Biodiv. Res. Conserv. 17: 39-46, 2010
BRC
www.brc.amu.edu.pl

10.2478/v10119-010-0005-3

Lindernia procumbens in Poland: the relationship between weather conditions and the occurrence of the species

Agnieszka Nobis[1], Marcin Nobis[1], Katarzyna Piotrowicz[2], Zygmunt Kącki[3] & Zygmunt Dajdok[3]

[1]Department of Plant Taxonomy and Phytogeography, Institute of Botany, Jagiellonian University, Kopernika 27, 31-501 Kraków, Poland, e-mail: agnieszka.nobis@wp.pl
[2]Department of Climatology, Institute of Geography and Spatial Management, Jagiellonian University, Gronostajowa 7, 30-387 Kraków, Poland
[3]Department of Biodiversity and Plant Cover Protection, Institute of Plant Biology, University of Wrocław, Kanonia 6/8, 50-328 Wrocław, Poland

Abstract: New data regarding the occurrence of *Lindernia procumbens* (prostrate false pimpernel) are discussed and its current geographical range in Poland is given. A comparison of its past and present distribution in Poland indicates an advancement of the distribution limit northwards, which may be caused by climate changes, mostly, by an increased number of heat waves in the warm half-year. The relationship between the occurrence of the species and specific meteorological conditions, especially, unusually hot and dry summer periods, is analysed using long-term meteorological surveys.

Keywords: meteorological conditions, climate changes, distribution, endangered species, *Lindernia procumbens*, Poland

1. Introduction

While the occurrence of vanishing species at new sites is very rare, it is extremely important for biodiversity preservation and therefore requires attention. *Lindernia procumbens* (Krocker) Borbás, which is thought to be one of the rarest vascular plants in Central Europe, represents such species. It belongs to the connecting Holarctic-Paleotropical element. A few centres of its occurrence, such as Europe, Western and Central Asia, Indian Peninsula, Eastern Asia, Indochina and Malay Peninsulas and Java, are distinguished within its range. In Europe, the species occurs in scattered localities ranging from Portugal, France, central and southern Germany, northern Italy, southern Poland and Danube countries, to southern and central Ukraine (Meusel *et al*. 1978; Latowski *et al*. 1988).

Lindernia procumbens was first collected in Poland on the bank of the Oder River in Dobrzeń Wielki (*leg*. H. Grabowski 1834, WRSL). However, it was first formally reported from Poland by Pampuch (1840), who recorded it from the Gniezno Lakeland. Unfortunately, the site was regarded as uncertain due to the lack of data concerning its precise location and the lack of herbarium material. The majority of *L. procumbens* sites were noted in Poland in the second half of the 19th century (Latowski *et al*. 1988). The species was not recorded in Poland between 1960 and 1985 and was therefore considered to be rare (Jasiewicz 1981). It was consequently listed as an extinct and vanished species, Ex (Zarzycki 1986). *L. procumbens* was rediscovered in Poland in the late 1980s. Zając & Zając (1988) noted it in the south-western part of the Oświęcim Basin. Its presence was reported from ten other sites in the following years (Popiela & Stasińska 1994; Wayda 1996; Banaś & Paul 2000; Spałek 2006).

Lindernia procumbens was included in the national red data book of plants as critically endangered (CR) owing to a small number of sites and a high probability that the species might vanish (Zając & Zając 2001). It was

CHOROLOGY

classified as a plant characterised by a considerable decrease in the number of localities over the last few decades in ecological studies of indicator numbers of vascular plants in Poland (Zarzycki *et al.* 2002). The plant was considered to be a vulnerable species (VU) in the latest edition of the national red list (Zarzycki & Szeląg 2006).

Lindernia procumbens is also treated as a threatened species in other central European countries, e.g. Germany, Austria, the Czech Republic and Slovakia (Korneck *et al.* 1996; Niklfeld & Schratt-Ehrendorfer 1999; Procházka *et al.* 1999; Holub & Procházka 2000). It is therefore covered by the Bern Convention and listed in Annex 4 to Council Directive 92/43/EEC (‘Habitat Directive’) as a species that requires strict protection in the Member States. The estimation of the current threat and protection methods of its sites and habitats is still needed.

The aims of this study are to examine the relationship between the occurrence of *Lindernia procumbens* and specific meteorological conditions and to determine whether climate changes could be a factor influencing its range extension.

2. Material and methods

Field investigations aimed at finding new sites of *Lindernia procumbens* were carried out in the Oder and the San River Valleys as well as in the adjacent regions in 2003-2005. Data collected in 2008 and 2010 were also taken into account. The distribution was mapped in the ATPOL cartogram grid covering entire Poland (Zając 1978). Literature data and herbarium materials deposited in Wrocław University – WRSL, Jagiellonian University – KRA and the Polish Academy of Sciences – KRAM were used to study the distribution of *Lindernia procumbens*. Herbarium acronyms follow Holmgren & Holmgren (1998).

Meteorological conditions observed in the years in which *Lindernia procumbens* was noted were analysed. Long-term air temperature and precipitation surveys from the meteorological station in Kraków in the period 1826-2006 were used. Data collected at the station represent climatic conditions in a considerable area of Central Europe located below 300 meters above the sea level (Kożuchowski *et al.* 1994; Brázdil *et al.* 1996; Domonkos *et al.* 2003).

3. Results

3.1. The distribution of *Lindernia procumbens* in Poland

The occurrence of *Lindernia procumbens* has been reported from southern Poland, mostly from Lower Silesia (17 historical sites are located near Wrocław). Its

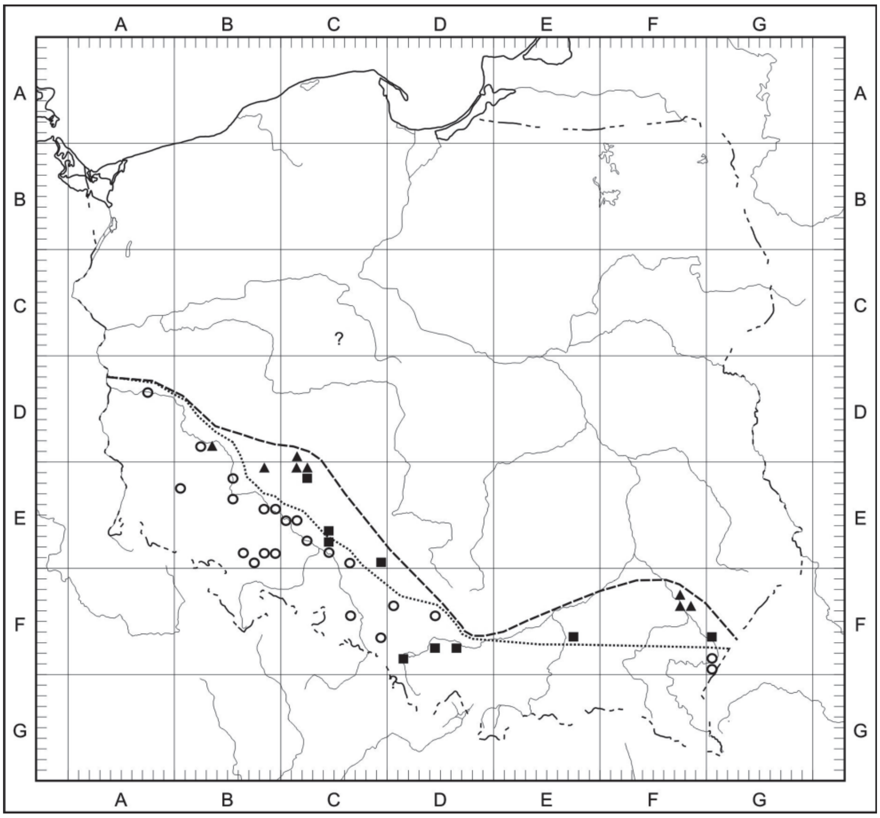

Fig. 1. Distribution and range limit of *Lindernia procumbens* in Poland

Explanations: ○ – historical locality (noted till 1960), ■ – locality known since the late 1980s, ▲ – new locality, ? – uncertain locality, ············ – historical range limit (known until 1960), - - - - - – present range limit northernmost site in Będów near Krosno Odrzańskie (Strech 1941), which is, at the same time, the only known site of this species above the latitude of 52°N. *L. procumbens* had been noted in south-eastern Poland in a few localities only until 2000. The present localities extend the distribution of the taxon and markedly shift its limit northwards (Fig. 1).

A list of the sites of *Lindernia procumbens* that were observed in 2003, 2005 and 2008 is given below (letter symbols correspond to the ATPOL squares 100 km × 100 km, each square is divided into 100 square units, 10 km × 10 km, described using numbers): **BD83** – oxbow lake along the Oder River, NE of Wojszyn near Głogów, 19.09.2003, leg. Z. Kącki; oxbow lake along the Oder River, Borkowice near Głogów, 19.09.2003, leg. Z. Kącki; **BE08** – bottom of a pond, Stawy Kokoty (Kokoty Ponds) near Nowe Dyminy (NE of Żmigród), 15.09.2003, leg. Z. Dajdok; **CD91** – bottom of a pond, Staw Mieszko (Mieszko Pond) Dyminy near Nowe Grodzisko (NE of Milicz), 25.08.2008, leg. B. Orłowska, Z. Dajdok; **CE01** – bottom of a pond, Stawy Jaskółcze (Jaskółcze Ponds) near Ruda Milicka (E of Milicz), 26.08.2003, leg. Z. Dajdok; **CE02** – bottom of a pond, Staw Trójkątny (Trójkątny Pond) Joachimiówka near Potasznia (SE of Milicz), 15.09.2003, leg. Z. Kącki; bottom of a pond, Staw Niezawodny Górny (Niezawodny Górny Pond), Joachimiówka near Potasznia (SE of Milicz), 15.09.2003, leg. Z. Kącki; **FF27** – alluvium on a pond bank, Naklik near Leżajsk, 17.09.2003, leg. A. Michalewska, M. Nobis; **FF37** – bank of the Złota River, Kuryłówka near Leżajsk (20 m S of the bridge over the Złota River), 4.09.2003, leg. A. Michalewska, M. Nobis; alluvium on the bank of a water-course close to the Złota River, Ożanna Mała near Leżajsk (100 m E of the bridge over the Złota River), 4.09.2003, leg. A. Michalewska, M. Nobis; sandy bank of a water-course close to the Złota River, Ożanna Mała near Leżajsk (40 m E of the bridge over the Złota River), 4.09.2003, leg. A. Michalewska, M. Nobis; sandy bank of the Złota River, Ożanna Mała near Leżajsk (600 m W of the western edge of the village), 11. 09. 2003, leg. A. Michalewska, M. Nobis; on the edge of an arable field, Rzuchów near Leżajsk (1 km NW of the bridge over the San River, 26.07.2005, leg. A. Nobis, M. Nobis; **FF38** – sandy bank of the Złota River, Ożanna Duża near Leżajsk (two populations located at a distance of about 100-150 m from each other), 31.08.2005, leg. A. Nobis.

3.2. The relationship between the occurrence of *Lindernia procumbens* and meteorological conditions

Total precipitation reports show that precipitation in Kraków is diversified and demonstrates considerablefluctuations (Niedźwiedź & Twardosz 2004; Twardosz 1999). There was a distinctive concentration of humid summers in the 1840s, at the turn of the 20th

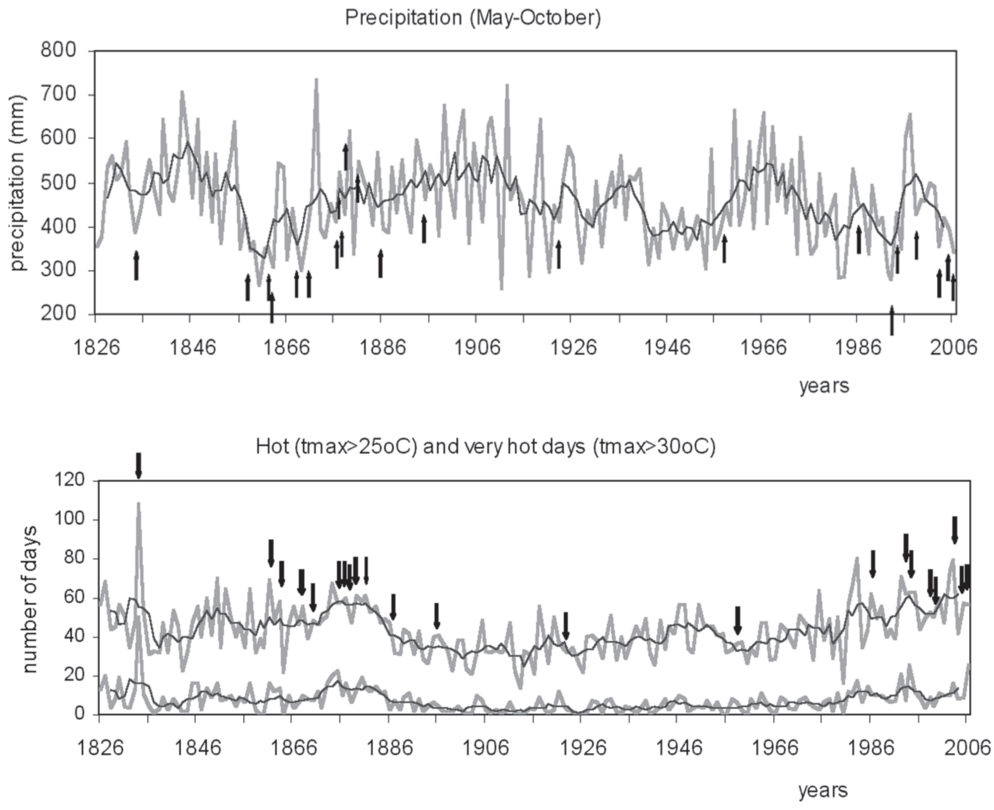

Fig. 2. Long-term variation in total annual precipitation, and incidence of hot and very hot days during warm half-year (May-October) in Kraków in the period 1826-2006 (black-line curve smoothed by 5-year moving average)

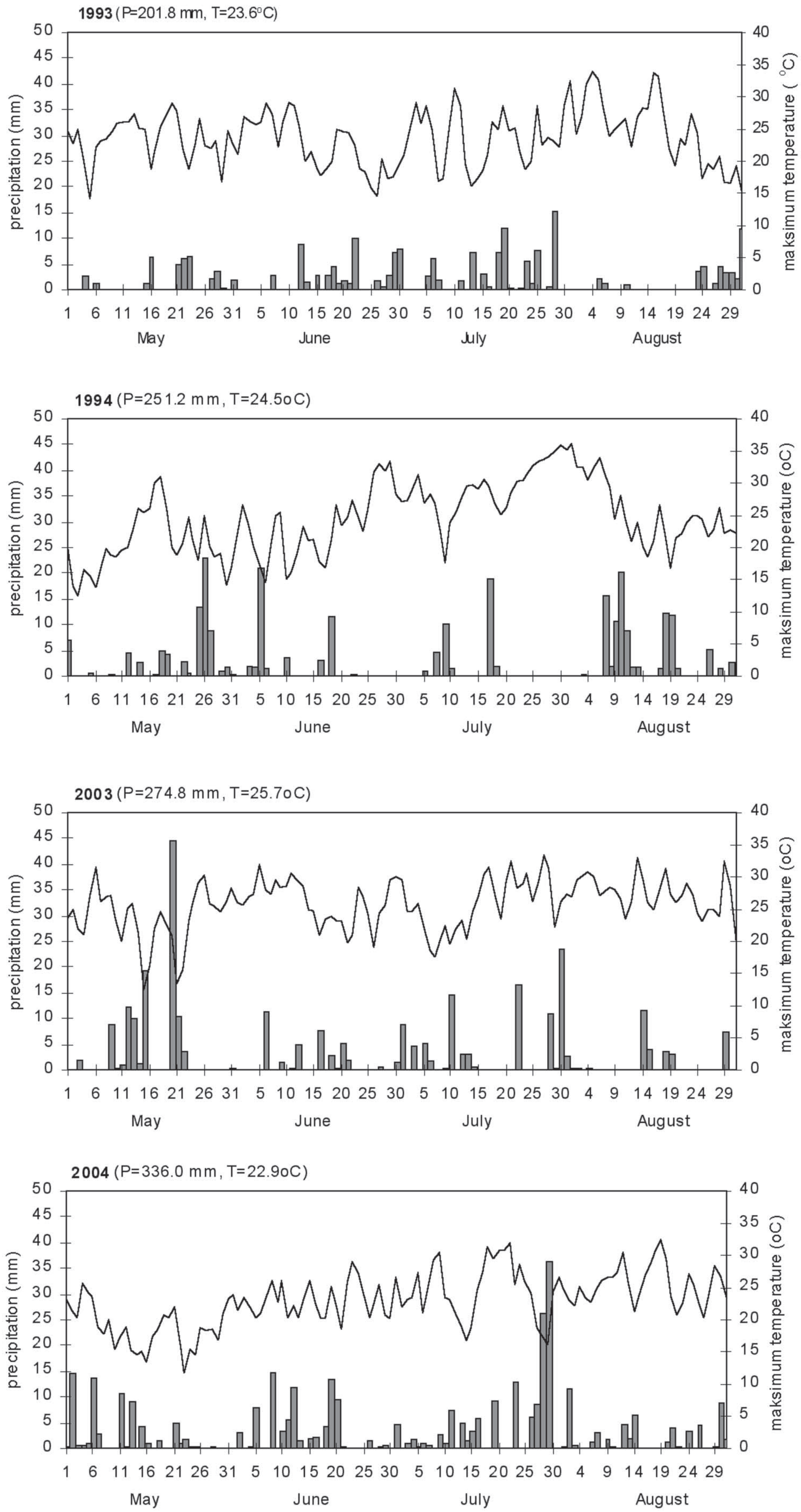

Fig. 3. Distribution of total daily precipitation and maximum air temperature from May to August in Kraków (P – totals sum [mm], T – mean maximum air temperature [°C])

century and in the 1960s. At these periods, *Lindernia procumbens* was not observed according to literature data and herbarium data. The 1850s, 1860s, 1980s and the early 1990s were characterized by a concentration of dry summers. *L. procumbens* was recorded by botanists during these periods (Fig. 2).

The analysis of dry periods shows the relationship between the occurrence of *Lindernia procumbens* and precipitation even better than the analysis of total annual or monthly precipitation alone as relatively high daily precipitation totals in summer can be connected with short storms that do not interrupt soil drought due to strong evaporation. Daily precipitation totals, dry periods and the course of maximum air temperatures (from May to August) in individual years are good examples (Fig. 3). *L. procumbens* was, for instance, noted in 2003. Precipitation was relatively high from May to August 2003 (274.8 mm) but it mostly consisted of downpours or short-time rainfalls that were accompanied by high air temperatures. By contrast, total precipitation between May and August in 2004 was higher (336.0 mm) and an exceptionally high amount of precipitation occurred in the second half of July when air temperature was considerably lower in comparison with the previous year. In 2004, the occurrence of *L. procumbens* was not confirmed at any of the localities observed in 2003. In the summer seasons 1993 and 1994, a long-lasting shortage of precipitation, accompanied by quite high average maximum daytime temperatures, occurred, which allowed for the sprouting and development of the species that was noted by Popiela & Stasińska (1994) and Wayda (1996) in both years (Fig. 3).

If total precipitation is high in a particular year, water level will be high not only in rivers but also in water basins. As a general rule, *Lindernia procumbens* will not occur as its typical habitats are flooded. However, it is interesting that since 1980s, the species has been noted mainly in anthropogenic habitats, mostly beds of drained fish ponds (Banaś & Paul 2000; Popiela & Stasińska 1994; Spałek 2006, Wayda 1996; Zając & Zając 1988). It may be assumed that the occurrence of *L. procumbens* is not strictly connected with total precipitation in some cases but with pond-water draining. Therefore, summer season air temperature values, which influence the water temperature of an alluvium, are more important for the occurrence of *L. procumbens* in anthropogenic habitats than total precipitation. According to greenhouse research, good sprouting results were obtained when the alluvia were heated up to the temperature of above 35°C, while sprouting did not occur in the temperature between 13-25°C (Lampe 1996). *L. procumbens* needs a relatively short but very warm period of vegetation as high temperature is especially required in the initial phases of plant development. The influence of temperature on the occurrence of *L. procumbens* has been analysed in relation to the different numbers of hot days (with the maximum temperature above 25°C; t_{max}>25°C) and very hot days (with the maximum temperature above 30°C; t_{max}>30°C) in Kraków. Importantly, there is a high correlation between the occurrence of those days in Kraków and Prague (Piotrowicz 2003). Days with t_{max}>25°C may occur in southern Poland from April to October and days with t_{max}>30°C from April to September. The greatest number of such days occurred in 1834, not only in Kraków but also in Prague (Piotrowicz 2003). *L. procumbens* was noted in Poland in that year (in the settlement of Dobrzeń Wielki near Opole, *leg.* H. Grabowski – WRSL). An exceptionally big number of hot and very hot days was recorded in 1983, 1986, 1992, 1994, 2002 and 2003 (Piotrowicz & Wypych 2006). *L. procumbens* was recorded in Poland in most of these years (Fig. 2).

As Fig. 2 shows, a very pronounced concentration of years with a large number of hot and very hot days occurred from the late 1840s until the mid 1880s. Approximately ca. half of the reports on the occurrence of *Lindernia procumbens* in Poland came from this period. Frequent discoveries of *L. procumbens* can be associated with the next concentration of years with quite a high number of hot and very hot days lasting from the early 1980s until now. The plant was recorded especially frequently by the present authors in 2003. Records from 2003 constitute more than a half of the total records of the species after 1980. Such a numerous occurrence may have been caused not only by an unusually early arrival of hot and very hot days (April and May) but also by record heat waves in July and August which took place both in Poland and in other parts of Central Europe.

Lindernia procumbens was not observed in all the years characterized by a particularly hot and dry summer season. This is related to the varying intensity of floristic field research. Despite weather conditions favourable for *L. procumbens*, botanical studies were not intensive in Poland, for instance, in the interwar period, during World War II or in the years following it, and the plant was not recorded. On the other hand, floristic studies have a long-standing tradition in southern Poland. The regions where the new finds of the species are located have been investigated for a long time and have detailed floristic elaborations. The collection of *L. procumbens* by the present authors is therefore not only the result of a strict goal-directed field research project.

4. Discussion

Lindernia procumbens is considered to be critically endangered (CR) in Poland according to Zając & Zając (2001). However, up-to-date information on population resources does not allow to include the species in the list of critically endangered plants. A broad range of habitats occupied by *L. procumbens* (oxbow lakes, ponds, river banks, and even arable fields) indicates its great adaptation abilities. Since this species was not previously recorded in arable fields in Poland, its presence in this habitat is highly interesting and may demonstrate a tendency towards a change in or the extension of the range of its habitats and phytocoenotic requirements. A similar tendency has been observed in the case of *Lythrum hyssopifolia*, a species with similar habitat preferences, which, at present, is mainly reported from anthropogenic habitats and less frequently from natural ones. The occurrence of *L. procumbens* in an arable field in 2005 was not accidental. The plant was noted there also in the following years (till 2010). Presence of *L. procumbens* in such habitats has been reported from the subtropical part of its distribution area, where it is a frequent and persistent weed in rice fields (Young Son & Rutto 2002).

A large number of *Lindernia procumbens* sites found in 2003 and 2005 confirms the connection between the occurrence of the species and weather conditions (warm and dry summers). The most favourable temperature and habitat conditions for its proliferation are found in river valleys. This is consistent with the classification of the species in the group of river corridor plants in Central Europe (Burkart 2001). The fact that, until recently, *L. procumbens* was reported mainly from anthropogenic habitats in Poland (Popiela 1997) may be connected with river flow control and the ongoing process of river damming. However, the most recent data imply that the species is found in natural habitats in the northernmost limit of its overall range when the water level in the rivers is exceptionally low. The occurrence of *L. procumbens* on farm ponds is more frequent and less dependant on weather conditions.

Polish and German localities of *Lindernia procumbens* are the northernmost sites in Europe. Only one locality is situated above the latitude of 52^{o} (vicinity of Krosno Odrzańskie). The localities of the species observed in the San and Oder River Valleys in 2003, 2005 and 2008 are considerably moved northwards in comparison to its previously known localities. Therefore the species may "advance" northwards and, in effect, extend its range in Central Europe. Presumably, it might be connected with climate changes, and specifically with a frequent occurrence of heat waves in the warm half-year. As research within the Prudence project shows (Prediction of regional scenarios and uncertainties for defining European climate change risks and effects; http://prudence.dmi.dk/), the number of very hot days (t_{max}>30^{o}C) will increase both in Poland and other countries of Central Europe. Moreover, prolonged heat waves in Poland are considerable: 3 days in 10 years on average (Kuchcik 2006). If climatological forecasts are confirmed, it is likely that *L. procumbens* will occur more often and it may even "advance" northwards. The problem needs further studies. Only monitoring of the occurrence of *L. procumbens* over a larger distribution area for a longer period of time will verify an assumption on the potential extension of its range.

References

BANAŚ B. & PAUL W. 2000. Distribution of *Lindernia procumbens* (Scrophulariaceae) in the Polish Carpathians and their foreland. Fragm. Flor. Geobot. Polonica 7: 365-368.

BRÁZDIL R., BUDÍKOVÁ M., AUER I., BÖHM R., CEGNAR T., FAŠKO P., LAPIN M., GAJIČ-ČAPKA M., ZANINOVIČ K., KOLEVA K., NIEDŹWIEDŹ T., USTRNUL Z., SZALAI S. & WEBER R. O. 1996. Trends of maximum and minimum daily temperatures in central and south-eastern Europe. Int. J. Climatol. 16: 765-782.

BURKART M. 2001. River corridor plants (Stromtalpflanzen) in Central European lowland: a review of a poorly understood plant distribution pattern. Global Ecol. Biogeogr. 10: 449-468.

DOMONKOS P., KYSELY J., PIOTROWICZ K., PETROVIC P. & LIKSO T. 2003. Variability of extreme temperature events in South-Central Europe during the 20th century and its relationship with large-scale circulation. Int. J. Climatol. 23: 987-1010.

HOLMGREN P. K. & HOLMGREN N. H. 1998. [continuously updated]: Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/ih/

HOLUB J. & PROCHÁZKA F. 2000. Red list of vascular plants of the Czech Republic – 2000. Preslia 72(2-4): 187-230.

JASIEWICZ A. 1981. Wykaz gatunków rzadkich i zagrożonych flory polskiej. Fragm. Flor. Geobot. 27(3): 401-414.

KORNECK D., SCHNITTLER M. & VOLLMER I. 1996. Rote Liste der Fern- und Blütenpflanzen (*Pteridophyta* et *Spermatophyta*) Deutschlands. Schr.-R. f. Vegetationskde 28: 21-187.

KOŻUCHOWSKI K., TREPIŃSKA J. & WIBIG J. 1994. The air temperature in Cracow from 1826 to 1990: persistence, fluctuations and the urban effect. Int. J. Climatol. 14: 1035-1049.

KUCHCIK M. 2006. Heat waves in Poland over the period 1993-2002. Przegl. Geogr. 78(3): 397-412.

LAMPE M. 1996. Wuchsform, Wuchsrhythmus und Verbreitung der Arten der Zwergbinsengesellschaften. Diss. Bot. 266: 1-355.

LATOWSKI K., ZAJĄC M. & ZAJĄC A. 1988. *Lindernia procumbens* (Krock.) Philcox. In: A. JASIEWICZ (ed.). Materials for knowledge of rare and endangered species of Poland. Part I. Fragm. Flor. Geobot. 33: 416-421.

MEUSEL H., JÄGER E., RAUSCHERT S. & WEINERT E. 1978. Vergleichende Chorologie der zentraleuropäischen Flora. II. Text xi+418 pp., Karten pp. 259-421. Gustav Fischer Verlag, Jena.

NIKLFELD H. & SCHRATT-EHRENDORFER L. 1999. Rote Liste gefärdeter Fern- und Blütenpflanzen (*Pteridophyta* et *Spermatophyta*) Österreichs. In: H. NIKLFELD (ed.). Rote Listen gefährdeter Pflanzen Österreichs, pp. 33-130. Austria Medien Service GmbH, Graz.

NIEDŹWIEDŹ T. & TWARDOSZ R. 2004. Long-term variability of precipitation at selected stations in Central Europe. Papers on Global Change IGBP 11: 1-28.

PAMPUCH A. 1940. Flora Tremesnensis, pp. 70. Verl. von G. Olawski, Trzemeszno.

PIOTROWICZ K. 2003. Dynamika zmian temperatury powietrza w Pradze i Krakowie. In: J. LACH (ed.). Dynamika zmian środowiska geograficznego, pp. 96-104. Narod. Fundusz Ochr. Środ. i Gosp. Wodnej, Akad. Pedag., Kraków.

PIOTROWICZ K. & WYPYCH A. 2006. Long-term variations in the number of hot, very hot and sultry days in Kraków. Papers on Global Change IGBP 13: 43-58.

POPIELA A. 1997. Occurrence of the *Isoëto-Nanojuncetea*-class communities in Poland. Monogr. Bot. 80: 1-59.

POPIELA A. & STASIŃSKA M. 1994. New locality of *Lindernia procumbens* (Scrophulariaceae) in the basin of the Barycz River. Fragm. Flor. Geobot. Polonica 1: 350-352.

PROCHÁZKA F., HUSÁK Š. & OŤAHEĽOVÁ H. 1999. *Lindernia procumbens* (Krocker) Philcox. In: J. ČEŘOVSKÝ, V. FERÁKOVÁ, J. HOLUB, Š. MAGLOCKÝ & F. PROCHÁZKA (eds). Červená kniha ohrozených a vzácnych druhov rastlín a živočíchov SR a ČR, Vyššie rastliny, Vol. 5, pp. 225-225. Príroda a. s., Bratislava.

SPAŁEK K. 2006. *Lindernia procumbens* (Krocker) Philcox in SW Poland. Thaiszia J. Bot. 16: 51-57.

STRECH A. 1941. *Lindernia pyxidaria* in der Mark Brandenburg. Verh. Bot. Ver. Berlin Brandenburg 81: 165-167.

TWARDOSZ R. 1999. Warunki pluwialne w Krakowie w latach 1792-1998. Czas. Geogr. 70(2): 221-234.

WAYDA M. 1996. New locality of *Lindernia procumbens* (Scrophulariaceae) in the Sandomierz Basin. Fragm. Flor. Geobot. Polonica 3: 401-402.

YOUNG SON C. & RUTTO K. L. 2002. Are Herbicides Essential for Paddy Weed-control in East Asia? Pakistan J. Biol. Agric. Sci. 5(12): 1352-1362.

ZAJĄC A. 1978. Atlas of distribution of vascular plants in Poland. Taxon 27(5-6): 481-484.

ZAJĄC M. & ZAJĄC A. 1988. Communities of *Isoëto-Nanojuncetea*-class at the bottom of drying up ponds in southern part of Kotlina Oświęcimska valley. Zesz. Nauk. UJ Prace Bot. 17: 155-160.

ZAJĄC M., ZAJĄC A. 2001. *Lindernia procumbens* (Krocker) Philcox. In: R. KAŹMIERCZAKOWA & K. ZARZYCKI (eds). Polish Red Data Book of Plants, Pteridophytes and Flowering Plants, pp. 322-324. W. Szafer Institute of Botany & Institute of Nature Conservation PAN, Kraków.

ZARZYCKI K. 1986. Lista wymierających i zagrożonych roślin naczyniowych w Polsce. In: K. ZARZYCKI & W. WOJEWODA (eds.). Lista wymierających i zagrożonych roślin naczyniowych Polski, pp. 11-27. PWN, Warszawa.

Zarzycki K. & Szeląg Z. 2006. Red list of the vascular plants in Poland. In: Z. Mirek, K. Zarzycki, W. Wojewoda & Z. Szeląg (eds.). Red list of plants and fungi in Poland, pp. 9-20. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Zarzycki K., Trzcińska-Tacik H., Różański W., Szeląg Z., Wołek J. & Korzeniak U. 2002. Ecological indicator values of vascular plants of Poland. In: Z. Mirek (ed.). Biodiversity of Poland 2, 183 pp. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.