Seasonal Abundance and Breeding Habits of *Aiolopus longicornis* sjostedt(Orthoptera : acrididae) in Cereal Crops in Central Ethiopia

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Abstract

Seasonal patterns in the abundance and breeding activity of *A. longicornis* in cereals in central Ethiopia, about 50 km south east of Addis Ababa, were studied from August 1986 to September 1988. Adult grasshoppers were sampled fortnightly by sweepnetting for 30 minutes and by making visual counts in strip-transects. In addition, adult females of *A. longicornis* were collected from tef (*Eragrostis tef*) fields during the same period and dissected. In all three years, peaks in the abundance and breeding activity of adult *A. longicornis* largely coincided with periods of short and long rains. The insect often started laying eggs very soon after the onset of rains, while spending the dry seasons as reproductively inactive adults. Peaks in abundance and breeding activity closely coincided with periods of active growth and development of tef and wheat crops, and it appears that up to four generations per year can occur. Differences in population levels between localities were apparently due to differences in the availability of surface water. The results are discussed in relation to the land use system and compared with the situation in a related species, *A. thalassinus*, in other parts of Africa.

Introduction

Seasonal variation in abundance and reproductive activity have been well documented in temperate zone insects. During recent years a considerable amount of information on tropical insects has appeared as well (Delinger, 1980; Young, 1982; Tauber et al., 1986; Wolda, 1988 and earlier). Several workers have demonstrated relations between the abundance or occurrence of various grasshopper species, both within and between years, and environmental factors such as soil and crop type and weather (for example, Fishpool and Popov, 1984; Capinera, 1987). Wide fluctuations in the seasonal abundance of tropical-subtropical insects (Wolda, 1988 and earlier), including grasshoppers (Fishpool and Popov, 1984; Uvarov, 1956), are correlated with, or caused by, precipitation. Temperature may also be involved (Uvarov, 1956).

However, for grasshoppers other than locusts, most of the information on tropical species is either from natural history studies or inventories (Fishpool and Popov, 1984). In Ethiopia knowledge about the seasonality and ecology of grasshoppers is generally lacking. The geography of the country is unique for Africa, consisting of largely highland plains at about 2000 m and above. The composition and structure of the grasshopper faunas of the region are influenced by the highland environment.

Tef, *Eragrostis tef* (Zucc.) Trotter, is the most important food crop in Ethiopia and is not used for human consumption anywhere else. Wheat is another of the most important crops, and both are often attacked by grasshoppers, which contribute to the recurrent famines. The tef grasshopper, *Aiolopus longicornis* Sjostedt, is of outstanding economic significance as a major pest of cereals in central Ethiopia (Tibebu and Landin, 1992).

The information about this species is scanty and fragmentary. It is mentioned as a pest in COPR (1982), and Stretch-Lilja (1977). Little or nothing is known about the seasonal abundance and life cycle of *A. longicornis* in the field, number of generations per year, reproductive periods and reproductive potential, etc.

In this study the seasonal abundance and breeding habits of *A. longicornis* in tef and wheat in central Ethiopia were investigated. The main purpose was to relate variations in abundance and reproduction to seasonal variation in precipitation and the phenology of tef and wheat. Such knowledge is of value when developing control programs and may be also interesting in the context of tropical insect seasonality. Since the biology and ecology of *A. longicornis* is largely unknown, results are discussed in relation to *A. thalassinus*, which has been studied in other parts of Africa.

Materials and Methods

The Study Area

This study was conducted at three mid-highland localities, Denkaka, Godino and Dukem, about 50 km southeast of Addis Ababa. They are located at about 1900 m elevation, approximately 15 km from the Agricultural Research Centre at the town of Debre Zeit.

Rolling plains obstructed by small hills characterise the landscape. Soils tend to be poorly drained, except for those on hilltops and mountainside. The soils are largely derived from volcanic rocks and are fertile. The larger group of soils, which are black clay vertisols, are commonly called black soils. They are found in the lower catenas. Those on sloping areas are called light soils and have a silty clay loam texture.

Three seasons can be distinguished: the dry season, from October to February, the short spring rains from the beginning of March to June, and the long rains from June to September or October. The long rains are actually a continuation of the short ones, except for an intervening drier period of three to four weeks in May and June. The long rains are characterised by torrents and storms, sometimes flooding flat land and eroding slopes. The dry period sharply curtails the growth of all vegetation except for a few perennial grass species.

According to the information provided by the Research Centre at Debre Zeit, the area has an average annual precipitation of 819 mm (SD = 82mm) and a monthly average temperature of 18.3^0 C (SD = 2.2 C) over 14 years (1973-1986). Precipitation varies greatly both within and between years (Fig. 1), while temperature varies much less. In 1987, the timing of the short rains was unusual; they started in late February and continued to the end of May. The maximum precipitation during 1987 was in May (Fig. 1).

The system of agriculture in the area is a seed-farming-complex (Westphal, 1974) suited for the production of cereals and pulses, particularly tef, wheat, chickpea and lentil. These are rain-fed crops and are grown in rotation. Tef is planted in the second and third weeks of July on black and light soils. It is ready for harvest by the third and fourth weeks of November, but harvesting may continue until January depending on rainfall. Wheat is sown in the first week of July and harvested sometime between November and January, depending again on precipitation.

Seasonal Abundance

(a) Linear strip-transect counting (Eberhardt, 1987, p. 236). Each strip was 4 m wide and 15 m long. The investigator walked slowly along the centre axis disturbing the grasshoppers by swinging a 2 m rod to both sides and counting individual adults jumping and flying away. Only the total numbers of grasshoppers were counted since species could not be identified with certainty while in flight.

Six parallel linear strips, 10 m apart from one another, were marked out in the central part of each field. Grasshoppers were counted in each strip, and the mean of the six counts were calculated after each sampling occasion. This mean was used as an estimate of the total number of grasshoppers present in the field, irrespective of species.

(b) Immediately after the strip-transect count, adult grasshoppers were randomly collected by one person for 30 min in each field using an insect net. Numbers collected in this way are regarded as relative estimates of the population size of each species in the fields (Southwood, 1978). Each 30 min collection is considered as one sample. The collected insects were preserved in 70% ethyl alcohol. Specimens were counted and determined to species. Only adults were examined since it was difficult to distinguish between nymphs of 20-29 simultaneously occurring species. All sampling was done between 0900 h and 1700 h. Sampling was postponed in rainy weather. Samples were taken from fields of tef and wheat. Each crop was grown on both black and light soils. There were three replicates for each crop and soil type at each locality, making a total of 24 fields. Since grasshoppers numbers vary independently of crop type (Tibebu and Landin, 1992), data from tef and wheat fields on the same soil were pooled, so that means for each soil/site combination were obtained for each sampling occasion. Each field measured 0.5-1 ha.

Seasonal Breeding

The reproductive status of adult *A. longicornis* females collected in tef fields on black vertisol at Denkaka and Godino was determined on each sampling occasion during the study period.

About ten insects from each collecting occasion and locality were dissects under a binocular microscope with an eyepiece micrometer. Four stages of reproductive development were recognised (Phipps, 1959): Stage I, females with immature ovaries with the largest (lowest) egg cell or "egg 1 " yolkless and without any signs of earlier oviposition; stage II, egg 1 faintly yellow, owing to deposited yolk, and larger than stage 1; stage III, egg 1 with yolk and larger than in stage II, stage IV, eggs in the oviducts or presence of corpora lutea. The number of ovulated eggs in the oviduct, length of egg 1, and the number of ovarioles in each ovary were recorded.

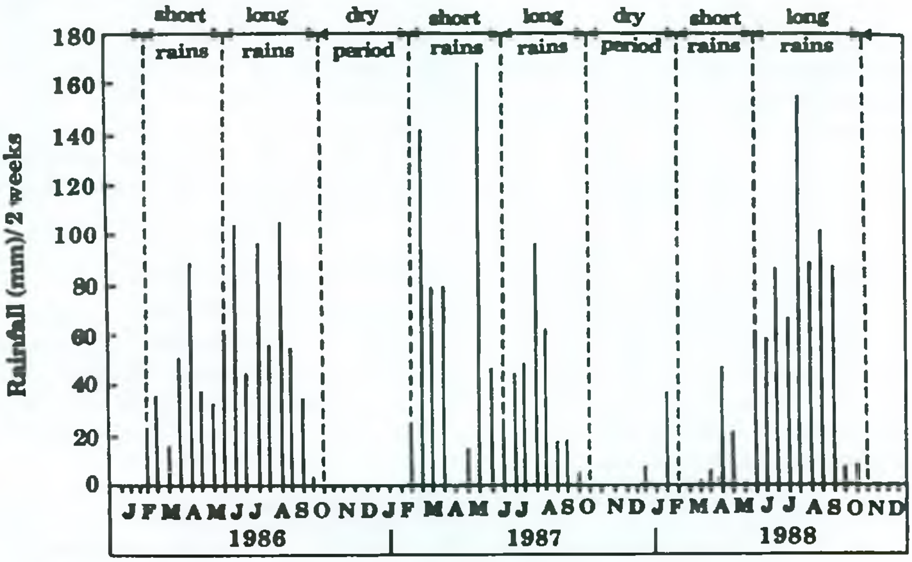

Fig. 1 Precipitation at the meteorological station of the Debre Zeit Agricultural Research Centre located at an elevation of about 1900 m, 380 58 E latitude and 08° 44' longitude. The bars represent total rainfall during 2 weeks.

Results

Comparison of Sampling Methods

Number caught per 30 min is a relative estimate, and its relation to absolute numbers or densities of grasshoppers is unknown. Numbers in strip transects can be regarded as a rough estimate of density regardless of the species composition. However, most of the specimens caught i.e, 35307 out of 73589 (48%) were *A. longicornis*. Therefore, both total numbers caught per 30 minutes and numbers of *A. longicornis* in the catches were correlated with the numbers in strip transects, assuming the relationship is linear (Table 1).

Table 1. Correlation between numbers of grasshoppers caught by sweepnetting for 30 minutes and counts in strip transects, and linear regression analysis of numbers in strip transects against numbers caught in 30 min. Column X_1 gives that total number of grasshoppers (all species) in 30 min; X_2 gives the number of *Aiolopus longicornis* only. The results are arranged according locality and soil type in central Ethiopia, 50 km S. E. of Ethiopia.

Locality and soil type	Correlation Coefficient		Regression Equation	
	X_1	X_2	X_1	X_2
Godino black soil	0.81	0.74	Y = 2.43x + 4.83	Y = 1.78x + 2.47
Denkaka black soil	0.93	0.87	Y = 2.55x + 6.20	Y = 2.13x - 5.73
Dukem black soil	0.94	0.92	Y = 3.02x - 2.02	Y = 2.26x - 6.04
Godino light soil	0.77	0.74	Y = 2.73x + 9.26	Y = 1.12x - 0.69
Denkaka light soil	0.68	0.38	Y = 1.74x + 11.11	Y = 0.43x + 0.29
Dukem light soil	0.62	0.65	Y = 1.53x + 16.18	Y = 0.83x + 0.14

Seasonal Abundance of *Aiolopus longicornis*

*A. longicornis*is the dominating species (Fig. 2). The confidence limits (95%) for the mean numbers collected on each occasion on black soil at Godino varied between 2.4-17.5 and 2.7-12.7during the rainy periods of 1987 and 1988, respectively. Corresponding values at Denkaka were 3.6-23.6 and 3.9-8.3. Thus, there was large variation in numbers of grasshoppers both within and between seasons. *A. longicornis* was more abundant during rainy periods than during other periods and was more abundant at Godino than at Denkaka. It was also more common on black soil than on light ones (Fig. 2 and 3). Seasonal abundance patterns were similar at both sites and soil types.

When the pest was most numerous, it comprised 45% and 90% of the total grasshopper fauna on light and black soil, respectively (Fig. 3). *A. longicornis* was also abundant in the fallow fields, with distinct seasonal peaks occurring during the short rains and early long rains of 1987 and 1988. These peaks were of different magnitude (Fig. 3). The peaks in 1987 indicated that two or three generations occurred that year. Peak abundance usually occurred at the seedling stage of the crops. Abundance usually declined in the later part of the long-rain period of August-September.

Seasonal Breeding of *Aiolopus longicornis*

Number of ovarioles: the number of ovarioles varied between females. The mean maximum number of ovarioles per female over all sampling occasions was 34.6 (SD=1.48) at Denkaka and 32.6 (SD= 1.24) at Godino, while the mean minimum number was 27.0 (SD=2.94) and 28.0 (SD=3.45), respectively. No seasonal variations were detected. Since the number of ovarioles determines the egg batch or clutch size, egg batches of *A. longicornis* should have contained between 25 and 35 eggs.

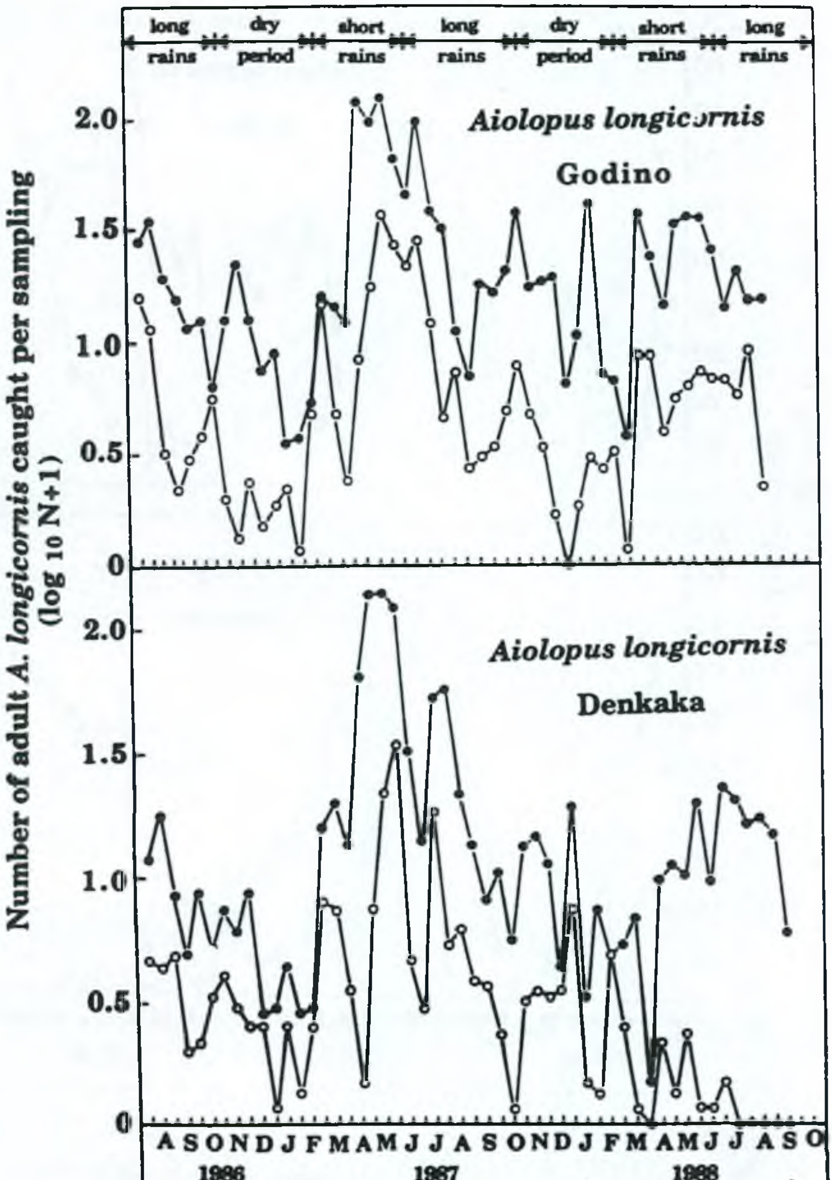

Fig. 2 Numbers of adult *Aiolopus longicornis* Sjostedt caught by sweepnetting for 30 min in cereal fields at Godino and Denkaka, each about 15 km from the town of Debre Zeit, Ethiopia. Solid circles, black soil; open circles, light soil. Each point is a mean for three tef fields and three wheat fields.

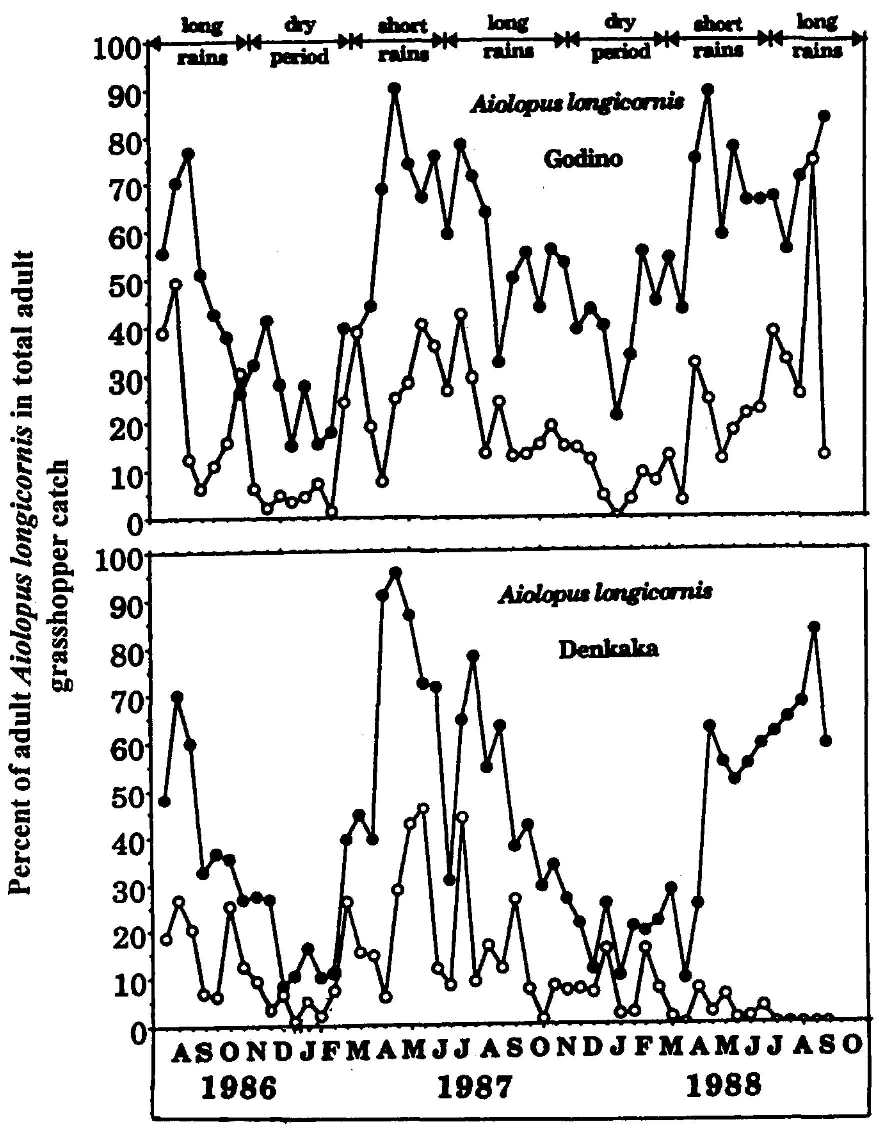

Fig. 3 Proportion (%) of adult *Aiolopus longicornis* Sjostedt in the total catch of adult grasshoppers collected by sweepnetting for 30 min in cereal fields at Godino and Denkaka, near Debre Zeit, southeastern Shoa, Ethiopia. The fields are the same as those referred to in Fig. 2.

Egg development and reproductive period: average numbers of eggs in the oviducts of females from Denkaka and Godino varied greatly between seasons (Fig. 4). Confidence limits (95%) for each occasion varied between 1.0-6.9 and 1.1-6.3 at Godino during the rainy periods of 1987 and 1988, respectively. Corresponding limits at Denkaka were 2.0-8.5 and 1.0-7.4. Thus, variation in the number of ovulated eggs per females was large.

As expected, most females were in stage IV at both localities during the rainy seasons, and in stage I during dry periods at Godino. At Denkaka many reached stage II or III during the beginning of the dry period. In February (usually part of the dry period), females with eggs in their oviducts were uncommon at Godino (Table 2).

The size of egg I (Fig. 5) and numbers of ovulated eggs showed similar patterns of seasonal variation (Fig. 4). The maximum and minimum length of egg 1 at Denkaka was 4.9 mm (SD=0.34) and 0.4 mm (SD=0.13), respectively. Corresponding values at Godino were 4.4 mm (SD=0.49) and 0.3 mm (SD=0, measurement method crude for the small sizes). These findings, together with the percentages of females in the four developmental classes (Table 2) indicate that *A. longicornis* reproduces during the rainy periods and, at least sometimes, it started egg laying 1 or 2 weeks after the onset of the rains. It reproduced to a small extent during the beginning of dry periods (October-November) and beginning of the short rains (February), but did not reproduce during the main parts of the dry periods (Fig. 4 and Table 2). Two or three overlapping generations occurred during the rains (Figs. 4 and 5).

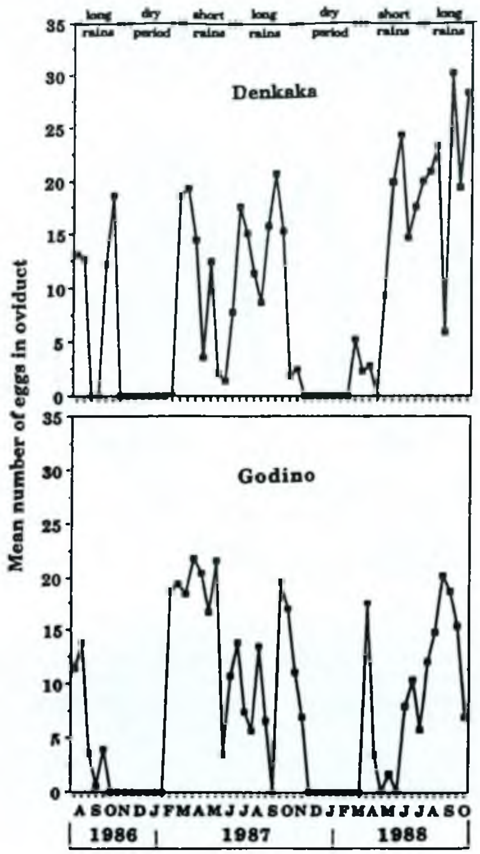

Fig. 4 Mean numbers of eggs in the oviducts of periodically collected and dissected females of *Aiolopus longicornis* Sjostedt from two localities, Denkaka and Godino, each about 15 km from the town of Debre Zeit, about 50 km southeast of Addis Ababa.

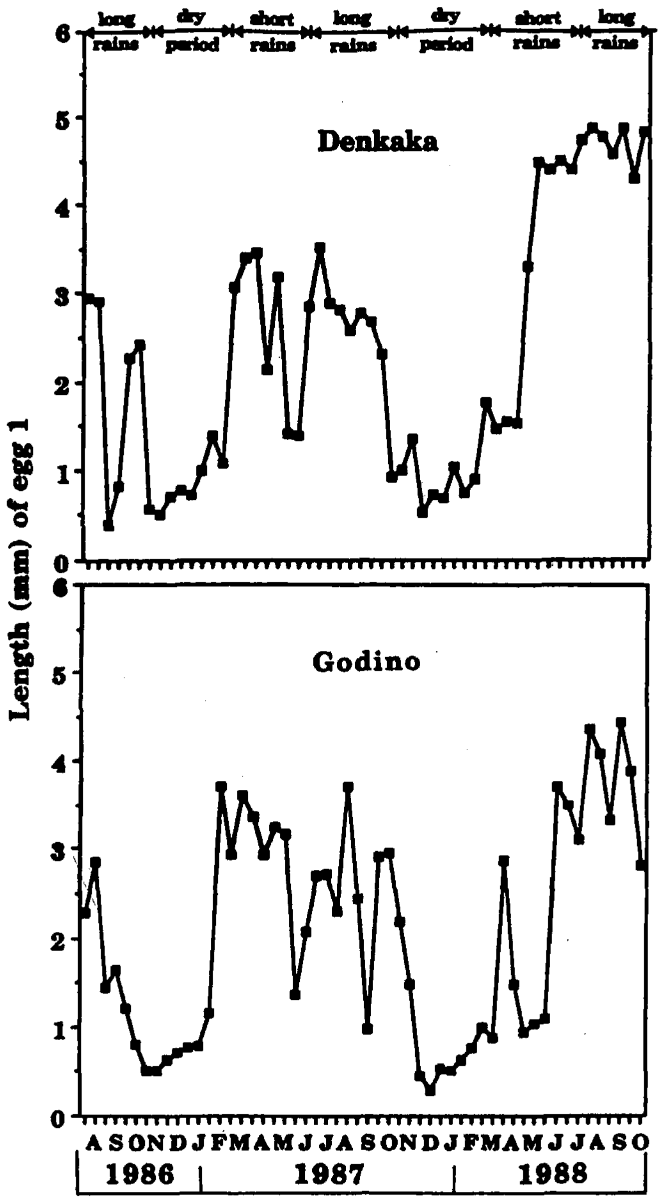

Fig. 5 Terminal oocyte length in the ovary of periodically collected and dissected females of *Aiolopus longicornis* Sjostedt from two localities, Denkaka and Godino, each about 15 km from the town of Debre Zeit, about 50 km southeast of Addis Ababa.

Discussion

The relationship between population estimates obtained with the two sampling methods seems to be linear. For total numbers only, correlation coefficients were larger for samples from black soil than for those from light soils (Table 1). Although the same holds true for *A. longicornis*, the correlation was weaker on light soils at Denkaka. For *A. longicornis,* the slope of the line was steeper on black soil than on light soil. This is to be expected since this species constitutes a larger proportion of the grasshopper fauna on black soils than on light soils. The difference in slope when considering total numbers is more difficult to explain. Perhaps it was caused by differences in species composition (Tibebu and Landin, 1992).

It is clear that the seasonal abundance and breeding habits of *A. longicornis* contributes to its status as a major pest in the cereal cultivation system in central Ethiopia. The species is most common when the crops are young and most vulnerable to damage.

In general, peaks in *A. longicornis* abundance were found to be closely associated with the rainy periods (Fig. 2) and its reproduction was mainly confined to these periods (Fig. 4). This seasonal pattern is in accordance with the general idea that precipitation, through its effects on vegetation, is the main factor causing tropical insect seasonality (Wolda, 1978, 1987; Young, 1982; concerning grasshoppers see also Phipps, 1968 and Capinera, 1987). The swift reproductive response of *A. longicornis* to the onset of the rains (Table 2, Fig. 4 and 5) is common in grasshoppers adapted to dry environments, which survive the dry period as adults Joern and Gaines, 1990, p. 443). The large variations in the abundance of adults (Fig. 2) as well as in the number and development rate of eggs (Fig. 4 and 5) are probably due to the fact that two to three overlapping generations develop during the rainy periods.

The increase in numbers that commonly occurs during or just after the short rains can have a number of explanations. For example, sorghum, maize and millet are generally planted during the periods of small rains in April. Together with wild grasses, they probably offer early breeding opportunities after the long dry seasons. Consequently, by July populations are present which invade the fields of sprouting tef and wheat. Furthermore, *A. longicornis* is already present in the fallow fields in relatively high numbers during the long dry period.

Table 2. Frequency of the four ovarian stages among females of *Aiolopus longicomios* Sjostedt and numbers of females with eggs in oviducts at Denkaka and Godino during different seasons, August - September 1988.

Seasonal periods	Site	Number dissected	Percentage in stage I	II	III	IV	Number with eggs in oviducts
Long rains	Denkaka	60	41.7	8.3	3.3	46.7	28
(Aug, 1986-Oct. 1986)	Godino	64	46.9	18.8	4.7	20.7	18
Dry period	Denkaka	77	10.4	48.1	33.3	7.8	1
(Nov. 1986-Feb.1987)	Godino	72	73.6	4.2	0.0	22.2	16
Short rains	Denkaka	87	1.2	16.1	13.1	69.0	60
(Nov. 1987-Feb. 1987)	Godino	91	8.8	2.2	7.7	81.3	78
Long rains	Denkaka	90	0.0	24.4	14.4	61.1	56
(July 1987-Oct. 1987)	Godino	86	24.4	16.3	10.5	48.8	43
Dry period	Denkaka	80	40.0	47.5	7.5	5.0	4
(Nov. 1987-Feb. 1987)	Godino	90	78.0	5.6	2.2	13.3	12
Short rains	Denkaka	78	5.1	28.2	15.4	51.3	44
(March 1988-June 1988)	Godino	89	22.5	18.8	17.5	41.3	33
Long rains	Denkaka	60	0.0	15.0	8.3	76.7	44
(July 1988-Sept. 1988)	Godino	40	7.5	10.0	5.0	77.0	30
Total dissected	Denkaka	532	70.0	147.0	76.0	239.0	236
	Godino	523	204.0	55.0	37.0	227.0	225
% of total in stage	Denkaka	13.2	27.6	14.3	44.9		
	Godino	39.0	10.5	7.1	43.4		

The short rains usually start around mid-March. In 1987, however, showers occurred as early as February. These rains may have led to an earlier than usual onset of breeding i.e in late February. The reason why the proportion of females with ovulated eggs was greater at Godino than at Denkaka during the dry seasons (Table 2, Figs. 4 and 5) could have been that the availability of food and moist sites at Godino was greater. The irrigated crops and fresh vegetation near the lakes at Godino probably serve as refugia for *A. longicornis,* from where it can spread to colonise non-irrigated crops. Irrigated crops are particularly prone to colonisation by *Aiolopus* species (Hollis, 1968). At Denkaka, where there are no irrigated crops or lakes, females in stages II and III (Table 2) probably hatched at the end of the long rains and continued developing until conditions become too dry.

According to Stretch-Lilja (1977), *A. longicornis* can form migrating swarms and travel long distances; however, she did not present any evidence.

The decrease in numbers that is commonly associated with the long rains may be due to the flooding of the fields, which sometimes lasts for more than a week. Although many grasshoppers need moist conditions for reproduction, prolonged wet periods can result in considerable mortality (Dempster, 1963; Mulkern, 1980).

The seasonality *A. longicornis* and its utilisation of different habitats have been studied little, whereas these aspects have been more investigated in its close relative *Aiolopus thalassinus* (Fabricius), which inhabits the same environment in central Ethiopia (Tibebu and Landin, 1992). During the present investigation *A. thalassinus* was the third most common grasshopper. Its abundance varied quite stochastically, resulting in abundance curves lacking any apparent pattern. Although its breeding dynamics in other parts of Africa are not well documented, there is a general consensus that breeding is usually associated with rainy periods or with moist or irrigated sites, where it may breed all year round (Joyce, 1952; Khalifa, 1956; Phipps, 1959, 1968; Chapman, 1962; Hafez and Ibrahim, 1962; Oyidi, 1978). *A. longicornis* may behave in a similar way. In the laboratory it has easily been bred continuously for more than 2 years (Tibebu *et al.* unpublished). Indications that its breeding habits are plastic were also obtained in the field in central Ethiopia, as mentioned earlier. Both species apparently use good availability of water was a proximate stimulus for reproduction, irrespective of season.

Two or more generations of *A. longicornis* probably occur each year in Ethiopia (Stretch-Lilja, 1977). Due to the length of its life cycle, four generations are even possible (Tibebu *et al.*, 1995) given the right environmental conditions. Peaks in abundance and egg development indicate that two or perhaps even three overlapping generations occur during the rains (Figs. 2, 3 and 4). The species probably spends the dry period in dry non-irrigated areas as reproductively inactive adults. Perhaps they hatch during the end of long rains and develop to adulthood but delay reproduction until the small rains begin. This agrees with Phipp's (1968) finding that 70% of the 33 grasshopper species he studied in Central Africa spend the dry season as reproductively inactive adults.

Eleven species of grasshoppers in central Tanzania did not show the seasonal behaviour characteristic of *A. longicornis* in central Ethiopia (Phipps, 1959). However, in that region precipitation is more evenly distributed throughout the year. Mean numbers of ovulated eggs per female of Tanzanian *Aiolopus* species (almost certainly *A. thalassinus*) varied little between wet and dry periods (22 and 27), respectively. None of the other species differed in a statistically significant way in this respect. By contrast, in Ethiopia *A. longicornis* produces few or no ovulated eggs during the dry periods, whereas 20-25 are produced during peaks in the wet periods (Fig. 4).

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References

Capinera JL. 1987. Population ecology of rangeland grasshoppers, pp. 162-181. In: *Integrated Pest Management on Rangelands, A Short Prairie Perspective* (Ed. J.L. Capinera), Westview Press Inc., USA.

COPR (Centre for Overseas Pest Research) .1982. *The Locust and Grasshopper Agricultural Manual* (VII). 690 pp. COPR, London.

Chapmann RF. 1962. The ecology and distribution of grasshoppers in Ghana. *Proceeding of Zoological Society of London* 139, 1-66.

Dempster JP. 1963. The population dynamics of grasshoppers and locusts. *Biological Review* 38, 490-529.

Denlinger DL.1980. Seasonal and annual variation of insect abundance in the Nairobi, National Park, Kenya, *Biotropica 12*, 100-106.

Eberhardt LL. 1978. Transect methods for population studies. *Journal of Wildlife Management* 42, 1-31.

Fishpool LDC and GB Popov .1984. The grasshopper fauna of the Savannas of Mali, Niger, Benin and Togo. *Bulletin de l' Institut Fundamental d' Afrique Noire Tome* 43, Se'rie A, No.3-4. DAKAR-IFAN.

Hafez M and MM Ibrahim. 1962. On the ecology and biology of the grasshopper *Aiolopus thalassinus* F. in Egypt. *Bulletin de la Societe Entomologique d' Egypte* XLVI, 189-214.

Hollis D. 1968. A review of the genus *Aiolopus* Fiber (Orthoptera : Acridoidea).*Bulletin of the British Museum (Natural History) Entomology* 22, pp.307-355, London.

Joern A and SB Gaines. 1990. Population dynamics and regulation in grasshoppers. pp. 415-482. In: RF Chapman and A Joern. (Eds). *Biology of Grasshoppers*. A Wiley-International Publication. John Wiley & Sons. New York, Chichester, Toronto, Singapore.

Joyce RJV. 1952. The ecology of grasshoppers in East Central Sudan.Anti-Locust Bulletin II, 99pp.

Khalifa A. 1956. The incidence of grasshoppers during winter months and the influence of irrigating fallow land on grasshopper population. *Bulletin de la Societe Entomologique d' Egypte*, XL, 217-229.

Mulkern GB. 1980. Population fluctuations and competitive relationships of grasshopper species (Orthoptera: Acrididae). *Transaction American Entomological Society* 106, 1-41.

Oyidi O. 1978. Ecological distribution, seasonal incidence and breeding patterns of Acridoidea (Orthoptera) in the Zaria Area, Nigeria. *Miscellaneous* No. 43. Centre for Overseas Pest Research, London.

Phipps J. 1959. Studies on East African Acridoidea (Orthoptera), with special reference to egg production, habitats, and seasonal cycles. *Transaction Royal Entomological Society London* III, 27-56.

Phipps J. 1968. The ecological distribution and life cycles of some tropical African grasshoppers Acridoidea). *Bulletin of Entomological Society of Nigeria* 1, 71-97.

Southwood TRE. 1978. Ecological methods, with particular reference to the study of insect populations. (2nd ed). 236 pp, London, Chapman & Hall.

Stretch-Lilja C. 1977. *Short-horned grasshopper pests in Ethiopia, their identification and control.* Institute of Agricultural Research, Addis Ababa.

Tauber MJ, Catherine AT and Sinzo M. 1986. *Seasonal Adaptations of Insects.* Oxford University Press, Oxford, New York.

Tibebu HW and Landin J. 1992. Composition and structure of Orthopteran faunas in cereal crops in Ethiopia. *Bulletin of Entomological Research*, 82, 29-39.

Tibebu H W, Landin J, Wenergen U and Bergman KO. 1995. Life Table of the Tef Grasshopper, *Aiolopus longicornis*, under Laboratory Conditions and Demographic Effects of the Pathogen *Nosema locustae*. Biological Control 5, 492-502(1995)

Uvarov BP. 1956. The locust and grasshopper problem in relation to the development of arid lands. *The Future of Arid Lands*, 43, 383-389.

Westphal E. 197. *Pulsesin Ethiopia, their taxonomy and agricultural significance.* Joint publication of the College of Agriculture, Haile Sellassie I University, Ethiopia, and Agricultural University of, Wageningen, The Netherlands.

Wolda H. 1978. Seasonal fluctuations in rainfall, food and abundance of tropical insects. *Journal of Animal Ecology*, 47, 369-381.

Wolda H. 1987. Seasonality and the community, pp 69-95. In : Gee JHR and P S. Giller (eds). *Organisation of communities, Past and Present.* Blackwell Scientific Publications, Oxford, London.

Wolda H.1988. Insect Seasonality : Why? *Annual Review of Ecology and Systematics,* 19: 1-18.

Young, A. M. 1982. *Population Biology of Tropical Insects*. Plenum Press, New York and London.