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SEASONAL FLUCTUATIONS OF ABUNDANCE AND AGE STRUCTURE OF *ARION LUSITANICUS* MABILLE, 1868 (GASTROPODA: PULMONATA: ARIONIDAE)

JAN KOZŁOWSKI[1], RAFAŁ SIONEK[2]

[1]Department of Zoology, Institute of Plant Protection, Miczurina 20, 60-318 Poznań, Poland
(e-mail: J.Kozlowski@ior.poznan.pl)

[2]Regional Plant Protection Inspectorate in Rzeszów, Langiewicza 28, 35-101 Rzeszów, Poland
(e-mail: sionekra@rz.onet.pl)

ABSTRACT: *Arion lusitanicus* Mab. has two peaks of abundance in the vegetation season. One falls on mid-May when immature individuals dominate in the slug population. The juveniles feed on young plants and grow rapidly. Another mass occurrence of the pest falls on August at the emergence stage of winter plants. The population density remains high during 4 to 6 weeks, almost till the end of September. Adult individuals are predominant in the slug population in late summer and autumn, whereas juveniles hatched from the eggs laid in August appear later.

KEY WORDS: *Arion lusitanicus*, abundance dynamics, age structure

INTRODUCTION

Various slug species (Gastropoda: Stylommatophora) are among serious pests of cultivated plants. They feed on seeds and seedlings and damage various organs of mature plants. The greatest losses are caused by *Deroceras reticulatum* (O. F. Müller, 1774). However, much damage is also induced by members of the genus *Arion*, e. g. *A. lusitanicus* Mabille, 1868. Quite recently this species has appeared also in Poland and, like in central and western Europe, is a serious pest of many plant species (SCHMID 1970, ALTENA VAN REGTEREN 1971, REISCHÜTZ 1984, DAVIES 1987, DE WINTER 1989, VON PROSCHWITZ 1992, VON PROSCHWITZ & WINGE 1994, KOZŁOWSKI 1995, 1999, KOZŁOWSKI & KOZŁOWSKA 1998a, b, BRINER & FRANK 1998). Damage caused by this slug concerns horticultural and agricultural crops, mostly vegetables, rape and cereals, and takes place mainly at the emergence stage of plants, e.g. winter rape (BRINER & FRANK 1998, FRANK 1998). Predicting plant damage by *A. lusitanicus* requires a detailed knowledge of the reproduction, and first of all, periods of appearance of particular age classes of the slug.

MATERIAL AND METHODS

The studies were conducted in 1997–1999 in the area of Rzeszów (E Poland), in the region of abundant occurrence of *A. lusitanicus*. Observations were made on the slug population inhabiting a ditch 100 m long and 1.7–2.7 m wide (ca. 240 m^2), extending along vegetable allotments heavily invaded by this pest. The ditch was overgrown by various herbaceous plants, mainly *Agropyron repens* and other grasses, as well as with dicotyledon weeds: *Arctium lappa*, *Urtica dioica*, *Tanacetum vulgare*, *Geranium pratense*, etc. Preliminary observations revealed that very often the slugs gathered in that ditch in search of shelters and of a higher humidity. Being subject to no agrotechnical procedures except weed mowing a few times a year, the habi-

tat ensured sufficiently stable conditions for the slugs. From January till December, the number and length of the slugs were determined once a week; the individuals were divided into 4 size classes (0.7–1.5 cm; 1.6–3 cm; 3.1–5 cm; >5 cm). During the vegetation season on each control, in the early morning hours, before retreating to their shelters, all the slugs found on the soil, on and among plants were counted along the entire length of the ditch and the air temperature was measured. In the winter the search for the slugs included also their winter shelters: superficial layer of the soil, litter and remnants of decaying vegetation. Detailed meteorological data were obtained from the weather station at Jasionka near Rzeszów several kilometers away from the study plot.

RESULTS

In 1997 (Fig. 1), by the end of February after the emergence of the first hibernating slugs (1 to 1.5 cm long) from their winter shelters, their number remained at a very low level of several individuals during nearly five weeks. By the end of April, there appeared single specimens over 3 cm long, and some days later – also individuals exceeding 5 cm in length. The latter probably migrated from horticultural crops in the neighbourhood. In May, the number of the smallest slugs (0.7–1 cm long), hatched from the overwintered eggs gradually increased due to their intense growth. Juvenile slugs initially occurred in their hatching places, where they fed on leaves of the burdock (*Arctium lappa*), nettle (*Urtica dioica*), tansy (*Tanacetum vulgare*), crane's-bill (*Geranium*) and other weeds. The number of active slugs reached its first peak at the beginning of the second decade of May. Individuals from 1.6 to 3 cm long, at a density of 60 per 100 m of the ditch, were predominant. In subsequent weeks the number of slugs of the first three size classes (0.7–1.5 cm; 1.6–3 cm and 3.1–5 cm) decreased, whereas the number of specimens over 5 cm long increased considerably from the third decade of June. By the end of June single individuals attained their adult length (ca. 10 cm). The number of large slugs (+5 cm long) gradually increased to reach more than 120 individuals per 100 m of the ditch by the end of August. The number of slugs remained comparatively high (over 40 individuals per 100 m of the ditch) until the second decade of October, and then it decreased. In that period (20 weeks of observations) young individuals (0.7–1.5 cm long) hatched from the eggs deposited in August. Their number continued to increase until the end of November. In December, when the temperature dropped below 0°C, young slugs moved to their winter shelters. Warming up to +4°C at the turn of December (1997/98) induced an increased activity of the slug. Its juveniles (0.7–1.5 cm long) were encountered most frequently in the litter and plant remnants.

In 1998 (Fig. 2), the presence of young slugs from 1 to 1.5 cm long was observed from the first days of January. They were found mainly in the litter and among plant remnants, their density being ca. 40 per 100 m of the ditch. At the air temperature of 4°C the slugs crawled on the soil and plants. A temperature decrease below 0°C in the second decade of March caused a decline in the slug activity and their migration to winter shelters. The slug density remained at the level of ca. 40 individuals/100 m of the ditch almost till the end of March. The number of young slugs (0.7–1.5 cm long) in the observed microhabitat increased rapidly at the beginning of the second decade of April after an increase in the mean diurnal air temperature to nearly 8°C. These were mainly slugs hatched from the overwintered eggs. In the same period, larger slugs, of the second size class (1.6–3 cm), began to appear. In the second half of April the number of slugs of both these size classes gradually increased, and individuals 3.1–5 cm long (third size class) began to appear. In the third decade of April, slugs of the first size class (0.5–1.5 cm long) reached the number of 550 individuals, and by the end of the first decade of May their number was the highest – 620 individuals per 100 m of the ditch. A week later, at the mean air temperature of over 16°C the density peak (600 individuals per 100 m of the ditch) was also reached by slugs of the second size class (1.6–3 cm long). The number of all slugs (over 1,100 individuals per 100 m) remained high from the end of April to mid-May. By the end of that period, mostly individuals 0.7–3 cm long continued to occur in the population and the number of larger slugs also gradually increased. In the second half of May and in early June the number of smaller individuals decreased much, while the number of slugs of the third size class (3.1–5 cm) increased. The number of these slugs increased till the end of the first decade of June, after which there was a noticeable reduction. From the end of June the number of individuals of the fourth size class (over 5 cm long) increased and reached its peak (ca. 450 individuals per 100 m) in the third decade of July. In September, the oldest slugs reached the adult length (10–12 cm). The number of active slugs, with a slight decreasing tendency, remained relatively high nearly until the end of September, whereas starting with the first days of October their number decreased rapidly. In mid-October, young slugs (0.7–1.5 cm)

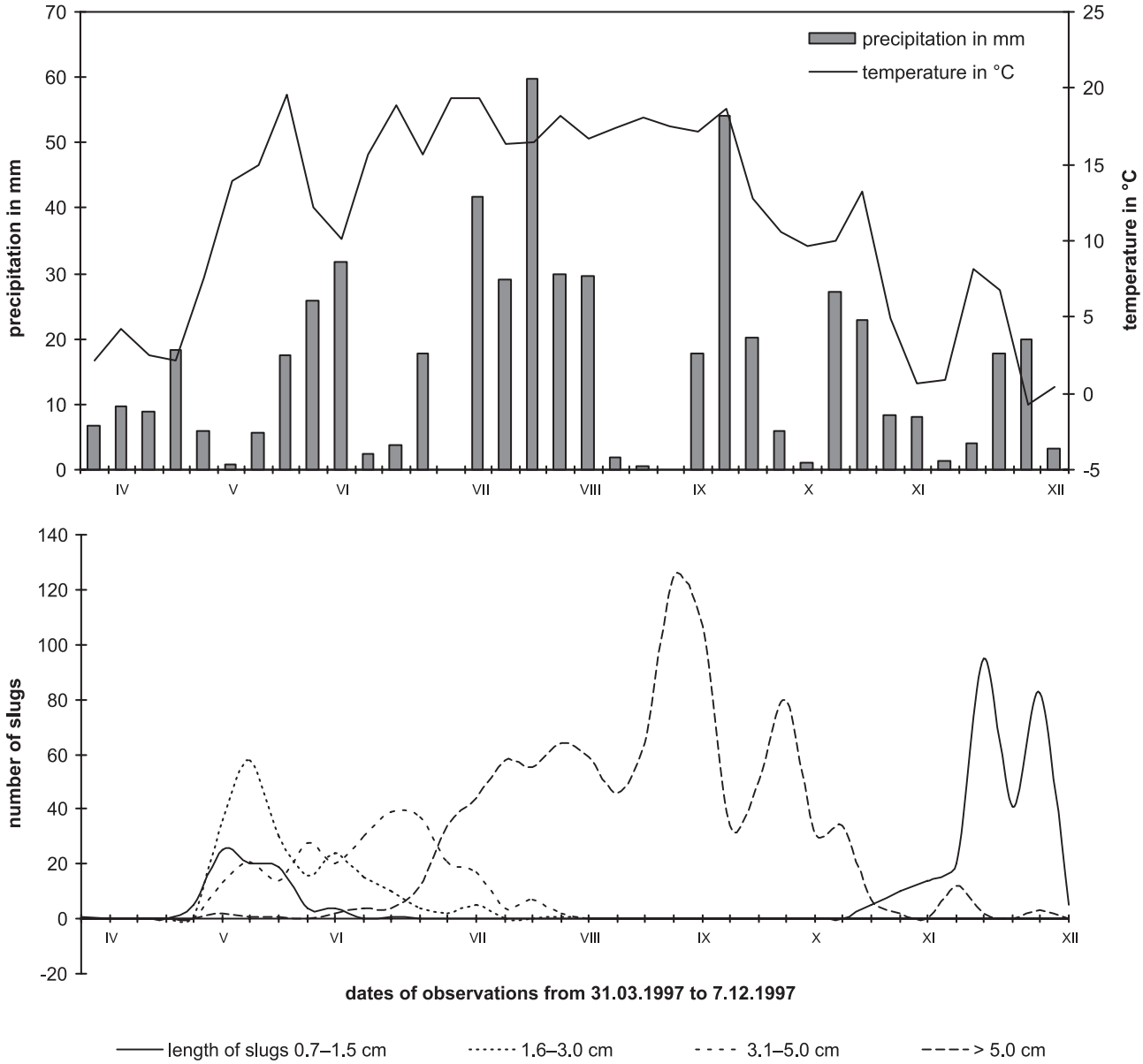

Fig. 1. Abundance of four size classes of *A. lusitanicus* and weather conditions in 1997

hatched from the eggs deposited in August and September, and their number slowly increased. The last individuals, both adult and juvenile, were observed almost until mid-November, when they hid in shelters as a result of the temperature decline below 0°C.

In 1999 (Fig. 3), the first overwintering young (1–1.5 cm long) were observed after thaw in the first days of March, when the mean diurnal air temperature was over 5°C. They occurred in the litter and their density amounted to 38 individuals per 100 m of the ditch. Their number remained at a similar level of over 30 individuals until the first days of April. In that period, the air temperature rose to over 10°C and continued to increase gradually in the subsequent weeks. By the end of the first decade of April, the number of active slugs increased four times as a result of hatching from overwintered eggs. The number of hatched slugs (0.7–1.5 cm long) increased rapidly to reach its peak of ca. 1,500 individuals per 100 m of the ditch by the end of the first decade of May. Earlier, in mid-April, slugs of the second size class (1.6–3 cm long) began to appear due to intense growth of overwintered individuals, whereas individuals of the third size class (3.1–5 cm) appeared in the third decade of April. In mid-May the number of the smallest slugs decreased, whereas the number of slugs of the second and third size classes increased. The first individuals over 5 cm long also appeared at that time. In May and June, slugs grew intensely. At the beginning of June, most individuals were 1.6 to 3 cm long, whereas from the second half of June the most numerous were slugs from 3.1 to 5 cm in length. From the first days of July, the number of active slugs of the fourth size class increased and that of smaller individuals decreased. In early August, only

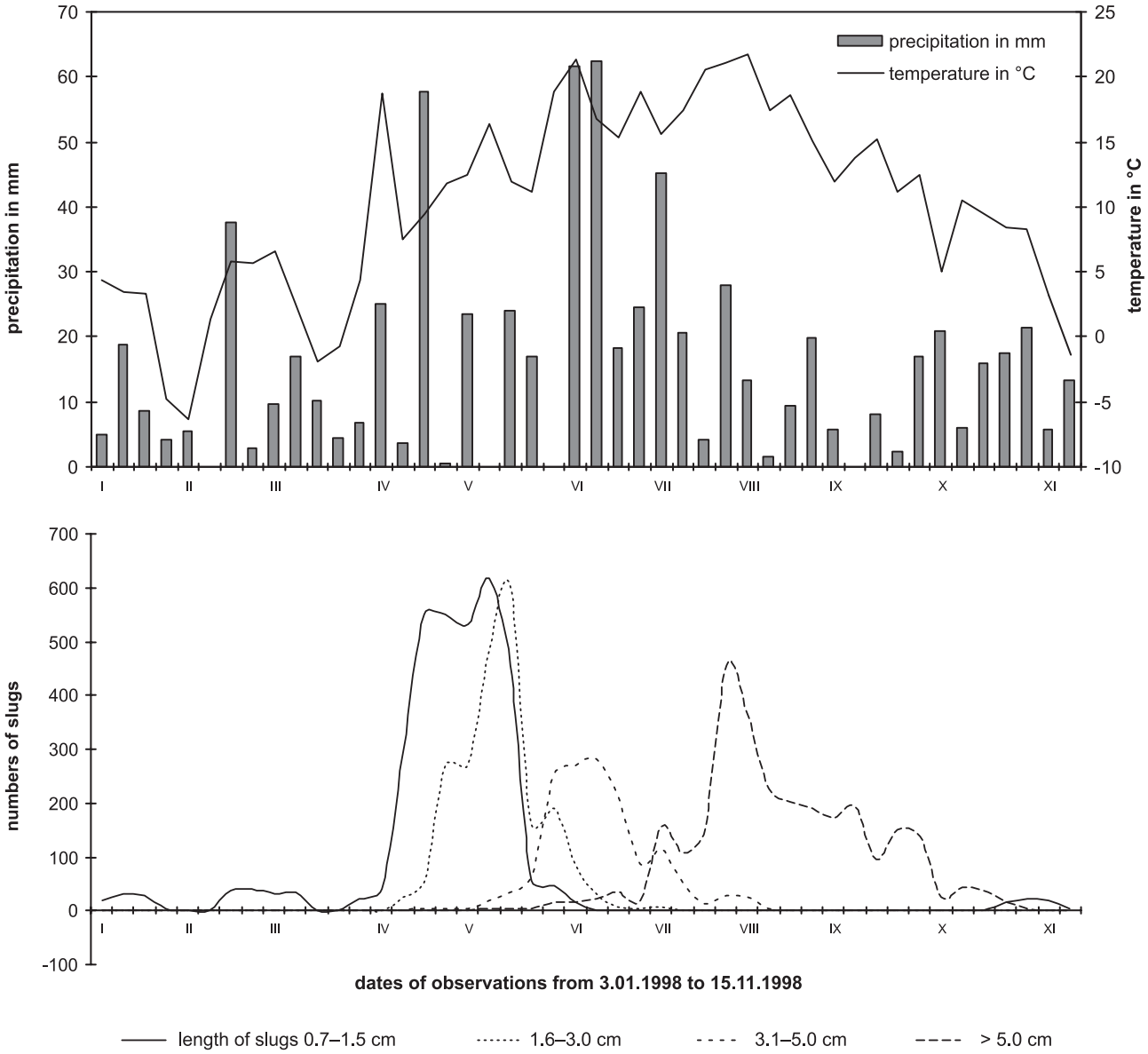

Fig. 2. Abundance of four size classes of *A. lusitanicus* and weather conditions in 1998

large slugs (over 5 cm long) were observed to occur in the ditch and their number reached ca. 300 individuals by the end of the first decade of August. In the second decade of September, the number of adult slugs reached its peak of ca. 500 individuals/100 m of the ditch, which was followed by a drastic decrease in the next week. In the third decade of September, young slugs that hatched from the eggs deposited in August began to emerge, and their number increased till mid-November. However, heavy snowfall in mid-November, precluded further observations.

DISCUSSION

The development and population dynamics of *A. lusitanicus* in the three consecutive study years (1997–1999) generally proceeded in a similar way, though the population abundance varied. These differences were caused by varying weather conditions in particular years of the studies, which determined the rate of slug development and growth; especially significant was the decrease in air temperature in the period of slug hibernation and hatching. According to WIKTOR (1989) the appearance of slugs and the time of their maturation in our climatic zone largely depend on thermal conditions of the environment. Precipitation seems to be of secondary importance, since only a few rainy weeks during a year are quite suffi-

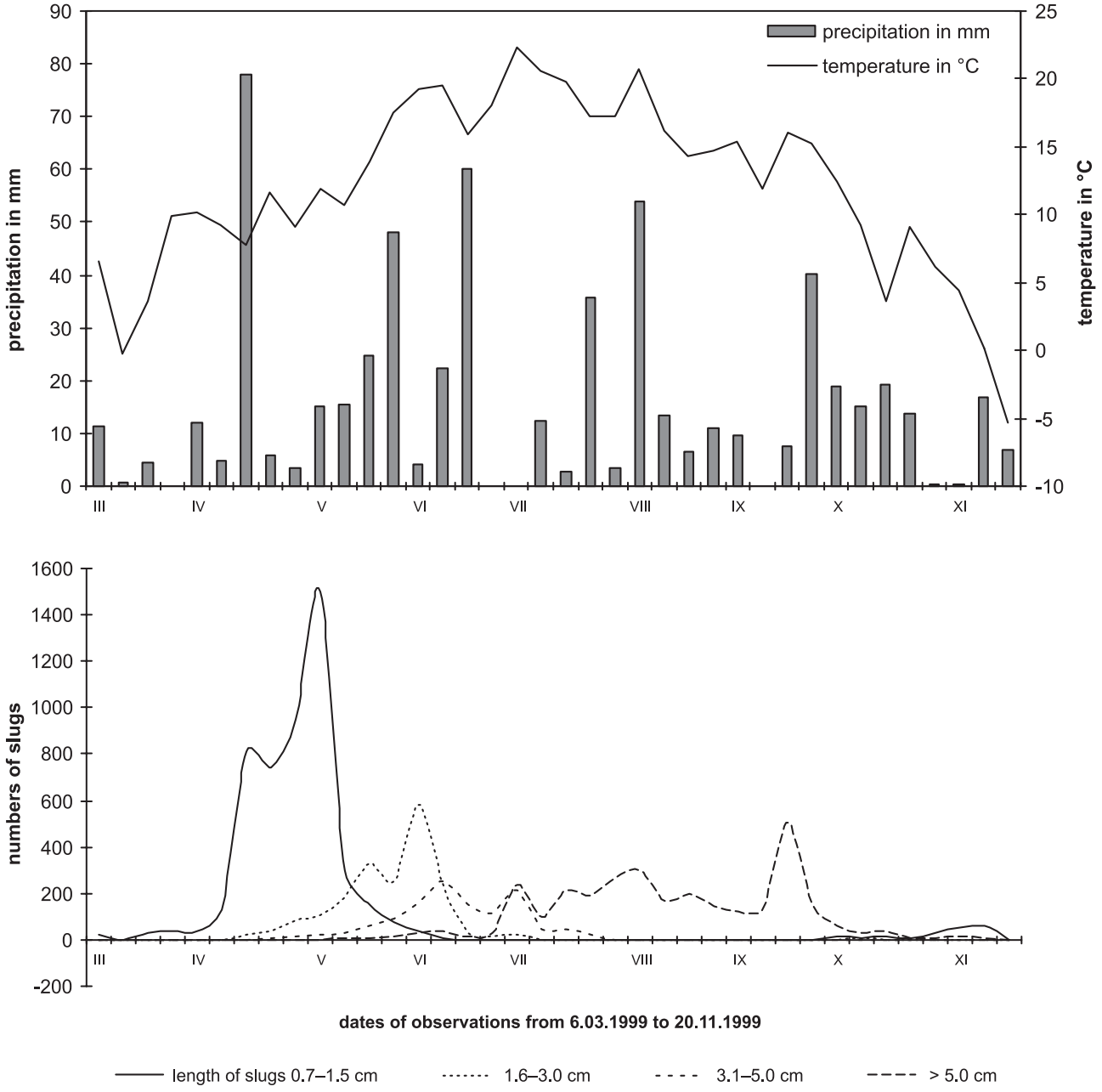

Fig. 3. Abundance of four size classes of *A. lusitanicus* and weather conditions in 1999

cient for a normal development of slugs. The number of active *A. lusitanicus* was lower in 1997 than in the other two years of the studies. This was probably caused by the fact that a considerable portion of the slug eggs and juvenile stages was frozen out as a result of the significant temperature decrease to –20°C and that there was no snow cover at the turn of 1996. Despite essential differences in the abundance of the slug population in particular study years, it is possible on the basis of the observations to ascertain general tendencies of the slug abundance and development under climatic conditions of the regions Pogórze Rzeszowskie and Pogórze Dynowskie.

A. lusitanicus emerges from its winter shelters at the turn of February, however, the first slugs can leave their shelters already in winter, when the temperature increases to over 4°C. These are young hibernated individuals 1–1.5 cm long, hatched in late autumn of the previous year. Besides them, larger slugs (over 3 cm long), hatched in August of the previous year, also appeared (KOZŁOWSKI & SIONEK 2000). Juvenile stages (0.7–1.5 cm long), hatched by the end of February and in March, began to appear from the first days of April. Their number gradually increased as the overwintered eggs hatched. An abundant occurrence of juvenile *A. lusitanicus* in April was also ob-

served in gardens of Great Britain (DAVIES 1987). In the first half of May, the number of slugs 0.7–3 cm long increases several times. The number of young slugs was high until mid-May (the first density peak). In the second half of May, mostly sexually immature individuals and few adults appeared in the population. In mid-June, the number of slugs over 3 cm long increased, whereas individuals over 5 cm long dominated in the second half of July, and their number subsequently increased to reach its peak (the second density peak) in early or mid-August. High numbers of slugs at that season were also reported by other authors. According to FRANK (1998), in August in the population of *A. lusitanicus,* inhabiting rape fields of Switzerland, large slugs occurred in the highest number. The number of individuals remained high almost until the end of September. Juveniles hatched from the eggs laid in August appeared in the first half of October. Their number slowly increased until mid-November. Also in Great Britain and in Switzerland, young *A. lusitanicus* begin to hatch in the autumn and continue hatching in the spring (DAVIES 1987, BRINER & FRANK 1998). In late autumn, after a drop in the temperature below 4°C, the juvenile slugs migrated to their winter shelters for hibernation. During warming up in winter months (December–February), young slugs left their shelters and returned to them only after the temperature decrease.

There are two visible abundance peaks of *Arion lusitanicus* during the vegetation season. The first falls on mid-May. In that period, immature individuals from 1 to 3 cm long dominate in the slug population. They feed on seedlings and young plants. Another mass appearance of the slugs takes place in August at the emergence of many crop species. The slug number remains high during 6 weeks. Adult specimens dominate in the population and later also juveniles appear. The slugs feed intensely, especially on winter plant seedlings and frequently cause considerable yield losses (BRINER & FRANK 1998, FRANK 1998). The mass occurrence of *A. lusitanicus* was associated with phenology of cultivated plants and fell on the period of appearance of early plant developmental stages, which are the most sensitive to slug-induced damage.

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