BIODIVERSITAS
Volume 21, Number 12, December 2020
Pages: 5632-5639

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d211208

Species diversity, abundance and damaged caused by rats in oil palm plantation in West and Central Sulawesi, Indonesia

MUHAMMAD IKHSAN[1,♥], SWASTIKO PRIYAMBODO[1], ALI NURMANSYAH[1], HENNY HENDARJANTI[2], BANDUNG SAHARI[2,3]

[1]Department of Plant Protection, Faculty of Agriculture, Institut Pertanian Bogor. Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia. Tel./fax. +62-51-8629364, ♥email: muhammad_ikhsan082@apps.ipb.ac.id

[2]PT. Astra Agro Lestari. Kawasan Industri Pulo Gadung, Blok OR 1-2, Jatinegara, Jakarta Timur 13920, Jakarta, Indonesia

[3]Center for Transdisciplinary and Sustainability Science, Institut Pertanian Bogor. Jl. Raya Dramaga, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia

Manuscript received: 11 August 2020. Revision accepted: 8 November 2020.

Abstract. *Ikhsan M, Priyambodo S, Nurmansyah A, Hendarjanti H, Sahari B. 2020. Species diversity, abundance and damaged caused by rats in oil palm plantation in West and Central Sulawesi, Indonesia. Biodiversitas 21: 5632-5639.* Oil palm is one of the plantation commodities which has an important role in Indonesia's economy. Indonesia is the largest producer and exporter of oil palm in the world with its export value capable of supplying 55.78% of global consumption. Rats are wild animals that are important pests for human life, both in agriculture plantations and urban areas. Rats can damage crops at various stages of plant growth. This study was aimed to determine the species abundance of rats in oil palm plantations, calculate the severity of crop damage due to rats infestation. Three blocks of mature plants were used in OC and OH plantation blocks were used to calculated, crop damage caused by rats, Identify the species of rats, and estimated rats abundance. The results of these studies showed there were four species of rats found in the oil palm plantation, namely *Rattus tiomanicus*, *R. tanezumi*, *Rattus* sp, and *Maxomys hellwaldii*. However, only *R. tiomanicus* and *R. tanezumi* were dominant species. There were significant differences in the number of, sex, and body weight between *R. tiomanicus* and *R. tanezumi*. The OC 12 block had the lowest infestation intensity than the other blocks since it was well maintained. The OH 02 block had the highest infestation intensity, infestation area, and abundance due to a lack of maintenance.

Keywords: Estimation population, rat species, species diversity

INTRODUCTION

Oil palm tree is one of the commodities of plantation products that has an important role in economic activities in Indonesia. Indonesia represents the largest producer and palm oil in the world with production from 2014-2019 averaging 36.5 million tons and its export value which is able to supply 55.78% of global consumption (Oil World 2019). Palm oil production is highly dependent on the production of fresh fruit bunches (FFB).

Rats are wild animals that are important for human life, especially in agriculture, plantations, and settlements. However, they can damage various types and stages of plant growth. They breed very fast, so monitoring needs to be done before their population rises. Ground cover in oil palm plantations is an important element in habitat selection by small mammals to provide shelter, foraging opportunities, and hiding from predators (Puan et al. 2011). A rat can eat about 6 to 14 g of fruit flesh per day and bring loose fruit into its nest as much as 30 to 40 times of consumption (Ditjenbun 2012). According to Adidharma (2009), if rats sliver and eat the growing spots on immature plants, the loss can reach 80% because it has to do embroidery due to dead plants. Also, fruit bunches that are injured due to rat sliver can spur an increase in free fatty acids in palm oil (Lukito and Sudrajat 2017). One of the limiting factors of production is the rat attack, which can reduce production by 5-10% of the total production (Wood and Chung 2003).

Rats are also involved in damaging the soil ecosystem. Digging in rats threatens soil conservation. Drains made by rats change the irrigation system, causing water loss. Furthermore, wood and bamboo debarking (Separation of bark from trees) causes great damage to nurseries and forest trees (Govinda 2018). The dominant species found in oil palm plantations are *Rattus tiomanicus* (Verwilghen 2015).

This study aims to determine the rat species that exist in oil palm plantations, obtain extensive data and intensity of crop damage due to rat attacks, and estimation of the rat population.

MATERIALS AND METHODS

Study area

The study was conducted in July 2019-January 2020. The research site was carried out in the oil palm plantations of Martasari Village (Pasangkayu Subdistrict, Mamuju Utara District, West Sulawesi Province, Indonesia), and Towiora Village (Rio Pakava Subdistrict, Donggala District, Central Sulawesi Province, Indonesia) (Figure 1).

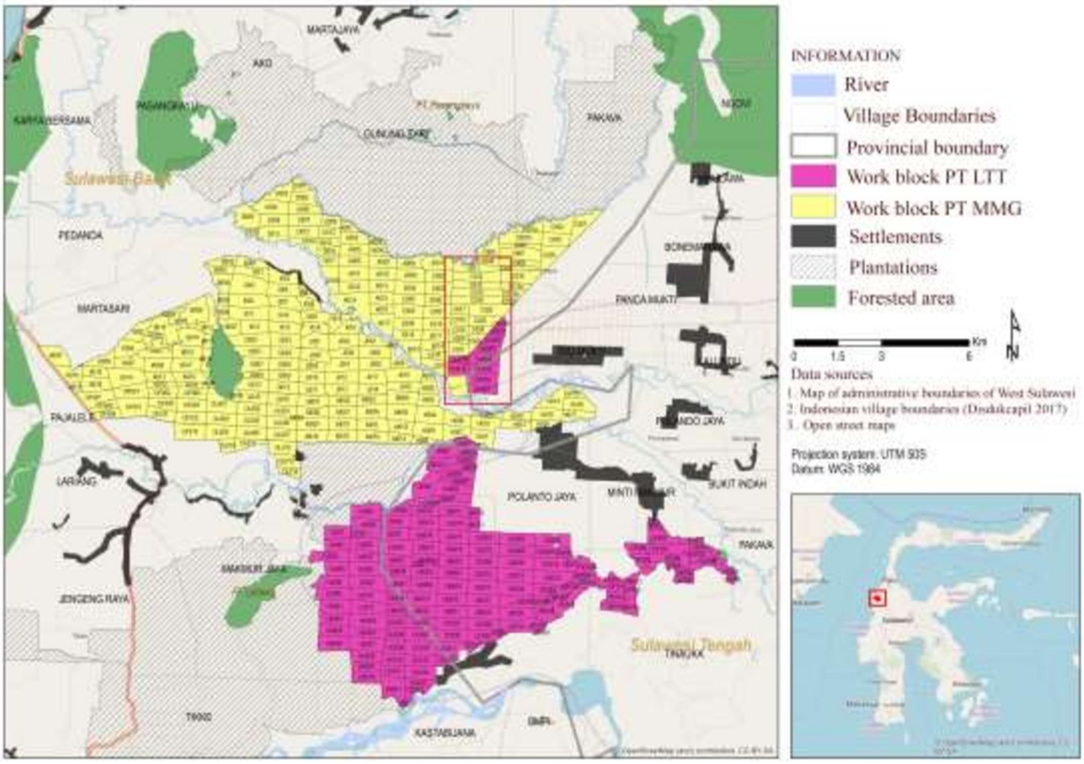


Figure 1. Research sites located in the provinces of West Sulawesi and Central Sulawesi, Indonesia

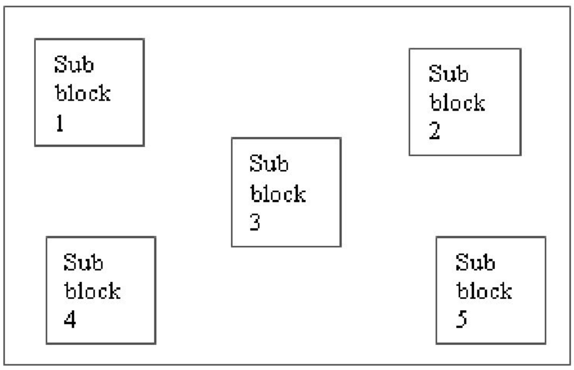


Figure 2. Determination of the observation block

Procedures

Determination of observation location

The plantation has a flat topography, tall trees, partially covered plant conservation there is also the part that is not covered. This oil palm cultivation technique is carried out with a triangular cropping pattern. The type of palm used is the tenera type. Block OC and OH are categories of mature plants (TM) with an average planting age of 17 and 18 years with a plant height of 4-5 m.

Location observations were made on different blocks. Observations were made on OC block in Martasari Village and OH block in Towiora Village which has the highest rat attack rate each year. Each block uses 3 blocks. Information on rat attack rates was interviews with estate workers. The size of each block ± 30 ha. In each block, 5 sub-blocks of observation were determined with the size of each plot of 1 ha. The average distance between sub-blocks and other sub-blocks is 360 m (Figure 2). The determination of the observation block was carried out by purposive sampling by looking at the symptoms of rat attacks in the field.

Identification and estimation of rat population

Each sub-block was set of traps; in total there were 20 traps per ha which were stored in each row of plants as many as four traps (Figure 3). Traps were placed inside a palm circle which is 2 m in diameter. Trapping was carried out for 3 consecutive days, the bait used for trapping was roasted coconut. If it trapped the rat on day 1, the trap would be replaced with a new one and the old trap was washed with detergent to remove the trap shyness. Then the same type of bait as the previous one would be used. The next traps on a different block were set one week later. Rats that are caught will be identified based on the species.

The trapped rats were then identified quantitatively and qualitatively using Identification keys, namely the Rodent book in Java by Suyanto (2006) and the Integrated Rat Pest Control Book by Priyambodo (2003). Estimated rat population used the trapping method without removal (removal method) using the Zippin Formula (1958). Estimation of the rat population was based on catches on the first, second and third day, where the rats that were caught would be counted and not be released again. The calculation of the intensity of damage and estimation is only done once during the study period in each sub-block that has been determined, then trapping is carried out in a different block in the next week.

Calculates the total catch

$$T = \sum_{i=1}^{3} Yi$$

Where: Yi = Catch per day

Calculate the ratio of the total catch

$$R = \sum_{i=1}^{3} (i\text{-}1)\ Yi/T = \frac{1}{T}\ Y_2 + 2Y_3)$$

Determine P, estimate the probability of capture to find using figure 4a, determine (1-qk) using figure 4b (Zippin 1958)

Calculating Ň (population estimate)

$$\acute{N} = \frac{T}{(1-q^k)}$$

Determine the (variant) of the estimate

$$V(\acute{N}) = \frac{\acute{N}\,(\acute{N}-T)\,T}{T^2 - \acute{N}\,(\acute{N}-T)(\frac{K.P2}{1-P})}$$

Calculating SD (Standard Deviation)

$$SD(N) = \sqrt{V(}\acute{N})$$

Observation of damage intensity

For each sub-block, 20 sample plants were selected to observe the intensity and extent of the attack. The damage intensity of the sample plants was conducted by counting the bunches attacked from the total bunches per plant. Then, damage scoring was done based on the cluster being attacked (Table 1). The area and intensity of rat attacks were calculated using the formula based on, Towsend and Hueberger (1948).

Area of attack:

$$L = \frac{n}{N} \times 100\%$$

Where:
L: area of attack
n: the number of plants showing symptoms of being attacked by rats
N: total number of plants observed

The intensity of damage:

$$\frac{\sum_{i=1}^{k} (n_i \times v_i)}{N \times Z} \times 100\%$$

Where:
ni: the number of bunches belonging to an attack category
vi: score in each category of attack
N: number of bunches observed
V: score for the heaviest attack category

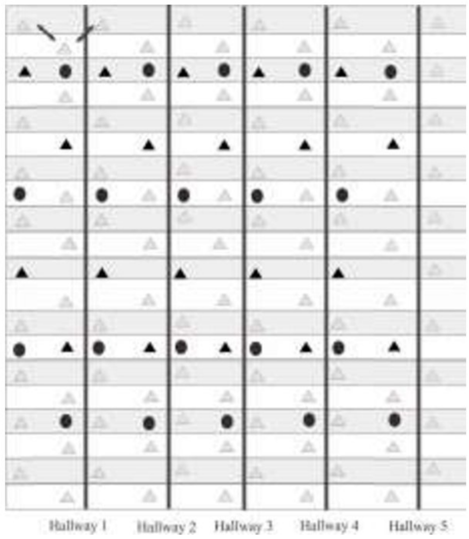
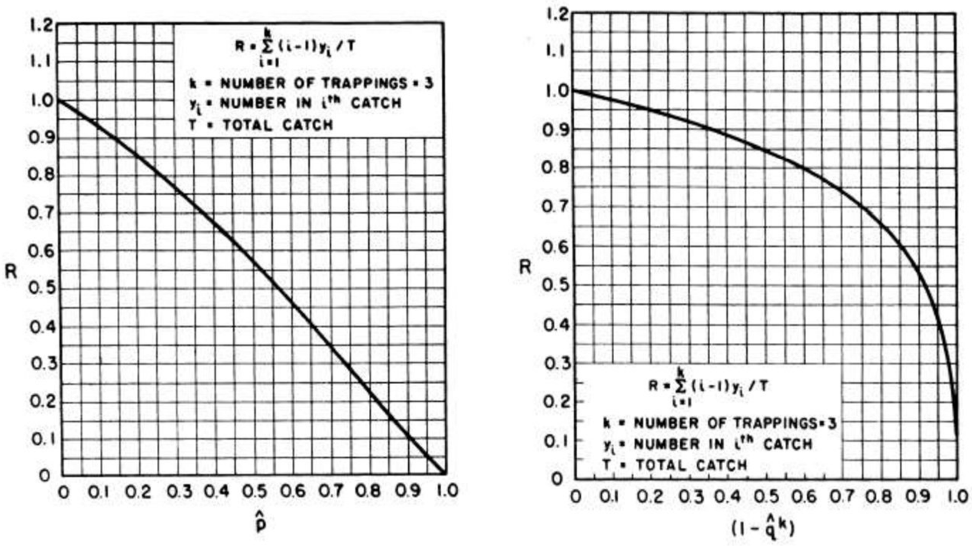


Figure 3. Determination of sample points and sample plants. Oil palm plantations (Δ), the distance between plants is 9.4 m (↔), 100 m (|) of the planting aisle, sample points traps are placed (●), sample plants (▲)



A B

Figure 4. A. Find the value P, B. Find the value (1-qk)

Table 1. Scoring crop damage based on bunches attacked

Attack category	Score	The scale of damage (%)
Without attack	0	0 %
Light	1	> 0-≤ 3 %
Light plus	2	> 3-≤ 5 %
Moderate	3	> 5-≤ 10%
Severe	4	> 10%

Source: PT Astra Agro Lestari

Data analysis

To compare the rat population in the two blocks (OC and OH), with the variables of species, sex, and bodyweight with the Mann Whitney test. The relationship between attack intensity and rat population density was analyzed by linear regression using the Minitab 18 program.

RESULTS AND DISCUSSION

Rat identification

Rats found in oil palm plantations in Mertasari Village and Towiora Village have four species, namely: *R. tanezumi* (32.20%), *R. tiomanicus* (67.04%), *Rattus* sp (0.37%), and *Maxomys hellwaldii* (0.37%). (Figure 5). According to Ditjenbun (2012) four species of the genus Rattus attack oil palm plantations, namely *Rattus tiomanicus*, *Rattus tanezumi*, *Rattus argentiventer*, and *Rattus exulans*. Rat identification was carried out on the quantitative and qualitative characters of the caught rats. Qualitative characters include hair texture, nose shape, body shape, the body color of the back, abdomen body-color, upper tail color, and lower tail color (Table 2). Quantitative characters include bodyweight, head and body length, body length, tail length, earlobe width, foot length, pair of rodent teeth, and several nipples (Table 3).

Rattus tiomanicus, R. tanezumi, Rattus sp that have almost the same qualitative character. The hallmark of the rat lies in the ventral body color, which is black gray *Rattus tanezumi* (Figure 6a) and white *R. tiomanicus* (Figure 6b). Also, Sulawesi white-tailed rats (*Maxomys hellwaldii*) (Figure 6d) are found as endemic to Sulawesi. Maxomys, are common rats that can be found in lowland and mountain forests up to 3000 m asl, from primary forests, secondary forests, plantations, and disturbed areas adjacent to forests (Payne et al. 1985). According to Harper and Bunbury (2015) Rat species have different population densities depending on the suitability of the habitat, such as forest ecosystems, rice fields, plantations create habitat niches that allow species of rats to be able to use available food sources so that they can breed well. *R. tanezumi* cosmopolitan distribution expands as their interaction with humans increases (Costa et al. 2017). *R. tanezumi* is known as a commensal pest, in Malaysia it was only seen near human habitation (Buckle and Smith 2015), but from the late 1980s until now *R. tanezumi* began to appear on oil palm plantations in several locations. *R. tiomanicus* is one of the rat species that are the major pest in oil palm plantations. *R. tiomanicus* normally found living mainly in scrub vegetation, secondary forests, and plantations. (Paramasvaran et al. 2013) if they are not controlled, they will cause huge economic losses. For *Rattus* sp (Figure 6c), it is difficult to identify based on quantitative and qualitative needs to be identified molecularly to confirm the species. This is because the morphological identification in the genus Rattus is very difficult (Chaval et al. 2010).

These four species have a longer tail compared to the head and body. The long rat's tail functions as a counterweight when the rats climb a tree, this makes it easier for the rats to climb, oil palm trees so that they can adapt to the habitat on the oil palm plantation. *R. tiomanicus*, known as "canopy rat" or "tree rat", has better climbing ability than *R. tanezumi* (Verwilghen 2015). Arboreal rats have a characteristic quantitative characteristic that is a long tail. The length of the tail exceeds the length of the head and body which makes it easy for rats to climb trees. The long tail functions as a balance when climbing (Carrizo et al. 2014). Terrestrial rat's tail is generally shorter than the head and body length.

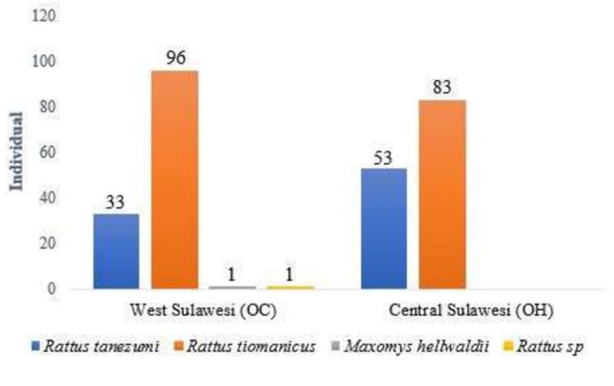


Figure 5. Trapping results based on location

Table 2. Qualitative characters of trapped rats

Species	Hair texture	Nose shape	Body shape	Dorsal body-color	Ventral body-color	Dorsal tail color	Ventral tail color
Rattus tanezumi	Rather rough	Cone	Cylindrical	Dark brown	Gray black	Dark brown	Dark brown
Rattus tiomanicus	Rather rough	Cone	Cylindrical	Brown yellowish	White	Dark brown	Dark brown
Rattus sp.	Rather rough	Cone	Cylindrical	Dark Brown	Dark Brown	Dark Brown	Dark Brown
Maxomys hellwaldii	Rather rough	Cone	Cylindrical	Brown	Cream white	Brown and white	Brown and white

Table 3. Quantitative characters of the trapped rat

Morphology	*Rattus tanezumi*	*Rattus tiomanicus*	*Rattus* sp.	*Maxomys hellwaldii*
Body weight (g)	35-245	45-260	180	150
Head length + body (mm)	70-200	80-202	170	240
Tail length (mm)	60-240	100-240	200	250
Total length (mm)	160-370	180-460	370	490
Earlobe width (mm)	12.5-24	15-21	20	25
Foot length (mm)	20-40	23-40	30	50
Pair width of rodent tooth (mm)	1-3	1-3	3	5
Number of nipples (pairs)	2+3	2+3	3+3	1+2

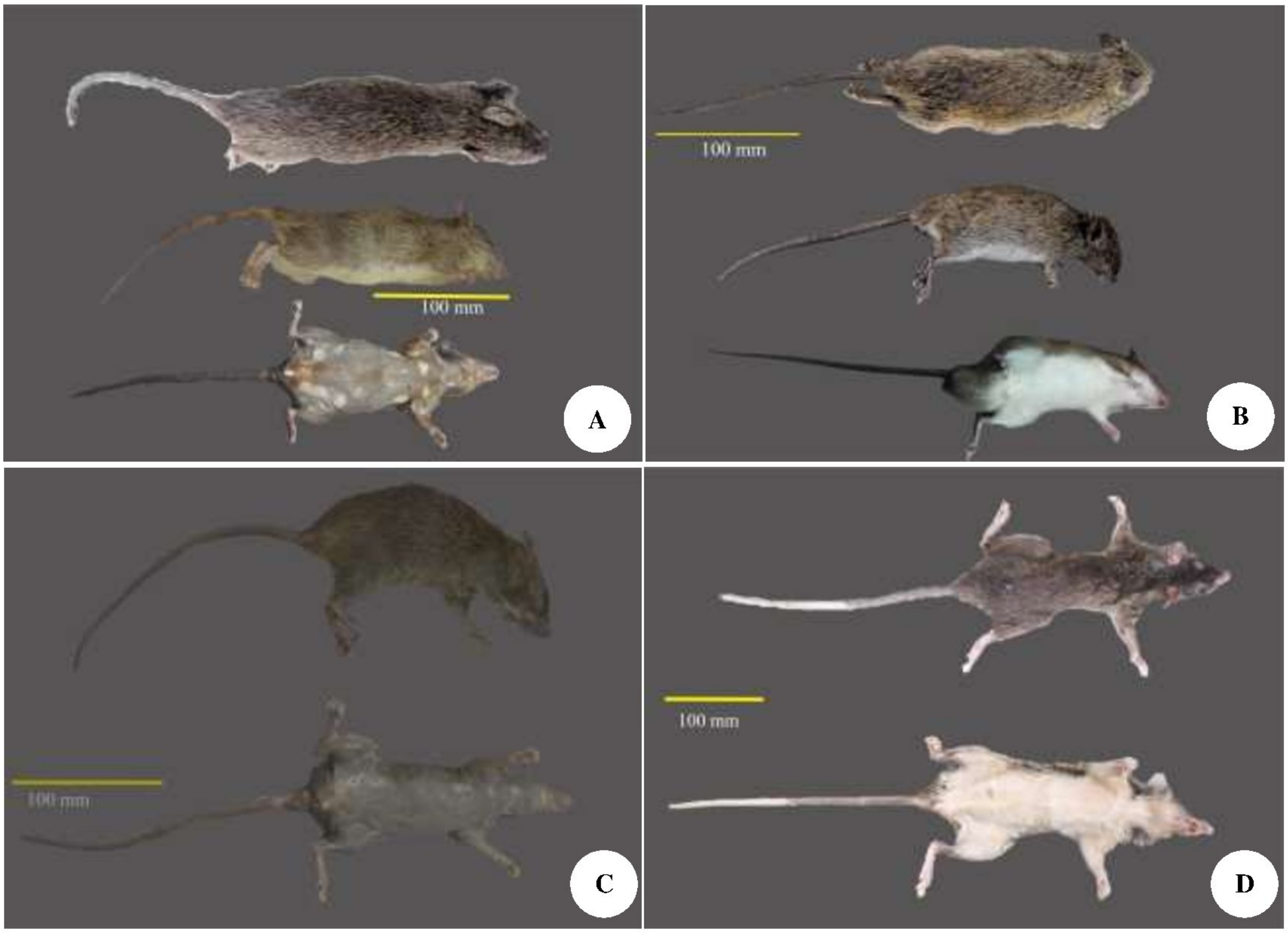


Figure 6. B. *Rattus tanezumi,* B. *Rattus tiomanicus*, C. *Rattus* sp., D. *Maxomys hellwaldii*

Only two dominant species were found, namely *Rattus tiomanicus* and *R. tanezumi*, this is because both species are easily adaptable to the environment of oil palm plantations. The differences between the two species in terms of several catches, sex, and body weight can be seen in (Table 4). Regarding the catching, there are two very significant differences in the species *R. tiomanicus* and *R. tanezumi*: sex and body weight. In terms of the dominant species found in oil palm plantations, *R. tiomanicus* is a rat that lives in forests and plantations, while *R. tanezumi* generally lives around settlements. *R. tanezumi* species are found in oil palm plantations because there are settlements around oil palm plantations, so that house rats migrate from one place to another. *R. tanezumi* is often found near human activities/settlements such as a town, villages, gardens, farms, and living quarters of plantations (Chung 2012). Based on the study of Kwatrina et al. (2018) *R. tanezumi* and *R. tiomanicus* were found in both places namely before plantation establishment (BFE) and after plantation establishment (APE).

More female rats were obtained than male one, this is reported in the statement of Priyambodo (2003) which said that female rats are easily caught compared with male. They are individual foraging for their children in the nest, male rats are territorial which means this rat guards his territory, so as not entered by another male (Takashi and Miczek 2014).

Trapped rats were dominated by adult rats. Rats are considered adults if they have exceeded the weight of > 70g, and already have a high cruising capacity compared to those that have not matured yet. It is suspected that immature rats spend a lot of time in the nest; the area of movement is not too broad and they do not know their habitats. Rat population damage and estimation

Block OC 12 has attack intensity (4.90%) the population was 12 individuals/ha with the light plus category, while the largest OH block (15.00%) had the population reaching 116 individuals/ha with the heavy category. The population of rats in oil palm plantations is expected to be 100-600 individuals/ha under heavy attack conditions that are not controlled (Wood and Chung 2003). Population estimates and intensity of attacks can be seen in (Table 5).

OC 12 Block was the cleanest compared to other blocks. The condition of conservation plants that are often pruned to maintain the health of the palm oil net with not too many shrubs prevents rats from making alternative nests and reproduction sites. In the mild plus category, generally, regular observations were made to avoid increasing the intensity and extent of the attacks. OH 02 block is a block that is classified as a heavy attack category due to dense weed conditions. The height of weeds in the neighborhood ranges from 60 cm to 100 cm, these habitat structures provide shelter (Michal and Rafal 2003). Unclean environmental conditions make it difficult for natural enemies (predators) to hunt rats easily hide around weeds and litter, besides these conditions are very favorable for rats to breed. Based on research by Puan et al. (2011a) an increase in the rat's population in oil palm plantations is positively correlated with land cover variables such as cover, height, and thickness of vegetation piles. The reduction of ground cover will affect rats in terms of restricting movement and breeding grounds so that the population growth of rats will decrease. Rats actively avoid predators, preferring to stay close to cover crop when moving between nest sites and foraging for food (Stryjek et al. 2018)

Severe attack categories require control measures. The highest rat population was estimated in Block OH 02, comparing to other blocks; this is because the block is adjacent to the community's oil palm plantations. Oil palm plantations owned by residents are not given much attention in terms of observation of pests and diseases, as well as their control. Therefore, it was suspected that many rats breed on the community-owned plantations and migrate to the next block. Many small mammals, expand their home ranges during the reproductive period (Cooney et al. 2015). Besides, OH02 Block haswas a lower place compared to another block, so if it rains, there will be flooding which will cause rats to migrate to higher places. Rats have a very wide home range. Ringler et al. (2014) stated that male rats have a variety of 0.4-0.85 ha and 0.35-0.75 ha for female rats so that the distribution and increase of individual rats in OH2 was very fast.

Table 4. The success of trapping by species, sex, and rat weight (N=265)

Observed variables	Number of rats (individual)	P-value
Species of rats		
Rattus tiomanicus	179	0.013 **
Rattus tanezumi	86	
Sex		
Male	106	0.025 **
Female	159	
Body weight		
> 70 g	192	0.005 **
< 70 g	73	

Note: ** = very significant

Table 5. Intensity of damage and population block of observations

Name of block	Land area (ha)	The intensity of damage (%)	Wide of damage (%)	Estimation population /ha
OC 20	17.15	5.11	32	15
OC 12	53.16	4.90	27	12
OC 21	39.47	8.91	48	34
OH 10	27.94	7.17	46	16
OH 04	36.75	10.08	46	44
OH 02	41.60	15.00	82	116

There was no significant difference in the rat population level between OC and OH fields (Table 6). This is because the two lands have almost the same environmental conditions, which are mostly overgrown by various conservation plants such as legume plants (*Mucuna bracteate)* and fern plants (*Nephrolepis* sp.*)*. The factors that influence the dynamics of rat populations are habitat conditions, the presence of predators, births, and food availability. In oil palm plantations, weeds and litter former oil palm fronds can be used as an alternative nest by rats to breed. Rats generally nest on the sidelines of oil palm bunches and fronds (Figure 7a). The conditions under which the leaves come into contact with each other make it easier for rats to move from tree to tree next to them and create favorable nesting conditions for the rats (Figure 7c).

In immature plants, rats attack male flowers, rooting areas, and oil palm fronds. The attack on the male flower, because rats also prey on pollinating insects *Elaedobius kamerunicus* (Coleoptera: Curculionidae) which are generally located in male flowers (Figure 7b). When rats grazed on male spikelets, they would undoubtedly consume the eggs, larvae, and pupae that live in the inner part of the spikelets (Luqman et al. 2017). These beetles can significantly increase the percentage of flowers into fruit. Rats like this beetle because it is a source of animal protein that is needed by rats. The results of the analysis of rat's stomach in the area of oil palm plantations showed that 80% of the food consumed by rats was oil palm fruit, 15% was insects, and 5% was other food (Adhidharma 2009). In addition to attacking mature plants, rats also cause damage to young plants. On young oil palms, the most favorite part is the petiole that forms the fronds, damage to this suppresses the formation of fronds. In matured palm, the attack is concentrated on the inflorescence and the fruit bunch (Tipawan and Jarun 2016). At the nursery stage, the rat eats apical tissue that causes death or affects the development of young shoots (Figure 7d). According to Adhidarma (2009) if rats cut off the point of growth and cause death in plants, then the loss will reach 80% because the plants must be replaced.

Relationship between rat population and intensity of the attack

The results of linear regression analysis between population density (X) and rat attack intensity (Y) have a coefficient of determination (R2) = 90.1% with the following equation Y = 4.911 + 0.091 X which means that every addition of 1 individual rat will increase the intensity of the damage by 0.091%. The P-value of 0.002 indicates that the intensity of damage to oil palms due to rats is strongly influenced by the abundance of rats (Figure 8). Based on the research results of Puan et al. (2011b) reported that the rat population has a positive relationship to attack intensity.

Table 6. Comparison of the number of rats OC and OH block (N=6)

Name of block	Comparison block OC and OH	P-value
OC	61	0.190 ns
OH	176	

Note: ns: not significant a=5%

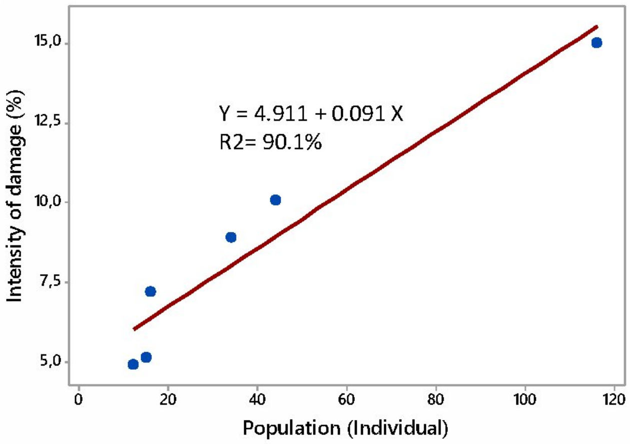


Figure 8. Relationship between rat population and percentage of attack intensity

Figure 7.A. Adult rat nesting in palm fronds, B. Rat attacks on male flowers, C. Palm fronds touch each other, D. Attacks on immature plants (TBM)

ACKNOWLEDGEMENTS

Our sincere thanks to PT Astra Agro Lestari, Jakarta, Indonesia for the support, and facilities that have been provided during field activities

REFERENCES

Adhidarma D. 2009. Socio-economic study of tree rat pest control, *Rattus tiomanicus* with Owl (*Tyto alba*) on oil palm plantations; Proceeding of National Seminary Plant Protection. Institut Pertanian Bogor, Bogor, 5-6 August 2009. [Indonesian]

Buckle AP, Smith R. 2015. Rodent Pests and Their Control 2nd Edition. CABI Internasional, Wallingford, UK.

Carrizo LV, Tulli MJ, Daniel ADS, Abdala V. 2014. Interplay between postcranial morphology and locomotor types in Neotropical sigmodontine rodents. J Anat (4): 469-481.

Chaval Y, Dobigny G, Michaux J, Pagès M, Corbisier C, Cosson JF. 2010. A multi-approach survey as the most reliable tool to accurately assess biodiversity: An example of Thai Murine rodents. Witthayasan Kasetsat 44 (4): 590-603.

Chung GF. 2012. Rat management in oil palm; Proceeding of International Seminary on Fourth MPOB-IOPRI International. Grand Royal Panghegar Hotel, Bandung, 13-14 December 2012. [Indonesian]

Cooney SA, Schauber EM, Hellgren EC. 2015. Ranging behavior of marsh rice rats in a southern Illinois wetland complex. J Mammal 96: 732-741.

Costa F, Carvalho PT, Begon M, Riley L, Childs J. 2017. Zoonotic and vector-borne diseases in Urban slums: Opportunities for intervention. Trends Parasitol 33 (9): 660-662.

[Ditjenbun] Direktorat Jenderal Perkebunan. 2012. Owls, predators of rats in plantation areas. http: //ditjenbun.pertanian.go.id/burung-hantu-predator-tikus-di-areal-tanaman-perkebunan/ [Indonesian]

Govinda RG. 2018. Pest and their Management. Department of the Zoology, University of Lucknow, Lucknow, India.

Tipawan T, Jarun T. 2016. The efficiency of material types of box fences to prevent rat damage in oil palm plantations. Intl J Agric Technol 12 (7.1): 1491-1498.

Harper GA, Bunbury N. 2015. Invasive rats on tropical islands: Their population biology and impacts on native species. Glob Ecol Conserv 3: 607-627.

Kwatrina RT, Santosa Y, Bismark M, Santoso N. 2018. The impacts of oil palm plantation establishment on type habitat type, species diversity, and feeding guild of mammals and herpetofauna. Biodiversitas 4: 1213-1219.

Lukito PA, Sudrajat. 2017. The effect of oil palm fruit damage on free fatty acid content and CPO yield in Talisayan 1 Berau Plantation. Bul Agrohorti 5 (1): 37-44.

Luqman MHA, Dzulhelmi MN, Idris A, Izfa RH. 2017. The potential natural predators of *Elaedobius kamerunicus* Faust, 1878 (Coleoptera: Curculionidae) in Malaysia. Serangga 2: 239-252.

Michal B, Rafal Z. 2013. Responses of small mammals to clear-cutting in temperate and boreal forests of Europe: A meta-analysis and review. Eur J For Res: 133: 1-11.

Oil World. 2019. Oil World Annual 2019. ISTA Mielke GmbH, Jerman.

Paramasvaran S, Sani RA, Krishnasamy M, Amal NM, Hassan L, Mohdzain SN, Latifah I, Rahmat MS, Jeffry J, Sananthana RL, Selvanesan S. 2013. Distribution of morphological measurement of wild and urban rodents from four habitat in the states of Selangor and Negeri Sembilan, Malaysia. Malay J Vet Res 4: 1-12.

Puan CL, Goldizen AW, Zakaria M, Baxter GS. 2011a. Understanding of relationships between ground cover and rat abundances: An integrative approach for management of the oil palm agroecosystem. J Crop Prot 10: 1263-1268.

Puan CL, Goldizen AW, Zakaria M, Hafidzi MN, Baxter GS. 2011b. Relationships among rat numbers, abundance of oil palm fruit and damage levels to fruit in an oil palm plantation. Integr Zool 6: 130-139.

Payne J, Francis CM, Philipps K. 1985. A Field Guide to the Mammals of Borneo. Sabah Society and World Wildlife Fund, Kinabalu, Sabah.

Priyambodo S. 2003. Integrated Rat Pest Management. Penebar Swadaya, Jakarta. [Indonesian]

Ringler D, Russell J, Jaeger A, Pinet P, Bastien M, Le Corre M. 2014. Invasive rat space use on tropical islands: Implications for bait broadcast. Basic Appl Ecol 15: 179-186.

Stryjek R, Mioduszewska B, Spaltabaka E, Gedek ES. Juszczak GR. 2018. Wild norway rats do not avoid predator scents when collecting food in a familiar habitat: A field study. Sci Rep 8 (1): 9475. DOI: 10.1038/s41598-018-27054-4.

Suyanto A. 2006. Rodent Field Guide Series in Java Center for Biological Research, Indonesian Institute of Sciences. Bogor. [Indonesian]

Towsend GR, Hueberger JW. 1948. The Basic Principles of Crop Protection Field Trials. Pflanzenschuts Nachrichten Bayer AG Leverkusen, Germany.

Takashi A, Miczek KA. 2014. Neurogenetics of aggressive behavior-studies in rodents. Curr Top Behav Neurosci 17: 3-44

Verwilghen A. 2015. Rodent pest management and predator communities in oil palm plantations in Indonesia: A comparison of two contrasting systems. [Disertation]. University of Franche-Comté, Besançon. [France]

Wood BJ, Chung GF. 2003. A critical review of the development of rat control in Malaysia agriculture since the 1960s. J Crop Prot 22: 445-461.

Zippin C. 1958. The removal method of population estimation. J Wildl Manag 22: 2-90.