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Distribution, ecological and taxonomic study of *Locusta migratoria migratoria* (Linnaeus, 1758) and long term monitoring of its outbreak in Cold desert of Ladakh (UT) India

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Abstract
Short horned orthopetra from the family acrididae in gregarious phase is generally known as locust. In solitary condition they are harmless and overlooked. In history no epidemic of locust was snoop in the cold desert of Ladakh. In the last two decades *Locusta migratoria migratoria* (Linnaeus, 1758) *is* enormously affecting the livelihood of the trans-Himalayan region. Present study emphasized in Changthang, Chusul and Pangom Tso area of the Ladakh from 2008 to 2019. The purpose of this study was to explore the distribution, ecological and taxonomical aspects of the outbreak of migratory locusts in the fragile ecosystem. The long term monitoring assessed the geographic coverage of the locust infestation, swarming hotspots; evaluate the population parameters such as densities and developmental stages in the region. It was observed that migratory locust impinge along the Indus river area from Tibet and China and swarms year to year in Ladakh. They drastically impacted on the livelihood of the region with demolish the greenery of the area.

Keywords: grasshopper, climate change, population, insecticides and outbreak

Introduction
Locusts are part of a large group of insects commonly called grasshoppers belonging to the family Acrididae. Locusts have been among the most destructive agricultural pests throughout the course of human history (Uvarov, 1969) [19]. Locust outbreaks have occurred on all continents except Antarctica and they can harm the livelihood and well-being of 10% of the world's population (Latchininsky, 2010) [9]. Locusts are the only grasshopper species that display extreme density dependent phase polymorphism. Their outbreaks are attributed mainly to swarm formation and migration of high-density gregarious form (Wang & Kang, 2013 *Locusta migratoria migratoria* (Linnaeus, 1758) is a highly polymorphic species, the differences in colour being so great that looks like a separate species. Low population densities produce the solitary phase, whereas crowded conditions produce the aggregating, migratory gregarious phase (Simpson & Sword, 2008) [16]. Locust and grasshopper outbreaks can be chronic or episodic where there are alternating periods of invasion and recession (Zhang, *et. al*., 2019) [22]. Locust swarms often brought devastation and famine to entire nations (Latchininsky, 2018). Grasshoppers (Orthoptera: Acrididae), like a large number of other insects, have close ecological connections with soil attributes and even inhabit the soil environment during part of their life cycle (Johnson, D.L., 1989) [7]. Recently, an independent study from China (Jin & Wang 2018) [6] showed that monsoon rains have increased in the Indo-Pak deserts by 30% over the last two decades. Locust comes in swarm and lays eggs in the moist soil up to 10 cm depth and hatched within two weeks. These eggs undergo in hibernation, which hatched in coming year in June-August. But remain viable in the soil up to one to four year (Pfadt, 2002) [11]. After hatching high population of nymphs can cause heavy infestation of to the crop and other green vegetation (Steedman, 1988) [17]. During unfavorable time, grasshoppers remain relatively harmless, but in favorable condition with lots of food, populations soar and then form large swarms which fly across the landscape, consuming much of the vegetation in their path (COPR, 1982) [4]. Locust swarms can number in the millions and can wipe out crops (Guo *et al*, 2020) [5], causing famine in places like Ladakh. An adult locust

consumes up to 5 g of fresh vegetation daily, which amounts to over 80 g during its entire life span (nymph and adult). Twelve thousand locusts would destroy one ton of food plants during their lifetime (Latchininsky, 2010) [9]. The consequences of the invasions can be disastrous for both the food security and livelihoods of the rural populations in affected areas (Belayneh, 2005) [2]. Fatalities due to locusts and grasshoppers are not restricted to damage to pastures and crops. The swift loss of vegetation cover may result in socioeconomic of the area.

Material and Methods

The present study of locust distribution and ecology was based upon the direct observations of authors in the month of July, 2008, 2009, August 2012 and August 2019. Regular collections were made by an insect net of conventional design of 30 cm diameter from 8:00 AM to 11:00 AM. The sampled grasshoppers were fixed by ethyl acetate and for taxonomical study, the insects were preserved dry after relaxation and pinned, labeled and stored in the collection boxes with insecticides. The other supported parameters i.e. environmental and soil temperature, humidity, wind velocity, altitude, morpho metric data of locust, measured with standard instruments. The statistical data is consequence of IBM SPSS 26. To assess the population of the migratory locust density counting from the vehicle method (Scheepers & Dunn, 1958) [14] was integrated in the study at 10:00 AM and surveyed the area Chusul to Pangom Pso Lake 6 kilometer/hour in straight line, with front width of vehicle 1.20 meter. We took 15 transects of 100 meter and noted the adult flying grasshopper in front of vehicle in a band as wide as the front of vehicle. We did not count the grasshopper flying at the sides of vehicle. The density (D) per hectare is calculated as 100G/L. where G is the mean of numbers counted over several 100 meter transects and L is the width of vehicle. The map was prepared with the help of DIVA-GIS 7.5.0 version.

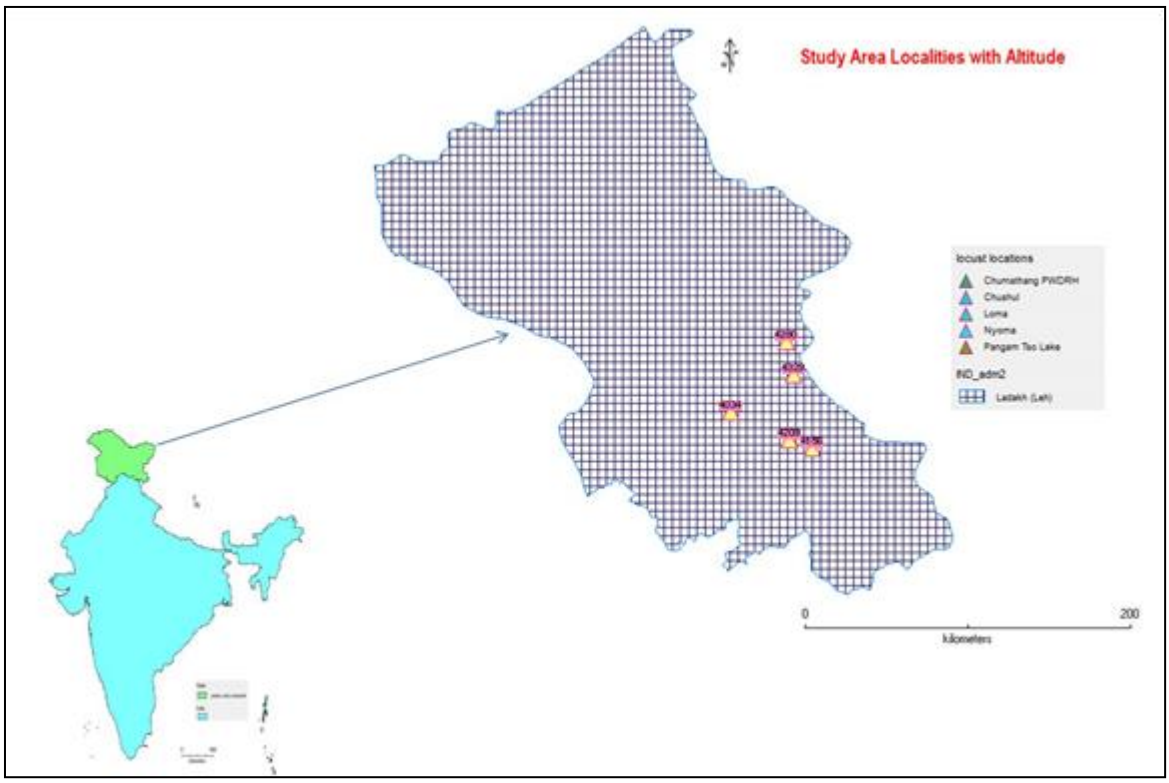

Fig 1: Diva-GIS Map Showing the study localities in Ladakh, UT

Results

Taxonomically the specimens are identified as:
Order: Orthoptera
Sub Order: Caelifera
Family: Acrididae
Sub family: Oedipodinae
Genus *Locusta* Linnaeus, 1758

***Locusta migratoria migratoria* (Linnaeus, 1758)**

1758. *Gryllus (Locusta) migratorius* Linnaeus, Systema Naturae per Regna Tria naturae, (10th ed.) 432.
1914. *Locusta danica* Kirby, Fauna Brit. India, Orth., 146.
1929. *Locusta rossica* Uvarov & Zolotarevsky, Bull. Ent. Res., 20:263.
1955. *Locusta migratoria solitaria* earthy, Ann. Mag. nat. Hist., 128:831-833.
2005. *Locusta migratoria migratoria*, Defaut, Materiaux Orthopteriques et Entomocenotiques,10:87.
2009. *Locusta migratoria*, Massa, *Jour. Orth. Res.*, 18(1) : 83.
Distribution: India: Himachal Pradesh, Jammu & Kashmir, Meghalaya, Orissa and Rajasthan. Elsewhere: All old Worlds except Europe.

Fig 2: Locust Nymph

Fig 3: Adult Locust

Observation

Migratory Locust (*Locusta migratoria migratoria* (Linnaeus, 1758) is reported in the swarming condition in Nyoma, Chushul, and Changthang area during the survey in the month of July, August 2008 and August 2009, August 2011. The invading and swarming of Locust was reported in the Cold Desert area entered through the only loophole of Palearctic region i.e. Tibet, and China. The Locust is known as migratory locust because of its long distance flying habit. Study found that the locusts route the Chinese border at Demchog approximately two years back. Since then the area has been incident locust invasion. But this year, the crisis has deteriorated due to favorable weather across the border. Maximum crops and pasture land greenery was affected in the Changthang area.

Adult Description

Color varies from mainly browns to greens in the solitary phase but some gregarious phase locusts have a bluish body with a yellow head and legs. In profile the head is slightly lower than the thorax but both are raised above the line of the wings. The thorax has a central ridge which is partly lost in the swarm phase. Folded forewings dark with thin light markings. Hind wings clear or sometimes faintly smoky blue/green. The rear leg tibia vary from straw to wine red colored. The mouth is dark. Throat peg absent but has a hairy 'chest' (underside of thorax). Migratory locust has 2 generations per year first from May to July, second from mid July to October in their natural circumstances. They laid the eggs in a pod in about 5 cm of soil depth during late summer and they hatch in the following spring. The Morpho metric observation in the fresh specimens of locust were recorded mean of five adult male and female are representing as:

Table 1: Morph metric measurement of locust male and female (All measurement in mm)

Specimen	Length of Body	Length of Tegmen	Length of Femur	Antennal Length	Distance between two compound eyes
Male	41.20±3.3	32.99±0.97	21.19±2.02	13.92±0.80	3.22±0.40
Female	55.33±2.2	35.48±0.9	29.46±0.9	15.69±0.6	4.18±0.1

Values are the mean of five readings; ± represents the value of Standard deviation.

The study area environmental parameters were recorded in different time period are represented in table-2

Table 2: Environmental Parameters of Study Localities in Ladakh (UT)

Location	Date	Vegetation Type	Altitude masl	Mean Temperature ^{0}C	Mean Humidity %
Loma	25-07-2008	Alpine pastures	4156	22.4	25
Chushul	01-08-2008	Agriculture field	4329	20.9	24
Pangom Tso	09-08-2008	Alpine pastures	4280	21.5	25
Chushul	24-08-2008	Alpine pastures	4329	22.3	22
Chushul	08-08-2009	Alpine pastures	4329	26.9	17
Chushul	13-08-2011	Alpine pastures	4329	20.9	24
Chushul	14-08-2019	Alpine pastures	4329	21.7	22
Chushul	21-08-2019	Agriculture field	4329	22.3	25

Values of mean temperature and humidity are of five readings

The population density through 15 transects of 100 meter each recorded the adult flying grasshopper in per hectare were observed in table-3. D=13,183/ specimens per hectare

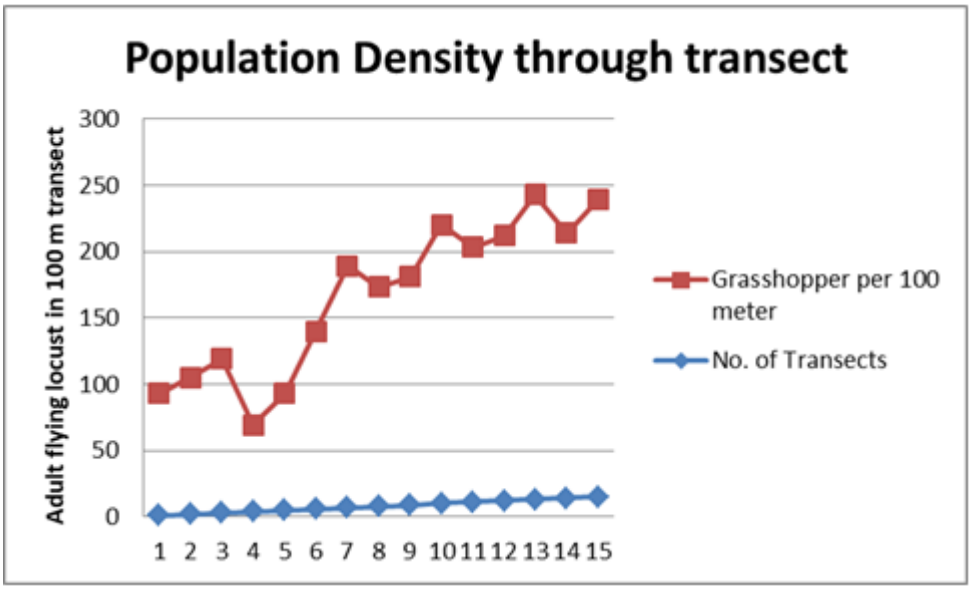

Fig 4: Showing the locust in each transect

Discussion

Monitoring of the locust in the fragile, cold desert ecosystem of Trans-Himalaya region was exceptionally complicated profession. The peoples of the area are totally confided on their modest agriculture turn out and there are no any other resources of living except few tourists. Present study accomplished that the locust species infestation was the *Locusta migratoria migratoria* (Linnaeus, 1758) and support the earlier study of Chandra & Sidhu, 2009; Kumar *et al*, 2009 and Veer *et al*, 2013 [3, 8, 20]. Outbreak of Locust was at the apex in the year of 2006 to 2008 and very minor swarms were testimony in the year 2011 and thereafter no such swarm description. Our study revealed that the ideal temperature for the swarming was the 22 ^{0}C and humidity was about 25 % validate the Wang and Kang, 2013, at such altitude our whole team suffer from the oxygen scarcity and these 40 to 60 mm creatures are fully active and flight up to 50 meters height and single leap more than 10-15 meters. Increased agricultural and developmental activities have further contributed to the loss of fragile ecosystem. Human life is very hard in the area due to altitudinal climatic situations. Their main agriculture crops once in the year are wheat, Barley, Peas and few vegetables. They also have to collect hay and grass for their cattle to feed them the whole of winter months. Agriculture and cattle farming are the only wealth of living. Locusts may harm agricultural crops but they are also important food sources for many raptors and other members of food web (Alexandre *et al*, 2011) [1]. Food and habitat are the most important factors determining survival and reproduction of animals (Schoener, 1974) [15]. The population density of locust per hectare was observed in good integer to infest the greenery of the area although this integer was very less compare to the desert locust recorded in the Jaisalmer, Rajasthan in 2019. Continuing monitoring revealed that *Locusta migratoria migratoria* (Linnaeus, 1758) are highly polyphagous, discontinuous distributed in the cold desert and took minimum 2-4 years for outbreak (Topaz *et al*, 2012) [18]. The assessment of locust risks and formulation of preventive measures our extensive ground based surveys primarily recommended the sustainable chemical insecticides to suppress locust outbreaks with concerns for human health and safety (Ralf, 2001) [13]. Locust management is essential for food security and viable agriculture economically. The ecological conditions largely determine the origin of outbreaks and managed by preventive strategies, the sustainability of locust seriously constrained by social, financial, economic, and organizational level (Lockwood *et al*, 2001) [10]. The religious sentiments of Buddhists in the area has deprived the spray uses to purge the locust. But the State Agriculture and Animal Husbandry Department have no any alternative to use the insecticides against the locust. Therefore the environmentalists are also concerned over the extreme use of pesticides in the plateau, due to a rare habitat of migratory and endangered birds.

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