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Penulis: Siti Herlinda, Sandi Yudha, Rosdah Thalib, Khodijah, Suwandi, Benyamin Lakitan, Marieska Verawaty

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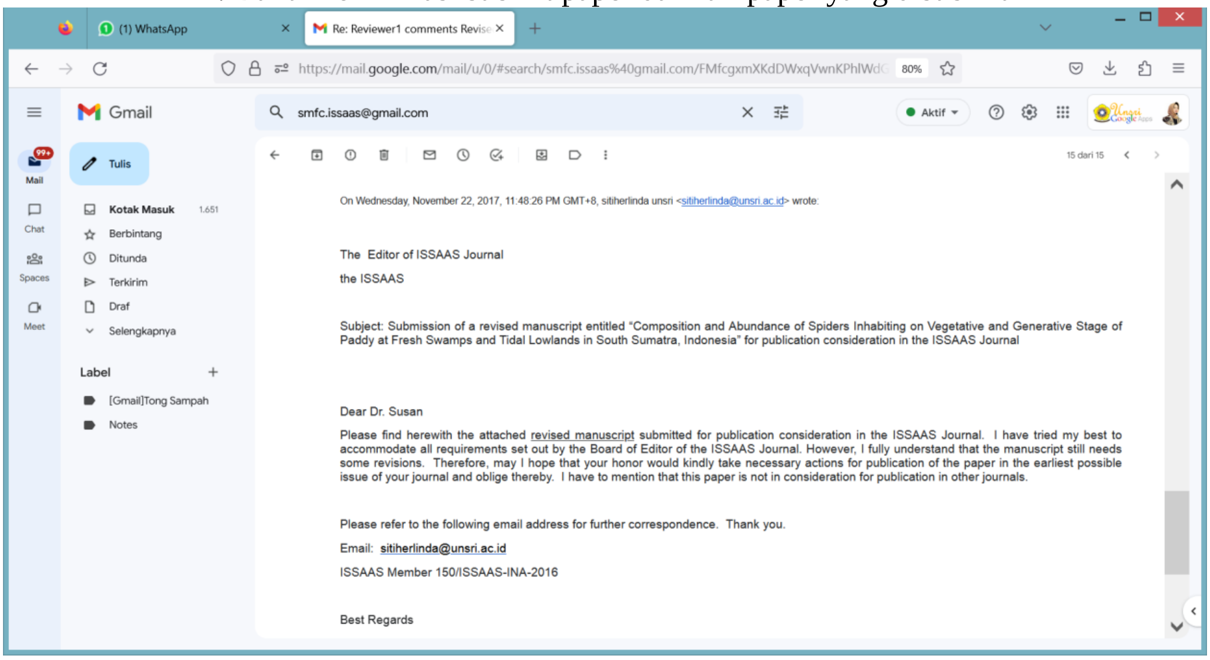
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Species Richness and Abundance of Spiders Inhabiting Vegetative and Generative Stage of Rice at Fresh Swamps and Tidal Lowlands in South Sumatra, Indonesia

Siti Herlinda[1, 2]*, Sandi Yudha[3], Rosdah Thalib[1], Khodijah[4], Suwandi[1,2], Benyamin Lakitan[1,2], Marieska Verawaty[5]
[1]College of Agriculture, Universitas Sriwijaya, Indralaya, South Sumatra, Indonesia 30662

[2]Research Center for Sub-optimal Lands (PUR-PLSO), Universitas Sriwijaya, Palembang, South Sumatra, Indonesia 30139
[3]Alumnus of College of Agriculture, Universitas Sriwijaya, Indralaya, South Sumatra, Indonesia 30662
[4]College of Agriculture, Universitas Palembang, Palembang, Indonesia 30139
[5]College of Mathematic and Natural Sciences, Universitas Sriwijaya, Indralaya, Indonesia
*Corresponding author: sitiherlinda@unsri.ac.id

ABSTRACT

Different planting methods at fresh swamps and tidal lowlands and rice stages may support different abundance and species richness of arthropods therefore quantifying arthropod assemblages needs to be carried out. This research objective was to analyze species richness and abundance of spiders inhabiting vegetative and generative stages of rice at fresh swamp and tidal lowland ecosystems in South Sumatra. Arboreal spiders were sampled using insect nets, and soil-dwelling spiders were sampled using pitfall traps. Families of the arboreal spiders found during the vegetative and generative stages of rice from both ecosystems were Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae and Salticidae. The most dominant family and species of the arboreal spiders found were Tetragnathidae and *Tetragnatha virescens*, respectively. Species richness of the arboreal spider during the vegetative (P = 0.1857) and generative (P = 0.8067) stages at the fresh swamp ecosystems was not significantly different from that at the tidal lowland ecosystems. Families of soil-dwelling spiders found during the vegetative and generative stages were Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae, and Salticidae. The most dominant family and species of the soil-dwelling spiders found were Lycosidae and *Pardosa pseudoannulata*, respectively. Species richness of the soil-dwelling spiders during the rice vegetative (P = 0.5290) and generative (P = 0.9813) stages at the fresh swamps was not significantly different from that at the tidal lowlands. This study suggest that the specific and eco-friendly planting methods at the fresh swamp and tidal lowland ecosystems supports existence of Tetragnathidae and Lycosidae, keystone predators of rice pest insects.

Keywords: arboreal, arthropod, rice, soil dwelling

INTRODUCTION

Wetlands in Indonesia, are characterized by two distinct ecosystems, differentiated based on sea tide influence; i.e. tidal lowlands for those directly influenced by sea tide but fresh swamps for those not affected by sea tide. At the tidal lowland ecosystems, soil needs specific handling due to thick pyritic layers therefore it should be preserved (Hidayat *et al*., 2010). The local farmers do not fully manage the soil to prevent the pyrite layers from destructions (Suriadikarta *et al*., 2013) and they generally plant rice twice a year (planting index) by using broadcast seeding, drum seeding, or seedling in a digged-hole ("tugal") (Raharjo *et al*., 2013). Contrary to the farmers at the tidal lowlands, farmers at fresh swamps usually plant rice using transplanting system and they only plant rice once a year (Mulyani & Sarwani, 2013; Lakitan *et al*., 2018). Different rice planting methods and index at the both ecosystems may also affect the arthropod abundance and species diversity or richness (Zhang *et al*., 2013; Parry *et al.*, 2015). Weedy paddies at direct planting ecosystems have more abundant arthropods than those at clean ecosystems (Hu *et al.*, 2012). No soil tillage or conservation tillage at paddies also support higher arthropod abundance (Pereira *et al*., 2010). No application of synthetic insecticides at fresh swamp ecosystems also enhances abundance of predatory arthropods, especially spiders (Herlinda *et al.*, 2004; Herlinda *et al.*, 2008).

In addition to planting method and index, vegetative and generative stages of rice also influence species richness and abundance of the arthropods (Herlinda *et al*. 2008). At the vegetative and generative stages, soil-dwelling arthropods are more abundant and more diverse at the tidal lowlands than those at the fresh swamp ecosystems (Khodijah *et al.*, 2012; Herlinda *et al.*, 2014). However, the arboreal artropods are more abundant and richer at the fresh swamp ecosystems than those at the tidal lowland ecosystems (Khodijah *et al.*, 2012; Sunariah *et al.*, 2016). Different planting methods and index at the both ecosystems and different stages of rice may support different abundance and species richness of arthropods, therefore quantifying arthropod assemblages needs to be carried out. The purpose of this study was to analyze species richness and abundance of spiders inhabiting vegetative and generative stages of rice at fresh swamps and tidal lowlands in South Sumatra.

MATERIAL AND METHODS

Time and Location

Surveys were carried out at rice production centers of fresh swamps and tidal lowlands in South Sumatra throughout February 2012 to March 2013. Survey locations of the rice production centers for fresh swamp ecosystems were: (1) Gandus, Palembang City; (2) Pelabuhan Dalam Village of Ogan Ilir District; (3) Maryana Village of Banyuasin District; and (4) Sungai Waru Village of Kabupaten Banyuasin District. Survey locations of the rice production centers for tidal lowlands were: (1) Banyu Urip Village of Tanjung Lago Subdistrict, Banyuasin District' (2) Telang Karya Village of Muara Telang Subdistrict, Banyuasin District; (3) Telang Rejo Village of Muara Telang Subdistrict, Banyuasin District; (4) Srikaton Damai Village of Air Saleh Subdistrict, Banyuasin District; (5) Srimulyo Village of Kecamatan Air Saleh Subdistrict, Banyuasin District; (6) Makarti Jaya Village of Makarti Jaya Subdistrict, Banyuasin District; (7) Tirta Mulya Village of Makarti Jaya Subdistrict, Banyuasin District; and (8) Tirta Kencana Village of Makarti Jaya Subdistrict, Banyuasin District. In each location, three sampling plots of a minimum size of 1 ha were surveyed twice during one rice season (4 mounts). The first survey was done when rice crop was 4 weeks old and the second one when rice crop was at milk grain stage (9 weeks old). Rice variety used at the fresh swamps was Ciherang, whereas Inpara variety was used at the tidal lowland ecosystems.

Sampling

Arboreal spiders. The arboreal spiders were sampled using insect nets, following methods used by Herlinda *et al.* (2014). Net sweeping consisted of 'double swings', totalling 30 swings/ha in all plots.

Soil-dwelling spiders. Soil-dwelling spiders were sampled using pitfall traps, following methods used by Herlinda *et al.* (2004). Plastic pitfall traps (60 mm in diameter and 90 mm in height) were filled to a volume of 70 mL with 4% formaldehide solution and buried in the ground flush with the soil surface. Traps were installed with density of 18 units/ha , spaced in a grid 3 x 6, then collected after 48 hours. All specimens collected were cleaned and sorted from other debris and stored in vials containing 70% ethanol. Identification to family- and species-level was carried out at Laboratory of Entomology, at the Plant Pest and Disease Department, College of Agriculture, Universitas Sriwijaya, using taxonomic keys provided in Barrion and Litsinger (1995).

Data Analysis

The spider abundance data between samples from the fresh swamp and tidal lowland ecosystems were not normally distributed. Hence, insect counts in this study were found to fit a negative binomial distribution and were analyzed by Proc Genmod using SAS University Edition (SAS Institute Inc., Cary, NC, U.S.A.). Species richness was analysed using Menhinick's index (D) (Magurran, 1988).

RESULTS

Arboreal Spiders at Fresh Swamp and Tidal Lowland Ecosystems

From this survey during rice vegetative stage, a total of 7 families of arboreal spiders found were Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae and Salticidae at the fresh swamp and tidal lowland ecosystems (Table 1). Tetragnathidae was the most dominant family of the arboreal spider found during the rice vegetative stage. A total of 92.750 spiders at the fresh swamp ecosystems and 62.875 spiders at the tidal lowland ecosystems were captured (P = 0.3124). The abundance of *Tetragnatha vermiformis* (P = 0.0011) and *Oxyopes bikakaeus* (P = 0.0074) at the fresh swamp ecosystems were significantly higher than those at the tidal lowland ecosystems. A total of the arboreal spider species found during the rice vegetative stage were 26 species from the fresh swamp ecosystems and 23 species from the tidal lowland ecosystem. Spider species richness at the fresh swamp ecosystems was not significantly different (P = 0.1857) from those at the tidal lowland ecosystems.

A total of spider families found during rice generative stage were only 5 families (Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae and Salticidae) at the fresh swamp ecosystems and 7 families (Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae) at the tidal lowland ecosystems (Table 2). However, abundance of Araneidae (P = 0.8030), Tetragnathidae (P = 1.0000), Linyphiidae (P = 0.7202), Oxyopidae (P = 0.0958), Thomisidae (P = 1.0000), Theridiidae (P = 1.0000), and Salticidae (P = 0.6336) at the fresh swamp ecosystems were not significantly different from those at the tidal lowland ecosystems. The most dominant family of the arboreal spiders found on the both ecosystems was Tetragnathidae. A total of spider abundance for all species at the fresh swamp ecosystems (47.750 spiders/30 nets) were not significantly different (P = 0.5206) from those at the tidal lowland ecosystems (54,250 spiders/30 nets). However, average of spider abundance from the both ecosystems was significantly different (P = 0,000). The most dominant arboreal species found on the both ecosystems was *Tetragnatha virescens.* A total of arboreal spider species recorded were 16 species from the fresh swamp ecosystems and 21 species from the tidal lowland ecosystem. However, the arboreal spider species richness at the fresh swamp ecosystems were not also significantly different (P = 0.8067) from those at the tidal lowland ecosystems.

Soil-dwelling Spiders at Fresh Swamps and Tidal Lowlands

At vegetative stage of rice, soil-dwelling spiders found were only 2 families (Lycosidae and Linyphiidae) from the fresh swamp ecosystems and 5 families (Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae) from the tidal lowland ecosystems (Table 3). We did not find Araneidae, Thomisidae, and Theridiidae at the fresh swamp ecosystems. The most dominant family of soil-dwelling spiders found during the rice vegetative stage was Lycosidae and the most dominant species was *Pardosa pseudoannulata.* A total of soil-dwelling spider species found were 9 species at the fresh swamp ecosystems and 16 species at tidal lowland ecosystems. Nonetheless, species richness of the soil-dwelling spider at the fresh swamp ecosystems were not significantly different (P = 0.5290) from those at the tidal lowland ecosystems.

A total of the soil-dwelling spider families found during generative stage of rice were 3 families (Lycosidae, Araneidae, and Linyphiidae) from the fresh swamp ecosystems and 4 families (Lycosidae, Araneidae, Linyphiidae, and Salticidae) from the tidal lowland ecosystems (Table 4). The most dominant family of the soil dwelling spiders found was Lycosidae. The species numbers of soil-dwelling spiders recorded were 8 and 12 from the fresh swamp and the tidal lowland ecosystems, respectively. Species richness of the soil-dwelling spiders during the rice generative stage at the fresh swamp ecosystems were not significantly different (P = 0.9813) from those at the tidal lowland ecosystems. A total of abundance of soil-dwelling spiders at the fresh swamp ecosystems were also not significantly different from those at the tidal lowland ecosystems (P = 0.2950).

DISCUSSION

Spider families found on rice canopy at fresh swamp and tidal lowland ecosystems during the rice vegetative and generative stages in this study consisted of Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae. These arboreal spiders found comprised both web- (Araneidae, Tetragnathidae, Linyphiidae, Theridiidae) and active-hunting (Oxyopidae, Thomisidae, and Salticidae) species, commonly found at the fresh swamp or tidal lowland ecosystems (Schmidt & Tscharntke, 2005). Abundance of species belonging to Tetragnathidae (*T. vermiformis*) and Oxyopidae (*O. bikakaeus*) at the fresh swamp ecosystems in this study were significantly higher than those at the tidal lowland ecosystems. Tetragnathidae and Oxyopidae are more dominant spiders at wetland ecosystems (Betz & Tscharntke, 2017) because the fresh swamp ecosystems are commonly submerged longer (more than 6 mounts) than those at the tidal lowland ecosystems (Mulyani & Sarwani, 2013).

Spider family, Tetragnathidae in this study was the most dominant family of the arboreal spider found during the rice vegetative and generative stages. Species of arboreal spiders dominantly found on paddies at the fresh swamp and tidal lowland ecosystems were similar which consisted of *T. virescens* and *T. javana*. Barrion et al. (2012) stated that in the species of Tetragnathidae, such as species of *T. virescens* and *T. javana* were classified as keystone species. Such species were playing a critical role in maintaining population of rice pest insect, such leafhopper (Betz & Tscharntke, 2017). Species from Tetragnathidae was reported by Shepard *et al.* (1987) and Betz and Tscharntke (2017) as dominant web spiders found at wetland ecosystems. The number of Tetragnathidae in this study were more abundant at the rice vegetative stage than those at the rice generative stage. Betz and Tscharntke (2017) stated that abundant of Tetragnathidae was influenced by the number of leafhoppers (Homoptera) which are commonly occured at vegetative stage of rice. The both species of spiders are predators of rice pest insects, such as order of Homoptera and Lepidoptera (Tahir *et al*., 2009). This also accords with findings of Betz and Tscharntke (2017), which showed highest increase of Tetragnathidae with increasing abundance of Lepidoptera and leafhoppers.

Species abundance of arboreal spiders either at the fresh swamp and tidal lowland ecosystems were higher at vegetative stage of rice than those at generative stage of rice because spider abundance is closely related to their prey population (Riechert & Lockley, 1984). Abundant prey population will attract these spiders to assemble on prey rich ecosystems (Widiarta *et al.*, 2006). The main prey for this spiders was rice insect pests, such as brown planthoppers (Karindah, 2011) that had higher population at vegetative stage of rice than that during generative stage of rice resulting in higher abundance of spiders at the vegetative stage of rice than that of the generative stage of rice. According to Arofah *et al.* (2013) dominant insect pests at vegetative stage of rice were planthoppers, whereas dominant insect pest at generative stage of rice was rice bugs. Thus, rice stages at both ecosystems affects the species abundance of spiders.

Spider families found on soil surface of the fresh swamp ecosystems only consisted of Lycosidae and Linyphiidae, whereas Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae, and Salticidae were found at the tidal lowland ecosystems. Web spiders, such as Araneidae, Linyphiidae, and Theridiidae could be found on soil surface. This was due to the fact that these spiders were found on immature stage. According to Iida and Fujisaki (2007) and Suana and Haryanto (2013), immature web spiders had capability to produce small like ballon ball so that they could be moved by wind or moving to other places or descend upon or fallen on soil surface.

A total of abundance and species richness of soil-dwelling spiders during the rice vegetative and generative stages at the fresh swamp ecosystems were not significantly different from those at the tidal lowland ecosystems. Nonetheless, the most dominant family of the soil-dwelling spiders was Lycosidae and the most dominant species was *P. pseudoannulata*. Barrion *et al.* (2012) list some species in the Lycosid family, such as wolf spider, *P. pseudoannulata* as keystone species. This wolf spider plays the role of a keystone predator within this rice ecosystem by preying leafhoppers (Lou *et al.* 2013). High mobility of the wolf spiders allow them to move and to run or to jump for capturing their preys (Ishijima *et al*., 2006). Abundance of Lycosidae during the rice generative stage at the fresh swamp ecosystems was higher than that at the tidal lowland ecosystems. One explanation why the abundance of Lycosidae was higher at the fresh swamp ecosystems is because farmers culturally do not apply synthetic insecticides to control pest insects. Herlinda (2010) reported that application of the synthetic insecticides at the fresh swamp ecosystems in South Sumatra was rare. Such ecosystems tend to produce high diversity of invertebrate fauna (Mahrub, 1999; Rizali *et al.*, 2002). Rice ecosystems without synthetic insecticides application had higher dominance of predatory arthropods, especially spiders (Herlinda *et al.*, 2008; Herlinda *et al.*, 2004; Zi-yang *et al.*, 2011).

CONCLUSION

The most dominant family and species of the arboreal spiders found were Tetragnathidae and *T. virescens*, respectively, while the most dominant family and species of the soil-dwelling spiders were Lycosidae and *P. pseudoannulata*, respectively. Species richness of the arboreal and soil-dwelling spiders during the rice vegetative and generative stages at the fresh swamp ecosystems was not significantly different from those at the tidal lowland ecosystems. This findings of the study suggest that the specific and eco-friendly planting methods at the fresh swamp and tidal lowland ecosystems supports existence of Tetragnathidae and Lycosidae, keystone predators of rice pest insects.

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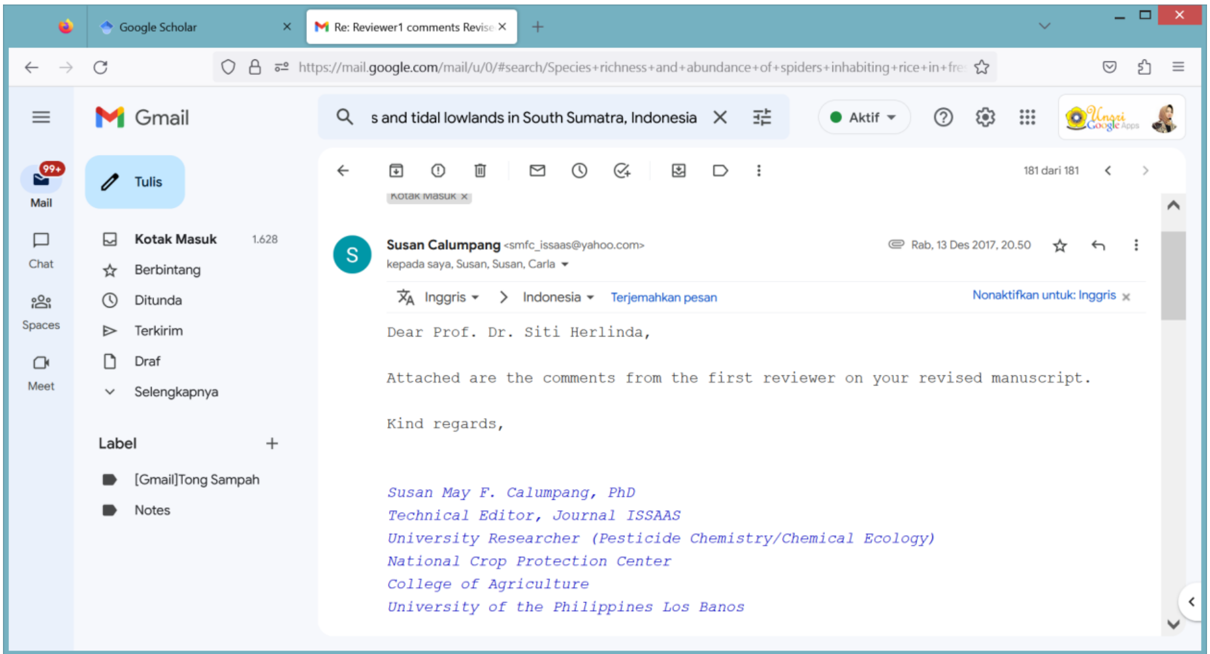
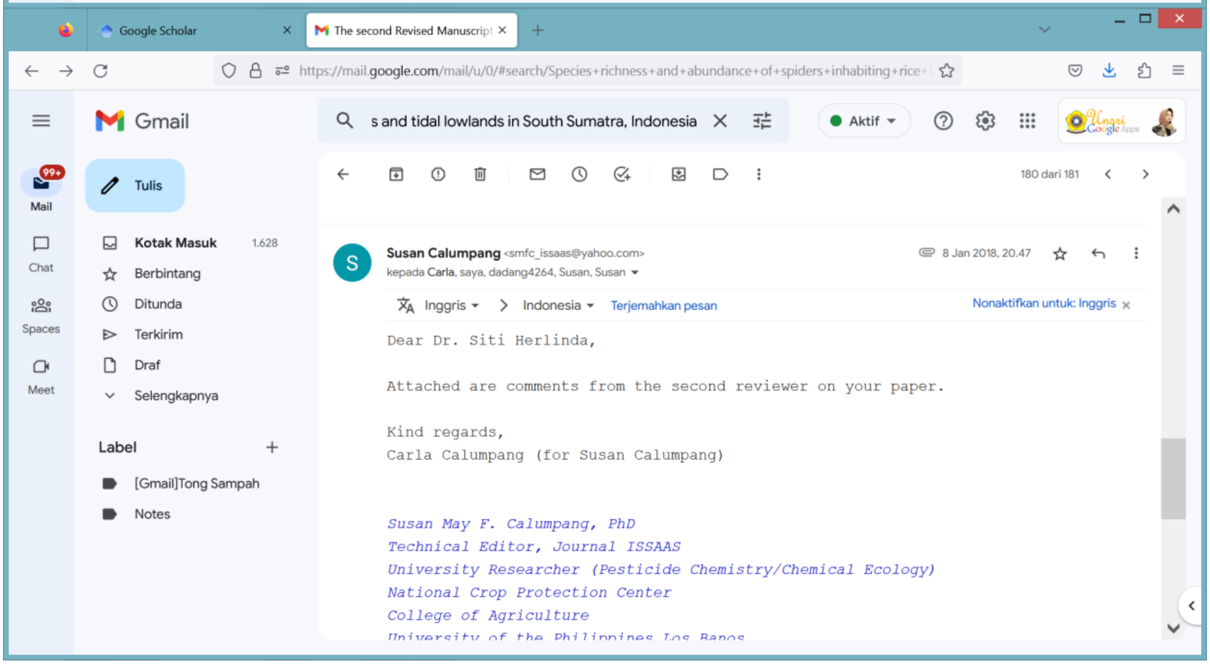
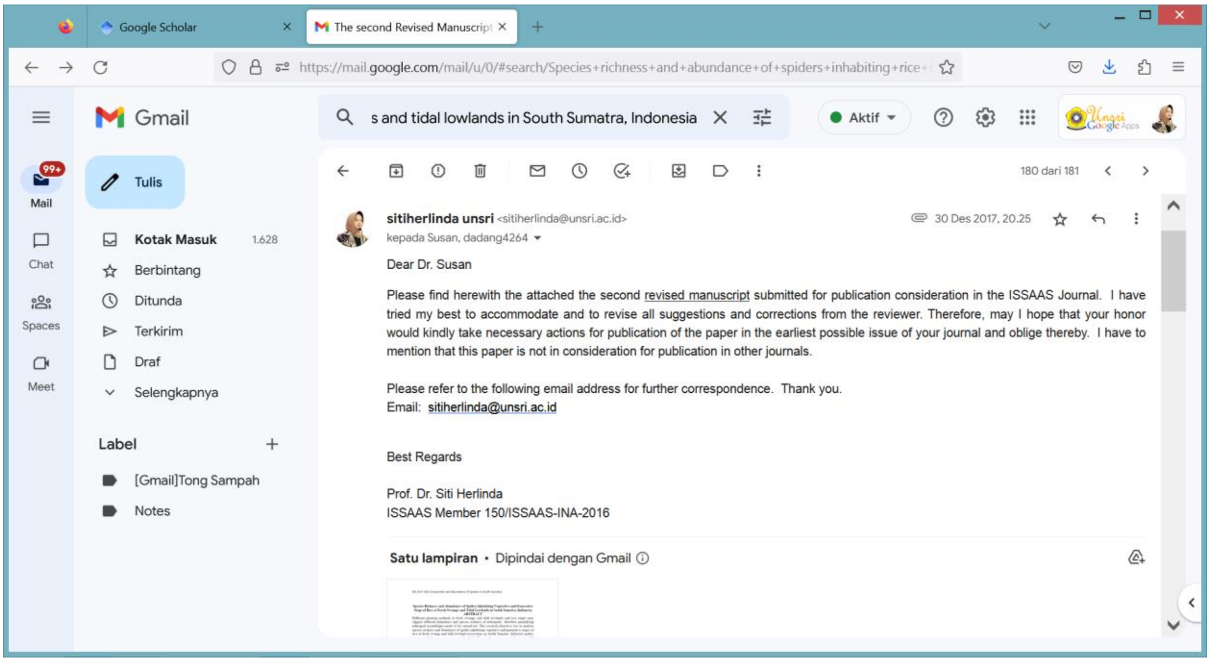
1. Bukti konfirmasi review pertama dan hasil revisi pertama







Species Richness and Abundance of Spiders Inhabiting Vegetative and Generative Stage of Rice at Fresh Swamps and Tidal Lowlands in South Sumatra, Indonesia

ABSTRACT

Different planting methods at fresh swamps and tidal lowlands and rice stages may support different abundance and species richness of arthropods therefore quantifying arthropod assemblages needs to be carried out. This research objective was to analyze species richness and abundance of spiders inhabiting vegetative and generative stages of rice at fresh swamp and tidal lowland ecosystems in South Sumatra. Arboreal spiders were sampled using sweep nets, and soil-dweller spiders were sampled using pitfall traps at the vegetative and generative stages of rice. Families of the arboreal spiders found during the vegetative and generative stages of rice from both ecosystems were Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae and Salticidae. The most dominant family and species of the arboreal spiders found were Tetragnathidae and *Tetragnatha virescens*, respectively. Species richness of the arboreal spider during the vegetative ($P = 0.186$) and generative ($P = 0.807$) stages at the fresh swamp ecosystems was not significantly different from that at the tidal lowland ecosystems. Families of soil-dweller spiders found during the vegetative and generative stages were Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae, and Salticidae. The most dominant family and species of the soil-dweller spiders found were Lycosidae and *Pardosa pseudoannulata*, respectively. Species richness of the soil-dweller spiders during the rice vegetative (P = 0.529) and generative (P = 0.981) stages at the fresh swamps was not significantly different from that at the tidal lowlands. This study suggest that the specific and eco-friendly planting methods at the fresh swamp and tidal lowland ecosystems supports existence of Tetragnathidae and Lycosidae, keystone predators of rice pest insects.

Keywords: arboreal, arthropod, rice field, soil-dweller

INTRODUCTION

Wetlands in Indonesia, are characterized by two distinct ecosystems, differentiated based on sea tide influence; i.e. tidal lowlands for those directly influenced by sea tide but fresh swamps for those not affected by sea tide (Mulyani & Sarwani, 2013). At the tidal lowland ecosystems, soil needs specific handling due to thick pyritic layers therefore it should be preserved (Hidayat *et al*., 2010). The local farmers do not fully manage the soil to prevent the pyrite layers from destructions (Suriadikarta *et al*., 2013) and they generally plant rice twice a year (planting index) by using broadcast seeding, drum seeding, or seedling in a digged-hole ("tugal") (Raharjo *et al*., 2013). Contrary to the farmers at the tidal lowlands, farmers at fresh swamps usually plant rice using transplanting system and they only plant rice once a year (Mulyani & Sarwani, 2013; Lakitan *et al*., 2018). Different rice planting methods and index at the both ecosystems may also affect the arthropod abundance and species diversity or richness (Zhang *et al*., 2013; Parry *et al.*, 2015). Weedy paddies at direct planting ecosystems have more abundant arthropods than those at clean ecosystems (Hu *et al.*, 2012). No soil tillage or conservation tillage at paddies also support higher arthropod abundance (Pereira *et al*., 2010). No application of synthetic insecticides at fresh swamp ecosystems also enhances abundance of predatory arthropods, especially spiders (Herlinda *et al.*, 2004; Herlinda *et al.*, 2008).

In addition to planting method and index, vegetative and generative stages of rice also influence species richness and abundance of the arthropods (Herlinda *et al*. 2008). At the vegetative and generative stages, soil- dweller arthropods are more abundant and more diverse at the tidal lowlands than those at the fresh swamp ecosystems (Khodijah *et al.*, 2012; Herlinda *et al.*, 2014). However, the arboreal artropods are more abundant and richer at the fresh swamp ecosystems than those at the tidal lowland ecosystems (Khodijah *et al.*, 2012; Sunariah *et al.*, 2016). Different planting methods and index at the both ecosystems and different stages of rice may support different abundance and species richness of arthropods, therefore quantifying arthropod assemblages needs to be carried out. The purpose of this study was to analyze species richness and abundance of spiders inhabiting vegetative and generative stages of rice at fresh swamps and tidal lowlands in South Sumatra.

MATERIAL AND METHODS

Study Site

Surveys were carried out at rice production centers of fresh swamps and tidal lowlands in South Sumatra throughout February 2012 and March 2013. Survey locations of the rice production centers for fresh swamp ecosystems were: (1) Gandus, Palembang City; (2) Pelabuhan Dalam Village of Ogan Ilir District; (3) Maryana Village of Banyuasin District; and (4) Sungai Waru Village of Kabupaten Banyuasin District. Survey locations of the rice production centers for tidal lowlands were: (1) Banyu Urip Village of Tanjung Lago Subdistrict, Banyuasin District' (2) Telang Karya Village of Muara Telang Subdistrict, Banyuasin District; (3) Telang Rejo Village of Muara Telang Subdistrict, Banyuasin District; (4) Srikaton Damai Village of Air Saleh Subdistrict, Banyuasin District; (5) Srimulyo Village of Kecamatan Air Saleh Subdistrict, Banyuasin District; (6) Makarti Jaya Village of Makarti

Jaya Subdistrict, Banyuasin District; (7) Tirta Mulya Village of Makarti Jaya Subdistrict, Banyuasin District; and (8) Tirta Kencana Village of Makarti Jaya Subdistrict, Banyuasin District. In each location, three sampling plots with a minimum size of 1 ha were surveyed twice during one rice season (4 mounts). The first survey was done when rice crop was 4 weeks old and the second one when rice crop was at milk grain stage (9 weeks old). Rice variety used at the fresh swamps was Ciherang, whereas Inpara variety was used at the tidal lowland ecosystems.

Sampling

Arboreal spiders. The arboreal spiders were sampled using sweep nets, following methods used by Herlinda *et al.* (2014). Net sweeping consisted of 'double swings', totalling 30 swings/ha in all plots.

Soil-dweller spiders. Soil-dweller spiders were sampled using pitfall traps, following methods used by Herlinda *et al*. (2004). Plastic pitfall traps (60 mm in diameter and 90 mm in height) were filled to a volume of 70 mL with 4% formaldehide solution and buried in the ground flush with the soil surface. Traps were installed with density of 18 units/ha , spaced in a grid 3 x 6, then collected after 48 hours. All specimens collected were cleaned and sorted from other debris and stored in vials containing 70% ethanol. Identification to family- and species-level was carried out at Laboratory of Entomology, at the Plant Pest and Disease Department, College of Agriculture, Universitas Sriwijaya, using taxonomic keys provided in Barrion and Litsinger (1995).

Data Analysis

The spider abundance data between samples from the fresh swamp and tidal lowland ecosystems were not normally distributed. Hence, insect counts in this study were found to fit a negative binomial distribution and were analyzed by Proc Genmod using SAS University

Edition (SAS Institute Inc., Cary, NC, U.S.A.). Species richness was analysed using Menhinick's index (D) (Magurran, 1988).

RESULTS

Arboreal Spiders at Fresh Swamp and Tidal Lowland Ecosystems

From this survey during rice vegetative stage, a total of seven families of arboreal spiders found were Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae and Salticidae at the fresh swamp and tidal lowland ecosystems (Table 1). Tetragnathidae was the most dominant family of the arboreal spider found during the rice vegetative stage. A total of 92.750 spiders/30 nets at the fresh swamp ecosystems and 62.875 spiders/30 nets at the tidal lowland ecosystems were captured (P = 0.312). The abundance of *Tetragnatha vermiformis* (P = 0.001) and *Oxyopes bikakaeus* (P = 0.007) at the fresh swamp ecosystems were significantly higher than those at the tidal lowland ecosystems. A total of the arboreal spider species found during the rice vegetative stage were 26 species from the fresh swamp ecosystems and 23 species from the tidal lowland ecosystem. Spider species richness at the fresh swamp ecosystems was not significantly different (P = 0.186) from those at the tidal lowland ecosystems.

A total of spider families found during rice generative stage were only five families (Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae and Salticidae) at the fresh swamp ecosystems and seven families (Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae) at the tidal lowland ecosystems (Table 2). However, abundance of Araneidae (P = 0.803), Tetragnathidae (P = 1.000), Linyphiidae (P = 0.720), Oxyopidae (P = 0.096), Thomisidae (P = 1.000), Theridiidae (P = 1.0000), and Salticidae (P = 0.6336) at the fresh swamp ecosystems were not significantly different from those at the tidal lowland ecosystems. The most dominant family of the arboreal spiders found on the both ecosystems was Tetragnathidae. A total of spider abundance for all species at the fresh swamp ecosystems (47.750 spiders/30 nets) were not significantly different (P = 0.521) from those at the tidal lowland ecosystems (54.250 spiders/30 nets). However, average of spider abundance from the both ecosystems was significantly different (P = 0.000). The most dominant arboreal species found on the both ecosystems was *Tetragnatha virescens.* A total of arboreal spider species recorded were 16 species from the fresh swamp ecosystems and 21 species from the tidal lowland ecosystem. However, the arboreal spider species richness at the fresh swamp ecosystems were not also significantly different (P = 0.8067) from those at the tidal lowland ecosystems.

Soil-dweller Spiders at Fresh Swamps and Tidal Lowlands

At vegetative stage of rice, soil-dweller spiders found were only two families (Lycosidae and Linyphiidae) from the fresh swamp ecosystems and five families (Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae) from the tidal lowland ecosystems (Table 3). We did not find Araneidae, Thomisidae, and Theridiidae at the fresh swamp ecosystems. The most dominant family of soil-dweller spiders found during the rice vegetative stage was Lycosidae and the most dominant species was *Pardosa pseudoannulata.* A total of soil-dweller spider species found were nine species at the fresh swamp ecosystems and 16 species at tidal lowland ecosystems. Nonetheless, species richness of the soil-dweller spider at the fresh swamp ecosystems were not significantly different (P = 0.5290) from those at the tidal lowland ecosystems.

A total of the soil-dweller spider families found during generative stage of rice were three families (Lycosidae, Araneidae, and Linyphiidae) from the fresh swamp ecosystems and four families (Lycosidae, Araneidae, Linyphiidae, and Salticidae) from the tidal lowland ecosystems (Table 4). The most dominant family of the soil-dweller spiders found was Lycosidae. The species numbers of soil-dweller spiders recorded were eight and 12 from the fresh swamp and the tidal lowland ecosystems, respectively. Species richness of the soil-dweler spiders during the rice generative stage at the fresh swamp ecosystems were not significantly different (P = 0.981) from those at the tidal lowland ecosystems. A total of abundance of soil-dweller spiders at the fresh swamp ecosystems were also not significantly different from those at the tidal lowland ecosystems (P = 0.295).

DISCUSSION

Spider families found on rice canopy at fresh swamp and tidal lowland ecosystems during the rice vegetative and generative stages in this study consisted of Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae. These arboreal spiders found comprised both web-building (Araneidae, Tetragnathidae, Linyphiidae, Theridiidae) and non-web building (Oxyopidae, Thomisidae, and Salticidae) species, commonly found at the fresh swamp or tidal lowland ecosystems (Schmidt & Tscharntke, 2005). Abundance of species belonging to Tetragnathidae (*T. vermiformis*) and Oxyopidae (*O. bikakaeus*) at the fresh swamp ecosystems in this study were significantly higher than those at the tidal lowland ecosystems. Tetragnathidae and Oxyopidae are more dominant spiders at wetland ecosystems (Betz & Tscharntke, 2017) because the fresh swamp ecosystems are commonly submerged longer (more than 6 mounts) than those at the tidal lowland ecosystems (Mulyani & Sarwani, 2013).

Spider family, Tetragnathidae in this study was the most dominant family of the arboreal spider found during the rice vegetative and generative stages. Species of arboreal spiders dominantly found on paddies at the fresh swamp and tidal lowland ecosystems were similar which consisted of *T. virescens* and *T. javana*. Barrion et al. (2012) stated that in the species of Tetragnathidae, such as species of *T. virescens* and *T. javana* were classified as keystone species. Such species were playing a critical role in maintaining population of rice pest insect, such leafhopper (Betz & Tscharntke, 2017). Species from Tetragnathidae was reported by Shepard *et al.* (1987) and Betz and Tscharntke (2017) as dominant web spiders found at wetland ecosystems. The number of Tetragnathidae in this study were more abundant at the rice vegetative stage than those at the rice generative stage. Betz and Tscharntke (2017) stated that abundant of Tetragnathidae was influenced by the number of leafhoppers (Homoptera) which are commonly occured at vegetative stage of rice. The both species of spiders are predators of rice pest insects, such as order of Homoptera and Lepidoptera (Tahir *et al*., 2009). This also accords with findings of Betz and Tscharntke (2017), which showed highest increase of Tetragnathidae with increasing abundance of Lepidoptera and leafhoppers.

Species abundance of arboreal spiders either at the fresh swamp and tidal lowland ecosystems were higher at vegetative stage of rice than those at generative stage of rice because spider abundance is closely related to their prey population (Riechert & Lockley, 1984). Abundant prey population will attract these spiders to assemble on prey rich ecosystems (Widiarta *et al.*, 2006). The main prey for this spiders was rice insect pests, such as brown planthoppers (Karindah, 2011) that had higher population at vegetative stage of rice than that during generative stage of rice resulting in higher abundance of spiders at the vegetative stage of rice than that of the generative stage of rice. According to Arofah *et al.* (2013) dominant insect pests at vegetative stage of rice were planthoppers, whereas dominant insect pest at generative stage of rice was rice bugs. Thus, rice stages at both ecosystems affects the species abundance of spiders.

Spider families found on soil surface of the fresh swamp ecosystems only consisted of Lycosidae and Linyphiidae, whereas Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae, and Salticidae were found at the tidal lowland ecosystems. Web spiders, such as Araneidae, Linyphiidae, and Theridiidae could be found on soil surface. This was due to the fact that these spiders were found on immature stage. According to Iida and Fujisaki (2007) and Suana and Haryanto (2013), immature web spiders had capability to produce small like balloon ball so that they could be moved by wind or moving to other places or descend upon or fallen on soil surface.

A total of abundance and species richness of soil-dweller spiders during the rice vegetative and generative stages at the fresh swamp ecosystems were not significantly different from those at the tidal lowland ecosystems. Nonetheless, the most dominant family of the soil-dweller spiders was Lycosidae and the most dominant species was *P. pseudoannulata.* Barrion *et al.* (2012) list some species in the Lycosid family, such as wolf spider, *P. pseudoannulata* as keystone species. This wolf spider plays the role of a keystone predator within this rice ecosystem by preying leafhoppers (Lou *et al.* 2013). High mobility of the wolf spiders allow them to move and to run or to jump for capturing their preys (Ishijima *et al*., 2006). Abundance of Lycosidae during the rice generative stage at the fresh swamp ecosystems was higher than that at the tidal lowland ecosystems. One explanation why the abundance of Lycosidae was higher at the fresh swamp ecosystems is because farmers culturally do not apply synthetic insecticides to control pest insects. Herlinda (2010) reported that application of the synthetic insecticides at the fresh swamp ecosystems in South Sumatra was rare. Such ecosystems tend to produce high diversity of invertebrate fauna (Mahrub, 1999; Rizali *et al.*, 2002). Rice ecosystems without synthetic insecticides application had higher dominance of predatory arthropods, especially spiders (Herlinda *et al.*, 2008; Herlinda *et al.*, 2004; Zi-yang *et al.*, 2011).

CONCLUSION

The most dominant family and species of the arboreal spiders found were Tetragnathidae and *T. virescens*, respectively, while the most dominant family and species of the soil-dweller spiders were Lycosidae and *P. pseudoannulata*, respectively. Species richness of the arboreal and soil-dweller spiders during the rice vegetative and generative stages at the fresh swamp ecosystems was not significantly different from those at the tidal lowland ecosystems. This findings of the study suggest that the specific and eco-friendly planting methods at the fresh swamp and tidal lowland ecosystems supports existence of Tetragnathidae and Lycosidae, keystone predators of rice pest insects.

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Table 1. The comparison of arboreal spider abundance found on vegetative stage of rice at fresh swamps and tidal lowlands in South Sumatra

No.	Family. and Species	Average spider abundance (per 30 nets)		$P_{value\ (0.05)}$
		Fresh Swamps	Tidal Lowlands	
	Araneidae	6.500	2.750	0.152
1.	*Araneus inustus*	1.500	0.625	0.303
2.	*Cylosa insulana*	1.750	0.750	0.241
3.	*Cylosa mulmeinensis*	0.500	0.000	0.225
4.	*Gea subarmata*	2.750	1.375	0.550
	Tetragnathidae	54.250	32.750	0.175
5.	*Tetragnatha javana*	8.250	12.000	0.495
6.	*Tetragnatha virescens*	21.000	8.875	0.107
7.	*Tetragnatha mandibulata*	8.500	8.500	1.000
8.	*Tetragnatha ilavaca*	1.000	0.125	0.089
9.	*Tetragnatha maxillosa*	3.000	1.500	0.500
10.	*Tetragnatha desaguni*	1.250	0.750	0.676
11.	*Tetragnatha vermiformis*	8.250	0.750	0.001*
12.	*Tetragnatha okumae*	1.750	0.000	1.000
13.	*Dyschiriognatha hawigtenera*	1.250	0.250	0.202
	Linyphiidae	8.750	9.375	0.944
14.	*Bathyphantes tagalogensis*	4.750	7.125	0.687
15.	*Atypena adelinae*	3.250	2.250	0.773
16.	*Erigone bifurca*	0.750	0.000	1.000
	Oxyopidae	18.000	13.875	0.616
17.	*Oxyopes javanus*	6.250	7.250	0.843
18.	*Oxyopes matiensis*	5.750	6.250	0.842
19.	*Oxyopes bikakaeus*	3.250	0.125	0.007*
20.	*Oxyopes pingasus*	2.750	0.250	0.118
	Thomisidae	0.750	0.750	1.000
21.	*Diaea tadtadtinika*	0.500	0.500	1.000
22.	*Stiphropus sangayus*	0.250	0.250	1.000
	Theridiidae	0.250	0.250	1.000
23.	*Coleosoma octomaculatum*	0.250	0.000	0.364
24.	*Theridion* sp.	0.000	0.250	0.495
	Salticidae	4.250	3.125	0.753
25.	*Myrmarachne bidentata*	0.500	0.250	0.677
26.	*Simaetha damongpalaya*	3.000	0.750	0.422
27.	*Hyllus maskaranus*	0.750	2.125	0.479
	Total of Abundance (N)	92.750	62.875	0.312
	Average of Abundance	13.250	8.982	0.309
	Species Richness (D)	1.700	1.195	0.186

*= significantly different

Table 2. The comparison of arboreal spider abundance found on generative stage of rice at fresh swamp and tidal lowland in South Sumatra

No.	Family. and Species	Average spider abundance (per 30 nets)	$P_{value\ (0.05)}$

		Fresh Swamps	Tidal Lowlands	
	Araneidae	5.000	4.500	0.803
1.	*Araneus inustus*	0.750	1.125	0.481
2.	*Cylosa insulana*	1.000	0.500	0.327
3.	*Cylosa mulmeinensis*	0.750	0.125	0.260
4.	*Gea subarmata*	2.500	2.750	0.912
	Tetragnathidae	26.000	26.000	1.000
5.	*Tetragnatha javana*	7.250	7.250	1.000
6.	*Tetragnatha virescens*	7.250	7.750	0.548
7.	*Tetragnatha mandibulata*	3.500	4.375	0.548
8.	*Tetragnatha ilavaca*	0.000	0.875	1.000
9.	*Tetragnatha maxillosa*	0.500	1.125	0.320
10.	*Tetragnatha desaguni*	0.000	0.000	1.000
11.	*Tetragnatha vermiformis*	6.750	4.625	0.188
12.	*Tetragnatha okumae*	0.750	0.000	1.000
13.	*Dyschiriognatha hawigtenera*	0.000	0.000	1.000
	Linyphiidae	6.250	4.750	0.720
14.	*Bathyphantes tagalogensis*	3.250	0.875	0.115
15.	*Atypena adelinae*	3.000	3.875	0.723
16.	*Erigone bifurca*	0.000	0.000	1.000
	Oxyopidae	8.500	15.625	0.096
17.	*Oxyopes javanus*	3.750	7.625	0.058
18.	*Oxyopes matiensis*	4.750	6.125	0.558
19.	*Oxyopes bikakaeus*	0.000	1.250	1.000
20.	*Oxyopes pingasus*	0.000	0.625	1.000
	Thomisidae	0.000	0.375	1.000
21.	*Diaea tadtadtinika*	0.000	0.250	1.000
22.	*Stiphropus sangayus*	0.000	0.125	1.000
	Theridiidae	0.000	0.250	1.000
23.	*Coleosoma octomaculatum*	0.000	0.250	1.000
24.	*Theridion* sp.	0.000	0.000	1.000
	Salticidae	2.000	2.750	0.634
25.	*Myrmarachne bidentata*	0.000	0.250	0.495
26.	*Simaetha damongpalaya*	1.250	2.500	0.560
27.	*Hyllus maskaranus*	0.750	0.000	1.000
	Total of Abundance (N)	47.750	54.250	0.521
	Average of Abundance	6.821	1.417	0.000*
	Species Richness (D)	1.467	1.573	0.807

*= significantly different

Table 3. The comparison of soil-dweller spider abundance found on vegetative stage of rice at fresh swamp and tidal lowland in South Sumatra

No.	Family. and Species	Average spider abundance (per 18 traps)		$P_{value\ (0.05)}$
		Fresh Swamps	Tidal Lowlands	
	Lycosidae	24.250	22.125	0.664
1.	*Pardosa pseudoannulata*	17.000	14.625	0.618
2.	*Pardosa sumatrana*	3.750	2.625	0.177
3.	*Pardosa birmanica*	0.750	0.625	0.836
4.	*Pardosa mackenziei*	0.500	1.875	0.135

5.	*Pardosa patapensis*	0.250	0.000	0.364
6.	*Hogna rizali*	0.000	1.750	1.000
7.	*Arctosa tanakai*	2.000	0.625	0.244
	Araneidae	0.000	1.625	1.000
8.	*Araneus inustus*	0.000	0.500	1.000
9.	*Cylosa insulana*	0.000	0.875	1.000
10.	*Gea subarmata*	0.000	0.250	1.000
	Linyphiidae	5.000	1.250	1.000
11.	*Bathyphantes tagalogensis*	2.500	0.250	0.009
12.	*Atypena adelinae*	2.000	0.500	0.112
13.	*Erigone bifurca*	0.500	0.500	1.000
	Thomisidae	0.000	0.875	1.000
14.	*Diaea tadtadtinika*	0.000	0.750	1.000
15.	*Stiphropus sangayus*	0.000	0.125	1.000
	Theridiidae	0.000	0.375	1.000
16.	*Coleosoma octomaculatum*	0.000	0.125	1.000
17.	*Theridion* sp.	0.000	0.250	1.000
	Salticidae	0.000	0.000	1.000
18.	*Hyllus maskaranus*	0.000	0.000	1.000
	Total of Abundance (N)	29.250	26.250	0.451
	Average of Abundance	4.875	4.375	0.466
	Species Richness (D)	0.983	1.272	0.529

*= significantly different

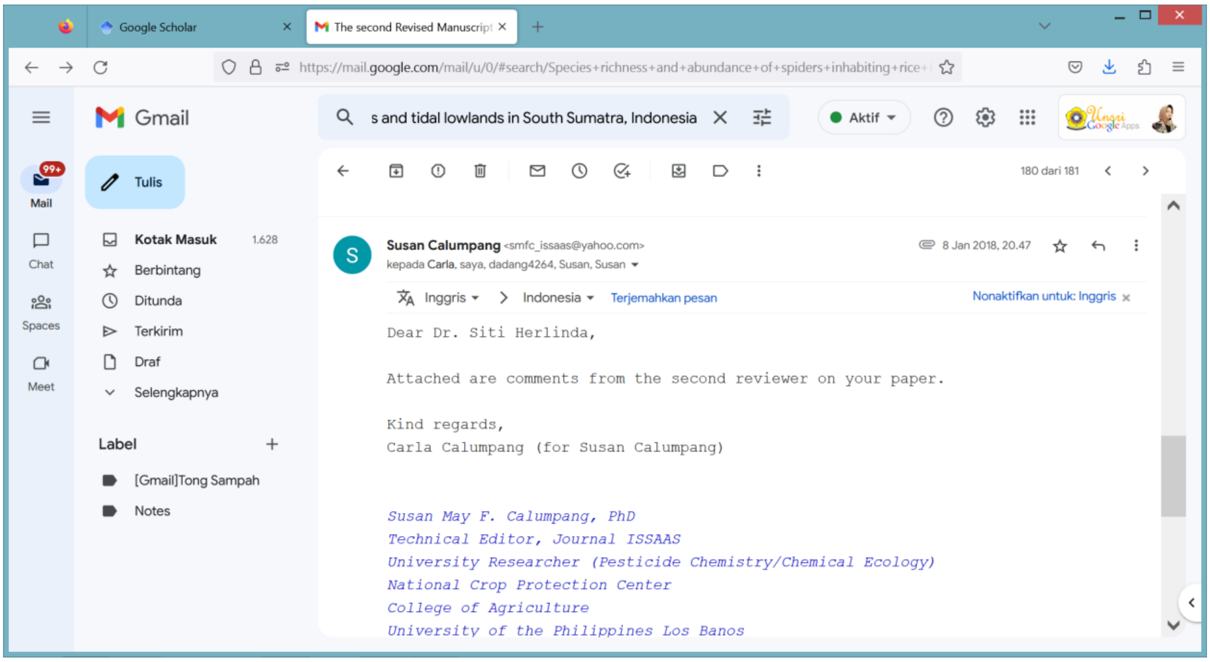
Table 4. The comparison of soil-dweller spider abundance found on generative stage of rice at fresh swamp and tidal lowland in South Sumatra

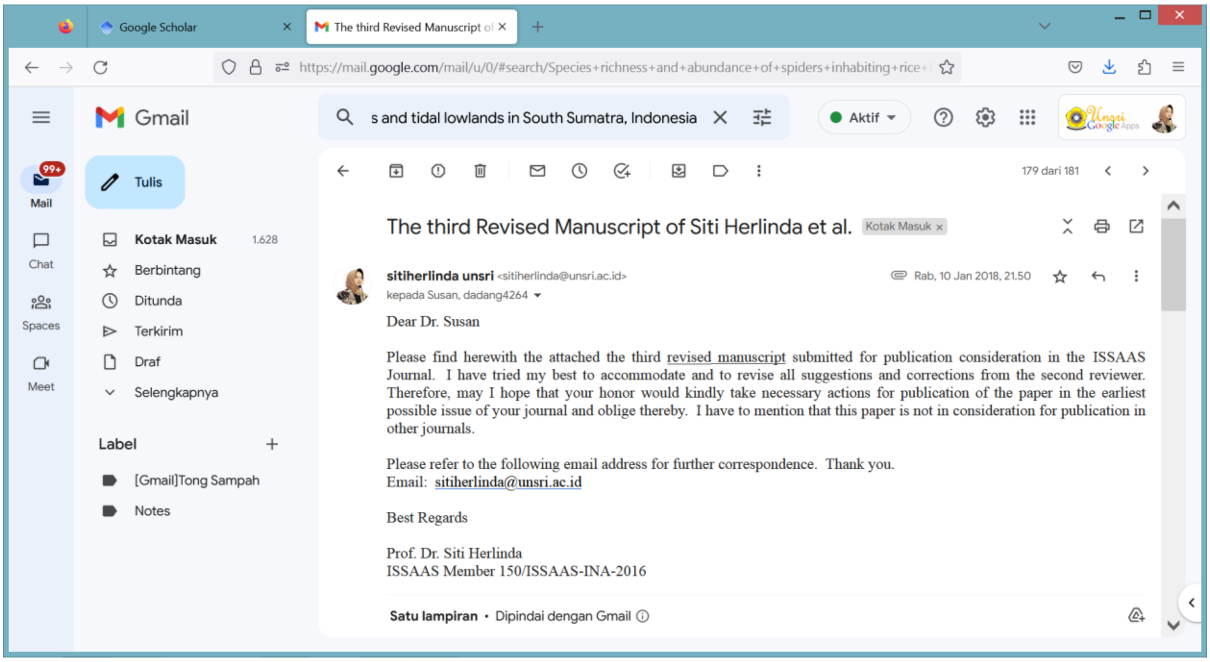
No.	Family. and Species	Average spider abundance (per 18 traps)		$P_{value (0.05)}$
		Fresh Swamps	Tidal Lowlands	
	Lycosidae	27.250	20.000	0.041*
1.	*Pardosa pseudoannulata*	15.750	12.250	0.326
2.	*Pardosa sumatrana*	5.500	5.125	0.699
3.	*Pardosa birmanica*	0.500	0.500	1.000
4.	*Pardosa mackenziei*	0.000	0.000	1.000
5.	*Pardosa patapensis*	0.000	0.625	1.000
6.	*Hogna rizali*	1.500	0.250	0.141
	Arctosa tanakai	4.000	1.250	0.012*
7.	**Araneidae**	0.000	0.250	0.495
8.	*Araneus inustus*	0.000	0.125	0.742
9.	*Cylosa insulana*	0.000	0.000	1.000
	Gea subarmata	0.000	0.125	0.742
10.	**Linyphiidae**	4.500	4.875	0.936
11.	*Bathyphantes tagalogensis*	3.000	2.250	0.753
12.	*Atypena adelinae*	1.250	2.250	0.532
	Erigone bifurca	0.250	0.375	0.715
13.	**Thomisidae**	0.000	0.000	1.000
14.	*Diaea tadtadtinika*	0.000	0.000	1.000
	Stiphropus sangayus	0.000	0.000	1.000
15.	**Theridiidae**	0.000	0.000	1.000
16.	*Coleosoma octomaculatum*	0.000	0.000	1.000

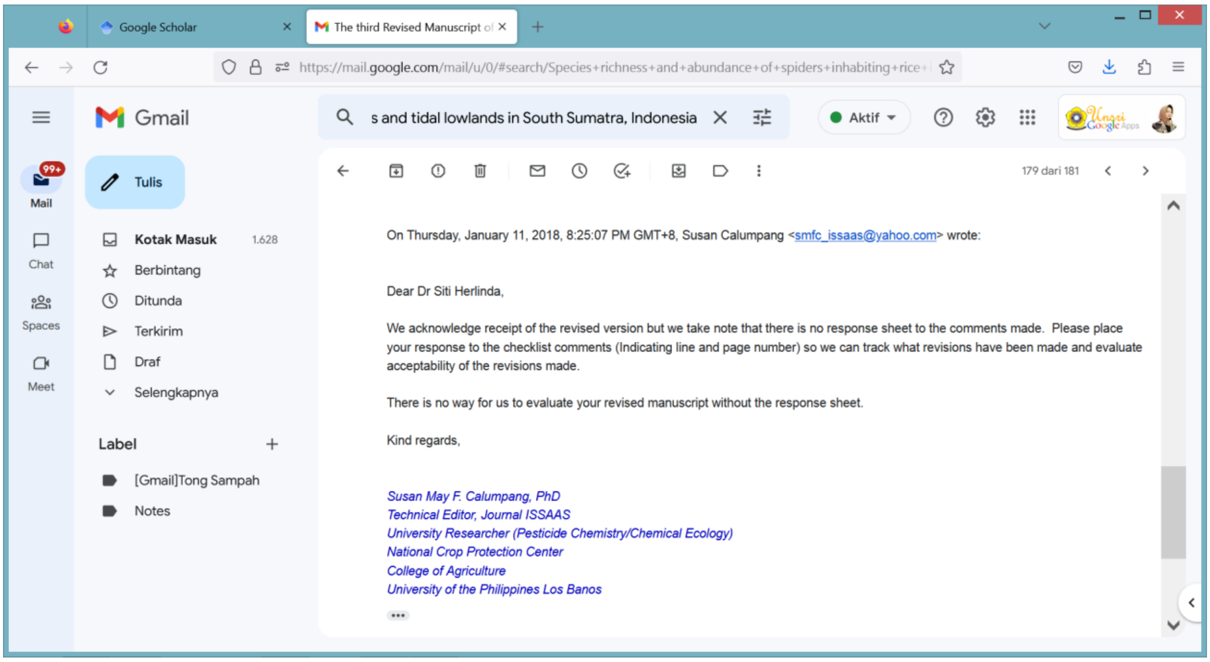
	Theridion sp.	0.000	0.000	1.000
17.	**Salticidae**	0.000	0.125	0.742
	Hyllus maskaranus	0.000	0.125	0.742
	Total of Abundance (N)	31.750	25.250	0.295
	Average of Abundance	5.292	4.208	0.329
	Species Richness (D)	1.058	1.052	0.981

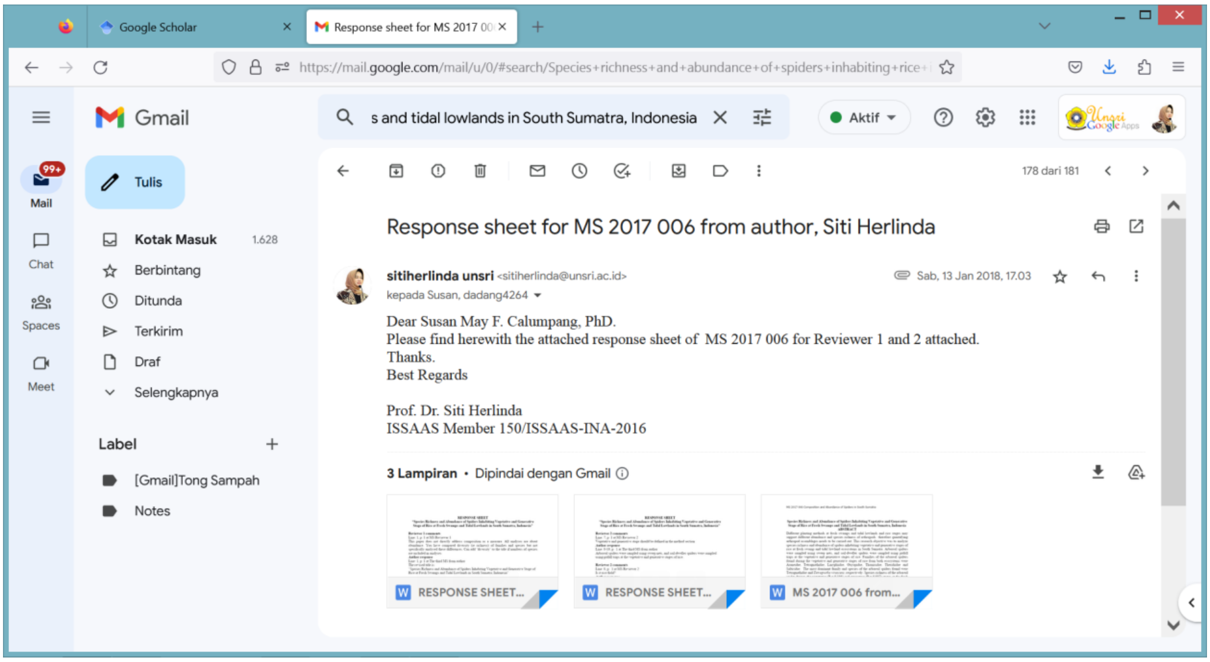
*= significantly different

3. Bukti konfirmasi review kedua dan hasil revisi kedua









RESPONSE SHEET

"Species Richness and Abundance of Spiders Inhabiting Vegetative and Generative Stage of Rice at Fresh Swamps and Tidal Lowlands in South Sumatra, Indonesia"

Reviewer 1 comments

Line: 1, p: 1 at MS Reviewer 1

This paper does not directly address composition as a measure. All analyses are about abundance. You have compared diversity (ie richness) of families and species but not specifically analysed these differences. Can add 'diversity' to the title if numbers of species are included in analyses

Author response

Line: 1, p: 1 at The third MS from author

The revised title is:

“Species Richness and Abundance of Spiders Inhabiting Vegetative and Generative Stage of Rice at Fresh Swamps and Tidal Lowlands in South Sumatra, Indonesia”

Reviewer 1 comments
Line: 5, p: 1 at MS Reviewer 1
Add sentence explaining importance of quantifying arthropod assemblages in these two ecosystems
Author response
Line: 4-5, p: 1 at The third MS from author
Different planting methods at fresh swamps and tidal lowlands and rice stages may support different abundance and species richness of arthropods therefore quantifying arthropod assemblages needs to be carried out.

Reviewer 1 comments
Line: 15-18, p: 1 at MS Reviewer 1
This sentence is confusing. I suggest it be re-worded
Author response
Line: 19-22, p: 1 at The third MS from author
Re-worded:
The most dominant family and species of the soil-dweller spiders found were Lycosidae and *Pardosa pseudoannulata*, respectively. Species richness of the soil-dweller spiders during the rice vegetative ($P = 0.529$) and generative ($P = 0.981$) stages at the fresh swamps was not significantly different from that at the tidal lowlands.

Reviewer 1 comments
Line: 21, p: 1 at MS Reviewer 1
What is the local custom?
Author response
Line: 22-23, p: 1 at The third MS from author
The revision:
“This study suggest that the specific and eco-friendly planting methods at the fresh swamp and tidal lowland ecosystems supports existence of Tetragnathidae and Lycosidae, keystone predators of rice pest insects”

Reviewer 1 comments
Line: 32, p: 2 at MS Reviewer 1
What is the ‘economical level’?
Author response
We have deleted the sentence.

Reviewer 1 comments
Line: 51-52, p: 2 at MS Reviewer 1
Need to explain why you assess assemblages in these two paddy stages and how this is relevant to the use of insecticides, which seems to be the main focus of the Introduction
Author response:
Line: 46-55, p: 1-2 at The third MS from author
We have explained it and put the ecosystems and rice stages for the main focus of the introduction, as follows:

“In addition to planting method and index, vegetative and generative stages of rice also influence species richness and abundance of the arthropods (Herlinda *et al*. 2008). At the vegetative and generative stages, soil- dweller arthropods are more abundant and more diverse at the tidal lowlands than those at the fresh swamp ecosystems (Khodijah *et al.*, 2012; Herlinda *et al.*, 2014). However, the arboreal artropods are more abundant and richer at the fresh swamp ecosystems than those at the tidal lowland ecosystems (Khodijah *et al.*, 2012; Sunariah *et al.*, 2016). Different planting methods and index at the both ecosystems and different stages of rice may support different abundance and species richness of arthropods, therefore quantifying arthropod assemblages needs to be carried out.”

Reviewer 1 comments
Line: 74-75, p: 4 at MS Reviewer 1
How many weeks following first survey, approximately?
Author response:
Line: 74-76, p: 4 at The third MS from author
the revisions made:
The first survey was done when rice crop was 4 weeks old and the second one when rice crop was at milk grain stage (9 weeks old).

Reviewer 1 comments
Line: 76, p: 4 at MS Reviewer 1
The different rice types used can surely affect the species present. Maybe good to raise this in the Discussion
Author response:
Line: 180-190, p: 9 at The third MS from author
We have raised and discussed them from Line 180, p 8 until Line 190, p 9.

Reviewer 1 comments
Line: 77, p: 4 at MS Reviewer 1
May be better to consistently use the term ‘aboreal’
Author response:
We have done it consistently

Reviewer 1 comments
Line: 96, p: 5 at MS Reviewer 1
Were traps spaced in a grid 2 x 9 or 3 x 6?
Author response:
Line: 84-85, p: 4 at The third MS from author
Traps were installed with density of 18 units/ha , spaced in a grid 3 x 6, then collected after 48 hours.

Reviewer 1 comments
Line: 105-108, p: 5 at MS Reviewer 1
Best to have this here because it applies to both sets of sampling
Author response:
We absolutely agree

Reviewer 1 comments
Line: 109, p: 5 at MS Reviewer 1

You have only analysed differences in species abundances not of species diversity nor of composition. Is this the goal?
Author response:
Line: 94-95, p: 5 at The third MS from author
Species richness was analysed using Menhinick's index (D) (Magurran, 1988).

Reviewer 1 comments
Line: 121, p: 6 at MS Reviewer 1
Habitat or ecosystem?
Author response:
We have replaces the word of habitat to ecosystem

Reviewer 1 comments
Line: 128, p: 6 at MS Reviewer 1
If species are given in the Table no need to list them in the text
Author response:
Line: 98-109, p: 5 at The third MS from author
We have removed them from the list

Reviewer 1 comments
Line: 138, p: 6at MS Reviewer 1
Give exact P-value
Author response:
Line: 103 and 109, p: 5 at The third MS from author
Give exact P-value

Reviewer 1 comments
Line: 142-145, p: 7 at MS Reviewer 1
Probably better to talk about families first, then species, so move this section to the beginning of the paragraph
Author response:
Line: 98-109, p: 5 at The third MS from author
We did it

Reviewer 1 comments
Line: 199, p: 9 at MS Reviewer 1
Does this sentence refer to species or family abundance?
Author response:
The sentence refer to species.

Reviewer 1 comments
Line: 233-235, p: 10 at MS Reviewer 1
Confusing. Re-word
Author response:
We removed the sentence.

Reviewer 1 comments
Line: 247, p: 11 at MS Reviewer 1
What does this mean? All spiders are surely predators of insect pests
Author response:
We removed the sentence.

Reviewer 1 comments
Line: 253, p: 11 at MS Reviewer 1
Has this been assessed here or in another study? If not, cant make this claim with such certainty
Author response:
Line: 180-184, p 8 at The third MS from author
We put references for the statements.

Reviewer 1 comments
Line: 264-265, p 12 at MS Reviewer 1
You haven't assessed this directly. Need to say that you speculate this is the cause for differences in assemblages, but you also mentioned differences in prey and in rice production.
Author response:
We removed the sentence.

Reviewer 1 comments:
Overall, I think it is a good article and is acceptable for publication pending some revisions to the text (and errors in the tables) and perhaps a few additional analyses on species richness if the 'diversity' aspect of the manuscripts means to be highlighted.
Author response:
We have added an additional analyses on species richness for all the data on the tables

RESPONSE SHEET

“Species Richness and Abundance of Spiders Inhabiting Vegetative and Generative Stage of Rice at Fresh Swamps and Tidal Lowlands in South Sumatra, Indonesia”

Reviewer 2 comments
Line: 7, p: 1 at MS Reviewer 2
Vegetative and generative stage should be defined in the method section
Author response
Line: 8-10, p: 1 at The third MS from author
Arboreal spiders were sampled using sweep nets, and soil-dweller spiders were sampled using pitfall traps at the vegetative and generative stages of rice.

Reviewer 2 comments
Line: 8, p: 1 at MS Reviewer 2
Is it rice field?
Author response
No. It is rice or paddy

Reviewer 2 comments
Line: 9, p: 1 at MS Reviewer 2
Insect net = sweep net?
Author response
Yes, it is, so that we replaced it

Reviewer 2 comments
Line: 11-12, p: 1 at MS Reviewer 2
Were there any other family groups of spiders which were not mentioned?
Author response
We just found those family groups and there were no the others.

Reviewer 2 comments
Line: 14, p: 1 at MS Reviewer 2
Three decimals would be better. Please correct it throughout the text.
Author response
We have corrected it throughout the text.

Reviewer 2 comments
Line: 17, p: 1 at MS Reviewer 2
Araneidae, Linyphiidae and Theridiidae are not soil-dwelling spiders. Is would be appropriate to define soil-dwellers. Normally, the terminology web-building and non-web building spiders
Author response
We have replace soil-dwelling to soil-dweller throughout the text.

Reviewer 2 comments
Line: 27-19, p: 2 at MS Reviewer 2
References?
Author response
Line: 30 p: 2 at The third MS from author
We have put the References

Reviewer 2 comments
Line: 79-81, p: 4 at MS Reviewer 2
Define arboreal spiders and define soil -welling spiders. I am a bit sceptical on the double swing methods as spiders on bark would not be captured. Normally, they would be hand picked.
Author response
The swing methods for capturing spiders on rice canopy were effective in this research.

Reviewer 2 comments
Line: 104, p: 5 at MS Reviewer 2
92.750 individuals?
Author response
Yes it is.

Reviewer 2 comments
Line: 105, p: 5 at MS Reviewer 2
How do you calculate this? In %?
Author response
No, it is not, it is in individuals.

Reviewer 2 comments
Line: 137-139, p: 6 at MS Reviewer 2
Write like this in the abstract and throughout the text
Author response
We did it.

Reviewer 2 comments
Line: 150, p: 7 at MS Reviewer 2
Three decimal point is sufficient. Correct throughout the text
Author response
We did it.

Reviewer 2 comments
Line: 159, p: 7 at MS Reviewer 2
Now you changed the term from arboreal and soil dwelling? Please be consistent with the terminology used throughout the text
Author response
We have been consistent with the terminology used throughout the text

Reviewer 2 comments
Line: 166-167, p: 8 at MS Reviewer 2
So they are able to adapt? Put a sentence after this the reason of the two species to be dominant
Author response
Yes. We have added the senteces at Line 157-163 p. 7 at The third MS from author

Reviewer 2 comments
Line: 333, p: 16 at MS Reviewer 2

There is a list of spiders for Indonesia. Be careful when you list the species name as some may not even be found in swamp ecosystem (Checklist of spiders from Indonesia and New Guinea)

Author response

All the species on the list were found in swamp ecosystem.

Species Richness and Abundance of Spiders Inhabiting Vegetative and Generative Stage of Rice at Fresh Swamps and Tidal Lowlands in South Sumatra, Indonesia

ABSTRACT

Different planting methods at fresh swamps and tidal lowlands and rice stages may support different abundance and species richness of arthropods therefore quantifying arthropod assemblages needs to be carried out. This research objective was to analyze species richness and abundance of spiders inhabiting vegetative and generative stages of rice at fresh swamp and tidal lowland ecosystems in South Sumatra. Arboreal spiders were sampled using sweep nets, and soil-dweller spiders were sampled using pitfall traps at the vegetative and generative stages of rice. Families of the arboreal spiders found during the vegetative and generative stages of rice from both ecosystems were Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae and Salticidae. The most dominant family and species of the arboreal spiders found were Tetragnathidae and *Tetragnatha virescens*, respectively. Species richness of the arboreal spider during the vegetative (P = 0.186) and generative (P = 0.807) stages at the fresh swamp ecosystems was not significantly different from that at the tidal lowland ecosystems. Families of soil-dweller spiders found during the vegetative and generative stages were Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae, and Salticidae. The most dominant family and species of the soil-dweller spiders found were Lycosidae and *Pardosa pseudoannulata*, respectively. Species richness of the soil-dweller spiders during the rice vegetative (P = 0.529) and generative (P = 0.981) stages at the fresh swamps was not significantly different from that at the tidal lowlands. This study suggest that the specific and eco-friendly planting methods at the fresh swamp and tidal lowland ecosystems supports existence of Tetragnathidae and Lycosidae, keystone predators of rice pest insects.

Keywords: arboreal, arthropod, rice field, soil-dweller

INTRODUCTION

Wetlands in Indonesia, are characterized by two distinct ecosystems, differentiated based on sea tide influence; i.e. tidal lowlands for those directly influenced by sea tide but fresh swamps for those not affected by sea tide (Mulyani & Sarwani, 2013). At the tidal lowland ecosystems, soil needs specific handling due to thick pyritic layers therefore it should be preserved (Hidayat *et al*., 2010). The local farmers do not fully manage the soil to prevent the pyrite layers from destructions (Suriadikarta *et al*., 2013) and they generally plant rice twice a year (planting index) by using broadcast seeding, drum seeding, or seedling in a digged-hole ("tugal") (Raharjo *et al*., 2013). Contrary to the farmers at the tidal lowlands, farmers at fresh swamps usually plant rice using transplanting system and they only plant rice once a year (Mulyani & Sarwani, 2013; Lakitan *et al*., 2018). Different rice planting methods and index at the both ecosystems may also affect the arthropod abundance and species diversity or richness (Zhang *et al*., 2013; Parry *et al.*, 2015). Weedy paddies at direct planting ecosystems have more abundant arthropods than those at clean ecosystems (Hu *et al.*, 2012). No soil tillage or conservation tillage at paddies also support higher arthropod abundance (Pereira *et al*., 2010). No application of synthetic insecticides at fresh swamp ecosystems also enhances abundance of predatory arthropods, especially spiders (Herlinda *et al.*, 2004; Herlinda *et al.*, 2008).

In addition to planting method and index, vegetative and generative stages of rice also influence species richness and abundance of the arthropods (Herlinda *et al*. 2008). At the vegetative and generative stages, soil- dweller arthropods are more abundant and more diverse at the tidal lowlands than those at the fresh swamp ecosystems (Khodijah *et al.*, 2012; Herlinda *et al.*, 2014). However, the arboreal artropods are more abundant and richer at the fresh swamp ecosystems than those at the tidal lowland ecosystems (Khodijah *et al.*, 2012; Sunariah *et al.*, 2016). Different planting methods and index at the both ecosystems and different stages of rice may support different abundance and species richness of arthropods, therefore quantifying arthropod assemblages needs to be carried out. The purpose of this study was to analyze species richness and abundance of spiders inhabiting vegetative and generative stages of rice at fresh swamps and tidal lowlands in South Sumatra.

MATERIAL AND METHODS

Study Site

Surveys were carried out at rice production centers of fresh swamps and tidal lowlands in South Sumatra throughout February 2012 and March 2013. Survey locations of the rice production centers for fresh swamp ecosystems were: (1) Gandus, Palembang City; (2) Pelabuhan Dalam Village of Ogan Ilir District; (3) Maryana Village of Banyuasin District; and (4) Sungai Waru Village of Kabupaten Banyuasin District. Survey locations of the rice production centers for tidal lowlands were: (1) Banyu Urip Village of Tanjung Lago Subdistrict, Banyuasin District' (2) Telang Karya Village of Muara Telang Subdistrict, Banyuasin District; (3) Telang Rejo Village of Muara Telang Subdistrict, Banyuasin District; (4) Srikaton Damai Village of Air Saleh Subdistrict, Banyuasin District; (5) Srimulyo Village of Kecamatan Air Saleh Subdistrict, Banyuasin District; (6) Makarti Jaya Village of Makarti Jaya Subdistrict, Banyuasin District; (7) Tirta Mulya Village of Makarti Jaya Subdistrict, Banyuasin District; and (8) Tirta Kencana Village of Makarti Jaya Subdistrict, Banyuasin District. In each location, three sampling plots with a minimum size of 1 ha were surveyed twice during one rice season (4 mounts). The first survey was done when rice crop was 4 weeks old and the second one when rice crop was at milk grain stage (9 weeks old). Rice variety used at the fresh swamps was Ciherang, whereas Inpara variety was used at the tidal lowland ecosystems.

Sampling

Arboreal spiders. The arboreal spiders were sampled using sweep nets, following methods used by Herlinda *et al.* (2014). Net sweeping consisted of 'double swings', totalling 30 swings/ha in all plots.

Soil-dweller spiders. Soil-dweller spiders were sampled using pitfall traps, following methods used by Herlinda *et al*. (2004). Plastic pitfall traps (60 mm in diameter and 90 mm in height) were filled to a volume of 70 mL with 4% formaldehide solution and buried in the ground flush with the soil surface. Traps were installed with density of 18 units/ha , spaced in a grid 3 x 6, then collected after 48 hours. All specimens collected were cleaned and sorted from other debris and stored in vials containing 70% ethanol. Identification to family- and species-level was carried out at Laboratory of Entomology, at the Plant Pest and Disease Department, College of Agriculture, Universitas Sriwijaya, using taxonomic keys provided in Barrion and Litsinger (1995).

Data Analysis

The spider abundance data between samples from the fresh swamp and tidal lowland ecosystems were not normally distributed. Hence, insect counts in this study were found to fit a negative binomial distribution and were analyzed by Proc Genmod using SAS University Edition (SAS Institute Inc., Cary, NC, U.S.A.). Species richness was analysed using Menhinick's index (D) (Magurran, 1988).

RESULTS

Arboreal Spiders at Fresh Swamp and Tidal Lowland Ecosystems

From this survey during rice vegetative stage, a total of seven families of arboreal spiders found were Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae and Salticidae at the fresh swamp and tidal lowland ecosystems (Table 1). Tetragnathidae was the most dominant family of the arboreal spider found during the rice vegetative stage. A total of 92.750 spiders/30 nets at the fresh swamp ecosystems and

62.875 spiders/30 nets at the tidal lowland ecosystems were captured (P = 0.312). The abundance of *Tetragnatha vermiformis* (P = 0.001) and *Oxyopes bikakaeus* (P = 0.007) at the fresh swamp ecosystems were significantly higher than those at the tidal lowland ecosystems. A total of the arboreal spider species found during the rice vegetative stage were 26 species from the fresh swamp ecosystems and 23 species from the tidal lowland ecosystem. Spider species richness at the fresh swamp ecosystems was not significantly different (P = 0.186) from those at the tidal lowland ecosystems.

A total of spider families found during rice generative stage were only five families (Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae and Salticidae) at the fresh swamp ecosystems and seven families (Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae) at the tidal lowland ecosystems (Table 2). However, abundance of Araneidae (P = 0.803), Tetragnathidae (P = 1.000), Linyphiidae (P = 0.720), Oxyopidae (P = 0.096), Thomisidae (P = 1.000), Theridiidae (P = 1.000), and Salticidae (P = 0.633) at the fresh swamp ecosystems were not significantly different from those at the tidal lowland ecosystems. The most dominant family of the arboreal spiders found on the both ecosystems was Tetragnathidae. A total of spider abundance for all species at the fresh swamp ecosystems (47.750 spiders/30 nets) were not significantly different (P = 0.521) from those at the tidal lowland ecosystems (54.250 spiders/30 nets). However, average of spider abundance from the both ecosystems was significantly different (P = 0.000). The most dominant arboreal species found on the both ecosystems was *Tetragnatha virescens.* A total of arboreal spider species recorded were 16 species from the fresh swamp ecosystems and 21 species from the tidal lowland ecosystem. However, the arboreal spider species richness at the fresh swamp ecosystems were not also significantly different (P = 0.8067) from those at the tidal lowland ecosystems.

Soil-dweller Spiders at Fresh Swamps and Tidal Lowlands

At vegetative stage of rice, soil-dweller spiders found were only two families (Lycosidae and Linyphiidae) from the fresh swamp ecosystems and five families (Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae) from the tidal lowland ecosystems (Table 3). We did not find Araneidae, Thomisidae, and Theridiidae at the fresh swamp ecosystems. The most dominant family of soil-dweller spiders found during the rice vegetative stage was Lycosidae and the most dominant species was *Pardosa pseudoannulata.* A total of soil-dweller spider species found were nine species at the fresh swamp ecosystems and 16 species at tidal lowland ecosystems. Nonetheless, species richness of the soil-dweller spider at the fresh swamp ecosystems were not significantly different (P = 0.5290) from those at the tidal lowland ecosystems.

A total of the soil-dweller spider families found during generative stage of rice were three families (Lycosidae, Araneidae, and Linyphiidae) from the fresh swamp ecosystems and four families (Lycosidae, Araneidae, Linyphiidae, and Salticidae) from the tidal lowland ecosystems (Table 4). The most dominant family of the soil-dweller spiders found was Lycosidae. The species numbers of soil-dweller spiders recorded were eight and 12 from the fresh swamp and the tidal lowland ecosystems, respectively. Species richness of the soil-dweler spiders during the rice generative stage at the fresh swamp ecosystems were not significantly different (P = 0.981) from those at the tidal lowland ecosystems. A total of abundance of soil-dweller spiders at the fresh swamp ecosystems were also not significantly different from those at the tidal lowland ecosystems (P = 0.295).

DISCUSSION

Spider families found on rice canopy at fresh swamp and tidal lowland ecosystems during the rice vegetative and generative stages in this study consisted of Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae. These arboreal spiders found comprised both web-building (Araneidae, Tetragnathidae, Linyphiidae, Theridiidae) and non-web building (Oxyopidae, Thomisidae, and Salticidae) species, commonly found at the fresh swamp or tidal lowland ecosystems (Schmidt & Tscharntke, 2005). Abundance of species belonging to Tetragnathidae (*T. vermiformis*) and Oxyopidae (*O. bikakaeus*) at the fresh swamp ecosystems in this study were significantly higher than those at the tidal lowland ecosystems. Tetragnathidae and Oxyopidae are more dominant spiders at wetland ecosystems (Betz & Tscharntke, 2017) because the fresh swamp ecosystems are commonly submerged longer (more than 6 mounts) than those at the tidal lowland ecosystems (Mulyani & Sarwani, 2013).

Spider family, Tetragnathidae in this study was the most dominant family of the arboreal spider found during the rice vegetative and generative stages. Species of arboreal spiders dominantly found on paddies at the fresh swamp and tidal lowland ecosystems were similar which consisted of *T. virescens* and *T. javana*. Barrion et al. (2012) stated that in the species of Tetragnathidae, such as species of *T. virescens* and *T. javana* were classified as keystone species. Such species were playing a critical role in maintaining population of rice pest insect, such leafhopper (Betz & Tscharntke, 2017). Species from Tetragnathidae was reported by Shepard *et al.* (1987) and Betz and Tscharntke (2017) as dominant web spiders found at wetland ecosystems. The number of Tetragnathidae in this study were more abundant at the rice vegetative stage than those at the rice generative stage. Betz and Tscharntke (2017) stated that abundant of Tetragnathidae was influenced by the number of leafhoppers (Homoptera) which are commonly occured at vegetative stage of rice. The both species of spiders are predators of rice pest insects, such as order of Homoptera and Lepidoptera (Tahir *et al*., 2009). This also accords with findings of Betz and Tscharntke (2017), which showed highest increase of Tetragnathidae with increasing abundance of Lepidoptera and leafhoppers.

Species abundance of arboreal spiders either at the fresh swamp and tidal lowland ecosystems were higher at vegetative stage of rice than those at generative stage of rice because spider abundance is closely related to their prey population (Riechert & Lockley, 1984). Abundant prey population will attract these spiders to assemble on prey rich ecosystems (Widiarta *et al.*, 2006). The main prey for this spiders was rice insect pests, such as brown planthoppers (Karindah, 2011) that had higher population at vegetative stage of rice than that during generative stage of rice resulting in higher abundance of spiders at the vegetative stage of rice than that of the generative stage of rice. According to Arofah *et al.* (2013) dominant insect pests at vegetative stage of rice were planthoppers, whereas dominant insect pest at generative stage of rice was rice bugs. Thus, rice stages at both ecosystems affects the species abundance of spiders.

Spider families found on soil surface of the fresh swamp ecosystems only consisted of Lycosidae and Linyphiidae, whereas Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae, and Salticidae were found at the tidal lowland ecosystems. Web spiders, such as Araneidae, Linyphiidae, and Theridiidae could be found on soil surface. This was due to the fact that these spiders were found on immature stage. According to Iida and Fujisaki (2007) and Suana and Haryanto (2013), immature web spiders had capability to produce small like balloon ball so that they could be moved by wind or moving to other places or descend upon or fallen on soil surface.

A total of abundance and species richness of soil-dweller spiders during the rice vegetative and generative stages at the fresh swamp ecosystems were not significantly different from those at the tidal lowland ecosystems. Nonetheless, the most dominant family of the soil-dweller spiders was Lycosidae and the most dominant species was *P. pseudoannulata*. Barrion *et al.* (2012) list some species in the Lycosid family, such as wolf spider, *P. pseudoannulata* as keystone species. This wolf spider plays the role of a keystone predator within this rice ecosystem by preying leafhoppers (Lou *et al.* 2013). High mobility of the wolf spiders allow them to move and to run or to jump for capturing their preys (Ishijima *et al*., 2006). Abundance of Lycosidae during the rice generative stage at the fresh swamp ecosystems was higher than that at the tidal lowland ecosystems. One explanation why the abundance of Lycosidae was higher at the fresh swamp ecosystems is because farmers culturally do not apply synthetic insecticides to control pest insects. Herlinda (2010) reported that application of the synthetic insecticides at the fresh swamp ecosystems in South Sumatra was rare. Such ecosystems tend to produce high diversity of invertebrate fauna (Mahrub, 1999; Rizali *et al.*, 2002). Rice ecosystems without synthetic insecticides application had higher dominance of predatory arthropods, especially spiders (Herlinda *et al.*, 2008; Herlinda *et al.*, 2004; Zi-yang *et al.*, 2011).

CONCLUSION

The most dominant family and species of the arboreal spiders found were Tetragnathidae and *T. virescens*, respectively, while the most dominant family and species of the soil-dweller spiders were Lycosidae and *P. pseudoannulata*, respectively. Species richness of the arboreal and soil-dweller spiders during the rice vegetative and generative stages at the fresh swamp ecosystems was not significantly different from those at the tidal lowland ecosystems. This findings of the study suggest that the specific and eco-friendly planting methods at the fresh swamp and tidal lowland ecosystems supports existence of Tetragnathidae and Lycosidae, keystone predators of rice pest insects.

ACKNOWLEDGEMENT

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Table 1. The comparison of arboreal spider abundance found on vegetative stage of rice at fresh swamps and tidal lowlands in South Sumatra

No.	Family. and Species	Average spider abundance (per 30 nets)		$P_{value\ (0.05)}$
		Fresh Swamps	Tidal Lowlands	
	Araneidae	6.500	2.750	0.152
28.	*Araneus inustus*	1.500	0.625	0.303
29.	*Cylosa insulana*	1.750	0.750	0.241
30.	*Cylosa mulmeinensis*	0.500	0.000	0.225
31.	*Gea subarmata*	2.750	1.375	0.550
	Tetragnathidae	54.250	32.750	0.175
32.	*Tetragnatha javana*	8.250	12.000	0.495
33.	*Tetragnatha virescens*	21.000	8.875	0.107
34.	*Tetragnatha mandibulata*	8.500	8.500	1.000
35.	*Tetragnatha ilavaca*	1.000	0.125	0.089
36.	*Tetragnatha maxillosa*	3.000	1.500	0.500
37.	*Tetragnatha desaguni*	1.250	0.750	0.676
38.	*Tetragnatha vermiformis*	8.250	0.750	0.001*
39.	*Tetragnatha okumae*	1.750	0.000	1.000
40.	*Dyschiriognatha hawigtenera*	1.250	0.250	0.202
	Linyphiidae	8.750	9.375	0.944
41.	*Bathyphantes tagalogensis*	4.750	7.125	0.687
42.	*Atypena adelinae*	3.250	2.250	0.773
43.	*Erigone bifurca*	0.750	0.000	1.000
	Oxyopidae	18.000	13.875	0.616
44.	*Oxyopes javanus*	6.250	7.250	0.843
45.	*Oxyopes matiensis*	5.750	6.250	0.842
46.	*Oxyopes bikakaeus*	3.250	0.125	0.007*
47.	*Oxyopes pingasus*	2.750	0.250	0.118
	Thomisidae	0.750	0.750	1.000
48.	*Diaea tadtadtinika*	0.500	0.500	1.000
49.	*Stiphropus sangayus*	0.250	0.250	1.000
	Theridiidae	0.250	0.250	1.000
50.	*Coleosoma octomaculatum*	0.250	0.000	0.364
51.	*Theridion* sp.	0.000	0.250	0.495
	Salticidae	4.250	3.125	0.753
52.	*Myrmarachne bidentata*	0.500	0.250	0.677
53.	*Simaetha damongpalaya*	3.000	0.750	0.422
54.	*Hyllus maskaranus*	0.750	2.125	0.479
	Total of Abundance (N)	92.750	62.875	0.312
	Average of Abundance	13.250	8.982	0.309
	Species Richness (D)	1.700	1.195	0.186

*= significantly different

Table 2. The comparison of arboreal spider abundance found on generative stage of rice at fresh swamp and tidal lowland in South Sumatra

No.	Family. and Species	Average spider abundance (per 30 nets)	$P_{value\ (0.05)}$

		Fresh Swamps	Tidal Lowlands	
	Araneidae	5.000	4.500	0.803
28.	*Araneus inustus*	0.750	1.125	0.481
29.	*Cylosa insulana*	1.000	0.500	0.327
30.	*Cylosa mulmeinensis*	0.750	0.125	0.260
31.	*Gea subarmata*	2.500	2.750	0.912
	Tetragnathidae	26.000	26.000	1.000
32.	*Tetragnatha javana*	7.250	7.250	1.000
33.	*Tetragnatha virescens*	7.250	7.750	0.548
34.	*Tetragnatha mandibulata*	3.500	4.375	0.548
35.	*Tetragnatha ilavaca*	0.000	0.875	1.000
36.	*Tetragnatha maxillosa*	0.500	1.125	0.320
37.	*Tetragnatha desaguni*	0.000	0.000	1.000
38.	*Tetragnatha vermiformis*	6.750	4.625	0.188
39.	*Tetragnatha okumae*	0.750	0.000	1.000
40.	*Dyschiriognatha hawigtenera*	0.000	0.000	1.000
	Linyphiidae	6.250	4.750	0.720
41.	*Bathyphantes tagalogensis*	3.250	0.875	0.115
42.	*Atypena adelinae*	3.000	3.875	0.723
43.	*Erigone bifurca*	0.000	0.000	1.000
	Oxyopidae	8.500	15.625	0.096
44.	*Oxyopes javanus*	3.750	7.625	0.058
45.	*Oxyopes matiensis*	4.750	6.125	0.558
46.	*Oxyopes bikakaeus*	0.000	1.250	1.000
47.	*Oxyopes pingasus*	0.000	0.625	1.000
	Thomisidae	0.000	0.375	1.000
48.	*Diaea tadtadtinika*	0.000	0.250	1.000
49.	*Stiphropus sangayus*	0.000	0.125	1.000
	Theridiidae	0.000	0.250	1.000
50.	*Coleosoma octomaculatum*	0.000	0.250	1.000
51.	*Theridion* sp.	0.000	0.000	1.000
	Salticidae	2.000	2.750	0.634
52.	*Myrmarachne bidentata*	0.000	0.250	0.495
53.	*Simaetha damongpalaya*	1.250	2.500	0.560
54.	*Hyllus maskaranus*	0.750	0.000	1.000
	Total of Abundance (N)	47.750	54.250	0.521
	Average of Abundance	6.821	1.417	0.000*
	Species Richness (D)	1.467	1.573	0.807

*= significantly different

Table 3. The comparison of soil-dweller spider abundance found on vegetative stage of rice at fresh swamp and tidal lowland in South Sumatra

No.	Family. and Species	Average spider abundance (per 18 traps)		$P_{value (0.05)}$
		Fresh Swamps	Tidal Lowlands	
	Lycosidae	24.250	22.125	0.664
19.	*Pardosa pseudoannulata*	17.000	14.625	0.618
20.	*Pardosa sumatrana*	3.750	2.625	0.177
21.	*Pardosa birmanica*	0.750	0.625	0.836
22.	*Pardosa mackenziei*	0.500	1.875	0.135

23.	*Pardosa patapensis*	0.250	0.000	0.364
24.	*Hogna rizali*	0.000	1.750	1.000
25.	*Arctosa tanakai*	2.000	0.625	0.244
	Araneidae	0.000	1.625	1.000
26.	*Araneus inustus*	0.000	0.500	1.000
27.	*Cylosa insulana*	0.000	0.875	1.000
28.	*Gea subarmata*	0.000	0.250	1.000
	Linyphiidae	5.000	1.250	1.000
29.	*Bathyphantes tagalogensis*	2.500	0.250	0.009
30.	*Atypena adelinae*	2.000	0.500	0.112
31.	*Erigone bifurca*	0.500	0.500	1.000
	Thomisidae	0.000	0.875	1.000
32.	*Diaea tadtadtinika*	0.000	0.750	1.000
33.	*Stiphropus sangayus*	0.000	0.125	1.000
	Theridiidae	0.000	0.375	1.000
34.	*Coleosoma octomaculatum*	0.000	0.125	1.000
35.	*Theridion* sp.	0.000	0.250	1.000
	Salticidae	0.000	0.000	1.000
36.	*Hyllus maskaranus*	0.000	0.000	1.000
	Total of Abundance (N)	29.250	26.250	0.451
	Average of Abundance	4.875	4.375	0.466
	Species Richness (D)	0.983	1.272	0.529

*= significantly different

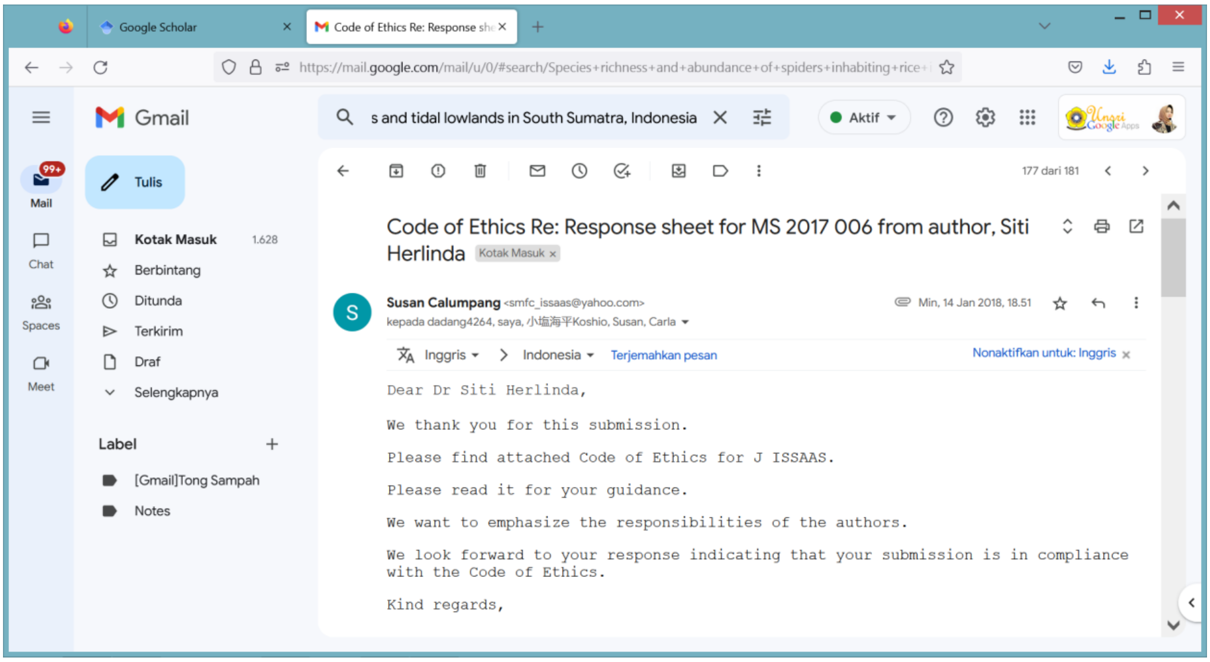
Table 4. The comparison of soil-dweller spider abundance found on generative stage of rice at fresh swamp and tidal lowland in South Sumatra

No.	Family. and Species	Average spider abundance (per 18 traps)		$P_{value\ (0.05)}$
		Fresh Swamps	Tidal Lowlands	
	Lycosidae	27.250	20.000	0.041*
18.	*Pardosa pseudoannulata*	15.750	12.250	0.326
19.	*Pardosa sumatrana*	5.500	5.125	0.699
20.	*Pardosa birmanica*	0.500	0.500	1.000
21.	*Pardosa mackenziei*	0.000	0.000	1.000
22.	*Pardosa patapensis*	0.000	0.625	1.000
23.	*Hogna rizali*	1.500	0.250	0.141
	Arctosa tanakai	4.000	1.250	0.012*
24.	**Araneidae**	0.000	0.250	0.495
25.	*Araneus inustus*	0.000	0.125	0.742
26.	*Cylosa insulana*	0.000	0.000	1.000
	Gea subarmata	0.000	0.125	0.742
27.	**Linyphiidae**	4.500	4.875	0.936
28.	*Bathyphantes tagalogensis*	3.000	2.250	0.753
29.	*Atypena adelinae*	1.250	2.250	0.532
	Erigone bifurca	0.250	0.375	0.715
30.	**Thomisidae**	0.000	0.000	1.000
31.	*Diaea tadtadtinika*	0.000	0.000	1.000
	Stiphropus sangayus	0.000	0.000	1.000
32.	**Theridiidae**	0.000	0.000	1.000
33.	*Coleosoma octomaculatum*	0.000	0.000	1.000

	Theridion sp.	0.000	0.000	1.000
34.	**Salticidae**	0.000	0.125	0.742
	Hyllus maskaranus	0.000	0.125	0.742
	Total of Abundance (N)	31.750	25.250	0.295
	Average of Abundance	5.292	4.208	0.329
	Species Richness (D)	1.058	1.052	0.981

*= significantly different

4. Bukti konfirmasi review kedua dan hasil revisi kedua



Code of Ethics Re: Response sheet for MS 2017 006 from author, Siti Herlinda

Susan Calumpang <smfc_issaas@yahoo.com> — Min, 14 Jan 2018, 18.51

kepada dadang4264, saya, 小塩海平Koshio, Susan, Carla

Dear Dr Siti Herlinda,

We thank you for this submission.

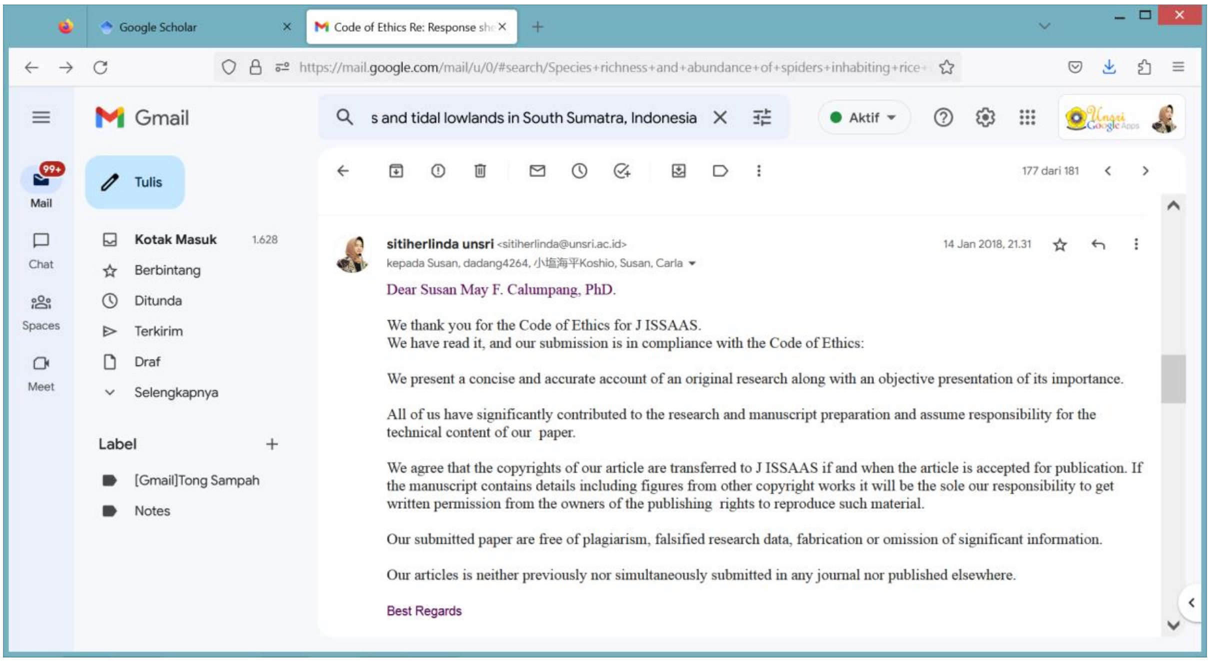
Please find attached Code of Ethics for J ISSAAS.

Please read it for your guidance.

We want to emphasize the responsibilities of the authors.

We look forward to your response indicating that your submission is in compliance with the Code of Ethics.

Kind regards,



sitiherlinda unsri <sitiherlinda@unsri.ac.id> — 14 Jan 2018, 21.31

kepada Susan, dadang4264, 小塩海平Koshio, Susan, Carla

Dear Susan May F. Calumpang, PhD.

We thank you for the Code of Ethics for J ISSAAS.
We have read it, and our submission is in compliance with the Code of Ethics:

We present a concise and accurate account of an original research along with an objective presentation of its importance.

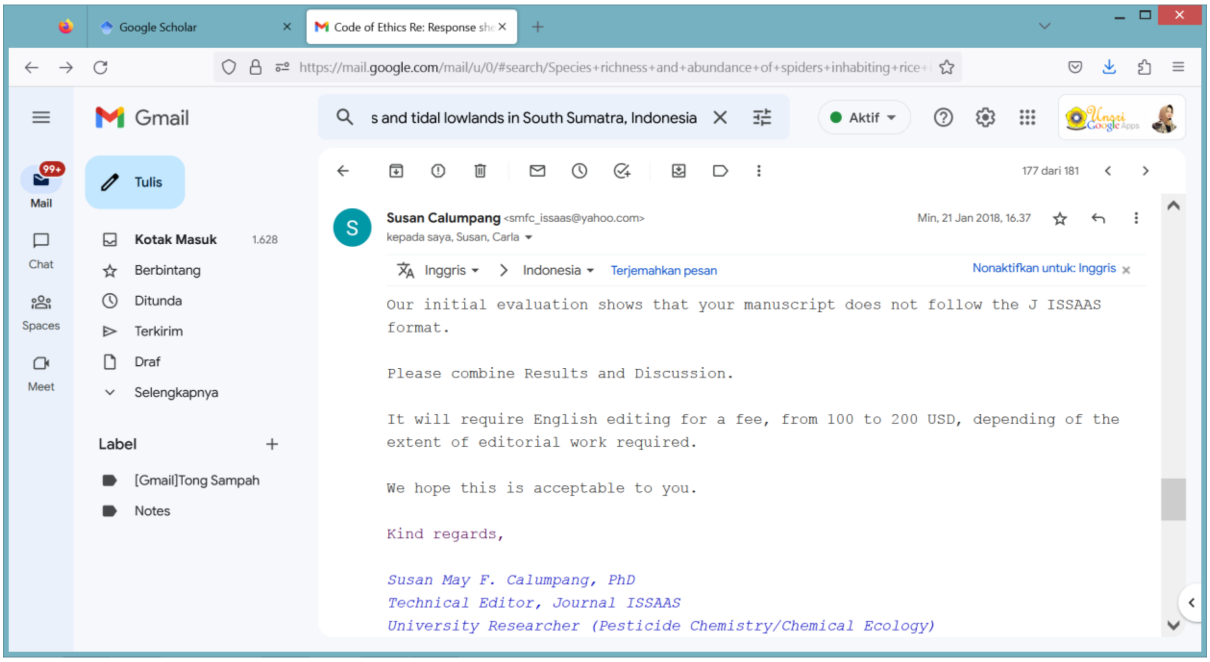
All of us have significantly contributed to the research and manuscript preparation and assume responsibility for the technical content of our paper.

We agree that the copyrights of our article are transferred to J ISSAAS if and when the article is accepted for publication. If the manuscript contains details including figures from other copyright works it will be the sole our responsibility to get written permission from the owners of the publishing rights to reproduce such material.

Our submitted paper are free of plagiarism, falsified research data, fabrication or omission of significant information.

Our articles is neither previously nor simultaneously submitted in any journal nor published elsewhere.

Best Regards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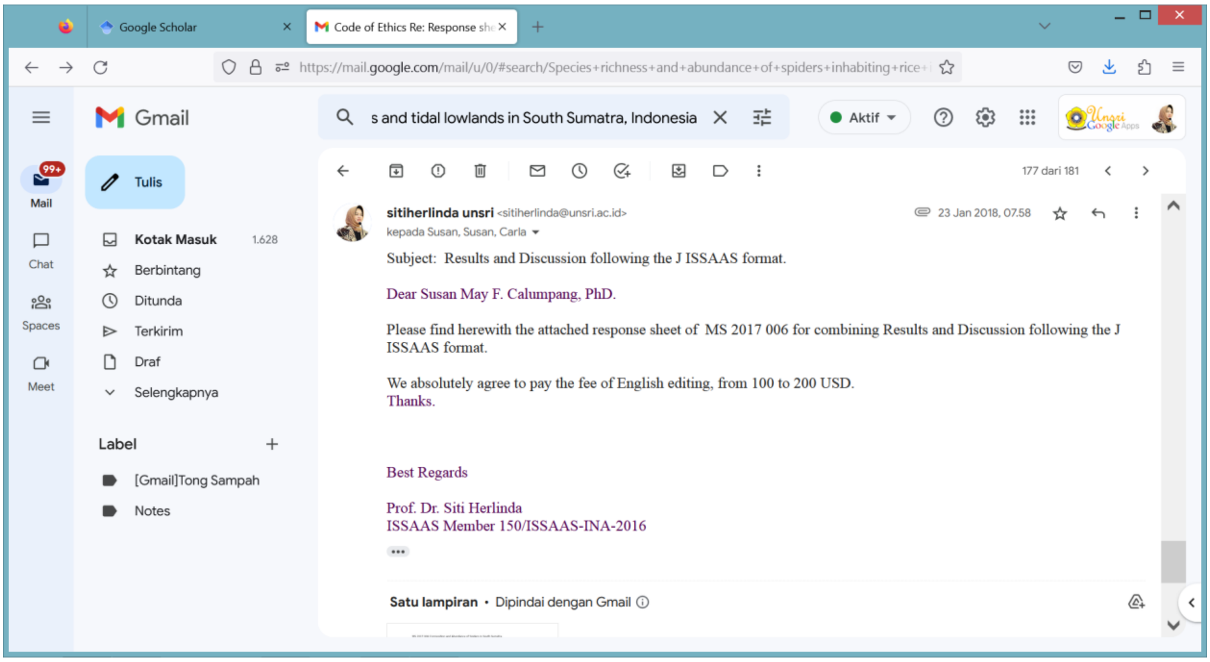
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SPECIES RICHNESS AND ABUNDANCE OF SPIDERS INHABITING VEGETATIVE AND GENERATIVE STAGE OF RICE AT FRESH SWAMPS AND TIDAL LOWLANDS IN SOUTH SUMATRA, INDONESIA

ABSTRACT

Different planting methods at fresh swamps and tidal lowlands and rice stages may support different abundance and species richness of arthropods therefore quantifying arthropod assemblages needs to be carried out. This research objective was to analyze species richness and abundance of spiders inhabiting vegetative and generative stages of rice at fresh swamp and tidal lowland ecosystems in South Sumatra. Arboreal spiders were sampled using sweep nets, and soil-dweller spiders were sampled using pitfall traps at the vegetative and generative stages of rice. Families of the arboreal spiders found during the vegetative and generative stages of rice from both ecosystems were Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae and Salticidae. The most dominant family and species of the arboreal spiders found were Tetragnathidae and *Tetragnatha virescens*, respectively. Species richness of the arboreal spider during the vegetative (P = 0.186) and generative (P = 0.807) stages at the fresh swamp ecosystems was not significantly different from that at the tidal lowland ecosystems. Families of soil-dweller spiders found during the vegetative and generative stages were Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae, and Salticidae. The most dominant family and species of the soil-dweller spiders found were Lycosidae and *Pardosa pseudoannulata*, respectively. Species richness of the soil-dweller spiders during the rice vegetative (P = 0.529) and generative (P = 0.981) stages at the fresh swamps was not significantly different from that at the tidal lowlands. This study suggest that the specific and eco-friendly planting methods at the fresh swamp and tidal lowland ecosystems supports existence of Tetragnathidae and Lycosidae, keystone predators of rice pest insects.

Keywords: arboreal, arthropod, rice field, soil-dweller

INTRODUCTION

Wetlands in Indonesia, are characterized by two distinct ecosystems, differentiated based on sea tide influence; i.e. tidal lowlands for those directly influenced by sea tide but fresh swamps for those not affected by sea tide (Mulyani & Sarwani, 2013). At the tidal lowland ecosystems, soil needs specific handling due to thick pyritic layers therefore it should be preserved (Hidayat *et al*., 2010). The local farmers do not fully manage the soil to prevent the pyrite layers from destructions (Suriadikarta *et al*., 2013) and they generally plant rice twice a year (planting index) by using broadcast seeding, drum seeding, or seedling in a digged-hole ("tugal") (Raharjo *et al*., 2013). Contrary to the farmers at the tidal lowlands, farmers at fresh swamps usually plant rice using transplanting system and they only plant rice once a year (Mulyani & Sarwani, 2013; Lakitan *et al*., 2018). Different rice planting methods and index at the both ecosystems may also affect the arthropod abundance and species diversity or richness (Zhang *et al*., 2013; Parry *et al.*, 2015). Weedy paddies at direct planting ecosystems have more abundant arthropods than those at clean ecosystems (Hu *et al.*, 2012). No soil tillage or conservation tillage at paddies also support higher arthropod abundance (Pereira *et al*., 2010). No application of synthetic insecticides at fresh swamp ecosystems also enhances abundance of predatory arthropods, especially spiders (Herlinda *et al.*, 2004; Herlinda *et al.*, 2008).

In addition to planting method and index, vegetative and generative stages of rice also influence species richness and abundance of the arthropods (Herlinda *et al*. 2008). At the vegetative and generative stages, soil-dweller arthropods are more abundant and more diverse at the tidal lowlands than those at the fresh swamp ecosystems (Khodijah *et al.*, 2012; Herlinda *et al.*, 2014). However, the arboreal artropods are more abundant and richer at the fresh swamp ecosystems than those at the tidal lowland ecosystems (Khodijah *et al.*, 2012; Sunariah *et al.*, 2016). Different planting methods and index at the both ecosystems and different stages of rice may support different abundance and species richness of arthropods, therefore quantifying arthropod assemblages needs to be carried out. The purpose of this study was to analyze species richness and abundance of spiders inhabiting vegetative and generative stages of rice at fresh swamps and tidal lowlands in South Sumatra.

MATERIAL AND METHODS

Study Site

Surveys were carried out at rice production centers of fresh swamps and tidal lowlands in South Sumatra throughout February 2012 and March 2013. Survey locations of the rice production centers for fresh swamp ecosystems were: (1) Gandus, Palembang City; (2) Pelabuhan Dalam Village of Ogan Ilir District; (3) Maryana Village of Banyuasin District; and (4) Sungai Waru Village of Kabupaten Banyuasin District. Survey locations of the rice production centers for tidal lowlands were: (1) Banyu Urip Village of Tanjung Lago Subdistrict, Banyuasin District' (2) Telang Karya Village of Muara Telang Subdistrict, Banyuasin District; (3) Telang Rejo Village of Muara Telang Subdistrict, Banyuasin District; (4) Srikaton Damai Village of Air Saleh Subdistrict, Banyuasin District; (5) Srimulyo Village of Kecamatan Air Saleh Subdistrict, Banyuasin District; (6) Makarti Jaya Village of Makarti Jaya Subdistrict, Banyuasin District; (7) Tirta Mulya Village of Makarti Jaya Subdistrict, Banyuasin District; and (8) Tirta Kencana Village of Makarti Jaya Subdistrict, Banyuasin District. In each location, three sampling plots with a minimum size of 1 ha were surveyed twice during one rice season (4 mounts). The first survey was done when rice crop was 4 weeks old and the second one when rice crop was at milk grain stage (9 weeks old). Rice variety used at the fresh swamps was Ciherang, whereas Inpara variety was used at the tidal lowland ecosystems.

Sampling

Arboreal spiders. The arboreal spiders were sampled using sweep nets, following methods used by Herlinda *et al.* (2014). Net sweeping consisted of 'double swings', totalling 30 swings/ha in all plots.

Soil-dweller spiders. Soil-dweller spiders were sampled using pitfall traps, following methods used by Herlinda *et al*. (2004). Plastic pitfall traps (60 mm in diameter and 90 mm in height) were filled to a volume of 70 mL with 4% formaldehide solution and buried in the ground flush with the soil surface. Traps were installed with density of 18 units/ha , spaced in a grid 3 x 6, then collected after 48 hours. All specimens collected were cleaned and sorted from other debris and stored in vials containing 70% ethanol. Identification to family- and species-level was carried out at Laboratory of Entomology, at the Plant Pest and Disease Department, College of Agriculture, Universitas Sriwijaya, using taxonomic keys provided in Barrion and Litsinger (1995).

Data Analysis

The spider abundance data between samples from the fresh swamp and tidal lowland ecosystems were not normally distributed. Hence, insect counts in this study were found to fit a negative binomial distribution and were analyzed by Proc Genmod using SAS University Edition (SAS Institute Inc., Cary, NC, U.S.A.). Species richness was analysed using Menhinick's index (D) (Magurran, 1988).

RESULTS AND DISCUSSIONS

Arboreal Spiders at Fresh Swamp and Tidal Lowland Ecosystems

From this survey during rice vegetative stage, a total of seven families of arboreal spiders found were Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae and Salticidae at the fresh swamp and tidal lowland ecosystems (Table 1). Tetragnathidae was the most dominant family of the arboreal spider found during the rice vegetative stage. A total of 92.750 spiders/30 nets at the fresh swamp ecosystems and 62.875 spiders/30 nets at the tidal lowland ecosystems were captured (P = 0.312). The abundance of *Tetragnatha vermiformis* (P = 0.001) and *Oxyopes bikakaeus* (P = 0.007) at the fresh swamp ecosystems were significantly higher than those at the tidal lowland ecosystems. A total of the arboreal spider species found during the rice vegetative stage were 26 species from the fresh swamp ecosystems and 23 species from the tidal lowland ecosystem. Spider species richness at the fresh swamp ecosystems was not significantly different (P = 0.186) from those at the tidal lowland ecosystems.

A total of spider families found during rice generative stage were only five families (Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae and Salticidae) at the fresh swamp ecosystems and seven families (Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae) at the tidal lowland ecosystems (Table 2). However, abundance of Araneidae (P = 0.803), Tetragnathidae (P = 1.000), Linyphiidae (P = 0.720), Oxyopidae (P = 0.096), Thomisidae (P = 1.000), Theridiidae (P = 1.000), and Salticidae (P = 0.633) at the fresh swamp ecosystems were not significantly different from those at the tidal lowland ecosystems. The most dominant family of the arboreal spiders found on the both ecosystems was Tetragnathidae. A total of spider abundance for all species at the fresh swamp ecosystems (47.750 spiders/30 nets) were not significantly different (P = 0.521) from those at the tidal lowland ecosystems (54.250 spiders/30 nets). However, average of spider abundance from the both ecosystems was significantly different (P = 0.000). The most dominant arboreal species found on the both ecosystems was *Tetragnatha virescens.* A total of arboreal spider species recorded were 16 species from the fresh swamp ecosystems and 21 species from the tidal lowland ecosystem. However, the arboreal spider species richness at the fresh swamp ecosystems were not also significantly different (P = 0.8067) from those at the tidal lowland ecosystems.

Spider families found on rice canopy at fresh swamp and tidal lowland ecosystems during the rice vegetative and generative stages in this study consisted of Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae. These arboreal spiders found comprised both web-building (Araneidae, Tetragnathidae, Linyphiidae, Theridiidae) and non-web building (Oxyopidae, Thomisidae, and Salticidae) species, commonly found at the fresh swamp or tidal lowland ecosystems (Schmidt & Tscharntke, 2005). Abundance of species belonging to Tetragnathidae (*T. vermiformis*) and Oxyopidae (*O. bikakaeus*) at the fresh swamp ecosystems in this study were significantly higher than those at the tidal lowland ecosystems. Tetragnathidae and Oxyopidae are more dominant spiders at wetland ecosystems (Betz & Tscharntke, 2017) because the fresh swamp ecosystems are commonly submerged longer (more than 6 mounts) than those at the tidal lowland ecosystems (Mulyani & Sarwani, 2013).

Spider family, Tetragnathidae in this study was the most dominant family of the arboreal spider found during the rice vegetative and generative stages. Species of arboreal spiders dominantly found on paddies at the fresh swamp and tidal lowland ecosystems were similar which consisted of *T. virescens* and *T. javana*. Barrion et al. (2012) stated that in the species of Tetragnathidae, such as species of *T. virescens* and *T. javana* were classified as keystone species. Such species were playing a critical role in maintaining population of rice pest insect, such leafhopper (Betz & Tscharntke, 2017). Species from Tetragnathidae was reported by Shepard *et al.* (1987) and Betz and Tscharntke (2017) as dominant web spiders found at wetland ecosystems. The number of Tetragnathidae in this study were more abundant at the rice vegetative stage than those at the rice generative stage. Betz and Tscharntke (2017) stated that abundant of Tetragnathidae was influenced by the number of leafhoppers (Homoptera) which are commonly occured at vegetative stage of rice. The both species of spiders are predators of rice pest insects, such as order of Homoptera and Lepidoptera (Tahir *et al*., 2009). This also accords with findings of Betz and Tscharntke (2017), which showed highest increase of Tetragnathidae with increasing abundance of Lepidoptera and leafhoppers.

Species abundance of arboreal spiders either at the fresh swamp and tidal lowland ecosystems were higher at vegetative stage of rice than those at generative stage of rice because spider abundance is closely related to their prey population (Riechert & Lockley, 1984). Abundant prey population will attract these spiders to assemble on prey rich ecosystems (Widiarta *et al.*, 2006). The main prey for this spiders was rice insect pests, such as brown planthoppers (Karindah, 2011) that had higher population at vegetative stage of rice than that during generative stage of rice resulting in higher abundance of spiders at the vegetative stage of rice than that of the generative stage of rice. According to Arofah *et al.* (2013) dominant insect pests at vegetative stage of rice were planthoppers, whereas dominant insect pest at generative stage of rice was rice bugs. Thus, rice stages at both ecosystems affects the species abundance of spiders.

Soil-dweller Spiders at Fresh Swamps and Tidal Lowlands

At vegetative stage of rice, soil-dweller spiders found were only two families (Lycosidae and Linyphiidae) from the fresh swamp ecosystems and five families (Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae) from the tidal lowland ecosystems (Table 3). We did not find Araneidae, Thomisidae, and Theridiidae at the fresh swamp ecosystems. The most dominant family of soil-dweller spiders found during the rice vegetative stage was Lycosidae and the most dominant species was *Pardosa pseudoannulata.* A total of soil-dweller spider species found were nine species at the fresh swamp ecosystems and 16 species at tidal lowland ecosystems. Nonetheless, species richness of the soil-dweller spider at the fresh swamp ecosystems were not significantly different (P = 0.5290) from those at the tidal lowland ecosystems.

A total of the soil-dweller spider families found during generative stage of rice were three families (Lycosidae, Araneidae, and Linyphiidae) from the fresh swamp ecosystems and four families (Lycosidae, Araneidae, Linyphiidae, and Salticidae) from the tidal lowland ecosystems (Table 4). The most dominant family of the soil-dweller spiders found was Lycosidae. The species numbers of soil-dweller spiders recorded were eight and 12 from the fresh swamp and the tidal lowland ecosystems, respectively. Species richness of the soil-dweler spiders during the rice generative stage at the fresh swamp ecosystems were not significantly different (P = 0.981) from those at the tidal lowland ecosystems. A total of abundance of soil-dweller spiders at the fresh swamp ecosystems were also not significantly different from those at the tidal lowland ecosystems (P = 0.295).

Spider families found on soil surface of the fresh swamp ecosystems only consisted of Lycosidae and Linyphiidae, whereas Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae, and Salticidae were found at the tidal lowland ecosystems. Web spiders, such as Araneidae, Linyphiidae, and Theridiidae could be found on soil surface. This was due to the fact that these spiders were found on immature stage. According to Iida and Fujisaki (2007) and Suana and Haryanto (2013), immature web spiders had capability to produce small like balloon ball so that they could be moved by wind or moving to other places or descend upon or fallen on soil surface.

A total of abundance and species richness of soil-dweller spiders during the rice vegetative and generative stages at the fresh swamp ecosystems were not significantly different from those at the tidal lowland ecosystems. Nonetheless, the most dominant family of the soil-dweller spiders was Lycosidae and the most dominant species was *P. pseudoannulata.* Barrion *et al.* (2012) list some species in the Lycosid family, such as wolf spider, *P. pseudoannulata* as keystone species. This wolf spider plays the role of a keystone predator within this rice ecosystem by preying leafhoppers (Lou *et al.* 2013). High mobility of the wolf spiders allow them to move and to run or to jump for capturing their preys (Ishijima *et al*., 2006). Abundance of Lycosidae during the rice generative stage at the fresh swamp ecosystems was higher than that at the tidal lowland ecosystems. One explanation why the abundance of Lycosidae was higher at the fresh swamp ecosystems is because farmers culturally do not apply synthetic insecticides to control pest insects. Herlinda (2010) reported that application of the synthetic insecticides at the fresh swamp ecosystems in South Sumatra was rare. Such ecosystems tend to produce high diversity of invertebrate fauna (Mahrub, 1999; Rizali *et al.*, 2002). Rice ecosystems without synthetic insecticides application had higher dominance of predatory arthropods, especially spiders (Herlinda *et al.*, 2008; Herlinda *et al.*, 2004; Zi-yang *et al.*, 2011).

CONCLUSION

The most dominant family and species of the arboreal spiders found were Tetragnathidae and *T. virescens*, respectively, while the most dominant family and species of the soil-dweller spiders were Lycosidae and *P. pseudoannulata*, respectively. Species richness of the arboreal and soil-dweller spiders during the rice vegetative and generative stages at the fresh swamp ecosystems was not significantly different from those at the tidal lowland ecosystems. This findings of the study suggest that the specific and eco-friendly planting methods at the fresh swamp and tidal lowland ecosystems supports existence of Tetragnathidae and Lycosidae, keystone predators of rice pest insects.

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Table 1. The comparison of arboreal spider abundance found on vegetative stage of rice at fresh swamps and tidal lowlands in South Sumatra

No.	Family and Species	Average Spider Abundance (Individuals per 30 Nets)		$P_{value (0.05)}$
		Fresh Swamps	Tidal Lowlands	
	Araneidae	6.500	2.750	0.152
55.	*Araneus inustus*	1.500	0.625	0.303
56.	*Cylosa insulana*	1.750	0.750	0.241
57.	*Cylosa mulmeinensis*	0.500	0.000	0.225
58.	*Gea subarmata*	2.750	1.375	0.550
	Tetragnathidae	54.250	32.750	0.175
59.	*Tetragnatha javana*	8.250	12.000	0.495
60.	*Tetragnatha virescens*	21.000	8.875	0.107
61.	*Tetragnatha mandibulata*	8.500	8.500	1.000
62.	*Tetragnatha ilavaca*	1.000	0.125	0.089
63.	*Tetragnatha maxillosa*	3.000	1.500	0.500
64.	*Tetragnatha desaguni*	1.250	0.750	0.676
65.	*Tetragnatha vermiformis*	8.250	0.750	0.001*
66.	*Tetragnatha okumae*	1.750	0.000	1.000
67.	*Dyschiriognatha hawigtenera*	1.250	0.250	0.202
	Linyphiidae	8.750	9.375	0.944
68.	*Bathyphantes tagalogensis*	4.750	7.125	0.687
69.	*Atypena adelinae*	3.250	2.250	0.773
70.	*Erigone bifurca*	0.750	0.000	1.000
	Oxyopidae	18.000	13.875	0.616
71.	*Oxyopes javanus*	6.250	7.250	0.843
72.	*Oxyopes matiensis*	5.750	6.250	0.842
73.	*Oxyopes bikakaeus*	3.250	0.125	0.007*
74.	*Oxyopes pingasus*	2.750	0.250	0.118
	Thomisidae	0.750	0.750	1.000
75.	*Diaea tadtadtinika*	0.500	0.500	1.000
76.	*Stiphropus sangayus*	0.250	0.250	1.000
	Theridiidae	0.250	0.250	1.000
77.	*Coleosoma octomaculatum*	0.250	0.000	0.364
78.	*Theridion* sp.	0.000	0.250	0.495
	Salticidae	4.250	3.125	0.753
79.	*Myrmarachne bidentata*	0.500	0.250	0.677
80.	*Simaetha damongpalaya*	3.000	0.750	0.422
81.	*Hyllus maskaranus*	0.750	2.125	0.479
	Total of Abundance (N)	92.750	62.875	0.312
	Average of Abundance	13.250	8.982	0.309
	Species Richness (D)	1.700	1.195	0.186

*= significantly different

Table 2. The comparison of arboreal spider abundance found on generative stage of rice at fresh swamp and tidal lowland in South Sumatra

No.	Family. and Species	Average Spider Abundance (Individuals per 30 Nets)	$P_{value (0.05)}$

		Fresh Swamps	Tidal Lowlands	
	Araneidae	5.000	4.500	0.803
55.	*Araneus inustus*	0.750	1.125	0.481
56.	*Cylosa insulana*	1.000	0.500	0.327
57.	*Cylosa mulmeinensis*	0.750	0.125	0.260
58.	*Gea subarmata*	2.500	2.750	0.912
	Tetragnathidae	26.000	26.000	1.000
59.	*Tetragnatha javana*	7.250	7.250	1.000
60.	*Tetragnatha virescens*	7.250	7.750	0.548
61.	*Tetragnatha mandibulata*	3.500	4.375	0.548
62.	*Tetragnatha ilavaca*	0.000	0.875	1.000
63.	*Tetragnatha maxillosa*	0.500	1.125	0.320
64.	*Tetragnatha desaguni*	0.000	0.000	1.000
65.	*Tetragnatha vermiformis*	6.750	4.625	0.188
66.	*Tetragnatha okumae*	0.750	0.000	1.000
67.	*Dyschiriognatha hawigtenera*	0.000	0.000	1.000
	Linyphiidae	6.250	4.750	0.720
68.	*Bathyphantes tagalogensis*	3.250	0.875	0.115
69.	*Atypena adelinae*	3.000	3.875	0.723
70.	*Erigone bifurca*	0.000	0.000	1.000
	Oxyopidae	8.500	15.625	0.096
71.	*Oxyopes javanus*	3.750	7.625	0.058
72.	*Oxyopes matiensis*	4.750	6.125	0.558
73.	*Oxyopes bikakaeus*	0.000	1.250	1.000
74.	*Oxyopes pingasus*	0.000	0.625	1.000
	Thomisidae	0.000	0.375	1.000
75.	*Diaea tadtadtinika*	0.000	0.250	1.000
76.	*Stiphropus sangayus*	0.000	0.125	1.000
	Theridiidae	0.000	0.250	1.000
77.	*Coleosoma octomaculatum*	0.000	0.250	1.000
78.	*Theridion* sp.	0.000	0.000	1.000
	Salticidae	2.000	2.750	0.634
79.	*Myrmarachne bidentata*	0.000	0.250	0.495
80.	*Simaetha damongpalaya*	1.250	2.500	0.560
81.	*Hyllus maskaranus*	0.750	0.000	1.000
	Total of Abundance (N)	47.750	54.250	0.521
	Average of Abundance	6.821	1.417	0.000*
	Species Richness (D)	1.467	1.573	0.807

*= significantly different

Table 3. The comparison of soil-dweller spider abundance found on vegetative stage of rice at fresh swamp and tidal lowland in South Sumatra

No.	Family. and Species	Average Spider Abundance (Individuals per 18 Traps)		$P_{value\ (0.05)}$
		Fresh Swamps	Tidal Lowlands	
	Lycosidae	24.250	22.125	0.664
37.	*Pardosa pseudoannulata*	17.000	14.625	0.618
38.	*Pardosa sumatrana*	3.750	2.625	0.177
39.	*Pardosa birmanica*	0.750	0.625	0.836
40.	*Pardosa mackenziei*	0.500	1.875	0.135

41.	*Pardosa patapensis*	0.250	0.000	0.364
42.	*Hogna rizali*	0.000	1.750	1.000
43.	*Arctosa tanakai*	2.000	0.625	0.244
	Araneidae	0.000	1.625	1.000
44.	*Araneus inustus*	0.000	0.500	1.000
45.	*Cylosa insulana*	0.000	0.875	1.000
46.	*Gea subarmata*	0.000	0.250	1.000
	Linyphiidae	5.000	1.250	1.000
47.	*Bathyphantes tagalogensis*	2.500	0.250	0.009
48.	*Atypena adelinae*	2.000	0.500	0.112
49.	*Erigone bifurca*	0.500	0.500	1.000
	Thomisidae	0.000	0.875	1.000
50.	*Diaea tadtadtinika*	0.000	0.750	1.000
51.	*Stiphropus sangayus*	0.000	0.125	1.000
	Theridiidae	0.000	0.375	1.000
52.	*Coleosoma octomaculatum*	0.000	0.125	1.000
53.	*Theridion* sp.	0.000	0.250	1.000
	Salticidae	0.000	0.000	1.000
54.	*Hyllus maskaranus*	0.000	0.000	1.000
	Total of Abundance (N)	29.250	26.250	0.451
	Average of Abundance	4.875	4.375	0.466
	Species Richness (D)	0.983	1.272	0.529

*= significantly different

Table 4. The comparison of soil-dweller spider abundance found on generative stage of rice at fresh swamp and tidal lowland in South Sumatra

No.	Family. and Species	Average Spider Abundance (Individuals per 18 Traps)		$P_{value\ (0.05)}$
		Fresh Swamps	Tidal Lowlands	
	Lycosidae	27.250	20.000	0.041*
35.	*Pardosa pseudoannulata*	15.750	12.250	0.326
36.	*Pardosa sumatrana*	5.500	5.125	0.699
37.	*Pardosa birmanica*	0.500	0.500	1.000
38.	*Pardosa mackenziei*	0.000	0.000	1.000
39.	*Pardosa patapensis*	0.000	0.625	1.000
40.	*Hogna rizali*	1.500	0.250	0.141
	Arctosa tanakai	4.000	1.250	0.012*
41.	**Araneidae**	0.000	0.250	0.495
42.	*Araneus inustus*	0.000	0.125	0.742
43.	*Cylosa insulana*	0.000	0.000	1.000
	Gea subarmata	0.000	0.125	0.742
44.	**Linyphiidae**	4.500	4.875	0.936
45.	*Bathyphantes tagalogensis*	3.000	2.250	0.753
46.	*Atypena adelinae*	1.250	2.250	0.532
	Erigone bifurca	0.250	0.375	0.715
47.	**Thomisidae**	0.000	0.000	1.000
48.	*Diaea tadtadtinika*	0.000	0.000	1.000
	Stiphropus sangayus	0.000	0.000	1.000
49.	**Theridiidae**	0.000	0.000	1.000
50.	*Coleosoma octomaculatum*	0.000	0.000	1.000

	Theridion sp.	0.000	0.000	1.000
51.	**Salticidae**	0.000	0.125	0.742
	Hyllus maskaranus	0.000	0.125	0.742
	Total of Abundance (N)	31.750	25.250	0.295
	Average of Abundance	5.292	4.208	0.329
	Species Richness (D)	1.058	1.052	0.981

*= significantly different

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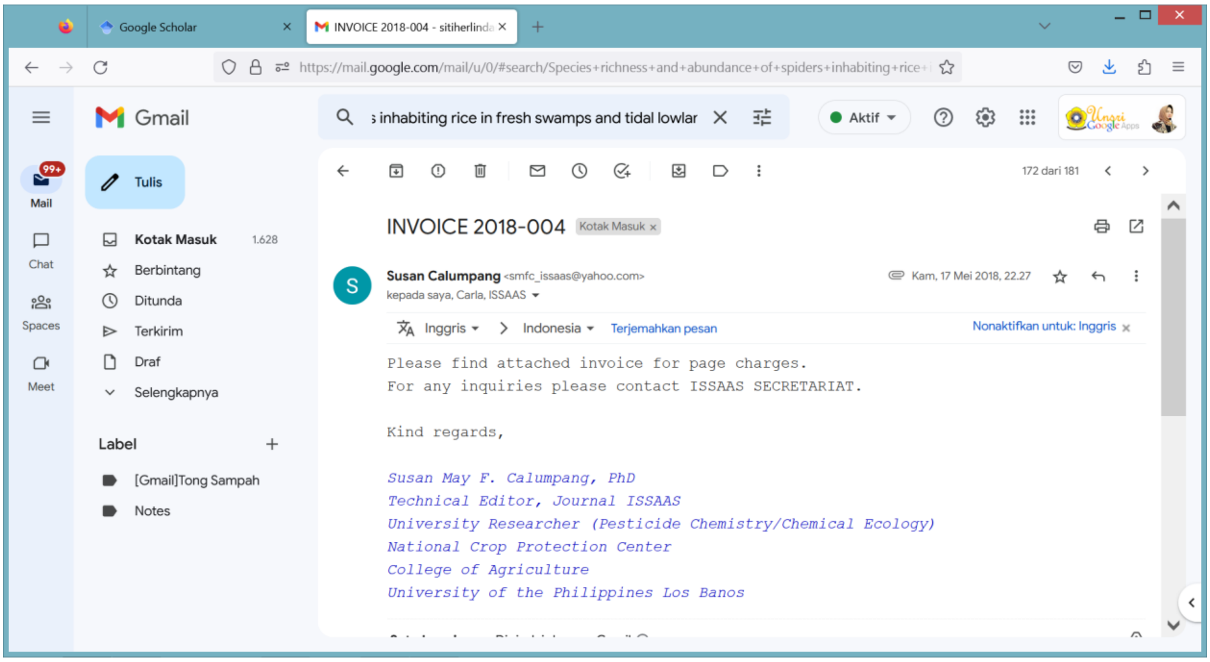
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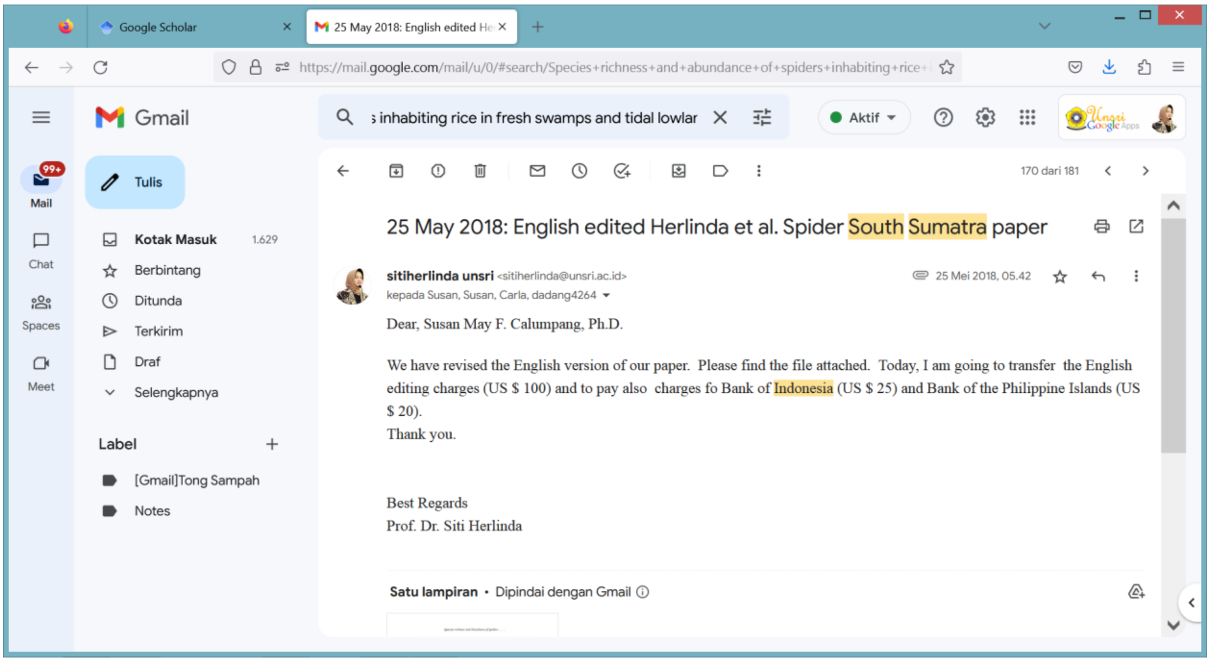
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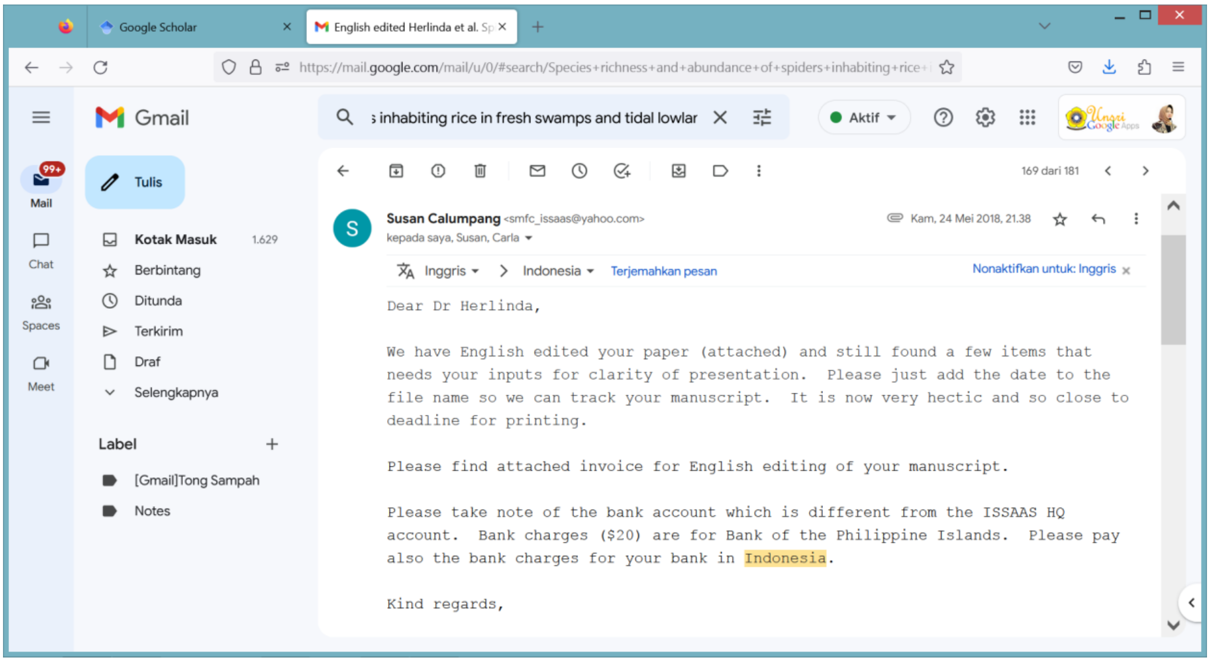

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SPECIES RICHNESS AND ABUNDANCE OF SPIDERS INHABITING RICE IN FRESH SWAMPS AND TIDAL LOWLANDS IN SOUTH SUMATRA, INDONESIA

Siti Herlinda[1, 2]*, Sandi Yudha[3], Rosdah Thalib[1], Khodijah[4], Suwandi[1,2], Benyamin Lakitan[1,2], Marieska Verawaty[5]

[1]College of Agriculture, Universitas Sriwijaya, Indralaya, South Sumatra, Indonesia 30662

[2]Research Center for Sub-optimal Lands (PUR-PLSO), Universitas Sriwijaya, Palembang, South Sumatra, Indonesia 30139

[3]Alumnus of College of Agriculture, Universitas Sriwijaya, Indralaya, South Sumatra, Indonesia 30662

[4]College of Agriculture, Universitas Palembang, Palembang, Indonesia 30139

[5]College of Mathematic and Natural Sciences, Universitas Sriwijaya, Indralaya, Indonesia

*Corresponding author: sitiherlinda@unsri.ac.id

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ABSTRACT

Species richness and abundance of arthropods can be affected by the growth stage of a plant and by specific planting methods in agroecosystems. Thus, there is a need to quantify arthropod assemblages, in order to analyze the species richness and abundance of spiders inhabiting rice. This study aimed to analyze the species richness and abundance of spiders inhabiting rice during both their vegetative and generative stages in fresh swamps and tidal lowlands of South Sumatra, Indonesia. The survey was carried out from February up to August 2012. Arboreal spiders were sampled using sweep nets, while soil-dwelling spiders were collected through pitfall traps. Families belonging to arboreal spiders present were: Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae. Soil-dwelling spiders present belonged to the family Lycosidae. Spider abundance was significantly greater in fresh swamps than in the tidal lowlands for both spiders (*Tetragnatha vermiformis* and *Oxyopes bikakaeus*) during the vegetative stage. On the other hand, the soil-dwelling spider *Arctosa tanakai* under family Lycosidae had a significantly greater abundance in fresh swamps than in tidal lowland ecosystems during the generative stage. Meanwhile, during the generative stage the average abundance of arboreal spiders was significantly greater in the fresh swamps than in the tidal lowlands, while there was no significant difference in species richness. For soil-dwelling spiders, there was no signifcant difference in abundance and species richness during the vegetative stage of rice. From the two groups of spiders for both ecosystems, the soil-dwelling family Lycosidae would make a better predator of rice pests.

Key words: arboreal, arthropod, rice field, soil-dweller

INTRODUCTION

Indonesian wetlands have two distinct ecosystems namely, tidal lowlands and fresh water ecosystems. Tidal lowlands are directly influenced by sea tides while fresh swamps are unaffected (Mulyani and Sarwani 2013). In tidal lowland ecosystems, the soil needs to be held in a specific technique due to its thick pyritic layers, thus the need for it to be preserved (Hidayat et al. 2010). Farmers from tidal lowlands cannot properly handle the soil soil to prevent pyritic layer degradation (Suriadikarta and Sutriadi 2007). Thus, they generally plant rice twice a year (planting index) through broadcast seeding, drum seeding, or planting seedlings in a dug hole ("tugal"), (Raharjo et al. 2013). Farmers from fresh swamps usually grow rice through transplanting which is conducted only once a year (Mulyani and Sarwani 2013, Lakitan et al. 2018). Arthropod abundance and species richness can be affected by different techniques in rice planting, as well as by indices in both ecosystems (Zhang et al. 2013, Parry et al. 2015). Weedy paddies in directly planted ecosystems have a higher abundance of arthropods than in ecosystems with no weeds (Hu et al. 2012). The absence of either soil or conservation tillage in rice fields also support a higher abundance of arthropods (Pereira et al. 2010). The absence of synthetic insecticides in fresh swamp ecosystems also increase the abundance of predatory arthropods (Herlinda et al. 2004, Herlinda et al. 2008, Heong et al. 2007, Furlan et al. 2018).

The growth stage of a plant also influences species richness and arthropod abundance (Zhong-xian et al. 2006). During the vegetative and generative growth stages in rice, there is a higher abundance and species diversity of soil-dwelling arthropods in tidal lowlands than in fresh swamp ecosystems (Khodijah et al. 2012, Herlinda et al. 2014). However, arboreal arthropods are more abundant and diverse in fresh swamp ecosystems than in tidal lowlands (Khodijah et al. 2012, Sunariah et al. 2016). Spiders play an important role in controlling the populations of planthoppers and leafhoppers (Ooi and Shepard 1994). Wolf spiders (*Pardosa pseudoannulata*) and dwarf spiders (*Atypena formosana*) are important predators of brown planthoppers (BPH) and *Nephotettix virescens* (Sigsgaard and Villareal 1999, Sigsgaard et al. 2001). Both spiders can also prey on leaffolders, stem borers, whorl maggot flies, and caseworms (Shepard et al. 1987, Rubia et al. 1990). Thus, species richness and abundance of spiders inhabiting rice can provide information on the regulation of the population of insect pests. Therefore, there is a need to quantify arthropod assemblages in order to determine species richness and abundance of spiders in rice, specifically during both their vegetative and generative stages, in fresh swamps and tidal lowland ecosystems in South Sumatra, Indonesia.

MATERIALS AND METHODS

Study site

Arthropod sampling was conducted in rice production areas of both fresh swamps and tidal lowlands in South Sumatra, Indonesia. The survey was conducted from February up to August 2012, and the identification of arthropod samples was done from September 2012 up to March 2013. Four survey sites from fresh swamp ecosystems were: (1) Gandus, Palembang City; (2) Pelabuhan Dalam Village in Ogan Ilir District; (3) Maryana Village in Banyuasin District; and (4) Sungai Waru Village in Kabupaten Banyuasin District. Eight survey sites from tidal lowlands were all from Banyuasin District, namely: (1) Banyu Urip Village in Tanjung Lago Subdistrict; (2) Telang Karya Village in Muara Telang Subdistrict; (3) Telang Rejo Village in Muara Telang Subdistrict; (4) Srikaton Damai Village in Air Saleh Subdistrict; (5) Srimulyo Village in Kecamatan Air Saleh Subdistrict; (6) Makarti Jaya Village in Makarti Jaya Subdistrict; (7) Tirta Mulya Village in Makarti Jaya Subdistrict; and (8) Tirta Kencana Village in Makarti Jaya Subdistrict. In each site, three sampling plots, with a minimum size of 1 ha per plot, were surveyed twice during a single rice season (4 months). The first survey was conducted when the rice was 4 weeks old upon transplant, while the second survey was during the milk grain stage (9 weeks old upon transplant). Ciherang was the rice variety type grown in fresh swamps, whereas Inpara was grown in tidal lowland ecosystems.

Sampling

Spiders sampled included both web-building and non-web-building spiders. Web-building spiders use their webs to catch prey while non-web-building spiders are more of hunters (Leroy and Leroy 2003). Web-building spiders have become habitat specialists, while the non-web-building spiders tend to be less specific in habitat preference (Gillespie 1999). Arboreal spiders inhabit plant canopies and consist mostly of web-building spiders, while soil-dwelling spiders consist mostly of non-web-building spiders (Leroy and Leroy 2003).

Arboreal spiders

Arboreal spiders were collected using sweep nets, based on the methods from Herlinda et al. (2014). Sweeping involved 'double swings', with a total of 30 swings/ha for each plot. The total number of plots were 12 in fresh swamps and 24 from tidal lowland ecosystems.

Soil-dweller spiders

Soil-dwelling spiders were collected using pitfall traps, based on the methods developed by Herlinda et al. (2004). Plastic pitfall traps (60 mm in diameter and 90 mm in height) were filled to a volume of 70 mL 4% formaldehyde solution, buried in the ground, and flushed with soil. Traps were set up to a density of 18 trap units/ha, spaced in a grid of 3 x 6, and then collected after 48 hours. All specimens collected were cleaned, sorted from other debris, and stored in glass vials (volume 30 ml) containing 70% ethanol. Identification of the specimens up to family- and species-levels was carried out at the Laboratory of Entomology, Plant Pest and Disease Department, College of Agriculture, Universitas Sriwijaya, using taxonomic keys provided by Barrion and Litsinger (1995).

Data Analysis

Spider abundance data of specimens from fresh swamps and tidal lowland ecosystems were not normally distributed. Insect counts in this study were found to fit a negative binomial distribution and were analyzed by Proc Genmod using SAS University Edition (SAS Institute Inc., Cary, NC, U.S.A.). Species richness was analysed using Menhinick's index (D) (Magurran 1988).

RESULTS AND DISCUSSION

Planting Methods and Index for Fresh Swamps and Tidal Lowlands

In fresh swamp ecosystems, farmers applied a transplanting system involving sequential steps. The first step was soil preparation involving full tilage, then seedling preparation by seeding on a floating seedbed, and lastly, by transplanting the seedlings on a rice field. Once finished, the rice should be protected from pests, but local farmers seldom do so because this is not their main concern. Most farmers from fresh swamps only grow rice annually from May-September (one planting index). Farmers in tidal lowlands, on the other hand, apply a direct planting system and grow rice two to three times a year (two to three planting indexes). The sequential steps for planting rice in tidal lowlands were first, soil preparation using minimum tillage, next was by spreading seeds directly by hand, or by a tool or machine. To protect rice from pests, local farmers sprayed synthetic pesticides if there are any pest or weed problems. Thus, the planting methods and index of rice are specific and different for each ecosystem.

Arboreal spiders from fresh swamp and tidal lowland ecosystems

During the vegetative growth stage of rice, seven families of arboreal spiders were present in both fresh swamp and tidal lowland ecosystems. Tetragnathidae was the most dominant family observed, while the other families of arboreal spider present were: Araneidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae (Table 1). A total of 92.750 spiders/30 nets were observed from fresh swamp ecosystems, while a total of 62.875 spiders/30 nets were captured from tidal lowland ecosystems. However, there was no significant difference (P = 0.312) between both ecosystems. The abundance of *Tetragnatha vermiformis* (P = 0.001) and *Oxyopes bikakaeus* (P = 0.007) from fresh swamp ecosystems were both significantly higher than their abundance in tidal lowland ecosystems. But, in the case of the other arboreal spiders, there was no significant difference. A total of 26 arboreal spider species was observed from fresh swamp ecosystems, while 23 species were present in tidal lowland ecosystems. However, there was no significant difference in species richness between fresh swamps (P = 0.186) and tidal lowland ecosystems. Thus, web-building spiders were more abundant in fresh swamps since these ecosystems are not exposed to synthetic insecticides.

Table 1. A comparison of arboreal spider abundance between fresh swamps and tidal lowland ecosystems during the vegetative growth stage of rice in South Sumatra, Indonesia.

No.	Family and Species	Average Spider Abundance (Individuals/30 Nets)		$P_{value\ (0.05)}$
		Fresh Swamps	**Tidal Lowlands**	
	Araneidae	6.5	2.75	0.15
1.	*Araneus inustus*	1.5	0.63	0.3
2.	*Cylosa insulana*	1.75	0.75	0.24
3.	*Cylosa mulmeinensis*	0.5	0	0.23
4.	*Gea subarmata*	2.75	1.38	0.55
	Tetragnathidae	54.25	32.75	0.18
5.	*Tetragnatha javana*	8.25	12	0.5
6.	*Tetragnatha virescens*	21	8.88	0.11
7.	*Tetragnatha mandibulata*	8.5	8.5	1
8.	*Tetragnatha ilavaca*	1	0.13	0.09
9.	*Tetragnatha maxillosa*	3	1.5	0.5
10.	*Tetragnatha desaguni*	1.25	0.75	0.68
11.	*Tetragnatha vermiformis*	8.25	0.75	0.001*
12.	*Tetragnatha okumae*	1.75	0	1
13.	*Dyschiriognatha hawigtenera*	1.25	0.25	0.2
	Linyphiidae	8.75	9.38	0.94
14.	*Bathyphantes tagalogensis*	4.75	7.13	0.69
15.	*Atypena adelinae*	3.250	2.250	0.773
16.	*Erigone bifurca*	0.75	0	1
	Oxyopidae	18	13.88	0.62
17.	*Oxyopes javanus*	6.25	7.25	0.84
18.	*Oxyopes matiensis*	5.75	6.25	0.84
19.	*Oxyopes bikakaeus*	3.25	0.13	0.007*
20.	*Oxyopespingasus*	2.75	0.25	0.12
	Thomisidae	0.750	0.75	1
21.	*Diaea tadtadtinika*	0.5	0.5	1
22.	*Stiphropus sangayus*	0.25	0.25	1
	Theridiidae	0.25	0.25	1
23.	*Coleosoma octomaculatum*	0.25	0	0.36

24.	*Theridion* sp.	0	0.25	0.5
	Salticidae	4.25	3.13	0.75
25.	*Myrmarachne bidentata*	0.5	0.25	0.68
26.	*Simaetha damongpalaya*	3	0.75	0.42
27.	*Hyllus maskaranus*	0.75	2.13	0.48
	Total Abundance (N)	92.75	62.88	0.31
	Average Abundance	13.25	8.98	0.31
	Species Richness (D)	1.7	1.2	0.19

*= significantly different

During the rice generative stage, five families of arboreal spiders were observed from fresh swamp ecosystems, namely: Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, and Salticidae. In tidal lowland ecosystems, seven spider families were present, namely: Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae), (Table 2). However, there was no significant difference in abundance between fresh swamp and tidal lowland ecosystems among members of families Araneidae (P = 0.803), Tetragnathidae (P = 1.000), Linyphiidae (P = 0.720), Oxyopidae (P = 0.096), Theridiidae (P = 1.000), and Salticidae (P = 0.633). Furthermore, there was no significant difference in total abundance of spiders between fresh swamp ecosystems (47.750 spiders/30 nets) and tidal lowlands (54.250 spiders/30 nets) (P = 0.521). However, there was a significant difference in average abundance of spiders between fresh swamps (6.82 spiders/30 nets) and tidal lowland ecosystems (1.42 spiders/30 nets), (P = 0.000).

Table 2. A comparison of arboreal spider abundance between fresh swamps and tidal lowland ecosystems during the generative growth stage of rice in South Sumatra, Indonesia.

No.	**Family and Species**	**Average Spider Abundance (Individuals/30 Nets)**		P_{value} (0.05)
		Fresh Swamps	**Tidal Lowlands**	
	Araneidae	5	4.5	0.803
1.	*Araneus inustus*	0.75	1.13	0.48
2.	*Cylosa insulana*	1	0.5	0.33
3.	*Cylosa mulmeinensis*	0.75	0.13	0.26
4.	*Gea subarmata*	2.5	2.75	0.91
	Tetragnathidae	26	26	1
5.	*Tetragnatha javana*	7.25	7.25	1
6.	*Tetragnatha virescens*	7.25	7.75	0.55
7.	*Tetragnatha mandibulata*	3.5	4.38	0.55
8.	*Tetragnatha ilavaca*	0	0.88	1
9.	*Tetragnatha maxillosa*	0.5	1.13	0.32
10.	*Tetragnatha desaguni*	0	0	1
11.	*Tetragnatha vermiformis*	6.75	4.63	0.19
12.	*Tetragnatha okumae*	0.75	0	1
13.	*Dyschiriognatha hawigtenera*	0	0	1
	Linyphiidae	6.25	4.75	0.72
14.	*Bathyphantes tagalogensis*	3.25	0.88	0.12
15.	*Atypena adelinae*	3	3.88	0.72
16.	*Erigone bifurca*	0	0	1
	Oxyopidae	8.5	15.63	0.1
17.	*Oxyopes javanus*	3.75	7.63	0.06
18.	*Oxyopes matiensis*	4.75	6.13	0.56
19.	*Oxyopes bikakaeus*	0	1.25	1
20.	*Oxyopespingasus*	0	0.63	1
	Thomisidae	0	0.375	1
21.	*Diaea tadtadtinika*	0	0.25	1
22.	*Stiphropus sangayus*	0	0.13	1
	Theridiidae	0	0.25	1
23.	*Coleosoma octomaculatum*	0	0.25	1
24.	*Theridion* sp.	0	0.00	1
	Salticidae	2	2.75	0.63
25.	*Myrmarachne bidentata*	0	0.25	0.5
26.	*Simaetha damongpalaya*	1.25	2.5	0.56
27.	*Hyllus maskaranus*	0.75	0	1

Total Abundance (N)	47.75	54.25	0.52
Average Abundance	6.82	1.42	0*
Species Richness (D)	1.47	1.57	0.81

*= significantly different

Among the arboreal spiders, families that were observed during both rice growth stages and ecosystems were: Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae. These families consisted of both web-building (Araneidae, Tetragnathidae, Linyphiidae, and Theridiidae) and non-web-building (Oxyopidae, Thomisidae, and Salticidae) species, commonly found in either fresh swamps or tidal lowland ecosystems (Schmidt and Tscharntke 2005). The abundance of *T. vermiformis* (Tetragnathidae) and *O. bikakaeus* (Oxyopidae) was significantly greater in fresh swamps than in tidal lowland ecosystems. Members from families Tetragnathidae and Oxyopidae were more dominant in wetland ecosystems (Betz and Tscharntke 2017), since fresh swamps are commonly submerged for a longer period of more than 6 months (November to April) than tidal lowland ecosystems (3 months, November to January), (Mulyani and Sarwani 2013). Furthermore, members from families Tetragnathidae and Oxyopidae were more abundant in fresh swamp ecosystems since farmers did not use synthetic insecticides in controling rice pests. The presence of more abundant tetragnathid web- or other types web-building spiders can be used as an indicator for farmers not to spray synthetic pesticides (Betz and Tscharntke 2017).

Sixteen species of arboreal spiders were observed in fresh swamp ecosystems, while 21 species were present in tidal lowlands. However, there was no significant difference in species richness of arboreal spiders between fresh swamp ecosystems (P = 0.8067) and tidal lowlands. Both the arboreal spiders *T. virescens* and *T. javana*, classified as keystone species (Barrion et al. 2012), were both abundant in fresh swamps and tidal lowland ecosystems. They play a critical role in maintaining the population of rice insect pests, such as leafhopper, by preying on these pests (Betz and Tscharntke 2017). Species from the family Tetragnathidae were the dominant web-building spiders present in wetland ecosystems in the Philippines (Shepard et al. 1987) and in India (Betz and Tscharntke 2017), with a greater abundance of spiders observed during the rice vegetative stage than during the generative stage. The abundance of spider from family Tetragnathidae was influenced by the number of leafhoppers (Homoptera), which commonly occur during the vegetative growth stage of rice (Betz and Tscharntke 2017). Both *T. virescens* and *T. javana* are predators of rice insect pests, such as insects belonging to the orders Homoptera and Lepidoptera (Tahir et al. 2009). In Indian rice fields, the highest increase of members from family Tetragnathidae was in accordance with an increasing abundance of members from Lepidoptera and Homoptera (leafhoppers), (Betz and Tscharntke 2017).

By comparing the total abundance (N) between tables 1 and 2, total abundance was higher during the vegetative growth stage than the generative growth stage for both fresh swamps and tidal lowland ecosystems. Abundance is also closely related with the population of their prey, attracting spiders to the area (Riechert and Lockley 1984, Widiarta et al. 2006). Insects pests, such as brown planthoppers, are the main prey of arboreal spiders (Karindah 2011). Brown planthoppers have a higher population during the vegetative growth stage of rice than during the generative stage, which results in a corresponding increase in spider abundance during the vegetative stage. Planthoppers, such the brown planthopper (BPH), were the dominant insect pests observed during the vegetative growth stage of rice, whereas rice bugs were the dominant insect pests present during the generative stage (Arofah et al. 2013). Thus, spider abundance is also affected by the growth stage of rice from both ecosystems.

However, in terms of average abundance, there was no significant difference between both ecosystems during the vegetative stage because synthetic insecticides were not yet applied. However, in tidal lowlands, spraying with synthetic insecticides generally occur when the rice reaches flowering or from panicle initiation to booting, which explains the significantly lower average spider abundance in this ecosystem during the generative stage.

Soil-dwelling spiders in fresh swamps and tidal lowland ecosystems

During the vegetative growth stage in rice of fresh swamp ecosystems, only two soil-dwelling spider families (Lycosidae and Linyphiidae) were observed. Meanwhile, during the vegetative phase in tidal lowlands, one soil-dwelling family (Lycosidae) and four arboreal spider families (Theridiidae, Araneidae, Linyphiidae, Thomisidae) were captured by pitfall traps (Table 3). No spiders belonging to the arboreal spider families Araneidae, Thomisidae, and Theridiidae were found in fresh swamp ecosystems. The most dominant family of soil-dwelling spiders observed during the rice vegetative growth stage in both ecosystems was Lycosidae, with *Pardosa pseudoannulata* being the most dominant species. Nine soil-dwelling spider species were found in fresh swamp ecosystems, while sixteen species were observed from tidal lowlands. Nonetheless, there was no significant difference in species richness (P = 0.5290) among soil-dwelling spiders between fresh swamp and tidal lowland ecosystems. Soil-dwelling spiders from both ecosystems had no significant difference in abundance and species richness. This was due to the minimum soil tillage in tidal lowlands and fields, while in fresh swamps rice was not grown for six months (the rice fallow period).

Table 3. Abundance of spiders observed in the soil in fresh swamps and tidal lowland ecosystems during the vegetative growth stage in rice in South Sumatra, Indonesia. (Edited).

No.	Family and Species	Average Spider Abundance (Individuals/18 Traps)		$P_{value\ (0.05)}$
		Fresh Swamps	**Tidal Lowlands**	
	Lycosidae	24.25	22.13	0.67
1.	*Pardosa pseudoannulata*	17	14.63	0.62
2.	*Pardosa sumatrana*	3.75	2.63	0.18
3.	*Pardosa birmanica*	0.75	0.63	0.84
4.	*Pardosa mackenziei*	0.5	1.88	0.14
5.	*Pardosa patapensis*	0.25	0	0.36
6.	*Hogna rizali*	0	1.75	1
7.	*Arctosa tanakai*	2	0.63	0.24
	Araneidae	0	1.63	1
8.	*Araneus inustus*	0	0.5	1
9.	*Cylosa insulana*	0	0.88	1
10.	*Gea subarmata*	0	0.25	1
	Linyphiidae	5	1.25	1
11.	*Bathyphantes tagalogensis*	2.5	0.25	0.01
12.	*Atypena adelinae*	2	0.5	0.11
13.	*Erigone bifurca*	0.5	0.5	1
	Thomisidae	0	0.88	1
14.	*Diaea tadtadtinika*	0	0.75	1
15.	*Stiphropus sangayus*	0	0.13	1
	Theridiidae	0	0.38	1
16.	*Coleosoma octomaculatum*	0	0.13	1
17.	*Theridion* sp.	0	0.25	1
	Salticidae	0	0	1
18.	*Hyllus maskaranus*	0	0	1
	Total Abundance (N)	29.25	26.25	0.45
	Average Abundance	4.88	4.38	0.47
	Species Richness (D)	0.98	1.27	0.53

*= significantly different

However, during the generative growth stage of rice, three families (Lycosidae, Araneidae, and Linyphiidae) were observed in the soil surface of fresh swamp ecosystems, while four families (Lycosidae, Araneidae, Linyphiidae, and Salticidae) were present in the soil surface of tidal lowlands (Table 4). Lycosidae was the most dominant family of soil-dwelling spiders present, with eight species of soil-dwellers from fresh swamp ecosystems and twelve from tidal lowlands. However, there was no significant difference in species richness (P = 0.981) of soil-dwelling spiders between both ecosystems during the generative growth stage.

In fresh swamp ecosystems, members of Lycosidae and Linyphiidae were observed on the soil surface while spiders belonging to families Lycosidae, Araneidae, Linyphiidae, Thomisidae, Theridiidae, and Salticidae were observed in tidal lowlands. In particular, arboreal web spiders belonging to families Araneidae, Linyphiidae, and Theridiidae, were also observed on the soil surface during their immature stage as a result of ballooning where they could move with the wind and descend, or fall on the soil surface (Iida and Fujisaki 2007, Suana and Haryanto 2013).

Table 4. Abundance of spiders observed in the soil in fresh swamps and tidal lowland ecosystems during the generative growth stage of rice in South Sumatra, Indonesia. (Edited)

No.	Family and Species	Average Spider Abundance (Individuals/18 traps)		$P_{value\ (0.05)}$
		Fresh Swamps	**Tidal Lowlands**	
	Lycosidae	27.25	20	0.04*
1.	*Pardosa pseudoannulata*	15.75	12.25	0.33
2.	*Pardosa sumatrana*	5.5	5.13	0.7

3.	*Pardosa birmanica*	0.5	0.5	1
4.	*Pardosa mackenziei*	0	0	1
5.	*Pardosa patapensis*	0	0.63	1
6.	*Hogna rizali*	1.5	0.25	0.14
7.	*Arctosa tanakai*	4	1.25	0.01*
	Araneidae	0	0.25	0.5
8.	*Araneus inustus*	0	0.13	0.74
9.	*Cylosa insulana*	0	0	1
	Gea subarmata	0	0.13	0.74
	Linyphiidae	4.5	4.88	0.94
10.	*Bathyphantes tagalogensis*	3	2.25	0.75
11.	*Atypena adelinae*	1.25	2.25	0.53
12.	*Erigone bifurca*	0.25	0.38	0.72
	Thomisidae	0	0	1
13.	*Diaea tadtadtinika*	0	0	1
14.	*Stiphropus sangayus*	0	0	1
	Theridiidae	0	0	1
15.	*Coleosoma octomaculatum*	0	0	1
16.	*Theridion* sp.	0	0	1
	Salticidae	0	0.13	0.74
17.	*Hyllus maskaranus*	0	0.13	0.74
	Total Abundance (N)	31.75	25.25	0.3
	Average Abundance	5.29	4.21	0.33
	Species Richness (D)	1.06	1.05	0.98

*= significantly different

There was no significant difference in total abundance and species richness of soil-dwelling families between both ecosystems. Nonetheless, the family Lycosidae had a significantly higher abundance (P=0.04) in fresh swamps than in tidal lowlands during the generative growth stage, especially for *Arctosa tanakai* (Table 4). This could be due to the absence of synthetic insecticides, with only a rare occurrence of synthetic insecticides in fresh swamp ecosystems in South Sumatra (Herlinda 2010). Such ecosystems tend to produce a high diversity of invertebrate fauna (Mahrub 1999, Rizali et al. 2002). Rice ecosystems, without synthetic insecticides use, have a higher abundance of predatory arthropods, especially spiders in Indonesia (Herlinda et al. 2008, Herlinda et al. 2004) and China (Zi-yang et al. 2011). Furthermore, Lycosidae was also the most dominant family of soil-dwelling spiders, with *P. pseudoannulata* or wolf spider, being the most dominant species. Wolf spiders are considered as a keystone species that are critical in preying on leafhoppers (Barrion et al. 2012, Lou et al. 2013). Their high mobility allows them to move, run, or jump to capture their prey (Ishijima et al. 2006).

For soil-dwelling spiders, there was no significant difference in abundance and species richness during the vegetative growth stage. However, during the generative stage, family Lycosidae specifically *Arctosa tanakai* had a significantly higher abundance in fresh swamps than in tidal lowland ecosystems. The reason for such an increase in abundance during the generative stage was that it was during this stage when farmers from tidal lowlands would start spraying synthetic insecticide. Farmers from fresh swamps do not use synthetic insecticides at all, hence the increase in abundance of soil-dwelling spiders during the generative stage in fresh swamp ecosystems.

Spider abundance was significantly greater in fresh swamps than in tidal lowlands for both the arboreal spiders *Tetragnatha vermiformis* and *Oxyopes bikakaeus*, but only during the vegetative stage), (Table 1). For the soil-dwelling spiders under family Lycosidae, specifically *Arctosa tanakai*, abundance was significantly greater in fresh swamps than in tidal lowlands during the generative stage (Table 4). Between the two groups of spiders selected from the arboreal and soil-dwelling spiders, the family Lycosidae is more effective in controlling populations of main insect pests, such as brown planthopper, because they could attack their prey directly. Members of the family Lycosidae are more aggressive in hunting their prey (the insect pest) than *Tetragnatha vermiformis* and *Oxyopes bikakaeus* (Shepard et al. 1987).

Rice is grown twice to three times a year in South Sumatra. Because of the occurrence of BPH problems in rice fields, most farmers (more than 50%) from tidal lowlands spray under a calendar pattern to control pests, such as spraying every two weeks or every month. The dose of insecticide was determined through trial and error, traditional habits, or from information from other farmers. They seldom knew the active ingredient of the insecticide used, some knew just the commercial names. The farmers practiced minimum tillage and because of that, outbursts of weeds always occured. To control such weed occurrence, farmers generally use more than 80% synthetic herbicides which could decrease spider populations (Heong et al. 2007, Barrion et al. 2012).

CONCLUSION

The families of arboreal spiders observed in South Sumatra, Indoesia were: Araneidae, Tetragnathidae, Linyphiidae, Oxyopidae, Thomisidae, Theridiidae, and Salticidae. For soil-dwelling spiders, only the family Lycosidae was present. During the vegetative growth stage in rice, spider abundance was significantly greater in fresh swamps than in the tidal lowlands for the arboreal spiders *Tetragnatha vermiformis* and *Oxyopes bikakaeus*. However, during the generative stage, the abundance of soil-dwelling spiders under family Lycosidae, specifically *Arctosa tanakai,* was significantly greater in fresh swamps than in tidal lowlands. From the two groups of both arboreal and soil-dwelling spiders that exhibit significantly greater abundance, the family Lycosidae would make a better predator of rice pests.

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