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Characteristics of *Serratia marcescens* isolated from dead workers of the termite, *Reticulitermes speratus* (Kolbe). Hideo Shinozaki\(^{1,8}\), Takashi Aburano\(^1\), Yoshitaka Sano\(^2\) and Tsuguo Matsumoto\(^1\)

**Abstract**

Dead workers of the termite species, *Reticulitermes speratus*, were frequently found on agar plates, using a simplified termite rearing method. They appeared red in color, and were softened. As these symptoms could be due to bacterial infection, we examined the gut contents of the termites, using bacteriological methods. A high incidence of the bacterium, *Serratia marcescens*, was detected in the intestinal cultures. *S. marcescens* was characterized as serovar O6 and biovar A2/6. However, a high dose of *S. marcescens* was apparently necessary for experimental infection of termites, and this bacterium was the predominant species found in the intestines of healthy workers. We therefore inferred that opportunistic infection by *S. marcescens* resulted in compromise of its host on agar.

**Key words**: *Reticulitermes speratus*, Simplified rearing method, *Serratia marcescens*, Biovar, Serovar

はじめに

している。先に寒天平板法を利用してシロアリの飼育法を改良することにより、長期間にわたりシロアリの飼育が可能となった（篠崎ら、2008）が、その飼育過程で体躯は原形をとどめながらも、赤く呈色しやがて乾燥死亡する個体の出現にしばしば遭遇した。この病徴は感染症によるものと容易に想定されたが、この発症に関する経緯や病原微生物に関する詳細な知見は見あたらない。今回観察した発症個体は急激に致死し、内部組織は可溶化して軟化・崩壊し、悪臭を伴うものであった。これらの所見から細菌感染症が疑われたため細菌学的な検討を行ったところ、ほぼ純粋培養の形で Serratia marcescens が分離されたので、その概要をここに報告する。

材料と方法

1. 供試個体

ヤマトシロアリ、Reticulitermes speratus を、篠崎らが改良した寒天平板法（2008）で飼育中に、現出した赤色に呈色した発症個体を用いた。

2. 細菌学的検討

死亡個体の腸管内容物を滅菌ビンセットで摘出し、液体培地（ハートインヒュージョン培地（ニッスイ）、以下 HIB と略す）で一夜飼育後、ハートインヒュージョン寒天培地（ニッスイ、以下 HIA と略す）および数種の選択培地（栄養）を併用して、細菌の分離を行った。得られた分離株は、グラム染色による形態学的所見のほか、以下に示す方法により生化学的性状を調べ、これらの結果に基づき Bergey's manual (9th ed. 1994) に準拠して同定した。まず分離菌の科・属を推定するための第 1 鉱別として① HIB による発育性状、② 3 % H2O2 を用いたカタラーゼ産生試験、③ペーパー（ニッスイ）によるオキシダーゼ産生試験、④ HIA 半流動寒天培地による運動性試験、⑤ 1 % ブトウ糖添加の OF 基礎培地（栄研）による酸化・発酵型発酵試験を実施した。さらに、種を推定するために、次の第 2 鉱別試験を行った。⑥ Triple Sugar Iron 塩基（以下 TSI と略す、ニッスイ）による発育性状、⑦ Sulfide Indole Motility 塩基（以下 SIM と略す、ダイゴ）による発育性状、⑧ DNase 塩基（栄研）による DNase 産生試験、⑨ブドウ糖リン酸ペプトン培地（栄研）による Voges-Proskauer 試験（以下 VP と略す）、⑩酵分解用半流動培地（栄研）による 1 % 添加グルコースおよびラクトースによる糖分解試験。

⑪クリストセン法によるウレアーゼ試験（栄研）、⑫ゼラチン液化試験（Difco）、⑬胆汁エスクリン培地（Difco）を利用したエスクリン加水分解試験等を実施した。

3. 血清型及び生物型の決定

分離株による感染像を追求するために、分離菌の血清型別および生物型別を行った。血清型別は市販の O 型別

Fig. 1 Dead termite workers, which had been reared on 2% agar plates

T: dead termite workers   P: paper
4. 感染実験
分離株のなかから 1 株を選別し、それを用いて感染実験を行った。まず供試菌を HIB で 24 時間培養し、3,000 rpm で 15 分の過心洗浄を繰り返した後、滅菌水にて細菌浮遊液を調製した。この菌液を波長 660 nm の吸光度にて菌量を調整し、供試個体に嘔吐する方法で感染させた。感染実験に供試した健全個体は、学内キャンパス（京都市左京区長ケ崎）より採取して研究室で栄養に調で約 2 ヵ月間観察中のコロニーから選別後、寒天平板法（篠崎ら、2008）で飼育中の 22 個体を用いた。感染は飼育個体の出現の可否で検討した。

5. 感染の拡大・伝播
分離菌の感染力を調べるために、寒天平板法（篠崎ら、2008）で飼育中の 22 個体のなかから、感染実験に用いられた菌株を十分に感染させたと想定される 1 個体を放倒し、共存後の感染の拡大と伝播およびその行動などを検討した。本観察は 1 ヶ月間継続した。

6. 健全個体の細菌学的検討
寒天平板法（篠崎ら、2008）で飼育中の試験区から健全な 6 個体を、またロール状状軸で簡易的な飼育を継続中の試験区（篠崎ら、2008）から健全な 1 個体を選別し、先の飼育個体にて用いた細菌の分離および同定法に照査の方法で細菌の検索を行った。

結 果

1. 食死個体
2％寒天平板でシロアリを飼育中に現出した典型的な食死個体を、Fig. 1 に示した。本図から明らかのように、食死個体はすべて赤色を呈し、体側は原形をとどめていた。内側の内側を軽度し、腸管内容物を溢出時に溶解状態となり、もはやその原形をとどめていなかった。この病態の変化は時間の経過に伴い顕著に現れた。この食死個体を顕微鏡下で剖検すると、健全なシロアリの腸内で認められる特有の原生動物 Trichonympha agilis, Teratonymphe mirabilis などはほとんど観察されなかった（篠崎ら、未発表）。

2. 細菌の分離・同定
飼育個体より軽度した組織や腸管内容物を摘出し、ホモジナイタ後 Fig. 2 に示した手順に従って細菌の分離を行った。HIB で一夜増菌培養後、細菌の分離に用いた培地においても、ほぼ純粋培養に近い状態で单一な細菌が分離された。コロニーより飼育した多数の菌株から、顕微鏡観察による形態的所見とコロニーの性状から 6 株に整理し、さらにグラム染色による形態的な性状検査に基づき選択した 3 株を、分離菌株 KIT-SH517, KIT-SH518, KIT-SH520 とした。

まず分離菌の科・属を推測する第 1 次鑑別の成績を、Table 1 にまとめた。本表の成績から分離株は全てグラム陰性桿菌、カルテーヌ性、鮮黄色酵素、ブドウ糖発酵型を有するなどの性状を示し、腸内細菌科に属する細菌種であることが判明した。次に菌を推測するために行った第 2 次鑑別試験の成績を、Table 1 に第二次推別性状として追加した。分離菌の第 1 次及び第 2 次鑑別試験の表現型性状を、Bergey's manual (9th ed. 1994) に準拠して同定したところ、全て色素産生型の Serratia marcescens と判明した。
3. 血清型および生物型

観察個体の感染経路を調べるために、血清型別および
生物型別を行い、その結果を Table 2 に示した。本表に
示すように分離菌は全て O 6 型抗体にのみ凝集し、また
色素産生に馬尿酸非利用型であったことから、Bergey's
manual (1984) に従って検査したところ、分
離菌の生物型は A 2 / 6 と判断した。

4. 感染実験

分離菌株の中から、継代培養時に赤色色素
(prodigiosin) の発現が極めて安定的な KIT-SH517 を
選択し、感染実験用の供試菌とした。供試菌を OD660 =
24 に調整し、2%寒天平板に放倒して培養した健全な 23
個体に喷霧し、感染の成否を検査した。その結果を
Fig. 3 に示し。菌株散布の当日より供試個体の挙
動が不活発となり、48 時間後には最初の観察個体が出
現した。その後は、およそ 1 日に観察個体が出現し、
菌株剖面後 27 日目にはその半数が観察死した。そして 41
日後には供試個体の全てが観察死し、これら観察死個
体は、Fig. 1 に示したものと同様に赤色に呈色した観察
個体で、解剖学的所見でも組織の軟化や腐敗臭を放つもの
であった。またこれらの死亡個体から Fig. 2 に従っ
て細菌の分離を行ったところ、得た分離株はすべて血清
型 O 6 、生物型 A 2 / 6 の S. marcescens であることが確
認された。

5. 感染の拡大・伝播の検討

KIT-SH517 を OD600 = 2.2 に調整した菌を十分に感
染したと考えられる 1 個体を、健全な 21 個体のなかに
放倒して、罹病個体の出現とその感染の拡大の可否につい
て検討した。その結果を Table 3 にまとめた。本表か
ら明らかのように、原液（10^6 ; OD600 = 2.2）感染を受け

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Biochemical reaction of isolates from dead termite workers</th>
</tr>
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<tr>
<td>tests of substrates</td>
<td>KIT-SH517</td>
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<td>1st differentiation</td>
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<tr>
<td>Gram stain</td>
<td>-</td>
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<tr>
<td>Shape</td>
<td>r^{1}</td>
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<tr>
<td>Catalase</td>
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<tr>
<td>Oxidase</td>
<td>-</td>
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<tr>
<td>Oxidation-fermentation</td>
<td>F^{0}</td>
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<td>Motility</td>
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2nd differentiation

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<th>R/Y^{3}</th>
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<td>gas</td>
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<td>Voges-Proskauer</td>
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<td>+</td>
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</tr>
<tr>
<td>Acid production</td>
<td>Glucose</td>
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<td>Lactose</td>
<td>-</td>
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</tr>
<tr>
<td>Esculin hydrolysis</td>
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<td>Urea hydrolysis</td>
<td>-</td>
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<tr>
<td>Gelatin hydrolysis</td>
<td>NT^{4}</td>
<td>NT</td>
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</tr>
<tr>
<td>Deoxyribonuclease</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

- : negative  + : positive
1）r : rod  2）F : Fermentation  3）R/Y (slant/butt) : Red／Yellow
4）NT : not tested

<table>
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<th>Table 2</th>
<th>Typing of Isolates from dead termite workers</th>
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<td>Serovor (O6)</td>
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<tr>
<td>Biovar</td>
<td>A2 / 6</td>
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<tr>
<td>hippurate hydrolysis</td>
<td>-</td>
</tr>
<tr>
<td>pigmentation</td>
<td>red</td>
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</tbody>
</table>

+ : agglutination to O6 antibody only  - : negative

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た個体が放倒された試験区では、共存2週間を通じた
61.9%の生存率が得られた。また供試捕獲区でもそれ
ぞれ61.9～90.5%の生存率を示し、急激に感染の拡大は
認められなかった。しかし、共存3週間後には、いずれ
の試験区でも徐々に生存率の低下が認められ、感染の拡
大する様子が観えた。しかし、決して供試個体が全て感
染死する完全致死には至らなかった。蒸留水を噴霧した
個体を放倒された対照区では、熟死個体や赤変症候のあ

Fig. 3 Experimental infection with S. marcescens in termite workers

strain used: KIT-SH517
No. tested termite workers: 23
administered dose of bacteria: OD600n=2.4
rearing temperature: 25℃（dark place）

Table 3 Spreading of Serratia infection in termite workers

<table>
<thead>
<tr>
<th>post-infection (day)</th>
<th>10^9*1</th>
<th>10^-1</th>
<th>10^-2</th>
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strain used: KIT-SH517
*10^9: bacterial dose of OD600=2.2
No. of workers used: 21 healthy termite workers in each experiment
6. 健全個体からの分離菌の性状

赤色微死個体から分離された S. marcescens の来歴を調べるために、寒天平板法で飼育中の健全 6 個体とコル状口紙で簡易飼育中の健全 1 個体から、S. marcescens の分離を Fig. 2 に準じて実施し、その分離菌株の性状を Table 4 にまとめた。寒天平板法で飼育している 6 個体からは 29 株を分離し、1 次・2 次鑑別培養液の発酵性や生化学的性状の差違から赤色色素の産生株 10 株（KIT-SH501〜KIT-SH504, KIT-SH509〜KIT-SH511, KIT-SH513, KIT-SH514, KIT-SH516）および色素非産生株の 1 株（KIT-SH521）の計 11 株を分離菌とした。またコル状口紙で簡易飼育中の 1 個体からは、色素非産生株 1 株（KIT-SH707）が分離された。これら分離菌株は Table 4 に示した性状から、すべて S. marcescens と同定され、血清型別はすべて 06 型、また生物型別は色素産生株のみ A 2/6 と判明した。

考 察

グラム陰性桿菌で腸内細菌科に属する Serratia 属は、塩化物や土中、汚水などあらゆる環境に広く分布する細菌種（Grimont and Grimont, 1978b）で、Bergeray's manual（9th ed. 1994）には、S. marcescens 以下 10 種の細菌種が記載されている。Steinhauser (1959) は、Zoothermosis angusticollis、をはじめ等翅目（Isoptera）、鱗翅目（Lepidoptera）、双翅目（Diptera）、鞘翅目（Coleoptera）など、約 50 種の昆虫に S. marcescens が関与することを指摘している。なかでもバッタの 1 種、Melanoplus bilinatus (Bucher, 1959) や、マイヤイガ、Lymantria dispar (Podgwaite and Cosenza, 1976) など野生昆虫には起病性があるとされる一方、古くからカイコ、Bombyx mori にも起病性を有する細菌とされ、たびたび逆作を誘起した事例がある (Steinhauser, 1959；有賀, 1973)。これら昆虫に起病性を有する細菌を、Bucher (1963) は宿主昆虫への依存度と侵襲性の差違から、偏性病原細菌、通性病原細菌、潜勢病原細菌に三段階に分けている。そのなかで S. marcescens は、人工培養が容易で、昆虫の体内での増殖も可能であり、組織崩壊や血体腔に侵入するための多種多様な毒素を産生することから、通性昆虫病原細菌と位置づけている。宿主昆虫が脱皮期など腸管防壁の弱まったとき血体腔に侵襲し、活発に増殖することにより敗血症を惹起し宿主昆虫を致死させる。その結果、本菌が産生する赤色色素により死亡個体が赤化するとの感染機序がある (福原, 1991)。しかし本菌には chitinase や多様な protease など、多くのビルレンスの存在が考えられており (Lysenko,
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- : negative,  + : positive
1) r : rod   2) F : Fermentation  3) R/Y (slant/butt) : Red/Yellow  4) NT : not tested
1976年，発病機序に関する詳細な記載は今日まであまり十分とは言えない。また本菌は、イエシロアリ、\textit{Coptotermes formosanus}、\textit{Mastotermes darwinianus}、\textit{Reticitermes hesperus} など多くのシロアリが保有していることが報告されており（Thayer, 1976; Kuhnigk et al., 1994; Varma et al., 1994）、シロアリの腸内細菌叢の構成員として生理的意義を有していると推測される一方、De Bach and McOmie (1939) が、\textit{S. marcescens} による \textit{Zootermopsis angusticollis} の感染例を報告しているが、詳細な感染様式の内容については知りえない。

今回の実験で、50%致死率を得るには 27 日程度を要し、全個体が飼育する完全致死に達するには感染後 41 日以上必要であった。さらに感染の拡大は、極めて緩慢な様相を呈することが判明した。高濃度の菌種接種で 100%の致死期間を得るのに、Khan えら（1977）は、\textit{Mastotermes championi} で 7 日、\textit{Bifiditermes beecroisi} で 12 日、\textit{Heterotermes indicola} で 13 日を要し、また Osbrink えら（2001b）や Connick えら（2001）はイエシロアリ、\textit{Coptotermes formosanus} の感染実験で 19 日を要したことを報告しているが、本実験で得た知見はこれらの結果と同様であった。一方健全な個体から \textit{S. marcescens} が分離された。Thayer (1976) は、シロアリの腸管倉を構成する細菌の一つとして \textit{S. marcescens} を報告している。これらの事実から本菌が血液腔へ侵入し敗血症をなすために、宿主の生理状態には依存することが極めて大きな要因と判断された。今回ヤマトシロアリの葉乾平板法による簡易飼育中に発見した感染症は、栃木県内ののみによる栄養条件の劣化に伴った宿主側の日間的な感染ではないかと推測される。ヒトの臨床所見においても \textit{S. marcescens} は、宿主の免疫機能の劣化に伴って肺感染症、尿路感染症、敗血症などの菌交代現象による日間感染や、院内感染の拡大に関与する代表的な起因菌の一つとされている（林, 2001; 数形, 2002）。

その臨床的立場から、\textit{S. marcescens} 感染には疫学的調査（Nasu えら, 1982）や疫学的調査が多用されており、ときに血液型別や bacteriocin 型別、生物型別などの常速用されている。それに臨床由来の \textit{S. marcescens} は \text{O}^1, \text{O}^3, \text{O}^4, \text{O}^8, \text{O}^{12}, \text{O}^{13} などの多様な特異型をもつ（Gaston と Pitt, 1989; Yanagawa えら, 2007）が、昆虫の \textit{S. marcescens} 感染では大流行病の発生が少ないことから、生物型別や血清型別など疫学上重要な情報は乏しく、Grimm と Grimon (1978a) が昆虫由来の \textit{S. marcescens} の生物型別を実施し、A 2 型を得ているにすぎない。Khan えら（1977）や Osbrink えら（2001b）も、\textit{S. marcescens} を分離しているが、それらの型別までは至っていない。今回の実験で分離した色素産生株は、すべて血清型別 B6 型のみに集積し、生物型別は A 2 /6 型であった。臨床由来の \textit{S. marcescens} が多様な血清型を示すのに対し、昆虫由来株では単一の型別しか示さない結果となったが、この結果は、今後さまざまな昆虫から \textit{S. marcescens} の分離を行い、型別を実施することにより昆虫起病性的 \textit{S. marcescens} の分布とその病原性をもとに昆虫特異型とする生態型別 (ecovar) を提案したいと考えている。

今回の感染実験で、健全な個体が飼育した個体を含める行動が認められた。人為的に飼育個体に分離した色素を取り除いても、再度分離を繰り返した。この行動はコロニー内での集団感染を抑制する効果があるとも思わわれるが、本知見は、シロアリの微生物的防除を今後考慮するための基礎的知見の一つと判断している。

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Population dynamics of an invasive grub moth *Parasa lepida* (Cramer) that damages ornamental trees: the seasonal and annual fluctuations of the cocoon density

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Abstract

We analyzed population dynamics of an invasive grub moth *Parasa lepida* (Cramer) (Lepidoptera : Limacodidae) in terms of the cocoon and adult density on various host plants consisting of 51 tree species of 404 individual trees at the campus of the University of Shiga Prefecture, Hikone, Shiga, western Japan during 5 years from 2003 to 2007. The cocoons occurred twice a year, the first generation in middle July - middle August and the second generation in middle September - late October. After hibernating as the pre-pupae within the cocoons, the adults of the second generation emerged during early June to early July in the following year. The mortality of cocoons was consistently higher in the second generation than in the first generation, resulting in the very low density of adults in the second generation. In the first generation, however, the survival rate of the cocoons decreased year by year from 91.0 % in 2003 to 45.1 % in 2007. The population growth rate from the second generation adults to the first generation cocoons (R_1) was higher when the adult density was higher, indicating the presence of the inversely density dependent processes in R_1. As the consequence the cocoon density fluctuated violently year by year in the first generation. In contrast, the population growth rate between the first generation adults and the second generation cocoons (R_2) functioned both density dependently and complementary with the adult density, resulting in the exclusively stable cocoon density in the second generation. We discussed ecological mechanisms in particular agents of larval mortality that were assumed to be responsible to the inversely density dependent processes and the density dependent processes in R_1 and R_2, respectively.

Key words: *Parasa lepida* (Cramer), Population dynamics, Annual population fluctuation, Density dependence, Inversely density dependence

Introduction

*Parasa lepida* (Cramer) (Lepidoptera : Limacodidae) is an invasive moth, widely distributed in tropical-subtropical regions such as southern China, south-east Asia, India, and sub-Saharan Africa (Hirashima, 1989; Zhang, 1994). In Japan *P. lepida* was first recorded in Kagoshima in 1921, thereafter expanding the distribution range north-eastward in Kyushu and Honshu, and in 1980s frequent outbreaks occurred by defoliating persimmons and cherry trees (Oda and Hattori, 1981). Recently, the range expansion reaches up to Kanto district (Nakano, 2003). *P. lepida* is regarded as a serious pest of street trees and garden trees, and also as a noxious pest that gives pain in human skin.

To establish an effective management system of a given pest it is necessary to understand ecological mechanisms that cause the population changes through quantification of mortality factors such as natural enemies as well as knowledge of the life history (Price and Waldbauer, 1982; Levins, 1986; Nakasuji, 1997). Yamazaki *et al.* (1994b) examined the cocoon density of *P. lepida* at 65 sites within Osaka,

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Kyoto and Shiga Prefectures, and speculated that the natural enemy was the major factor that determined the distribution and abundance, on the ground that *P. lepida* occurred exclusively in urban areas with few enemies, but it was absent in its surrounding areas with abundant enemies. On the basis of detailed analyses of the cocoon mortality at the campus of the University of Shiga Prefecture in the suburbs of Hikone, Nishida *et al.* (2006) documented a very high mortality due to bird predation on the cocoon during winter. At the same site Sawada *et al.* (2008a) conducted detailed population censuses that covered all the developmental stages and documented following results: (1) *Trichogramma dendrolimi* Matsumura, a parasitoid wasp was the major agent of the egg mortality, (2) the larval mortality in the first generation was caused by generalist predators such as paper wasps, spiders, ladybird beetles and mantis, but the mortality rate was fairly low, (3) the larval mortality in the second generation was very high primarily due to a putative nuclear polyhedrosis virus (NPV) and a fungal disease, and (4) the occurrence of the putative NPV was strongly density dependent, with frequent occurrence in the year of the high larval density and in the hosts of the great larval density.

In the present article we analyzed the seasonal and annual fluctuations of *P. lepida* population based on the density of the cocoon and the adult, and the respective mortality factors and survival rate of each generation on 404 host trees of 51 species over 5 years during 2003 and 2007. And also we interpreted the observed seasonal and annual trends of *P. lepida* population in relation to the egg and larval mortality documented in our previous studies (Sawada *et al.* 2008a, b).

**Materials and Methods**

**Parasa lepida** (Cramer)

*P. lepida* is a notorious pest of street trees and ornament trees particularly in urban areas. The larvae, forming a compact aggregation in the early stage, feed on tree leaves. This species is also regarded as a noxious pest because contact with its larval spines can cause dermatitis in humans (Oda and Hattori, 1981; Miyata, 1981).

*P. lepida* occurs twice a year in western Japan with the first generation adults in early to late June and the second generation adults in early August to middle September, and hibernates as the cocoon stage (Oda and Hattori, 1981). This species is a typical polyphagous herbivore feeding on a wide range of trees. For instance, Yamazaki *et al.* (1994a) found the cocoon on all the 62 tree species of 31 families examined except for conifers, the tulip tree *Liriodendron tulipifera*, the southern magnolia *Magnolia grandiflora*, and the oleander *Nerium indicum* in Osaka, Kyoto and Shiga Prefectures. In the original distribution range such as India and south-east Asia, the host range consisted of 78 host plant species of 35 families including legumes (Fabaceae), palms (Arecaceae), and Euphorbias (Euphorbiaceae) (Robinson *et al.*, 2001). Additionally, in India and south-east Asia *P. lepida* is known as a pest of mango, coconut, coffee, cacao and so on (Kalshevan, 1981; Kapoor *et al.*, 1985; Jeyabalan and Murugan, 1996).

**Study site and census trees**

The population censuses were conducted at the campus of the University of Shiga Prefecture (USP) (36°11'N, 136°15'E) locating in the suburbs of Hikone City, Shiga Prefecture. USP was founded in 1995 when approximately 70 species of trees were planted at 30 ha of the campus. The campus was similar to a large city garden, in which a large number of *P. lepida* cocoon were observed. We chose 282 individual trees of 36 deciduous species and 122 individual trees of 15 evergreen species as the census trees among a total of approximately 70 tree species. The majority of deciduous species were Chinese tallow tree *Triadica sebifera*, Yoshino cherry *Prunus X yedoensis* and Japanese zelkova *Zelkova serrata*, and that of evergreen species were oaks *Quercus myrsinefolia* and *Q. glauca*, and camphor laurel *Cinnamomum camphora*. On each census tree we recorded the number of cocoon formed, the mortality factors of the cocoons, and the number of the cocoons from which the adults emerged. To standardize the number of tree species examined we chose 10 individual trees for each tree species unless the tree density was less than 10.

**Census of the cocoon density**

The cocoon density was examined every week during which the larvae formed the cocoon, middle July–late August for the first generation and middle September–early November for the second generation, over 10 generations of 5 years, from the first generation of 2003 to the second generation of 2007. To avoid double counting, the cocoons were
marked with water resistant paint. The cocoon density per tree of a given generation (C1 and C2) was thus defined as the total number of the cocoons marked at the generation divided by the total number of the census trees. Similarly we calculated the date of 50% cocoon formation for each generation. The census area for each census tree was limited to the tree trunk and branches less than 25 m at height because a majority of the cocoons were formed there.

Mortality factors during the cocoon stage and the adult density at emergence

We examined the density of newly emerged adults during the period from the start of the cocoon formation to the end of the adult emergence: middle July - early September and middle September - the following early July for the first and the second generations, respectively. The intervals of the censuses were one week for the first generation and one to three weeks for the second generation in consideration of the far longer cocoon stage in the second generation. We recorded the number of the cocoons killed by each mortality factor and the number of the cocoons from which the adults emerged for each census tree. By summing up all these data we estimated the cocoon mortality per tree and the density of newly emerged adults per tree for each generation (A1 and A2).

A considerable proportion of the cocoons had emergence holes without exuviae remained, which were regarded as being killed by birds. This was because 1) observations by field-set video recorders revealed that small birds such as great tit Parus major manipulated to open emergence holes of the cocoons in addition to leaving various types of predation scars, and preyed on the pupae by excavating them, 2) the laboratory rearing of the cocoons confirmed that the adults always left the exuviae at the emergence holes, and 3) the cocoons with emergence hole but without exuviae occurred mostly during winter when no adult emergence occurred. Consequently we regarded only the cocoons with both the emergence holes and the exuviae as those of successful adult emergence, and thereby estimated the proportion of the adult emergence for each generation (S1 and S2). Other minor mortality factors of the cocoons were parasitoid wasps, diseases (blackened to death within the cocoons without predation scars), emergence failure and so on. The emergence failure often occurred if other larvae pupated just above the cocoons and thereby prevented the emergence. By summing up the number of the newly emerged adults at each census we calculated the date of 50% adult emergence, indicating the day when 50% of adults emerged among the total number of the adults for each generation.

From a small proportion of the cocoons produced during July - August in 2006 and 2007, neither adults nor parasitoids emerged after the normal emergence period of August and September. We found that these cocoons had univoltine life cycle, the adults occurring only one generation a year in June (Sawada et al., unpublished). Thus we regarded that the cocoons, produced in the first generation but no adults emerged by the end of September, were of the univoltine life cycle and were excluded from the estimation of the adult emergence rate of the cocoons of the first generation.

Estimation of population growth rate

Here, the population growth rates of the first and the second generations were defined respectively as R1 (=C1/A0), the rate of the cocoon density of the first generation (C1) to the adult density of the second (over wintering) generation (A0 or A2), and as R2 (=C2/A1), the rate of the cocoon density of the second generation (C2) to the adult density of the first generation (A1). By comparing R1 and R2 we analyzed patterns of the seasonal and annual fluctuations of the P. lepida population.

Results

The seasonality of the cocoon formation and the adult emergence

In Table 1, the date of 50% cocoon formation and of 50% adult emergence were described as well as the average period of the cocoon stage (the period between the above two dates) over 5 years, 2003 - 2006. In the first generation of 2003 the larvae formed the cocoon approximately over one month, from July 21 to August 25, with the date of 50% cocoon formation (t1) on August 5. The adult emergence occurred during August 13 and September 8, with the date of 50% adult emergence (t2) of August 22, indicating the average period of the cocoon stage (t1 - t2) as 17 days (Table 1). Over 5 years during 2003 - 2007, the date of 50% cocoon formation and the date of
Table 1  The dates of 50% cocoon formation \((t_1)\), of 50% adult emergence \((t_2)\), and the average periods (days) of the cocoon stage \((t_2 - t_1)\) in the first and the second generations of *Parasa Lepida* from 2003 to 2007.

<table>
<thead>
<tr>
<th></th>
<th>First Generation</th>
<th>Second Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(t_1)</td>
<td>(t_2)</td>
</tr>
<tr>
<td>2004</td>
<td>27 Jul</td>
<td>16 Aug</td>
</tr>
<tr>
<td>2005</td>
<td>2 Aug</td>
<td>20 Aug</td>
</tr>
<tr>
<td>2007</td>
<td>6 Aug</td>
<td>27 Aug</td>
</tr>
</tbody>
</table>

Table 2  The adult density per tree of the second (over wintering) generation \((A_0)\), the population growth rate \((R_0)\), the cocoon density \((C_i)\), the adult emergence rate from the cocoon \((S_i)\), the average rate of adult emergence from the cocoon per 10 days \((S_i')\), and the adult density \((A_1)\), of the first generation from 2003 to 2007.

<table>
<thead>
<tr>
<th></th>
<th>(A_0 (= A_2))</th>
<th>(R_0 (= C_i / A_0))</th>
<th>(C_i)</th>
<th>(S_i (= A_i / C_i))</th>
<th>(S_i')</th>
<th>(A_1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>0.062</td>
<td>7.56</td>
<td>1.29</td>
<td>0.910</td>
<td>0.946</td>
<td>1.171</td>
</tr>
<tr>
<td>2004</td>
<td>0.045</td>
<td>4.61</td>
<td>0.47</td>
<td>0.804</td>
<td>0.897</td>
<td>0.376</td>
</tr>
<tr>
<td>2005</td>
<td>0.176</td>
<td>45.77</td>
<td>0.21</td>
<td>0.627</td>
<td>0.771</td>
<td>0.129</td>
</tr>
<tr>
<td>2006</td>
<td>0.084</td>
<td>20.88</td>
<td>1.76</td>
<td>0.653</td>
<td>0.824</td>
<td>5.255</td>
</tr>
<tr>
<td>2007</td>
<td>0.080</td>
<td>13.5</td>
<td>1.12</td>
<td>0.670</td>
<td>0.819</td>
<td>0.749</td>
</tr>
</tbody>
</table>

mean  | 0.065          | 0.199                   | 0.365   | 0.014                  | 0.003   | 0.357   |

\(^a\): Variance were calculated after log-transformation.

Table 3  The adult density per tree of the first generation \((A_1)\), the population growth rate \((R_1)\), the cocoon density \((C_2)\), the adult emergence rate from the cocoon \((S_2)\), the average rate of adult emergence from the cocoon per 10 days \((S_2')\), and the adult density \((A_2)\), of the second generation from 2003 to 2007.

<table>
<thead>
<tr>
<th></th>
<th>(A_1)</th>
<th>(R_1 (= C_2 / A_1))</th>
<th>(C_2)</th>
<th>(S_2 (= A_2 / C_2))</th>
<th>(S_2')</th>
<th>(A_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>1.171</td>
<td>1.31</td>
<td>1.54</td>
<td>0.040</td>
<td>0.876</td>
<td>0.062</td>
</tr>
<tr>
<td>2004</td>
<td>0.376</td>
<td>6.41</td>
<td>2.41</td>
<td>0.018</td>
<td>0.850</td>
<td>0.045</td>
</tr>
<tr>
<td>2005</td>
<td>0.129</td>
<td>23.94</td>
<td>3.08</td>
<td>0.057</td>
<td>0.891</td>
<td>0.176</td>
</tr>
<tr>
<td>2006</td>
<td>5.255</td>
<td>0.42</td>
<td>2.22</td>
<td>0.038</td>
<td>0.879</td>
<td>0.084</td>
</tr>
<tr>
<td>2007</td>
<td>0.792</td>
<td>4.52</td>
<td>3.58</td>
<td>0.049</td>
<td>0.905</td>
<td>0.088</td>
</tr>
</tbody>
</table>

mean  | 0.749   | 3.29                    | 2.46    | 0.036                  | 0.874   | 0.080   |

\(^b\): Variance were calculated after log-transformation.
50% adult emergence were July 27 – August 6 and August 16 – August 27, respectively, and the average periods of the cocoon stage were 17 – 22 days (Table 1). We excluded the cocoons of the univoltine life cycle, from which no adults emerged by the end of September, from the above calculations.

In the second generation of 2003, the cocoon formation occurred during September 22 – October 26, and the adult emergence occurred during June 2 – July 1, 2004. The date of 50% cocoon formation (t1) and the date of 50% adult emergence (t2) were October 11 in 2003 and June 11 in 2004, respectively, indicating the average period of the cocoon stage (t1 - t2) as 243 days (Table 1). Over 5 years from 2003 to 2007, t1 and t2 were October 5 – 12 and June 10 – 17 in the subsequent years, with the average period of the cocoon stage of 243 – 254 days (Table 1).

Patterns of population growth in the first generation

In Table 2, the adult density of the second (over wintering) generation, A0 (=A1), and the cocoon density and the adult density in the first generation, C1 and A1, respectively, were described. Using these densities, the population growth rate R1 (=C1/A0) and the emergence rate of the adults, S1 (=A1/C1) were also calculated (Table 2). In addition, as indices to examine the relative magnitude of variations of these population parameters, the geometric means and their log-transformed variances were described (Table 2). Moreover, the average rate of cocoon survival per 10 days, S' (=S^10; L denotes the average period of the cocoon stage) was shown, considering that the average period of the cocoon stage was markedly different between the first and the second generations.

The adult density per tree of the over wintering generation (A0) was on average 0.080, smallest as 0.045 in 2005 and largest as 0.176 in 2006, with the degree of variation of 3.9 (=0.176/0.045) over the four years. The log-transformed variance, as an index of the variability, was 0.065. The population growth rate (R1) fluctuated largely from 4.61 to 45.8, with the average of 13.5. The cocoon density in the first generation (C1), as the product of A0 and R1, was on average 1.12 and fluctuated from 0.21 to 8.04, with the magnitude of 39.2 (=8.04/0.21). The log-transformed variance was 0.365 (Table 2). These results indicated that the cocoon density of the first generation (C1) fluctuated more largely than the adult density of the over wintering generation (A0), though not statistically significant (F=2.63, df=3.4, p=0.19; F-test) due to the small sample size despite of the five years of the study period.

The adult emergence rate from the cocoons in the first generation (S1) ranged 0.451 to 0.910, with the geometric mean of 0.670 over the five years. It is noteworthy that S1 gradually dropped over the five years (Wald's χ² =256.95, df=4, p<0.0001; logistic regression). The adult density was greater in the first generation (A1) than in the over wintering generation (A0), indicating a positive population growth during the first generation (t=4.35, df=3, p=0.02, paired t-test). In the first generation, similarly as the cocoon density, the adult density fluctuated largely, as indicated by the large log-transformed variance of 0.357.

Patterns of population growth in the second generation

Table 3 shows the population parameters in the second generation during 2003 – 2007; the adult density of the first generation, A1, the density of the cocoons and the adults in the second generation, C2 and A2, respectively, the population growth rate in the second generation, R2 (=C2/A1), and the survival rate of the cocoon in the second generation, S2 (=A2/C2). Similarly as in the analyses of the first generation, the geometric means of these population parameters and their log-transformed variance were also shown.

The adult density per tree just before the start of the second generation (A1) was on average 0.749, and was 0.129 at minimum in 2005 and 5.26 at maximum in 2006, with the magnitude of variation of 40.7 (=5.26/0.129). The log-transformed variance was 0.357. The population growth rate (R2) was 3.29 on average, ranging from 0.42 to 23.9. The cocoon density (C2), as the product of A1 and R2, was 2.46 on average, and was quite stable over the five years, fluctuating from 1.54 to 3.58, with the variability of 2.31 (=3.58/1.54). Consequently, the log-transformed variance was 0.020, far smaller than that in the first generation adults (F=12.25, df=4.4, p=0.02; F-test) (Table 3), indicating the presence of the density dependent stabilizing processes in the second generation.

The adult emergence rate from the cocoons in the second generation (S2) was very low, 0.036 as the geometric mean over the four years, ranging from 0.018 to 0.057. The difference between the first and the second generations (S1 vs. S2) was statistically significant (z = -30.04, df=6, p<0.0001, GLMM). The
difference between the generations, however, may be largely ascribed to the large difference in the period of the cocoon stage between the two generations, on the ground that the standardized rate per 10 days (S\textsuperscript{*} and S\textsuperscript{**}) did not differ significantly (t = -1.14, df=4, p=0.32, paired t-test, after being arcsine transformed) (Tables 2 and 3). The adult density of the second generation (A\textsubscript{2}) was 0.080 per tree on average, and was smaller than that in the first generation (A\textsubscript{1}) though not statistically significant (t = -2.37, df=3, p=0.10, paired t-test). Moreover, the log-transformed variance of A\textsubscript{2} was very small, 0.065 on average, indicating the stable adult density in the second generation over the years, similarly as that of the cocoon density (C\textsubscript{2}) as described above.

Comparisons of annual fluctuations of the first and second generations

Fig. 1 shows the annual fluctuations of the adult and the cocoon density, A\textsubscript{1} and C\textsubscript{1}, respectively, the population growth rates, R\textsubscript{i} (=C\textsubscript{i}/A\textsubscript{i}), and the adult emergence rate from the cocoon, S\textsubscript{i} (=A\textsubscript{i}/C\textsubscript{i}), in the

![Graphs showing log-transformed densities over years for first and second generations.](image)

**Fig. 1** Yearly changes in log-transformed *Parasa lepida* adult densities per tree (A\textsubscript{0}, A\textsubscript{1}, A\textsubscript{2}), the population growth rates (R\textsubscript{i}, R\textsubscript{2}), the cocoon densities per tree (C\textsubscript{i}, C\textsubscript{2}) and the adult emergence rate from the cocoon (S\textsubscript{i}, S\textsubscript{2}) in the first (left-handed) and the second (right-handed) generations from 2003 to 2007.
first (i=1) and the second (i=2) generations during 2003 - 2007, in the logarithm scale. The cocoon density, \( C_i \), is expressed as the sum of the adult density in the previous generation, \( A_{i-1} \), and the population growth rate in that generation, \( R_i \), in the logarithm scale.

\[ \log C_i = \log A_{i-1} + \log R_i \quad (i=1 \text{ or } 2) \]

In a similar manner, the adult density, \( A_i \), is expressed as the sum the cocoon density, \( C_i \), and the adult emergence rate from the cocoons, \( S_i \).

\[ \log A_i = \log C_i + \log S_i \quad (i=1 \text{ or } 2) \]

**Fig. 1** (left) illustrates the large annual fluctuations of \( C_i \), which is expressed as the sum of fluctuations of \( A_0 \) and \( R_1 \), in the logarithm scale. There was a positive correlation between \( A_0 \) and \( R_1 \) (t=6.06, df=2, p<0.05, regression analysis) (Fig. 2, upper left), implying that both of the annual fluctuations were enhanced through the developmental processes. In other words, the population growth rate \( R_1 \) was inversely density

**Fig. 2** Relationships between the *Parasa lepida* population growth rates (\( R_i, R_i \)) and the adult densities per tree of the previous generations (\( A_0, A_1 \); upper), and between the adult emergence rate from the cocoon (\( S_1, S_2 \)) and the cocoon densities (\( C_1, C_2 \); lower) in the first (left-handed) and the second (right-handed) generations from 2003 to 2007.
dependent to the adult density in the previous generation (A0). Indeed, A0 was high and low, and Ri was high and low, respectively in 2005 and 2006, resulting in the large annual variations documented in Fig. 1 (left).

In contrast, the annual fluctuations of S1 were exclusively stable, resulting in the closely similar annual fluctuations between C1 and A1 (Fig. 1, left). No significant relation was detected between C1 and the adult emergence rate from the cocoons (S1) (z = -0.47, df = 2, p = 0.64, GLMM), though S1 gradually decreased annual from 2003 to 2007 (Fig. 2, left).

In the second generation, the cocoon density (C2) was very stable over the years (Fig. 1, right). In contrast to the first generation, there were density dependent processes that greatly stabilized C2: A1 and R2 were negatively correlated each other (t = 8.96, df = 3, p < 0.01; regression analysis) (Fig. 2, right). Indeed, R2 was high and low respectively in 2005 and 2006 when A1 were low and high, respectively (Fig. 1, right). The annual fluctuations of the adult density of the second generation (A2), being expressed as the sum of those of C2 and S2; were closely similar with those of S2, because C2 was very stable over the years (Fig. 1, right).

**Discussion**

The annual fluctuation of the cocoon density in the first and the second generations exhibited the markedly different patterns: the large variability in the first generation whereas the contrasting stability in the second generation, being indicated by the log-transformed variations (Fig. 1). In the first generation of 2006 when the cocoon density was highest, more than 100 cocoons were found on 6 host trees, such as *T. sebifera* and the matsumurae maple *Acer palmatum var. matsumurae*, among 404 census trees. Virtually almost all the leaves were consumed up in these 6 trees by intensive feeding of a large number of the old instar larvae. Contrastingly, no such serious feeding damage was observed in the second generation, even though the cocoon density itself was on average 2.2 times higher (but not statistically significant) in the second generation than in the first generation.

The analyses of the population dynamics revealed that the population growth rate was inversely density-dependent in the first generation, but was density-dependent in the second generation (Fig. 1). In other words, there were the positive feedback processes which destabilized the population density, between the adult density (A0) and the subsequent population growth rate (Ri) in the first generation, further increasing the annual fluctuation of the cocoon density (C1). On the other hand, the intense negative feedback processes, implying the stabilizing effect, occurred in the second generation, thereby greatly stabilizing the cocoon density in the second generation (C2).

The population growth rate in the i-th generation (Ri) is expressed by the product of following three component factors: the number of eggs laid per adult, the survival rate of eggs and the proportion of larvae that reached the cocoon stage.

\[
R_i = \frac{C_i}{A_{i-1}} = \frac{E_i}{A_{i-1} \times L_i} = \frac{C_i}{L_i} = F_i \times S(E_i) \times S(L_i)
\]

Here, Ei, Li, Fi, S(Ei), and S(Li) denote the egg density in the i-th generation, the larval density, the number of eggs laid per adult, the survival rate of eggs, and the survival rate of larvae, respectively. By taking logarithm the formula can be described as follows.

\[
\log R_i = \log F_i + \log S(E_i) + \log S(L_i)
\]

Thus in the logarithm scale, the population growth rate in the i-th generation is the sum of the realized fecundity per adult, the survival rate of eggs, and the survival rate of larvae.

Sawada et al. (2008a) documented the detailed population processes of *P. leptida* in the same population during 2005–2007, and suggested the inversely density dependent mortality of larvae in the first generation on the ground that (1) at the scale of the local population, the larval mortality was lower in the year of higher larval density as in 2006, and (2) within a year the larval mortality was lower in host trees of higher larval density. As the larval mortality factors in the first generation, predation by paper wasps, spiders, and ladybird beetles, a fungal disease, and a storm were identified (Sawada et al. 2008b). Hence, it is necessary to quantify the degree of the inverse density dependence for each of the above factors.

In contrast, the larval mortality was strongly density dependent in the second generation: The larval mortality was substantially higher in the year and the trees of the higher larval density (Sawada et al.
2008a). As the major mortality factor nuclear polyhedrosis virus (NPV), though not precisely identified in a strict sense, was suggested (Sawada et al. 2008b). We speculated that the density dependent occurrence of the presumed NPV realized the negative correlations between the adult density (A) and the subsequent population growth rate (R), and thereby greatly stabilized the cocoon density in the second generation. In this context, it is interesting to refer that the density dependent mortality due to NPV plays a critical role to put an end to outbreaks of forest pests, such as the gypsy moth, *Lymantria dispar* (L.) (Koyama and Katagiri 1959; Stairs 1971, 1972).

Other than the larval mortality, the population growth rate may be affected by either the fecundity per adult or the egg survival. It is necessary to quantify the relative contributions of these two factors in addition to the larval mortality, and their interactions to understand fully the ecological mechanisms that may bring the density dependent and the inversely density dependent mortality observed in *P. lepida*.

Acknowledgements

We would like to thank Y. Araki, Y. Mizuno, Y. Masumoto, T. Kato, S. Shimomura and M. Kida for their kind support with the field survey.

References


緑化害虫ヒロヘリアオイラガの個体群動態：密度の季節的年次的変動

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滋賀県彦根市にある滋賀県立大学構内において、2003〜2007年の5年間、51種404株の樹木を対象に、ヒロヘリアオイラガの発生と羽化成虫の調査を行い、個体数の季節的年次的変動様式を解析した。発生は2回発生し、第1世代発生は7月中旬〜8月中旬に形成された。第2世代発生は9月中旬〜10月下旬に形成され、そのまま越冬して翌年の6月上旬〜7月上旬に発生した。第1世代発生の羽化率は、2003年の61.0%から2007年の44.1%まで、年を経るにつれ低値下する傾向が認められた。第2世代発生の羽化率は、4年間で18.6〜5.7%まで変化し、第1世代発生の羽化率に比べ著しく低く、そのため、越冬後の第2世代成虫密度は低いレベルに抑えられた。第2世代（越冬世代）成虫発生から第1世代発生までの個体群増加率R1は、密度依存的な増加を示すが、最終結果でR1に密度依存的な過程が作用することが示唆される。第1世代発生の密度増加率R1は、密度増加の増加に伴い減少する傾向、すなわちR1に密度依存的な過程が作用することが示唆される。その結果、第2世代発生密度は年次変動は著しく安定化することが明らかになった。R1とR2に作用する密度依存的、及び密度依存的な過程のメカニズムとして、特に成虫期に働く死亡要因との関連について考察した。
Insect Communities Associated with an Invasive Plant, the Common Ragweed, *Ambrosia arte\hspace{-.1em}m\hspace{-.1em}e\hspace{-.1em}si\hspace{-.1em}t\hspace{-.1em}is\hspace{-.1em}i\hspace{-.1em}ifo\hspace{-.1em}lia* L., in Western Japan

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Abstract

The insect community, including herbivores, predators and parasitoids associated with the common ragweed was surveyed along the banks of the Yodogawa River and the Yasukawa River, Western Japan, in 2001–2005. Ten herbivores and 20 predators (including three parasitoids) were recorded. Of the herbivores, five species, including the dominant three herbivores, were exotic, while two species were indigenous. Of these, *Lixus acutipennis* and *Aneccerus coffeae* were newly recorded as common ragweed feeders. All 11 species of predators were indigenous. The two dominant herbivores, *Opelaea communis* and *Corythucha marmorata*, were most abundant in August. Mortality of the common ragweed was greatest in early September, just after the densities of these two invasive herbivores peaked. As a result, all the plants died in mid September, and only 45% of the plants could set seeds. This catastrophic plant death was thought to be caused by heavy infestations of these two exotic herbivores. The growth period of *O. communis* reared on ragweed leaves infested by *C. marmorata* was significantly longer than those reared on intact leaves. This result suggests that an indirect interspecific relationship via food plants exists between the two dominant herbivores.

Key words: Common ragweed, *Ambrosia artemisiifolia*, insect community, invasive species, *Epiblema sugii*, the *Epiblema strenuana* species-group, *Opelaea communis*, *Corythucha marmorata*

Introduction

The common ragweed, *Ambrosia art\hspace{-.1em}e\hspace{-.1em}m\hspace{-.1em}si\hspace{-.1em}t\hspace{-.1em}is\hspace{-.1em}i\hspace{-.1em}ifo\hspace{-.1em}lia* L. (Asteraceae) (hereafter abbreviated as CRW), is a North American annual pest weed which has invaded Europe, Asia, Africa, Central America, the Caribbean, South America and Oceania (ISSG, 2007). CRW causes serious yield losses of cereals and other crops, and its pollen is known to bring on attacks of human hay fever or contact dermatitis (EPPO, 2000). This weed, which was introduced into Japan at the beginning of the Meiji Era of 1860–70s (Okuda and Takeda 1985; Asai 1993), thrives in vacant lots, roadsides and riversides throughout Japan.

The herbivorous leaf beetle of CRW, *Opelaea communis* La\hspace{-.1em}S\hspace{-.1em}age that originates from North America, was discovered in the Chiba Prefecture of Japan in 1996 (Takizawa et al., 1999). In addition, the lace bug, *Corythucha marmorata* (Uhler), also originally from North America, was found in Japan on CRW as well as tall goldenrod, *Solidago altissima* L., in 2000 (Tomokuni, 2002). In 1976, the stem boring moth of CRW, *Epiblema sugii* Kawabe, was described from Japan based on specimens collected in the 1960s (Kawabe, 1976). This species is very closely related to the North American *Ep. strenuana* species-group which includes a few undescribed species, and Dr. Yoshitsugu Nasu (pers. comm.) suggests that the Japanese population belongs to this species-group. Thus at least three invasive CRW herbivores might be established now in Japan, and heavy damage to CRW by them in fields have been observed in recent years. However, there have
been no studies on interspecific competition among these herbivores or their natural enemies. Furthermore, there are no records of indigenous herbivores, though the insects community on CRW is a good example of the structure of the insect community on the invasive plant.

To clarify the composition of the insect community on CRW and the seasonal fluctuations of the dominant invasive herbivores, we have carried out a field survey of CRW on the banks of the Yodogawa River (Osaka Prefecture) and the Yasukawa River (Shiga Prefecture) since 2001. In addition, we examined the survival and phenology of CRW with reference to the occurrence of the dominant herbivores, and tried to find the indirect interaction between the lace bug and the leaf beetle on CRW.

Materials and Methods

Study sites

Field surveys were carried out at the Yodogawa and Yasukawa sites. The former site was located at the side of the Yodogawa River, in the city of Moriguchi, Osaka Prefecture (34°46' 29" N, 135°34' 05" E, ca. 6 m a. s. l.). The main vegetation here was Italian ryegrass, Lolium multiflorum Lam., and tall goldenrod, Solidago altissima. This study site was set in a small and dense patch of CRW (100 m x 50 m), and 22 to 48 individuals of CRW were observed in each of the survey years. The Yasukawa site was located at the side of the Yasukawa River, in the city of Konan, Shiga Prefecture (34°59' 02" N, 136°07' 20" E, ca. 150 m a. s. l.). This site was set along a trail across a meadow mainly covered with Italian ryegrass, tall goldenrod, Japanese pampas grass (Miscanthus sinensis Anderss.) and kudzu-vine (Pueraria lobata Ohwi) with sparse patches of CRW (20 m x 50 m). Seventeen to 22 individuals of CRW were observed during each survey year.

Survey of the insect community on CRW

The insects infesting the leaves and stems of 10 to 22 individuals of CRW were counted every month during the growing seasons in 2001 at the Yodogawa site. Females of Aphis gossypii Glover (n=46) were reared under laboratory conditions to investigate their parasitoids. From 2003 to 2005, all the insects infesting CRW, and also the number of holes ejecting the frass of stem borers were counted one to four times a month. The sample sizes of the plants were 21 in 2003 and 48 in 2004 at the Yodogawa site, and 17 in 2003 and 22 in 2004 at Yasukawa. Predation of herbivores by natural enemies was also recorded. In January 2004, dead stems of CRW (n=20) obtained at the Yodogawa site were brought back to the laboratory and examined for over-wintering insects. The insects found were reared under laboratory conditions, and the adults that emerged or the parasitoids were recorded.

Seasonal prevalence of the two dominant herbivores

In 2003, the two dominant herbivores, the leaf beetle, Op. communa, and the lace bug, Cor. marmorata, infesting leaves (100 leaves from June to July, 200 leaves from August to September) of 22 individuals of CRW were counted at the Yodogawa sites on the same day as the 2003 insect community survey. The survivorship and phenology of CRW (n=22) were also recorded at the same time.

Interspecific relationship between the two dominant herbivores

Although the two dominant herbivores of CRW occur together in high densities, there have been no reports of how one species may influence the other. We tried to determine the influence of leaves damaged by lace bugs, Cor. marmorata, on the growth of leaf beetles, Op. communa. To examine the indirect interspecific relationship, leaf beetles were reared on CRW leaves of different quality. Some were reared on leaves that had been damaged by lace bugs, while others were reared on healthy leaves. All test beetles were obtained from an adult female leaf beetle that had been caught at the Yodogawa site in the early summer of 2006. This female was kept in a petri dish with fresh leaves of CRW, and newly deposited egg masses were used for the experiment. Hatched larvae were divided into two groups, and fed either damaged leaves (n=41) or intact leaves (n=53). Both groups were reared in an incubator at 25°C and a 16L:8D photoperiod. The developmental period from hatching to emergence, and wet weight of adults were recorded.

Results

Insect community of the CRW

Ten species of herbivores belonging to three orders of insect were recorded on the CRW at the two observation sites (Table 1). These were Evacanthus interruptus L. (Delticofthalidae), Cor. marmorata
Table 1  Herbivores of Common Ragweed in two study sites.  

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Yo: Yodogawa site</th>
<th>Ya: Yasukawa site</th>
<th>Feeding sites and methods</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homoptera</td>
<td></td>
<td></td>
<td>Stems / sucking</td>
<td>Dominant in the Ragweed.</td>
</tr>
<tr>
<td>Deltocephalis antennata</td>
<td>+</td>
<td>+</td>
<td>Leaves / sucking</td>
<td></td>
</tr>
<tr>
<td>Tingida: Corynephora marmorata</td>
<td>+</td>
<td>+</td>
<td>Leaves and stems / sucking</td>
<td></td>
</tr>
<tr>
<td>Aphididae: Aphis gossypii</td>
<td>+</td>
<td>+</td>
<td>Stems / sucking</td>
<td></td>
</tr>
<tr>
<td>Eriococcidae: Eriococcus sp.</td>
<td>+</td>
<td>+</td>
<td>Stems / boring</td>
<td>Dominant in the Ragweed.</td>
</tr>
<tr>
<td>Lepidoptera</td>
<td></td>
<td></td>
<td>Leaves / chewing</td>
<td></td>
</tr>
<tr>
<td>Euphotocampa sugii</td>
<td>+</td>
<td>+</td>
<td>Leaves / chewing</td>
<td></td>
</tr>
<tr>
<td>Geometridae: g. et sp.</td>
<td>+</td>
<td>+</td>
<td>Leaves / chewing</td>
<td></td>
</tr>
<tr>
<td>Psychidae: g. et sp.</td>
<td>+</td>
<td>+</td>
<td>Stems / boring</td>
<td></td>
</tr>
<tr>
<td>Coleoptera</td>
<td></td>
<td></td>
<td>Leaves / chewing</td>
<td>Dominant in the Ragweed.</td>
</tr>
<tr>
<td>Chrysomelidae: Ophraella communis</td>
<td>+</td>
<td>+</td>
<td>Stems / boring</td>
<td></td>
</tr>
<tr>
<td>Curculionidae: Lixus acutilineus</td>
<td>+</td>
<td>+</td>
<td>Stems / boring</td>
<td></td>
</tr>
<tr>
<td>Anthribidae: Anthriscus coffeae</td>
<td>+</td>
<td>+</td>
<td>Stems / boring</td>
<td>Emerging from over-wintering dead stems in Yo.</td>
</tr>
</tbody>
</table>

(Tingidae), Ap. gossypii (Aphididae) and Eriococcis sp. (Eriococcidae) (Homoptera), Epiblema sugii (Euxomsmidae), two undetermined lepidopteran species from the Geometridae and Psychidae, and three coleopteran species, Op. communus (Chrysomelidae), Lixus acutilineus Rendals (Curculionidae) and Anthriscus coffeae (Fabricius) (Anthribidae). The dominant species at both sites were the lace bug, Cor. marmorata (81.55% of herbivores), the leaf beetle, Op. communus (16.37%), and the stem boring moth, Ep. sugii (1.50%), all of which are exotic.

Several natural enemies, thought to attack these herbivores, were found (Table 2). The spider, Misumenops tricuspidatus (Fabricius) (Thomisidae) was one of the dominant predators (74.00% of predators) attacking the larvae and adults of the lace bug, and also the larvae of the leaf beetle. Two chrysopid species, Chrysopa septempunctata Wesmael and Ch. nipponensis (Okamoto) were recorded at the Yodogawa site as predators of leaf beetles. The lady beetle, Coccinella septempunctata L. preyed on the larvae of the leaf beetle and Ap. gossypii. Two braconid parasitoids (undetermined) emerged from the laboratory reared female Ap. gossypii. Moreover, larvae of two predatory dipteran species, Cecidomyiidae sp. and Chamaemyiidae sp. were collected from the Ap. gossypii colonies. Predators that were uncommon included Tenthreda chinensis (Stoll), Stelis maculate Thunberg (Mantiidea) and Hierodula patellifera Servile (Dictyoptera); Orius sp. and Miridae species (Homoptera); Syrphidae species (Diptera); Harmonia axyridis (Pallas) (Coleoptera); Ozyopus seratus L. Koch, Argiope amoena (L. Koch), Arg. bruennichii Scopoli and Salticidae species (Araneae).

Ichneumonid larvae along with the larvae of Ep. sugii (Table 2) were found to over-winter in the dead stems of CRW (n=20). In this survey, 76 moth larvae were found and seven of them were parasitized by the Ichneumonidae. These were reared together under laboratory conditions, and nine individuals of the ichneumonid wasps, Scambus sp. were produced. As a consequence, 20 species of natural enemies that attack CRW herbivores were recorded.

Seasonal prevalence of lace bugs and leaf beetles

In 2003, lace bugs were first found on the leaves of CRW on the 7th of June (Fig. 1). The population gradually increased up until the 6th of July, and then rapidly increased and reached the first peak on the 21st of July (Fig. 1). The population decreased slightly until the 3rd of August, after which it rapidly increased reaching a second peak on the 17th of August (Fig. 1). After the second peak, the population rapidly decreased in the middle of September.

Leaf beetles were first found on the 21st of July, and then the population increased greatly until the 6th of September.

By the 14th of September, almost all of the host plants had died off, and both the lace bugs and leaf beetles disappeared.

Survival process and phenology of CRW

The survivorship of CRW and its phenology at the Yodogawa site in 2003 is shown in Fig. 1 together with the prevalence of the lace bugs and leaf beetles. CRW germinated in the middle of April (n=22), and a few
Table 2  Predators observed in Common Ragweed in two study sites.  

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Yo.</th>
<th>Ya.</th>
<th>Indigenous</th>
<th>Exotic</th>
<th>Impossible to judge</th>
<th>Preys in Common Ragweed and observation date of predation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DICTYOPTERA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mantidae Tenebrio chinensis</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>unknown</td>
</tr>
<tr>
<td>Staliidae maculata</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>unknown</td>
</tr>
<tr>
<td>Hieradula patellifera</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>unknown</td>
</tr>
<tr>
<td>HEMIPTERA</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Anthocoridae Orius sp.</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>unknown</td>
</tr>
<tr>
<td>Miridae g. et sp.</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>unknown</td>
</tr>
<tr>
<td>NEUROPTERA</td>
<td></td>
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<td></td>
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<tr>
<td>Chrysopidae</td>
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<td></td>
</tr>
<tr>
<td>Chrysopa saptempunctata</td>
<td>+</td>
<td>+</td>
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<td></td>
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</tr>
<tr>
<td>Chrysopa nipponensis</td>
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<tr>
<td>DIPTERA</td>
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<td></td>
</tr>
<tr>
<td>Cecidomyidae g. et sp. Larvae</td>
<td>+</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Chamaemyidae g. et sp. Larvae</td>
<td>+</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Syrphidae g. et sp. Larvae</td>
<td></td>
<td>+</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>COLEOPTERA</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Coccinellidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harmonia axyridis Larvae</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coccinella septempunctata brauckii Adult</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HYMENOPTERA</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Braconidae g. et sp.</td>
<td></td>
<td>+</td>
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<tr>
<td>Ichneumonidae Scoubs sp</td>
<td></td>
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</tr>
<tr>
<td>ARANEAE</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Thomisidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misumenops tricuspidatus</td>
<td>+</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thomisidae g. et sp. Oxyopidae</td>
<td></td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxyopidae sertatus</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>unknown</td>
</tr>
<tr>
<td>Salticidae g. et sp. Areneidae</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>unknown</td>
</tr>
<tr>
<td>Argiope amoena</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argiope bruennichi</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>unknown</td>
</tr>
</tbody>
</table>

of them died during May to June. However more than 80% (n=19) of the censused plants survived until late August. From the end of August to the middle of September, the survival rate suddenly decreased, which coincided with the rapid growth of the herbivore population. All CRW plants had died by the 14th of September. In this site, 45.5% (n=10) of the plants had been able to flower, and only 4.5% (n=1) of the plants had set seeds because of the catastrophic die-off of the plants.

Interspecific relationship between the two dominant herbivores
The developmental periods and wet weights of leaf beetles fed on leaves damaged by lace bugs, and on intact leaves, are shown in Table 3. The mean larval developmental period for beetles fed on damaged leaves was 16.60 days (n=41) and only 14.30 days (n=53) when fed on intact leaves. This difference was significant (t = 5.028, P < 0.01). The mean pupal developmental period when fed on damaged leaves was 5.08 days (n=35) compared with 3.63 days (n=53) when fed on intact leaves. This difference was also significant (t = 3.519, P < 0.01). However, the wet weights of the adult leaf beetles in the two feeding groups were not significantly different (t = 0.122, P > 0.01).
Insect Communities of Common Ragweed

![Graph showing survivorship and leaf beetle population](image)

**Fig. 1** Seasonal prevalence of occurrence of the two dominant herbivores and survivorship of common ragweed with phenology of the plant.

Table 3 Developmental period and wet weight of the leaf beetle fed on damaged leaves by lace bug or intact leaves

<table>
<thead>
<tr>
<th>Group</th>
<th>Developmental periods (Day: mean ± S.D.)</th>
<th>Wet weight of the adults (mg:mean ± S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Larval periods</td>
<td>Pupal periods</td>
</tr>
<tr>
<td>Roared by infested leaves</td>
<td>16.60 ± 3.04 (n=41)</td>
<td>5.09 ± 2.38 (n=35)</td>
</tr>
<tr>
<td>Roared by intact leaves</td>
<td>14.30 ± 1.20 (n=53)</td>
<td>3.63 ± 1.30 (n=53)</td>
</tr>
</tbody>
</table>

Discussion

During our field survey of the CRW community in the Kawan district of Japan, 10 species of herbivores were recorded. One of these species, *Ep. sugii* Kawabe, 1976, was described from Japan, but it is now thought to be a member of the *Ep. strenuana* species-group which is originally North American in its distribution (Dr. Yoshitsugu Nasu, pers. comm.), though the monospecific procedure is not yet resolved. *Ep. sugii* was first found in Japan during the 1960s, where it is supposed to have been accidentally introduced. Another two dominant herbivores, the leaf beetle, *Op. communis* and the lace bug, *Cor. marmorata* were introduced to Japan in 1996 (Takizawa et al., 1999) and 2000 (Tomokuni, 2002), respectively. These three exotic species all originated from North America, which is the site of origin of CRW.

In the present study, two coleopteran species were newly recorded as CRW feeders. *L. acutipennis* (Curculionidae) were observed to lay eggs on the stem of CRW at the Yodogawa site. This is a species indigenous to Japan and China, and two host plants, *Artemisia* spp. (Morimoto, 1984) and *Cirsium* spp. (Nakane, 1964) have been recorded. The coffee bean weevil, *Ara. coffeae*, was collected from the pith of dead stems of CRW at Yodogawa site. This weevil, which is a cosmopolitan storage pest of coffee, cotton and corn (Morimoto, 1984), originated from India (Matsumoto, 1998), and now is a serious pest of oranges in western Japan (e.g. Etoh et al., 1996; Matsumoto, 1998). Yamazaki and Sugiuura (2004) found it from the pith of giant ragweed, *Am. trifida* L. growing along the banks of the Yamato River, in the Osaka Prefecture. They recommended the remove of this weed from around the orange orchards to avoid offering them the
over-wintering places. CRW, which belongs to the same genus as *Am. trifida*, is thought to have same risk for orange growing.

These dominant three herbivores, and the coffee bean weevil, *Ara. coffeae*, are exotic, and two species, *Li. acutipennis* and *Ev. interruptus* are indigenous (the origin of the remaining four species is unclear). On the other hand, all of the natural enemies (17 predators and 3 parasitoids) of these herbivores, are indigenous.

When organisms invade a new territory, they can escape from many of their natural enemies, giving them an advantage over natives, and leading to their spread (Elton, 1968). This 'enemy release hypothesis' has gained popularity in the studies of invasive species (Genton et al., 2005). When CRW first invaded Japan it might have been free from influential specialist herbivores from North America. This means that CRW enjoyed a condition of 'enemy release' during this period. In our current study, the herbivores of CRW included both native generalist and three dominant exotic specialists. We suggest that CRW was not in a state of 'enemy release' when we started the investigation at our study sites.

At least nine herbivores, including the leaf beetle, *Op. communia*, and the stem boring moth *Ep. strenuana*, have been studied for the biological control of CRW (Shepperd et al., 2006; EPPO, 2007). Of these, the leaf beetle was evaluated as an ideal biological control agent (ISSG, 2007), and was released in Canada and Hungary (EPPO, 2007). In addition, a device was developed for the collection, short-term storage and transport of leaf beetles (Teshler et al., 2004). In Japan, however, it will be difficult to use the leaf beetle as a biological control agent because the commercial sunflower plant, *Helianthus annuus L.* (Emura, 1999) is one of the hosts of the leaf beetle.

On the other hand, the stem boring moth, *Ep. strenuana* was released in Russia, China and Australia to control the CRW (Shepperd et al., 2006; ISSG, 2007; EPPO, 2007), and it has proved to be a most effective agent (Shepperd et al., 2007).

At the Yodogawa site, in 2003, we observed that most of the CRW were unable to produce any seeds (Fig. 1). This catastrophic plant death was caused by heavy infestations of the two exotic herbivores, the leaf beetle and the lace bug. In recent community ecology, indirect herbivore interactions via plants are well established (e.g. Ohgushi, 1995; Kaplan et al., 2007). In the case of the leaf beetle and the lace bug, interspecific competition via the quality of plant tissue is also assumed. Our result showed developmental delay of leaf beetles reared on leaves damaged by lace bugs, when compared with beetles reared on intact leaves (Table 2). This suggests that leaf damage by lace bugs increases the risk of predation on the leaf beetle by its natural enemies because developmental delay increases the frequency of encounters with them. On the other hand, the heavy damage to host plants by leaf beetles decreases food resources for lace bugs. Thus indirect competition between the two herbivores via plants may occur mutually.

The CRW in our study site seemed to be controlled biologically by a combination of the leaf beetle and the lace bug. The results of laboratory experiments showed indirect interspecific competition between the leaf beetle and the lace bug. However, further observations and manipulative experiments in the field will be necessary to verify indirect interspecific competition and its influence on the population growth of the leaf beetle and the lace bug.

Acknowledgments

We are much obliged to Dr. Y. Sakuratani of Kinki University, Dr. Y. Nasu and Dr. M. Shibao of Osaka Prefecture Government, and Mr. Y. Miyatake of Kansai University for giving us several useful information. We also thank Mr. R. Matsumoto, Osaka Museum of natural History, for identification of *Scambus* species.

References


EPPO (The European and Mediterranean Plant


http://www.issg.org/database/species/managemet

info.asp?s=1125&st=  [Accessed on 1 January 2008]


西日本における外来雑草ブタクサ *Ambrosia artemisiifolia* L. の昆虫群集

加藤敦史・大林延夫
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侵入雑草ブタクサ群落における昆虫群集を 2001 年から 2005 年にかけて淡川と野洲川の河川敷で調査した。その結果、10 種類の植食者と 20 種類の捕食者（寄生者を含む）が認められた。植食者では優占する 3 種を含む 5 種が侵入種で、在来種は 2 種に過ぎなかった。これらのうちハスジカツオソウムシとワタミヒゲナガソウムシはブタクサ植食者として初めての記録である。捕食者では、未同定種を除く 11 種が在来種で、侵入種は認められなかった。9 月初旬に記録されたブタクサの一斎枯死現象は、その直前にいずれも個体群密度が最大となった優占植食者であるブタクサハムシとアワダチソウグンバイによる強度の被食によるものと推察された。また、一斎枯死したブタクサ群落で種子生成に成功した株は、発苗個体の 4.5% にすぎなかった。飼育実験の結果、アワダチソウグンバイに吸汁されたブタクサの葉で飼育したブタクサハムシは、健全葉で飼育したものに比べて羽化までの期間が有意に延長し、両優占植食者間に食草の質を介した間接的な種間競争が存在することが示唆された。
Distribution of adult *Cheumatopsyche brevilineata* (Trichoptera: Hydropsychidae) along the shore of Lake Suwa, Japan

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Abstract

We collected adult *C. brevilineata* with light traps to clarify the distribution along the shore of Lake Suwa. Light traps were located 0 m (St. 0), 1,375 m (St. 1), 2,700 m (St. 2), 3,650 m (St. 3), 4,600 m (St. 4) and 5,325 m (St. 5) from the outlet stream of the lake. A total of 105,874 adults were collected, and the sex ratio of the adults was biased to females throughout the study period except on July 23. The daily mean abundance of adults was highest at St. 0 (3,968.4 ± 8,569.1 ind. day⁻¹) and declined rapidly the further the distance from the outlet of the lake. The mean relative proportion of the daily abundance at St. 1-5 to that at St. 0 was less than 5%. In addition, there was a significant negative correlation between the daily abundance at a site and the distance from the lake outlet to the site. These results suggest that adult *C. brevilineata* can move at least 5,325 m, although most adults do not move so much.

Key words: Adult caddisfly, *Cheumatopsyche brevilineata*, Flight distance, Lake outlet, Lake Suwa, Light trap

Introduction

Outlet streams of lakes and reservoirs are noted for high densities of filter feeding invertebrates, e.g. net-spinning caddisflies (Trichoptera: Hydropsychidae, Steganoplectidae, etc) and blackflies (Diptera: Simulidae) (Armitage, 1976; Harding, 1992, 1994; Hofsten, 1998; Katagami et al., 2004, O'swood, 1979; Sheldon and O'swood, 1977; Wotton, 1982, 1988, 1992). The large quantity and high quality of suspended solid (sediment from lakes and reservoirs provide food for filter feeders in outlet streams (Armitage, 1977; Casiling, 1963; Gibson and Galbraith, 1975; Malmqvist and Brommark, 1984; Richardson, 1984; Wotton, 1998). The density of filter feeders decreases downstream as the quality and/or quantity of sediment decreases (Armitage & Caper, 1976; Maciolek and Tumi, 1968; Morin and Peters, 1988; O'swood, 1979). Therefore, the outlets of lakes and reservoirs are likely to provide a good habitat for filter feeders.

The Tenryu River flows from the Kamaguchi Floodgate as the sole outlet stream of Lake Suwa in the central part of Nagano Prefecture. Several species of filter feeders live in the Tenryu River at a high density (Katagami et al., 2004; Komatsu, 1974; Kumakawa and Uchida, 2001) because Lake Suwa supplies a large quantity of sedent to the upper reaches (Katagami et al., 2004). Recently, a large number of adults of a caddisfly, *Cheumatopsyche brevilineata* (Iwata), has occurred at the outlet of Lake Suwa (Kimura et al., 2006). *C. brevilineata* is a small-sized species that belongs to the Hydropsychidae, and widespread in the southern part of the Eastern Palearctic Region, including Japan and Russia (Tanida et al., 2005). Trichoptera is sometimes the most abundant benthic macroinvertebrate of rivers (Tanida et al., 2005; Wiggins, 1996), especially *C. brevilineata* in Japanese rivers (e.g., Adachi et al., 1987; An et al., 1993; Murakami et al., 1987; Yagi and Sasaki, 1992). Larvae of *C. brevilineata* distribute in the upper to middle reaches of the Tenryu River (Katagami et al., 2004; Komatsu, 1974; Kumakawa and Uchida.

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2001; Tenryu River Upper Reaches Construction Work Office, 1996), however, they have never been recorded either in Lake Suwa or around the mouth of inflows (Chino, 1918; Uchida, 2005; Yoshida et al., 1997; Yoshida, 1998). Therefore, the adult C. brevilineata distributed along the shore of Lake Suwa quite likely came from the Tenryu River, at the outlet of the lake.

In this study, we collected adult C. brevilineata with light traps placed along the shore to clarify the distribution of adults in Lake Suwa. In addition, we examined the relationship between the abundance of adults at a site and the distance from the outlet to the site to estimate the maximum flight distance of the adults.

Materials and Methods

Study Site

Lake Suwa is a eutrophic shallow lake located in the central highlands of Honshu, Japan, at the altitude of 759 m a.s.l (36°03' N, 138°05' E). The lake has a surface area of 13.3 km² and a mean depth of 4 m (maximum 6.5 m). Thirty-one rivers flow into Lake Suwa, but the Tenryu River is the sole outlet (Fig. 1).

Collection of adult C. brevilineata

Adult C. brevilineata were collected along the shore of Lake Suwa using light traps from June 3 to 7 and July 22 to 29 in 2004, i.e., 11 days. Each trap was equipped with a 6-W black fluorescent lamp. The traps were placed along the north shore at the distance of 1,375 m (St. 1), 2,700 m (St. 2), 3,650 m (St. 3) and 4,600 m (St. 4), and the furthest 5,325 m (St. 5) from the outlet of Lake Suwa. In addition, we also set traps on the south shore of the lake 2,650 m (St. 6) and 3,700 m (St. 7) from the lake outlet. Trap was also set at the lake outlet (0 m: St. 0) to clarify the daily emergence of adult C. brevilineata. All traps were operated throughout the day, and the cages to capture adults were replaced every morning between 7:30 and 9:30. The numbers of males and females of adult C. brevilineata were counted under a binocular microscope and stored in 70% ethyl alcohol in the laboratory. The abundances were indicated as the sum of the numbers of males and females unless otherwise stated.

Environmental Data

Environmental conditions, e.g., air temperature, wind velocity and direction, cloud cover, relative humidity and moon age, may directly influence flight behavior of

Fig. 1  Map of Lake Suwa, showing distance of sampling sites from lake outlet and Suwa Station of Nagano Local Meteorological Observatory.
insects. In this study, we focused on the air temperature, wind velocity and wind direction as environmental factors that affect dispersal behavior (Johnson, 1969). Daily mean wind velocity and wind direction between 17:00 and 22:00 were used. This may be the same as the swarming time of adult caddisflies (Mori and Matsutani, 1953; Kato and Ohgushi, 1959) during the study period. Modal wind direction was used for the wind direction. All these environmental data were obtained from the Suwa Station of Nagano Local Meteorological Observatory (Japan Meteorological Agency, 2004).

Data Analysis
The significance of the differences in daily abundance of adults between males and females among the sites were tested using the Wilcoxon signed-rank test. The significance of the Pearson correlation coefficients between the daily total abundance of adult C. brevilineata and the environmental factors were tested. The significance of the differences in daily abundance of adults between St. 2 and St. 6, and St. 3 and St. 7 were also tested using the paired-sample t test or Wilcoxon signed-rank test. Moreover, the significance of the Spearman's rank correlation coefficient between the distance from the outlet to a site and the daily total abundance of adult C. brevilineata at the site was tested, and a linear regression model was fitted to these data. All the data analyses were conducted using the software SPSS version 11.5.1 [SPSS Japan Inc.].

Results

Environmental conditions
Mean air temperature during the swarming time of adults were 20.1 ± 2.7°C (ranged from 18.2 ± 2.2°C to 21.8 ± 2.9°C), and 25.5 ± 2.8°C (ranged from 21.4 ± 0.2°C to 27.4 ± 2.0°C) in June and July, respectively (Table 1). In addition, mean wind velocity during the swarming time averaged 3.1 ± 1.5 m s⁻¹ (n = 11), and ranged from 1.7 ± 0.8 m s⁻¹ (July 25) to 4.9 ± 2.3 m s⁻¹ (July 22) (Table 1). The most frequent direction of the wind was southeast followed by south during the study period.

Abundance of adult C. brevilineata
A total of 110,511 adult C. brevilineata (21,014 males

Fig. 2 Daily abundance of C. brevilineata at each distance from the lake outlet.
Table 1  Daily abundance of C. brevilineata and environmental conditions (mean air temperature, mean wind velocity, modal wind direction between 17:00 and 22:00) during the sampling periods. Data from Suwa Station of Nagano Local Meteorological Observatory were used during the investigation (Japan Meteorological Agency, 2004).

<table>
<thead>
<tr>
<th>Date</th>
<th>Sex</th>
<th>Mean air temperature (°C)</th>
<th>Mean wind velocity (m s⁻¹)</th>
<th>Modal wind direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 June 03</td>
<td>Male / Female</td>
<td>18.2 ± 2.2</td>
<td>3.7 ± 1.7</td>
<td>SE</td>
</tr>
<tr>
<td>2004 June 04</td>
<td>84 / 197</td>
<td>21.4 ± 3.2</td>
<td>3.6 ± 1.0</td>
<td>SE/SE</td>
</tr>
<tr>
<td>2004 June 05</td>
<td>987 / 5655</td>
<td>21.8 ± 2.9</td>
<td>2.7 ± 1.0</td>
<td>SE</td>
</tr>
<tr>
<td>2004 June 06</td>
<td>231 / 1473</td>
<td>19.0 ± 0.3</td>
<td>2.0 ± 0.4</td>
<td>SSE</td>
</tr>
<tr>
<td>2004 July 22</td>
<td>5653 / 19062</td>
<td>26.1 ± 2.1</td>
<td>4.9 ± 2.3</td>
<td>WNW/W</td>
</tr>
<tr>
<td>2004 July 23</td>
<td>437 / 293</td>
<td>26.5 ± 2.2</td>
<td>3.7 ± 0.5</td>
<td>ESE</td>
</tr>
<tr>
<td>2004 July 24</td>
<td>2792 / 7817</td>
<td>26.9 ± 2.0</td>
<td>3.0 ± 1.4</td>
<td>S</td>
</tr>
<tr>
<td>2004 July 25</td>
<td>246 / 12846</td>
<td>21.4 ± 0.2</td>
<td>1.7 ± 0.8</td>
<td>S</td>
</tr>
<tr>
<td>2004 July 26</td>
<td>474 / 12122</td>
<td>23.1 ± 1.1</td>
<td>2.7 ± 0.5</td>
<td>SE</td>
</tr>
<tr>
<td>2004 July 27</td>
<td>5156 / 21523</td>
<td>27.1 ± 1.8</td>
<td>1.9 ± 0.6</td>
<td>E/SE</td>
</tr>
<tr>
<td>2004 July 28</td>
<td>4490 / 10146</td>
<td>27.4 ± 2.0</td>
<td>3.8 ± 2.1</td>
<td>NNE/ENE</td>
</tr>
</tbody>
</table>

Total 20564 / 85310
Mean ± SD 189.5 ± 221.5 / 7755 ± 694.6 23.5 ± 3.8 3.1 ± 1.5

and 89,497 females) were collected over 11 days of the study period, and the sex ratio of the adult C. brevilineata was significantly biased to female (p < 0.01, Wilcoxon signed-rank test). Daily abundance of the adults did not show significant correlations either with the daily mean air temperature or wind velocity.

Distribution pattern of adult C. brevilineata

Figure 2 shows daily abundance of adult C. brevilineata in each station. The daily abundance of adult C. brevilineata at St. 0 was the highest among the stations throughout the study period. At St. 0, the maximum abundance was 26,417 ind. on July 27, and the minimum was 111 ind. on June 3. The daily abundance at St. 0 accounted for 86.3 ± 19.0% (n = 11) of the daily total abundance of all stations. The daily mean abundance was 52.3 ± 52.5 ind. day⁻¹ at St. 2, located on the north shore of the lake, and 39.5 ± 29.2 ind. day⁻¹ at St. 6 on the south shore. In addition, the daily mean abundance was 65.0 ± 89.3 ind. day⁻¹ at St. 3 on the north shore, and 27.6 ± 24.6 ind. day⁻¹ at St. 7 on the south shore. There was no significant difference in the daily abundance between St. 2 and St. 3, and St. 4 and St. 5, i.e. among stations with almost the same distance from the lake outlet. The daily mean abundance was 9,368.4 ± 8,569.1 ind. day⁻¹ at St. 0, 48.0 ± 60.8 ind. day⁻¹ at St. 1 (relative proportion to the daily abundance of adults at St. 0: 1.8 ± 2.5%), 52.3 ± 52.5 ind. day⁻¹ at St. 2 (1.2 ± 1.9%), 65.0 ± 89.3 ind. day⁻¹ at St. 3 (2.8 ± 5.4%), 14.3 ± 33.0 ind. day⁻¹ at St. 4 (3.1 ± 9.0%), and 9.9 ± 13.2 ind. day⁻¹ at St. 5 (12 ± 3.4%). The daily abundance at St. 1 was much lower than at St. 0.

Figure 3 shows the relationship between the daily abundance of adults at a site and the distance from the lake outlet to the site. The daily abundance at a site declined with the distance from the lake outlet (r = 0.61, n = 66, p < 0.01, Spearman’s rank correlation coefficient) (Fig. 3).

Fig. 3 Relationship between total abundance of C. brevilineata in light traps and distance from the lake outlet. Solid line corresponds to the regression equation ln (daily abundance + 1) = 6.42 - 0.001 × (distance).
Discussion

Movement of the aquatic insects enables them to avoid inbreeding, migrate to a new site with low-density occupation and few resource competitors, and escape from unfavorable conditions, e.g. limited resources, presence of predators, pathogens and parasites (Bilton et al., 2001). In particular, adult movement of aquatic insects has attracted a considerable interest combined with Muller's colonization cycle hypothesis that describes the sequence of downstream drift of larvae and supposed upstream flight for oviposition by females (Muller, 1954, 1982). However, only a few studies have so far reported how far adults of aquatic insect taxa move. Our study provided knowledge of the adult movement of *C. brevilineata* for the first time.

In the present study, we collected adult *C. brevilineata* with light traps. Light trap is one of the most useful methods to measure adult movement (Collier and Smith, 1998; Kovats et al., 1996; Svensson, 1974). Because the adults of this species show high positive phototaxis to artificial light (e.g., Kimura et al., 2006; Nozaki & Gyohtoku, 1990; Sasaki et al., 1989), we can easily collect them with light traps. With the high air temperature, adult hydropsychid species, including *Cheumatopsyche*, are abundant in summer season when the air temperature is high (Kimura et al., 2008; Waringer, 1991). In the present study, we often collected more than 10,000 ind. day⁻¹ in July. Moreover, the influence of environmental conditions, e.g. wind velocity less than 10 km h⁻¹ (approximately 2.8 m s⁻¹), cloud cover, and precipitation, on adult caddisfly activity can be neglected (Kovats et al., 1996; Waringer, 1991). The daily abundance of adults was not directly influenced by wind velocity (range: 17 ± 0.8 m s⁻¹ - 4.9 ± 2.3 m s⁻¹) during the study period.

In this study, daily abundance of adult *C. brevilineata* at a site decreased with distance from the lake outlet to the site. Moreover, there was no significant difference in the daily abundance of adults between St. 2 and St. 6, and St. 3 and St. 7, namely, between north and south shore sites, although the wind blew frequently from the southeast and south during the study period. Wind is one of the most important environmental factors that affect flight behavior (Johnson, 1999). However, the present study suggests that the influence of wind on the flight behavior of adult *C. brevilineata* can be neglected during the study period. In addition, larvae of *C. brevilineata* have never been recorded either in Lake Suwa or around the mouth of inflows (Chino, 1918; Uchida, 2005; Yoshida et al., 1997; Yoshida, 1998), although they were common in lake outlet and outflows (Katagami et al., 2004; Komatsu, 1974; Kumakawa and Uchida, 2001; Tenryu River Upper Reaches Construction Work Office, 1996). These facts indicate that the distance from the lake outlet directly determined the daily adult abundance at each sampling station.

Total abundance of other two *Cheumatopsyche* species (*Cheumatopsyche campylia* Ross and *Cheumatopsyche speciosa* (Banks)) in traps also decreased with the distance from the shore (Kovats et al., 1996). The relative proportion of abundance of adults collected at a site to that at the shore was approximately 20% at the site 625 m from shore, and a few percent at sites located between 1250 and 5000 m from the shore (Kovats et al., 1996). On the other hand, *Hydropsyche* species exhibited inland maxima at 625 m from the shore, so the distribution pattern is different among the hydropsychid species (Kovats et al., 1996). In this study, we did not collect adult *C. brevilineata* at sites along the shore from the lake outlet for 1375 m. However, the distribution pattern at sites more than 1375 m from the outlet was fairly similar to that reported by Kovats et al. (1996). For the same reasons mentioned above, the abundance of adult *C. brevilineata* also decreased rapidly with the distance from the emergence source. We collected adult *C. brevilineata* at St. 5, which was furthest from the lake outlet among the stations. A wide dispersal range has been reported for Hydropsychidae, Limnephilidae, and Stenopsychidae, and these adults were collected more than 1,000 m away from their larval habitats (Johnson, 1969; Kovats et al., 1996; Svensson 1974; Sode and Wibe-Larsen, 1993; Nishimura, 1967; Nishimura, 1981). In particular, *Hydropsyche pellucidula* (Curtis) female was collected 8,000 m from the nearest larval habitat (Sode and Wibe-Larsen, 1993). Kovats et al. (1996) reported that two *Cheumatopsyche* species collected with traps 5,000 m from shore suggested the potential for long-distance (> 5,000 m) flight by adults. In this study, the distance for potential movement of adult *C. brevilineata* was estimated to be at least 5,325 m.

The density of filter feeding caddisflies at lake outlets often becomes high (Harding, 1992, 1994; Hoffsten, 1999; Oswood, 1979). Density of filter
feeding caddisflies declined with distance from the outlet downstream (Maciolek and Tunzi, 1968; Osworth, 1979), however, the change in density with distance from the outlet upstream is not known. Daily abundance of adult *C. brevilineata* also decreased with distance from St. 0, suggesting that the density of filter feeding caddisflies decreases in both directions from the outlet of the lake. Several species of filter feeding caddisflies distribute in the upper to middle reaches of the Tenryu River (Katagami et al., 2004; Komatsu, 1974; Kumakawa and Uchida, 2001; Tenryu River Upper Reaches Construction Work Office, 1996), however, most of them have never been recorded both in Lake Suwa and around the mouth of inflows (Chino, 1918; Uchida, 2005; Yoshida et al., 1997; Yoshida, 1998). Flight distance of a caddisfly species increases with the wing length of a given species (Kovats et al., 1996). Our future studies should clarify the relationship between flight distances and wing length of filter feeding caddisflies.

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References


Distribution of adult Chessmatopse bivertilis in Lake Suwa


諏訪湖沿岸部におけるコガタシマトビケラ成虫の分布

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コガタシマトビケラ成虫の移動・分散を明らかにするために、ライトトラップを用いて諏訪湖沿岸部における成虫の分布を調査した。トラップは湖の流出部から、直線距離で0 m（St. 0）、1,375 m（St. 1）、2,700 m（St. 2）、3,650 m（St. 3）、4,600 m（St. 4）、5,325 m（St. 5）の湖岸に設置した。調査期間中、合計105,874個体のコガタシマトビケラ成虫が捕獲され、成虫の性比は雌に偏っていた。St. 0における成虫の日平均捕獲数は9,368.4 ± 8,569.1個体/日であり、流出部から離れると急激に捕獲数が減少した。St. 0の発生量に対する相対的な捕獲割合は、St. 1からSt. 5の間で数パーセント程度であった。諏訪湖沿岸部におけるコガタシマトビケラ成虫の捕獲数は、流出部からの距離に有意な負の相関が認められた。本研究により、コガタシマトビケラ成虫は少なくとも5,325 mは移動可能であることが示唆された。
ヤマトシロアリ, *Reticulitermes speratus*, の簡易飼育法

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Improvement in the rearing method of termite, *Reticulitermes speratus*. Hideo Shinozaki**<sup>1)</sup>, Takashi Aborono<sup>1)</sup>, Yotshika Sano<sup>1)</sup> and Tsuguo Matsumoto<sup>1)</sup>

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Abstract

A simplified rearing method designed to investigate the behavior of termite, *Reticulitermes speratus* under visible conditions was examined.

This method was required for evaluating the effectiveness of microbial control of termite. Two percent agar preparation have been used with remarkable success on the rearing of termite for a long period. Oviposition, hatching and growth of the termite on the agar plate were observed during the rearing period.

Key words: *Reticulitermes speratus*, Simplified rearing method, Termite, Agar plate

はじめに

シロアリ（等翅目，Isoptera）は，現在281属2,600種以上が存在し，7科に分類されている（Abe et al., 2000）。その多くは熱帯や亜熱帯地域の森林や枯死木を中心にに生息しており，リター層の分解者として物質循環を担う重要な昆虫とされている（安部，1989；Abe et al., 2000）。しかし，木質屋敷や建造物に木造文化財の保存が重要であるため，それを食害する害虫の一つである（山野，1988）。

シロアリによる被害の防除法には，忌避剤の散布や殺虫剤を散布などによる化学的防除法や，シロアリの侵入を阻止するステンレス製の網を築石を利用した物理的防除法などがあり（Su et al., 1991；平尾，1996；角田，1998）。


材料及び方法

1. 飼育装置の設計

Fig.1 に今回開発したシロアリの簡易な飼育容器の概略を示した。市販の粉末コーヒーの空瓶に緑花を敷き，その上に円盤状のヨコラ（Whatman 3 MM）を置いた，さらにロール状に巻いたヨコラを入れ，オートクレープ処理（121℃ 15分）後使用した。

2. 供試虫

本学キャンパス内（京都市左京区松ヶ崎）にあるアカマツ，*Pinus densiflora*，枯木の切株の根元に，ヤマトシロアリ，*Reticulitermes speratus*の営巣が確認された。その営巣をステンレス製の飼育容器（直径約25 cm，高さ約40 cm）に収まるように枯木ごと直径約15 cm，高さ約30 cmの大きさに切り出し，研究室で寒天末混25℃，暗営巣の条件で飼育に移し約2ヶ月飼育し，この個体を実験に供した。搬入したコロニーに飼育する個体数の計測は行わなかったが，各実験には主として飼育を供試した。
3. 飼育方法

Fig. 1 の飼育容器に兵アリ 3 匹、職アリ 47 匹の計 50 個体を放倒し、25℃常暗の飼育庫で飼育した。飼育期間中は給餌せず、定期的に蒸留水をロール状口紙に散布した。また、挙動観察として鈴木（1991）の方法に準拠した寒天塩地平板を調製した。この寒天による飼育方法は、滅菌後プラスチックシャーレ（φ 9 cm）に所定量の普通寒天（Nakalai）を分注し、その表面に 2 cm 角に切ったロ紙を載せた。この寒天平板上に 20 頭の健全な駒アリ個体を放倒し、25℃の暗所で飼育した。飼育期間中は、容器内の飼育と同様に給餌は一切行わずロ紙の乾燥時にのみロ紙と蒸留水を噴霧した。また乾燥による寒天の固化を防ぐため、定期的に所定量の寒天を部分的に塗布した。

4. 飼育期間と観察

飼育期間は、供試個体の全滅を限度と定め、その間の行動を観察（駒個体の作業状況）、産卵と孵化、成長と生殖虫の出現を中心として観察した。

結果と考察

Fig. 1 に示した飼育容器に放倒したシロアリは、約 1 年 4 ヶ月の長期にわたる飼育が可能であった。容器へ放飼直後の個体は、綿花やロール周辺を活発に覗いていたが、数週間後にロール状口紙（以下ロールと略す）と綿花との設置部位の周囲に集合し、ロールを利用して気配がうかがえた。その後、ロールの両端開口部から内部へと移動が始まり、綿花とロール間の活発な移動が観察された。そして飼育開始から約 2 ヶ月後にロール内にとどまる機会が多くなり、ロール外での挙動が観察される機会は少なくなった。

飼育期間中の個体数は、生活環境の急変による死亡や共食いなどのため若干その数を減じたが、腹部に錘針や十文字状の穿孔も観察され、残余した個体は生存が継続し、副生殖虫の発生や子アリの出現を観察された。飼育開始後 1 年 4 ヶ月に飼育を中断して、ロールを解体しその後の生活状況を観察した。Fig. 2-A (a), (b) に示したようにロール内部に錘針状の穿孔の形跡が認められ、さらにロールの内側壁面にも線状の形成が確認された。ロール解体時の生存個体数を Table 1 にまとめた。

兵アリを含む当初の 50 個体は、1 年 4 ヶ月後に副生殖虫を含め 18 個体（生存率 36%）にまで減少していた。

表記、図表、データの記述においては、各表、図表、および最適な寒天濃度について観察し、その結果を Table 2 にまとめた。表に示したように、寒天濃度 0.5%～1.5%は水分含有率過多で多くの供試虫は滞死状態で数日間死亡し、一方、2.5%以上の寒天濃度では、寒天の固化・乾燥が著しくいずれの寒天濃度でも長期間の飼育が可能であった。これらの観察結果から、寒天濃度 2.0%が最適と判断された。この結果に基づき、2%寒天平板を調製し、15 個体を放倒して挙動の観察を行った。結果、飼育された個体は平板上を散数日間駐在した後、寒天内部に孵化や空間を縫い構築し、副生殖虫や子アリ（Fig. 2-B）および卵（Fig. 2-C）なども認められた。これらの挙動は、容器飼育で認められた行動と同様であり、寒天平板法でも 1 年以上の飼育が可能であった。この寒天平板による飼育法で、Su et al. (1982) は 5%濃度の寒天平板を使用しており、また鈴木（1991）は寒天による方法で 3 週間程度が飼育の限界と推測しているが、本実験による寒天濃度では、寒天固化に係る水分補給を十分に注意すれば 1 年以上の飼育は可能であり、その間のシロアリの挙動も常時観察できることが判明した。また、今回導入したロ紙に飼育する直接的な効果は認められていないが、現在のところ飼育環境の整備に必要なものと判断している。次に要望平らによる寒天層の構築化を図ることで構築行動を観察しようとした。その結果、1 ～ 3 cm の高層では寒天平板の乾燥が激しく、孵化する動物の構築は見られなかった。一方 7 ～ 9 cm の高層では、水分含有量が過多状態となり供試個体は数日間で全滅した。一方 5 cm の高層寒天での飼育では、副生殖虫や子アリおよび卵などの存在も確認され、先の平板飼育で得られた観察結果と同様であった。しかし、この高層法では、高層
Fig. 2 Termite behavior after 1 year and 4 months
A: roll of paper
   (a: external, arrow: termite tunnel)
   (b: internal, arrow: termite tunnel)
B: agar plate
   (a: Worker)
   (b: Larval instars)
   (c: Nymph)
   (d: Soldier)
C: eggs laid on the plate

Table 1 Population of termite workers in rearing apparatus

<table>
<thead>
<tr>
<th>class</th>
<th>period</th>
<th>start</th>
<th>1 year and 4 months later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker</td>
<td>47</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>Soldier</td>
<td>3</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Nymph</td>
<td>0</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>total</td>
<td>50</td>
<td></td>
<td>18</td>
</tr>
</tbody>
</table>

The rearing temperature was maintained at 25°C

Table 2 Behavior of termite workers on agar plate

<table>
<thead>
<tr>
<th>agar (%)</th>
<th>behavior of termites</th>
<th>suitability of rearing conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 - 1.5</td>
<td>wandering onto agar surface, sluggish, slight termite tunnelling</td>
<td>No (drowning because too watery)</td>
</tr>
<tr>
<td>2.0</td>
<td>highly active, communication, oviposition, hatching and development termite tunnelling</td>
<td>Yes</td>
</tr>
<tr>
<td>2.5 - 5.0</td>
<td>active, slight termite tunnelling</td>
<td>No (dry solidity of agar)</td>
</tr>
</tbody>
</table>

Termite behavior on agar plate was observed at 25°C
寒天全彙に之を説ぶされた之等の観察を観察することが可能である一方、寒天中心部での生育状況が外部から観察できず、また長期間の観察に際しての寒天の乾燥、その際の水分の補給が挙げて困難なため、観察期間が限られるという難点があった。本報で示した2％寒天平板によるシロアリの簡易観育法は、長期間の観育が可能であり、また常時可視条件下で観察が容易である。さらに観育そのものが極めて簡便なものと判断される。これに対し、各種のバイオアセットにも十分に有用な観育方法と考えられた。

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東京都港区における
アオドウガネ成虫の発生状況

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105-0014 Japan.

Seasonal prevalence and food plants for adult of green chafer, Anomala albipilosa albipilosa (Hope) on the road, a park along the canal and a pathway with the street lamp, were investigated by eye watching from 2005 through 2007 in Minato-ku, Tokyo. Adult green chafer were occurred from early July through early October. Individuals of green chafer were a downward trend since 2005 on the road by daytime observation. Activity period of green chafer were from early July through mid-October in a park and a pathway by night observation. Adult of green chafer food plants which was 19 families 33 species in Minato-ku, Tokyo.

Key words: Green chafer, Urban environment, Seasonal prevalence, Food plant

アオドウガネ成虫の季節消長と食餌植物について。2005年〜2007年に東京都港区の道路上ならびに運河沿いの公園と街灯のある道路において調査を行った。道路では、本種は7月中旬〜10月下旬にかけて確認されたが、その個体数は2005年以降、減少傾向であった。夜間における公園と運河での本種の活動期間は、7月中旬〜10月中旬で、本種は港区内で19科33種の植物を食害した。

アオドウガネ Anomala albipilosa albipilosa (Hope, 1839) は、体長 17.5 〜 25.0 mm、背面がつやのある緑色、腹部は緑黄色に少し赤銅色のコガネムシである。本種の中東部は、四国、九州、琉球列島などに広く分布しており、琉球列島では数種の亜種が確認されている（酒野・藤岡, 2007）。

日本では1960年代後半から、コガネムシ類の異常発生が報告されるようになり、それ以前では農薬害虫として注目されていなかった本種も、南日本で1000 ha以上の大規模に大発生した（西尾, 1977)。本種の幼虫はサトウキビ、バイナップル、サツマイモ、ニンジン、イチゴなど農作物の地下部を害する。害虫はアカギ、ガジュマル、ソウシジュなどの街路樹や、原野に生じるデリハノプドウ、チシャノキなど多種の植物の芽、若葉を好んで食害する（気質, 1985）。

近年、本種の北上傾向が認められ、以前は見られなかった関東地方でも個体数が増加している（酒井・藤岡, 2007）。

筆者は東京都港区で2004年にアオドウガネ成虫（以下、特に表記がない場合はアオドウガネとする）を調査し、アオドウガネは8月を中心に6月下旬〜9月中旬に区内の植栽や路上等で確認され、本種が発生している公園で行ったマーキング法による個体数密度測定では、527個体を確認した（中野, 2005）。

本調査はアオドウガネが港区内のような東京都心部の環境で、何を食餌植物としてどのくらい生息しているのか、その発生が年によってどのように変化するかを明らかにするため、2004年に引き続き、2005〜2007年に調査を行った結果をまとめたものである。

調査方法

1. 道路等における昼間の個体数調査

通勤道路である東京都港区の舗装道路（国道、都道、区道）を歩きながら、歩道上に立ちている植栽等に確認されたアオドウガネの個体を記録した。調査範囲は区内の東部から中央部にあたる芝公園、三田、東麻布、六本木の一部で、基本的な調査ルートの距離はおよそ3 kmである（図1）。調査時の天候は原則、雨天を除き、調査時間は主に午前7:30〜8:00および午後5:30〜6:00である。目視により道路上に見つかる本種の死骸ならびに静止をしていた個体と路上周辺の植物を摂食していた個体を計数した。

2. 夜間の目視調査（表1）

①運河沿いの区立公園

アオドウガネが発生しているひとつの区立公園で、本種の発生消長を把握するため、夜間に目視調査を行った。この公園は東京都へ注がずと運河が接した場所にあり、三角形の形で面積は約450 m²である。中央部にある芝を取り巻くようにマルバシャリホシ Rhaphiolepis indica, アジサイ Hydrangea macrophylla, ヒラドツツジ Rhododendron spp. が植栽されている。また、運河と川との境にあるフェンス沿いにはマルバシャリホシ、キョウチクトウ Nerium indicum var., セイヨウキコナ Hederan canariensis が植栽されている（図2）。生じたネズミ

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モチ Ligu Trie japonicum やホソバタブ Machilus japonica などもみられた。2005 年と 2006 年の 7 月～11 月の夜間（午後 8 時～10 時の間）に、この公園の周囲を歩きながら懐中電灯で植栽の地上 1 〜 2 m を照らし、植物上で観察し静止しているアオドウガネを記録した。昼間の調査と異なり死体は対象にしなかった。週 1 回の頻度で 2005 年は計 14 回、2006 年は計 18 回調査した。なお、調査は道路上の本種の初見日以降から行った。

図 1 昼間の個体数調査場所

ため、2006 年に街灯が設置されている通路において夜間調査を行った。この通路は、運河沿いの区立公園から約 300 m 離れた芝生や緑化樹の生える公園空地の中にある。調査範囲は幅約 10 m、長さ約 80 m で、通路の中央にソメイヨシノ Prunus × yedoensis（高さ 5 〜 6 m）とサザンカ Camellia sasanqua（高さ 0.5 m）の植栽があり、その中に街灯が設置されていた（図 3）。街灯は地上 1.3 m の高さにあり、直径 26 cm の白熱球であった。街灯 8 箇所の周囲（半径 2 m）でアオドウガネを調査した。調査方法は運河沿いの区立公園とほぼ同様に、7 月～10 月の夜間（午後 9 時～11 時の間）に懐中電灯で植栽を
図1 目視による調査方法

<table>
<thead>
<tr>
<th>調査内容</th>
<th>調査月日</th>
<th>調査時刻</th>
<th>調査方法</th>
</tr>
</thead>
<tbody>
<tr>
<td>区立公園での夜間目視調査</td>
<td>2005年7月</td>
<td>p.m.8:00 - p.m.10:00</td>
<td>週1回の頻度で、2005年は14回、2006年は16回調査した。</td>
</tr>
<tr>
<td>街灯のある通路での夜間目視調査</td>
<td>2006年7月</td>
<td>p.m.9:00 - p.m.11:00</td>
<td>懐中電灯で、植物上で摂食や静止しているアオウダガネを記録した。</td>
</tr>
<tr>
<td>終夜目視調査</td>
<td>2006年</td>
<td>p.m.6:00 - a.m.6:00</td>
<td>日没から夜明けまでに1時間ごとに調査した。</td>
</tr>
<tr>
<td>(区立公園・街灯のある通路)</td>
<td>8月20日 - 8月21日</td>
<td></td>
<td>懐中電灯で、植物上で摂食や静止しているアオウダガネを記録した。</td>
</tr>
</tbody>
</table>

調査場所 区立公園：450m²（芝生と植栽） 街灯のある通路：幅10m長さ80mの範囲 中央部に植栽あり

図2 運河沿いの区立公園
照らし、植物上のアオドウガネを週1回程度の頻度で計11回記録した。確認された個体数は、総数と8ヶ所の街灯周辺の平均確認数とその標準偏差を表示した。

③終夜の目視調査
終夜のアオドウガネの活動を把握するため、運河沿いの区立公園と外灯のある通路において、2006年7月20～21日の日没から夜明けまで（午後6時～午前6時）、1時間ごとに目視で確認個体数を記録した。街灯のある通路では、8ヶ所の街灯周辺でアオドウガネを目視した。

3. 成虫の食餌植物調査
都市におけるアオドウガネの食餌植物を把握するため、2002年から区内で本種が摂食した植物を記録している。本種が摂食していることを確認した植物については、原色日本植物図鑑木本編I（北村・村田、1971）、II（北村・村田、1979）、日本の樹木（林、1985）、緑化樹木ガイドブック（日本緑化センター・日本植木協会、2002）、原色日本囲花植物図鑑（長田、1976）、日本の植物I、II（長田、1973）を参考にして同定した。学名の記載は主にこれらの書籍に従った。

結果と考察

1. 道路等における昼間の個体数調査
調査を行ったアスファルト舗装された道路の路面は、
日射による幅射熱も厳しく、周辺に植栽がなければ昆虫の生息に適さない環境である。道路上でみられるアオドウガの死骸は、街の照明で誘引され、斬断した個体を思わせる。死骸を含めた確認数は、区内に生息するアオドウガの発生数の指標と考えている。なお、死骸の多くは清掃、風雨などにより調査場所から除去され、再度確認された個体は少なかった。道路上でアオドウガの確認できた期間は、2005年7月1日～9月29日、2006年7月7日～10月2日、2007年7月1日～10月1日である。道路上におけるアオドウガの死骸を含む確認数は、2005年は114個体、2006年は94個体、2007年は57個体であった。アオドウガの確認数は、年に差異が見られるが、9月中旬以降減少した（図2）。生存個体の多くは道路上で見られが、道路周辺にあるアジサイ、セイヨウキサ、ヘクソカズラやカシバノミの葉やヤブガラシ、カレイサナギの花などを反食する個体も確認された。2005年では路上に面した植物を反食している個体が多く見られた。しかし、それ以降、路上等でのアオドウガの確認数は減少傾向にある。都市の緑化樹と土壌は、生産地から都市へ搬入される。それらの緑化植物と共にアオドウガ幼虫が持ち込まれ、一時的に増加したが、何らかの原因により次第に減少している可能性もある。アオドウガ若令幼虫は地表下20cmまでにとどまらず分布し、主として腐植質を摂食して生育する（外間，1979）。そのため、土壌の有機物の存在が幼虫の発育に影響する（法橋・長嶺，1978）。また、成虫は有機物が堆積し、塩分が低い場所に産卵する（比嘉ら，1978a,b）。都市では若令幼虫の生育に適した有機物の多い土壌の量に限界があることが減少要因のひとつとして考えられる。

| 図2 道路等におけるアオドウガの発生状況の年間の発生数（図面内） |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| 7月 | 1 | 8.14 | (1) | 8.15 | (2) | 1 | (1) | 2 |
| 8月 | 3 | 8.16 | (2) | 8.17 | (1) | 1 | (1) | 2 |
| 9月 | 1 | 8.18 | (1) | 8.19 | (1) | 1 | (1) | 2 |
| 10月 | 1 | 8.21 | (2) | 8.23 | (1) | 1 | 2 |
| 11月 | 2 | 8.24 | (1) | 8.25 | (1) | 1 | 1 |
| 12月 | 2 | 8.26 | (1) | 8.27 | (3) | 1 | 1 |
| 1月 | 1 | 8.28 | (1) | 8.29 | (2) | 3 | (1) | 2 |
| 2月 | 1 | 8.30 | (3) | 8.31 | (1) | 2 | (1) | 2 |
| 3月 | 2 | 9.1 | 2 | 9.2 | 2 | 3 |
| 4月 | 1 | 9.3 | 3 | 9.4 | 1 | 1 |
| 5月 | 2 | 9.5 | 6 | 9.6 | 1 | 1 |
| 6月 | 1 | 9.8 | 1 | 9.9 | 2 | 1 |
| 7月 | 1 | 9.10 | (1) | 9.13 | 1 | 1 |
| 8月 | 1 | 9.14 | (1) | 9.20 | (2) | 1 |
| 9月 | 1 | 9.22 | (1) | 9.29 | (1) | 1 |
| 10月 | 4 | 10.1 | 1 | 10.2 | 1 | 1 |

－149－
2. 夜間の目視調査
①運河沿いの区立公園

夜間観察によるアオドウガネは、生存個体のみを対象としたが、調査箇所が狭小であるにもかかわらず目撃数が多かった。その総確認数は、2005年は420個体、2006年は820個体であった。2006年の発生は2月上旬に最も多く、2005年の発生は4月上旬に最も多く、10月中旬までアオドウガネが確認された（表3）。

アオドウガネは沖縄、九州、四国では、サトウキビやサツマイモなどを害害する農業害虫であり、発生地域では、その防除のためにライトトラップによる誘殺が行われている。ライトトラップによる発生消長は、沖縄の宮古島では4月上旬から10月下旬（6月上旬に最も多く）、鹿児島では6月上旬から10月下旬（8月上旬から9月上旬に最も多く）、徳島県では9月上旬から10月下旬（7月中旬から8月上旬に最も多く）であった（比嘉ら、1978；山下ら、1998；行成、2003）。成虫を誘引するライトトラップと目視調査では調査法が異なり正確な比較ではないが、東京都港区でのアオドウガネ成虫の発生期間は7月上旬から10月中旬（8月上旬に最も多く）であり、沖縄、九州、四国より発生がやや早い。これは東京の気温がそれらの地域より低く、生育に時間がかかるためと思われる。

②緑地内に街灯のある通路

アオドウガネが夜間、街灯に飛来し、街灯の下にあるサザンカを摂食していた。観察場所とした8ヶ所の街灯付近では、2006年7月30日から10月9日までの観察で、アオドウガネの総確認数は357個体であった。街灯1ヶ所当たりの平均確認数は0.9〜30.5個体であった。最も発生の多い日は8月20日であり、それ以降、確認数は減少した（表4）。

| 表3 夜間目視調査による食餌植物上のアオドウガネ個体数（区立公園） |
|-----------------|-----------------|-----------------|-----------------|
| 調査年 | 月日 | 時刻p.m. | 気温℃ | アジサイ | キツネザルハイ | その他 | 計 |
| 2005 | 7.12 | 8:45 | 23 | 3 | 0 | 0 | 0 | 3 |
| | 7.18 | 9:20 | 28 | 17 | 0 | 0 | 0 | 17 |
| | 8.1 | 9:15 | 27 | 48 | 2 | 0 | 0 | 51 |
| | 8.7 | 9:00 | 29 | 65 | 0 | 0 | 0 | 72 |
| | 8.14 | 9:05 | 28 | 36 | 7 | 3 | 0 | 51 |
| | 8.20 | 10:25 | 28 | 51 | 0 | 13 | 15 | 79 |
| | 8.27 | 9:30 | 27 | 23 | 1 | 1 | 0 | 25 |
| | 9.9 | 9:40 | 28 | 5 | 1 | 0 | 0 | 10 |
| | 9.9 | 10:10 | 25 | 3 | 0 | 0 | 0 | 3 |
| | 9.17 | 10:30 | 23 | 11 | 0 | 0 | 0 | 11 |
| | 9.23 | 9:30 | 26 | 10 | 0 | 0 | 0 | 10 |
| | 10.1 | 8:20 | 23 | 2 | 0 | 0 | 0 | 2 |
| | 10.14 | 9:15 | 22 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 7.7 | 8:10 | 25 | 2 | 0 | 0 | 0 | 2 |
| | 7.15 | 8:00 | 29 | 6 | 0 | 0 | 0 | 6 |
| | 7.22 | 9:00 | 24 | 49 | 1 | 0 | 0 | 50 |
| | 7.30 | 10:10 | 22 | 88 | 1 | 0 | 0 | 89 |
| | 8.6 | 8:10 | 28 | 31 | 0 | 0 | 0 | 31 |
| | 8.13 | 9:15 | 27 | 30 | 0 | 0 | 0 | 30 |
| | 8.20 | 8:00 | 28 | 37 | 0 | 2 | 0 | 39 |
| | 8.27 | 10:30 | 25 | 22 | 0 | 0 | 11 | 33 |
| | 9.9 | 8:40 | 26 | 56 | 0 | 1 | 29 | 86 |
| | 9.9 | 10:30 | 26 | 111 | 0 | 0 | 34 | 145 |
| | 9.18 | 8:20 | 26 | 63 | 0 | 1 | 39 | 103 |
| | 9.24 | 10:35 | 20 | 83 | 0 | 0 | 24 | 107 |
| | 10.1 | 9:05 | 18 | 26 | 0 | 0 | 14 | 40 |
| | 10.9 | 9:45 | 20 | 15 | 0 | 0 | 2 | 17 |
| | 10.14 | 10:15 | 17 | 14 | 0 | 0 | 0 | 14 |
| | 10.21 | 10:00 | 18 | 7 | 0 | 0 | 0 | 7 |
| | 10.29 | 9:40 | 19 | 1 | 0 | 0 | 0 | 1 |
| | 11.5 | 8:50 | 18 | 0 | 0 | 0 | 0 | 0 |

1) 2005年：ネズミミチリ、セシダグサ、ヒナグサ、ヘアコウガラ
2) 衣笠より北西約150mにあるビル屋面に電光表示される気温を参考に記録した。
3 終夜の視調査

運河沿いの区立公園での消長は母体よりも増加し、午前3時頃までには30個体程度であったが、午前3時過ぎの夜明け前後に増加していた（表5）。街灯のある通路の緑地（街灯1ヶ所当りの平均確認数は5.5～36.1個体であった。その後は区立公園と同様に午前3時まで街灯に発来し、サザンカに落下する個体が多くなかったが、夜明けと共に減少した（表6）。なお、各観察時間帯の確認数は、重複してカウントされた個体数を含んでいる。区立公園における植物上の個体の行動は比較的穏やかであったが、灯火飛来個体は盛んに飛び出し、サザンカやソメイヨシノの幹を盛んに徘徊するなど活動が活発であった。灯火飛来個体と植物上の個体の関係は、ドウガネイブライでは、植物上の個体は摂食・交尾に関係し、灯火飛来個体は産卵行動に関与したと個体と考えられている（西植, 1976）。一方、ヒメコガネでは、灯火飛来個体は摂食行動や産卵活動が活発になる以前の若い成虫であり、むしろ摂食行動に関与した個体と報告される

表4 夜間目視調査によるオアドウガネ個体数（街灯のある通路）

<table>
<thead>
<tr>
<th>時刻</th>
<th>街灯A</th>
<th>街灯B</th>
<th>街灯C</th>
<th>街灯D</th>
<th>街灯E</th>
<th>街灯F</th>
<th>街灯G</th>
<th>街灯H</th>
<th>計</th>
<th>平均値</th>
<th>標準偏差</th>
</tr>
</thead>
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<td>7</td>
<td>29</td>
<td>14</td>
<td>5</td>
<td>12</td>
<td>5</td>
<td>87</td>
<td>10.9</td>
<td>7.99</td>
</tr>
<tr>
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<td>6</td>
<td>8</td>
<td>7</td>
<td>14</td>
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<td>5</td>
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<td>14</td>
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<td>12</td>
<td>5</td>
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<td>7.99</td>
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<tr>
<td>07:30</td>
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<td>14</td>
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<td>5</td>
<td>87</td>
<td>10.9</td>
<td>7.99</td>
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</tr>
</tbody>
</table>

表6 終夜目視調査（06.8.20～21）によるオアドウガネ個体数（街灯のある通路）

<table>
<thead>
<tr>
<th>時刻</th>
<th>街灯A</th>
<th>街灯B</th>
<th>街灯C</th>
<th>街灯D</th>
<th>街灯E</th>
<th>街灯F</th>
<th>街灯G</th>
<th>街灯H</th>
<th>計</th>
<th>平均値</th>
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</table>

1）公開より北西約160mにあるビル壁面に電光表示される気温を参考に記録した。
ている（瀬戸口, 1984）。アオドウガネの場合、灯火飛来個体と植物上の個体の関係は不明であり、今後調査を検討していきたい。

3. 食餌植物調査
港区でアオドウガネが摂食した植物を調査した結果、19科33種の植物を記録した（表7）。2004年以降新たな成虫の食餌植物として17種の植物を確認した。本種成虫の食餌植物は常緑や落葉の緑化樹が多く、特にアジサイ、セイヨウキツツ、ヘクソサズラを摂食する個体が多くみられた。2004年ではアジサイの傷が顕著になり、7月下旬から8月中旬までセイヨウキツツを摂食する

<table>
<thead>
<tr>
<th>科</th>
<th>Family</th>
<th>種名</th>
<th>Scientific name</th>
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<td>ヤマモモ科</td>
<td>Myricaceae</td>
<td>○ヤマモモ</td>
<td>Myrica rubra Sieb. et Zucc.</td>
</tr>
<tr>
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<td>ホソバタブ</td>
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<td>アジサイ</td>
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<td>マルバシャリンバイ</td>
<td>Rhamnus indicus (L.)</td>
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<tr>
<td></td>
<td></td>
<td>○カマツカ</td>
<td>Paurthiaea villosa (Thunberg)</td>
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<tr>
<td></td>
<td></td>
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<td>Rubus hirsutus Thunberg</td>
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<tr>
<td></td>
<td></td>
<td>○ヤザベキ</td>
<td>Kerria japonica (L.)</td>
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<td>アカメガシワ</td>
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<td>Daphniphyllum macropodum Miqel</td>
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<td>Vitis spp.</td>
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<td></td>
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<td>Parthenocissus tricuspidata (Sieb. et Zucc.)</td>
</tr>
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</tr>
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<td></td>
<td>○サザンカ</td>
<td>Camellia sasanqua Thunb.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>サカキ</td>
<td>Cleveya japonica Thunberg pro parte emend. Sieb. et Zucc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ヒサカキ</td>
<td>Eurya japonica Thunberg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>○ヒメシャラ</td>
<td>Stewardia monadelpha Sieb. et Zucc.</td>
</tr>
<tr>
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</tr>
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<td>アオキ</td>
<td>Ascura japonica Thunb.</td>
</tr>
<tr>
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<tr>
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<td>ネズミモチ</td>
<td>Ligustrum japonicum Thunb.</td>
</tr>
<tr>
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<td>サンゴジュ</td>
<td>Viburnum odoratissimum Ker.</td>
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<td>Weigela caraeensis Thunberg</td>
</tr>
<tr>
<td>草本植物</td>
<td>Compositae</td>
<td>○センダングサ</td>
<td>Bidens itamn (Lour.) Merr. et Sherff</td>
</tr>
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<td>アカネ科</td>
<td>Rubiaceae</td>
<td>ヘクソサズラ</td>
<td>Paederia scandens (Lour.) Merr. var. mairii (Leveille) Hara</td>
</tr>
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<td>○オオマツヨイグサ</td>
<td>Oenothera erythrosepal Borbas</td>
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<td>Polygonum perfoliatum L.</td>
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<td></td>
<td>○イタドリ</td>
<td>Polygonum cuspidatum Sieb. et Zucc.</td>
</tr>
<tr>
<td>ブドウ科</td>
<td>Vitaceae</td>
<td>ヤブガラシ</td>
<td>Cayratia japonica (Thunb.) Gagn.</td>
</tr>
<tr>
<td>カンナ科</td>
<td>Cannaceae</td>
<td>○カンナ</td>
<td>Canna generalis</td>
</tr>
</tbody>
</table>

○2004年以降新たに確認した食餌植物  *葉脈だけを残して葉を網目状に摂食することがある。

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成体が急増した（中野，2005）。2005年では公園内のアカジリを主に観察し、セイヨウキスラを観察する個体はほとんどみられなかった。しかし、マラバジャンパライヤや草本植物であるトウカツグラやセウサシクフラ、Bidens fruticosa を観察する個体が確認された。2006年も阿木にアカジリを観察したが、発生の後半にはヒラドウナボジを観察する個体が増えた。ドウガネアイナビ、ヒメコガネ、アクドウガネなどのコガネムシ成虫は、一般に幼虫の寄生植物と異なる好適な食齢植物を食して卵巣を発育させ、その後幼虫が生息地へ移動分散すると考えられている（阿木，2003）。同じ生息場所において、食齢植物が異なれば、成虫が発育に好適な栄養のある食齢植物を選択している可能性も考えられる。アクドウガネ（成虫・幼虫の区分なし）は、21種の農作物等に寄生することが報告されている（阿木，2006）。アクドウガネが多く見られる沖縄では、成虫がアカギ Bischofia japonica、Humea、ガジュマル Acrotrichia microcarpa L., サゴシソウ Acacia confusa Merrill などの街路樹や原野に自生するテリハナブドウ Ambelopsis brevipedunculata var. hainei Rehd., ナシヤシキ Ehretia ovalifolia Hassk., モンサキク M. argentea L., テリハナブドウ A. sciadophila Vahl. などを観察している（気賀澤, 1986; 田邉, 1978）。これらの結果から、草本植物の構成が異なる緑地帯で発生することが分かった。都市の緑地帯には本種の成虫にとって、多種の食齢植物が存在していた。さらに、本種は食齢植物である緑化樹の近くに生えていたトウカツグラ、センガ ナサリオマツヨイガサ Oenothera erythrosepala などの草本植物も観察されている。

都市ではアクドウガネにとって、成虫の食齢植物を容易に採集することができる環境が推定される。最近は都市化が進む傾向の中で、形状の変化を伴うと共に緑化が推進されている。今後は、都市緑化とアクドウガネの関係について調査を実施していきたい。

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