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DIVERSITY OF THE PARASITOID WASPS OF THE EULOPHTD SUBFAMILY EULOPHINAE (INSECTA: HYMENOPTERA, EULOPHIDAE) OF JAVA, INDONESIA AND THEIR DISTRIBUTION

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ABSTRACT

Diversity of the Parasitoid Wasps of the Eulophid Subfamily Eulophinae (Insecta: Hymenoptera, Eulophidae) of Java, Indonesia and their distribution is presented for the first time. Most of eulophines are ectoparasitoids that attack concealed hosts in protected situations, such as leafminers, woodborers and leaf rollers. The subfamily are frequently involved in biological control programs directed against dipteran and lepidopteran leaf-mining pests, and many eulophine genera have been considered economically important. The taxonomy and distribution of the species in Asia, especially in Java, are however still poorly studied despite the fact that the subfamily is an important group for sustainable agriculture. This study is based on the specimens newly collected from many localities in Java and Bali using sweep netting, Malaise trapping, yellow-pan trapping and rearing from their hosts. All the three tribes (Elasmini, Cirrospilini and Eulophini) of the subfamily Eulophinae are recognized in the islands. A single genus of Elamini, three genera of Cirrospilini and 19 genera of Eulophini are recognized in the islands and they included 14 genera as new records for the islands and 66 undescribed species. A total of 110 species are recognized in Java and Bali; of those about 86% are new records for the islands and about 60% are undescribed species. Considering the species so far known for their world distribution pattern, eulophine species occurring in Java are mainly Oriental elements, a few species are Australian and a very small number of species is endemic, while several species that could have been artificially introduced with their hosts are worldwide in their distribution. Based on the climatic and geological features, the species diversity and geographical distribution of the Eulophine in Java and neighboring island are discussed.

Key words: Diversity, Eulophinae, Eulophidae, Hymenoptera, insect, Java, distribution.

INTRODUCTION

In the chalcidoid wasp family Eulophidae, the Eulophinae are the second largest subfamily in terms of the numbers of recognized species and genera, after the Tetrastichinae, and followed by the Entedoninae. With approximately 1,320 species in 101 genera currently recognized (Noyes, 2002), the Eulophinae occur in all geographical regions including Antarctica, where a species, *Sympiesis campbellensis* (Kerrich & Yoshimoto, 1964), has been recorded. A large proportion of the currently recognized eulophine species has so far been described and/or recorded from the Holarctic region (556 species or 42% of the total species) and Australasia (345 species or 26%), whereas only 182 species are known for the Oriental region (Noyes, 2002). However, this does not necessarily mean that the Oriental eulophine fauna is poorer than that of the Holoarctic or Australasian regions, but this could be simply because of the low intensity of research.

Parasitoids of the Eulophinae are generally small to minute (0.4-3.0 mm), with a few exceptions being longer than 3 mm. The recent studies suggest that the Eulophinae are one of the most derived subfamilies in the Eulophidae (Gauthier *et al.* 2000; Ubaidillah *et al.*, 2003). The subfamily can be defined by the combination of the following characters: submarginal vein smoothly joining to parastigma; postmarginal vein well developed, usually longer than stigmal vein; dorsal surface of submarginal vein with three or more setae; scutellum with two pairs of setae (Graham, 1987;Boucek, 1988).

The Eulophinae are entomophagous, attacking other arthropods; 5 insect orders and spiders (Araneida) have so far been recorded as their hosts. The subfamily contains a wide diversity of parasitoid life forms, which can be endoparasitoids or ectoparasitoids; idiobionts orkoinobionts; solitary or gregarious; primary parasitoids, hyperparasitoids or facultative hyperparasitoids; or specialists or generalists. Parasitoid species can attack eggs, larvae, and pupae. Predatory Eulophinae display a specialized form of parasitism where a parasitoid larva consumes many preys in an enclosed space (such as a gall or an egg sac). Phytophagous species again display a variety of

life styles, and may be inquilines within galls (Sheng & Zhao 1995), gall-formers (Hawkins & Goeden, 1982; Headrick *et al.*, 1995) or internal seed feeders (Boucek, 1988; LaSalle, 1994).

Eulophinae are frequently used in biological control programs directed against dipteran and lepidopteran leaf-mining pests, and many eulophine genera have economically important species; for example, *Cirrospilus* Westwood, *Diaulinopsis* Crawford, *Hemiptarsenus* Westwood, *Sympiesis* Förster, *Diglyphus* Walker, *Semielacher* Boucek, and *Zagrammosoma* Ashmead all contain species parasitic on leafinining Lepidoptera and Diptera (Noyes, 2002).

The first taxonomic work that treated Indonesian species of the Eulophinae is Zehntner (1887), who described *Eulophus femoralis* as a parasitoid on a sugarcane pest, *Cosmopterix dulcivora* (Lepdoptera: Cosmopterigidae), from Pasuruan, East Java. Later, Gahan (1922) described two species, *Sympiesis javensis [Diaulomella javensis* (Gahan, 1922)] and *Elasmus brevicornis* Gahan, 1922, both from West Java, adding the second and third species to the Indonesian eulophine fauna. In a series of eulophid taxonomic works, Ferrière (1930,1933,1940-1941) made important progress in understanding Javanese eulophines and nine new species of the Eulophinae from Java were then described by him. Other useful regional work covering Indonesia is Boucek (1988), who extensively studied the Asutralasian Eulophidae. Wijesekara and Schauff (1994) studied the tribe Euplectrini in the sense of Boucek (1988) in Sri Lanka, but they also included some specimens from Indonesia. Very recently I have committed myself to the taxonomy of Indonesian Eulophinae (Ubaidillah *et al.*, 2000; Ubaidillah and Kojima, 2002; 2005; Ubaidillah, 2003; 2006).

As in other tropical regions of the world, the parasitic wasps of the subfamily Eulophinae are rich and abundant in Indonesia, and some of them have potential as biological control agents. In spite of such abundance and economical importance, however, the taxonomy of the Indonesian fauna is still not in a satisfactory state. Consequently, accurate identification of species, which is indispensable for any ecological, biogeographical or evolutionary study, is often difficult. Therefore, a revisional study of the wasps of subfamily Eulophinae in Indonesia should be completed as soon as possible.

MATERIALSANDMETHODS

Materials examined

The major source of the materials used in the present study is my personal collection, deposited in the Museum Zoologicum Bogoriense (MZB), the Indonesian Institute of Sciences (LIPI). Most specimens were freshly collected in 2002 through 2006, and thus they are no more than 5 years old. Additional materials were borrowed from the Australian National Insect Collection (ANIC), CSIRO, Canberra, Australia; Queensland Museum (QM), Brisbane, Australia; United States National Entomological Collection, US National Museum of Natural History (USNM), Washington, DC; and Systematic Entomology, Faculty of Agriculture, Hokkaido University (SEHU), Sapporo, Japan.

The methods of collection of eulophine parasitoids adopted in the present study can be divided into the following two categories. The first is use of the versatile tools of mass collecting, such as *sweeping nets, Malaise traps* and *yellow pan traps.* The Sweep nets and yellow pan traps and sometime the Malaise traps were applied especially to habitats where eulophinae species diversity is presumed to be high (e.g. secondary and primary forests, forest edges, agriculture areas, grasslands). The second category is of methods that focus on the search for the hosts of eulophinae wasps that cannot be effectively collected by conventional sampling techniques.

Geographic area covered

The eulophine fauna mainly targeted in this study is that of Java and Bali including the adjacent moderate- and small-sized islands (namely, Madura, Nusa Barong, Sempu, Nusa Kambangan, Panaitan and Krakatau) (Fig. 1).

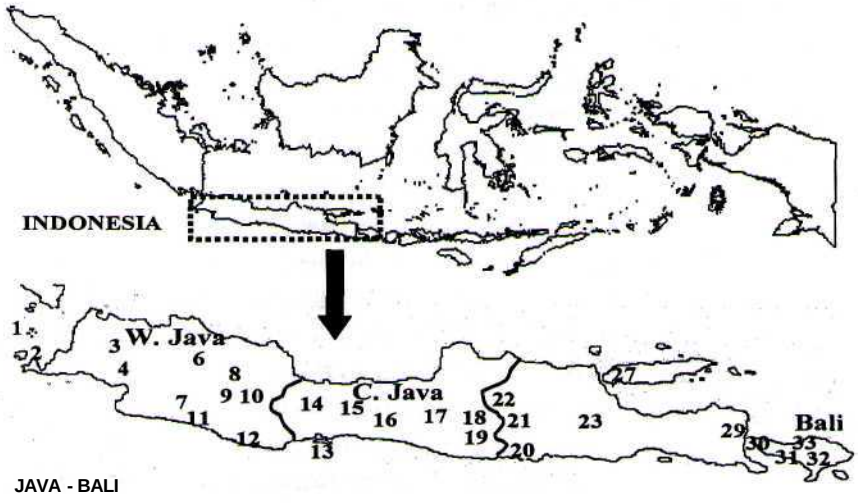

Figure 1, Java and Bali, showing the collecting localities from which all Eulophinae were collected. These are: *West Java,* 1. Krakataus Isl, 2. Ujung Kulon, 3. Bogor, 4. Sukabumi, 5. Bandung, 6. Tangkuban Prahu, 7. Garut, 8.Ciamis, 9. G. Sawal, 10. Panjalu, 11. Pangandaran, 12. Leuweng Sancang; *Central Java,* 13. P. Nusakambangan, 14. Purwokerto, 15. Baturaden, 16. Merapi Jogjakarta, 17. Karanganyar, 18. Tawang Mangu, 19. Wonogiri; *East Java;* 20. Pacitan, 21. Magetan, 22. Ngawi, 23. Malang, 24. G. Bromo Pasuruan. 25. P. Serapu. 26, P. Nusa Barung, 27. Bangkalan Madura, 28. Mem Betiri Jember, 29. Baluran; *Bali.* 30. Negara, 31. Badung, 32. Bedugul, 33. Singaraja.

The area of Java is about 130,000 km^2, and just north of East Java lies a moderate-sized island, Madura Island, which is about 5,620 km^2. Bali, lying east of Java, is slightly smaller than Madura and has an area of about 5,560 km^2 (Whitten *et al.,* 1996). The geographic area covered in this study is the eastern margin of Sundaland; this area has always been interesting for any studies on Oriental and Australian faunal boundaries (Moss and Wilson, 1998). The region is also well known as a boundary that separates the geographical regions of Asian and Australian faunas (Wallace, 1880), which have very complex geographic features, therefore this Eulophinae taxonomic treatment here can only act as a preliminary part of a more complete future study of the whole Indonesian eulophine fauna.

RESULTS AND DISCUSSION

The faunas of the chalcidoid subfamily Eulophinae in Java and Bali are discussed below based on the specimens that were collected in various habitats in 33 localities (Fig. 1). The nearly 2,000 specimens that I have examined undoubtedly do not yet represent all the eulophine species occurring in Java and Bali, but this number far exceeds any previous inventories of eulophine parasitoids in any other areas of Southeast Asia. Thus, the specimens also represent our best estimate of the Javanese eulophine fauna and provide the best basis for analyses of the species composition and species richness of parasitoid wasps in this part of tropical Asia.

The present section addresses four key perspectives. The first is to characterize the genus-level composition of the Eulophinae in Java and Bali by comparing it with that for other regions. Second, the species richness of the Eulophinae in Java and Bali is discussed in comparison with global species diversity. Third, biological aspects of the Eulophinae are referred to and their perspective as biological control agents in Indonesia is remarked upon. Finally, the biogeographic accounts of Javanese and Balinese eulophines are discussed with reference to the historical geography of the Sunda Islands.

Genus level composition of Javanese ***eulophines***

The Eulophinae are the second most diverse subfamily in the Eulophidae, and they are abundant also in all habitats in Java. Twenty-two of the 101 currently recognized genera of the world and of 29 genera of Oriental region have been recorded in Java and Bali (Table 1) or about 80% of genera known for the Oriental region. Of these genera 13 *(Allophomorphella, Deutereulophus, Diglyphomorpha, Dyglyphomorphomya, Elachertus,*

Eulophomorpha, Euplectrophelinus, Euplectrus, Metaplectrus, Notanisomorphella, Pnigalio, Stenomesius, Stenopetius) are new genus records for Java.

The Javanese Eulophinae fauna is very rich in genera in comparison with the eulophine faunas of several other regions and/or countries (Fig. 2). The number of eulophine genera occurring in Java and Bali (22 genera) is nearly comparable to that of India (24 genera), and more than half of that for Australia (43 genera) of which the eulophine fauna is well studied. Although the number of eulophine genera occurring in Java may well increase, there is substantial semi-quantitative evidence suggesting that the figure given above is nearly complete. That is, during the intensive and extensive collection that I made in the last four years (2003-2006), 14 of the 22 genera recorded from Java and Bali were collected in the first two years and the collections made in the last year, in localities and habitats different from those of the previous years, did not add any newly recorded genera.

The only genus that was recorded from Java but has not yet been collected since it was firstly reported is *Eulophus;* Zehntner (1896) described *Eulophus femoralis* from Pasuruan, East Java. The genus *Eulophus* is mainly Holarctic in distribution and its occurrence in tropical Asia is doubtful; I tried in vain to locate the type material(s) of *E. femoralis* and to collect a parasitoid that matches Zehntner's description.

The largest eulophine genera in terms of the number of species, *Euplectrus, Pnigalio* and *Sympiesis,* all occur in Java and Bali. Species-level taxonomy of these genera in the Oriental region is still poorly studied, and there are several species in the present study that appear to be undescribed. The *Euplectrus,* which is a new record for Java, was first recorded in Indonesia by Crawford (1911) who described two species, *Euplectrus medanensis* and *E. bussyi,* from Sumatra. In my recent study of eulophines in the Eastern Lesser Sunda Islands (Ubaidillah, 2003), I recognized eight species of *Euplectrus* including five species described as new to science. *Euplectrus* is now known to occur across Java and the Javanese fauna comprises at least 20 species. *Pnigalio,* which is also a new record for Java and known to contain parasitoids of leaf-mining Lepidoptera, Coleoptera, Diptera, and gall-forming^sawfiies (Noyes, 2002), is often extremely abundant in shrub habitats of forest edges in highlands (500-1.500 m altitude) of Java. While *Sympiesis* is particularly diverse in Palearctic and Nearctic regions, nine species of the genus are recognized in Java and Bali. This genus was recorded from Java firstly by Gahan (1922), who described *Sympiesis javensis* (in original combination with *Diaulimella)* as a parasitoid on gracillarid moths.

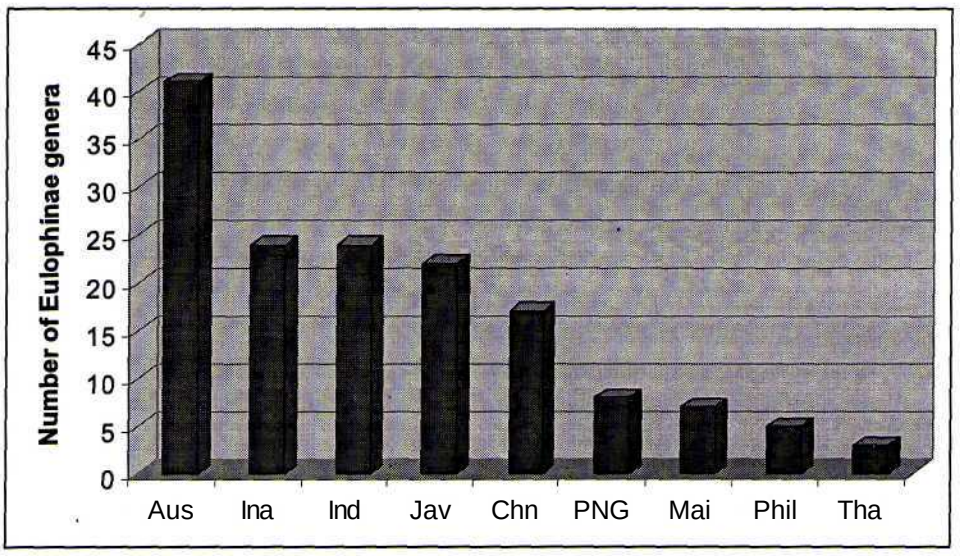

Figure 2. Number of genera of the Eulophinae recorded in some Oriental and Australasian countries. Abbreviations: Aus (Australia), Ina (Indonesia), Ind (India), Jav (Java), Chn (China), PNG (Papua New Guinea), Mai (Malaysia), Phil (Philippine) and Tha (Thailand)

Three of the 18 genera of the tribe Cirrospilini, *Cirrospillus, Trichopilus* and *Zagrammosoma* occurs in Java. *Cirrospillus* is the largest genus in terms of number of species in the Eulophinae, being with 135 species and cosmopolitan in its distribution though more diverse in Australian and Holarctic regions; nine species have been recorded from Java, but no parasitoids of the genus are known from Bali. For the Indonesian fauna, the genus was firstly recorded in West Java by Gahan (1932) with the description of *Cirrospilus ingenuus.* Two species of the genus *Trichospilus* have so far been recorded in Java and two other species of the genus known to constitute the Indonesian fauna seem to be endemic to Sulawesi (Ubaidillah, 2006). *Zagrammosomawas* firstly recorded for Java by Ubaidillah *et al.* (2000) with the description of *Zagrammosoma latilineatum* Ubaidillah, 2000, and the present study added one undescribed species from West Java.

Three genera *Euplectromorpha, Platyplectrus* and *Metaplectrus* that share the elongated metatibial spur as a distinctive character are recorded in Java and Bali. The genus *Euplectromorpha* which is known to parasitize limacodid moths, has not had any species added since the earliest study by Ferrière (1940); five of the 34 species recognized worldwide have been recognized in Java. The genus *Platyplectrus,* which is known to occur mainly in Old World by high number of species, especially in the Oriental and Australian tropical regions (38 species), has been recorded in Java and Bali by 12 species; six species are known as new to science and two species are new records for Indonesia. The *Metaplectrus,* a small assemblage (five species) that attacks the larvae of limacodiid moths, is found in Java as a new record and recognized by a single species, *M. thoseae.*

Hemiptarsenus, one of important parasitoids of agromyzid leafmining pests on many ornamental and vegetable crops does not seem to be a natural part of the eulophine fauna of Java. The only species, *H. varicornis, has been* suggested as having been introduced together with the agromyzid pest *Liriomyza huidobrensis* on chrysanthemum cut flowers (Rauf *et al,* 2000). In Java, *L. huidobrensis* was first recorded together with its parasitoids in 1994 (Shepard *et al.,* 1998) and has now been recorded from 45 kinds of vegetables, and ornamental and weed plants, such as celery, cucumber, spinach, snap bean, snow peas, red bean, shallot, faba bean and tomato (Rauf *et al.,* 2000). *Hemiptarsenus* is often extremely abundant in long bean fields all over Java, especially in highlands (300-1.000 m altitude).

Eight genera, namely *Elachertus, Deutereulophus, Euplectrophelinus, Diglyphomorphomyia, Stenopetius, Stenomesius, Necremnoides, Alophomorphella,* currently recorded in Java were considered to form a group in the tribe EJachertini by Boucek (1998), the opinion followed by Zhu and Wang (2001), based on the observation that they share the characters: scutellum with sublateral grooves present and with complete notauli. However, in the present study, they are placed in the tribe Eulophini, following Gauthier *et al.* (2000).

Elachertus, consisting of 115 described species worldwide (Noyes 2002), is represented by ten species in Java and Bali. Considering the area size, Java has a quite high species number (11 species), compared to Australian *Ealachertus* fauna (22 species). Five of the 11 species found in Java belong to undescribed species.

The *Deutereulophus* is a small genus, consisting of 19 recognized species worldwide, and five species including three undescribed species are found in Java. Until this study their hosts have not been known. *Euplectrophelinus* is a very small genus, consisting of only two species distributed in Madagascar, India and Australia (Noyes, 2002). Three species of the *Euplectrophelinus* are currently recognized in Java, of which two belong to undescribed species. *Diglyphomorphomyia* is also a small genus with six described species worldwide (Zhu and Huang, 2003; Noyes, 2002). This genus has so far been recorded from Queensland of Australia to South China. Seven species of *Diglyphomorphomyia* are recognized in Java, all of which are newly recorded from the island, and five species are undescribed species. In *Stenopetius,* for which the only single species from Australia has so far been known, the present study recognized two species in Java, including one undescribed species. The Javanese fauna of the genus *Stenomesius,* which is known to be parasitoids of lepidopteran and curculionid coleopteran leaf miners, is represented by six species and four of them are known also from the Oriental region.

Necremnoides, which was originally described from Australia and currently consists of three species, is now found in Java, represented by one of the three species.

Alophomorphella is represented by only one species *{A. illustris)* in Java and Bali. The small genus was intensively studied by Ubaidillah and Kojima (2006) and they described three new species, all of which are probably endemic to Sulawesi and Halmahera.

The genera that are relatively large in terms of the number of included species but are not represented in Java are *Ophelimus* Haliday, 1844,,4«/ogym«w,sFo'rster, 185 \,*Diglyphus* Walker, 1844, *Necremnus* Thomson, 1878, and *Dicladocerus* Westwood, 1832. *Ophelimus,* containing about 50 described species is the largest among the gall-forming eulophine genera (Boucek, 1988), and may be exclusively restricted to *Eucalyptus* plants (Withers *et al.,* 2000). Although the host plant, *Eucalyptys globulus* Labill, was introduced to Pasuruan, East Java from Australia in 1800 (Budi *et al.,* 2005), no gall-forming eulophids have been reported in Java. While *Aulogymnus* is Holoarctic in its distribution and primarily consists of parasitoids on cynipid gall formers associated with oaks (Askew, 1961; Boucek and Askew, 1968; Boucek, 1988), one and three species are known in India and Australia, respectively. Presence of *Melalauca* in Java has not always been followed by the occurrence of the gall forming cynipids and their parasitoid. *Diglyphus,* which parasitizes mainly dipteran leaf miners on herbaceous plants, seems to be Holoarctic origin (Boucek, 1988), and several species of the genus have been used for biological control of agromyzid leaf mining pests.

Species composition of the Javanese eulophine fauna in comparison with that of other Oriental areas

Based on currently available data (Table 1), eulophine species in Java and Bali are the most diverse in any areas or countries in Oriental region. However, it does not necessary mean that other areas in Oriental region are poorer than that in Java and Bali, but is likely to reflect be a considerable underestimate because many areas are still very poorly surveyed. The species number of the Indonesian eulophine wasps summed across genera is 116 species, of which 110 are recorded in Java and Bali. The real number of Javanese eulophine "species is probably higher than the figure, but there is a semi-quantitative proof that the figure given above is not excessively low. That is, the number of eulophine species newly found in Java and Bali increased by a very small number in the last two years (2005-2006) of the four years of intensive and extensive sampling. Such intensive sampling allowed me to record in Java several species belonging to some genera that have been considered to occur only in Palearctic and Australian regions, such us *Cirrospilus, Pnigalio, Sympiesis, Deuterulophus,* and *Diglyphomorphomyia* (Boucek, 1988). These species were found mainly on the highland of Java, such as Mounts Sawal, Gede and Pangrango (West Java), Slamet and Merapi (Central Java), Ardjuna, and Meru Betiri (East Java), and Mt. Agung in Bali. Moreover, several species belonging to poorly known genera, such as *Stenopetius, Necremnoides,* and *Euplectrophelinus,* which had been known only in the Australian region (Boucek, 1988), were also revealed to occur in Java.

Biology of Eulophinae and their biological control agent prospective in Indonesia

The subfamily of Eulophinae exhibit remarkable diversity in life form. The majorities of species are parasitoids, and attack insects in 5 orders, as well as spider eggs. Phytophagy has arisen secondarily in a few genera and comprises species that are gall formers.

The natural enemies most commonly selected against insect pests in modern biological control practices are host-specific or relatively host-specific parasitoids such as some species of the Eulophinae. The Eulophinae have been responsible for the successes of biological control programs among parasitic wasps and many species have been introduced into several countries for this purpose.

Traditional agricultural systems have been largely adopted in Java and Bali by a large number of small holdings of no more than 1 ha per household. Crop production takes place under extremely variable agro-ecological conditions, with annual rainfall ranging from 1.500 to 5.000 mm (Whitten *et al.,* 1996). Farmers often select well-

adapted, stable crop varieties, and cropping systems are such that two or more crops are grown in the same field at the same time. These traditional crop systems enhance abundance of natural enemies such as parasitoids and predator and generally keep pest population sizes at low levels. My experience to collect eulophine waps in the long bean fields in Bali and Sukabumi (West Java) revealed that the parasitoids of *Liriomyza* are high in species number (four species) and individual number there. LaSalle (1993) suggested that parasitic Hymenoptera including the Eulophinae are the most important groups in biological control and can be used for biological control programs in any crop system. Unfortunately, our understanding of the species diversity of natural enemies of pests of crops as well as of the methods to increase their population sizes to enhance biological control programs in Java and Bali is still poor. However, continuing efforts in studying of parasitic wasps would likely contribute to a reduction of pesticide use.

Increase in plant material movements has been facilitating the accidental introduction of exotic pests, such as the recently introduced, most destructive leaf mining pests, *Liriomyza* spp., on vegetable crops to Indonesia (Rauf *et al.*, 2000). Consequently, the natural enemies of these introduced pests should be studied. At present about two dozen species of insect pest in Java (Kalshoven, 1981), both introduced and native, are recognized as one of the major constraints on agricultural production and productivity in Java (Kalshoven, 1981). Unfortunately, their natural enemies in Indonesia are yet poorly understood. On the other hand, the Indonesian government has promoted the intensification of agriculture programs by applying insecticides to control pests of commercial crops such as rice, sugarcane, apple, vegetables, coffee and cocoa, and to some extent for combating outbreaks of stem borer of paddy and sugarcane, *Scirpophaga* spp. and for *Locusta migratoria manilensis* in many crops. However, in the last five years, some Javanese farmers still rely on the indigenous pest management approaches to cope with pest problems despite the many government agriculture extension programs that encourage the use of pesticides.

Inventory of natural enemies, particularly parasitic wasps, could be am important stage in developing pest management programs. In addition, the applications of pesticides are to be performed only after alternative methods, such as biological control, have been exhausted. In the recent studies, inventory of the eulophine species in Java and Bali is strongly encouraging and suggests that practical biological control programs in Javanese farms are possible. With an exception of the classical biological control of the steam bores of sugarcane in Java, using parasitic wasps has not been widely adopted by farmers. A shining example of such success is the control of the stem bores of sugarcane by inundating with a large individual number of the parasitic wasps *Trichogramma* spp. (Boedijono, 1980) and the method should be adopted to solve other pests problems.

Geographical distribution of Javanese Eulophinae

Geological history of Java and Bali is discussed explicitly by Hall (1998). Based on climatic and geological features, islands from Java to the Lesser Sunda can be divided into the following subregions, West Java, Central Java, East Java, Bali and Lesser Sunda Islands, at east (Whitten *et al.*, 1996). In climatic features, especially seasonally of precipitation, West Java is classified in the tropical wet climate zone (Whitten *et al.*, 1996) and seasonality of precipitation and dryness increases eastwards. The geological history and the types of climate may have affected the current distribution patterns of eulophine wasps in Java and Bali. Based on currently available data (Table 2), eulophines of Java, Bali and the Lesser Sunda Island can be categorized into the following groups in terms of their distribution patterns:

1) Species occurring in only a single subregion. They are probably endemic to each subregion and are as follow:
   (1-1) West Java 43 species, consisting of five species *Cirrospilus,* four of *Elachertus,* two of *Deutereulophus,* tree of *Euplectrus,* two of *Notanisomorphella,* one *oiNecremnoides,* three of *PIatyplectrus,* seven of *Pnigalio,* one of *Stenomesius,* five of *Sympiesis* and one *of Zagrammosoma.*
   (1-2) Central Java species: *Stenomesius* sp3 and *Elachertus* nr. *isadas.*
   (1-3) East Java species: *Diglyphomorphomyia* spl, *Eulophusfemoralis, Platyplectrus* sp2 and

Sympiesis sp4.

(1-4) Bali species: *Euplectrophelinus* sp3, *Sympiesis* sp3 and *Sympiesis* sp7.

(1-5) West Lesser Sunda species: *Elachertus* sp6.

(1-6) East Lesser Sunda species: *Euplectrus spinosus, E. sumbaensis, E. striatus, E. partitus* and *Dyglyphomorphomyia floresensis.*

2) Species occurring in two neighboring sub-regions. They are as follows:

(2-1) West Java and Central Java: 19 species consisting of two species of *Diglyphomorphomyia,* one of *Euplectromorpha,* 11 *of Euplectrus,* three *of Pnigalio,* one of *Stenomesius,* one of *Stenopetius,* three of *Sympiesis.*

(2-2) East Java and Bali: *Euplectrophelinus* sp3 and *Sympiesis* spl.

(2-3) Bali and West Lesser Sunda: *Euplectrus* spl.

(2-4) West and East Lesser Sunda: *Notanisomorphellafuscocauda.*

3) Species occurring both in Java and Bali *Elachertus auripes, Deutereulophus* sp3, *Eupletromorpha euplextriformis, Pnigalio* sp2 and *Pnigalio* sp9.

4) Species widely distributed from West Java to East Lesser Sunda: *Hemiptarsenus varicornis, Sympiesis dolichogaster, Euplectrus parvulus, Diglyphomorphomya* sp7, *Deutereolophus tennysoni.*

As summarized above and also shown in Figure 3, eulophine wasps are richest in number of species in West Java, and the number of species occurring in each subregion decreases eastward from West Java to the Lesser Sunda Islands. A similar tendency has been reported for the social wasps in the Sunda Islands (Kojima *et al.,* inpress), in which the current social wasp faunas in Java through the Lesser Sunda Islands are considered to have been formed by eastward dispersal of the wasps from continental Southeast Asia (including Malay Peninsula) or Sumatra and/or Borneo and by speciation of some species endemic to the islands. Although our knowledge on the eulophine faunas in continental Southeast Asia, Sumatra and Borneo is very limited, which allows only a tentative discussion of the processes of formation of eulophine faunas in Java, Bali and the Lesser Sunda Islands, the distribution pattern of eulophine wasps in Java through the Lesser Sunda Islands and the observation that

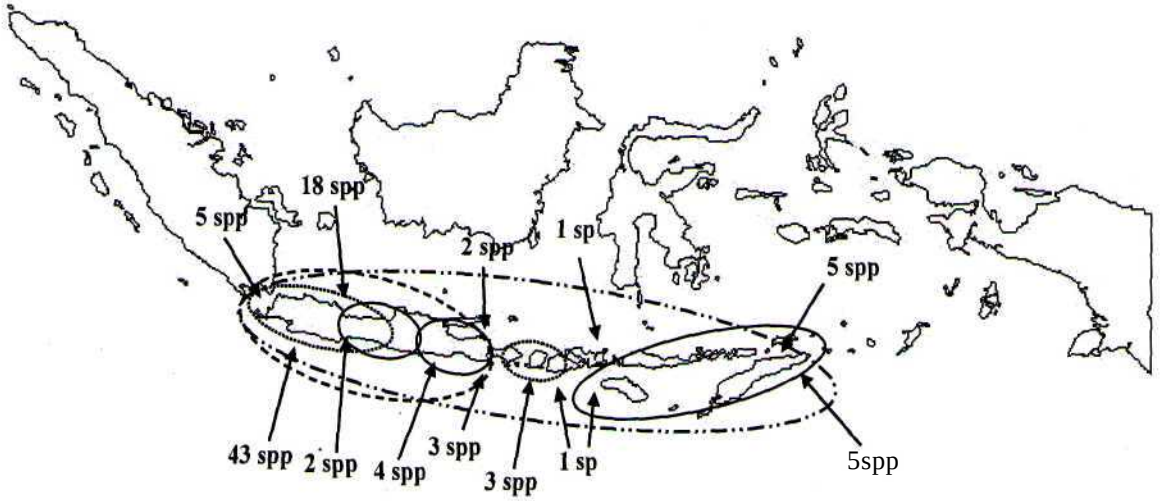

Figure 3: Current geographic distribution of the eulophine species within Java, Bali and Lesser Sunda Islands.

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Table 1. Approximate numbers of extant, recognized Eulpphinae species of Java compared to several countries in Orientat region (after Noyes, 2002)

Taxa/ **localities**	**Species-richness**					
	Java	**India**	**Malaysia**	**Thailand**	**Vietnam**	**Philippines**
Cirrospilini						
1. Cirrospilus	**8**	**6**	**1**	**1**	**1.**	1
2. Trichospilus	**2**	**2**	**1**	**0**	**0**	0
3. Zagrammosoma	**2**	**0**	**0**	**0**	**0**	0
Eulophini						
4. Allophomorphella	**1**	**0**	**0**	**0**	**0**	0
5. Deutereulophus	**5**	**0**	**0**	**0**	**0.**	0
6. Diglyphomorpha	**2**	**0**	**0**	**0**	**0**	0
7. Diglyphomorphomyia	**7**	**0**	**0**	**0**	**0**	0
8. Eulophus	**1**	**0**	**0**	**0**	**0**	0
9. Elachertus	**9**	**1**	**0**	**0**	**0**	0
10. Eulophomorpha *,	**1**	***X***	**0**	**0**	**0-**	0
11. Euplectromorpha	**5**	**0**	**2-**	**0**	**0**	0
12. Euplectrophelinus	**3**	0	**0**	**0**	**0**	0
13. Euplectrus	**21**	16	**1**	**0**	**1**	2
14. Hemiptarsenus	**1**	6	**1**	**0**	**0**	0
15. Metaplectrus	**1**	0	**0**	**0**	**0**	0
16. Necremnoides	**1**	0	**0**	**0**	**0**	0
17. Notanisomorphella	**3**	1	**0**	**0**	**0**	1
18. Platyplectrus	**10**	2	**1**	**0**	**0**	2
19. Pnigalio	**10**	0	**0**	**0**	**0**	0
20. Stenomesius	**5**	**3**	**0**	**0**	**0**	0
21. Stenopetius	**1**	**0**	**0**	**0**	**0**	0
22. Sympiesis	**10**	**3**	**1**	**2**	**0**	2
Total species	**110**	**41**	**8**	**3**	**1**	**8**

Table 2. Species distribution of Eulophinae within Java and Bali and showing new records of species collected from Java

No	Genus/ Species	New Record	West. Java	Central. Java	East Java	Bali
1	***Alophomorphella* Girault, 19131**					
	1. *illustris* Girault	+	+	+	+	+
2	***Cirrospilus* West, 1883**					
	2. *ambiguus* Hansson and LaSalle	_	+	+	+	+
	3. *variegatus* (Masi)	+	+	_	_	_
	4. *ingenuus* Gahan	+	+	_	_	_
	5. *Cirrospilus* spl	+	+	_	_	_
	6. *Cirrospilus* sp2	+	+	_	_	_
	7. *Cirrospilus* sp3	+	+	_	_	_
	8. *Cirrospilus* sp4	+	+	_	_	_
	9. *Cirrospilus* sp5	+	+	_	_	_
3	***Deutereulophus* Schulz,1906**					
	10. *tennysoni* Girault, 1913	+	+	+	+	_
	11. *timorensis* Ubaidillah, 2003	+	+	_	_	_
	12. *Deuterelophus* spl	+	+	_	_	_
	13. *Deuterelophus* sp2	+	+	_	_	_
	14. *Deuterelophus* sp3	+	+	+	+	_
4	***Diglyphomorpha* Asmead, 1904**					
	15. *Diglyphomorpha aurea* (Howard)	+	+	_	_	_
	16. *Diglyphomorpha* spl	+	+	+	_	_
5.	***Diglyphomorphomyia* Girault, 1913**					
	17. *Diglyphomorphomyia* spl	+	_	_	+	_
	18. *Diglyphomorphomyia* sp2	+	+	_	_	_
	19. *Diglyphomorphomyia* sp3	+	+	_	_	_
	20. *Diglyphomorphomyia* sp4	+	+	+	_	_
	21. *Diglyphomorphomyia* sp5	+	+	+	_	_
	22. *Diglyphomorphomyia* sp6	+	+	+	_	_
	23. *Diglyphomorphomyia* sp7	+	+	+	+	_
6	*Elachertus* **Spinola,1811**				_	
	24. *auripes* (Girault, 1913)	+	+	+	+	+
	25. *petiolifuniculus* Zhu and Wang, 2001	+	-	+	-	_
	26. *simithorax* (Girault, 1915)	+	+	_		_
	27. *sobrinus* (Girault and Dodd, 1915)	+	_	_	+	+
	28. *Elachertus* ***nr. isadas* (Walker)**	+	_	+	_	_
	29. *Elachertus* spl	+	+	_	_	_
	30. *Elachertus* sp2	+	+	_	_	_
	31. *Elachertus* sp3	+	_	+	_	+
	32 *Elachertus* sp4	+	+	_	_	_
	33. *Elachertus* sp5	+	+	_	_	_
7	***Eulophomorpha* Dodd,1915**					
	iA.flavicornis Dodd, 1915	+	+	_	_	_
8	***Eulophus* Geoffroy,1762**					
	35.,/e/«ora/«Zehntner, 1896	_	_	_	+	_

lanjutan Table 2. Species distribution of Eulophinae within Java and Bali and showing new records of species collected from Java

No	Genus/ Species	New Record	West. Java	Central. Java	East Java	Bali
9	*Euplectromorpha* **Girault, 1913**					
	36. *bicarinata* (Ferrière, 1940)	_	+	+	+	+
	37. *euplectriformis* (Crawford, 1911)	_	+	_	+	_
	38. *maculata* (Ferrière, 1940)	_	+	_	_	_
	39. *Euplectromorpha* spl	+	+	+	_	+
	40. *Euplectromorpha* sp2	+	+	+	_	_
10	*Euplectrophelinus* **Grault, 1913**					
	41. *Euplectrophelinus* sp. 1	+	+	_	_	_
	42. *Euplectrophelinus* sp. 2	+	_	_	+	_
	43. *Euplectrophelinus* sp. 3	+	_	_	_	+
11	*Euplectrus* **Westwood, 1832**					
	44. *ceylonensis* Howard, 1896	+	+	+	_	_
	45. *cinctiventris* Ferrière, 1941	+	+	_	_	_
	46. *colliosilvus* Wijesekara & Schauf, 1994	+	-	+	+	-
	47. *euplexiae* Rohwer, 1921	+	_	+	_	_
	48. *fulvicoxis* Ferrière, 1941	+	+	_	_	_
	49. *laphygmae* Ferrière, 1941	+	+	+	_	_
	50. *manilae* Ashmead, 1904	+	+	+	_	_
	51. *noctuidiphagus* Yasumatsu, 1953	+	+	+	_	_
	52. *parvulus* Ferrière, 1941	+	+	+	_	_
	53 *xanthocephalus* Girault, 1910	+	+	+	_	_
	54. *E. nr platyhypenae* Howard	+	+	+	_	_
	55. *Euplectrus* spl	+	+	_	_	_
	56. *Euplectrus* sp2	+	+	+	_	_
	57. *Euplectrus* sp3	+	+	+	_	_
	58 *Euplectrus* sp4	+	_	+	_	_
	59. *Euplectrus* sp5	+	+	+	_	_
	60. *Euplectrus* sp6	+	+	+	_	_
	61. *Euplectrus* sp7	+	+	+	_	_
	62. *Euplectrus* sp8	+	+	_	_	_
	63. *Euplectrus* sp9	+	+	+	_	_
	64. *Euplectrus* splO	+	+	_	_	_
12	*Hemiptarsenus* **Westwood, 1833**					
	65. *varicornis* Girault, 1913	_	+	+	+	+
13	*Metaplectrus* **Ferrière,1941**					
	66. *thoseae* Ferrière, 1941	+	+	+	+	+
14	*Necremnoides* **Girault, 1913**					
	67. *Necremnoides* sp	+	+	_	_	_
15	***Notanisonwrphetta* Girault, 1913**					
	68. *fuscocauda* **Ubaidillah, 2003**	+	_	_	+	_
	69. *Notanisomorphella* **spl**	+	+	_	_	_
	70. *Notanisomorphella* **sp2**	+	+	_	_	_

No	Genus/ Species	New Record	West. Java	Central. Java	East Java	Bali
16	***Platyplectrus* Ferrière, 1941**					
	71. *artonae* (Ferrière)	-	+			
	72. *medius* Zhu and Huang, 2001	+	+			
	73. *truncatus* Wijesekara & Schauff, 1994	+		+		
	74. *viridiceps* (Ferrière), 1941	+	+		+	+
	75. *orthocraspedae* Ferrière, 1940	-	+			
	76. *Platyplectrus* spl	+		+	+	
	77. *Platyplectrus* sp2	+			+	
	78. *Platyplectrus* sp3	+	+			
	79. *Platyplectrus* sp4	+	+			
	80. *Platyplectrus* sp5	+	+			
17	***Pnigalio* Schrank,1802**					
	81.fartoMis(Ishii), 1953	+	+	+	+	
	82 *Pnigalio* spl	+	+	+		
	83.Pmga//osp2	+	+		+	
	84. *Pnigalio* sp3	+	+			
	85. *Pnigalio* sp4	+	+	+		
	86. *Pnigalio* sp5	+	+	+	+	+
	87. *Pnigalio* sp6	+	+	+		
	88. *Pnigalio* sp7	+	+	+	+	+
	89. *Pnigalio* sp8	+	+			
	90. *Pnigalio* sp9	+	+	+	+	
18	***Stenomesius* Westwood, 1833**					
	91. japonicus (Ashmead, 1904)	+	+	+	+	+
	92. *Stenomesius* spl	+			+	
	93. *Stenomesius* sp2	+	+			
	94. *Stenomesius* sp3	+		+		
	95. *Stenomesius* sp4	+	+	+	+	
19	***Stenopetius* Bouček,1988**					
	96. *Stenopetius* spl	+	+	+		
20	*Sympiesis* **F6rster,1856**					
	97. *dolichogarter* Ashmead 1888		+			+
	98. *javanica* (Ferrière), 1933	+	+	+		
	99. *javensis* (Gahan), 1922	+	+	+		
	100. *Sympiesis* spl	+			+	+
	101. *Sympiesis* sp2	+	+	+		+
	102. *Sympiesis* sp3	+				+
	103. *Sympiesis* sp4	+			+	
	104. *Sympiesis* sp5	+	+			
	105. *Sympiesis* sp6	+	+			
	106. *Sympiesis* sp7	+				+
21	***Trichospilm* Ferrière, 1930**					
	107. *pupivorus* Ferrière, 1930	+	+			
	108. p o / t o Ubaidillah, 2006	+	+			
22	*Zagrammosoma* Ashmead, 1904					
	109. *latilineatum* Ubaidillah, 2000		+	+		
	110. *Zagrammosoma* spl	+	+			
	Total	**100**	**98**	**52**	**29**	**19**
	Percentage	**90**	**89**	**40**	**31**	**17**