FOLIA MALACOLOGICA
Folia Malacol. 21(4): 275–283
ISSN 1506-7629
The Association of Polish Malacologists
Faculty of Biology, Adam Mickiewicz University
Bogucki Wydawnictwo Naukowe
Poznań, December 2013
http://dx.doi.org/10.12657/folmal.021.028

# GROWTH RATE OF *CHILOSTOMA FAUSTINUM* (ROSSMÄSSLER, 1835) (GASTROPODA: PULMONATA: HELICIDAE) UNDER NATURAL CONDITIONS

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ABSTRACT: Growth of *Chilostoma faustinum* (Rossmässler, 1835) was recorded under natural conditions in Romincka Forest (NE. Poland), one of the northernmost localities of the species. During the growing season (April–October) the average growth rate was 0.22 whorl/month. In the local conditions *Ch. faustinum* needs three growing seasons to complete its shell growth. Shells of *Ch. faustinum* from Romincka Forest are slightly smaller than in the other studied populations: their average width is 16.5 mm (range 13–19 mm); and the average number of whorls is 4.5 (range 4–5).

KEY WORDS: *Chilostoma faustinum,* land snails, growth rate

## INTRODUCTION

*Chilostoma faustinum* (Rossmässler, 1835) (Gastropoda: Pulmonata: Helicidae: Ariantinae) lives in Europe and is considered to be a mountain species (KERNEY et al. 1983, WIKTOR 2004, WELTER-SCHULTES 2012). Its main range of occurrence covers the Carpathians, the Sudetes and the Świętokrzyskie Mts (RIEDEL 1988). However, there are *Ch. faustinum* localities also in lowland forests in Lithuania (SKUJIENE 2002), Poland (MARZEC 2005) and west Ukraine (SVERLOVA & GURAL 2005).

This paper presents results of *Ch. faustinum* shell growth measurements in a lowland locality, under natural conditions. Although observations of growth of land snails in the wild (e.g. TERHIVUO 1978, BAUR & RABOUD 1988, MALTZ 2003, KUŹNIK-KOWALSKA & ROKSELA 2009, SULIKOWSKA-DROZD 2010, 2011) are less numerous than analogous observations under laboratory conditions (CAMERON & CARTER 1979, BAUR 1986, 1989, POKRYSZKO 1990, KUŹNIK-KOWALSKA 1999, THAKUR 2004, MEIRELES et al. 2008, MYZYK 2011 and many others), yet their results are more applicable for purposes of environmental protection and natural resources management.

## RESEARCH AREA

The research was conducted in Romincka Forest (NE. Poland), which is a compact forest of ca. 360 km$^2$ situated on both sides of the Polish–Russian border north-west of Suwałki. It is a part of the East European Lowland and belongs to the Lithuanian Lakeland macroregion (KONDRACKI 2000). In the geobotanical division of Poland Romincka Forest belongs to the North Section – Augustowski-Suwalski land (MATUSZKIEWICZ 2007). This area is characterised by the most severe climate in the Polish lowlands, with the lowest mean annual temperature (6.2°C), the shortest growing season: number of days in the year with the mean temperature over 5°C (194 days), the highest number of days in the year with the maximum temperature under 0°C (66 days), the highest number of days in the year with snow-cover (100 days) (MATUSZKIEWICZ 2007).

The topography of the area has been shaped by the Pleistocene glaciations, leaving an undulating surface between 150 and 300 m a.s.l., which gives rise to a great variety of soil types dependent both on underlying deposits and drainage. Typical dry-ground forest (*Tilio-Carpinetum*) is abundant on better drained land, and swampy forest is found in badly drained areas. Most of the forest is affected by human activity, and managed conifer forests now dominate. The Polish part of the forest is protected within Natura 2000 (Special Area of Conservation PLH 280005) and as the Romincka Forest Landscape Park.

So far, three localities of *Ch. faustinum* have been found in Romincka Forest, in valleys of small streams in riparian forest. The research plot covered a part of an ash-alder forest *Fraxino-Alnetum* in the Duży Budier stream valley. The stand consists mainly of alder trees ca. 60 years old, with single birch, spruce and oak trees. The understory is formed by hazel. The ground cover layer is abundant and dense, with dominant nettle *Urtica dioica*. Detailed information on mollusc communities of Romincka Forest is presented elsewhere (MARZEC 2010).

## MATERIAL AND METHODS

About 50 individuals of *Ch. faustinum* were caught at the beginning of each month from August 2005 to October 2007. The snails were collected from plants and soil surface, in a plot of ca. 400 $m^2$. Previous studies showed no effect of shell painting on growth rate (BAUR 1984), thus all the individuals were marked with nail varnish: a transverse stripe was painted on the shell near its aperture so that it marked the current size of the shell and the increment could be read on recapture. Each month a different colour of varnish was used. The whorls of each snail were counted to the nearest 0.1 whorl (WIKTOR 2004), and the shell width was measured with a ruler to the nearest 1 mm. After marking, the snails were always released in the same place in the centre of the research plot. No observations were conducted in winter, when the plot was snow-covered. Live *Ch. faustinum* were found in the plot from April or May to October. In March and in November, even during warm and snowless years, no live snails were found.

In total, 692 individuals of *Ch. faustinum* were marked and 71 were re-captured (10.3%) (Table 1). Among these, 62 individuals (87.3%) were re-captured once, five (7%) – twice and four (5.6%) – three times. The material for morphometric studies included the shells of live snails (n = 692) and fresh empty shells found in the plot (n = 122). Individuals with completed lip were regarded as adult.

Nomenclature used in this paper follows KERNEY et al. (1983) but *Chilostoma faustinum* is also referred to as *Faustina faustina* (e.g. FALKNER et al. 2001) or *Helicigona faustina* (e.g. WELTER-SCHULTES 2012).

## RESULTS

### GROWTH RATE

Under natural conditions the average growth rate of *Ch. faustinum* during the growing season was 0.22 whorl/month (Table 2). Individuals of different size classes did not differ in growth rate (One-Way ANOVA, F = 0.31; df = 2, 49; p = 0.73). During winter the growth was limited (Fig. 1). The overall mean annual growth rate, including winter, was 0.12 whorl/month (growth rate of one individual observed precisely for one year).

Under the local conditions *Ch. faustinum* needs three growing seasons to complete the shell growth. Depending on the year, the snails here are active for six to seven months, and with the observed mean growth rate (0.22 whorl/month) the shell can be completed within 14 months of activity (Fig. 2). The three year period of snail's growth is also confirmed by the analysis of growth of individuals observed for a year or longer. For example, an individual observed for the longest time (14 months) was marked in April 2006 (2.7 whorls) and re-ceptured in June 2007 (4.4 whorls, shell growth still not completed). This individual could not hatch in the spring 2006, because before it was caught in April, it may have been active for at most one month, which is not enough to achieve the observed size even assuming the maximum observed growth rate. Thus, that individual hatched in 2005 and probably completed its growth in the autumn 2007, in the third year of its life.

No clearly distinguishable cohorts were observed in the studied population of *Ch. faustinum*; individuals of all size classes were found during all the observation months (Fig. 3).

### SHELL SIZE DISTRIBUTION

The shells of *Ch. faustinum* from Romincka Forest reach 13 to 19 mm in width (mean 16.5, SE ± 0.091, n = 157), with the number of whorls ranging from 4 to 5 (mean 4.48, SE ± 0.015, n = 157). The ranges of shell size in all growth classes are shown in Fig. 4.

Table 1. *Chilostoma faustinum*: number of whorls of re-captured individuals with dates of sampling

| No. | Time elapsed between marking and last re-capture [months] | Date of first marking | Number of whorls on first marking | Date of last re-capture | Number of whorls on last re-capture | Number of re-captures |
|---|---|---|---|---|---|---|
| 1 | 1 | 2005-08-05 | 4.2 | 2005-09-13 | 4.3 | 1 |
| 2 | 1 | 2005-08-05 | 3.4 | 2005-09-13 | 3.6 | 1 |
| 3 | 1 | 2005-08-05 | 3.2 | 2005-09-13 | 3.4 | 1 |
| 4 | 1 | 2005-09-13 | 3.0 | 2005-10-04 | 3.4 | 1 |
| 5 | 1 | 2005-09-13 | 4.0 | 2005-10-04 | 4.1 | 1 |
| 6 | 1 | 2006-05-06 | 4.2 | 2006-06-05 | 4.5 | 1 |
| 7 | 1 | 2006-05-06 | 4.2 | 2006-06-05 | 4.5 | 1 |
| 8 | 1 | 2006-06-05 | 3.8 | 2006-07-04 | 4.0 | 1 |
| 9 | 1 | 2006-06-05 | 3.9 | 2006-07-04 | 4.2 | 1 |
| 10 | 1 | 2006-06-05 | 4.2 | 2006-07-04 | 4.4 | 1 |
| 11 | 1 | 2006-06-05 | 4.3 | 2006-07-04 | 4.5 | 1 |
| 12 | 1 | 2006-07-04 | 3.4 | 2006-08-02 | 3.5 | 1 |
| 13 | 1 | 2006-07-04 | 3.5 | 2006-08-02 | 3.9 | 1 |
| 14 | 1 | 2006-07-04 | 3.7 | 2006-08-02 | 3.8 | 1 |
| 15 | 1 | 2006-08-02 | 3.6 | 2006-09-04 | 3.9 | 1 |
| 16 | 1 | 2006-08-02 | 3.7 | 2006-09-04 | 3.9 | 1 |
| 17 | 1 | 2006-08-02 | 3.0 | 2006-09-04 | 3.6 | 1 |
| 18 | 1 | 2006-09-04 | 4.0 | 2006-10-06 | 4.1 | 1 |
| 19 | 1 | 2007-05-10 | 4.2 | 2007-06-01 | 4.5 | 1 |
| 20 | 1 | 2007-05-10 | 3.4 | 2007-06-01 | 3.5 | 1 |
| 21 | 1 | 2007-05-10 | 3.6 | 2007-06-01 | 3.8 | 1 |
| 22 | 1 | 2007-06-01 | 4.0 | 2007-07-06 | 4.3 | 1 |
| 23 | 1 | 2007-07-06 | 3.5 | 2007-08-01 | 3.7 | 1 |
| 24 | 1 | 2007-07-06 | 4.4 | 2007-08-01 | 4.6 | 1 |
| 25 | 1 | 2007-08-01 | 3.6 | 2007-09-10 | 3.9 | 1 |
| 26 | 1 | 2007-08-01 | 4.1 | 2007-09-10 | 4.3 | 1 |
| 27 | 1 | 2007-09-10 | 3.3 | 2007-10-02 | 3.5 | 1 |
| 28 | 2 | 2005-08-05 | 3.6 | 2005-10-04 | 3.9 | 2 |
| 29 | 2 | 2006-04-09 | 4.1 | 2006-06-05 | 4.6 | 1 |
| 30 | 2 | 2006-04-09 | 3.7 | 2006-06-05 | 4.2 | 1 |
| 31 | 2 | 2006-06-05 | 4.4 | 2006-08-02 | 4.6 | 1 |
| 32 | 2 | 2006-06-05 | 3.6 | 2006-08-02 | 3.8 | 1 |
| 33 | 2 | 2006-07-04 | 3.8 | 2006-09-04 | 4.1 | 1 |
| 34 | 2 | 2006-07-04 | 4.3 | 2006-09-04 | 4.5 | 1 |
| 35 | 2 | 2006-07-04 | 4.4 | 2006-09-04 | 4.5 | 1 |
| 36 | 2 | 2007-06-01 | 4.1 | 2007-08-01 | 4.5 | 1 |
| 37 | 2 | 2007-06-01 | 4.2 | 2007-08-01 | 4.6 | 1 |
| 38 | 2 | 2007-07-06 | 3.7 | 2007-09-10 | 4.1 | 1 |
| 39 | 3 | 2006-05-06 | 3.2 | 2006-08-02 | 3.6 | 2 |
| 40 | 3 | 2006-05-06 | 3.0 | 2006-08-02 | 3.5 | 1 |
| 41 | 3 | 2006-06-05 | 3.7 | 2006-09-04 | 4.1 | 2 |
| 42 | 3 | 2007-05-10 | 2.7 | 2007-08-01 | 3.5 | 1 |

| No. | Time elapsed between marking and last re-capture [months] | Date of first marking | Number of whorls on first marking | Date of last re-capture | Number of whorls on last re-capture | Number of re-captures |
|---|---|---|---|---|---|---|
| 43 | 3 | 2007-05-10 | 3.6 | 2007-08-01 | 4.4 | 1 |
| 44 | 3 | 2007-05-10 | 3.9 | 2007-08-01 | 4.6 | 1 |
| 45 | 3 | 2007-05-10 | 3.7 | 2007-08-01 | 4.9 | 1 |
| 46 | 3 | 2007-06-01 | 2.5 | 2007-09-10 | 3.4 | 1 |
| 47 | 3 | 2007-06-01 | 3.7 | 2007-09-10 | 4.2 | 1 |
| 48 | 4 | 2006-04-09 | 2.4 | 2006-08-02 | 3.2 | 1 |
| 49 | 4 | 2006-04-09 | 3.2 | 2006-08-02 | 3.9 | 1 |
| 50 | 4 | 2006-04-09 | 3.5 | 2006-08-02 | 4.4 | 1 |
| 51 | 4 | 2007-05-10 | 2.6 | 2007-09-10 | 3.7 | 2 |
| 52 | 6 | 2005-10-04 | 3.2 | 2006-04-09 | 3.3 | 1 |
| 53 | 7 | 2005-10-04 | 3.1 | 2006-05-06 | 3.5 | 1 |
| 54 | 8 | 2005-09-13 | 3.5 | 2006-05-06 | 3.7 | 1 |
| 55 | 8 | 2005-10-04 | 2.9 | 2006-06-05 | 3.2 | 1 |
| 56 | 8 | 2005-10-04 | 2.6 | 2006-06-05 | 3.0 | 1 |
| 57 | 8 | 2006-09-04 | 3.3 | 2007-05-10 | 3.8 | 1 |
| 58 | 9 | 2005-08-05 | 3.8 | 2006-05-06 | 4.0 | 2 |
| 59 | 9 | 2005-08-05 | 3.6 | 2006-05-06 | 4.0 | 3 |
| 60 | 9 | 2005-08-05 | 3.8 | 2006-05-06 | 4.1 | 1 |
| 61 | 9 | 2005-10-04 | 3.3 | 2006-07-04 | 4.3 | 3 |
| 62 | 9 | 2005-10-04 | 2.8 | 2006-07-04 | 3.3 | 1 |
| 63 | 9 | 2006-09-04 | 3.7 | 2007-06-01 | 4.5 | 1 |
| 64 | 9 | 2006-10-06 | 3.8 | 2007-07-06 | 4.6 | 1 |
| 65 | 10 | 2005-09-13 | 3.4 | 2006-07-04 | 4.2 | 1 |
| 66 | 10 | 2005-09-13 | 3.0 | 2006-07-04 | 4.0 | 3 |
| 67 | 10 | 2006-09-04 | 3.7 | 2007-07-06 | 4.6 | 1 |
| 68 | 11 | 2005-08-05 | 3.8 | 2006-07-04 | 4.5 | 1 |
| 69 | 12 | 2005-08-05 | 3.0 | 2006-08-02 | 4.4 | 1 |
| 70 | 13 | 2006-05-06 | 3.2 | 2007-06-01 | 4.5 | 3 |
| 71 | 14 | 2006-04-09 | 2.7 | 2007-06-01 | 4.4 | 1 |

Table 2. *Chilostoma faustinum*: growth rate of individuals of different size (April to October)

| Initial shell size [whorls] | Number of snails | Mean growth rate [whorls/month] | Standard error | Minimum growth rate [whorls/month] | Maximum growth rate [whorls/month] |
|---|---|---|---|---|---|
| 2.4–2.9 | 4 | 0.26 | 0.021 | 0.2 | 0.3 |
| 3.0–3.4 | 12 | 0.24 | 0.040 | 0.1 | 0.6 |
| 3.5–3.9 | 27 | 0.21 | 0.023 | 0 | 0.5 |
| 4.0–4.4 | 13 | 0.20 | 0.023 | 0.1 | 0.3 |
| 2.4–4.4 | 56 | 0.22 | 0.015 | 0 | 0.6 |

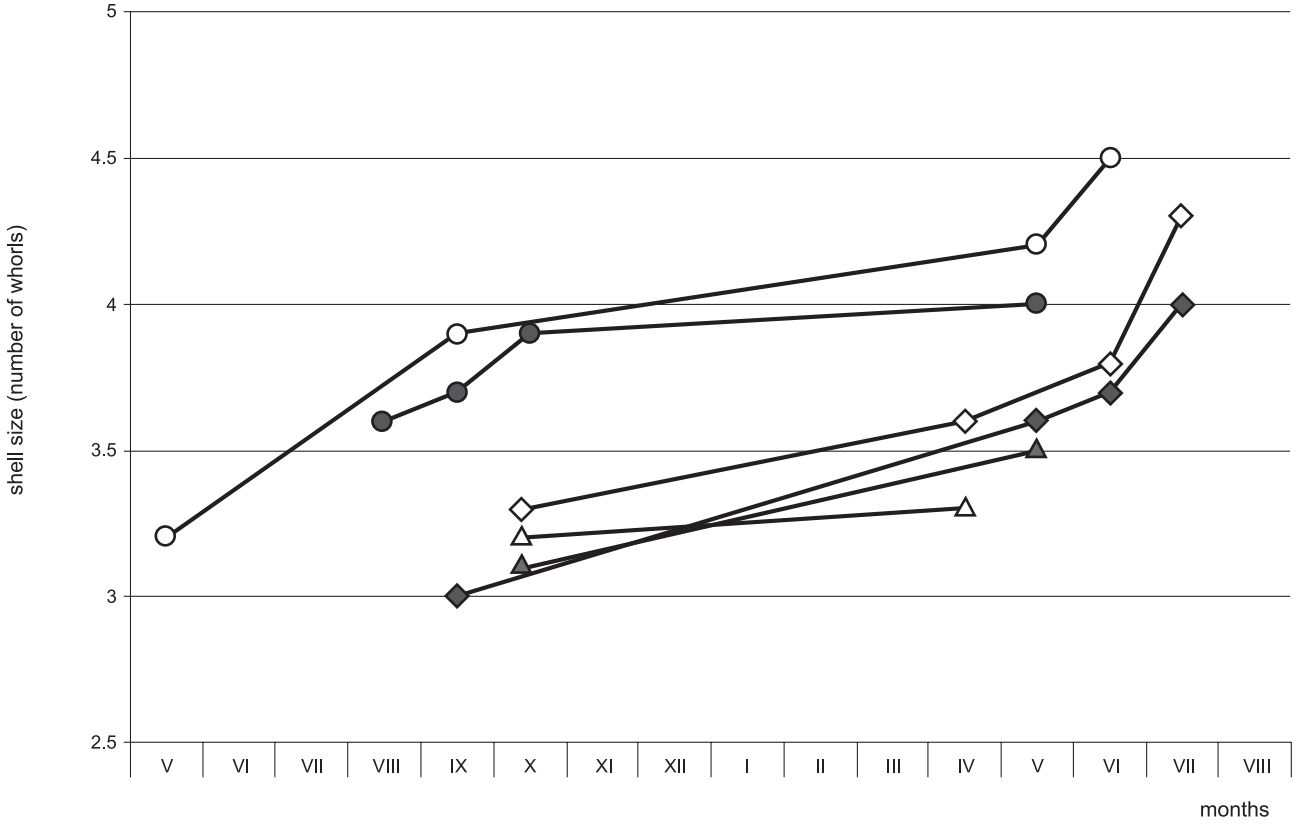


Fig. 1. *Chilostoma faustinum*: growth of selected individuals, for which the observation time included winter

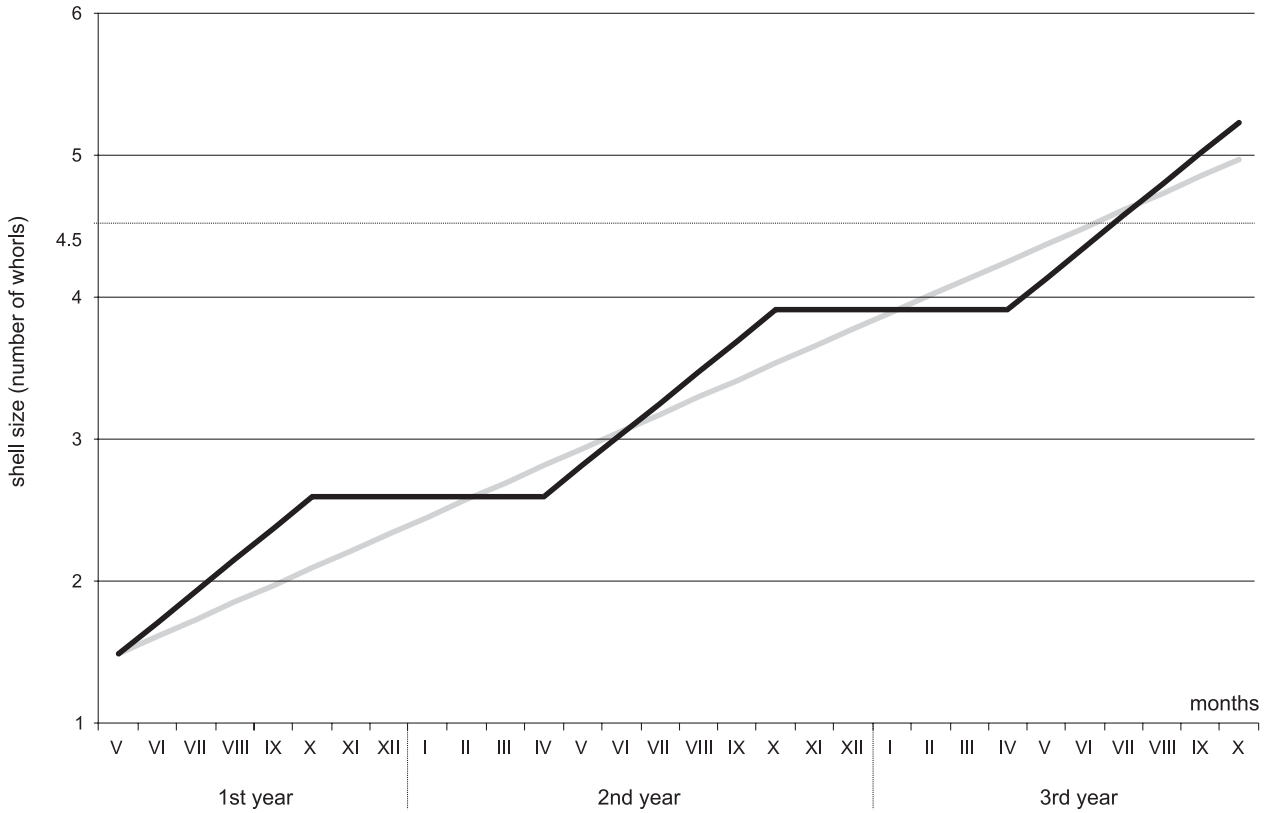


Fig. 2. *Chilostoma faustinum*: model of growth under natural conditions; black line: during growing season mean growth of 0.22 whorl/month, outside growing season without growth; grey line: growth rate of 0.12 whorl/month throughout the year. Average adult size (4.5 whorls) marked

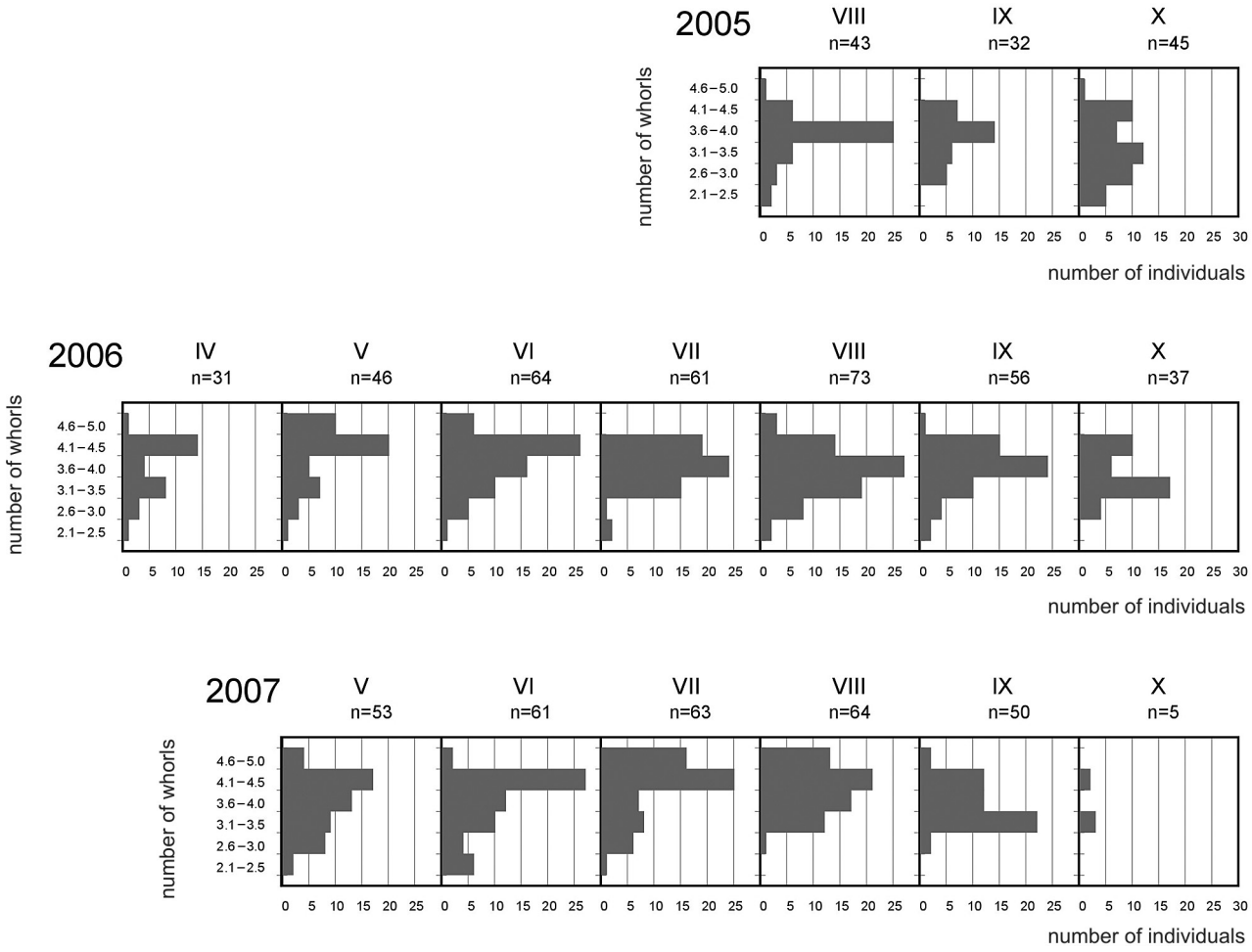


Fig. 3. *Chilostoma faustinum*: shell size distribution among individuals caught in consecutive months of the study

## DISCUSSION

Snails of the subfamily Ariantinae from lowland populations reach maturity usually within one or two years (GASSIES 1849, GERMAIN 1930, FRÖMMING 1954). Under natural conditions the growth rate of land snails often depends on climate conditions. In localities characterised by a shorter growing season and lower temperature more time is needed to complete shell growth (UMIŃSKI 1975, TERHIVUO 1978, SULIKOWSKA-DROZD 2010, 2011). In the case of Alpine populations of *Arianta arbustorum,* it can take as long as five years (BAUR & RABOUD 1988). In the Mediterranean region analogous slowing down of growth resulting in an extended growth period is caused by heat and drought (LAZARIDOU & CHATZIIOANNOU 2005, KISS et al. 2005).

The average growth rate, together with the analysis of individual growth histories, indicates that under the conditions of Romincka Forest growth of *Ch. faustinum* takes three years. Although in theory, at the average growth rate, it is possible for the snail to complete shell building within two years (14 months of growth with two growing seasons of seven months each), yet under the actual conditions it is unlikely. The time necessary to incubate eggs should also be considered, and in most helicid snails it is two to three weeks (FRÖMMING 1954, TERHIVUO 1978, HELLER & ITTIEL 1990, MALTZ 2003, KISS et al. 2005). Development rate depends on the temperature: the lower it is, the slower the embryo develops and hatching occurs later (TOMPA 1984). Under particularly favourable conditions and with the maximum growth rate it might be possible for some individuals to complete shell building within two growing seasons, however, there are no indications that *Ch. faustinum* can complete its growth within one season.

The growth model presented in Fig. 2 assumes that hatchlings of *Ch. faustinum* have shells of ca. 1.5 whorls. Hatchlings of other Helicidae are of a similar size, for example *Helicodonta obvoluta* – 1 whorl (MALTZ 2003) or *Perforatella bidentata* – 1.5 whorls (KUŹNIK-KOWALSKA & ROKSELA 2009). The size of the smallest individuals of *Ch. faustinum* found in the field

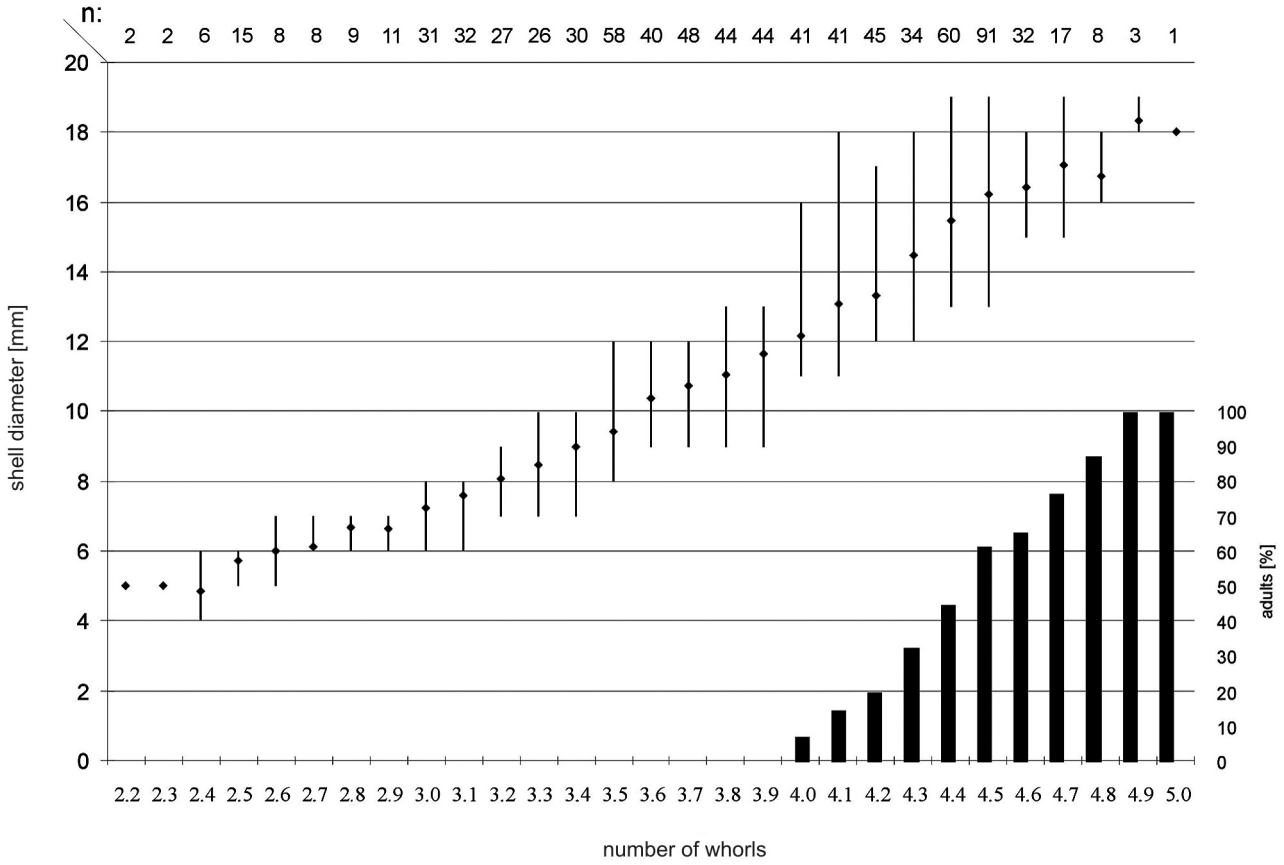


Fig. 4. *Chilostoma faustinum*: width of shells with various numbers of whorls (mean and range). Black bars show the proportion of adults in each size group

(Fig. 4) indicates that snails with two whorls are at least 4 mm in width. If *Ch. faustinum* hatched with two whorls, its eggs would have to be ca. 4 mm in diameter, while a species of comparable size, *Arianta arbustorum,* lays eggs of ca. 3 mm diameter (BAUR 1984), and eggs of 4.1–6.1 mm diameter are laid by the much bigger *Helix pomatia* (GOŁĄB & LIPIŃSKA 2009).

The growth rate in some members of Helicoidea is irregular, faster during the early development stages, when the shell is still small, and slower at the later development stages (TERHIVUO 1978, MALTZ 2003, KUŹNIK-KOWALSKA & ROKSELA 2009). A similar tendency was observed for *Ch. faustinum* (Table 2), however, possibly due to too small sample sizes, the differences were not statistically significant.

The shells of *Ch. faustinum* from Romincka Forest are relatively small, compared to the previously studied populations (Fig. 5).

Shells smaller than average were found for example in high-altitude populations of *Arianta arbustorum* (BAUR 1984), *Vestia turgida* (SULIKOWSKA-DROZD 2001), and *Vestia gulo* (SULIKOWSKA-DROZD 2011), as well as in a population of *Chilostoma banaticum* (DOMOKOS 2001) living in unfavourable conditions; the authors explain this by harsher climate conditions in these localities: mainly shorter growing season and lower temperature. In Romincka Forest, characterised by the most severe climate in the Polish lowlands (MATUSZKIEWICZ 2007), the effect of climate conditions on the ultimate shell size of *Ch. faustinum* is analogous. The shell size may also be influenced by other factors. Shells of *Arianta arbustorum* from populations of high density were by 1.5 mm smaller than those from low-density populations (BAUR 1988).

*Chilostoma faustinum* is considered to be a mountain species (KERNEY et al. 1983, RIEDEL 1988, WIKTOR 2004, WELTER-SCHULTES 2012). Until the end of the 20th century an isolated site of *Ch.*

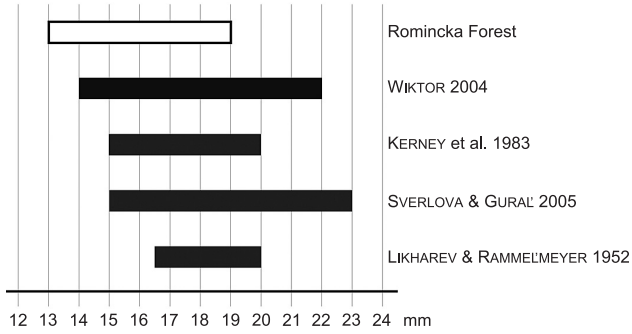


Fig. 5. *Chilostoma faustinum*: adult shell width according to various authors

*faustinum* near Kaunas (Lithuania) was the only known lowland record of this species (SKUJIENE 2002). Therefore, its presence in the lowlands was regarded as a result of accidental introduction (SOÓS 1948, WIKTOR 2004). At present also other lowland sites of *Ch. faustinum* are known (MARZEC 2005, SVERLOVA & GURAL 2005). It indicates that in the past the species' range may have been much larger and the locality in Romincka Forest may have a relic character. It is highly probable that *Ch. faustinum* is a species of primary forests from periods of colder climate. This can be concluded from its current localities, which are mainly well-preserved fragments of mountain forests (SZYBIAK 2000, DELI 2002, HLAVAČ 2002, SZYBIAK et al. 2005, JUŘIČKOVÁ et al. 2005, 2006, KAPPES et al. 2006, SULIKOWSKA-DROZD & HORSÁK 2007). Unfortunately, so far the species has not been found in Białowieża Forest (CAMERON & POKRYSZKO 2004) to further support this hypothesis.

ACKNOWLEDGEMENTS

I am grateful to Professor ANDRZEJ WIKTOR for his valuable comments on the first version of the manuscript. I would also like to thank KATARZYNA SIWAK for her help with the field work.

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*Received: June 19th, 2013*
*Revised: September 30th, 2013*
*Accepted: October 2nd, 2013*