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Population of *Spodoptera pectinicornis* as biological insect control of water lettuce weeds *(Pistia Stratiotes* L.) in some district of South Kalimantan

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Abstract

Spodoptera pectinicornis is a herbivorous insect that can be used as a biological control agent of water lettuce weeds (*Pistia stratiotes*) due to its high destructive ability and host specificity. The population of *S. pectinicornis* at the field is still low. This research aimed to study the presence of *S. pectinicornis* and to calculate the abundance of individual insects of *S. pectinicornis* found in water lettuce weeds in the field. The data can be used as an information and a recommended reference for biological control of water lettuce weeds. The method used was *purposive sampling* and the site selection was based on a survey of the presence of apu weeds in the field. Weed sampling was conducted by taking 1-5 individuals of water lettuce every 5-10 steps according to its distribution in the field. The collection was carried out repeatedly until 100 individuals of water lettuce were obtained from each selected location. Individuals from water lettuce samples were then counted for the eggs, larvae, prepupa, pupae and adult stages. Observations from ten sampling locations indicated that *S. pectinicornis was* always present in habitats where water lettuce weeds were invested. The number of *S. pectinicornis* individuals fluctuated but in general, the number of larvae was relatively low with < 3-5 individuals each.

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Introduction

Water lettuce (*Pistia stratiotes* L.) is a type of weed that can cause various disturbances in water areas. The speed of growth and reproduction as well as good adaptability to various environmental conditions cause it to be able to dominate the water area into an area of water lettuce monoculture. It does not directly affect the diversity of organisms as an indicator of disruption to the ecological balance disturbance.

Water lettuce population density can inhibit water flow in dams, rivers, lakes and so on, reduce the aesthetic value of water bodies. In addition, healthwise, water lettuce weeds can be the host of mosquito larvae which are vectors of malaria, encephalitis, and filariasis as well as other dangerous diseases (Lounibos and Dewald, 1989; EPPO, 2017; Hill and Coetzee, 2017; Pratiwi *et al.*, 2018) and also decrease in rice production. According to Diara (2017) in the organic rice farming system, water lettuce weeds grow rapidly, covering 90-95% of rice fields.

The water lettuce takes and absorbs NPK fertilizer that is given for the growth and development of rice so that NPK fertilizer is inefficient and results in a decrease in the growth and rice yield (Sakanov, 2012).

Control of water lettuce can be done physically, mechanically and chemically but requires a lot of energy and costs and can cause environmental damage. A more environmentally friendly control is to take advantage of natural enemies. This method can maintain the balance of the population in nature. One of the classes of weed natural enemies is herbivorous insects.

Insects that are specifically associated with water lettuce weeds are *Spodoptera pectinicornis* (Lepidoptera: Noctuidae) (Mangoendihardjo, 1982; Aphrodyanti, 2007; Kurugundla *et al.*, 2016).

George (1963) *in* Habeck & Thomson (1994) reported that *S. pectinicornis* is a specific insect host and causes very severe damage to water lettuce weeds. The results of Aphrodyanti (2007) showed that 3-5 larvae of *S. pectinicornis* were able to cause 90-100% damage to one individual of water lettuce. According to Habeck anndThomson (1994) 300 larvae of *S. pectinicornis* per square meter are able to destroy the water lettuce quickly and effectively compared to herbicides.

Although some research results showed the success of *S. pectinicornis* to control the weeds but their population is still high in several aquatic habitats. Based on this fact, it is necessary to determine the presence of populations of *S. pectinicornis* in habitats where water lettuce weeds are invested. In addition, quantitative data is needed regarding the number of individuals *S. pectinicornis* found in water lettuce weeds.

This research aimed to study the presence of *S. pectinicornis* and to calculate the abundance of individual insects of *S. pectinicornis* found in water lettuce weeds in the field.

Materials and methods

Place and time

The research was carried out in water areas where water lettuce weeds were invested covering Banjarmasin Municipality; Banjar Regency; Banjarbaru City; Tanah Laut Regency; and Barito Kuala Regency, South Kalimantan Province, Indonesia (Fig. 1).

The calculation and identification of the insect population of *S. pectinicornis were* carried out at the Laboratory of Biological Control, Department of Plant Pests and Diseases, Faculty of Agriculture, Lambung Mangkurat University, Banjarbaru. This research was conducted from November - December 2020.

Materials and instruments, software

Water lettuce (*Pistia stratiotes*), *Spodoptera pectinicornis*, insect nets, containers, Thermo-Higro meters, Total Dissolved Solid (TDS) meters, pH meters, microscope, loop, hand counter, Global Positioning System (GPS).

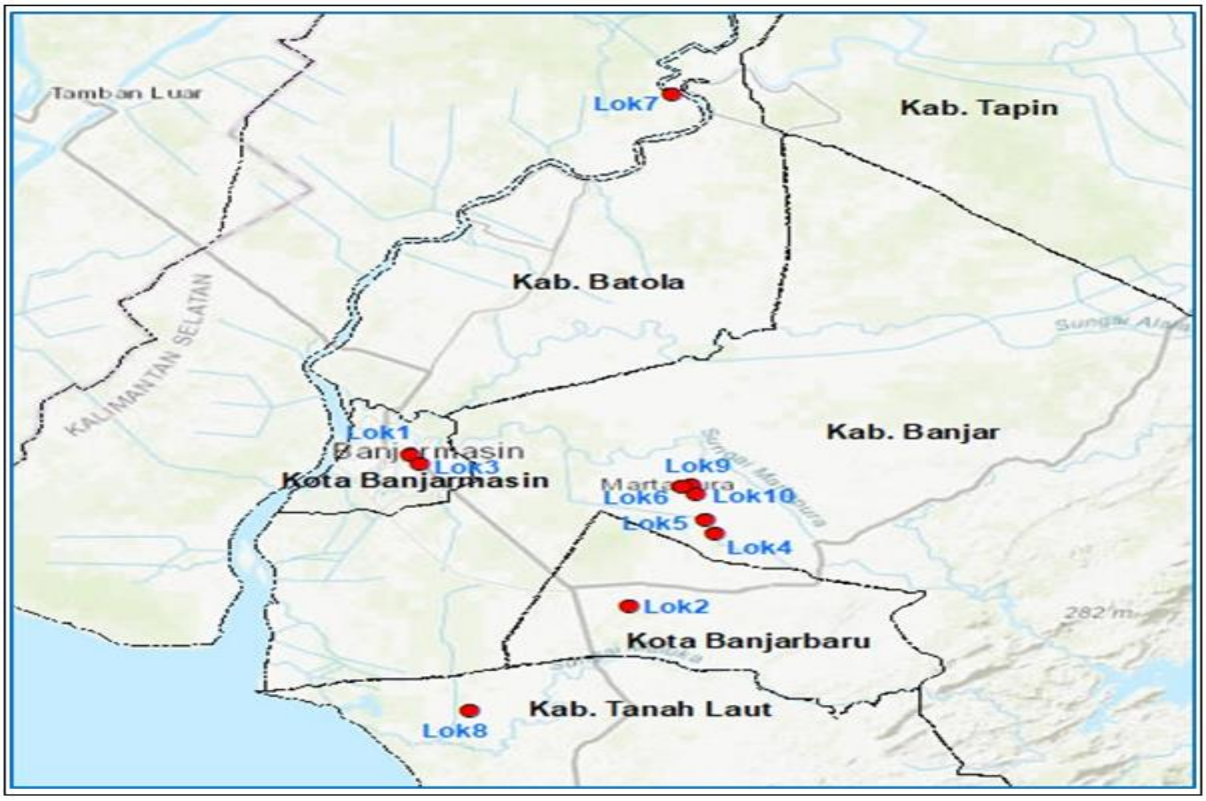

Fig. 1. Map of locations for sampling.

Sampling and collection in the field

The sampling method used was *purposive sampling* based on the presence of water lettuce at the observation location. Sampling was based on Mangoendihardjo (1982) method that was done by taking 1-5 individuals of water lettuce weeds every 5-10 steps according to their distribution in the field. The collection was carried out repeatedly until 100 individuals of water lettuce were obtained at each sampling location.

Observation parameters

Observations were made on 10 water locations including streams of tributaries, ponds and rice fields. The population of *S. pectinicornis* was counted for the eggs, larvae, prepupae, pupae, and adults in the collected water lettuce weeds. Other supporting data were the measurement of the growing medium of water lettuce including temperature, pH and Total Dissolved Solids (TDS); the measurement of environmental conditions including temperature and humidity, whereas the rainfall data was obtained from the Center for Hydrometeorology and Remote Sensing (CHRS) data (http://chrsdata.eng.uci.edu/). The data obtained will be displayed in the form of observation tables and graphs and descriptive information.

Results and discussion

Populations of S. pectinicornis

Water lettuce weeds have had adverse effects on several water locations, especially inhibiting water flow and disrupting the use of water on this location. The observations of these water lettuces showed some damage signs appeared on the leaves surface due to the insect bites. This gave clues to the presence of *S. pectinicornis* in the field. Based on visual observations and individual calculations of the eggs, larvae, prepupae, pupae and adult stages obtained from the collection of water lettuce samples, it is known that these numbers are still relatively low and unable to compensate the water lettuce population in the field (Table 1).

Eggs

Eggs were only found in 2 observation locations, i.e; the Veteran and Sei Batang II locations, respectively 132 and 34 items (Fig. 2). Eggs that are laid by a female adult are generally laid in groups but sometimes are also found solitary.

A female adult can lay as many as 113-561 eggs during her life (Mangoendiharjo, 1982). Eggs are slightly yellowish white and covered in some kind of whitish-yellow fibers which are released by the female Adult from the end of her abdomen. According to Habeck and Thomson, (1994) and Aphrodyanti (2007), the whitish-yellow fibers are thought to function to protect the eggs from drying out and protect them from being attacked by other organisms.

Table 1. The population of *S. pectinicornis* per 100 individuals of water lettuce (*P. stratiotes*) in the field.

No	Location	Eggs (individual)	Larva (individual)	Prepupa (individual)	Pupa (individual)	Adult (individual)
1	Jl. Veteran Sei Bilu Melayu Kec. Banjarmasin Tengah Kota Banjarmasin (-3°19' 12,617"S 114° 36'13,212"E)	132	171	14	29	1
2	Jl. Peramuan Kec. Landasan Ulin Tengah Kota Banjarbaru (-3°27'51"S 114° 44'3"E)	0	11	0	0	0
3	Jl. Gerilya Karang Mekar Kec. Banjarmasin Timur Kota Banjarmasin (-3°19'44,534"S 114° 35,3"E)	0	3	0	0	0
4	Jl. Sei Batang Kec. Martapura Barat Kab. Banjar (-3°23'38,658"S 114° 47'11,105'E)	0	20	1	2	0
5	Jl. Sei Batang (II) Kec. Martapura Barat Kab. Banjar (-3°22'54,659" S 114° 46'51,087"E)	34	25	2	1	0
6	Jl. Penggalaman Kec. Martapura Barat Kab. Banjar (-3°21'0,384"S 114° 46'20,524"E)	0	30	0	1	0
7	Jl. Putri Junjung Buih Kec. Bakumpai Marabahan Kab. Batola (-2°58'43,524'S 114° 45,39,222"E)	0	47	2	4	0
8	Jl. Raya Bumi Makmur Kec. Kurau Kab. Tanah Laut (-3°33'43,387"S 114° 38'17,869"E)	0	94	1	8	0
9	Jl. Martapura Lama Penggalaman Kec. Martapura Barat Kab. Banjar (-3°20'57,145'S 114° 46'22,332"E)	0	24	2	4	0
10	Jl. Martapura Lama (II) Penggalaman Kec. Martapura Barat Kab. Banjar (-3°21'25,339'S 114° 46'31,566"E)	0	8	0	0	0

Larvae

The larvae of *S. pectinicornis* were known to have a high destructive capability due to their feeding activity on weed water lettuce. The presence of these larvae in the field was indicated by the symptoms that appeared on the damaged leaves caused by their bites. Generally, the greater the number of larvae the more damage they cause. The results of the observations indicated that larvae were found at all observation locations with a variety of numbers. The highest number of *S. pectinicornis* larvae was found at the Veteran location, i.e; 171 individuals, followed by the Bumi Makmur location with 94 individuals per 100 water lettuce.

Table 2. Measurement of water temperature, water pH, TDS, air temperature and humidity.

No	Location	Water temperature (°C)	Water pH	TDS (ppm)	Temperature (°C)	RH (%)
1	Jl. Veteran Sei Bilu Melayu Kec. Banjarmasin Tengah Kota Banjarmasin (-3°19' 12,617"S 114° 36'13,212"E)	28.9	7.2	172	28.5	69
2	Jl. Peramuan Kec. Landasan Ulin Tengah Kota Banjarbaru (-3°27'51"S 114° 44'3"E)	30.3	6.3	50	31.9	79
3	Jl. Gerilya Karang Mekar Kec. Banjarmasin Timur Kota Banjarmasin (-3°19'44,534"S 114° 35,3"E)	28.7	7.4	127	26.9	74
4	Jl. Sei Batang Kec. Martapura Barat Kab. Banjar (-3°23'38,658"S 114° 47'11,105'E)	28.8	7.1	167	28.5	92
5	Jl. Sei Batang (II) Kec. Martapura Barat Kab. Banjar (-3°22'54,659" S 114° 46'51,087"E)	29,4	7,3	135	30,3	92
6	Jl. Penggalaman Kec. Martapura Barat Kab. Banjar (-3°21'0,384"S 114° 46'20,524"E)	28 , 0	7,2	98	32,6	66
7	Jl. Putri Junjung Buih Kec. Bakumpai Marabahan Kab. Batola (-2°58'43,524'S 114° 45,39,222"E)	27,4	7,1	136	29,5	77
8	Jl. Raya Bumi Makmur Kec. Kurau Kab. Tanah Laut (-3°33'43,387"S 114° 38'17,869"E)	29,7	6,4	75	33,4	71
9	Jl. Martapura Lama Penggalaman Kec. Martapura Barat Kab. Banjar (-3°20'57,145'S 114° 46'22,332"E)	31,7	7,7	57	32,0	63
10	Jl. Martapura Lama (II) Penggalaman Kec. Martapura Barat Kab. Banjar (-3°21'25,339'S 114° 46'31,566"E)	32.1	7.0	286	32.7	68

The lowest number was found at the Karang Mekar location, i.e; 3 larvae. At the Martapura Lama II and Peramuan, there were 8 and 11 individual larvae with approximately the same conditions as the Karang Mekar location, while at other observation locations the number of larvae was in the range of 20-47 individuals (Fig. 3). This indicated that the larvae of *S. pectinicornis* were not at the optimal numbers to control water lettuce in the field. The results of research by Habeck and Thomson (1994) and Aphrodyanti (2007) showed that *S. pectinicornis* was able to control water lettuce weeds in the range of 3-5 larvae per individual water lettuce or 300 larvae per square meter.

Table 3. Amount of rainfall in several research locations.

Location	November 2020 (mm)	December 2020 (mm)
Banjarmasin Municipality	353.2	500.9
Banjar Regency	284.9	554.4
Banjarbaru City	573.9	459.4
Tanah Laut Regency	546, 7	413.7
Barito Kuala Regency	464.7	431.0

Prepupae

Prepupae is the stage before the insects turn out into the pupae stage. Larvae of *S. pectinicornis* late-instar will start broaching the base of the leaf water lettuce then will undergo morphological changes. This change can be seen in its size which is getting shorter because the body is shrunken and light green. This stage lasts for about 1-2 days before turning into a pupa (Aphrodyanti, 2007).

The results showed that prepupae were found mostly at Veteran locations, while other locations were quite low, only around 1-2 prepupae and there were no prepupae locations (Fig. 4).

Pupae

The newly formed pupae are light brown and the part of the wing will be green. The color of the pupae will change to dark brown, while the wing will be light yellowish-brown. According to Aphrodyanti, (2007) the pupal stage can last around 6-7 days.

The results of the calculation of the pupa showed that the highest number of pupae was at the Veteran location which was as many as 29 individuals, then at the Bumi Makmur location as many as 8 individuals, the Marabahan and Martapura Lama locations with 4 individuals each. At the locations of Sei Batang, Sei Batang II and Penggalaman, only 1-2 individuals were found while at other locations there were no pupae found (Fig. 5).

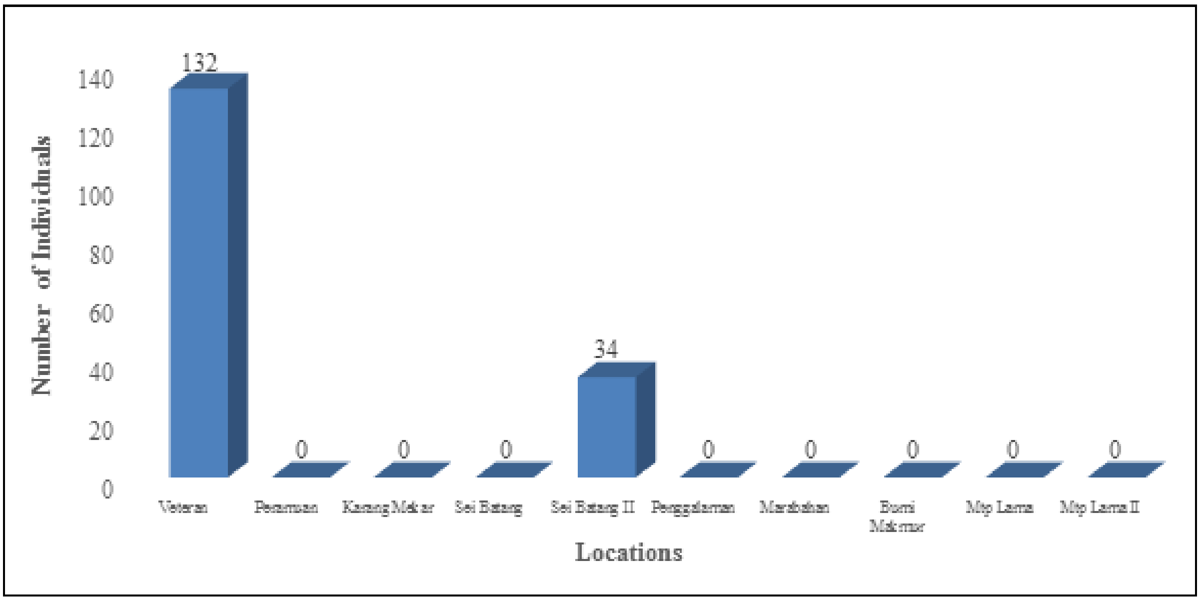

Fig. 2. Number of eggs of *S. pectinicornis* per 100 individuals of water lettuce.

Adult

The presence of adult or adult insects was only found at the Veteran observation location with only 1 (one) female individual. *S. pectinicornis* belongs to the Noctuidae family which is a nocturnal insect. Insects of this group are known to be active at night, so it may be difficult to find them during the daytime sampling. Generally, when inactive, nocturnal insects will take cover or hide and fly away when they feel disturbed or threatened.

Factors affecting populations of S. pectinicornis

Ability to reproduce

The results of the life balance study of *S. pectinicornis* showed that female adult was able to produce an average of 326.88 eggs but the net reproduction rate was only 49.91 eggs. This means that female adult has a fairly large meridian, but the success of the offspring to survive is still relatively low. This is an indication that the fitness of *S. pectinicornis is* still not optimal (Aphrodyanti, 2007). In addition, the mortality of larvae in the early instar is also quite high because of their low adaptability.

Research on the ability of female adults of *S. pectinicornis* to produce eggs was carried out by Aphrodyanti *et al.*, (2017) which showed that the average egg produced was 350.29 but the individual that was able to survive was only 19.59. This value is smaller than previous studies and indicates that there has been a decrease in the fitness of *S. pectinicornis*. This could be the cause of the inability of *S. pectinicornis* to catch up with the growth and development of water lettuce.

Physical

Water lettuce has good adaptability to various environmental conditions so that in a short time it can quickly cover the waters. Water lettuce grows optimally at temperatures between 22°-30° C with high nutritional conditions (Henry-Silva *et al.*, 2008). According to Hussner *et al.*, (2014) in low environmental temperatures with extreme conditions, water lettuce can survive and adapt to smaller leaf sizes. Water lettuce also has the ability to survive in an acidic environment in the pH range 4 and grow optimally in the pH range 7 (US Fish and Wildlife Service, 2018). The results showed that the water temperature at the observation location ranged from 27.4°-32.1° C and the water pH was 6.3-7.7 (Table 2). This showed that water lettuce was in a sufficiently optimal condition for its growth and development. The measurement results for *Total Dissolved Solids* (TDS) were in the range of 50-286 ppm (Table 2). These results indicated that the dissolved particles were low enough for the needs of leafy plants. According to Susilawati (2019), TDS for leafy plants such as lettuce ranges from 560-840 ppm.

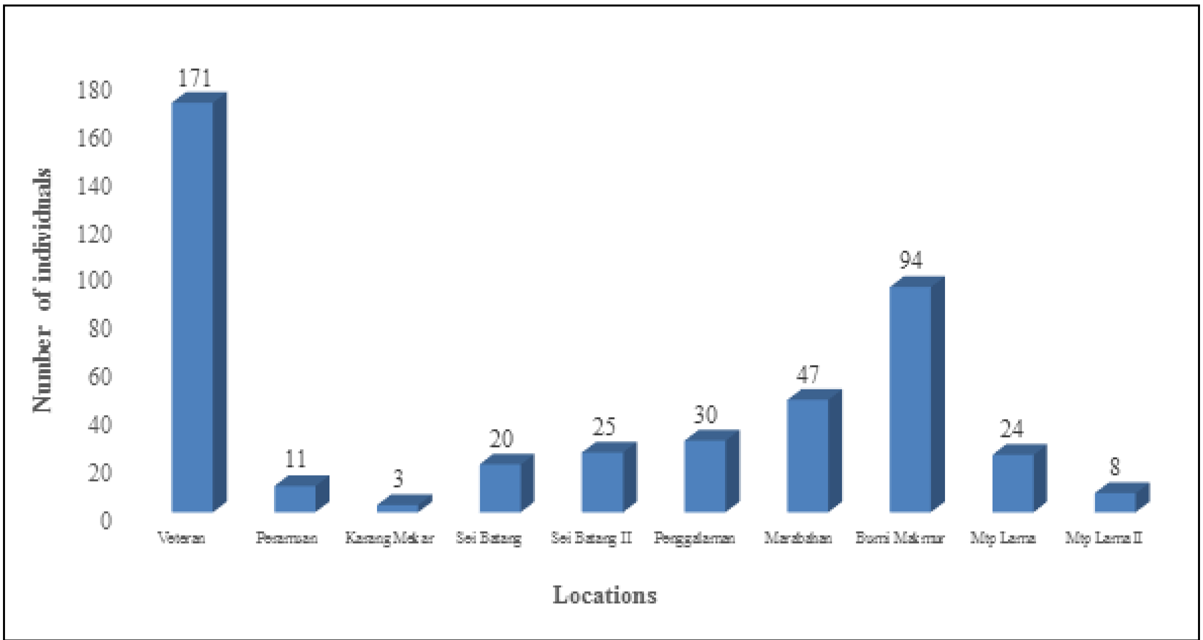

Fig. 3. Number of larvae of *S. pectinicornis* per 100 individuals of water lettuce.

The influence of physical factors in an ecosystem such as temperature and humidity conditions can cause an increase or decrease in the insect population. The results of the measurement of the ambient temperature (Table 3) showed that this condition was quite normal for insect development, which was in the range 26.9-33.4° C and humidity in the range of 69-92%. The optimum temperature range for insects is 25° C but is still capable adapt to a minimum temperature of 15° C and a maximum temperature of 45° C. The speed of an insect's metabolic process will be directly proportional to the increase in the temperature of its environment. Therefore, if the environmental temperature rises, the insect's metabolic process will increase rapidly and will determine the speed of growth and development of an organism, meanwhile, the time of insect development will be inversely proportional to environmental temperature conditions. Increasing environmental temperature will make the metabolic process faster so that the time needed to complete the development of insects getting shorter. This is in accordance with the results of research conducted by Cui *et al.* (2018), that the development time of the larvae, pupae, pre-oviposition and adult of the *Heliotis viriplaca* (Lepidoptera: Noctuidae) will increase with increasing temperature.

Insects have the ability to carry out flight activities so they can avoid attacks by other organisms. In addition, insects can spread their offspring to maintain population stability in the ecosystem. Some research results show that insect flight activity is influenced by temperature. According to Fu *et al.*

(2017), the insect *Macdunnoughia crassisigna* which is the order of Lepidoptera and the Noctuidae family can carry out flying activities in the temperature range of 24° -28° C with an optimum temperature of 24° C. The insect *Mamestra brassicae* (Lepidoptera: Noctuidae) has its flight activity at an optimum temperature range of 23° -25° C (Guo *et al.*, 2020). There has been no research yet on the effect of temperature on the flight activity of *S. pectinicornis*, so it is assumed that the optimal temperature for flight activity is not different from the order Lepidoptera and other Noctuidae families.

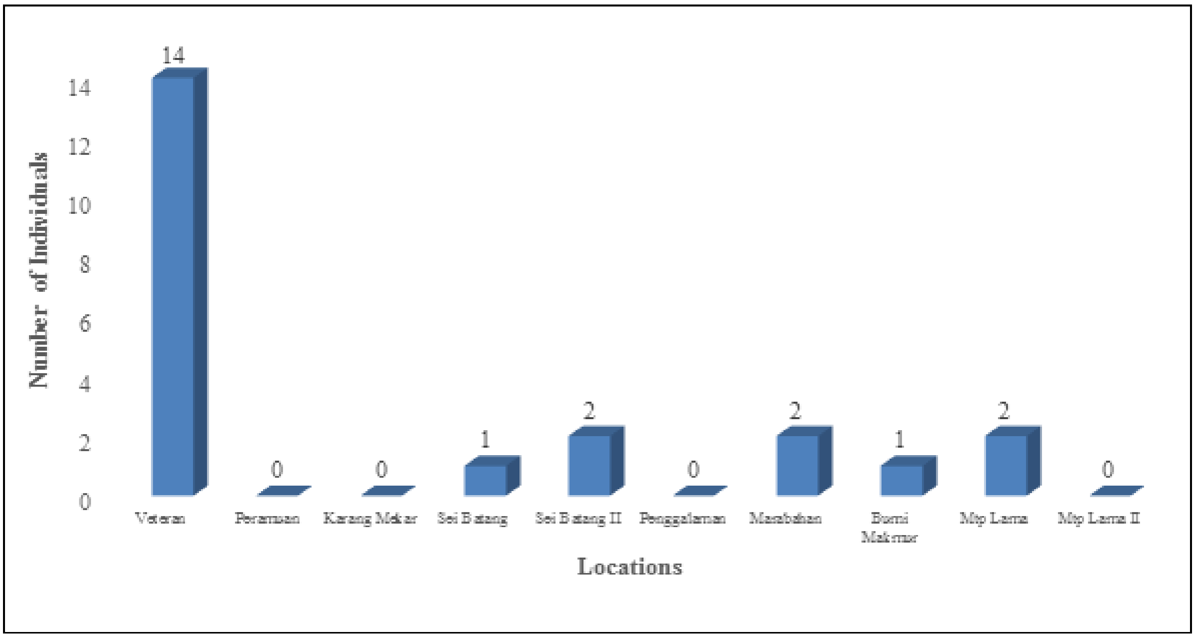

Fig. 4. Number of prepupae of *S. pectinicornis* per 100 individuals of water lettuce.

The temperature state is closely related to humidity, where the relationship between temperature and humidity is inversely proportional. At a relative humidity in the range of 60-75% insects are able to carry out flight activities and the optimum is at a relative humidity of 75% (Fu *et al.*, 2017). The ability to fly for insects that act as weed biological control agents can be one of the factors that can support its success because it can reach a wider area of target weeds.

Another factor affecting directly to insects is rainfall. The relatively high intensity of rainfall will cause insects unable to survive because insects can fall on account of the raining mechanical force. Based on the rainfall data at the time of the study, it was found that the amount of rainfall was quite high, which was in the range of 284.9-573.8 mm (Table 3). The results of research by Aphrodyanti *et al.* (2017) and Mangoendihardjo, (1982) showed that heavy rain would make the water lettuce leaves slightly fall and touch the surface of the water so that it caused the death of larvae or pupae of *S. pectinicornis* under the leaf surface or decayed due to the water submerging. This is a strong suspicion as one of the causes of the low population of *S. pectinicornis* in the field.

Natural enemies

The breeding of *S. pectinicornis* can be hampered due to the presence of natural enemies from predators, parasitoids and pathogens. Predators are animals or insects that eat other animals or insects. The results of the research by Aphrodyanti *et al.*, (2017), showed that the types of larvae and pupae predators that were associated with *S. pectinicornis* from the Aracnida class (spiders) and the insect class (insects) originated from the order Coleoptera from the Carabidae and Coccinellidae families, order Hemiptera from the Gerridae and Naucoridae families, the Odonata order from the Libellilidae and Coenagrionidae families and the Hymenoptera order from the Formicidae families.

According to Dray *et al.* (1993), the failure of *S. pectinicornis* to be released and established as biological agents in the field can be caused by predation activities by predators such as bird species (*boat-tailed grackles*), fire ants and spider species.

Another natural enemy that is thought to attack *S. pectinicornis* is the parasitoid group. According to Evawaty *et al.* (2016) parasitoids that were known to be associated with Lepidoptera insects included those of the Braconidae, Ichneumonidae and Lonchaeidae, Chalcididae and Tachinidae families. The results of research by Aphrodyanti (2007) and Aphrodyanti *et al.* (2017) showed that parasitoids that attacked larvae and pupae of *S. pectinicornis* are from the order of Hymenoptera, Ichneumonidae family and also from the Braconidae, Chalcidiodae, and Platigastroidae.

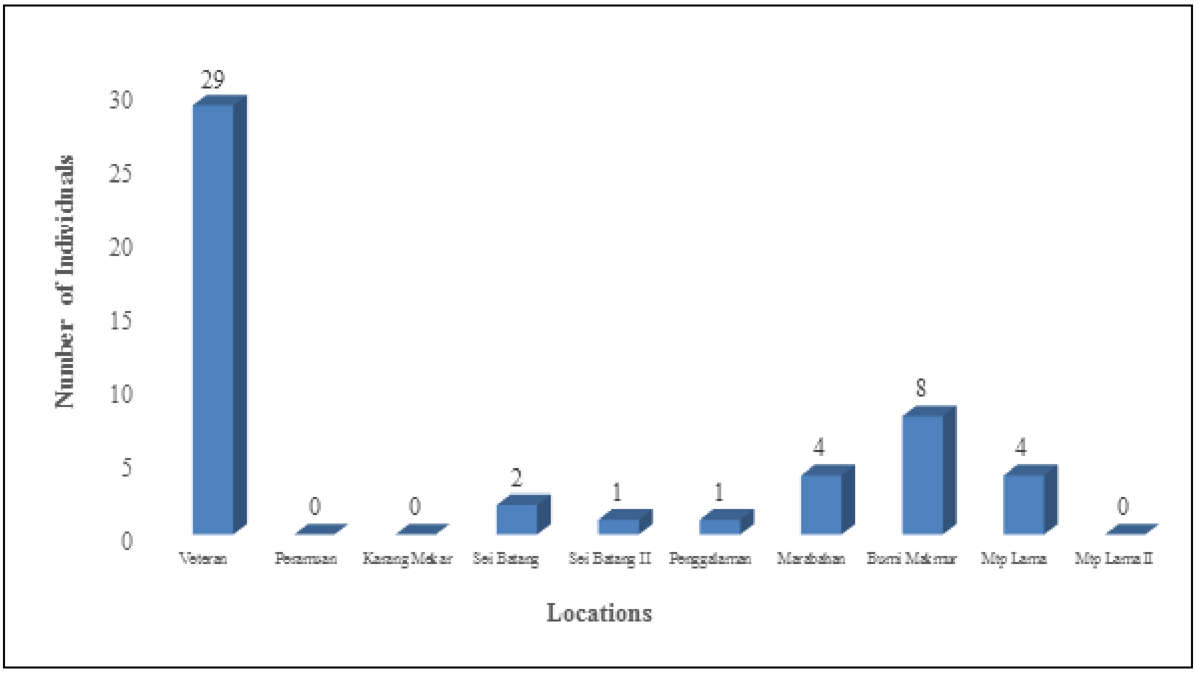

Fig. 5. Number of pupae of *S. pectinicornis* per 100 individuals of water lettuce.

Insects can also be attacked by various pathogens such as bacteria, fungi, viruses, protozoa, rickets, and nematodes. Pathogens can enter the body of insects by damaging the instrument through the spiraculum, anus, or through the mouth and digestion of insects. According to Aphrodyanti (2007), larvae *S. pectinicornis* can be infected with pathogens with symptoms of lazy eating, slow movement and a slightly reddish color. The infected larvae will be brown and black and the internal body decomposes. Based on these symptoms, it is suspected that it is caused by the *Nuclear Polihidrosis Virus* (NPV) but it needs further research and analysis.

Food

The insect population is influenced by the availability of food. The food consumption must be in accordance with the needs of insects to grow and develop optimally. The indication of suitability can be seen from the ability of insects to complete their normal life cycle followed by other biological parameters such as their morphological and physiological conditions. According to Gacemi *et al.* (2019), each type of host plant has a variety of different nutrients so that the response of herbivorous insects to eat is also different. *S. pectinicornis* is a herbivorous insect that is a specific water lettuce host so that the availability of water lettuce greatly affects the state of its population.

The results showed that the veterans' location had a higher abundance of *S. pectinicornis* compared to other locations (Table 2). Water lettuce can be seen covering the waters. The morphology of water lettuce, such as the dark green leaves and hard texture and the stolon that looks strong and solid, shows that the water lettuce has adapted to this ecological condition, and so is *S. pectinicornis*. However, the population of *S. pectinicornis was* still insufficient to compensate for the population of water lettuce so that the damage caused was also not significant. The location of the observation with the least abundance of insects was thought to be the cause of why the water lettuce had colonized the waters. This can be seen from the young water lettuce with light green leaf color, thin and brittle texture, relatively small size and no visible damage to the leaves due to the feeding activity of larvae *S. pectinicornis*. Thus it can be seen that the abundance of water lettuce in an aquatic habitat is not in line with the population abundance of *S. pectinicornis*. This can also be caused by the speed of growth and development of water lettuce weeds faster than *S. pectinicornis* so that the population of the two becomes unbalanced in the field.

Potential of S. pectinicornis as a biological control agent

Efforts to control water lettuce weeds by utilizing *S. pectinicornis are* still very potential. These insects are always associated with water lettuce weeds in the field but their population is relatively low. A solution that can be done is of what mass rearing in the laboratory and the release of *S. pectinicornis* on the target weed area. This method is known as the augmentation method, which is the transfer or flooding of biological agents to the target weed area, either in terms of increasing population numbers or in terms of beneficial effects to achieve the expected level of control. According to Weaver *et al* (2016) *in* Hill and Coetzee (2017) augmentation is the release of a large number of biological control agents that have fitness when the population in the field tends to be low.

The development and success of a biological control program using insects in the target weed area are highly dependent on a number of important factors including bioecological research such as preference for the host, its potential and effectiveness, adaptability, population conditions and the possible impacts (Cofrancesco, 2000; Fauvergue *et al.*, 2012; Evans, 2013; Madsen and Wersal, 2017; Ani *et al.*, 2018). Biological control is an environmentally friendly control but it is important to carry out in-depth studies, monitoring, assessment and evaluation altogether to reduce the risk of failure so that time, cost and energy spent can be more effective and efficient.

Conclusion

Spodoptera pectinicornis is always present in the habitats where water lettuce weeds are invested and the calculation of the number of individuals has fluctuated, but in general, it can be stated that the number of larvae is relatively low, with <3-5 individuals per individual water lettuce. It is necessary to do further research on the factors influencing the low population of *S. pectinicornis* in the field and the propagation efforts, for example by providing an artificial diet.

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