BioOne COMPLETE

Management and Conservation Dilemmas Surrounding a Near-Threatened Grasshopper, Aularches miliaris Linn. (Orthoptera: Pyrgomorphidae) in South India

Authors: Josephrajkumar, A., Rajan, P., Chandra Mohanan, R., and Jacob, P.M.

Source: Journal of Orthoptera Research, 20(1) : 103-107

Published By: Orthopterists' Society

URL: https://doi.org/10.1665/034.020.0110

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://bioone.org/journals/Journal-of-Orthoptera-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Management and conservation dilemmas surrounding a Near-Threatened grasshopper, *Aularches miliaris* Linn. (Orthoptera: Pyrgomorphidae) in south India

A. Josephrajkumar, P. Rajan, R. Chandra Mohanan and P.M. Jacob

(AJ, PR, PMJ) Central Plantation Crops Research Institute, Regional Station, Kayangulam – 690 533, Alappuzha district, Kerala, India.
Email: entojoe2003@yahoo.co.in
(RCM) Central Plantation Crops Research Institute, Kasaragod 671 124, Kerala, India.

Abstract

The world is facing severe biodiversity loss and agencies worldwide are attempting to stem this threat. However problems arise when a rare or threatened species is also an agricultural or medical pest. In this paper we discuss the case of *Aularches miliaris*, the spotted coffee grasshopper. This species exists as several subspecies across south Asia, perhaps representing local genetic adaptation. It is polyphagous and a minor agricultural pest, and is usually managed via insecticides and egg-bed destruction. For much of its range, populations appear healthy and are not threatened. In contrast, within the Western Ghats Biodiversity Hotspot in south India, *A. miliaris* is sparse and listed as Near-Threatened. In this area the insect is an occasional minor agricultural pest. Considering its local rarity, versus its abundance in other geographic areas, we recommend that in south India *A. miliaris* needs to be conserved at the present time. During localized outbreaks, we recommend that *A. miliaris* be managed via mechanical collection of nymphs and adults, and destruction of egg pods, rather than intervention using insecticides.

Key words

spotted coffee grasshopper, *Aularches miliaris*, Western Ghats, Kerala, *Erythrina indica*, coconut

The world is currently facing massive biodiversity loss due to human overpopulation, habitat destruction and fragmentation, climate change, the effects of invasive species, disease, pollution, excessive recreational use and harvesting, and natural ongoing geological processes (Wagner & Van Driesche 2010). Mawdsley & Stork (1995) estimate that 11,200 insect species may have gone extinct since the 1600s, and that butterfly species are disproportionally affected. The 2008 World Conservation Union's "Red List of Threatened Species" lists 17,000 threatened species of which more than 600 are insects and 68 are Orthoptera.

Considerable efforts are being made to avert further biodiversity loss. Among these are actions which include captive breeding, establishing seed and gene banks, bans on fishing and harvesting, creation and management of parks, preserves, sanctuaries, and conservation areas, and regulatory enforcement (Williams & Hoffman 2009). However, while we are attempting to preserve some species, we are attempting to eradicate others. Excessive human population growth requires ever-increasing agricultural production in the face of declining farmland, fisheries, water, energy, and fertilizer availability. As such, it is evermore imperative to reduce or eradicate populations of agricultural pests.

But, herein lies a conundrum: what do we do when a population is both a pest and endangered? In such cases there is a conflict between reducing and increasing population numbers (Samways & Lockwood 1998). Hence, conservation of rare and threatened species can be quite complex. An example of conflicting management strategies is seen when a species is rare in one geographic area, but common or pestiferous in another geographic area. The katydid *Decticus verrucivorus* (L.) is threatened in Britain, yet common in parts of continental Europe (Samways & Harz 1982), and the cricket *Gryllotalpa gryllotalpa* L. is listed as endangered in Britain (Haes 1987), yet is a well-known pest elsewhere within its natural range in Europe, Asia and North America (Hill 1987).

Pest management also conflicts with conservation when blanket application of pesticides harms hundreds of other nontarget species (Ware 1980). Examples include area-wide spraying for mosquitoes, fire ants, and locusts (Peveling *et al.* 1994, Lockwood 1998).

A great many species that can harm humans are threatened or endangered. Examples include tigers, lions, panthers, wolves, bears, and sharks that sometimes kill humans or livestock (Quammen 2003). Elephants and some threatened primates sometimes invade the gardens of subsistence farmers (Jayant *et al.* 2007). In the western USA, poisonous snakes are often killed on sight, and some communities encourage "rattlesnake roundups", whereby people catch and kill as many snakes as they can find in a day (Hayes *et al.* 2008). Despite their potential to harm humans, many of these "harmful" species are charismatic, play essential roles in the community, are biologically unique and fascinating and therefore deserve preservation (Quammen 2003).

Other species can be harmful at high density but beneficial at low density. For example, high density populations of *Melanoplus sanguinipes* (F.) can devastate rangeland and cropland, but at low densities this species may be beneficial, preferring to feed on low-value forbs or noxious weeds (Pfadt 1994). This pattern of feeding on low-value plants at low densities and high-value plants at high densities appears common in *Melanoplus*, so that labeling these grasshoppers as pests (Vickery 1994) is a simple but an inaccurate approach to grassland management.

The ~24,000 described species of Orthoptera (Orthoptera Species File) span the range of harmful to beneficial, abundant to rare. Many endangered Orthoptera species are confined to a small geographical area and are highly threatened by anthropogenic impacts that coincide with their restricted ranges. Some formerly widespread and abundant species have become extinct in the recent past (Lockwood & DeBrey 1990, Samways & Lockwood 1998). Other orthopterans can reach very high numbers without becoming pests because their feeding does not threaten, and may even benefit, humans. For example, although potentially devastating to crops, high densities of the Mormon cricket, *Anabrus simplex* Haldeman, rarely if ever cause significant damage to rangeland (Redak *et al.* 1992). So also is the case of the snakeweed grasshopper, *Hesperotettix viridis* (Scudder), which can reach densities of 30 m^{-2}, but feeds exclusively on poisonous plants (Pfadt 1994).

The above examples serve to illustrate that management of pest

Downloaded From: https://bioone.org/journals/Journal-of-Orthoptera-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

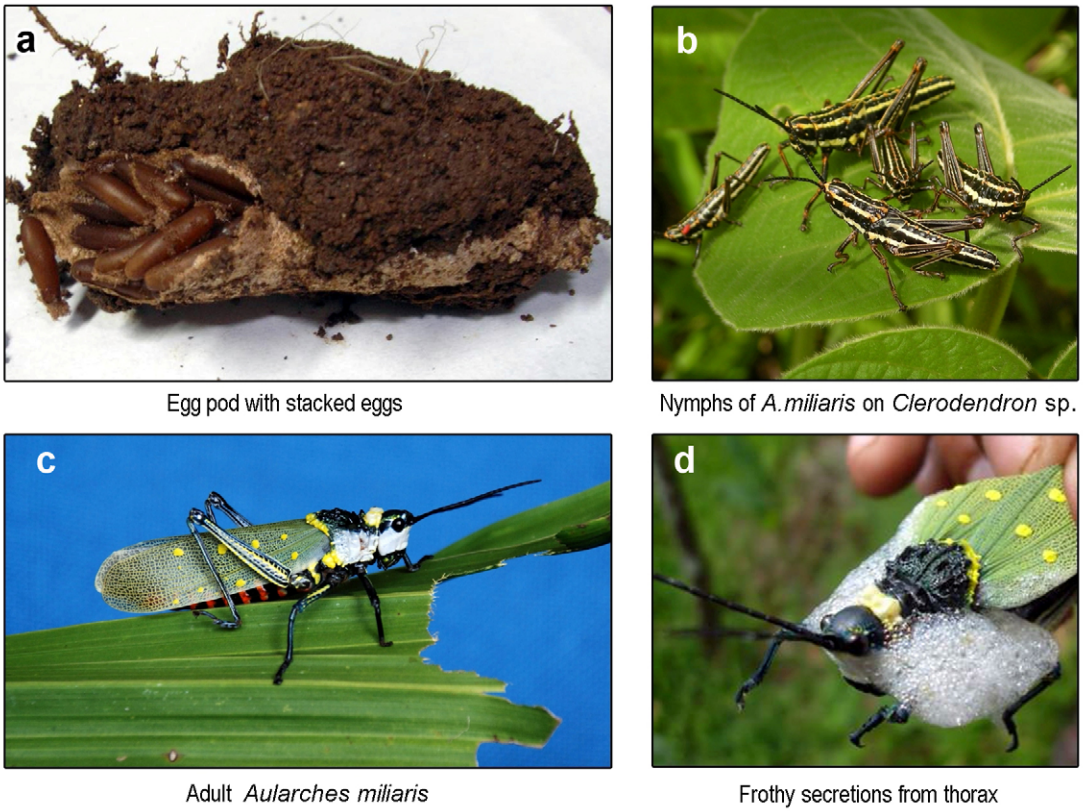


Fig. 1. a) Egg pod of *Aularches miliaris* broken open to show cigar-shaped eggs. b) Nymphs of *A. miliaris* aggregating on *Clerodendron* sp. leaf in Kerala, India. c) Adult male showing aposematic coloration. d) Adult *A. miliaris* ejecting bitter defensive secretion from thorax in response to handling. For color version, see Plate VII.

populations frequently conflicts with conservation. We report here on an interesting grasshopper, the spotted coffee grasshopper, which is both Near-Threatened (NT) in south India, and an agricultural pest. We first provide background on the bionomics of this insect, and then present some management recommendations for populations in Kerala, south India

Bionomics and life-history of the spotted coffee grasshopper.— *Aularches miliaris* Linn. (Orthoptera: Pyrgomorphidae) is a south Asian species, distributed across much of India, Bangladesh, Cambodia, Sri Lanka, the Malay Peninsula, Thailand, Union of Myanmar, and Java, and parts of Pakistan, Tibet, Nepal, and China (Lever 1969, Hsiung 1987, Roffey 1979). In India, it has been collected from down near sea level on the flat plains of the Brahmaputra river, in Jorhat, Assam (Senthilkumar *et al*. 2006) and up at 1700 m from a green pasture surrounded by thick forest in Kashmir (Bei-Bienko & Mishchenko 1951). It is also reported from Pong Dam Sanctuary, a wetland area of 423 acres situated at the base of the Dhauladhar ranges in Kangra district, Himachal Pradesh, India (Shishodia *et al*. 2002).

As such, the species can survive in a wide range of habitats, including tropical evergreen forest (Senthilkumar *et al*. 2006), wetlands (Shishodia *et al*. 2002), hilly forest (Mahmood & Yousuf 2000) and upland forest (Chandrasekhar *et al* 2008). Habitats also include the plains and hilly districts of Travancore, India (Jones 1940). In peninsular Thailand, Roffey (1979) claims that *A. miliaris* is confined to the "coconut belt", just above the shore line. The species is phytophilous, generally remaining off the ground, inhabiting plants from near ground level to the tops of trees (Roffey 1979).

Across its range, the species appears to be univoltine. In Kerala, India, adults lay up to 80 eggs in egg pods inserted into soil during September-November. Eggs are largely confined at the bottom of the egg pod, stacked one over the other, and these egg pods measured 5-7 cm (Fig. 1a). Egg laying takes place mostly in uncultivated patches in and around cultivated area. The incubation period is about 5 months. Hatching occurs in February-March, at the beginning of summer season. Nymphs are blackish with three yellowish stripes on the dorsum (Fig. 1b) and undergo six instars before becoming adults in three months (Nair 1990, Lever 1969).

The adults are large, bulky, and brightly colored, with adult males 37-55 mm long and adult females 47-69 mm long (Katiyar 1955, Roffey 1979). Adults in Kerala, India are aposematically colored with a black head, yellow tuberculate thorax, greenish forewings with yellow spots and a black and red-striped abdomen (Fig. 1c). These bright colors warn potential predators that the insect is chemically defended (Roffey 1979, Whitman 1990). Indeed, *A. miliaris* exhibits the Chemical Defense Syndrome, which includes toxicity, large size, bright warning coloration and clumping behavior (Whitman & Vincent 2008). Both nymphs and adults have a tendency to aggregate (Fig. 1b), with nymphal bands reaching up to 300,000 individuals (Nigam 1959, Roffey 1979) and adults sometimes flying in swarms (Jones 1940, Roffey 1979). When attacked, *A. miliaris* adults make a squeaking sound similar to that produced during mating (Vander Laan 1981), and discharge up to a teaspoon of a slimy, bitter tasting white froth from openings distributed on the thorax (Fig. 1d) (Hingston 1927, Carpenter 1938, McCann 1953, Whitman 1990). As a result, this insect has few vertebrate predators (Katiyar 1955, Roffey 1979, Whitman 1990).

Populations of this species fluctuate widely in numbers from year-to-year. In some habitats and years, densities in Thailand can reach as high as 2000 nymphs per m^2 (Roffey 1979), and in others,

Downloaded From: https://bioone.org/journals/Journal-of-Orthoptera-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

no *A. miliaris* can be found. Nymphs sometimes form bands that march (Roffey 1979). Adults are moderate fliers, with long wings, and will swarm and migrate short distances (Roffey 1979). In June 1939, a swarm a quarter of a mile long and fifty yards wide, was reported from Kalanjoor, Central Travancore, south India (Jones 1940). Hence this species can establish new populations in previously uninhabited locations.

Green (1906) and Hutson (1926) claim that nymphs are highly polyphagous, consuming almost any wild or cultivated plant. Across its range, *A. miliaris* is a minor insect pest of coffee, banana, arecanut (*Areca catechu*), coconut, teak, dadap (*Erythrina lithosperma*), mango, cardamom, cassava, castor, durian, guava, maize, mango, mulberry, oil palm, rice, sugar cane, chillies, cocoa, cotton, custard apple, jute, pigeon pea, rubber, sesame, sorghum and pine, causing occasional economic damage to these and many other crops (Jones1940, Roffey 1979, Nair 1990, Josephrajkumar 2007). Roffey (1979) notes that "while the number of species of food plants recorded is large, *Aularches* appears to be only a minor pest of most". In Sri Lanka, *A. miliaris* is said to prefer dadap, but when that crop is unavailable, will invade coconut, arecanut, jack (*Artocarpus integrifolia*) and banana (Hutson 1926). In Sri Lanka, the coconut plantations near dense forests are most often attacked by this grasshopper (Mahindapala & Pinto 1991). Jones (1940) reported large populations of *A. miliaris* in the plains and in the hilly districts of Travancore, Kerala, India which completely defoliated a young teak (*Tectona grandis*) plantation and also attacked other trees including coconut palms, mango, arecanut palm, jack and banana.

Control measures attempted against this pest include the use of insecticide sprays and dusts (Roffey 1979), spraying soap solution onto young nymphs, collection and destruction of egg masses and adults (Jones 1940). Mechanical collection and destruction of adults followed by raking of breeding grounds and exposure of eggs were suggested by Hutson (1926).

This species is subdivided into several subspecies or color morphs with similar life-histories. All can attack agricultural plants. For example, *Aularches miliaris pseudopunctatus* Kevan, 1972 was reported from Gibbon Wild Life Sanctuary, Assam, India, where it comprised nearly 10% of all Orthoptera individuals collected out of 25 Orthoptera species at that site (Senthilkumar *et al.* 2006). This sanctuary is a tropical semi-evergreen forest located on the flat plains of the Brahamaputra river (100-120 m altitude) (Senthilkumar *et al.* 2006). Another subspecies, *Aularches punctatus* Drury, the northern spotted grasshopper, is common in north India. Roffey believed that *A. punctatus* was a "color variety" of *A. miliaris* and Katiyar (1955) described its life-history and ecology.

Status as a threatened species.—According to the International Union for Conservation of Nature and Natural Resources (IUCN), *A. miliaris* is designated as a Lower Risk Near-Threatened taxon for south India. As such, it is not Critically Endangered, Endangered, or Vulnerable, but faces a risk of being threatened. Near-Threatened is a conservation status assigned to a species or lower taxon (an evolutionarily significant unit) that may be considered threatened with extinction in the near future, although it does not currently qualify for the threatened status (Daniel *et al.* 1998). The IUCN designation suggests that the species should be carefully monitored in south India, which encompasses part of Western Ghats.

In this context, the recent occurrence of *A. miliaris* in high altitudes of the Idukki district, Kerala, south India presents a dilemma as to whether a conservation or suppression strategy should be employed for this species. *A. miliaris* was reported from different upland forest areas in this district in 1983, 1994, 2003, 2005 and 2008 in relatively small proportions without causing any appreciable economic damage (Chandrasekhar *et al.* 2008). In the present investigation, conducted in April-May 2010, we found nymphs of *A. miliaris* in a garden near Melekuppachampady, 15 km north from Kattapana (lat 9.765°N, long 77.116°E), Idukki district, Kerala, India. This hill city of Kerala (> 900 masl) is part of the Western Ghats-Sri Lanka Biodiversity Hotspot, which possesses high species diversity and endemism, and is under protection.



Fig. 2. *Erythrina indica* tree (~ 8 m tall) showing *A. miliaris* feeding damage. In south India this tree is pruned to 3-4 m and then used to support and shade black pepper vines. Although the grasshoppers will feed readily on *E. indica*, they generally do not feed on the black pepper vines.

In total, the grasshopper population encountered in our survey consisted of about 1000 nymphs belonging to different instars with a density ranging from 0-30 nymphs/m^2. The nymphs fed on a wide array of plants, including mango, banana, coffee, arecanut, and weeds like *Macaranga indica*, *Clerodendron* sp. and *Abutilon indicum*. However, the highest nymphal feeding damage was on *Erythrina indica*, a common live-standard used for trailing (training) black pepper. On some plants, leaves were eaten down to their mid-ribs (Fig. 2). Other crops were less damaged. There was some nibbling of coconut leaflets in one of the coconut palms. Otherwise the pest was predominantly confined to *E. indica* and the above weeds. Though *A. miliaris* was found voraciously feeding on *E. indica*, the black pepper vines trained on the *E. indica* were untouched by the grasshopper.

Currently, *A. miliaris* in the Idukki district, Kerala appears to be restricted to elevations between 900-1300 masl where mean air temperature does not exceed 34-35°C during the summer (Jose-

Downloaded From: https://bioone.org/journals/Journal-of-Orthoptera-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

phrajkumar *et al*. 2007, Chandarsekhar *et al*. 2008). According to the biotic theory of locusts, periodic locust outbreaks follow periods of climate extremes which annihilate natural enemies of the locust (Pradhan 1969). However, such extreme weather conditions do not occur in this hilly district. Despite scattered reports of *A. miliaris* in the Idukki district since 1983, it has never caused severe crop damage in the area or attained any outbreak status on any of the plantation crops including cardamom, the major cash crop of the area. However when *A. miliaris* is seen, local cardamom planters sometimes indiscriminately apply insecticides, fearing potential damage to this high-value crop. This has led to outbreaks of minor, secondary pests like whiteflies and red spider mites on cardamom due to insecticide-reduction of natural enemies (Chandrasekhar *et al*. 2008).

Management recommendation for the spotted coffee grasshopper.— Many factors must be considered when assessing the conservation status of a species. These include size of the residual population, population fluctuations, breeding success rates, known threats, abundance in other geographic areas, *etc*. On the one hand, *A. miliaris* is a widespread species, with many healthy populations scattered across south Asia (Roffey 1979). Occasionally, this insect can be a severe pest on a very local scale (Roffey 1979). On the other hand, the species is variable, with many subspecies and color morphs that may represent valuable evolutionarily significant populations that should be saved. In the Western Ghats Biodiversity Hotspot, this species is sparse, primarily feeds on weeds, and only occasionally causes economic damage. Although the Central Travancore area of Kerala witnessed a severe outbreak of this pest during 1939, there have been no reports of similar outbreak or economic damage on high-value crops since that time. Although scattered occurrence of this pest has been noticed in different pockets of Idukki district from 1983 onwards, population density has not reached an economic threshold warranting insecticide application.

Owing to the irregular appearance of *A. miliaris* in the ecologically sensitive Ghats Hotspot, and its current Near-Threatened conservation status, we recommend that this insect be conserved for the time being. IUCN periodically reviews the status of Near-Threatened species, and unless high numbers start to appear naturally, we should aim to maintain *A. miliaris* in a similar way to that of the Nilgiri tahr (*Nilgiritragus hylocrius*), an endemic mountain goat of Western Ghats (Daniels 2006). Consequently, a serious effort for combining and coordinating various conservation programmes, including hotspot-specific safeguard tactics, should be followed as a viable and ecologically safe strategy in conserving the evolutionarily significant subspecies and races of *A. miliaris*. However, in a localized outbreak situation, an eco-friendly management strategy involving mechanical collection of the grasshoppers and destruction of egg laying sites by tillage is recommended, rather than intervention using insecticides.

References

Bei-Bienko G.Y., Mishchenko L.L. 1951. Locusts and grasshoppers of USSR and adjacent countries. Part I & II, Monson, Jerusalem

Carpenter G.D.H. 1938. Audible emission of defensive froth by insects. Proceedings Zoological Society of London, Series A. 108: 243-252.

Chandrasekhar S.S., Varadarasan S., Ansar Ali M.A., Gopakumar B. 2008. Yellow spotted green grasshoppers in cardamom. Do not panic. Spice India 21: 24-25.

Daniel B.A., Molur S., Walker S. 1998. Report of the Workshop Conservation Assessment and Management Plan for selected soil invertebrates of Southern India (BCPP Endangered Species Project), p 70. Zoo Outreach Organization, Coimbatore, India.

Daniels R, J.R. 2006. The Nilgiri Tahr: An Endemic South Indian Mountain Goat. Macmillan India, New Delhi, India.

Green E.E. 1906. The spotted locust (*Aularches miliaris*. L.). Journal Royal Botanical Gardens Peradeniya 3: 227-236.

Haes E.C.M. 1987 Orthoptera, pp. 49-53. In: Shirt D.B. (Ed.) British Red Data Books 2. Insects, Peterborough, Nature Conservancy Council, UK.

Hayes W.K., Beaman K.R., Cadwell, M.D., Bush S.P. 2008. Biology of the Rattlesnakes, Lema Linda University Press.

Hill D.S. 1987. Agricultural Insect Pests of Temperate Regions and their Control, Cambridge University Press, UK.

Hingston R.W.G. 1927. The liquid-squirting habit of oriental grasshoppers. Transactions Entomological Society of London 75: 65-68.

Hsiung C.C. 1987. The present status of orthopterology in China, pp. 260-272. In: Baccetti B. (Ed.). Evolutionary Biology of Orthopteroid Insects. Ellis Horwood, Chichester, UK.

Hutson J.C. 1926. The spotted locust, *Aularches miliaris* L. Yearbook Department of Agriculture, Ceylon pp.36-44.

Jayant K., Mehta P., Boominathan D., Chaudhuri S. 2007. A study of man-elephant conflict in Nagarhole National park and surrounding areas of Kodagu district in Karnataka, India, Final Report, Envirosearch, Pune.

Jones S. 1940. A visitation of the spotted locust (*Aurlarches miliaris* L.) in Travancore. Journal of the Bombay Natural History Society 41: 676-678.

Josephrajkumar A., Backiyarani S., Sivakumar G. 2007. Compendium on cardamom, KAU publications, Thrissur.

Katiyar K.N. 1955. The life-history and ecology of the northern spotted grasshopper, *Aularches punctatus* Drury (Orthoptera: Acrididae). Agra University Journal of Research 4: 397-414.

Lever R.J.A.W. 1969. Pests of Coconut Palm, Food and Agriculture Organization, Rome, Italy.

Lockwood J.A. 1998. Management of orthopteran pests: a conservation perspective. Journal of Insect Conservation 2: 253-261.

Lockwood J.A., DeBrey L.D. 1990. A solution for the sudden and unexplained extinction of Rocky Mountain grasshopper (Orthoptera : Acrididae). Environmental Entomology 22: 503-518.

Mahindapala R., Pinto J.L.J.G. 1991. Coconut Cultivation. Coconut Research Institute, Luniwila, Sri Lanka.

Mahmood K., Yousuf M. 2000. Taxonomic study of some Pyrgomorphidae and Catantopinae (Acridoidea : Orthoptera) from Azad Jammu & Kashmir. Pakistan Journal of Biological Sciences 3: 1914-1916.

Mawdsley N.A., Stork N.E. 1995. Species extinctions in insects: ecological and biogeographical considerations, pp. 321-369. In: Harrington R., Stork N.E. (Eds) Insects in a Changing Environment, Academic Press, London.

McCann C. 1953. Aposematic insects and their food plants. Journal of the Bombay Natural History Society 51: 752-754.

Nair M.R.G.K. 1990. A monograph on crop pests of Kerala and their control. Kerala Agricultural University, Thrissur.

Nigam L.N. 1959. Outbreaks of the spotted grasshopper in Assam and West Bengal. Plant Protection Bulletin, New Delhi 9 (1957): 13-15.

Orthoptera Species File. http://orthoptera.speciesfile.org/HomePage.aspx

Peveling R., Weyrich J., Müller P. 1994. Side-effects of botanicals, insect growth regulators and entomopathengic fungi on epigeal non-target arthropods in locust control, pp. 147-176. In: Krall S. and Wilps H. (Eds). New Trends in Locust Control. Deutsche Gesellschaft für Technische Zusammenarbeir (GTZ) GmbH, Eschborn, Germany.

Pfadt R.E. 1994. Field Guide to the Common Western Grasshoppers. Wyoming Agriculture Experiment Station, Bulletin 912.

Pradhan S. 1969. Insect Pests of Crops, National Book Trust, New Delhi, India.

Quammen D. 2003. Monster of God: the man-eating predators in the jungles of history and the mind. WW Norton, New York, USA.

Redak R.A., Capinera J.L., Bonham C.D. 1992. Effects of sagebrush removal and herbivory by Mormon crickets (Orthoptera: Tettigoniidae) on understorey plant biomass and cover. Environmental Entomology 21: 94-102.

Roffey I. 1979. Locusts and grasshoppers of economic importance in Thailand. Anti-Locust Memoir 14: 1-200.

Samways M.J., Lockwood J.A. 1998. Orthoptera conservation: pests and paradoxes. Journal of Insect Conservation 2: 143-149.

Downloaded From: https://bioone.org/journals/Journal-of-Orthoptera-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Samways M.J., Harz K. 1982. Biogeography of intraspecific morphological variation in the bush cricket *Decticus verrucivorus* (L.) and *Decticus albifrons* (F.) (Orthoptera : Tettigoniidae). Journal of Biogeography 9: 243-254.

Senthilkumar N., Barthakur N.D., Borah N.J. 2006. Fauna of Protected Areas-29. Orthopteran Fauna of the Gibbon Wildlife Sanctuary, Assam. Zoo's Print Journal 21: 2347-2349.

Shishodia M.S., Mehta H.S., Mattu V.K., Thakur S.K. 2002. Orthoptera (Insecta) from Pong Dam Wetland, District Kangra, Himachal Pradesh, India. Zoo's Print Journal 18: 1047-1048.

Vander Laan P.A. 1981. Pests of Crops in Indonesia, Ichtiar Baru P.T-Van Hoeve, Jalan Majapahit 6, Jakarta, Indonesia.

Vickery V.R. 1994. The Pest Grasshoppers of North America, North of Mexico, Quebec, Canada.

Wagner D.L., Van Driesche R.G. 2010. Threats posed to rare or endangered insects by invasions of nonnative species. Annual Review of Entomology 55: 547-568.

Ware G.W. 1980. Effect of pesticides on non-target organisms. Residue Reviews 76: 173-201.

Williams S.E., Hoffman E.A. 2009. Minimizing genetic adaptation in captive breeding programs: a review. Biological Conservation 149: 2388-2400.

Whitman D.W. 1990. Grasshopper chemical communication, pp. 357-391. In: Chapman R.F., Joern A. (Eds) Biology of Grasshoppers. Wiley, New York.

Whitman D.W., Vincent S. 2008. Large size as an antipredator defense in an insect. Journal of Orthoptera Research 17: 353-371.

Downloaded From: https://bioone.org/journals/Journal-of-Orthoptera-Research on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use