Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(3): 29-34

Received: 15-03-2018
Accepted: 19-04-2018

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Diversity and abundance of cockroaches (Insecta: Dictyoptera) in ships at Bau-Bau port

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Abstract
The cockroaches' presence in ships became global health problems because it can transmit potentially outbreak diseases to passengers and the crew. The research was conducted at Baubau Port from November to December 2017. Cockroaches were collected manually in four spots of observation (bridge, deck, galley and bathroom) using flushing agent. Total collected cockroaches were about 3,196 individuals that were grouped into 7 species, 5 genera and 3 families. The index of cockroaches' diversity in passenger ships and cargo ships were low (H'= 0.72 and H'= 0.53, respectively). *Periplaneta americana* was the highest abundance, both on passenger ships (57.81%) and cargo ships (80.87%). The highest distribution of cockroaches' infestation on the passenger ship and cargo ships were found in the galley (53.73% and 66.81%, respectively). The two species (*P. americana* and *Blattella germanica*) were the very high degree of infestation.

Keywords: diversity, abundance, cockroaches, ship type

1. Introduction
Indonesia is an archipelagic country that has various transportation modes, one of them is sea transportation mode. The sea transportation mode like ships becomes a necessary vehicle mode in transporting passengers and goods from one place to another. Availability of cockroaches are possible to be distributed in ships and other kinds of sea transportations that are potential to transmit diseases for the ship's passengers and crews, especially including for landing ships in the Baubau Port. Ship traffics plays an important role in distributing various disease vector insect species among ports in the worldwide including cockroaches [32]. A condition of ports that functions at receiving and managing goods from around the world is one of the risk factors for infesting cockroaches in ships [31]. Infestations of cockroaches in sea transportation are found in various types of ships. In 1993, they were found in 511 (53.4%) ships at Dalian Port, China [30]. They were reported infesting in 6 cargo ships (10.2%) in Hamburg Port, Germany [20] and 11 ferries (52.3%) at the Piraeus Port, Greece [16]. The existence of cockroaches in ships becomes a global health problem because they are potential to spread various diseases for ships' passengers and crews, both among ports and even nations [17, 32]. They also inflict directly diseases to human. Cockroach's body is known contained allergens that can cause asthma for human [12, 24], lung obstruction and a risk factor for asthma for ships' crew [9, 21]. Allergy process happens through inhalation as a result of direct contact with cockroaches or contaminated environment of cockroach allergens [1, 3, 7]. A report about diversity and abundance of cockroaches in ships is very important to be proposed here because it is not conducted yet in Indonesia priorly. Therefore, this study was conducted to know the status of the cockroaches' infestation in ships.

2. Materials and Methods
2.1 Collection and identification of cockroaches
Collecting cockroaches was conducted in November to December 2017 in two types of ships (passenger and cargo), at Baubau Port. There were 24 observed ships, a half number for passenger ships and another half for cargo ships, respectively. Collecting cockroaches were taken manually by spraying flushing agent into observing spots (Fig. 1 A - D). Observing spot rooms consisted of bridge, deck, galley and a bathroom. Every room was observed during 30 minutes long on night and cockroaches were taken by involving four enumerators. Caught cockroaches were put into sampling bags which had been named by spots, ships and ship types. Furthermore, those bags were pinned and identified in the Entomology Laboratory,

Faculty of Veterinary Medicine, Bogor Agricultural University. The cockroaches then were identified by using stereomicroscope and with a help of morphological identification keys based on Pratt (1953) [22], Hadi and Soviana (2013) [5]. Classification of the cockroaches was started from family, genus and species.

2.2 Data Analysis

The observations were tabulated and data were statistically analyzed using Microsoft Excel. The collected cockroaches were counted their total, species, genus, and family. Relative abundance, dominance of each species and diversity index was determined using the formula [14, 29]:

$$\text{Relative Abundance (RA) of a species} = \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all species}} \text{ X } 100$$

$$\text{Species Frekuensi (SF)} = \frac{\text{Number of ship with each cockroach's species}}{\text{Number of ship of all observed}}$$

Species Dominance (SD) = RA X SF

Shannon-Wiener Index (H') = $-\sum$ (Pi ln Pi); Pi = ni/N

Where,

pi = Proportion of i^{th} species in the total sample

ni = Number of individuals of i^{th} species

N = Total number of individuals

ln = Natural logarithm

High (H'>3); Moderate (1≤H'≤3); Low (H'<1)

Infested distribution of each cockroach species in the four observed spots was measured in the form of a percentage. While infest degree of its' each species was classified based on five categories such as (1) negative infestation (-): there is not cockroach or 0 (zero); (2) low infestation (+):1-5 of cockroaches; (3) moderate infestation (++): 6-10 of cockroaches; (4) high infestation (+++): 11-20 of cockroaches and (5) very high infestation (++++): > 20 of cockroaches [4].

3. Results and Discussion

3.1 Diversity and abundance of cockroaches

Total of found cockroach species in the two types of ships (passenger and cargo ships) in the Baubau Port is 7 species where is categorized into 5 genera and 3 families with 3,196 individuals (Table 1 and Fig. 2). Furthermore, a number of cockroach species in passenger ships is about 1,569 individuals that are classified into 5 species, 3 genera and 3 families. Numbers of species and families in this type of ship are equal with the cargo ships, however, they are different in the number of genera and individuals. The found cockroaches in cargo ships are categorized into 4 genera with 1,627 individuals. From seven collected species, there are two species are not found in the passenger ships, *Pycnoscelus surinamensis*, *Nauphoeta cinerea*, and cargo ships, *Periplaneta australasiae*, *Blaberus* sp., respectively.

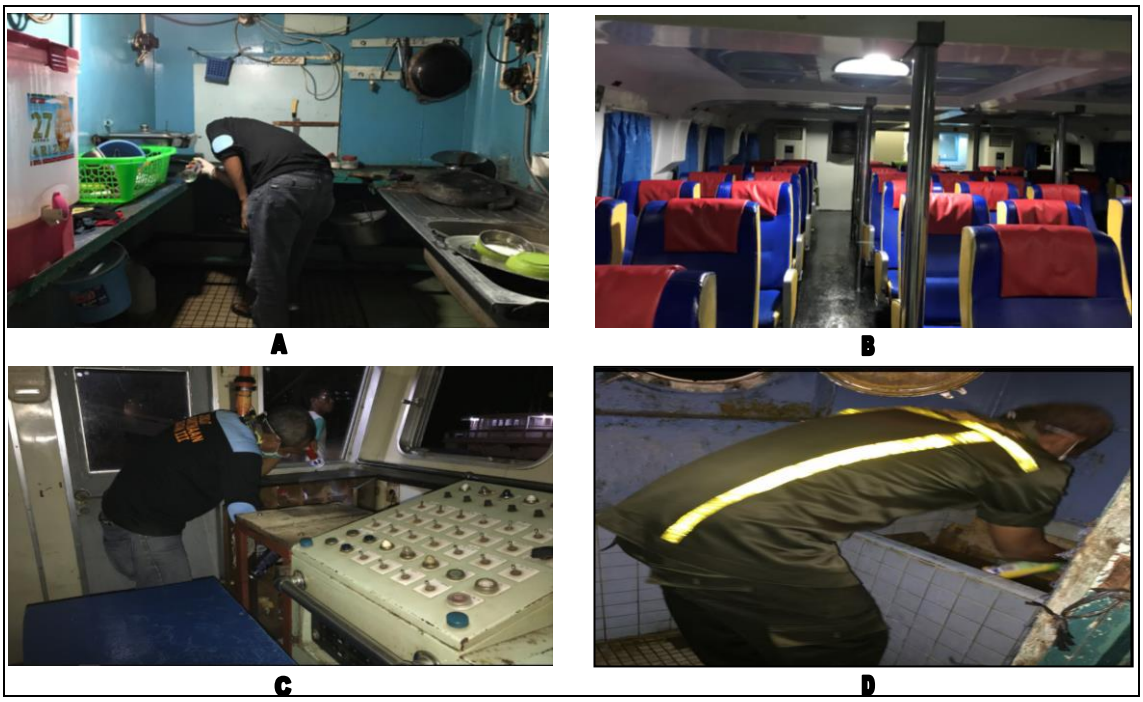


Fig 1(A - D): Observed room spots of cockroaches: bridge (A); deck (B); galley (C); bathroom (D)

The species of *P. americana* is the highest number of individuals found in both kinds of ships, 907 and 1,316 individuals, respectively, and followed by *Blattella germanica*, 652 and 296 individuals, respectively (Table 1). These both species and *Blatta orientalis* were found for the first time in ships in the medieval age [15]. Previous researchers reported that only one species (*B. germanica*) was found in the ferries at Piraeus Port, Greece [16], two species (*B. germanica* and *B. orientalis*) were found in cargo ships at Hamburg Port, Germany [20]. Infestation of cockroaches also was reported in passenger ships in Manado Port, Indonesia, however, their specific species are unknown [10].

Table 1: Species and number of individuals of collected cockroaches in ships at Baubau Port (November-December 2017)

Family; Genus (Species)	Total individuals of cockroaches in each observed spot									
	Passenger ships					Cargo ships				
	RKM	RDK	RDP	KMD	Σ	RKM	RDK	RDP	KMD	Σ
Blattidae										
Periplaneta americana	45	414	303	145	907	19	262	814	221	1316
Periplaneta brunnea	0	1	6	1	8	0	5	7	1	13
Periplaneta australasiae	0	0	1	0	1	0	0	0	0	0
Blattellidae										
Blattella germanica	21	61	533	37	652	0	31	265	0	296
Blaberidae										
Blaberus sp.	0	1	0	0	1	0	0	0	0	0
Pycnoscelus surinamensis	0	0	0	0	0	0	0	1	0	1
Nauphoeta cinerea	0	0	0	0	0	0	1	0	0	1
Jumlah total individu	66	477	843	183	1569	19	299	1087	222	1627
H’	0.72					0.57				

*RKM: bridge; RDK: deck; RDP: galley; KMD: bathroom; Σ: sum of individual; H’: Shannon-Wiener diversity index

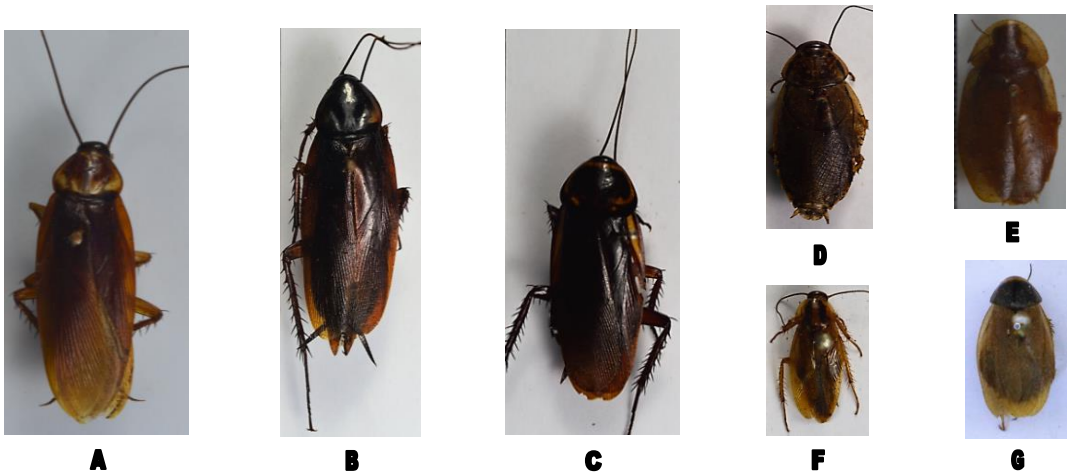
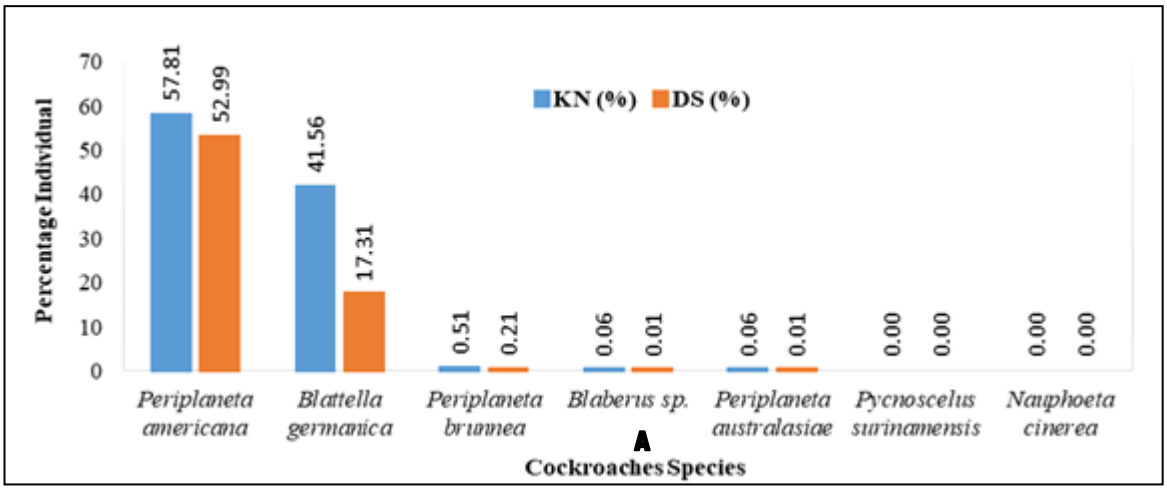


Fig 2(A - G): Diversity of cockroaches collected on two types of ship at the Baubau Port: *Periplaneta americana* (A); *Periplaneta brunnea* (B); *Periplaneta australasiae* (C); *Nauphoeta cinerea* (D); *Blaberus* sp. (E); *Blattella germanica* (F); *Pycnoscelus surinamensis* (G)

Relative abundance and dominance of cockroach species that have been collected in both ship types indicate results which are not so significant differently (Fig. 3 A, B). The highest abundance is *P. americana* (57.81% and 80.89%, respectively), and followed by *B. germanica* (41.56% and 18.19%, respectively), and *Periplaneta brunnea* (0.51% and 0.80%, respectively). The lower abundances of cockroaches’ species are *P. australasiae*, *Blaberus* sp., *P. surinamensis* and *N. cinerea* (about 0.06%, respectively).



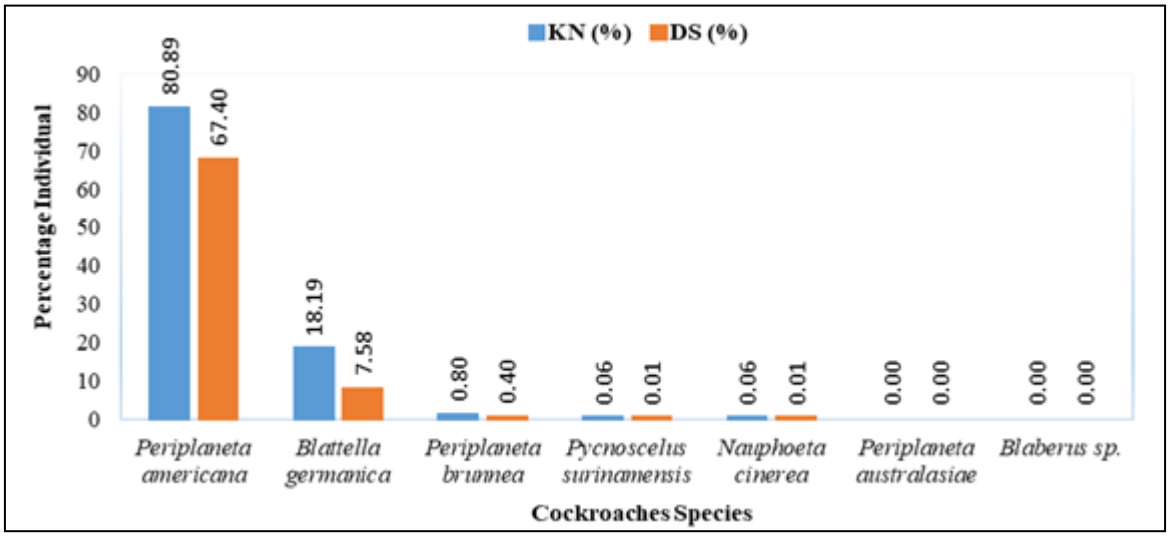


Fig 3(A - B): Relative Abundance (KN) and Species Dominance (DS) of cockroaches in ships at Baubau Port: Passenger Ships (A) and Cargo Ships (B)

The two species of cockroaches (*P. americana* and *B. germanica*), are abundant species in both types of ships. This abundance is caused by the moistered and dirty condition of the ships which supports the life of cockroaches. These two species can coexist and the population was abundant in humid, food-available and near-water conditions [19]. The *B. germanica* was known to be the very abundant species on ferries and cargo ships in the European ports [16, 20]. A similar research on land transportation modes reports that the species of *P. americana* and *B. germanica* are the abundant cockroaches of buses operating in Bogor, Indonesia [23]. Memona *et al*. (2017) [13] also reported that the abundant cockroach species in public places in Lahore, Pakistan were *B. germanica* and *P. americana*.

In term of dominance, the both species (*P. americana* and *B. germanica*) are categorized into high dominance in the both types of ships (Fig. 3 A, B). That dominance level indicates environmental condition in the ships where are suitable for these both species life. This result is in line with a research conducted in operating buses in Bogor reporting that both species are very dominant species [23]. While in species diversity index point of view, the cockroaches in the two types of ships, passenger (0.72), and cargo (0.52), are categorized low (H'<1). This points that cockroach species in the two types of ships are not varied. However, they play a role as a vector for infectious diseases that potentially outbreaks in the ship's [6, 26].

3.2 Distribution of cockroaches infestation

Percentage of cockroach species distribution in each observed spot in two types of ships are various (Table 2). There is one species (*P. americana*, 45.64%) had been found in the passenger ships with the highest distribution in deck (45.64%), while two species (*B. germanica*, 81.75% and *P. brunnea*, 75%) are abundance in the galley. Furthermore, three species (*P. americana*, 61.85%; *B. germanica*, 89.53% and *P. brunnea*, 53.85%) are in cargo ships with the highest distribution is found at the galley. Others species (*P. australasiae*, *Blaberus* sp., *P. surinamensis* and *N. cinerea*) have 100% distribution, however, their number of individuals are not dominance.

According to Table 2 below, there are three species (*P. americana*, *P. brunnea* and *B. germanica*) are almost distributed in all observed spots in both ship types. This is caused by those ship's structures have many crevices, cracks and dark holes in floors, walls and palafons. Rafiuddin *et al*. (2005) [23] reported that cockroach *P. americana* and *B. germanica* have the highest percentage of distribution on cracks and floors of operating buses in Bogor. Crevices and cracks are also reported as infested area distribution of cockroach *B. germanica* in student dormitories in Yasuj City, Iran [28]. Cockroach itself is thigmotactic insects (avoiding lights) that's why it prefers to stay in crevices, cracks and dark holes [3, 25].

Table 2: Distribution of cockroaches' species in ships at Baubau Port (November-December 2017)

Species	Percentage of cockroaches (%) in each observed spot							
	Passenger ships				Cargo ships			
	RKM	RDK	RDP	KMD	RKM	RDK	RDP	KMD
Periplaneta americana	4.96	45.64	33.41	15.99	1.44	19.91	61.85	16.79
Periplaneta brunnea	0	12.50	75	12.50	0	38.46	53.85	7.69
Periplaneta australasiae	0	0	100	0	0	0	0	0
Blattella germanica	3.22	9.36	81.75	5.67	0	10.47	89.53	0
Blaberus sp.	0	100	0	0	0	0	0	0
Pycnoscelus surinamensis	0	0	0	0	0	0	100	0
Nauphoeta cinerea	0	0	0	0	0	100	0	0

*RKM: bridge; RDK: deck; RDP: galley; KMD: bathroom

Distribution of all cockroach species in each observed spot in the two types of ships were presented in Fig. 4 A, B. The highest distribution of cockroaches is found at galley (53.73% and 66.81%). It was followed by deck (30.40% and 18.38%), and bathroom (11.66% and 13.64%). Bridge is an observed room with the lowest distribution of cockroaches (4.21% and 1.17%).

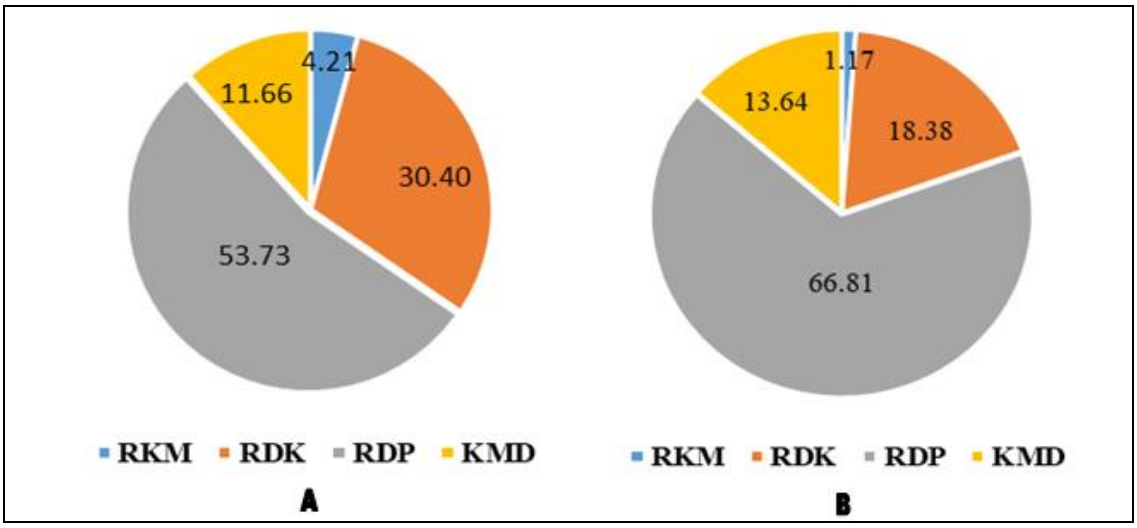


Fig 4(A - B): Distribution of cockroaches in four observed spots in two types of ships at Baubau Port, Passenger Ships (A) and Cargo Ships (B)

Ships' galleys are the highest observed spots of cockroaches in the both types of ships than other spots. The galley conditions which are dirty, moist, and watery, are supporting factors for its high distribution. The result of this research is in line with Mouchtouri *et al*. (2008) [16] that the highest cockroach in ferries at Piraeus Port, Greece, was found in the galley. The same result also was reported from Hamburg Port, Germany [20]. Another report in the Hamburg Port, Germany, stated that the highest distribution of cockroaches was in three types of ships such as cargo, container and tanker, were discovered in the galley [21]. Kitchen was a suitable habitat for breeding of cockroaches in appropriate environmental conditions (temperature and humidity) with poor sanitation [11, 18].

3.3 Degree of Cockroaches Infestation

Infestation degree of cockroaches in both types of ships are presented in Table 3 below. From seven species, only two species (*P. americana* and *B. germanica*) are categorized into very high infestation (++++). One species (*P. brunnea*) is categorized into moderate (++) and four species (*Blaberus* sp., *P. australasiae*, *N. cinerea* and *P. surinamensis*) are grouped into low infestation (+). Species of cockroaches *P. americana* and *B. germanica* are very high degree infested species than others. This result is similar to the finding of Rafiuddin *et al*. (2015) [23] on operating busess in Bogor, Indonesia. This is caused by poor ship's sanitary level, thus supports establishment of these both species. Shahraki (2013) [27] reported that aspects of sanitation, especially environmental hygiene can reduce the population of cockroaches. However, this has no effect when cockroaches were established [8]. Moreover, the both species are synantropic, readily reproductive and able to survive in the tropics [2].

Another supporting factor is a breakage of ships' building elements due to the circumstance of aging that are being places for cockroaches to hide and breed. Some similar researches were conducted in Piraeus Port, Greece, reported that infestation of *B. germanica* is higher in older ferries [16] and Hamburg Port, Germany, reported that it is infested higher in the 7 years old of cargo ships [20]. Whilst, infestation of cockroaches in the settling areas, reported that it has a higher infestation in the ≥ 10 years old of buildings [28].

Table 3: Degree of cockroaches' infestation in ships at Baubau Port (November- December 2017)

Species	Degree of cockroaches' infestation							
	Passenger ships Cargo ships							
	RKM	RDK	RDP	KMD	RKM	RDK	RDP	KMD
Periplaneta americana	++++	++++	++++	++++	+++	++++	++++	++++
Periplaneta brunnea	-	+	++	+	-	+	++	+
Periplaneta australasiae	-	-	+	-	-	-	-	-
Blattella germanica	++++	++++	++++	++++	-	++++	++++	-
Blaberus sp.	-	+	-	-	-	-	-	-
Pycnoscelus surinamensis	-	-	-	-	-	-	+	-
Nauphoeta cinerea	-	-	-	-	-	+	-	-

*RKM: bridge; RDK: deck; RDP: galley; KMD: bathroom; -: no cockroaches; +: low (1-5 cockroaches); ++: moderate (6-10 cockroaches); +++: high (11-20 cockroaches); ++++: very high (> 20 cockroaches)

4. Conclusion

This study found 7 species of cockroaches in two types of ships (passenger ships and cargo ships) belonging to 5 genera (*Periplaneta*, *Blattella*, *Pycnoscelus*, *Blaberus* and *Nauphoeta*). There are three genera (*Pycnoscelus*, *Blaberus* and *Nauphoeta*) of cockroaches that have been discovered first time in ships. This research is very important for related parties in managing of controlling cockroach in ships.

5. Acknowledgments

Authors thanks to The Health Ministry of the Republic of Indonesia that had funded this research. Acknowledgments also the authors convey to all the Staff Division of Parasitology and Entomology, Faculty of Veterinary Medicine, Bogor Agricultural University which has supported during the research and drafting of this manuscript. Expression of gratitude is addressed to all Health Staffs of Baubau Port which had helped during data collection. Authors

also thanks to all people whose involving in this research.

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