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Long-term monitoring of *Himantoglossum adriaticum* H. Baumann population in Keszthely Hills, Hungary

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Bódis, J. & Molnár, E.: *Long-term monitoring of Himantoglossum adriaticum H. Baumann population in Keszthely Hills, Hungary.*

Abstract: Long-term monitoring of populations contributes to the better understanding of population dynamics of species. A population of the orchid *Himantoglossum adriaticum* H. Baumann was monitored in Keszthely Hills in western Hungary during the period 1992-2008. To assess reproductive output in each year, the number of flowering individuals, as well as the number of flowers and fruits produced per plant were recorded. The reproductive traits studied (except the number of flowering plants and seedpods) did not varied considerably, they showed low temporal variability over years, while the other two characteristics mentioned had high temporal variability. Mean number of flowers produced per plant over all years was 31. Fruit-production was often low or zero. Significant correlations between the rate of fecundity and any of the flowering traits could not be found. Years with high fruit-production do not coincide with years of great number of inflorescences. Thus, the number of inflorescences measured in any one year can not be used as a substitute for reproductive performance measurements. Years with high fruit-set may be able to insure long-term survival of the population.

Keywords: orchid, *Himantoglossum adriaticum,* flowering, fruit-set production

Introduction

In general "the term 'monitoring' has been used to describe many types of activities", and it can be defined as "the process of gathering information about some system" (Yoccoz et al. 2001). The monitoring is an essential tool for science, conservation and management, even if it has been last for long periods. In this case the long-term responses of species and ecosystems to different disturbances (e.g. climate change, experimental manipulations) can also be evaluated (Lindenmayer and Likens 2009). The goal of species monitoring is to detect the temporal changes in population size (e.g. stable, declining, or increasing over time) and find out trend in population dynamics (Kull et al. 2008). In Hungary the monitoring of protected and endangered species has been carried out in the framework of the Hungarian Biodiversity Monitoring System since 1998 organized by the Hungarian National Parks and controlled by government. The species studied, *Himantoglossum adriaticum* is included in the list of species to be monitored.

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The changes of orchid population size have been studied for a long time in Europe (e.g. the historical records of *Himantoglossum hircinum* in British Isles have been dated back almost 300 years, GOOD 1936). Their rarity and conspicuous inflorescence might contribute notably to this fact. Recently (ca. in the last 60-70 years) the investigations have already been tended not only to detect the occurrences and to estimate rough abundances (many, frequent, few etc.) but also to study detailed the temporal and spatial variability of population size, demographic traits, flowering frequency, life-cycle, etc. in order to get new knowledge of orchids which facilitate the more effective conservation and management (WILLEMS J. H. and MELSER 1998, WOTAVOVÁ et al. 2004). In cases of orchids different kinds of methods were applied for observations. There are more complicated, time-consuming procedures when permanent quadrats, individual marks have been used, and in such a way the population sizes of orchids can be estimated more exactly. Another, more simple and easily practicable method is to follow the population dynamics counting the flowering individuals in a given site. KULL (2002) summarized the researches of the European north temperate orchids collecting data from 67 species studied at least for three years. In 40% of cited references only flowering individuals were studied. The lengths of the monitoring periods of different orchid species are varied from some years to more than ten years in Europe. The advantage of the long-term investigations is that a more reliable picture can get on the dynamics of populations depending from the environment (including for example the transitions of stages, survival possibility etc.). Among the numerous studies it is remarkable Tamm and his colleagues'observations (TAMM 1972, INGHE and TAMM 1988) who followed the survival and flowering frequency of four orchid species in permanent quadrats nearly for five decades in Sweden. Long-term demographic studies of two orchid species (*Orchis morio* and *Herminium monorchis*) concentrated mainly on the flowering behaviour affected by the climatic factors influencing the flowering processes (WELLS et al. 1998). The demographic traits of *Orchis simia* were analysed over 18 years to find out the long-term survival strategy of an isolated orchid population by WILLEMS and BIK (1991). The variation in population size of *Orchis morio* were assessed by the dynamics of flowering spikes over a 26 year period using unfertilized plots in a fertilizer experiment in Britain (GILMANN and DODD 1998).

In spite of many investigations, there is no general explanation for the yearly change of the flowering intensity. In the case of many orchid populations there have been successful explorations of the environmental effects which influenced the number of flowering individuals, the fruit-set formation (e.g. weather conditions: WELLS 1981, INGHE and TAMM 1988, WELLS and COX 1989, WILLEMS and BIK 1991, CAREY 1999, PFEIFER et al. 2006a,b; herbivores: WELLS and COX 1991, KINDLMANN 1999, KINDLMANN and BALOUNOVÁ 1999).

Among the recent *Himantoglossum* species *H. hircinum* is the best known. It was mentioned several times from many countries over centuries ((e.g. in the British Isles since 1641) (GOOD 1936). In Germany there is a valley (Leutra valley near Jena, Thuringia) where the flowering and vegetative individuals of *H. hircinum* have been monitored since 1878. The exact number of plants found between 1976 and 2001 was 13,687 (HEINRICH 2000, PFEIFER et al. 2006a). *H. hircinum* has large distribution area, and almost every European speciemens was considered as *H. hircinum* until 1978, when Baumann described *H. adriaticum* from the Istrian Peninsula (BAUMANN 1978). The distribution area of the *H. adriaticum* is much smaller, than that of *H. hircinum*, but it is not limited to the region of the Adriatic Sea as the name would suggest. It also appears in Italy, Slovenia, Croatia, Austria, Hungary, in Slovakia up to Moravia and in Bohemia (near Ketkovice) (RYBKA et al. 2005, VUKOVIČ and NIKOLIČ 2006).

The *H. adriaticum* populations are not too frequent in Hungary. The present Hungarian populations show spatial and temporal variability in sizes. The abundances small in the majority of sites, varied from 2-3 individuals to 60-70 ones, but there are populations with more hundred speciemens (data originated from the reports of the Hungarian Biodiversity Monitoring System).

In this paper we concentrate on the following questions:

- do the reproductive traits studied vary over time, what extent is the temporal variability?
- does a so called 'good orchid year' mean a reproductive success also, that is, in the years when there are a lot of flowering individuals, do they grow higher and develop more flowers and seedpods than in the years when there are only a few flowering individuals (a so called 'bad orchid year')?

Material and methods

The species studied

Himantoglossum adriaticum is a perennial herb with two underground tubers. *H. adriaticum* has no strong goat odour as *H. hircinum*, and there are narrower leaves in the rosette, the inflorescence is looser and has fewer flowers, the helmet is smaller and closed, the spur is shorter, the colour of the flower is reddish-brown and the labellum is less twisted, but the cut is deep (BAUMANN 1978). The morphometrical values of aboveground parts, both reproductive and vegetative organs of the species was described by BAUMANN and KÜNKELE (1982), DÉNES et al. 1993, MOLNÁR V. (1999), BÓDIS and ALMÁDI (1998). The leaves of *H. adriaticum*, similarly to other species distributed in Mediterranean region, appear after the late August and/or early September rainfalls and have an intensive growth period until the frosts come. The plants assimilate during the winter, except if there is a snow cover. A new growth period follows in early spring, when the medium sized and the large individuals grow 2-3 new leaves. After this period the inflorescence, which had been initialized in the former vegetation year, begins to develop. The time of flowering is generally the middle of June, and it lasts for 2-3 weeks. It takes another 3 weeks until the seedpods will be ripened. The leaves of the rosette will have withered till the flowering time, but it can be delayed by wet weather (BÓDIS and BOTTA-DUKÁT 2008).

Study site

H. adriaticum was studied in Keszthely Hills, in western Hungary, at the boundary of the village Gyenesdiás and Keszthely town (Fig. 1). The orchid population was found by I. Szabó, on both sides of the Pilikán-Szoroshad minor road, in dolomite grassland, on the edge of the forest (SZABÓ 1987). In the study area calciphilous oak woodland, shrub woodland and pine plantation form a vegetation mosaic with dolomite grassland. Habitats are disturbed, the vegetation is degraded (owing to mainly human activities). *H. adriaticum* grows in the grassland near the road and on the edge of the expanding shrubs and trees.

Methods and data analysis

The flowering individuals were searched and counted along the 1 km long section of the road in every June, from 1992 to 2008. The number of inflorescences and the number of flowers per spike were counted, the heights of the spikes and the lengths of the inflo-

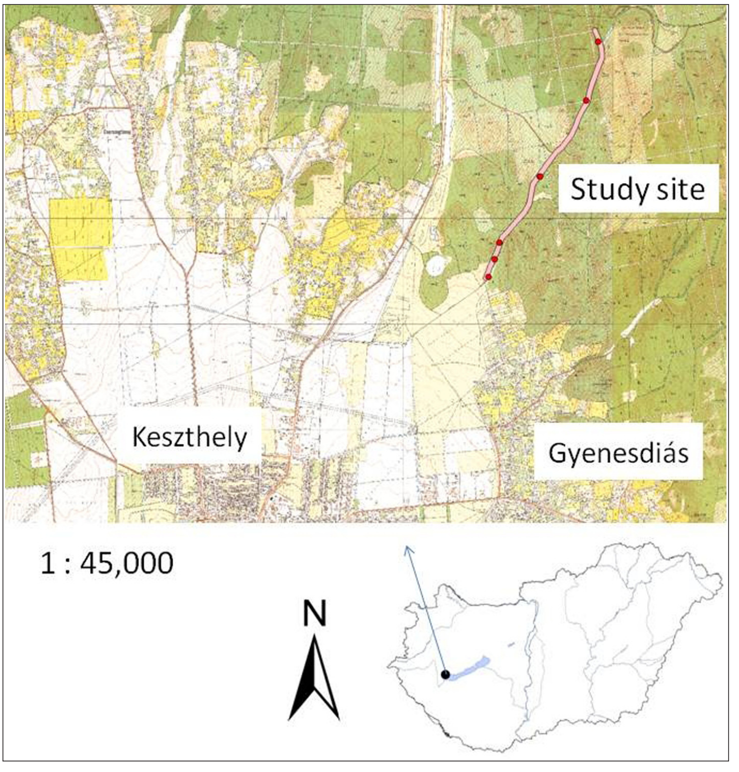

Fig. 1: The occurrences of *Himantoglossum adriaticum* population studied in Keszthelyi Hills, western Hungary

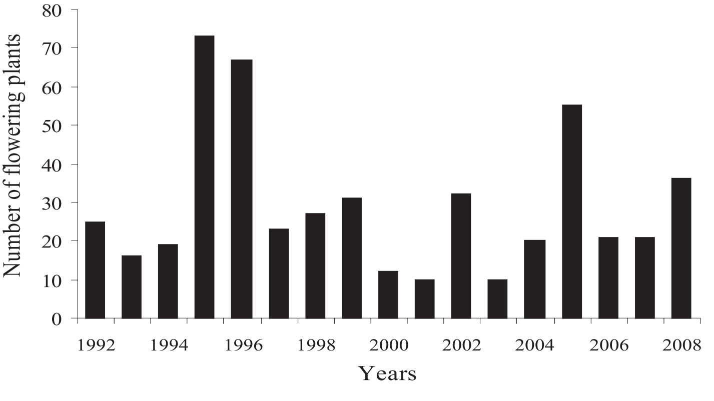

Fig. 2: The number of flowering plants in the study period (1992-2008)

rescences were measured. The latter ones were recorded only from 1998. The fruits were counted three weeks after the flowering time. The inflorescences which were not able to develop in consequence of the drought were not taken into consideration, because they could not be found only by chance. The damaged inflorescences and spikes without any flowers bitten off by caterpillar were also neglected.

The data of reproductive characteristics (height of flowering plant, number of flowers and fruits) were evaluated in the whole investigation period (17 years), but the lengths of inflorescences were measured over 11 years. The Q-Q plot and if this method gave ambiguous results Kolmogorov-Smirnov test were applied to test the normality of data. The majority of the reproductive characteristics studied (except the fruit number) show normal distribution. Duncan test was used for comparing reproductive traits to detect inter-annual fluctuations. In the case of the fruit number due to the lack of normality non-parametric tests (Mann-Whitney and Kruskal-Wallis H test) were used for the same purpose. Linear correlation was calculated to detect the relationship between reproductive characteristics. All statistical analysis were carried out using the software package SPSS 13.1.

Results

The number of flowering individuals varied considerably between years (between 10 and 73 individuals) (Fig. 2). Richest years in inflorescences were 1995, 1996 and 2005, while the poorest were 1993 and 1994 and the beginning of 2000's (2000, 2001, 2003), respectively.

The average height of flowering plants was 51.0 cm, while the lowest value was 18 cm, the highest was 97 cm (Fig. 3). There was a significant relationship between the number of flowering individuals and the average height of flowering individuals ($r = 0.654$, $p<0.05$, $df=16$).

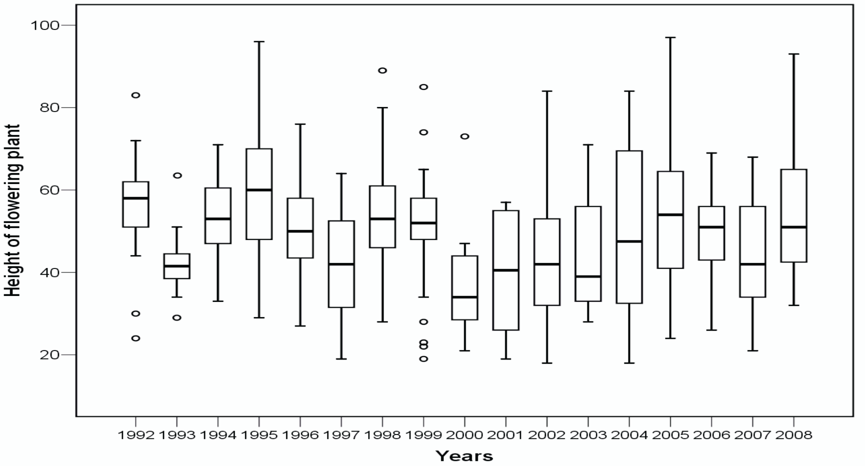

Fig. 3: The heights of flowering plants. The lower quartile, median and upper quartile are shown. (Outliers are that data wich lies more than 1.5 times the interquartile range lower than the first quartile or 1.5 times the interquartile range higher than the third quartile)

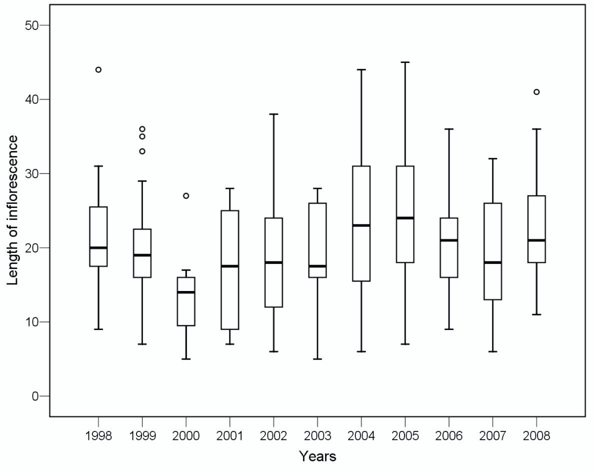

Fig. 4: The lengths of the inflorescences. The lower quartile, median and upper quartile are shown. (Outliers are that data wich lies more than 1.5 times the interquartile range lower than the first quartile or 1.5 times the interquartile range higher than the third quartile)

The flowers appear generally on the 20 cm top section of the spike. The average length of the inflorescences was 20.8 cm (minimum 5 and maximum 45 cm) (Fig. 4). A significant relationship with the number of flowering individuals ($r=0.661$, $p<0.05$, $df=10$) was detected.

The individuals develop 31.8 flowers on average (minimum 4 and maximum 84 flowers per spike) (Fig. 5). There is no significant relationship between the number of flowering plants and the average number of flowers per plant.

In many cases only a few or no fruit (seedpod) develops on the stems. The highest value was 33 seedpods per inflorescence. There were years when only 1-2 seedpods per individual were developed (e.g. 1994, 1997, 1999, 2000 and 2001) (Fig. 6A). The fecun-

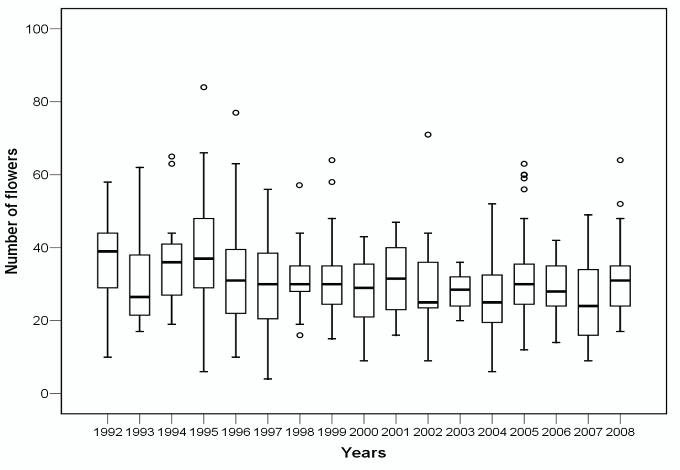

Fig. 5: The number of flowers. The lower quartile, median and upper quartile are shown. (Outliers are that data wich lies more than 1.5 times the interquartile range lower than the first quartile or 1.5 times the interquartile range higher than the third quartile)

dity (the number of seedpods produced) was extremely good in 2004, when 14 seedpods per plant were detected. The non-parametric tests prove the differences between the years (Kruskal-Wallis H test = 88.6, df=16, p<0.001). There was no relationship between the number of flowering individuals and the average number of fruits per plant.

The fecundity rate greatly varies over the years (Fig. 6B). The best year was 2004, when more than half part of the flowers got fertilised, while the number of flowering individuals was low. In other years, from much larger flower number much fewer seedpods developed. A good example is 2008, when there were twice as many flowers as in 2004, with only half the number of seedpods, so the fertility rate was only 11%. The worst years were 2000 and 2001, when the extremely dry spring damaged much of the inflorescence, so only few plants were able to bloom. The flowers withered very fast in the dry, unusually hot weather, so there was no time for pollination, the fertility rate was approximately 5%.

Comparising the coefficients of variation (CV%), among the reproductive traits studied, three ones (except the number of seedpods) have low variability over years (Table 1). In the case of the number of seedpods, however, the variability was of very large extent.

There was significant correlation between the height of flowering plants and the number of flowers regarding the whole investigation period (Table 2). The higher the

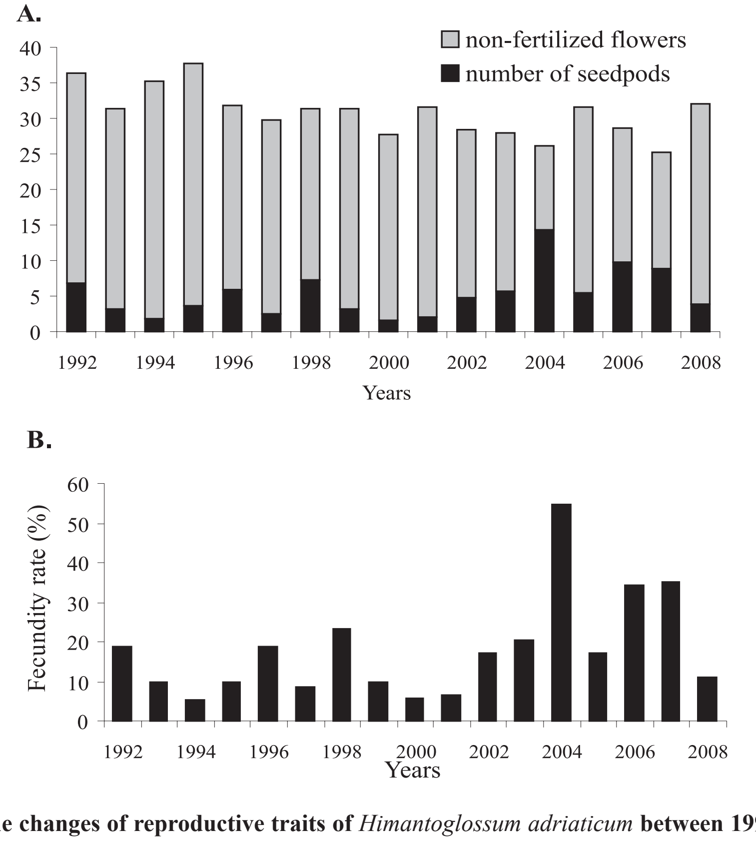

Fig. 6: The changes of reproductive traits of *Himantoglossum adriaticum* between 1992-2008. A. The number of sterile and fertile flowers per plant, B. The rate of fecundity

Table 1: The coefficient of variation (%) of the reproductive traits

Year	Height of flowering plant (cm)	Lenght of inflorescence (cm)	Number of flowers	Number of fruits
1992	22.4		36.1	99.2
1993	18.4		41.3	139.7
1994	20.1		36.9	151.2
1995	24.1		37.4	157.7
1996	21.6		40.2	105.0
1997	31.6		39.8	199.3
1998	22.6	33.6	26.1	81.7
1999	28.3	39.6	34.1	177.9
2000	37.9	41.2	34.8	175.5
2001	37.4	44.8	32.0	85.3
2002	38.6	44.0	41.4	134.6
2003	32.5	37.1	18.4	69.7
2004	41.0	43.3	41.7	59.9
2005	33.3	38.9	40.4	86.6
2006	23.9	29.9	27.5	100.2
2007	30.2	41.6	43.3	70.1
2008	27.0	31.0	35.4	112.1
pooled data	**30.0**	**39.9**	**38.5**	**119.9**

stem grows up the more flowers can develop on it. This relation is supported by the value of significant high correlation between the length of the inflorescences and the number of flowers. The stem height, in itself, does not influence the pollination; even if the stem is higher, the plant will not produce more seedpods. Although there is significant correlation between the number of flowers and the number of fruits (seedpods), but the value of correlation coefficient is very low referring to a slight relationship (Table 2).

Table 2: Relationships between reproductive traits (the correlation coefficients with asterisk are significant at p<0.05; the italic number refers to the mean value per individual; the length of inflorescence was measured from 1998 to 2008, others from 1992 to 2008)

	Length of inflorescences	Number of flowers	Number of capsules
Height of flowering plants	0.8903* *0.8629**	0.6738* *0.6715**	0.2614* *0.2222*
Length of inflorescences		0.7577* *0.3528*	0.4206 *0.3828*
Number of flowers			0.3974* *-0.4362*

Discussion

Number of flowering individuals

Counting flowering plants at a given site can be used to estimate trends in population performance. Although it does not show population size or flowering percentage.

During the 17-year monitoring period the number of flowering plants of *H. adriaticum* varied considerably between years (coefficient of variation 64.2). There were sevenfold difference in the number of flowering plants between the richest flowerful year and the poorest one. It was only three years when more than 50 individuals were able to flowering. From this point of view especially 1995 and 1996 proved to be very good years for *H. adriaticum* in the Keszthely Hills. The number of flowering *H. adriaticum* speciemens in this site is few comparing with that of *H. hircinum* in Germany or in England.

Other European orchid species have also great temporal fluctuations in the number of flowering plants. According to the results of long-term monitoring of *H. hircinum* population in the Leutra Valley (in Germany) carried out since 1960, the number of flowering plants reached almost 300 in 1974 and 1975, in other years it remained under 100 individuals. There began a long-lasting rise in 1988, which was disturbed by intensive fluctuations and with an extremely high value in 1995, when there were nearly 1400 inflorescences. Although in the next year were only a few inflorescences, there were 900-1000 flowering plants in 1997 and 1998 (HEINRICH 2000). The number of the flowering individuals changed very similarly to another population in Thuringia, where was also a large increase in 1995 (HEINRICH and VOELCKEL 1999).

The number of flowering individuals has been observed in the two largest populations of *H. hircinum* in England for a long time. Both populations had a small peak around 1950 and then had very low numbers until the 1980s. Later an intensive increase was observed in the abundance of flowering individuals, which resulted in 250 and 6000(!) inflorescences in the two sites (CAREY et al. 2002).

In the comparisons of spatial and temporal variation of *Orchis morio*'s flowering spikes in a 26-year meadow experiment GILMANN and DODD (1998) established that the number of flowering orchids were varied to much higher degree from site to site than in time. In many cases of orchid species similar findings were published by KULL (2002) in his review.

According to Kindlmann and Balounová's study with *Dactylorhiza majalis* the irregular flowering pattern may be typical for sites with temporarily or steadily declining populations. Several environmental factors (e.g. unsuitable habitat, wrong management, unsuitable weather conditions) can contribute to the irregular flowering in a given site (KINDLMANN and BALOUNOVÁ 1999).

The only conclusion can be drawn from the intensive fluctuation of the flowering individuals is whether the environmental conditions were favourable for the reproduction or not (when there are many flowering individuals, such year is called a "good orchid year"). To follow the dynamics of the population, we cannot leave out of consideration that the fluctuations in the number of flowering plants counted is not a true indicator of population size because juvenile plants were not counted in the population and only a proportion of the adult plants flower each year (CAREY et al. 2002).

Number of flowers and fruits on the spike

The number of flowers is a characteristic feature in the identification of the different *Himantoglossum* species. While *H. hircinum* is characterised by dense inflorescence with many (40-120) flowers, the *H. adriaticum* has a loose inflorescence with only 25-50 flowers (BAUMANN and KÜNKELE 1982, BUTTLER 1986, ADLER et al. 1994).

In spite of the considerable differences between the extreme values of reproductive traits studied, among them three (except for number of seedpods) showed low temporal variability in the whole study period (cf. Table 1). In the case of the number of seedpods, however, the variability was of very large extent indicating the great uncertainty in the annual fecundity.

The number of flowers and the height of the stem are similarly stable characteristics in the case of the *Dactylorhiza lapponica* (OIEN and MOEN 2002) and the number of flowers per inflorescence does not vary greatly in *Tipularia discolor* and *Liparis lilifolia* populations. Observed differences in flowering and fruiting are most likely to be influenced by historical events at the individual level, especially costs associated with sexual reproduction and leaf herbivory (WHIGHAM and O'NEIL 1991). Otherwise, the height of spike and the number of flowers per inflorescence were also a year-depending characteristics in the case of *Ophrys apifera* (WELLS and COX 1991).

The rate of the fecundity is usually a variable character and the low levels of fruit-set are typical among wild orchids (PROCTOR and YEO 1973, SUMMERHAYES 1968). Only 7% of the flowers got fertilized in *Orchis purpurea* populations in Belgium, and the number of seedpods seems to be depended on the number of flowers on spike. The large inflorescences produced significantly more fruits than the smaller inflorescences and this phenomenon proved to be independent of population (JACQUEMYN et al. 2002). Other orchid species show just the opposite.

Fruit-set production is not related to the number of flowers or their density, suggesting that pollination and/or seed set varies between years (CAREY et al. 2002, CAREY and FARRELL 2002). For *H. adriaticum* 2004 was an extremely good year, when the orchid produced 14 seedpods per plant, in spite of the fact that the number of flowering plants was relatively low and the average number of flowers per plant was the lowest in that year. No correlation was found between the fecundity rate and the height of flowering plants as well as the average length of the inflorescences. In the case of *H. hircinum* populations in South-England 1993 was an outstanding year, when the mean number of seedpods produced per plant was exceptionally high, nearly 20, in contrast with the regular 5 or even lower values (CAREY et al. 2002). No significant relationship was found between the fruit set and inflorescence size in the case of *Dactylorhiza fuchsii* and *Epipactis helleborine* (WAITE et al. 1991). The reproductive success was not correlated with the number of flowers, but the correlation with the length of inflorescence was found to be significant by other investigations in the case of *Dactylorhiza fuchsii*, in Bohemia (JANECKOVA and KINDLMANN 2002).

Probably, the complicated pollination biology also contribute to the variations of reproductive traits. One of the most important feature is whether the flower produces nectar or not. There is no certainty in the case of the *Himantoglossum* genus, that there is nectar in the spur or not (CAREY and FARRELL 2002). Another important factor is the weather at the time of flowering. If the weather is favourable for the pollinator insects, the fecundity rate is better (LIGHT and MACCONAILL 2002).

Conclusion

There are only few data about *Himantoglossum adriaticum*, because the species was only described not long ago. Although the total number of population, flowering frequency could not be estimate if only flowering individuals are used for monitoring, however due to the long time period it enable tendencies and temporal variation in population size to be detected.

The examined population is small, and the fluctuation in the number of flowering individuals is relatively large between years, that is, on the basis of flowering plants the population has temporal variability in this site. There are years when the orchid has extremely good fruit productions. On the other hand, these good fruit-producing years, which will insure the long-term survival of the population under suitable environmental conditions, do not coincide with the 'good orchid years', that is years of great number of inflorescences.

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