NATURAL HISTORY OF *REDUVIUS PERSONATUS* LINNAEUS (HEMIPTERA: HETEROPTERA: REDUVIIDAE) IN NORTH AMERICA

M. Javahery*

*c/o Lyman Entomological Museum & Research Laboratory, Macdonald Campus, McGill University, St-Anne-de-Bellevue, Quebec, CANADA H9X 3V9. E-mail: javahery@videotron.ca

[Javahery, M. 2013. Natural history of *Reduvius personatus* Linnaeus (Hemiptera: Heteroptera: Reduviidae) in North America. Munis Entomology & Zoology, 8 (2): 685-703**]**

ABSTRACT: *Reduvius personatus* is commonly known as the masked bed bug hunter. It is a European species which has successfully adapted to life in North America, where it was introduced at an unknown date. My study of the biology, ecology and distribution of this insect is from 1997-2012 in southern Quebec and Ontario, Canada. Adults were found in spring and summer, both inside and outside dwellings. Third and fifth nymphs were present indoor during the winter as well. Third and fifth nymphal instars exhibited dormancy during the first and second winter, respectively. Nymphs exude a sticky substance which facilitates body-masking with dust particles. This camouflage has given rise to the alternative names "masked bug" or "masked bed bug hunter". Mating occurs in a lateral orientation. Four successive generations reared over a decade showed a two-year life cycle. The adult morphology, first instar, characteristics of egg, embryonic development, feeding, mating, and cannibalistic behaviour were studied and are illustrated. The distribution in its adapted (North America) and native (Western Palaearctic) habitats was studied and mapped. This insect was not found to be harmful to humans and household pets. This is the first long-term natural history study of *R. personatus,* in North America.

KEY WORDS: Assassin bug, Life cycle, Ecology, Dormancy, Distribution.

Reduvius personatus is an European insect species described by Linnaeus (1758) and now widely distributed in the Western Palaearctic and parts of North America (Fig. 8) (Blatchley, 1926; Southwood & Leston, 1959; Schuh & Slater, 1995; Ambrose, 1999, 2000; Dusoulier, 2007; Putshkov & Moulet, 2009). The species is nocturnal, employs camouflage, and is known as "the Assassin bug" or "the masked bed bug hunter". Adults and very rarely nymphs have been reported from Quebec (Moore, 1950; Larochelle, 1984; Javahery, 2002; Boucher, 2006), Ontario (Marshall, 2006; Javahery, 2008), British Columbia (Scudder, 1961, 1992), Kansas (Readio, 1927) and Illinois (McPherson, 1999). European researchers have undertaken numerous studies on this insect (De Geer, 1773; Butler, 1923; Fabre, 1923; Harz, 1952; Immel, 1955; Southwood, 1956; Putshkov, 1980, 1981, 1986, 1987; P. Putshkov & V. Putshkov, 1996; Moulet, 2002; Putshkov & Moulet, 2009). However, very little is known about its new world natural history and distribution.

The main objective of the present study was to undertake a long-term biological and ecological investigation of *R. personatus* over several generations using representative samples from southeastern Canada.

Four successive generations of this species were produced from adults collected in Quebec and Ontario over the last 10 years in order to determine the life cycle (especially nymphal dormancy), reproductive potential, embryonic development, and cannibalism. Another objective was to study and illustrate feeding and mating behaviour, characteristics of eggs, egg-shell, instars, adults, terminalia, and aedeagus. Distribution maps of *R. personatus* in its adaptive (Nearctic) and native (Western Palaearctic) habitats were also prepared. Results

are compared with relevant publications on this insect in Europe and North America.

This is the first long-term natural history study of *R. personatus,* in North America.

MATERIALS AND METHODS

The present study was based on 345 adults (143 males, 202 females), 57 nymphs (39 third, 18 fifth) collected manually in 12 localities in the western suburbs of Montreal, Ottawa and Toronto. Adults and nymphs were reared in clear-polystyrene vessels (10 x10 x 25 cm) with a mesh cover and containing several pieces of crumpled paper towels and twigs. They were fed 2-3 times /week with small (5-10 mm) soft-bodied, field-collected insects or larvae or laboratory–cultured larvae of the flour moth *Anagasta kiehiella* (Zeller). Eggs from the laboratory culture (n=500) were incubated in 35-mm clear-plastic Petri dishes. Embryonic development was monitored by dissecting 10 randomly selected eggs every generation in isotonic solution of 0.9% NaCl. The egg- cup was cut off just below the cup circle and placed in a drop of xylene and was later mounted on a microscope slide in Canada balsam. The micropylar processes were examined under 200X magnification with an electronic binocular microscope. Ten specimens of adults, nymphs, eggs and terminalia were selected at random and measured (in mm). The terminalia, aedeagus, egg-cup, and egg- burster were removed with fine forceps in a relaxing fluid of 75% ethanol and illustrated on graph papers with the aid of an eyepiece graticle (Figs. 1. 5). The drawings were then scanned and transferred to the computer. Images of live bugs were taken at night. All cultures were maintained under ambient room conditions of variable temperature (12- to 36°C), relative humidity (55-to 98%) and light.

Voucher specimens of eggs, nymphs and adults have been deposited in the Lyman Entomological Museum, McGill University. Nymphal specimens are very rare because of their camouflage with dust particles (Fig. 4). Only two third instar nymphs were checked at the Canadian and B.C. National insect Collections in Ottawa and Victoria, B.C., respectively. Adult specimens (n >1000) from the Nearctic (southern Canada and eastern United States) and Western Palaearctic Regions, deposited in the following institutions or museums, were examined. In addition, reduviid collections in eastern Argentina, Australia and China were checked:

ANHM American Natural History Museum, New York, United States.
ANIC Australian National Insects Collection, (CSIRO), Canberra, Australia.
BUAC Barcelona University, Arthropod Collection, Spain.
BNHMA Buenos Aires Natural History Museum, Argentina.
CBCMS Centre for Biodiversity and Conservation Museum, Sydney, Australia.
CNIC Canadian National Collection of Insects, Ontario, Ottawa, Canada.
CAUBC China Agricultural University, Insect Collections, Beijing, China.
FUIC Ferdowsi University, Insect Collections, Mashhad, Iran.
FSCAG Florida State Collection of Arthropoda, Gainsville, United States.
KUZKP Karachi University, Zoology, Insect Collections, Karachi, Pakistan.
LSEBB Laboratoire de Systématique et d'Ecologie animale, Bruxelles, Belgium.
MNPA La Plata Museum, Universidad National de La Plata, Argentina.
LEM Lyman Entomological Museum, McGill University, Canada.
MNHN Museum National d'Histoire Naturelle, Paris, France.
NUZNC Nankai University, Zoology, Insect Collection, Nankai, China.

NNML Nationaal Natuurihistorisch Museum, Leiden, the Netherlands.
NSMJ National Science Museum (TZNSM), Tokyo, Japan.
PPDRI Plant Pests and Diseases Research Institute, Tehran, Iran.
QNHM Queensland Natural History Museum, Brisbane, Australia.
RBCM Royal British Columbia Museum, Victoria, B.C., Canada.
ROM Royal Ontario Museum, Toronto, Ontario, Canada.
SEM Spencer Entomological Collection, Beaty Biodiversity Museum, University of British Columbia (UBC), Vancouver, BC, Canada.
EEIMF Unité d'entomologie, ENSAM – INRA, Zoologie, Montpellier, France.
ZISPC Zoological Institute, Insect Collection, St. Petersburg, Russia.
ZMTF Zoological Museum, University of Turku, Turku, Finland.

RESULTS AND DISCUSSION

The habitats

Adults and nymphs were mostly found in houses and rarely in out-houses. The favorite habitats of adults and 2nd, 3rd, 4th, and 5th instar nymphs were floors, stairs, basements, garages, crevices, cracks, corners, underneath household objects, storehouses, cellars and stables. Adults and nymphs were not detected outdoors during daylight hours but adults were often found after sunset on walls and foliage close to light fixtures. Mature insects were observed to fly short distances towards light and were commonly sighted outdoors in June and July. Only two live female adults were captured indoors mid-January and February, 2005. Several adults were captured on spider's webs near light fixtures in out-houses, near roof corners inside garages, and indoors within air conditioning-heating canals. Two live 3rd instar nymphs were found outdoors in late winter (March 18, 2001), on the wall of a dwelling in a dusty hole (2 x 9 cm) covered by a spider's web , in South Beaconsfield, Quebec. The hole was located between two bricks and under an external light fixture. Adults were also collected in the West Island area of Montreal which includes the townships of Beaconsfield, Ste-Anne-de-Bellevue, Kirkland, Pointe Claire, Ile Perrot, St. Lazare and Oka. Scudder (1961,1992) reported a large number at dockside warehouses in Vancouver, and also indoors and in garden sheds in Osoyoos, British Columbia. DeGeer (1773), Fabre (1903), Butler (1923), and Readio (1927,1931) reported the habitats of this insect, in Europe and Kansas, USA. Popov (pers. comm.) observed that a number of adults of *R. personatus* flew towards the light after sunset in early July 2002, near the Black sea area of Russia.

Characteristics of Egg, Nymph and Adult

Description of different stages were reported by several researches. Readio (1927, 1931), Putshkov & Moulet (2009) reviewed the literature and described the life stages from materials collected in Kansas, USA, and Europe, respectively.

The following brief descriptions of the egg, nymphs, and adult of *R. personatus* are based on materials from southeastern Canada, field-collected or cultured by the writer.

Eggs - Oblong-oval, 1 mm long and 0.4 mm wide, shining brownish-yellow colour, distinct brown cap and minute micropylar processes (Figs. 1A, B).

First instar - Length of body 2-3 mm; colour whitish, eyes reddish and bean-shaped. Hind legs longer than body (Figs. 2A, B).

Second instar- Length of body 3.5- 4.5 mm; slightly darker in colour than the first instar. Dorsum of head and thorax distinctly sclerotized and brownish (Fig. 7. Top row of A).

Third instar- Length of body 6-7 mm; Colour darker than the second instar; abdomen whitish; head, thorax, legs and antennae more sclerotised and brownish; eyes reddish; wing pads present (Figs. 4A, B; 7 top row of A).
Fourth instar - Length of body 8-9 mm; colour as in third instar; abdomen slightly darker with five dark spots on lateral margins of segment 2-6; wing pads extending to second abdominal segment (Figs. 3A; 7 top row of A).
Fifth instar - Length of body 12-14 mm; head elongate, narrowed to neck basally, and widest across eyes; wing pads extend to middle of abdomen; colour similar to fourth instar (Figs. 3B; 7 top row of A).
Adult - Length of body 17-21 mm; Antennae four-segmented and filiform particularly segments III and IV; the ocelli very large, shining brownish-black hue; the femora-tibia joint and tarsi pale or honey-coloured; wings fully developed and extending to end of abdomen (Figs. 6A, B; 7A, B).
The antennae and legs of adult and instars are covered with dark fine and long setae.

Food

Fabricius (1775), in his first reference to this insect stated "Larva horrida, personata, consumit *C. lectularius*" , and Linnaeus (1758) gave a very brief statement, " The larva preys upon the common house bug".

De Geer (1773), Fabre (1923), Butler (1923) and Readio (1927,1931) commented that this insect feeds on the larva and adult of a number of other insects. Ambrose (1999, 2000) stated that this insect feeds on insects and ticks. Putshkov and Moulet (2009) reviewed the prey taken by this insect and mentioned that it attacks and feeds on ectoparasites and arthropods such as dermestids, flies , mites, as well as the larva and adult of Lepidoptera and other Coleoptera.

The writer has had excellent success in rearing four successive generations of this insect on a diet of flies, small larvae and adults of other insects, swept from fields. As well, nymphs and adults of this insect were fed on cultured larvae and adults of the flour moth, when prey were scarce in the field in early spring and late summer (Table, 1).

Throughout the present studies, many observations on habits of this insect, such as capturing, killing and feeding have been made. A summary of these follows.

Adults and nymphs are attracted to prey by their movement. They approach a potential prey, quietly touching it gently with their antennae, then grabbing it with their front legs. It insert its stylets into the softer parts of the victim, and injects its venom (Fig. 6A). The prey is paralyzed within 0.5 to 3 minutes. Feeding continues for several hours during which the predator may change its feeding position to the head, thorax, or the abdomen. The process of capturing and killing the prey is thus distinct from that of predatory pentatomids (Javahery, 1986). Although this reduviid was able to grab carpenter ants, it could not kill them, because this potential prey reacted quickly with bites to fend off attacks. Extensive feeding was observed during the pre-maturation stage. Cannibalism was observed in the adult stage in the absence of prey (Fig. 7B). Additionally, first instar nymphs fed on other immatures or eggs. The insects caught in field or reared in the laboratory to feed *R. personatus* in this study are shown in Table 1.

This bug has not been known to be harmful to humans, but Leconte (1855) reported that "when caught or unskillfully handled it always stings with its beak." J.T. Polhemus (pers. comm.) observed that the two cats in his home in Englewood, Colorado near Denver, left their sleeping pads after this reduviid began feeding on them. Also, M. Giroux (pers. comm), reported that a person in

Montreal, received a painful bite on his foot from this bug when putting on his boots. However, no biting incidents of humans or pets were observed during this study.

The venom responsible for killing prey or causing pain or irritation in humans and pets has not been analyzed.

Reproductive Biology

The terminalia of the male , the aedeagus and claspers (Figs. 5A to F) and female genital plates (Figs. 5G, H) are illustrated. Captured and reared insects were reproductively active during summer. Females exhibited a maximum of three upright eggs within each ovariole. The eggs within the ovariole are honey-coloured. Eggs are fertilized in the common oviduct through the micropyle channels on the egg-cap. This mechanism is similar to other Heteroptera as seen through scanning electron microscope (e.g., *Acrosternum hilare* (Say), Pentatomidae; (Javahery, 1994). Adults survived without food for 2-3 weeks but were sensitive to food deprivation during the development of eggs and oviposition. Extensive feeding, walking and short flights were observed during reproduction.

Mating behavior

Mating in most Heteroptera is end-to-end (e.g., *Eurygaster integriceps* Puton, Javahery 1995). However, in *R. personatus*, mating was observed to occur in a lateral orientation (Fig. 6B). In this case, the responsive female would move slightly forward, and then the male would mount it, holding on to both sides of the female's thorax with its front legs and would rapidly touch the head, front legs, and antennae of the female. Several seconds later, the male would move slightly backward with his genitalia out-stretched and insert its aedeagus into the genitalia of the female. The male would then lie laterally alongside the body of the female throughout the mating episode. Dispons (1955) reported that the male of *R. personatus* puts its rostrum on the anterior margin of the female's pronotum. Mating was observed to last several minutes to five hours, during which the female would feed or move short distances, carrying the male on her side. Females usually mate 4-6 times while nonresponsive females moved away quickly. Harz (1952) states that many matings are necessary to fertilize all the eggs.

Fecundity and Longevity

The number of eggs deposited by each female of *R. personatus* is reported by several writers. Fabre (1923) obtained from 30 to 40 eggs, but Readio (1927) stated the total number deposited during the life of the female was 273. The writer observed that on average a female deposits 3-5 eggs in 24 hours with a total of 48-157 eggs over her life time. Males lived an average of 68 days and females 88 days. The maximum longevity of a female was 217 days.

Oviposition, Incubation, Embryonic development, and Hatching

Fabre (1923) and Readio (1927) noted June was the time of egg laying, and that eggs are not attached to the substrate. Fabre gave an interesting account of the hatching process of this reduviid. The writer has had excellent success in observing the oviposition, incubation, embryonic development, and hatching of this insect during the study. My observations indicated that mated females began to lay eggs in June and continued until early autumn with 85 percent of the eggs laid in July to mid-August. Incubation of the eggs and development of the embryo occurred within a 2-3 week period (Fig. 1C). Up to 98 percent of the eggs hatched in the morning period in July and August. Fabre (1923) observed hatching during the night or early morning but Dispons (1955) states that in North Africa hatching in R. personatus take place at night as well as during the day. The role of

the egg-burster in hatching is similar to a number of other true bugs (Javahery, 1994). The egg-burster was found to be of distinct shape; it had two very long semi-chitinized horns attached to the embryonic membrane (Figs. 1D, E). The tooth of the egg-burster is located between the horns and the underlying eyes of the embryo (Fig. 1D). The chorionic incision for lifting the egg-cap to hatch, results from peristalsis and focused pressure of the egg-burster within the circle of micropylar processes (Figs. 1D, E). The first instars appeared from early August to the end of September and moulted into the 2nd stadium after two weeks. Aggregation of 1st instars around egg-shells, common in some true bugs (Javahery, 1994), was not observed in this insect.

Nymphal diapauses

Different accounts on the life cycle of *R. personatus* are reported in Europe and North America, particularly on nymphal diapause or overwintering. Diapause starts in early winter and terminate in spring. Third, 4th and 5th instars, but rarely 2nd instars, do not feed during winter in southern Quebec and Ontario.

The habits, stages of development, and life cycle of this insect have been mostly studied by European workers. References on the life cycle of this species in North America are very limited, especially in Canada. However, there is variation in the length of the stages, particularly during nymphal diapauses. A summary of what is known of nymphal development is given below:

Butler (1923) reported that the life cycle of *R. personatus* was nonseasonal in England, because the species is a household insect and lives indoors. He states that the imago has been found from May to September, but is associated more or less with places of human occupation, and has no definite seasons for the different stages.

Readio (1927) points to a seasonal life history; winter was spent as a nymph usually in the 4th or 5th instar, although as 3rd instars in a few instances, and normally became adults in May or June. Some, however, did not undergo the final moult until July and possibly August. De Geer (1773) and Poujade (1888) (in Butler, 1923) reported similar overwintering nymphal dormancy in the fifth stage and moulting to the adult in June of the following year. Putchkov (1986) observed one generation per year while overwintering as a 4th or 5th instar in England, Germany and the Ukraine. He also mentioned a two-year life cycle in Germany and the United States, where the nymphs spend the first winter in the third instar. Scudder (1992) reported a two-year life cycle, overwintering in the 3rd and the 5th instars in British Columbia, Canada.

This writer's experience on overwintering nymphs in Quebec and Ontario during four generations points to a two-year life cycle with an obligatory diapause during the first winter in the 3rd instar and overwintering the following winter in the 5th (Table, 2). The insect normally becomes an adult in May and June. However, the writer has collected two individual adults indoors at a temperature of 20°C in late January 2005 and at 22°C in early February 2008. It would seem that two successive winter dormancies in *R. personatus* is obligatory and not induced by the environmental conditions as mentioned by Readio (1931) and Scudder (1992).

The two-year life cycle observed in the writer's study in eastern Canada appears to be similar to that reported for *R. personatus* in the west coast of this country (Scudder, 1992). However, it is not yet clear, that this insect also has a proportion of its population with a single generation a year as in its habitats as in England, Germany and the Ukraine (Butler, 1923; Putchkov, 1986).

Origin and Distribution

There is no definite information as to the time that *R. personatus* was introduced into North America (Blatchley, 1926; Readio, 1927; Schaefer, 1988; Schuh & Slater, 1995; Maw et al., 2000; Putshkov & Moulet, 2009). However, examination of specimens deposited in the National Collection of Insects in Ottawa, other collections in Canada, and several in the USA, showed that the first female was captured in 1905 by Arthur Gibson in Ottawa, and the second in July 20, 1917 by C.E. Petch in Hemingford, Quebec. One specimen of *R. personatus* collected in the USA was in June 20, 1917 by R.I. Mitchelle in Norwalk, Ohio.

This alien true bug, like the predatory *Picromerus bidence* (L.) and the plant feeder *Acrosternum hilare* (Say) (Javahery, 1986, 1990), is well adapted in its new environment in Canada and the eastern USA (Fig. 8). Because there is no record of the importation of this bug for evaluation as a potential biocontrol agent of house pest insects or spiders by either the Canadian or the U.S. Department of Public Health, Environment or Agriculture, it is believed to have been introduced accidentally, perhaps carried with household goods (probably transported in the 3rd or 5th instars) when people migrated from Europe sometime in the late eighteenth or early nineteenth century into Canada and eastern US.

R. personatus has a wide distribution (30°-52° latitude and 12W-67 E longitude) in North America (Uhler, 1886; Van Duzee, 1917; Blatchley, 1926; Readio, 1927; Maldonado-Capriles, 1990; Scudder, 1992; Maw et al., 2000; Javahery, 2002, 2008), and within 35°-63° latitude and 10 W to 65 E longitude in the Western Palaearctic (Southwood & Leston, 1959; Putshkov & Moulet, 2009).

This bug has rarely been reported from the west coast of USA. Wygodzinsky and Usinger (1964) stated: that it has been collected from the states of Washington, Oregon, Utah, Nevada, and Colorado, and also some from Arizona, but the species is significantly very rare in California, and was never reported in the literature. They also reported having seen only one specimen, a male, in the Department of Entomology, University of California, Davis.

Adults, and nymphs, deposited in the institutions and collections listed have been examined by the writer and in several cases by curators or heteropteran colleagues. According to the current survey, distribution of this insect appears to be expanding in Canada, with a gap in the central states (Alberta, Manitoba, Saskatchewan), and in the east (Nova Scotia, Prince Edward Island, Newfoundland). The species is established in eastern USA (Fig. 8). In Europe, the insect has been found from southern Sweden and Norway to North Africa, and from England and Estonia to the southern Caspian Sea. It has not been found in Finland (Fig. 8). The writer has not seen specimens of this insect in collections in eastern China, Australia, and Argentina.

CONCLUSIONS

Reduvius personatus, was introduced into Canada and the USA probably sometime in the late eighteenth or early ninteenth century. This alien species is established, although not numerous in Canada (southern Ontario, Quebec, New Brunswick, British Colombia) and in the eastern USA above 32° latitude.

The life cycle and distribution of this insect has been studied in Europe, but very little was done in North America.

This large assassin bug has a two-year life cycle, overwintering the first winter in the 3rd instar and in the second winter as a 5th instars. Mating is side-by-side (lateral orientation), whereas, this is end to end in a number of other Heteroptera. It oviposits singly, dropping eggs which do not adhere to the substrate or to other

eggs. The egg-shell is relatively thick with minute micropylar processes. The embryonic membrane has two long semi-chitinized hooks connected to the egg-burster. The bug can withstand food deprivation but cannibalism occurs in the absence of prey.

The two-year life cycle of this insect is also recorded in the USA, Germany, and Canada. Single generation or seasonal development reported in England, Germany, and the Ukraine, was not observed in Canada in Ontario, Quebec, and British Colombia. However, two individual adults where collected in January and February in Beaconsfield, west of Montreal, Quebec. Nymphs exude a sticky substance which facilitate body-masking with dust particles. This camouflage has given rise to the alternative names "masked bug" or "masked bed bug hunter."

Nymphs did not feed from December to April, although food was always provided and temperature was maintained between 16-19° C with variable day light. They entered into dormancy for the two winters. It seems dormancy in this bug is obligatory and not induced by environmental temperature or humidity and light.

This species may depress the population of small, soft-bodied insects in houses and out houses and may be considered a useful predatory true bug. However, its long period of nymphal development, its low rate of reproduction, and the wide range of prey acceptance, are disadvantages if this species were to be considered for biological control of specific insect pests in houses.

More rearing experiments from different populations of this reduviid both in the original habitats (Europe) and its newly adapted environments (Canada and USA) would be desirable to determine whether a single generation occurs as well in North America. It will also be useful to rear this bug at different photoperiods during nymphal development to determine whether photoperiodism is a regulator of dormancy in this insect.

ACKNOWLEDGEMENTS

My thanks to all colleagues associated with the institutions and collections listed in the text for allowing me to examine specimens under their care. Special thanks to C.W. Schaefer, P. Moulet, R. Manuel and the late N. Barthakur for reviews on the manuscript; S. Boucher, J. Brambila, A. Buchaman, C. Buddle, M.Carver, G. Cassis, M. Coscaron, the late I.M. Kerzhner, R.E. Linnavuori, J. E. McPherson, G. Monteith, V. Rinne, G.G.E. Scudder, and T. A.Wheeler for useful comments or providing references.I also thank, I. Ahmad, P. Azmayesh Fard, W. Cai. Guo-Qing, F. Cherot, C. Copley, M. Goula, M. Modarres Awal, J. Mohaghegh, K.M. Needham, D. Pluot-Sigwalt, Y.A. Popov, E. Ribes, J.F. Roch, J-C Streito, M. Tomokuni for data on locating; Belgique Hainaul Centre for image 5 (top) and R. Lemke for image 5 (bottom).

Further thanks are due to S. Brooks, M. Giroux, J. Mlynarek, and C. Borkent for the identification of dipteran preys; J. Macdonald, D. Edge, and A. Ghassemian for running computers.

Finally, I am indebted to my family for their patience and help in collecting bugs and preys.

LITERATURE CITED

Ambrose, D. P. 1999. Assassin bugs. Science Publishers. Inc., Enfield, New Hampshire, U.S.A. 337 pp.

Ambrose, D. P. 2000. Assassin Bugs (Reduviidae excluding Triatominae). pp. 695-712. In: C. W. Schaefer & A. R. Panizzi (Eds.), Heteroptera of Economic Importance. CRC Press, Boca Raton, Florida. USA. 828 pp.

Blatchley, W. S. 1926. Heteroptera or True Bugs of Eastern North America with Especial Reference to the Faunas of Indiana and Florida. Nature Publ.Co.,Indianapolis.Indiana, U.S.A. 1116 pp.

Boucher, S. 2006**.** Les Insectes de nos jardins. Broquet. Inc. Québec, Canada. 208 pp.

Butler, E. A. 1923. A Biology of the British Hemiptera–Heteroptera. H. F. and G. Witherby, London, U.K. 682 pp.

De Geer, C. 1773. Mémoires pour servir à l'Histoire des Insects. Volume 3. P. Hosselberg, Stockholm. viii + 696 pp.

Dispons, P. 1955. Les Reduviidae de l'Afrique nord occidentale. Mémoires du Museum national d'histoire naturelle, Zoologie, 10: 93-240.

Dupuis, C. 1955. Les genitalia des Hémiptères Hétéroptères. Mémoires MNHN, 6: 183-278.

Dupuis, C. 1970. Heteroptera. in: S.L. Tuxeu (Ed.) Taxonomist's Glossary of Genitalia in Insects. Munksgaard. Copenhagen. pp. 190-201.

Dusoulier, F. 2007. An historic French record in the archives: discovery of a 15th Century bug. Het News. 9: 2.

Fabre, J - H. 1923. Le Réduve à Masque. Souvenires Entomologiques, 8° Serie: 95-110.

Fabricius, J. C. 1775. Systema entomologiae, sistens insectorum classes, ordines genra, species, adjectis synonymis, locis, descriptionibus, observationibus. Flensburgi et Lipsae. Korte. Xxvii + 832 pp.

Froeschner, R. C. 1988. Family Reduviidae Latreille, 1807. The Assassin Bugs. pp. 148-265. In: T. J. Henry & R. C. Froeschner, (Eds.). Catalog of the Heteroptera or true bugs of Canada and the Continental United States. E.J.Brill, Leiden, the Netherlands. 958 pp.

Harz, K. 1952. Ein Beitrag zur Biologie von *Reduvius personatus* L. (Rhynchota Heteroptera). Nachrichtenblatt der bayerischen Entomologen, 1: 73-75.

Immel, R. 1954. Biologische Beobachtungen an der Staubwanze (*Reduvius personatus* L.). Zool. Aenz. Leipzig, 152: 96-98.

Immel, R. 1955. Zur Biologie und physiologie von *Reduvius personatus* L. Zeitschrift der Morphologie und Ökologie der Tiere, 44: 163-195.

Javahery, M. 1986. Biology and Ecology of *Picromerus bidens* (Hemiptera: Pentatomidae) in southeastern Canada**.** Entomological News, 97 (3): 87-98.

Javahery, M. 1990. Biology and ecological adaptation of the Green Stink Bug (Hemiptera : Pentatomidae) in Quebec and Ontario. Annals of the Entomological Society of America. 83: 201-206.

Javahery, M. 1994. Development of Eggs in some true bugs (Hemiptera-Heteroptera). Part I. Pentatomoidea. Canadian Entomologist, 126: 401-433.

Javahery, M. 1995. A technical Review of Sunn Pests (Heteroptera: Pentatomoidea) with special reference to *Eurygaster integriceps* Puton. FAO. Regional Office for the Near East, Cairo, Egypt. 80 pp.

Javahery, M. 2002. Abstract: Biology and distribution of *Reduvius personatus* (Hemiptera: Heteroptera) in Canada. Second Quadrennial Meeting of the HIS. St. Petersburg, Russia.

Javahery, M. 2008. Abstract: Biology of *Reduvius personatus* and its distribution around the world. XX III, ICE. Durban, South Africa. p. 227.

Larochelle, A. 1984. Les Punaises Terrestres (Hémiptères:Géocorises) du Quebec. Fabreries Supplement, 3 : 513 pp.

Leconte, J. L. 1855. Remarks on two species of American *Cimex*. Proc. Acad. Nat. Sci. Philadelphia 7: 404.

Linnaeus, C. 1758. *Cimex personatus*. Syst. Nat., end. 10, i, p. 446.

Maldonado-Capriles, J. M. 1990. Systematic Catalogue of the Reduviidae of the World (Insecta:Heteroptera). University of Puerto Rico, Mayaguez. Puerto Rico. U.S.A. 694 pp.

Marshal, S. A. 2006. Insects. Their Natural History and Diversity. With a photographic guide to insects of eastern North America. Firefly book. 718 pp.

Maw, H. E. L., Foottit, R. G., Hamilton, K. G. A. & Scudder, G. G. E. 2000. Checklist of the Hemiptera of Canada and Alaska. NRC Research Press. Ottawa. 220 pp.

McPherson, J. E. 1999. Survey of the Reduviidae (Heteroptera) of Southern Illinois, Excluding the Phymatidae, with notes on biology. Great Lakes Entomol., 32: 151.

Moore, G. A. 1950. Catalogue des Hemiptères de la Provence de Québec. Nature. Can., 77: 233-271.

Moulet, P. 2002. Systématique, biologie, écologie et éthologie des Reduvidae (Heteroptera) du Ventoux (Sud Est France). PhD Dissertation. Avignon. 203 p.

Moulet, P. 1980. Description of eggs and larvae of certain assassin bugs (Heteroptera,Reduviidae) of the European south Ukraine. Vestnik Zoologii, 1980 (4): 30-38 [in Russian].

Moulet, P. 1981. The egg morphology of the assassin bugs (Heteroptera,Reduviidae) from the European part of the USSR. Ventnik Zoologii, 1981 (6): 25-33 [in Russian].

Moulet, P. 1986. Local distribution and life cycle of assassin bugs (Heteroptera, Reduviidae) of the Ukraine. Ent. Rev. 65 (3):1-13 (Scripta Techica Inc. translation) [Original in Russian Ent. Obozr., 65 (2): 313-324].

Moulet, P. 1987. Reduviidae. In Fauna Ukrainy. 21. 248 pp.

Putshkov, P. V. & Moulet P. 2009. Hémiptères Reduviidae d'Europe occidentale. Faune de France, vol. 92. F. F. S. S. N., éd. Paris. 668 pp.

Putshkov, P. V. & Putshkov, V. G. 1996. Family Reduviidae Latreille, 1807. Assassin bugs. pp148-265. In: Aukema, B. & Rieger, C. (Eds.). Catalogue of the Heteroptera of the Palaearctic Region. Vol. 2. Cimicomorpha I. Wageningen. The Nederlands. 361 pp.

Rahimi, M., Modarres Awal, M. & Hashemi Mehneh, A. 2010. Introduction to Assasian Bugs (Het.: Reduviidae) in Mashhad Region (Khorasan Razavi Province) and their Distribution. Munis Entomology & Zoology, 5 (Suppl.): 945-948.

Readio, P. A. 1927. Studies on the biology of the Reduviidae of America north of Mexico. Univ. Kans. Sci. Bull., 17: 6-291.

Readio, P. A. 1931. Dormancy in *Reduvius personatus* (Linnaeus). Annal Entomological Society of. Amer., (24): 19-39.

Schaefer, C. W. 1988. Reduviidae as agent of biological control; in: Biocovas, K.S. Ananthasubramanian, P. Venkatesan and S. Sivaraman (Eds.). Loyola College, Madras, 1: 27-33.

Schaefer, C. W. & Panizzi, A. C. 2000. Heteroptera of Economic Importance. CRC. Press. LLC, Florida, U.S.A. 828 pp.

Schuh, R. T. & Slater, J. A. 1995. True Bugs of the world (Hemiptera:Heteroptera): Classification and Natural History. Cornell University Press, Ithaca, New York, USA, 336 pp.

Scudder, G. G. E. 1961. Some Heteropteran new to British Columbia. Proc. Entomol.Soc. Br. Columbia. 58: 26-29.

Scudder, G. G. E. 1978. Hemiptera. Reduvioidea. In: Canada and its Intsect Fauna.H.V. Danks (ed.), Mem. Entomol. Soc. Can., 108: pp. 337; 573 pp.

Scudder, G. G. E. 1992. The distribution and life cycle of *Reduvius personatus* (L.)(Hemiptera;Reduviidae) in Canada. J. Entomol. Soc. British Columbia, 89: 38-42.

Southwood, T. R. E. 1956. The structure of the eggs of the terrestrial Heteroptera and its relationships to the classification of the group. Transactions of the Entomological Society of London, 108: 163-221.

Southwood, T. R. E. & Leston, D. 1959. Land and Water Bugs of the British Isles. Frederick Warne & Co. Ltd., London & New York. 436 pp.

Uhler, P. R. 1886. Check list of the Hemiptera Heteroptera of North America. Brooklyn Entomological Society. Brooklin, New York iv +32 pp.

Van Duzee, E. P. 1917. Catalogue of the Hemiptera of America North of Mexico. Excepting the Aphididae, Coccidae and Alevrodidae. University of California Publications. Technical Bulletin, Entomology, 2: xiv + 902 pp.

Wygodzinsky, P. & Usinger, R. L. 1964. The Genus *Reduvius* Fabricius in Western North America (Reduviidae, Hemiptera, Insecta). American museum Novitates, 2175.

Yang, C.-T. & Chang, T-Y. 2000. The external male genitalia of Hemiptera (Homoptera-Heteroptera): National Chung Hsing University. Shih Way Publication. Taiwan. 746 pp.

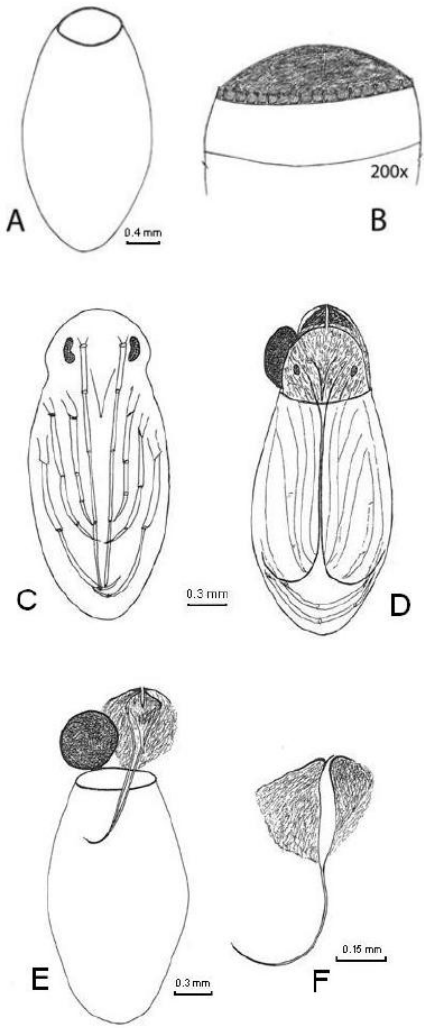

Figure 1. *Reduvius personatus* – Egg, A; operculum with minute micropylar processes, B; 200X; developed embryo, C; hatching process while embryo is enveloped in membrane, D; operculum and egg-burster are attached on top of egg-shell, E; egg-burster, F.

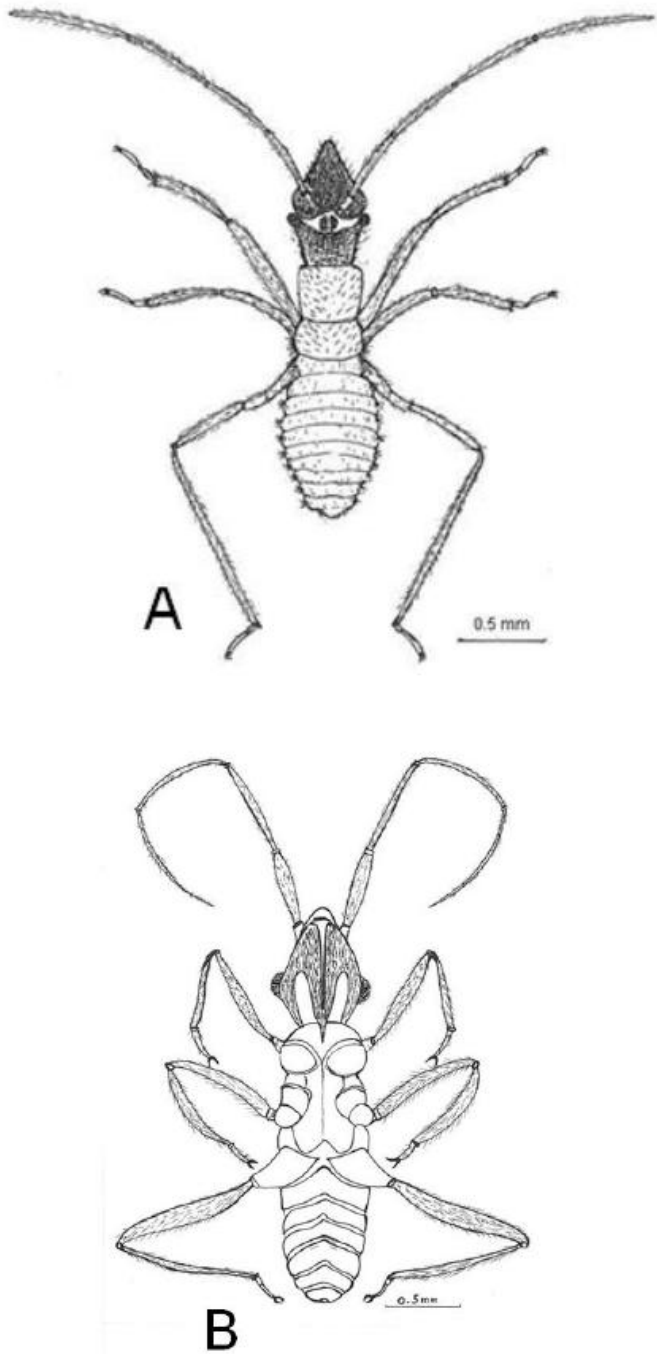

Figure 2. *Reduvius personatus* – First instar, dorsal view, A; ventral view, B.

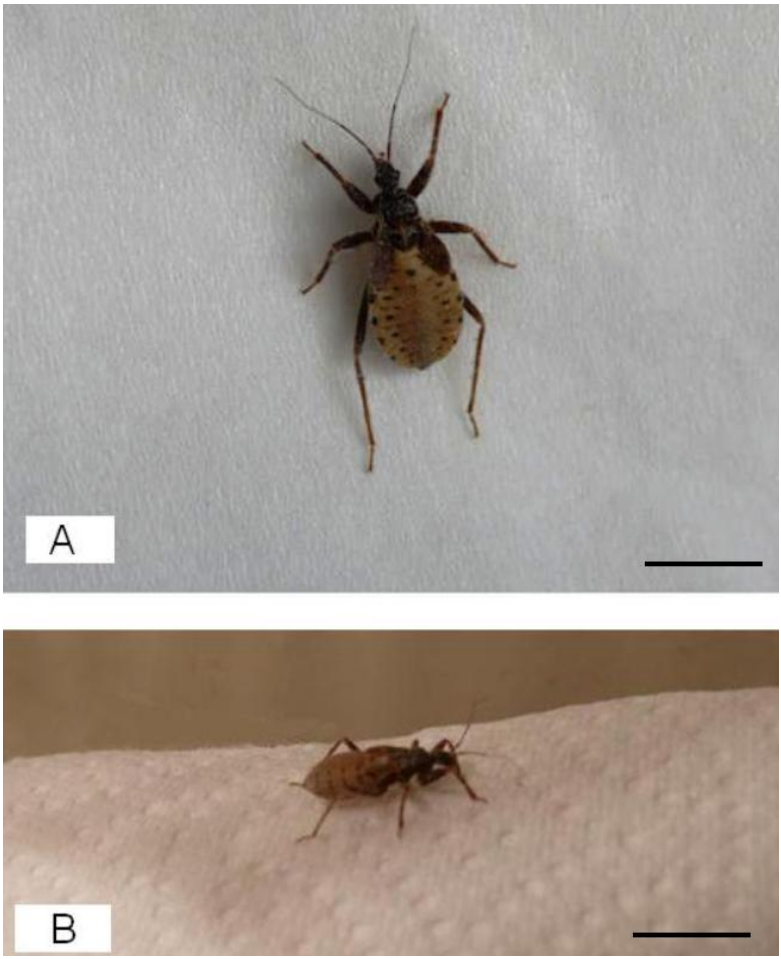

Figure 3. *Reduvius personatus* – 4th instar, A; 5th instar nymph, B.

Figure 4. Masked 3rd instar of *Reduvius personatus* A and B.

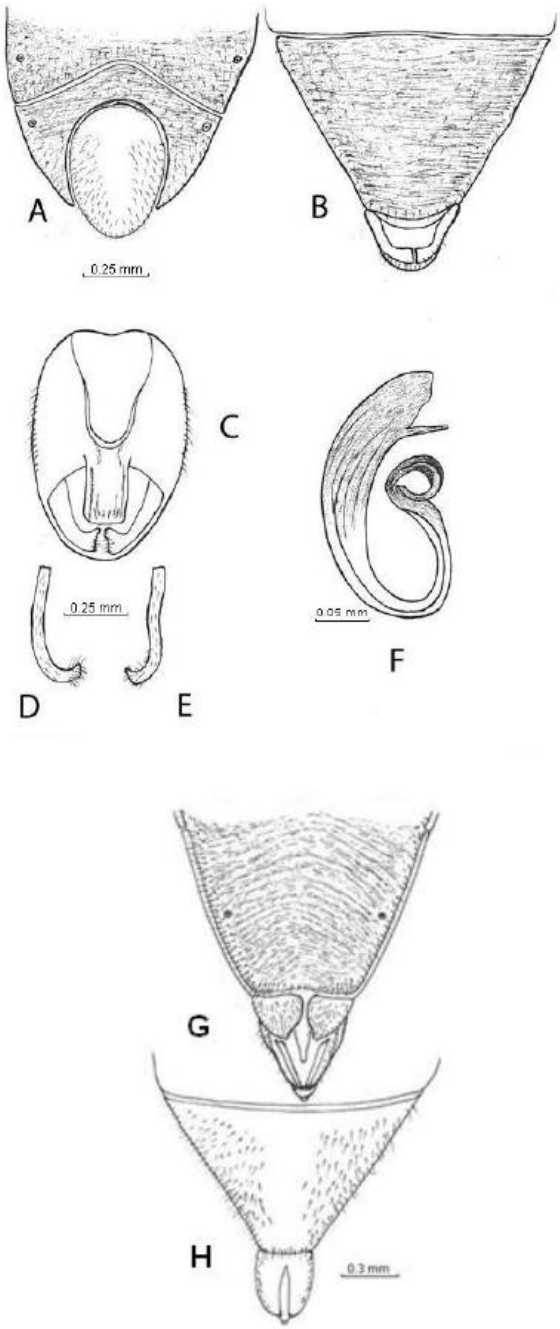

Figure 5. *Reduvius personatus* – Male terminalia: Ventral view, A; dorsal view, B; genital organs,C ; right and left clasper D and E; aedeagus, F. Female terminalia: Ventral view, G; dorsal view, H.

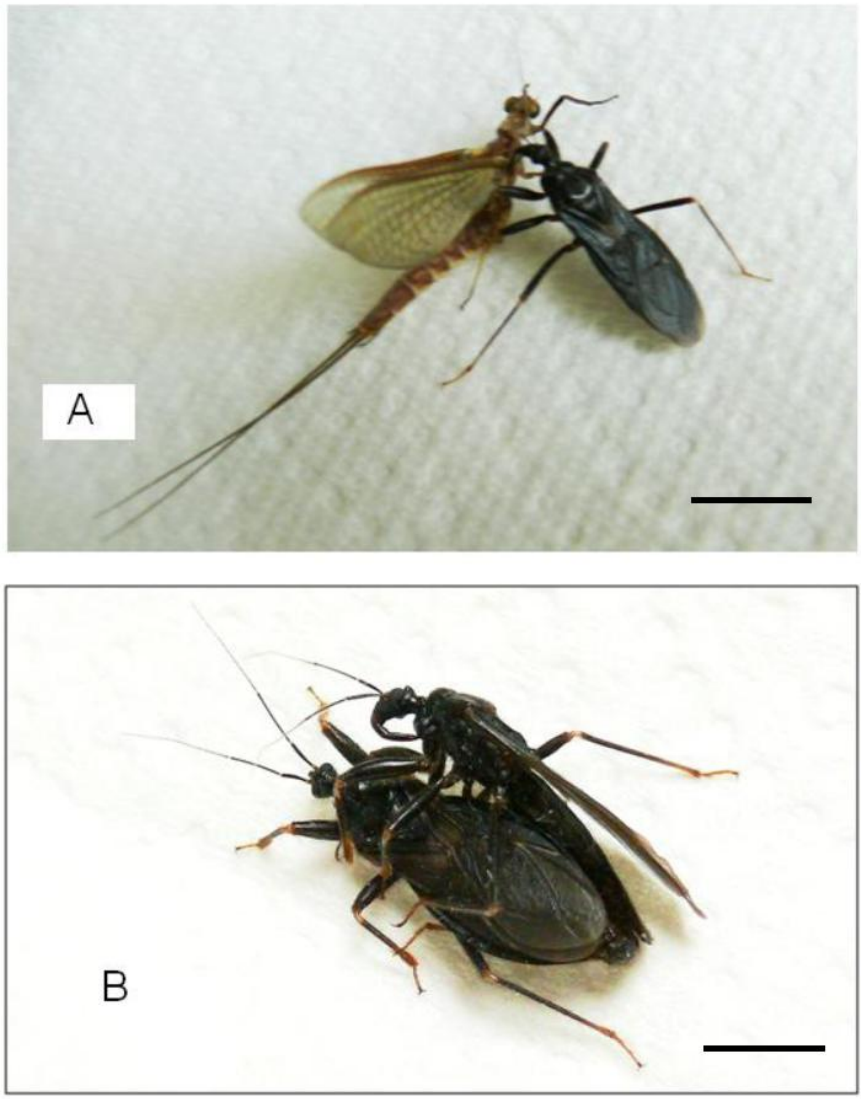

Figure 6. Female *Reduvius personatus* feeding on a mayfly, A (scale bar = 8 mm); side by side (lateral) copulation of *Reduvius personatus*, B (scale bar = 10 mm).

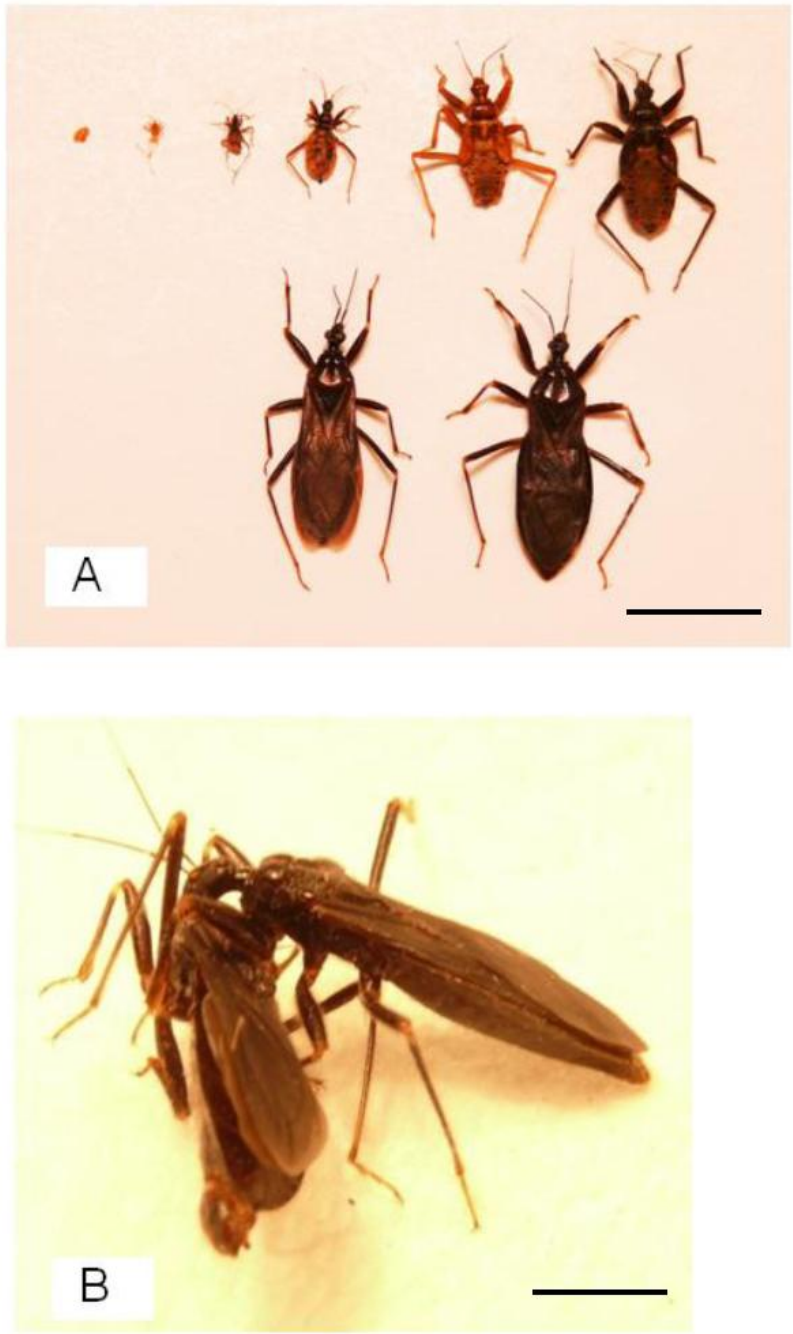

Figure 7. Development of *Reduvius personatus,* A: Egg to nymphal development (top row of A); a pair of adult *R. personatus* with female on the right (bottom row of A) (scale bar = 8mm). B. Cannibalism (*Reduvius personatus* : female feeding on male).

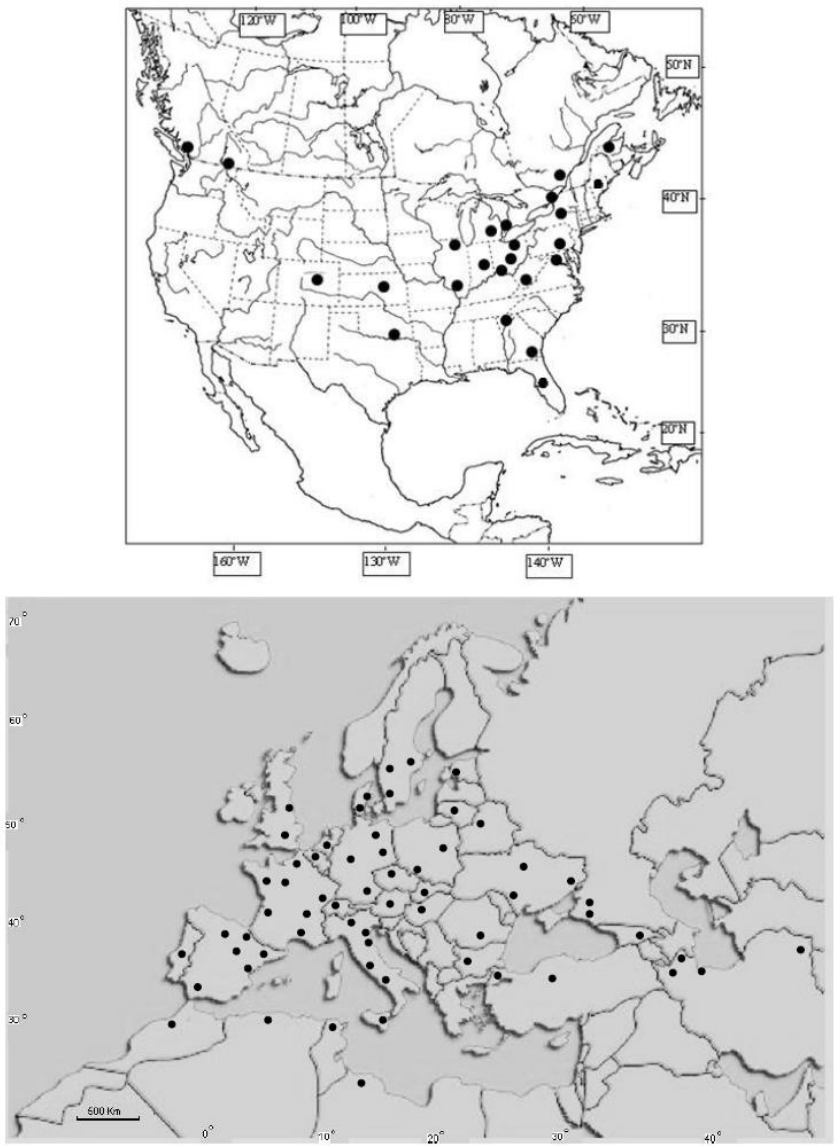

Figure 8. Geographical distribution of *Reduvius personatus* in Canada and the U.S.A. (top). Distribution of *Reduvius personatus* in Western Palaearctic in this study (bottom).

Table 1. Insect prey of *R. personatus* in this study

Taxa	Family	Genus & Species	Common Names
Diptera	Anthomyiidae	*Hilemia brassicae* (Bouchi)	Root-Maggot flies
	Calliphoridae	*Pollenia rudis* (L.)	Cluster fly
	Dolichopodidae	*Condylostylus sipbo* (Say)	Long-legged fly
	Muscidae	*Musca domestica* (F.)	House fly
		Stomoxys calcitrans (L.)	Stable fly
	Sarcophagidae	*Sarcophaga* sp.	Flesh fly
	Syrphidae	*Syrphus torvus* O.S.	Hover fly
	Tabanidae	*Tabanus similans* Macquart	Horse fly
Ephemeroptera	Ephemeridae	*Ephemera* sp.	Mayfly
	Heptageniidae	*Heptagenia limbata* Pict	
Odonata	Libellulidae	*Libellula insesta*	Dragonfly
Homoptera	Cicadellidae	*Chlorotettis unicolor* (Fitch)	
Heteroptera	Miridae	*Lygus lineolaris* P. de B.	Tarnished Plant bug
Lepidoptera	Pyralidae	*Anagasta kuehniella* (Zeller) *Plodia interpunctella* (Hubner)	Flour mouth
Orthoptera	Tettigoniidae	*Scudderia furcata* Brunner	Grig

Table 2. Nymphal development time of *R. personatus*.

Nymphal stedia	First	Second	Third	Forth	Fifth	Adult
Occurrence	July To Sept.	Aug. to Sept.	Spring After First Winter of Dormancy	Spring and Summer	Spring and Summer and second Winter dormancy	Spring and Summer
Duration	15 - 25 (day)	18 - 28 (day)	5 – 6 (month)	3 - 4 (month)	6 - 7 (month)	4 - 6 (month)