period1, and collected between around 9:00 AM and the afternoon on the next day (Table 3). In the other days, the traps were set between 11:00AM to 15:00PM, mostly. At that time most cakes of dry ice had already melted. After collecting the traps, the samples were stored in a refrigerator. Several data points were missing in this survey due to technical issues of sample collection (Table 3) and the average number of trapped MQs was determined for each of the points. Species identification was conducted, focusing on *Ae. albopictus* and *Cx. pipiens* group by several research assistants as well as two of the authors.

Table 1 Variable development and selected variables (#) for the trap statistical analysis

Variables	Description	
Hitosuji_T	Trapped number of *Ae. albopictus* in average in each point	(1)
Hitosuji_ln (Dependent variable)	ln(Hitosuji_T+0.5)	
Land use potential variables		
Forest50, Forest100, Forest150	% of forest within 50m, 100m and 150m radii from each trap	(2)
Grass50, Grass100, Grass150	% of grassland within 50m, 100m and 150m radii	
Agri_land50, Agri_land100#, Agri_land150	% of agricultural land within 50m, 100m and 150m radii	
Water50, Water100#, Water150	% of water area within 50m, 100m and 150m radii	
Urban50, Urban100, Urban150	% of urban area within 50m, 100m and 150m radii	
RoadW2_50#	Each way not less than two lanes within 50m from each trap	(3)
Slope potential variables		
Slope1	Slope situation1 (1: in a middle of slope, 0: other)	(3)
Slope2#	Slope situation2 (1: edge of slope with flat area, 0: other)	

Source: (1) by the trap survey, (2) developed by ArcGIS based on Nagoya City(2010), (3)author's assessment on site

Next, the identification of explanatory variables was performed using a GIS and data collected on site (Table 1). By analyzing the Green coverage GIS data (Nagoya City, 2010), the percentage of five land use types (forest, grassland, agricultural land, water area, and urban area) were calculated in 50 m, 100 m and 150 m radii. According to Tsuda (2013), the individual range of *Ae. albopictus* was within several hundred meters. Using this as a reference, the three ranges of radii were employed. The other variables are listed in Table 1. The “Hitosuji_ln” was used as the dependent variable, calculated from “Hitosuji_T”. The correlations among the potential explanatory variables were checked by Pearson correlation coefficients with avoiding multi-collinearity by checking the variance inflation factor (VIF). The high correlated variables were excluded. Finally the variables (“#” in Table 1) were selected for multiple regression analysis (MR). Each variable was selected for the proxy of land use types including road, and slope. Because several studies have included land use parameters for the analysis of the distribution status of MQ species (Johnson et al., 2008; Yonejima et al., 2011; Landau and van Leeuwen, 2012). Also the slope variable was selected as a still water parameter which could be used for nursery ground for MQ larva based on Tsuda (2013).

Lyytimäki and Sipila (2009) indicated that the same ESs can be understood to be positive or negative, depending on the person questioned. Therefore, subjective assessment of the people was conducted as a secondary step. An internet-based questionnaire survey was conducted from September to the beginning of October in 2013 for Nagoya citizens by Rakuten Research Inc. The survey requests were sent out to the monitor registrants of the company. The respondents could get small amount of rakuten points after the answer. At the first screening stage, 39,340 requests were sent out to the monitors and received 5,272 responses which could be used as a stock of the subsequent survey. Then requests were sent to each monitor from the stock. Before sending the requests, the targets of collected number of samples in each gender and age range were decided based on population data as of July 2013 (Nagoya City: http://www.city.nagoya.jp/shisei/category/67-5-5-0-0-0-0-0-0-0.html). Once a target was fulfilled, the collection of relevant samples was stopped by each gender and age range category. However after collecting the samples, we noticed sampling errors. After the examination of this issue, finally we decided to conduct additional collection of samples to complement 171 samples in the middle of October 2013 to the same monitor pool by the same company. Finally in total 1,400 samples were collected. Among them, a total of 565 samples were weightedly collected close to the trap points: the Chikusa, Showa, Meito and Tenpaku wards of the city. The samples took into consideration gender and age range balances for each ward, as much as possible, and the remaining 835 samples covered the other 12 wards, which were treated as one region from the perspective of gender and age ranges.

Table 2 Questionnaire contents and selected variables (#) for the EDS statistical analysis

Questions/ variables	Detailed
Disamenity of MQs(mosquitoes)	1.no; 2.a bit; 3. either; 4.a bit; 5.very strong disamenity. This was converted to two-scale. New "1" means old "1" to "3", and new "2" means old "4" and "5".
Individual attributes and subjective assessment by questionnaire survey	
Forest_preference#	1.do not prefer - 3.rather prefer - 5.very prefer: in 5-level
Nature_vs._development	Priority on 1.nature; 2.rather nature; 3.either; 4.rather development; 5. development
Number of MQs near home#	1.few; 2.not many; 3.normal; 4.a bit large number; 5.large number
Source of MQs near home#	1.trees, garden#; 2.gutter, drain#; 3.forest, park, cemetery; 4.river, pond, water area; 5.other
Most noxious things(two choices)	1.MQs; 2.insects; 3.birds; 4.fallen leaves and branches; 5.others: 1st & 2nd choices
Gender	1.male; 2.female
Age range	20s, 30s, 40s, 50s, 60s, 70years ≦
Under junior high school children#	Are there any children in the family? 1: Yes, 2: No
Others: Distance and visiting frequency of important forest or frequent visit forest, Appearance_of_MQs, Distance from source of MQs, Occupation, Education, Family number, Income, Zip code, etc.	
Land use potential variables developed by ArcGIS	
Pond_zip#, River_zip#, Agri_zip#, Forest_zip	% of each land use type area in each zip code area (1)
Build_zip	% of building area in each zip code area (2),
Road_zip#	% of road area (width ≧10m) in each zip code area (3)
Slope potential variables developed by ArcGIS	
Difference_DEM#	Difference between max and minimum elevation values in each zip code area (4)

Source: (1): Nagoya City (2010), (2): Nagoya City (2011), (3): digital map by MLIT, (4): DEM by GIA-J

The questionnaire contents, including zip codes to roughly identify the geographical location of each sample, were summarized in Table 2. Two types of data sets were developed. One aimed to understand the general tendency of the city average; therefore, randomly adjusted resampling (1,080 samples) was conducted to reflect a total population balance (gender and age ranges) of the city, except "women 70years ≦" samples which was compensated from "women 60s", because in 1,400 samples there were some shortages of the number of samples in some slots of age ranges and the five ward samples were collected weightedly.

The other set focused on *Ae*. *albopictus*, targeting the surveys with the answer "MQs appearing frequently during the day", for further analysis (141 samples). Because the most frequently trapped MQs in the city were *Ae*. *albopictus* which is common during the day, and *Cx*. *pipiens* group (Sugiyama, 2007; Yokoi, et al., 2014; Nagoya City, 2015). Parameters related to land use type including road, slope, and building shade were also developed using a GIS. Variables in Table 2 were used to check the Pearson and Spearman correlation coefficients to avoid multi-collinearity. As small scale MQ source information, "source of MQs near home" parameters were considered based on the questionnaire survey even if these were subjectively assessed. Also EDS might have a relation with personal way of thinking so the subjective assessment of nature (such as, "forest_preference"), and individual attributes including, age range, gender, education, income, children, etc. were examined. The selected variables ("#" in Table 2) were chosen for the binary logistic regression (BLR) analysis.

Statistical analyses were conducted using SPSS statistics ver.22 (IBM). ArcGIS10.2.2 (ESRI Japan) was used for GIS analysis.

RESULTS AND DISCUSSION

In Table 3, the basic results of the trap survey were presented. The NO4 which was located at the edge of forest near agriculture land was the highest in the number of *Ae. Albopictus*. On the other, forest (NO1, 2 and 5) and urban area near a big road (NO10, 11 and 12) were relatively low in the number of trapped MQs. Next the MR results were summarized in Table 4. As for land use variables, agriculture and urban related variables, namely, Agri_land100 and RoadW2_50, were the significant variables ($p < .10$). Agri_land50 was also significant ($p < .10$) instead of Agri_land100 in the Model 1.

Table 3 Trap points and collected number of MQs

Site	Site description	Average number of trapped MQs		
		Ae. albopictus	*Cx. pipiens* group	Other
NO1	Forest	3.6	0.2	1.2
NO2	Forest	4.8	1.2	0.2
NO3	Edge of forest*	18.8	2.5	0.0
NO4	Forest edge near agriculture land	58.4	6.4	0.4
NO5	Forest**	5.6	1.8	0.2
NO6	Edge of forest**	12.0	16.4	0.2
NO7	Edge of forest**	12.8	24.8	0.0
NO8	Urban residential area**	12.8	9.4	0.0
NO9	Urban residential area	1.2	1.6	0.2
NO10	Urban area near a big road	1.0	0.4	0.0
NO11	Urban area near a big road	1.4	2.0	0.0
NO12	Urban area near a big road***	0.3	1.8	0.0
NO13	Urban residential area****	7.6	41.4	0.0

Note1: period1: July 31to Aug. 1, period2: Aug. 7-8, period3: Aug. 20-21, period4: Sep. 11-12, period5: Sep. 25-26 in 2013. The cakes of dry ice in NO1, 2 and 3 only were stored in steal small cages requested by the government for security reason.
Note2: The time difference between the first and the last settings of the traps in each day were 4h25m, 3h15m, 2h3m, 2h14m and 1h17m, for period 1 to 5, respectively, except NO13. The traps of NO13 were set at 15:00PM except period5 at 16:00PM.
*: Data missing in period2, and as for period4 the trap NO3 was set again on Sep.13-14 instead of Sep. 11-12 by technical issues; **: in a university campus; ***: Data missing in period3 by technical issues, in a temple; ****: in a different university

According to Tsuda (2013), *Ae. albopictus* normally does not breed from paddy field. One explanation for agriculture factor was as follows. Agricultural site near the traps was limited, namely, NO4. The paddy field near NO4 was located in a university campus with a small water reservoir tank for the paddy field and many artificial small containers, such as, bowls and planters, for university research purposes, which could be used for the container habitats by *Ae. Albopictus*. Also there was small wetland close to NO4.

Forest was not recognized as a significant factor, which was similar to the results of Tsuda (2013). Water100, also same with Water150 instead of Water100 in the Model 1, and Slope2 were not significant in this study. Thus further studies are required with increasing the number of traps to study spatial structure of abundance of MQs.

There were several issues remaining. One was that the setting time of each trap was different. Most traps were set around noon to 14:00. But some were set around 15:00-16:00 even if the trap settings were conducted by three separate teams with the effort to minimize the setting time differences. In the future it is better to set all traps almost same time because *Ae. Albopictus* is mostly appearing in the day time. Also at the trap setting, the effect of wind should be considered in detailed, such as, daily monitor of wind. And the sky openness factor should also be considered and treated as one parameter of the analysis.

Regarding the questionnaire survey in Table 5, MQs were recognized as the “most noxious things” compared to other environmental pests claimed by nearly 76.9% in the 1,080 sample survey. Also the majority of citizens felt that the “disamenity of MQs” was high, concentrating on level 4 and 5. The “5.very strong disamanety” reached to 46.9%. These showed that, especially in urban areas like Nagoya, the disamenity of MQs could be identified as one of the most important targets for EDS analysis. Also the “source of MQs near home” was high in “1.trees, garden (34.6%)” and “2.gutter, drain (38.7%)”. Then the public assessment on “number of MQs near home”, which might be related to MQ abundance by the trap survey, was the highest at level 3 (41.3%).

Focusing on *Ae. albopictus*, the citizen’s subjective assessment of MQs was studied in Table 6 (N = 141). The number of MQs near home was negatively correlated with Road_zip by the Spearman's rank correlation coefficient, which was similar result with the Model 1 for the trap survey. Then road variables were identified as one of the important factors of MQ abundance for both the trap and questionnaire surveys. Also the source of MQs near home (trees, garden) was significantly correlated with the number of MQs near home. The source of MQs variable represented small scale land situation including tree and green distributions even if these were subjectively assessed by the citizens. The number of MQs might be impacted by small scale land usage.

Next, to analyze the main factors of the disamenity of MQs, the BLR was conducted for 141 samples, focusing on *Ae. albopictus*. After checking the correlation coefficients, the selected variables ("#" listed in Table 2) were used for the analysis. Finally, two types of models were developed in Table 7. As a full model, Model 2 included all potentially related variables: land use, slope, the number of MQs near home, the source of MQs, the subjective assessment of nature, and individual attributes, referring to the trap survey results and above mentioned correlation. Model 3 was developed by a variable reduction step wise method by Wald ($p \leqq .20$ (in), $p \geqq .25$ (out)) from Model 2.

Table 4 MR result for the trap survey: Model 1 (N=13)

MR Model 1 for the trap survey

Variables	Unstandardized Coefficients		Standardized Coefficients	t	*p*	VIF
	B	Std. Error				
(Constant)	1.827	.264		6.906	.000	
Agri_land100	.199	.090	.407	2.199	.059	1.273
Water100	-.842	.889	-.183	-.948	.371	1.385
RoadW2_50	-1.311	.556	-.472	-2.360	.046	1.490
Slope2	.540	.527	.194	1.024	.336	1.341

Note1: Dependent Variable: Hitosuji_ln,
Note2: R^2 = .785, adjusted R^2 = .677 (model evaluation test: p = .009)

Table 5 Basic results of questionnaire survey (%)

Questions	1	2	3	4	5
Most noxious things	76.9	7.5	13.2	0.5	1.9
Number of MQs near home	4.4	16.4	41.3	20.9	17.0
Disamenity of MQs	1.6	8.1	13.5	29.9	46.9
Source of MQs near home*	34.6	38.7	14.5	15.6	1.7

Note: each choice of 5-level(1 to 5) is presented in Table 2
*: multiple answer questions. In addition, "do not know" answer was 23.6%. (N=1,080)

Table 6 Correlations with Number of MQs near home

Spearman's rank correlation coefficient (N=141)

		RD	S_TG
Number of MQs near home	correlation	-.235	.346
	sig.	.005	.000
Road_zip(RD)	correlation		-.147
	sig.		.082

S_TG: Source of MQs near home (trees and garden)

The R^2 values for both were relatively low; however, three significant variables were identified in both models (Table 7). The citizen's subjective assessment on MQs, such as, the number of MQs near home ($p < .01$) and the source of MQs near home (trees, garden and gutter, drain) ($p < .05$) were significant variables.

However, all land use variables developed by GIS were not recognized as significant variables. One reason for that was that these GIS based land use variables were the percentage of each land use type within each zip code area so the assessment scale of the variables were relatively large compared with land use parameters impacted on MQ appearance which might be much smaller scale such as trees, garden, gutter and drain existences. In this study each questionnaire sample location was roughly identified by the coordinates of the center of gravity for each zip code. Concrete coordinate point data are required for detailed analyses reflecting the specific land use situation in the future.

Regarding individual subjective assessment on nature and its attributes, all the variables tested in this study were not identified as significant variables. As mentioned above, MQs were recognized as the most noxious pests so the most of citizen feel MQ's disammenity might be high.

Table 7 BLR models for disamenity of MQs (N=141)

Model 2 (full model) and Model 3(variable reduction step wise (Wald): $p \leqq .20$ (in), $p \geqq .25$ (out))

Model	B	Std. Error	Wald	p	Exp(B)	95% C.I.for EXP(B)		B	Std. Error	Wald	p	Exp(B)	95% C.I.for EXP(B)	
	Model 2							Model 3						
Agri_zip	5.096	8.749	.339	.560	163.370	.000	4.577E+09							
Pond_zip and River_zip	7.834	12.368	.401	.526	2.525E+03	.000	8.504E+13							
Road_zip	3.530	4.649	.577	.448	34.131	.004	3.093E+05							
DifferenceDEM	.025	.020	1.596	.206	1.025	.986	1.065	.024	.019	1.620	.203	1.025	.987	1.064
Number_of_MQs_near_home	1.008	.287	12.307	.000	2.740	1.560	4.812	.983	.284	12.015	.001	2.673	1.533	4.661
Source of MQs near home(trees, garden)	1.634	.592	7.605	.006	5.124	1.604	16.366	1.547	.573	7.276	.007	4.697	1.526	14.452
Source of MQs near home(gutter, drain)	1.157	.511	5.129	.024	3.179	1.168	8.650	1.111	.479	5.384	.020	3.038	1.188	7.768
Forest_preference	-.037	.198	.036	.850	.963	.654	1.419							
Under junior high school children	.297	.525	.320	.572	1.346	.481	3.770							
(Constant)	-3.519	1.268	7.703	.006	.030			-3.152	.949	11.033	.001	.043		

Note 1: Dependent variable: Disamenity of MQs (1, 2, 3 level →0; 4, 5 level →1)

Note 2 for model 2: -2 Log likelihood=135.44, Cox&Snell R^2 = .227, Nagelkerke R^2 = .322, model evaluation test p = .000, Hosmer & Lemeshow test p = .434

Note 3 for model 3: -2 Log likelihood=137.17, Cox&Snell R^2 = .217, Nagelkerke R^2 = .309, model evaluation test p = .000, Hosmer & Lemeshow test p = .586, VIF for DifferenceDEM(1.021), Number_of_MQs_near_home (1.166), Source of MQs near home(trees, garden) (1.151), Source of MQs near home(gutter, drain) (1.017)

CONCLUSION

The EDSs, focusing on the disamenity of mosquitoes and its abundance, was studied based on data from trap survey as well as the questionnaire survey. According to the trap survey, agricultural and road parameters were identified as significant factors. One possibility for the agricultural factor was that the paddy field near a trap was located in a university with a small water reservoir tank and many small containers which could be used for container habitats by *Ae. Albopictus*. However, the number of traps was limited, therefore an increase in the number of traps should be considered to further study on the relation between mosquito abundance and land use. As for the disamenity, subjective assessment of mosquito numbers, and source of mosquitos might be important factors. Land use parameters impacted on mosquito appearance might be much smaller scale such as trees, garden, gutter and drain existences than those developed by GIS. Concrete coordinate point analysis is required for detailed analyses reflecting small scale land use situation in a future study.

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