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NATURAL ENEMIES OF THE RICE GREENHORNED CATERPILLAR *MELANITIS LEDA ISMENE* (LEPIDOPTERA: SATYRIDAE) AND RICE SKIPPER *PELOPIDAS MATHIAS* (LEPIDOPTERA: HESPERIIDAE) IN THE PHILIPPINES

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ABSTRACT

The natural enemy complex of the two most common rice butterflies in the Philippines, namely, the rice greenhorned caterpillar *Melanitis leda ismene* Cramer (Lepidoptera: Satyridae) and rice skipper *Pelopidas mathias* (Fabricius) (Lepidoptera: Hesperiidae), was described. More predators (83 species) were recorded than parasitoids (30 species) or pathogens (4 species). Of the predators, 59% preyed on both butterflies, whereas only 37% of the parasitoids shared hosts. Among the predators 52% attacked larvae, 28% the eggs, 19% adults, and 1% pupae. One-third of the parasitoid records were each larval and larval-pupal, 21% egg, and 13% pupal. From 1977-91, periodic collections in 12 locations representing three rice environments recorded parasitization rates averaging 12.2% vs 14.5% for egg and 11.0% vs 12.6% for larval-pupal stages of *M. leda ismene* and *P. mathias,* respectively. Monthly *P. mathias* egg and larval-pupal parasitization levels for 1988-89 were consistent between life stages but ranged from 10-80%. The impact of parasitoids was concluded to be insufficient alone to cause the observed low population densities of both butterflies. While the role of pathogens was judged minimal, greenhouse studies indicated predators had high potential and have been overlooked as regulatory agents of rice butterflies.

Key words: *Melanitis leda ismene; Pelopidas mathias;* biological control; parasitoid; predator; pathogen; parasitization rates; rice environments.

INTRODUCTION

Worldwide there is a wide array of rice-feeding species of satyrid and hesperiid butterflies whose larvae defoliate rice wherever it is cultivated. Nine species occur in the Philippines (five satyrids and four hesperiids) dominated by the rice greenhorned caterpillar *Melanitis leda ismene* Cramer (Litsinger *et al.,* 1995) and rice skipper *Pelopidas mathias* (Fabricius) (Litsinger *et al.,* 1994).

These two rice butterflies develop best on species of Poaceae and have wide host ranges within this plant family. Most are migratory and can pass a dry season in dormancy, thus are equally adapted to dryland and wetland rice environments.

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Low fecundity and broad host range dilute their numbers in rice crops where they rarely reach pest status (Litsinger *et al.,* 1994; 1995). Another reason offered for their low densities in rice fields is the activity of natural enemies.

Natural enemy records are scattered in the literature. *M. leda ismene* has 30 parasitoids, 4 predators, and 6 pathogens (Table 1), while those of *P. mathias* include 77 parasitoids, 5 predators, and 5 pathogens (Table 2). Few records are from the Philippines. Quantification is lacking on the role of natural enemies on these two butterfly species. The only reports found were in India from several seasons of egg and larval parasitization rates based on rearing field collected eggs and larvae (Murthy, 1957; Chhabra and Singh, 1978; CRRI, 1974; 1975; 1976; 1980).

M. leda ismene and *P. mathias* appear to be highly vulnerable to natural enemy activity having apparently limited defensive behavioral mechanisms. All life stages are relatively large and thus not easily camouflaged. Eggs are laid openly in small clusters on leaf blades. *M. leda ismene* larvae (5-6 cm in length) openly feed on foliage, whereas *P. mathias* larvae (4-4.5 cm in length) build a shelter by folding leaves. There are five larval stages and their coloration allows them to blend into the surroundings as protection against predators that depend on visual cues. Most natural enemy parasitoids locate their hosts through chemical cues (Vinson, 1976) which are stronger in large insects. *M. leda ismene* has pairs of prominent black or red tubercles on the head and tip of the abdomen which may play a defensive role against large predators such as birds. Older larvae of *M. leda ismene* possess short peg-like spines that may act to deter predators. The pupal chrysalis of *M. leda ismene* is naked and hangs suspended from vegetation while that of *P. mathias* is protected within a folded leaf. The adult *M. leda ismene* has brown-grey underwings and rests at the base of foliage with its wings held upright camouflaging well despite a wing expanse of 6.5 to 8 cm. The adult is crepuscular whereas that of *P. mathias* is diurnal. *P. mathias* is a quick flier typical of skippers.

We set out to document the species array of parasitoids, predators, and pathogens in the Philippines from each of the four life stages of *M. leda ismene* and *P. mathias.* In addition we noted behavioral traits of parasitoids and predators in the field and quantified the impact of parasitoids through periodically rearing field collected immature stages over a 15-year period. Egg and larval parasitization levels were determined monthly based on prey enrichment for *P. mathias* in Los Baños in 1988-89. The prey consumption rates of representative species from each of six predator guilds against egg, larval, and pupal stages of *M. leda ismene* were quantified from controlled experiments.

MATERIALS AND METHODS

General

Greenhouse studies were carried out at the International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines. Colonies of *M. leda ismene* (Litsinger *et al.,* 1995) and *P. mathias* (Litsinger *et al.,* 1994) were established in a shaded area of a greenhouse (29 ± 5 °C, relative humidity 81 ± 15%, and 11-13 hours daily photophase) from field collected adults. *M. leda ismene* adults were found under the shade of trees while those of *P. mathias* were collected on the flowers of santan, *Ixora chinensis* Lammark, an ornamental plant. Pathogens were identified

Table 1. Natural enemies of *Melanitis leda ismene* as reported worldwide.

Species	Stage	Reference
PARASITOIDS		
Hymenoptera		
Encyrtidae		
Ooencyrtus sp. nr. *malayensis* Ferriere	Egg	CRRI, 1980
Scelionidae		
Telenomus sp.	Egg	Rao, 1964
T. sp. nr. *lucullus* Nixon	Egg	van Vreden & Ahmad Zabidi, 1986
Trichogrammatidae		
Trichogramma chilonis Ishii	Egg	Chen & Chiu, 1985
T. sp. nr. *hesperidis* Nagaraja	Egg	IRRI, 1988
T. japonicum Ashmead	Egg	CRRI, 1976
Chalcididae		
Brachymeria deesensis (Cameron)	Larva	Yunus & Hua, 1980; van Vreden & Ahmad Zabidi, 1986
B. jayaraji Joseph, Narendran & Joy	1/	Joseph *et al.*, 1973; Narendran, 1984
B. lasus (Walker)	Larva-pupa	van Vreden & Ahmad Zabidi, 1986; CRRI, 1980
B. marginata Cameron	Larva-pupa	van Vreden & Ahmad Zabidi, 1986
Brachymeria sp.	Larva-pupa	CRRI, 1974
Braconidae		
Apanteles sp. 1	Larva	Rao, 1964
Apanteles sp. 2	Larva	Rao, 1964
Rogas sp.	Larva	Anon., 1979; He & Pang, 1986; Xia *et al.*, 1988
? *Chelonus* sp.	Pupa	CRRI, 1983
Eulophidae		
Pediobius inexpectatus Kerrich	Pupa	van Vreden & Ahmad Zabidi, 1986
Pediobius sp.	Larval-pupal	Xia *et al.*, 1988; IPP-HAAS, 1978
Pediobina (prob. *Pediobius*) sp.	Pupa	Rao, 1964
Ichneumonidae		
Amauromorpha accepta schoenobii (Viereck)	Pupa	Rao, 1964
Eccoptosage sp. ? *schizoaspis major* (Cushman)	Pupa	Rao, 1964
? *Haplojoppa* sp.	Pupa	Rao, 1964; CRRI, 1974
Ichneumon sp.	Pupa	CRRI, 1980
Pimpla poesia Cameron	Pupa	Rao, 1964

Theronia sp.	Pupa	Rao, 1964
Xanthopimpla stemmator Thunberg	Pupa	Rao, 1964
Diptera		
Tachinidae		
Argyrophylax nigrotibialis (Baranov)	Larva	He & Pang, 1986
Exorista japonica (Townsend)	Larva	He & Pang, 1986
E. larvarum L.	Larva	Rao, 1964
Halidaia (= *Halydaia*) *luteicornis* (Walker)	Pupa	Rao, 1964
Nematoda		
Mermithidae		
Parasitorhabditis sp.	Larva	Anon., 1977
PREDATORS		
Hemiptera		
Pentatomidae		
Amyotea (Asopus) malabarica (Fabricius)	Larva	Pati & Mathur, 1986
Andrallus spinidens Fabricius	Larva	van Vreden & Ahmad Zabidi, 1986; Rao & Rao, 1979
Cantheconidae (= Eocanthecona) furcellata (Wolff)	Larva	Rai, 1978
Salientia		
Ranidae		
Rana tigrina Daud	1/	Kharat *et al.*, 1983
PATHOGENS		
Moniliales		
Moniliaceae		
Beauveria bassiana (Balsamo) Vuillemin	Larva	Anon., 1977
Tuberculariaceae		
Fusarium oxysporum Schlecht	Larva	Rombach *et al.*, 1987
Entomophthorales		
Entomophthoraceae		
Entomophthora fumosa Speare	Larva	CRRI, 1980
Eubacteriales		
Bacillaceae		
Bacillus subtilis (Ehrenberg) Cohn	1/	Nayak & Srivastava, 1978; Rombach *et al.*, 1987
B. thuringiensis Berliner	1/	Rombach *et al.*, 1987
Enterobacteriales		
Enterobacteriaceae		
Serratia marcescens Bizio	1/	Rombach *et al.*, 1987

1/ No stage mentioned.

Table 2. Natural enemies of *Pelopidas mathias* as reported worldwide.

Species	Stage	References
PARASITOIDS		
Hymenoptera		
Scelionidae		
Telenomus beneficiens Zehntner	Egg	Anon.; 1979
Telenomus parnarae Wu & Chen	Egg	He & Pang, 1986
Trichogrammatidae		
Trichogramma sp.	Egg	CRRI, 1976
T. chilois Ishii	Egg	Chen & Chiu, 1985; Subba Rao & Hayat, 1986; Anon., 1979
T. sp. nr. *hesperidus* Nagaraja	Egg	IRRI, 1988
Trichogrammatoidea bactrae bactrae Nagaraja	Egg	Nagarkatti & Nagaraja, 1977; Nagaraja, 1978
Chalcididae		
Brachymeria albotibialis (Ashmead)	Larva-pupa	CRRI, 1980; Joseph *et al.*, 1973; Hayat & Subba Rao, 1986
B. excarinata Gahan	Larva-pupa	Joseph *et al.*, 1973
B. euploeae (Westwood)	Pupa	Rao, 1964; Yunus & Hua, 1980
B. jayaraji Joseph, Narendran & Joy	1/	Joseph *et al.*, 1973
B. lasus (Walker)	Larva	JICA, 1981; van Vreden & Ahmad Zabidi, 1986; Anon., 1979
B. marginata Cameron	Larva	van Vreden & Ahmad Zabidi, 1986
B. nigricorporis Husain & Agarwal	1/	Husain & Agarwal, 1982; Hayat & Subba Rao, 1986
B. tachardiae (Cameron)	Larva	Chopra, 1928
Braconidae		
Apanteles agilis Ashmead	Larva	Rao, 1964; CRRI, 1975
A. baoris Wilkinson	Larva	Wilkinson, 1930; Lever, 1955; Nixon 1874; Watanabe, 1967; JICA, 1981; Yasumatsu *et al.*, 1982; Anon., 1979; van Vreden & Ahmad Zabidi, 1986
A. javensis Rohwer	Larva	Rao, 1964; Kalshoven, 1981
Apanteles sp.	Larva	Rao, 1964; Chhabra & Şing, 1978; CRRI, 1982
Bracon alguei Ashmead	Larva	Rao, 1964
B. gelechiae Ashmead	Larva	Rao, 1964
Bracon sp.	Larva	Rao 1964; CRRI, 1982
Clinocentrus indicum (Gupta)	Larva	Chhabra & Sing, 1978
Cotesia (= Apanteles) ruficrus Haliday	Larva	Rao, 1964; Anon., 1979; Misra *et al.*, 1984

Iphiaulax sp.	Larva	Rao, 1964
Oncophanes sp.	Larva	Rao, 1964
Rhysipolis hesperidis (Rohwer) [= *Oncophanes hesperidis* Rohwer]	Larva	Rao, 1964
Rhysipolis sp.	Larva	Rao, 1964
Ichneumonidae		
Anilastus sp.	Larva	Rao, 1964
Casinaria pedunculata pedunculata Szepligeti (= *C. colacea* Sonan)	Larva	Anon., 1979; Gupta & Maheswary, 1977; Townes, 1984 Xia *et al.*, 1988
Charops bicolor (Szepligeti)	Larva	Van Vreden & Ahmad Zabidi, 1986; CRRI, 1980; Chhabra & Singh, 1978; JICA, 1981; Xia *et al.*, 1988; Anon., 1979; Gupta & Maheswary, 1977
Charops sp.	Larva	Rao, 1964; CRRI, 1982
Coccygominus parnarae (Viereck)	Larva	IPP-HAAS, 1978; Anon., 1979
Gregopimpla himalayensis Cameron	Larva	Anon., 1979; Townes, 1984
G. kuwanae Viereck	Larva	Anon., 1979
Hyposotes vierecki Townes	Larva	Anon., 1979
Ischnojoppa luteator (F.)	Pupa	CRRI, 1980, 1982; Townes *et al.*, 1961; Rao, 1964; Anon., 1979
Itoplectis narangae Ashmead	Larva	Anon., 1979
I. sp. nr. *maculator* Fabricius	Larva	Rao, 1964
Lissosculpta alecto Morley	Larva	Townes *et al.*, 1961
Nythobia sp.	Larva	Rao, 1964
Scenocharops sp.	Larva	Rao, 1964
Theronia sp.	Larva	Anon., 1979
Triptonatus sp.	Pupa	Con, 1986
Xanthopimpla flavolineata Cameron [= *X. emculata* Szepligeti] [= *X. immaculata* Morley] [= *X. immaculata* Ayyar]	Larva	CRRI, 1980 Townes *et al.*, 1961; Anon., 1979 Townes & Chiu, 1970
X. punctata F.	Larva	Yunus & Hua, 1980; Anon., 1979
Xanthopimpla sp.	Larva	Rao, 1964; Lever, 1955
Elasmidae		
Elasmus sp.	Larva	Rao, 1964
Eulophidae		
Euplectrus nuctermnerae Crawford	Larva	Rao, 1964; Hayat & Subba Rao, 1986
Sympiesis parnarae Chu & Liao	Larva	He & Pang, 1986
Sympiesis sp.	Larva	Rao, 1964; Anon., 1979
Tetrastichus sp. .	Pupa	CRRI, 1982

Tetrastichus ayyari Rohwer [= *T. howardi* (Olliff)]	Pupa	Puttarudriah & Sivashankara Sastry, 1958
<u>Eurytomidae</u>		
Eurytoma manilensis Ashmead	Larva	Rao, 1964
<u>Pteromalidae</u>		
Trichomalopsis apanteloctena (Crawford) [= *Eupteromalus parnarae* Gahan]	Larva-pupa	Rao, 1964; Barrion & Litsinger, 1983; Kamijo & Grissell, 1982; CRRI, 1983
Diptera		
<u>Tachinidae</u>		
Actia nigroscutellata Lundbeck	Larva	Anon., 1979
A. perispoliata Mesnil	Larva	Rao, 1964
Actia sp.	Larva	Rao, 1964
? *Alsomyia anomala* Villen	Larva	Kalra & Srivastava, 1967
Argyrophylax nigrotibialis (Baranov)	Larva	Rao, 1964; Yasumatsu & Torii, 1968;
	JICA, 1981	
Argyrophylax sp.	Larva	CRRI, 1982
Blepharipa sp.	Larva	CRRI, 1980
Ceromya silacea (Meigen)	Larva	IPP-HAAS, 1978
Chetogena (= Spoggosia) acuminata Rd. subsp. *bezziana* (name not traced)	Larva	Rao, 1964
Clytho argentea (Egger)	Larva	IPP-HAAS, 1978; Anon., 1979
Drino unisetosa Baranov	Larva	Rao, 1964
Exorista japonica (Townsend)	Larva	IPP-HAAS, 1978; Anon., 1979
Halydaia luteicornis (Walker)	Larva	Rao, 1964; Yasumatsu & Toril, 1968; JICA, 1981; Siwi *et al.*, 1989; CRRI, 1982
H. luteipennis Walker	Larva	JICA, 1981; Yasumatsu *et al.*, 1982
H. rufa Bezzi	Larva	Yunus & Hua, 1980; Dammerman, 1929
Halidoia (= Halydaia) sp.	Larva	Lever, 1955
Nemorilla maculosa Meigen	Larva	IPP-HAAS, 1978; Xia *et al.*, 1988
Peribaea orbata (Weidemann)	Larva	van Vreden & Ahmad Zabidi, 1986
Pseudoperichaeta insidiosa (Robineau-Desvoidy)	Larva	IPP-HAAS, 1978; Anon., 1979 Xia *et al.*, 1988
Thecocardelia oculata (Baranov) [= *Gymnocardelia oculata* (Baranov)]	Larva	Yunus & Hua, 1980; Rao, 1964; CRRI, 1975; 1982
T. parnarae Chao	Larva	IPP-HAAS, 1978; Anon., 1979; Xia *et al.*, 1988
T. thrix (Townsend)	Larva	Rao, 1964; Yunus & Hua, 1980

PREDATORS		
Dermaptera		
Chelisochidae		
Proreus simulans (Stal)	Larva	Barrion & Litsinger, 1985
Hemiptera		
Pentatomidae		
Andrallus spinidens Fabricius	Larva	van Vreden & Ahmad Zabidi, 1986; Rao & Rao, 1979; Rao, 1965
Amyotea (Asopus) malabarica (Fabricius)	Larva	Pati & Mathur, 1986
Eocanthecona furcellata (Wolff)	Larva	Cherian & Brahmachari, 1941
Salientia		
Ranidae		
Rana tigrina Daud	1/	Kharat *et al.*, 1983; Nigam, 1979
PATHOGENS		
Aspergillales		
Aspergillaceae		
Aspergillus flavus Thompson	Larva	Romback *et al.*, 1987
Moniliales		
Moniliaceae		
Beauveria bassiana (Balsamo) Vuillemin	Larva	Velusamy *et al.*, 1973; Rombach *et al.*, 1987
Beauveria brongniartii Tenella	Larva	Nayak *et al.*, 1978
Enterobacteriales		
Enterobacteriaceae		
Serratia marcescens Bizio	Larva	Srivastava & Nayak, 1978
Virus		
Nuclear polyhedrosis (PmNPV)	Larva	Nayak & Godse, 1986; Rombach *et al.*, 1987; Cheng *et al.*, 1990

[1] No Stage mentioned

at the Boyce Thompson Institute, Ithaca, New York. Predation and parasitization studies were conducted on the IRRI Experimental Farm in an insecticide untreated area where weekly a new rice plot (500 m2) was planted to IR64 in continuous rice cultivation. Rice was transplanted by hand into clumps or hills, 20 cm apart.

Natural enemy associations

Eggs, larvae, and pupae of both butterflies were collected from locations representing the three major rice environments in the Philippines. These locations were at collaborative IRRI-Philippine Department of Agriculture outreach sites and collections were made from farmers' fields during periods of abundance of *M. leda ismene* or *P. mathias* from 1977-1991. There were four irrigated wetland sites, five rainfed wetland sites, and three rainfed dryland sites. The relative abundance of each natural enemy species was estimated as very common, common, or rare. Very common natural enemies were encountered in at least 33% of the fields per site during any sampling date, while rare indicated presence in less than 5% of the fields.

Field collected eggs (n = 1276 and 882 for *M. leda ismene* and *P. mathias*, respectively) were held for parasitoid emergence in petri dishes on filter paper moistened with a solution of 1% fungistatic agent (Tegosept M, Ward's Natural Science Establishment, Inc., New York).

Field collected larvae and pupae (n = 5753 and 3448 for *M. leda ismene* and *P. mathias*, respectively) were held in plastic jars for parasitoid emergence and fed bouquets of rice foliage (Chandra, 1978). Pupae were held in similar cages until host or parasitoid emergence. Field observations on the behavior of predators capturing and feeding on the various life stages of *M. leda ismene* and *P. mathias* were made during collecting trips. Predator-prey relationships were verified by caging field collected species on rice plants with host eggs, larvae, pupae, or adults. Pathogens were recovered from the various stages as noted in the field as well as in rearing colonies.

The list of natural enemies of *M. leda ismene* and *P. mathias* compiled in the Philippines was compared with that reported in the literature.

***M. leda* predation rates under controlled conditions**

We compared the effectiveness of six predators against *M. leda ismene* in the greenhouse. Each predator, representing a different guild, was evaluated following the method of van den Berg *et al.* (1992). None of the common ricefield predators selected had ever been tested against either of the butterfly species.

Adults and nymphs of *Conocephalus longipennis* (de Haan), a large katydid, are effective predators of rice planthopper and leafhopper nymphs (Rubia *et al.*, 1990, Cohen *et al.*, 1994) and *Leptocorisa* spp. ricebug eggs (Rothschild, 1970), and feed on yellow rice borer *Scirpophaga incertulas* (Walker) eggs despite the protective mat of hair (Pantua and Litsinger, 1984). It is also a voracious aphid (*Aphis craccivora* Koch) predator on mungbean grown after rice (Litsinger *et al.*, 1988).

Agriocnemis femina femina (Brauer) and *Agriocnemis pygmaea* (Rambur) are damselfly predators of planthopper and leafhopper nymphs and adults. They are excellent hunters that generally search for prey under the plant canopy (IRRI, 1978; 1981; Shepard *et al.*, 1987; Cohen *et al.*, 1994). Damselfly adults also prey on stem borer and leaffolder *Cnaphalocrocis medinalis* (Guenée) moths and adults of whorl maggot *Hydrellia philippina* Ferino (Cohen *et al.*, 1994) and *H. sasaki* Yuasa & Isitani (Shiraki, 1917).

The ground beetle *Ophionea ishii ishii* Habu, is a common ricefield predator and feeds on pyralid leaffolder and stem borer larvae as well as planthopper and leafhopper nymphs and adults (Shepard *et al.*, 1987; Cohen *et al.*, 1994). *O. nigrofasciata* Schmidt-Goebel and *Archicolliuris bimaculata* (Redtenbacher) are also natural control agents and as effective as *O. ishii ishii*. Predation occurs both in adult and larval stages.

Micraspis hirashimai Sasaji is one of a number of ricefield inhabiting ladybeetles. It is an egg predator of the pyralid leaffolder (Bandong and Litsinger, 1986) and the noctuid defoliator *Rivula atimeta* Swinhoe (van den Berg *et al.*, 1992) as well as planthoppers both as adults and larvae (Cohen *et al.*, 1994). It is an aphid predator on mungbean after rice (Litsinger *et al.*, 1988).

Adults and nymphs of *Metioche vittaticollis* (Stål), a black sword-tailed cricket, are egg predators of rice pyralid leaffolders (Bandong and Litsinger, 1986) but are not large enough to consume a yellow rice borer egg mass with the protective hair mat. However, naked eggs of striped rice borer *Chilo suppressalis* (Walker) are readily consumed. It is an egg predator of the noctuids *R. atimeta* and *Naranga aenescens* Moore, and the ephydrid rice whorl maggot (van den Berg *et al.*, 1992).

The common rice wolf spider, *Pardosa (= Lycosa) pseudoannulata* (Boesenberg et Strand), is a key predator of rice leafhopper and planthopper nymphs and adults in the Philippines (Hsieh and Dyck, 1975; Gavarra and Raros, 1975) and in Japan (Kiritani and Kakiya, 1975). Other recorded prey are rice stem borer larvae (Chen *et al.*, 1984; Than Htun, 1976) and moths (Shepard *et al.*, 1987; Rubia *et al.*, 1990) and rice leaffolder moths (Barrion *et al.*, 1991).

Individuals of each of the six predators were collected from insecticide untreated fields, placed in holding cages and starved for 24 hours before testing. Only adult stages of predators were utilized and were not separated by sex. The predators were placed singly on a potted 35-d-old IR36 rice plant thinned to five tillers. Each plant was covered by a mylar tube cage 12 cm diameter and 75 cm tall with nylon mesh (0.5 mm) vents at the top and sides pushed into the soil.

Fifty freshly laid *M. leda ismene* eggs were clipped from leaves in the rearing culture. Leaf sections with eggs were glued to each caged plant. In a similar manner, larval and pupal predation rates were compared between the six predator species by offering fifteen prey of each stage, including all five larval instars on potted plants. Observations were made over a 3-day period, and daily each predator was transferred to a new potted plant with 50 fresh eggs or 15 larvae or pupae. There was a separate experiment for each *M. leda ismene* life stage where the six predators were the treatments, replicated twelve times over time in a randomized complete block design in the greenhouse. The experiments with fourth and fifth instar larvae and pupae were stopped after two replications when it was found that no predator was able to prey on these larger life stages.

Monthly *P. mathias* egg and larval parasitization rates

We recorded the seasonal incidence of *P. mathias* egg, larval, and pupal parasitoids in the field using Otake's (1977) prey enrichment method. Each month 10 hills of late vegetative stage IR64 rice plants were removed from the continuous rice culture and brought to the greenhouse on the IRRI Farm. Each hill was placed in a pot and held overnight in oviposition cages with a sufficient number of butterflies to achieve a minimum of 20 eggs per hill. High numbers of eggs were needed to compensate for the expected high rates of predation in the field. The following morning the potted hills with eggs were returned in the field and left uncaged. After 3 days the potted hills were retrieved and leaves with eggs were cut from the plants and placed in a test tube to record parasitoid emergence following the technique of Barrion and Litsinger (1985).

A mixture of second and third instar larvae was also placed on late vegetative stage plants in the same field, 10 per hill and 20 hills per month. Preliminary experiments showed that the larvae were sedentary and no caging was necessary. High numbers were placed in the field to overcome expected high rates of predation. The larvae were retrieved after 7 days and caged (Chandra, 1977) for parasitoid emergence. Most of the common larval and larval-pupal parasitoids attack second to fourth instar larvae. Most of the third instar larvae molted into the fourth instar while in the field.

Rainstorms occurred during two of the 11 monthly exposures which washed off many eggs and larvae forcing us to repeat the replications. The number of eggs recovered each month ranged from 83-145 with a mean of 122.5. The number of larvae recovered each month ranged from 72-137 with a mean of 117.6.

RESULTS

Natural enemy associations

In the Philippines we found more predators (83 species) of *M. leda ismene* and *P. mathias* than species of parasitoids (30) or pathogens (4) (Table 3). Of the 83 predators, 72 were recorded on *M. leda ismene* and 60 on *P. mathias* with 59% attacking both species.

Predators

Comparing the stage attacked by predators for both butterflies, more species preyed on larvae (52) than eggs (28), adults (19), or pupae (1). Some predators preyed on more than one life stage. More predator records occurred on *M. leda ismene* than *P. mathias* in each life stage: egg (27 vs 19), larva-pupa (50 vs 43), and adult (13 vs 11), respectively.

Predatory guilds comprised ten orders: Hemiptera (22 species), Araneae (17 species), Coleoptera, Hymenoptera, and Orthoptera (10 species each), Odonata (5 species), Dermaptera (4 species), Neuroptera and Squamata (2 species each), and Salientia (1 species).

The hemipterans are among the most important egg and larval predators of *M. leda ismene* and *P. mathias*. *Cyrtorhinus lividipennis* Reuter is an egg and nymph predator of rice leafhoppers and planthoppers with preference for *Nilaparvata lugens* (Stål) (Heong *et al.*, 1990) and occurs in all rice environments being most abundant towards maximum tillering (Heong *et al.*, 1992). Adults and nymphs puncture eggs

Table 3. Natural enemies of *P. mathias* and *M. leda ismene* recorded in the Philippines, 1977-91.

Beneficial species	**Host**[a/]	**Stage attacked**[b]	**Relative frequency**[c/]
INVERTEBRATES			
Parasitoids			
Diptera			
Phoridae			
Megaselia sp. nr. *scalaris* Loew	Pe; M	L-P	+++
Stratiomyidae			
Odontomyia sp.	M	P	+
Tachinidae			
Argyrophylax nigrotibialis Baranov	Pe	L3-5	++
Halydaia luteicornis (Walker)	Pe	L2-5	+++
Peirbaea sp. nr. *orbata* (Wiedemann)	Pe	L4	+
? *Thecocarcelia* sp.	Pe	L4	+
Hymenoptera			
Braconidae			
Cotesia baoris (Wilkinson)	Pe	L2-4	+
Chelonus sp. 1	M	P	+
Chelonus sp. 2	M	P	+
Chalcididae			
Brachymeria excarinata Gahan	Pe; M	L-P	++
B. lasus (Walker)	Pe; M	L-P	+
B. marginata Cameron	M	L-P	+
Brachymeria sp.	M	L-P	+
Eulophidae			
Tetrastichus howardi (Olliff)	Pe; M	P	++
Euplectrus sp.	Pe	L	+
Pediobius sp.	Pe; M	L-P	+
Sympiesis sp nr. *parnarae* Chao	Pe	L-P	+
Eurytomidae			
Eurytoma braconidis Wilkinson	Pe	L2-3	+
Ichneumonidae			
Xanthopimpla stemmator Thunberg	Pe; M	L-P	++
Charops bicolor (Szepligeti)	Pe; M	L4-5	+
C. brachypterum (Cameron)	Pe; M	L4-5	+
Ischnojoppa luteator (Fabricius)	Pe	L-P	+

<u>Pteromalidae</u>			
Trichomalopsis apanteloctena (Crawford)	Pe; M	L-P	+++; +
<u>Scelionidae</u>			
Telenomus sp. nr. *lucullus* Nixon	M	E	++
Telenomus sp.	Pe	E	+
Psix sp.	M	E	+
Platyscelio abnormis Crawford	M	L4-5	+
<u>Trichogrammatidae</u>			
Trichogramma hesperidis Nagaraja	Pe; M	E	+++
Trichogramma sp.	Pe; M	E	++
Trichogrammatoidea sp.	M	E	+
Predators			
Coleoptera			
<u>Carabidae</u>			
Archicolliuris bimaculata (Redtenbacher)	Pe; M	L1-2	+
Desera geniculata Klug	Pe; M	L1-2	+
Drypta japonica Bates	Pe; M	L1-2	++
Ophionea ishii ishii Habu	Pe; M	E; L1-2	+++
Ophionea nigrofasciata (Schmidt-Goebel)	Pe; M	E; L1-2	+++
<u>Coccinellidae</u>			
Coccinella repanda Thunberg	Pe; M	L1	++
Harmonia octomaculata Thunberg	Pe; M	L1	+++
Menochilus sexmaculatus Fabricius	Pe; M	L1	+
Micraspis hirashimai Sasaji	Pe; M	E; L1-2	+++
<u>Staphylinidae</u>			
Paederus fuscipes Curtis	Pe	L1	+++
Dermaptera			
<u>Carcinophoridae</u>			
Euborellia annulata (Fabricius)	Pe; M	L1-2	+
Euborellia philippinensis Srivastava	Pe	L1-2	++
<u>Chelisochidae</u>			
Proreus simulans (Stål)	Pe	L1-2, P	++
<u>Labiduridae</u>			
Nala lividipes (Dufour)	Pe	L1	+
Hemiptera			
<u>Anthocoridae</u>			
Orius tantillus Motschulsky	Pe; M	E; L1	++
<u>Gerridae</u>			
Limnogonus fossarum Fabricius	Pe; M	L1-2	+++

Limnogonus nitidus (Mayr)	Pe; M	L1-2	++
Rheumatogonus luzonicus (Kirkaldy)	M	L1-2	+
<u>Lygaeidae</u>			
Geocoris flaviceps (Burmeister)	Pe; M	E; L1	+
Geocoris sp.	Pe; M	E; L1	+
<u>Mesoveliidae</u>			
Mesovelia vittigera (Horvath)	M	L1	++
<u>Miridae</u>			
Cyrtorhinus lividipennis Reuter	Pe; M	E	+++
Deraecoris sp.	M	E	+
<u>Nabidae</u>			
Nabis sp.	M	L1	+
Stenonabis tagalicus Stål	M	L1	++
<u>Pentatomidae</u>			
Menida sp.	M	E; L1	+
Pygomenida bengalensis (Westwood)	Pe; M	E; L1	++
Pygomenida varipennis (Westwood)	M	E	++
<u>Reduviidae</u>			
Lisarda sp.	M	L1-2	+
Polytoxus sp. 1	Pe; M	L1	+
Polytoxus sp. 2	Pe; M	L1	+
Rhinocoris fuscifes (Fabricius)	M	L2	+
Scipinia horrida Stål	Pe; M	L1	+
Sirthenea sp.	Pe; M	L1-2	+
Staccia diluta Stål	Pe; M	L1	+
<u>Veliidae</u>			
Microvelia douglasi atrolineata Bergroth	Pe; M	L1	+++
Hymenoptera			
<u>Formicidae</u>			
Diacamma sp.	Pe; M	L1-2	+
Camponotus sp.	Pe; M	L1-2	+
Monomorium pharaonis (Linnaeus)	Pe; M	E; L1	++
Odontoponera transversa (Fabricius-Smith)	Pe; M	L1-2	++
Oecophylla smaragdina Fabricius	Pe; M	A; L1-2	+
Solenopsis geminata (Fabricius)	Pe; M	E; L1-2	+++
Tapinoma sp.	M	E; L1	+
<u>Vespidae</u>			
Ropalidia sp. 1	Pe; M	L1-3	++
Ropalidia sp. 2	Pe; M	L1-3	++
Vespa philippinensis Saussure	Pe	L2	+

Mantodea			
Mantidae			
Tenodera sp.	M	A	+
Neuroptera			
Chrysopidae			
Chrysopa basalis Baker	Pe; M	E; L1	+
Chrysopa sp.	Pe; M	E; L1	+
Odonata			
Coenagrionidae			
Agriocnemis femina femina (Brauer)	M	E	+++
Pseudagrion pilidorsum pilidorsum (Brauer)	Pe; M	E; L1	++
Ischnura senegalensis (Rambur)	Pe; M	E; L1	+
Libellulidae			
Orthethrum sabina (Drury)	Pe; M	A	+
Orthethrum testaceum (Burmeister)	Pe; M	A	+
Orthoptera			
Acrididae			
Oxya sp. 1	Pe; M	E	++
Oxya sp. 2	Pe; M	E	++
Gyllidae			
Anaxipha longipennis (Serville)	Pe; M	E	+++
Anaxipha sp.	M	E	+
Euscyrtus concinnus (Haan)	Pe; M	E	++
Metioche vittaticollis (Stål)	Pe; M	E; L1	+++
Metioche sp.	M	E	+
Tettigoniidae			
Conocephalus longipennis (Haan)	Pe; M	E; L1-3	+++
Conocephalus maculatus (Le Guillou)	Pe; M	E; L1-3	++
Araneae			
Araneidae			
Araneus inustus L. Koch	Pe	A	++
Argiope aemula (Walckenaer)	Pe	A	+
Argiope catenulata Doleschall	Pe; M	A	+++
Nephila maculata Fabricius	M	A	+
Nephila malabarensis (Walckenaer)	M	A	+
Eusparassidae			
Heteropoda venatoria Linnaeus	Pe; M	A	+
Olios sp.	Pe	A	+
Thelctocopis sp.	M	A	+
Lycosidae			
Pardosa pseudoannulata (Boesenberg et Strand)	Pe	A	+++

Trochosa sp.	M	A	+
Oxyopidae			
Oxyopes javanus Thorell	Pe; M	L1-2	+++
Oxyopes lineatipes C.L. Koch	Pe; M	L1-2	+
Oxyopes sp.	M	L1-2	+
Salticidae			
Bianor hotingchiehi Schenkel	Pe; M	L1	+
Marpissa calcuttaensis Tikader	M	L1	+
Menemerus sp.	Pe	A	+
Thomisidae			
Thomisus sp.	Pe	A	+
VERTEBRATES			
Salientia			
Bufonidae			
Bufo marinus Linnaeus	M	A	++
Squamata			
Scincidae			
Dasia sp.	M	A	+
Spheromorphus sp.	M	A	+
PATHOGENS			
Pseudomonadales			
Pseudomonadaceae			
Pseudomonas sp.	Pe; M	L1-3	+
Eubacteriales			
Bacillaceae			
Bacillus thuringiensis Berliner	Pe; M	L1-3	+
Moniliaceae			
Undetermined fungus	M	L2-4	++
Baculoviridae			
Nuclear polyhedrosis virus	Pe; M	L1-3	++

[a]Pe = *Pelopidas;* M = *Melanitis;* [b]E = egg; L1-5 = 1st-5th larval instars; P = P\pupa; A = adult; L-P = larval-pupal;[c] + + + = very common; ++ = common; and + = rare; [d]accidental predators.

with their mouthparts killing the embryo. Preyed-upon eggs turn black in 5 days.

The semi-aquatic hemipterans (gerrids, mesoveliids, and veliids) capture young butterfly larvae which fall off plants, apparently a common event. The small water strider *Microvelia douglasi atrolineata* Bergroth collectively attacks fallen prey and often more than five individuals participate in the kill. The first larval instars (L I) of *M. leda ismene* and *P. mathias* tend to float on the water surface due to surface tension and their light weight, while older, heavier instars sink. Gerrids are larger and can dive underwater to locate them. The most abundant gerrids are *Limnogonus fossarum* Fabricius and *L. nitidus* (Mayr). Due to their powerful legs a single gerrid can tackle a butterfly larva. *L. nitidus* is larger than *L. fossarum* and more swift but is less abundant.

The feeding behavior of the water treader *Mesovelia vittigera* (Horvath) is similar to that of the veliids but occasionally an individual will prey singly as with the gerrids. In the laboratory, an apterous adult consumed only one L I per day. Older nymphs appear to be more voracious and consumed 2-4 L I larvae per day. Nymphs and adults seldom hunt on the foliage for prey.

Nabids are general predators but *Stenonabis tagalicus* Stål and *Nabis* sp. feed on L I, consuming 1-3 per day. Only adult nabids were observed to actively search rice foliage and prey on *M. leda ismene* larvae.

Adults and nymphs of the anthocorid minute pirate bug *Orius tantillus* Motschulsky can prey on 1-5 eggs per day despite its small size but may not feed on all of them. Its numbers are generally higher from maximum tillering to flowering.

O. tantillus and the nabids prefer dryland habitats and attack L I from behind. The predators pierce their prey and drag each one backwards to avoid retaliation. A paralytic toxin must be injected as prey soon becomes immobilized.

Being larger, pentatomid nymphs and adults attack their larval prey head-on. *Pygomenida varipennis* (Westwood) is known only as an egg predator and occurs in both wetland and dryland habitats. *P. bengalensis* (Westwood) and *Menida* sp., however, mainly inhabit the drylands, predominantly in reproductive stage rice. These stink bugs are also pests as they feed on grain.

The lygaeids and reduviids are only occasional predators. The big-eyed bug *Geocoris flaviceps* (Burmeister) prefers dryland environments preying on both eggs and L I. The reduviids are larger and as hunters prefer L I or L II. They can mount frontal attacks but are not abundant as a group. *Rhinocoris fuscifes* (Fabricius) and *Sirthenea* sp. can attack L II prey. The other reduviids *Polytoxus, Scipinia,* and *Staccia* are an insignificant mortality factor for *M. leda ismene* and *P. mathias* larvae. *Scipinia horrida* Stål may puncture a L IV, but rarely make a kill.

O. ishii ishii is more prevalent in the wetlands, while the other four carabid species listed are more adapted to the drylands. Most carabids are larval predators attacking only L I and L II. *O. ishii ishii* also preys on eggs. *O. nigrofasciata* (Schmidt-Goebel) is abundant in dryland and rainfed wetland areas. Its black and long tailed larva hunts L I to L II rice skipper larvae inside folded leaves.

Ladybeetles prey on L I but *M. hirashimai (= M. crocea)* can prey on eggs and L II even though it is smaller than the equally abundant *Harmonia octomaculata* Thunberg. *Menochilus sexmaculatus* Fabricius is more adapted to the drylands.

The staphylinid *Paederus fuscipes* Curtis is a predator as an adult and enters larval feeding chambers of *P. mathias* to corner its prey. *P. fuscipes* can attack only L I, but has not been observed to attack *M. leda ismene*.

As a group, orthopterans are prevalent in riceland environments becoming increasingly abundant with crop maturity. Several species of crickets and katydids are effective predators. Most orthopterans prey on eggs but *M. vittaticollis,* and particularly *C. longipennis*, can consume larvae. *C. longipennis* grows as large as its prey. *C. maculatus* (Le Guillou) is smaller and less abundant than *C. longipennis*. The sword-tailed crickets *M. vittaticollis* and *Anaxipha longipennis* (Serville) are smaller but densities can become high. Occasionally we observed a praying mantid *Tenodera* sp. feeding on the adult stage of *M. leda ismene*. Skipper adults, being more nimble, appear harder for mantids to capture.

Egg predation by *Oxya* spp. grasshoppers and the cricket *Euscyrtus concinnus* (de Haan) was indirect as eggs of both butterflies are consumed incidentally during leaf removal by these defoliators.

Ants prevail in the drylands but also occur in wetland ricefield bunds and dikes. The weaver ant *Oecophylla smaragdina* Fabricius nests in trees and only forages in rice fields adjacent to its nesting sites. *Diacamma* sp. and *Camponotus* sp. capture larval prey in the crop and bring them to their nest in adjacent non-cultivated border habitats. *O. smaragdina* and the fire ant *Solenopsis geminata* (Fabricius), however, devour their prey at the point of capture. *S. geminata* occurs along rice bunds in wetland fields where it can only climb on rice foliage that touches the bunds, making it of limited value. *Monomorium pharoaonis* (Linnaeus) can prey on 1 larva or 2-4 eggs per day. Prey are devoured on the spot. *Tapinoma* sp., the smallest ant species occasionally feed on newly hatched larvae but prefers eggs. The large ant *Odontoponera transversa* (F. Smith) climbs the foliage for larval prey which are transported to nests in the soil. A single ant was observed to collect 1 to 6 larvae per day and transport its prey live to the nest.

Vespid mud wasps pick off larvae from the foliage and bring them to their nests as feed for their young. *P. mathias* is particularly vulnerable when it exits its feeding chamber in the early morning and late afternoon. The relatively small and slender bodied *Ropalidia* spp. can take L III, while the large *Vespa philippinensis* Saussure can handle all larval instars.

Damselfly adults are effective egg and larval predators as they continuously search within the rice canopy. They are quick fliers and hover while searching for prey which they capture with their long legs. Eggs are also detected by damselflies which land on the foliage where eggs are deposited. *A. femina femina* is smaller but more numerous than *Pseudagrion pilidorsum pilidorsum* (Brauer) and *Ischnura senegalensis* (Rambur).

Libellulid dragonflies capture butterflies in midair. *Orthethrum sabina* (Drury) and *O. testaceum* (Burmeister) are large and can take large adult prey. Dragonflies are particularly abundant over rice fields before a rainstorm or during harvest when the butterflies are disturbed and take flight.

Earwigs nest in the soil and thus are more prevalent in the drylands where they search for prey on rice foliage. We have recorded earwigs feeding only on L I and L II, but probably feed on eggs as well. The two most prevalent earwigs are *Proreus simulans* (Stål) and *Euborellia philippinensis* Srivastava. Most of the prey records are on *P. mathias* perhaps because earwigs, being thigmotropic, seek shelter such as a folded leaf chamber. Earwigs readily enter the larval feeding chamber of *P. mathias*. *P. simulans* may occasionally feed on pupae that fail to eclode.

The chrysopid lacewings are of less importance as they are not normally abundant in rice fields. Lacewing adults prey on eggs whereas their larvae are larval predators. *Chrysopa basalis* Baker and *Chrysopa* sp. are more common in drylands than wetlands and their green color allows them to blend in with the foliage.

Foliage-dwelling hunting spiders (oxyopids and salticids) can prey on larvae but the majority attacks adults. The most prevalent oxyopid is *Oxyopes javanus* Thorell. The salticid *Bianor hotingchiehi* Schenkel even stalks *P. mathias* larvae within their feeding chambers. The wolf spider *P. pseudoannulata* prefers to hunt more at ground level than on the foliage. They can attack adult butterflies which seek shelter during the day at the base of plants. The orb web spiders are dominated by *Argiope catenulata* Doleschall and *Araneus inustus* L. Koch, which capture butterflies that collide on their large circular webs. The spiders quickly wrap them up with silk to subdue them. As a rule, spiders do not completely devour adult butterflies as perhaps their scales interfere with feeding. The thomisid crab spiders lurk for their prey, often in flower heads. *Thomisus* sp. was found preying on skipper adults while in search of nectar in santan flowers. Three species of eusparassid spiders are associated with satyrid and skipper adults. *Heteropoda venatoria* Linnaeus and *Thelcticopis* sp. often capture butterflies resting in banana fields and orchards while *Olios* sp. hunts *P. mathias* on santan.

Three vertebrate predators were noted. The toad *Bufo marinus* Linnaeus is aquatic while the scincid lizards (*Dasia* sp. and *Spheromorphus* sp.) are adapted to the drylands. Both toads and lizards capture adult butterflies with their long tongues. The toad, however, is prevalent mainly on rice bunds and not in the field itself. *M. leda ismene* adults are more vulnerable as prey as they rest at the base of plants during the day when the toads and lizards are active. *P. mathias* only alights in the upper portions of foliage during the day and thus does not come near these potential predators.

Parasitoids

Of the 30 parasitoid species, 21 were recorded on *P. mathias* and 20 on *M. leda ismene* with 37% parasitizing both species. Larval and larval-pupal parasitoids (10 species each) outnumbered egg (6 species) and pupal (3 species) parasitoids for both butterflies (Table 3).

Egg. M. leda ismene has five recorded egg parasitoids while *P. mathias* has only three, and both species share two egg parasitoids in common. Of the six egg parasitoids recovered, *Trichogramma hesperidis* Nagaraja is the most abundant (>90% of individuals) egg parasitoid of *P. mathias.* Two to four wasps emerged per host egg from individual round holes. More wasps tend to develop in larger eggs. *Telenomus* sp. nr. *lucullus* Nixon is most abundant on *M. leda ismene* and is not recorded on *P. mathias.* It prefers a dryland habitat and produces one wasp per egg -- the wasp cuts an irregular exit hole. Only two (*T. hesperidis* and *Trichogramma* sp.) of the six parasitoids attack both butterfly species.

Larval. P. mathias has nine larval parasitoids but only three are recorded from *M. leda ismene;* both share two in common. Tachinids are the dominant larval parasitoids of *P. mathias* and attack older host larvae. *P. mathias* larvae are attacked mainly by two species *Halydaia luteicornis* (Walker) and *Argyrophylax nigrotibialis* Baranov. The former is more abundant. Three to four *H. luteicornis* flies emerge from each host larva. The parasitoid pupal cocoons are located adjacent to the moribund host larva but not close together. The cocoons are coated by a white waxy substance. The *A. nigrotibialis* adult is larger and more than five flies emerge (its pupae are clustered tightly together and have no white coating).

Larval-pupal. Both *M. leda ismene* and *P. mathias* have eight larval-pupal parasitoids, sharing six in common. The two most frequently encountered species were the pteromalid *Trichomalopsis apanteloctena (*Crawford) and the phorid fly *Megaselia* sp. nr. *scalaris* Loew. *T. apanteloctena* was more frequent on *P. mathias,* whereas *M.* sp. nr. *scalaris* was commonly reared from both butterflies. The pteromalid *T. apanteloctena* behaved as a hyperparasitoid of *Xanthopimpla stemmator* Thunberg on two occasions with *P. mathias* but not *M. leda ismene.* The phorid fly, on the other hand, emerged from both butterflies. Phorids apparently are attracted to clusters of larval prey as no phorid was reared from isolated larvae of either species. *Brachymeria excarinata* Gahan and *X. stemmator* are common chalcid and ichneumonid larval-pupal parasitoids of both butterflies.

Pupal. M. leda ismene has four pupal parasitoids to only one for *P. mathias,* sharing only the eulophid *Tetrastichus howardi* (Olliff). *T. howardi* is particularly common in the drylands and is more prevalent on *M. leda ismene.* The adult parasitizes the pre-pupal and pupal stages and an average of 80 wasps emerge through numerous exit holes per pupa. A 5:1 ratio of emerged females:males was observed. Several individuals may parasitize a pupa but at widely separated sites on the host's body. All parasitoids emerge in less than one hour after completing development inside the host. Males emerge first and wait for the females. Mating occurs quickly and multiple mating is frequent. A single male mates with 2-15 females in 4-5 minutes. *P. mathias* seems to be a poor host for *T. howardi* because of its covered pupa. In contrast, pupae of *M. leda ismene* are naked and directly exposed to the parasitoids.

Pathogens

Four species of larval pathogens were encountered in the field. Two were bacteria: *Pseudomonas* sp. was found on both butterfly species while *Bacillus thuringiensis* Berliner was only found on *M. leda ismene.* A nuclear polyhedrosis virus was commonly recovered from *P. mathias* and *M. leda ismene.* An undetermined fungus was noted from *M. leda ismene* larvae.

Egg, larval, and pupal parasitization rates by environment and location

Egg parasitization levels of *M. leda ismene* (12.2%) and *P. mathias* (14.5%) averaged over three environments and twelve locations were similar (Table 4). There was, however, much variation between locations within each environment. Higher egg parasitization of *M. leda ismene* than *P. mathias* occurred in the irrigated (20.8 vs 14.2%) and rainfed (7.4 vs 0%) wetlands than in the rainfed drylands (9.8 vs 29.4%), respectively. The highest percentage parasitization of *P. mathias* eggs was 42.8% in the dryland site in Tanauan, Batangas. On the other hand, no parasitoid activity was recorded in Solana, Cagayan for either species. The site is often flooded for periods of several weeks after typhoons.

A look at the egg parasitization averages for *M. leda ismene* for similar months

Table 4. Parasitization of *P. mathias* and *M. leda ismene* from field-collected eggs, larvae and pupae in three rice environments and 12 locations in the Philippines 1977-91.

Environment	Period	Location		Egg parasitization				Larval parasitization			
		Town	Province	*M. leda ismene*		*P. mathias*		*M. leda ismene*		*P. mathias*	
				%	n	%	n	%	n	%	n
Irrigated	1979-86	Los Baños	Laguna	27.9 ± 7.7	667	28.4 ± 6.4	744	8.2 ± 5.7	2031	12.9 ± 4.7	1842
Wetland	1979-90	Cabanatuan	Nueva Ecija	19.3 ± 2.1	142	-	-	9.5 ± 6.4	127	9.6 ± 7.7	51
	1979-87	Estrella	Palawan	-	-	-	-	10.7 ± 10.7	44	19.9 ± 4.5	93
	1985-91	Koronadal	So. Cotabato	15.2 ± 9.9	35	0	18	11.8 ± 6.9	159	11.4 ± 7.7	91
	Mean				20.8		14.2		10.1		13.5
	Total				844		762		2361		2077
Rainfed	1979-81	Oton	Iloilo	14.7 ± 5.8	119	0	21	12.8 ± 2.2	199	26.0 ± 1.0	37
Wetland	1977-81	Pototan	Iloilo	0	57	-	-	9.3 ± 7.9	127	6.7 ± 4.8	61
	1981-82	Bani	Pangasinan	-	-	-	-	2.5 ± 0.5	54	2.5 ± 1.5	52
	1978-81	Manaoag	Pangasinan	14.9 ± 6.6	40	-	-	22.4 ± 6.7	857	10.4 ± 10.1	146
	1981-84	Solana	Cagayan	0	86	0	21	6.9 ± 4.0	163	7.8 ± 0.4	118
	Mean				7.4		0		10.8		10.7
	Total				302		42		1400		414
Rainfed	1977-84	Tanauan	Batangas	7.9 ± 3.7	38	42.8 ± 14.6	42	7.5 ± 2.5	1789	8.1 ± 5.3	877
Dryland	1987-88	Claveria	Misamis Oriental	0	41	-	-	11.6 ± 0.4	156	28.0 ± 5.3	48
	1984-85	Siniloan	Laguna	21.6 ± 11.5	51	15.9 ± 12.1	36	19.2 ± 7.9	47	7.9 ± 5.9	32
	Mean				9.8		29.4		12.8		14.7
	Total				130		78		1992		957
	Grand Mean				12.2		14.5		11.0		12.6
	Grand Total				1276		882		5753		3448

in all years, shows a high degree of year to year variability: 1980 (9%, n = 80), 1981 (5%, n = 53), 1983 (14%, n = 90), 1985 (22%, n = 184), and 1986 (60%, n = 67). It is instructive to note that a similar trend also occurred with *P. mathias* over the same years for similar months: 1980 (4%, n = 72), 1981 (19%, n = 122), 1983 (21%, n = 142), 1985 (24%, n = 85), and 1986 (93%, n = 39).

More consistent parasitization trends between butterfly species were evident from the larvae and pupae averaging 11.0 and 12.6% on *M. leda ismene* and *P. mathias,* respectively (Table 4). Averages were highly consistent between environments for each species and between species in each environment. The highest larval-pupal parasitization was 28.0% for *P. mathias* in Claveria and 22.4% for *M. leda ismene* in Manaoag. Lowest was 2.5% for both species in Bani, Pangasinan.

Monthly *P. mathias* egg and larval parasitization rates

P. mathias egg parasitization averaged 36.3% over the exposure period from *T. hesperidis* and *Trichogramma* sp. (Fig. 1). Parasitization peaked at 80.0% in January 1989 after harvest of the normal wet season (July-November) crop. The dry season (January-April) peak reached 39.1% on the April exposure date, near harvest of the dry season crop.

The larval parasitization levels followed the same pattern as with egg parasitoids with a single peak in January at the end of the wet season (74.3%). Incidence declined through the dry season, where no peak activity period was apparent for that crop. Larval parasitization averaged 27.3% for the 11 monthly exposure periods. The most common larval parasitoids were *H. luteicornis, M.* sp. nr. *scalaris,* and *T. apanteloctena.*

M. leda predation rates under controlled conditions

Six predators, each representing a different guild, were evaluated in the greenhouse with *M. leda ismene* eggs and larvae as prey. Larval predation by the six predators tested was confined to L I-III as no predator accepted the large L IV-V, nor the pupal stage. *C. longipennis* showed the greatest egg consumption rate averaging 50 eggs/day (Table 5). Each *C. longipennis* adult tested consumed all 150 *M. leda ismene* eggs offered over the 3-day period indicating a potentially higher egg consumption rate than was recorded (Fig. 2). The predatory capacity of *A. femina femina* averaged 10.4 eggs/day, similar to that of *O. ishii ishii* adults 7.7 eggs/day, but both significantly less than that of *C. longipennis.* Fewer eggs were consumed by *A. femina femina* on the third day compared to that of the first two days. Egg consumption of *O. ishii ishii* declined from over 10 eggs on the first day to less than 5 eggs by the third day.

Predation levels of *M. hirashimai* and *M. vittaticollis* were uniformly low ranging from 4.2 and 4.0 eggs per day, respectively, but at a level statistically similar to that of *O. ishii ishii. P. pseudoannulata* failed to prey on eggs.

C. longipennis also showed the highest predation rate for *M. leda ismene.* It consumed an average of 9.4 L I, 6.2 L II, or 1.7 L III over the 3-day period (Table 5). Consumption rates were from 10-11 L I and 8-9 L II per day on the first two days but declined to 6-7 L I or 2-3 L II per day by the third day (Fig. 2). The consumption of L III progressively declined from 4 to 1 per day from the first to third days.

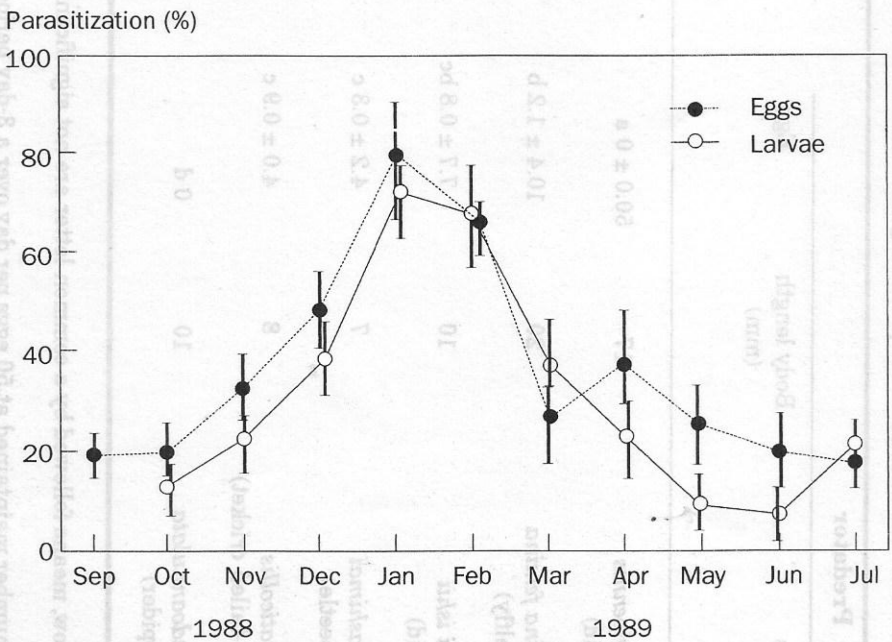

Figure 1. Parasitoid activity on *P. mathias* eggs and larvae exposed in the field. IRRI Farm, 1988-89.

Table 5. Predation rates of six predator guilds on *M. leda ismene* egg and larval stages. IRRI headhouse.

Predator		Predation per arthropod (no./day)			
Species	Body length (mm)	Egg[b]	Larval stage[c] LI	LII	LIII
C. longipennis (katydid)	17	50.0 ± 0 a	9.4 ± 0.8 a	6.2 ± 0.9 a	1.7 ± 0.4 a
A. femina femina (damselfly)	20	10.4 ± 1.2 b	3.3 ± 0.4 b	0.8 ± 0.3 b	0.1 ± 0.1 b
O. ishii ishii (carabid)	10	7.7 ± 0.8 bc	1.6 ± 0.3 c	0.4 ± 0.1 bc	0 b
M. hirashimai (lady beetle)	7	4.2 ± 0.3 c	1.5 ± 0.2 c	0.2 ± 0.1 c	0 b
M. vittaticollis (sword-tailed cricket)	8	4.0 ± 0.9 c	0.1 ± 0.1 d	0 c	0 b
P. pseudoannulata (wolf spider)	10	0 d	1.3 ± 0.3 c	0.9 ± 0.4 b	0.7 ± 0.2 ab

[a]In a row, means followed by a common letter are not significantly different ($P > 0.05$) by LSD.

[b]Prey number maintained at 50 eggs per day over a 3-day period.

[c]Prey number maintained at 15 larvae per day over a 3-day period (L1-111 = first-third larval instar).

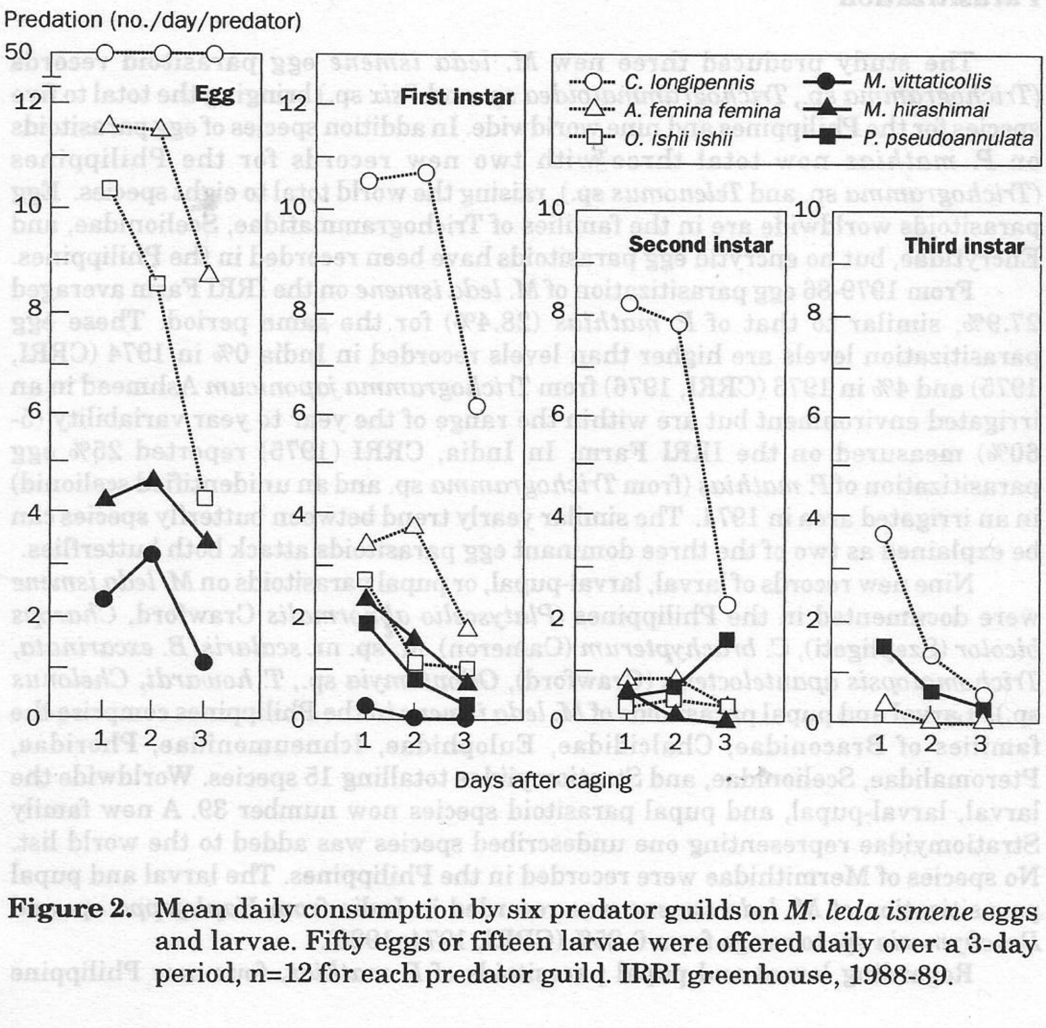

Figure 2. Mean daily consumption by six predator guilds on *M. leda ismene* eggs and larvae. Fifty eggs or fifteen larvae were offered daily over a 3-day period, n=12 for each predator guild. IRRI greenhouse, 1988-89.

A. femina femina averaged 3.3 L I per day which was significantly less than the consumption rate of *C. longipennis* but greater than those of the other predators tested. The rate declined from 3-4 per day for the first two days to 1-2 larvae per day by the third day. Consumption rates on L II averaged 0.8 per day and declined to 0.1 L III per day. *A. femina femina* adults only fed on the first day on L III indicating one larva satiated an adult over at least a 3-day period. The adults managed to kill a few L III but clearly they were outsized.

O. ishii ishii, P. pseudoannulata, and *M. hirashimai* had similar L I consumption patterns averaging 1.6, 1.3, and 1.5 larvae per day, respectively. Rates progressively declined from the first to the third larval instar prey for the three predators. Consumption of L II and L III by *P. pseudoannulata* was similar at 0.9 and 0.7 per day, respectively. *O. ishii ishii* and *M. hirashimai* could not consume larvae older than L II. *M. vittaticollis* had the lowest larval consumption rate and preyed on only 0.1 L I per day but not on older instars.

DISCUSSION

Parasitization

The study produced three new *M. leda ismene* egg parasitoid records (*Trichogramma* sp., *Trichogrammatoidea* sp. and *Psix* sp.) bringing the total to five species for the Philippines and nine worldwide. In addition species of egg parasitoids on *P. mathias* now total three with two new records for the Philippines (*Trichogramma* sp. and *Telenomus* sp.), raising the world total to eight species. Egg parasitoids worldwide are in the families of Trichogrammatidae, Scelionidae, and Encrytidae, but no encrytid egg parasitoids have been recorded in the Philippines.

From 1979-86 egg parasitization of *M. leda ismene* on the IRRI Farm averaged 27.9%, similar to that of *P. mathias* (28.4%) for the same period. These egg parasitization levels are higher than levels recorded in India 0% in 1974 (CRRI, 1975) and 4% in 1976 (CRRI, 1976) from *Trichogramma japonicum* Ashmead in an irrigated environment but are within the range of the year to year variability (5-60%) measured on the IRRI Farm. In India, CRRI (1975) reported 25% egg parasitization of *P. mathias* (from *Trichogramma* sp. and an unidentified scelionid) in an irrigated area in 1974. The similar yearly trend between butterfly species can be explained as two of the three dominant egg parasitoids attack both butterflies.

Nine new records of larval, larval-pupal, or pupal parasitoids on *M. leda ismene* were documented in the Philippines (*Platyscelio abnormalis* Crawford, *Charops bicolor* (Szepligeti), *C. brachypterum* (Cameron), *M.* sp. nr. *scalaris, B. excarinata, Trichomalopsis apanteloctena* (Crawford), *Odontomyia* sp., *T. howardi, Chelonus* sp.). Larval and pupal parasitoids of *M. leda ismene* in the Philippines comprise the families of Braconidae, Chalcididae, Eulophidae, Ichneumonidae, Phoridae, Pteromalidae, Scelionidae, and Stratiomyiidae totalling 15 species. Worldwide the larval, larval-pupal, and pupal parasitoid species now number 39. A new family Stratiomyidae representing one undescribed species was added to the world list. No species of Mermithidae were recorded in the Philippines. The larval and pupal parasitization of *M. leda ismene* was recorded in India from *Haplojoppa* sp. and *Brachymeria* sp. to range from 0-25% (CRRI, 1974; 1980).

Regarding larval and pupal parasitoids of *P. mathias,* four new Philippine records occurred *(Euplectrus* sp., *Eurytoma braconidis* Wilkinson, *C. brachypterum,* and *M.* sp. nr. *scalaris).* The world total is now 75 species. Philippine records do not include species in Elasmidae and Pteromalidae. As a family, Phoridae has been added to the world list.

P. mathias larval and pupal parasitoids as reported from India were highly varied and parasitization ranged from 3-13% by *Apanteles baoris* (Murthy, 1957), 13-52% by *Brachymeria albotibialis* (Ashmead) (CRRI, 1976; 1980), and 76% by *Clinocentrus indicum* (Gupta), *Apanteles* sp., and *C. bicolor* (Chhabra and Singh, 1978).

Egg and larval parasitization rates measured monthly by the prey enrichment method were very similar between stages indicating a response of the parasitoids to similar factors. In fact the reason for the peaks of both egg and larval parasitoids may have been that our continuous plantings resulted in a concentration of parasitoids out of season as the surrounding rice area was mostly harvested by that time.

The greater site to site variability of egg compared to larval and pupal parasitization levels may be due to the fewer species of egg parasitoids. Looking at the yearly egg parasitization percentages on the IRRI Farm over five years from 1980-86 suggests parasitization rates are similar between butterfly species but without relation to host abundance. The high variability of parasitoid activity between years and seasons and the consistency of results between egg and larval/ pupal stages suggests that consistent low butterfly populations are determined by other population regulatory factors than parasitoids.

Predation

P. mathias and *M. leda ismene* are prey to 83 recorded predators in the Philippines (63 insects, 17 spiders, and 3 vertebrates). Prior to the present study only six predators had been recorded worldwide. This total contrasts with only 30 parasitoid species recorded in the Philippines for both butterfly species. The percentage of predators attacking both butterfly species (59%) should increase over time with more observations, as most predators are able to prey on both species.

No field evaluation of the effect of predators was attempted in this study and high numbers of predator species do not necessarily mean that predation rates are high. In the controlled experiments, however, all six predators tested showed high rates of predation. Body size seemed to be important in predation potential. Larger predators demonstrated greater predatory capacity against butterfly eggs and L I-III. Butterfly stages larger than the L III were more difficult prey items.

Greatest potential was exhibited by the katydid *C. longipennis.* Its large size (17 mm body length) and high predation rates in a no-choice test make it a good biocontrol candidate for rice butterfly eggs and young larvae. The damselfly *A. femina femina* (20 mm length) was a surprisingly good predator of both eggs and larvae. This is the first known record of its egg predatory capacity in rice ecosystems. This is also the first known record of *M. vittaticollis* and *M. hirashimai* as predators of Lepidoptera larvae. With the exception of the wolf spider the best egg predators were also the best larval predators. The wolf spider, *P. pseudoannulata* fed only on mobile prey and did not consume butterfly eggs. The cricket *M. vittaticollis* was a better egg than larval predator. The carabid *O. ishii ishii* and the ladybeetle *M.*

hirashimai were good egg and larval predators.

The fact that *P. mathias* constructs a tube out of foliage to shelter the larvae and pupae does not seem to offer much protection from natural enemies over *M. leda ismene* that has none. In fact several natural enemies (earwig, salticid spider and staphylinid) appear to have been attracted to the shelter.

Overall impact

Biological factors of both butterfly species auger against their potential for rapid population buildup. Average fecundity levels of *M. leda ismene* and *P. mathias* (50-60 eggs/female) (Litsinger *et al.*, 1994; 1995) are three to six times less than the more common ricefield pests which frequently reach outbreak proportions (Pathak, 1968). In addition *M. leda ismene* and *P. mathias* are more polyphagous than more prominent ricefield insect pests, diluting their populations on rice. The impact of natural enemies against *M. leda ismene* and *P. mathias* needs to be reassessed based on the results of the present study. There is no evidence that pathogens play a major role in regulation of butterfly populations. The impact of parasitoids is mixed based on records from the literature and from our Philippine studies. At times very high levels of parasitization are reached but at other times levels are very low. Even adjusting for the compounding effect of average parasitization rates of 10-20% for each of the major life stages (egg, larvae, and pupae) fails to reach significant mortality levels that explain observed low populations.

This study does point out for the first time the potential role of predators in population regulation of the two rice butterfly species. Our field observations from over a decade indicate that over 80 species of predators in the Philippine rice agroecosystems contribute to *M. leda ismene* and *P. mathias* mortality. Each of the six predators guilds that was selected for controlled studies showed great promise. Future work should quantify the role of predators in the population dynamics of both butterflies in the field.

M. leda ismene and *P. mathias* are not early colonizers of rice fields (Litsinger *et al.*, 1994; 1995). Their late arrival, however, is timed with the buildup of ever increasing predator numbers (van den Berg *et al.*, 1988, 1992). The cumulative effect of both parasitoid and predator loads may play a significant role in causing the low field populations normally observed for *P. mathias* and *M. leda ismene*.

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