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Impact of Invasive Ant Species in Shaping Ant Community Structure on Small Islands in Indonesia

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ABSTRAK

Dampak Invasiv Species Semut pada Pembentukan Struktur Komunitas Semut di Kawasan Pulau-Pulau Kecil di Indonesia. Peneletian tentang pengaruh spesies invasif di kawasan pulau-pulau kecil menjadi perhatian konservasi yang sangat penting,teristimewa pengaruhnya terhadap fauna lokal dan teristimewa untuk semut-semut endemik yang menjadi kajian pada penelitian ini. Pada kajian ini penelitian dilakukan di tiga pulau yaitu Pulau Bokor, Rambut dan Untung Jawa. Semut diambil menggunakan metode pitfall trap. Metode penghitungan dengan model korelasi dan linier digunakan untuk mengukur penyebarannya secara acak di setiap pulau. Diperoleh tiga species invasif dua diantaranya yaitu *Solenopsis geminata* dan *Paratrechina longicornis* dapat dijumpai di ketiga pulau tersebut sedangkan untuk *Anoplolepis gracilipes* hanya dijumpai di Pulau Rambut. *A. gracilipes* dan *S. geminata* merupakan spesies yang melimpah dan komposisi keterdapatannya berkorelasi dengan faktor habitat ($F_{2, 52}$ = 19.469, $p<0.001$).

Kata kunci: Semut, keragaman jenis, spesies invasif

INTRODUCTION

Alien invasive ant species are major threats to local biodiversity especially indigeneous ants in certain area (Holway *et al*. 2002). As anthrophilic species, invasive ants have ability to occupy human-modified habitats, e.g. in urban habitat (Gibb & Hochli 2002), ability for nesting in human structure (Schultz & McGlynn 2000) and are easily dispersed by humans. Therefore, with its rapid adaptive mechanism and high competitive ability, invasive ants have negative impacts on the existence of local ants. For example, invasive species *Linepithema humile* (Argentine ant) has strongly affected native ant communities in fragmented coastal scrub habitats in Southern California (Suarez *et al.* 1998).

Habitat fragmentation facilitates the establishment of invasive ants (Holway *et. al.* 2002). In small island, habitat fragmentation and occurrence of invasive

ants can have a great negative impact on local species since the survival of species is very restricted by the availability of limited nature resource and space (Donlan & Wilcox 2008). Invasive species in small island are able to displace indigeneous species and shape biotic homogenization which makes populations of native species especially prone to extinction (e.g. Cole *et al*. (1992), the occurrence of *Hypoponera opaciceps* and *Solenopsis papuana* caused disappearing native ants in Hawaii Islands). As consequences, this invasion may affect to change the ecological function on whole ecosystem in the small island.

This research investigated the implication of invasive ant to local ant community in Thousand Islands Archipelago, Indonesia that has never been conducted in this area. The archipelago is located in the northern sea of Jakarta Bay and consisted of 160 unique islands with size less than 1 km2 (Alamsyah 2003). Although, this number does not include several islands that have been disappeared several years ago (UNESCO 1997). Several islands of the Sanctuary have been dramatically modified and used for living and tourism and those will bring new threats for many ant species (some of which may be endemic) through habitat modification and migration of invasive species from other places. Previous study by Rizali *et al*. (2008) indicated that human activities have aided the distribution of invasive alien ant species *Anoplolepis gracilipes* and *Solenopsis geminata* in several small islands of Thousand Islands.

MATERIALS AND METHODS

Ecological observation was conducted in three different islands of Thousand Islands Archipelago (Figure 1) i.e. (1) Untung Jawa Island (represents high populated island), (2) Rambut Island (represents as unique habitat where from 160 islands, only this island marine birds breed and live), and (3) Bokor Island (represents as unexplored island characterized by very diverse habitats and as a protected area) (Figure 1; detail see Table 1). To determined the habitat types on each island, Quick bird maps were used for mapping and quantify the islands characteristics with GIS software.

To assess the impact of invasive ants on local ant species, pitfall trapping and leaf litter sampling were carried out in 5 m x 5 m plots. The number of plots on each island differs based on habitat types (Table 1) and randomization using GIS tool (with minimum distance among plots is 75 m).

Plot observations were carried out two days on each island from March to May 2008 (Table 1). In each plot, four pitfall traps were positioned 5 m apart on a diagonal line across the sample plot. All specimens were stored in small vials with 70% alcohol and given a label in the field before being sorted and identified in the laboratory. Ants were identified using relevant taxonomic literature (e.g. Bolton 1994) and the reference collection of Seiki Yamane (Kagoshima University,

Table 1. Number of plots and description for each island in Thousand Island Archipelago

Island	No. plot	Description	Date of sampling
Bokor	16	Natural forest with dense canopy dominating with *Dysoxylum amooroides*, *Sterculia futida*, and *Allophylus cobbe*. Area 16,34 ha include sea shore	17& 18 March 2008 8 & 9 April 2008 16 & 17 May 2008
Rambut	17	Natural forest with dominance mangrove plants (*Dysoxylum amooroides*, *Guettarda speciosa*, *Allophylus cobbe*. Area 45,80 ha but only around 20 ha that possible for plotting. This island is island marine birds	14 & 15 March 2008 10 & 11 April 2008 18 & 19 May 2008
Untung Jawa	25	High populated island and tourist island. Area 39,12 ha, dominancy by settlement and with planted tree *Annona squamosa*, *Thespesia populena* and *Artocarpus communis*	12 & 13 March 2008 12 & 13 April 2008 13 & 14 May 2008

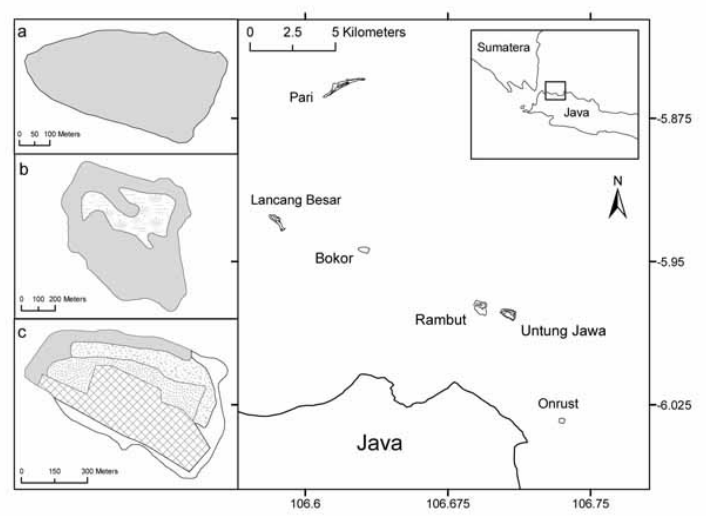

Figure 1. Map of study sites in the Thousand Islands Archipelago (Kepulauan Seribu) off Jakarta, Indonesia (inset). (a) Bokor Island (represents as unexplored island characterized by very diverse habitats and as a protected area), (b) Rambut Island (represents as protected area with swamp forest), and (c) Untung Jawa Island (represents as high populated island).

Japan) regarded as one of the most complete collections of identified Asian ants in the world.

Diversity partitioning modified from Clough *et al*. (2007) was used to determine the difference of ant communities among islands. The total observed ã-obs, for each island can be partitioned as ã-obs = á + $\hat{a}_P$ + $\hat{a}_I$ where á is the mean á-diversity per plot on each island, $\hat{a}_P$ is the between-plots â-diversity, and $\hat{a}_I$ the mean between-islands â-diversity

The correlation between invasive ant and ant diversity were assessed using Spearman rank correlation. The occurrence of invasive ant (presence-absence) was compared with number of individual and species richness of the other ants within island and between islands. Impacts of invasive ants and the habitat types (island) were tested simultaneously in general linear models (GLMs) with island as a fixed variable and plots nested within island. All analyses were done with STATISTICA 6.0 (StatSoft 2001).

Differences in ant community structure were quantified using Sørensen's index for similarity based on presence/absence of species, which was calculated with the Biodiv97 macro for Microsoft Excel (Messner, pers. comm.). The similarity matrix was then reduced to a two-dimensional ordination using non-metric multidimensional scaling (NMDS) performed with STATISTICA 6.0 (StatSoft 2001).

RESULTS

Ant diversity partitioning between islands

In total from three islands, we found 62,902 individual belongs to 32 species of ant (Table 2). The most abundance and highest ant species richness was found in Untung Jawa (27 species). However, five other ant species were not found in this island and only found in Bokor and Rambut. Based on diversity partitioning shown similar pattern that the highest mean á is also found in Untung Jawa (Figure 2). Although, Bokor has lowest mean á, the â between islands is highest compare with the others (Fig 2). This means that there still many of ant species in Bokor unexplored from this research.

Spatial distribution and abundance of invasive ant species

Three invasive ant species were recorded during this observation i.e. *Anoplolepis gracilipes, Paratrechina longicornis*, and *Solenopsis geminata*. *P. longicornis* and *S. geminata* were found in all islands, whereas *A. gracilipes* was only found in Untung Jawa (Table 2 and 3). Based on the occurrences of invasive ant per plot on each island, *P. longicornis* seems to have ability to spread on whole habitat within island (Table 3). In contrast, *S. geminata* seems does not have ability to spread especially in Bokor which is only 8 plots recorded from 16 plots in total (Table 3).

The most abundance of invasive ant was found in Untung Jawa which is domi-

Table 2 Number of individual and ant species diversity per month in each island in Thousand Island Archipelago; Tramp species are printed in bold. SKY = from the reference collection of Seiki Yamane (Kagoshima University, Japan).

Species		Bokor				Rambut				Untung Jawa			
		Mar	Apr	May	Tot	Mar	Apr	May	Tot	Mar	Apr	May	Tot
	Dolichoderinae												
1.	*Dolichoderus thoracicus*									5	2	9	16
2.	*Iridomyrmex anceps*	3			3	9	31	9	49	30584	5476	8802	44862
3.	*Tapinoma melanocephalum*	6		5	11	23	41	55	119	221	204	414	839
	Formicinae												
4.	*Anoplolepis gracilipes*									1747	2559	1451	5757
5.	*Camponotus reticulatus*		1		1			1	1				
6.	*Camponotus* sp.47 of SKY	40	30	48	118	23	35	56	114	26	41	17	84
7.	*Oecophylla smaragdina*					1	1	1	3	6	3	6	15
8.	*Paratrechina longicornis*	35	93	116	244	279	309	386	974	822	314	1101	2237
9.	*Paratrechina* sp.17 of SKY									8	8	5	21
10.	*Paratrechina* sp.24 of SKY	3	6	20	29	4	5	23	32	190	128	123	441
11.	*Polyrachis acuata*					1			1			5	5
	Myrmicinae												
12.	*Cardiocondyla nuda*					1			1	9		3	12
13.	*Crematogaster difformis*			1	1	5	9	8	22			1	1
14.	*Crematogaster* sp.10 of SKY	1	1	1	3	1	4	3	8	1		2	3
15.	*Monomorium destructor*	28	14	54	96	117	94	209	420	150	36	70	256
16.	*Monomorium floricola*	1	8		9	6	3	4	13	421	136	149	706
17.	*Monomorium monomorium*			1	1	10	3	16	29	47	30	93	170
18.	*Monomorium* sp.04 of SKY									4		1	5
19.	*Oligomyrmex* sp.10 of SKY			1	1		1	2	3	2	3	2	7
20.	*Pheidole* sp.01	117	143	194	454	191	164	254	609	93	26	49	168
21.	*Pheidole* sp.02	2		4	6								
22.	*Pheidole* sp.03		3		3								
23.	*Solenopsis geminata*	11	6	12	29	31	29	30	90	2053	897	1057	4007
24.	*Solenopsis* sp.02	12	16	7	35	8	1	6	15	17	3	7	27
25.	*Strumigenys emmae*	1		2	3		1	1	2	1		1	2
26.	*Tetramorium pacificum*	7	23	48	78	1	2	1	4				
27.	*Tetramorium smithi*					32	22	7	61	48	2	13	63
28.	*Tetramorium walshi*	1	23	28	52	160	173	199	532	1014	833	1291	3138
	Ponerinae												
29.	*Anochetus graeffei*	1	1	2	4	2		5	7		1	8	9
30.	*Hypoponera* sp.01						2		2	2		3	5
31.	*Odontomachus similimus*	33	56	60	149	220	228	283	731	11	16	19	46
32.	*Ponera*					1			1				

nated by *A. gracilipes* (Figure 3). Based on box-plot analysis, abundance of invasive ant per plot every month in Untung Jawa is always higher than other islands. While, Bokor has lowest population of invasive species especially *S. geminata* which only 29 individual collected from three months sampling in this island.

Impact the occurrence of invasive species

Within all islands, the occurrences

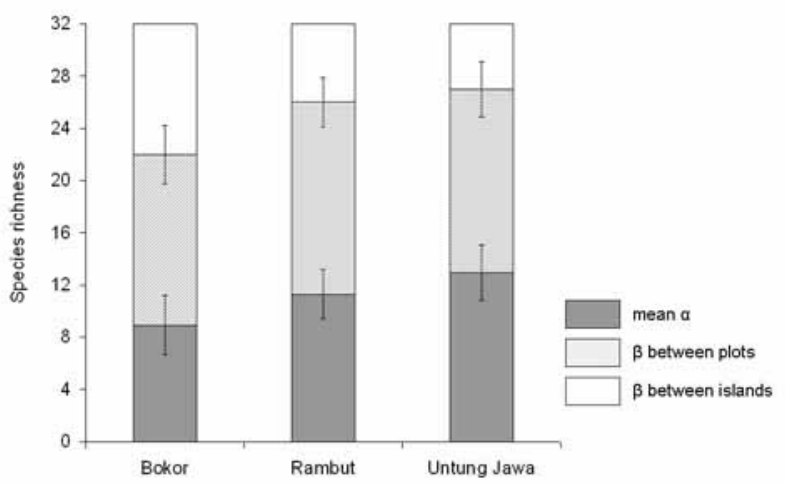

Figure 2. Alpha and beta- (between-plot and between-islands) and ãobs-diversity values for the ant species richness in the Thousand Islands Archipelago; Error bars are ± 1 SE of the means.

Table 3. Proportion of (a) plots with and without invasive ant species, (b) species richness and (c) number of individual of invasive and non-invasive ant that found in each island in Thousand Island Archipelago.

Items	Island		
	Bokor	Rambut	Untung Jawa
(a) Plot			
Total of plots	16	17	25
Plots with invasive ant	15	17	25
A. gracilipes			18
P. longicornis	14	15	25
S. geminata	8	14	22
(b) Species richness			
Total of species	22	26	27
Non-invasive	20	24	24
Invasive	2	2	3
(c) Number of individual			
Total of individual	1,330	3,843	62,902
Non-invasive	1,057	2,779	50,901
Invasive			
A. gracilipes			5,757
P. longicornis	244	974	2,237
S. geminata	29	90	4,007

of invasive ant have correlations with ant abundance and species richness on each plot within island. Based on Spearman rank correlation, the presence of *A. gracilipes* has correlation with ant abundance ($r=0.71$, $p<0.05$) and ant species richness ($r=0.46$, $p<0.05$) on each plot. The similar pattern also found in *S. geminata* that has correlation with ant abundance ($r=0.51$, $p<0.05$) and ant species richness ($r=0.38$, $p<0.05$). We also found that *A. gracilipes* and *S. geminata* can co-occur which has correlation both in abundance and ant species richness ($r=0.38$, $p<0.05$).

From the GLM analysis, the occurrences of invasive species have no significant effects to ant communities ($p>0.05$). Island (habitat types) is the main factor that affects ant species composition ($F2, 52 = 19.469$, $p<0.001$). However, based on NMDS analysis, the similarities of ant species composition between plots per month on each island are differed and unstable (Fig 4). There are other factors that affect ant species composition on the islands.

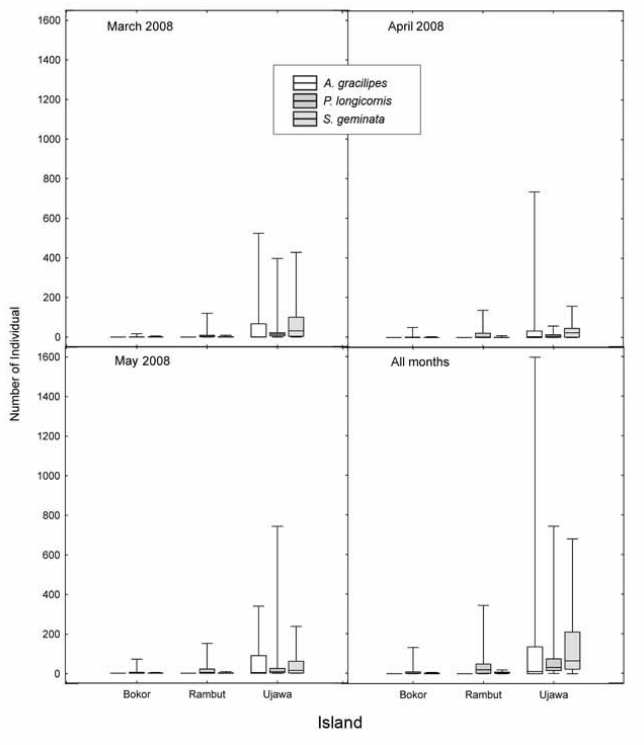

Figure 3. Box-plot of three invasive species on each island per month and all months sampling in the Thousand Islands Archipelago

DISCUSSION

Untung Jawa as high populated island consists of high population of invasive species. The highest abundance of invasive species in this island depicted that habitats in Untung Jawa are suitable for invasive species which can co-exist with human. The human structure and their activities can support the nesting sites and food for invasive species (McKinney & Lockwood 2001; Olden *et. al*. 2004). Although invaded by invasive species, Bokor and Rambut both as protected area and with low intensity of human disturbance have very low abundance of invasive species. Habitat conditions on these islands may have contribution to protect from increasing population by invasive species.

For example, *S. geminata* as hot climate specialist, this species can well adapt in habitat such as settlement area, forest edge, and agriculture area (Ness & Bronstein 2004), whereas Bokor and Rambut have only few area suitable for this species due to covered by forest (Figure 1, Table 1). Therefore, this species is able to act efficiently in open area (Perfecto & Vandermeer 1996), such as Untung Jawa, *S. geminata* has correlation with both abundance and species richness of other ants. It means that the occurrence of this species may affect the other ant species.

Another finding, *A. gracilipes* was only found in Untung Jawa. The existence of settlements and human activities in this island may role as an important factor for *A. gracilipes* to well adapt and has high abundance. In previous research, this species was also only recorded in the islands that have settlement and human activities inside (Rizali *et al*. 2008). Even if the island have a lot of Homopteran insects, this species could well adapt and will have high densities due to associations with them (Hill *et al*. 2003). Agroforestry habitat such as cacao plantation was also possible as suitable habitat for *A. gracilipes* due to habitat disturbance and suitable of microclimate (Bos *et al*. 2008). In Untung Jawa, the occurrence of this species has correlation with other ant species. The high abundance of this species in Untung Jawa may have negative impact to local ant communities due to very competitive and has occupation mechanism.

The different pattern was found for *P. longicornis.* Although this species is less abundance than other invasive species, they could widely spread in different habitat within island as well as different island. Based on McGlynn (1999) and Brown (2000), *P. longicornis* have ability to spread and well adapt in various habitat condition. In Thousand Island Archipelago, the occurrence of this species seems have no effect to local ant communities.

However, the occurrence of invasive ant in certain habitat may have direct and indirect effect to local ant communities. Invasive ant that have ability in occupying and dominating in new habitat, as consequence cause disappearing of local ant communities and even become extinct due to can not compete with invasive species (Holway *et al*. 2002). Habitat disturbance and habitat fragmentation also have important role in support-

ing the existence of invasive ant (Suarez *et. al*. 1998). In conclusion, the combination of both invasive species and habitat fragmentation will significantly effect on decreasing local ant species.

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