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Department of Animal Ethology and Wildlife Management,
University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland
*e-mail: piotr.czyzowski@up.lublin.pl

MARIUSZ WÓJCIK, SŁAWOMIR BEEGER, PIOTR CZYŻOWSKI*

Assessment of the occurrence of the pond turtle *Emys orbicularis* in Polesie National Park based on drone monitoring

Abstract. This study aimed to determine the habitat preferences of the pond turtle *Emys orbicularis* L. in Polesie National Park and assess the effectiveness of drone use across different seasons. Monitoring was conducted with three DJI drone models (Mavic Air 2, Air 2S and Air 3), which carried out surveys on 27 selected sites covering a total area of 49.73 ha, using optical cameras and orthophoto software. Turtle activity was highest in spring, especially during mating, when individuals are more likely to come to the surface for thermoregulation and reproduction. As temperatures rose and drought progressed, the number of sightings decreased, which was associated with the drying of water bodies and a change in turtle behaviour. Most turtles were observed in sedge meadows and drainage ditches, which acted as migration corridors and places of refuge during the drought. The survey confirmed the high usefulness of drones in monitoring the species, especially in hard-to-reach areas.

Keywords: European pond turtle, *Emys orbicularis*, drone monitoring, wetland habitats

INTRODUCTION

The pond turtle (*Emys orbicularis* L.) is the only native turtle species in Poland and is classified as a high-risk, endangered species. It is listed in both the *Polish Red Book of*

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Animals and the *Red List of Threatened and Endangered Animals in Poland* with an EN (Endangered) status [Głowaciński 2001, 2002]. The species is protected under the EU Habitats Directive 92/43/EEC (Annexes II and IV) and the Bern Convention [Najbar 2012]. In Poland, it is strictly protected and subject to active conservation measures under the Regulation of the Minister of the Environment of 16 December 2016 [Najbar 2012]. While it occurs throughout the country, its largest population is found in the Lublin Polesie region. It is considered one of Poland's most distinctive and well-studied reptile species [Dziedzic 2002, Kosik et al. 2013]. Pond turtles inhabit a variety of habitats across extensive park areas, including bogs, sedge meadows, alder thickets, ponds, drainage ditches and peat bogs [Mitrus 2006]. Eleven breeding sites have been identified in the park and its buffer zone. The population size is estimated at 350–450 adult individuals; based primarily on the number of females laying eggs in a given year. A systematic increase in the number of females at breeding sites, including the appearance of previously unmarked individuals, suggests that active protection efforts by park staff are effective. The exact number of males and juveniles remains unknown [Olszewski 2024].

In recent years, drones have gained popularity as a tool for monitoring wildlife in natural environment, especially in hard-to-reach areas where traditional ground-based methods prove insufficient [Chamoso et al. 2014, Rey et al. 2017, Ezat et al. 2018, Kellenberger et al. 2018, Prosekov et al. 2020, Rančić et al. 2023, Czyżowski et al. 2024]. Their use in turtle population inventories surpasses the effectiveness of classic techniques based on direct observation [Wójcik et al. 2024]. Drones allow monitoring areas inaccessible to humans without disturbing wildlife. When equipped with optical and thermal cameras, and combined with deep learning technology, they enable the automatic processing and identification of captured images [Rey et al. 2017, Ezat et al. 2018, Prosekov et al. 2020, Rančić et al. 2023].

The main objective of this study was to determine the habitat preferences of the pond turtle in Polesie National Park using consumer drones and to assess the seasonal effectiveness of using drones for turtle monitoring.

MATERIALS AND METHODS

The research was conducted with the consent of the Director of Polesie National Park (permit no 24/2024), authorising scientific research and movement within the park. Additionally, permission for exemptions from prohibitions related to research on the European pond turtle in Polesie National Park was granted under DOP-WOPPN.61.74.2024.MŚP.

Preliminary field surveys, along with information from the park service and the literature allowed the selection of probable turtle habitats. The size of the areas monitored varied, usually limited by the natural features of the habitats, such as a group of mid-forest bogs, sedges bounded by drainage ditches, fishponds, etc. Monitoring was carried out in six study periods: 1 (13–28 IV), 2 (5–15 V), 3 (17–29 V), 4 (18–21 IV), 5 (10–21 VII) and 6 (19–23 VIII). Monitoring hours were adapted to the time of turtle activity, typically from 9 am to 2 pm, adjusting for weather conditions. Habitat preference was determined by recording the number of turtles observed in specific habitats relative to the total number of turtles. Drone monitoring was carried out on 27 separate survey plots covering a total area of 49.73 ha (Fig. 1). Taking into account the six countings in each plot (with a few exceptions), a total area of 246.72 ha was surveyed, within which turtles were photographed and counted.

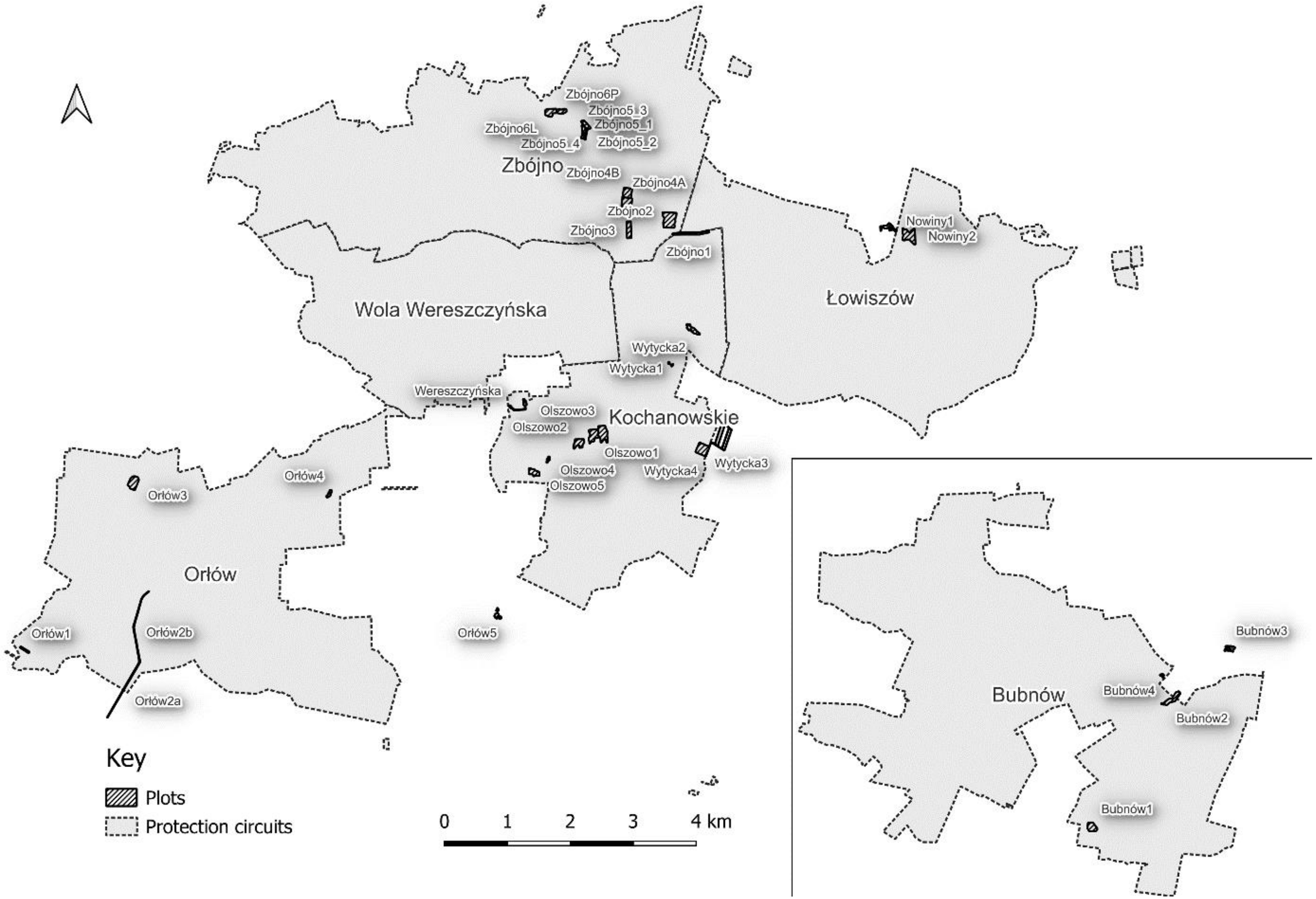

Fig. 1. Location of monitoring plots within the park and buffer zone surveyed using drones

Three consumer drone models were used for monitoring: the DJI Mavic Air 2, the DJI Air 2S and the DJI Air 3 (SZ DJI Technology Co., Ltd.). The DJI Mavic Air 2 drone features a 1/2″ Quad Bayer sensor with 48 Megapixel resolution. The DJI Air2s is equipped with a 1″ CMOS sensor with 20 Megapixel resolution. The DJI Air 3 has dual cameras – 24 and 70-mm supported by a 48-megapixel sensor. Depending on the terrain conditions and the presence of obstacles such as trees, the drone flight altitude was adjusted and ranged from 17 to 25 m, resulting in a photo resolution of 0.3–0.6 cm/pixel depending on the drone model. Dji Mavic Air2 and Air2S were used together on 24 plots with predominantly low grass or scrub vegetation due to the ease of flight path planning in Grid Mission Designer and Litchi for DJI Drones software. Both models enabled the capture of high-resolution images and efficient recognition of turtle silhouettes. For three sites with tall trees, the newer and more advanced DJI Air3 model was employed. Its 70 mm telephoto lens, flown at approximately 50 m altitude provides magnification comparable to that of a 24 mm lens flown at 17 m. However, planning and executing missions with this model is only possible with the original DJI Fly software using Waypoints which is significantly more difficult and less precise.

The response of turtles to drone presence has been tested in previous studies, which reported no signs of disturbance when drones were flown at altitudes above 15 m [Wójcik et al. 2024].

The work started by determining the drone's flight paths on the monitoring plots. The Mission Grid Designer tool (https://ancient.land) was used to determine the initial flight parameters. The flight template thus prepared was imported into the Litchi Mission Hub (https://flylitchi.com/), where the flight parameters were adjusted in detail. Aerial inspections of several areas were complemented by visual monitoring using binoculars.

Drones were also used to produce area-based maps to show turtles' locations in the most current habitat. Using WebODM (Web Open Drone Map) version 2.5.5 software, orthophotos were taken in WGS 84 / UTM zone 34N projection (EPSG:32634) at 3 cm per 1-pixel resolution. Pearson's chi-square (χ^2) test of independence was used to assess the relationship between the number of turtles observed and factors such as the date of observation, habitat type and air temperature range. Calculations were made for contingency tables covering the respective combinations of levels of these factors (date × habitat, habitat × temperature range). Results with a significance level of $p < 0.05$ were considered statistically significant. The relationship between the minimum daily temperature during the season and the decline in the number of turtles observed was assessed using the Pearson correlation coefficient calculated in Statistica 13.3.

RESULTS AND DISCUSSION

An analysis of turtle abundance over six consecutive research periods (Fig. 1) revealed a decline in the number of observed individuals, particularly noticeable during the latest research seasons. The highest number of observations was recorded in the first and second research periods (second half of April – first half of May), likely reflecting seasonal patterns in the species' biology. After their winter dormancy, turtles begin to move actively in search of food and breeding partners; additionally, they are more likely to appear at the water surface or on the banks and overgrowing vegetation, basking in the sun for thermoregulation [Najbar and Mitrus 2001]. The decline in observed individuals can also be attributed to the specific meteorological conditions during the study period. The low rainfall and high temperatures in the summer of 2024 caused a hydrological drought, manifested by reduced river flow, lower river levels, and the drying of small water bodies. As poikilothermic animals, turtle activity is strongly influenced by ambient temperature. During the study period, an increase in minimum daily temperature was significantly correlated with a decrease in the number of observed individuals (r = –0.8151, p = 0.048; Fig. 2). The decrease in the number of turtles observed on successive dates (April to August) with increasing minimum air temperature may be due to a change in their behaviour during the warmer months. At low spring temperatures, turtles spend more time in the sun, basking multiple times a day. During summer, with high temperatures, they reduce basking activity and spend less time in warm water [Bodie and Semlitsch 2000, Cash and Holberton 2005] .

During the season, an increase in vegetation cover is also correlated with a rise in temperature, which in turn reduces the visible area of observation. At the same time, the water level decreases during summer, and this factor was particularly intensified in the study season and resulted in a significant reduction in the surface area of the water table. Turtles can survive prolonged periods of drought by hiding under moss, ferns or alder roots [Roe and Georges 2008, Roe et al. 2009].

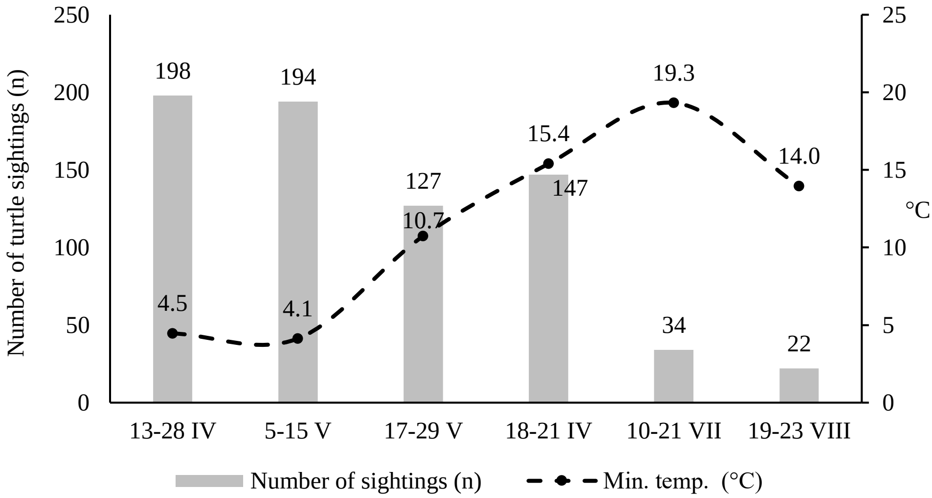

Fig. 2. Number of turtle sightings in successive survey periods (n) against changes in mean minimum air temperature

Throughout the study, there was an apparent variation in the number of turtle observations depending on the characteristics of the water bodies in each study period (Figs. 3 and 4). The notable decrease in turtle sightings on successive dates in habitats that dry out periodically (such as sedge meadows, reed beds, willow thickets, and peat bogs) is attributed to the drying of these bodies of water caused by the ongoing drought. The turtles will likely have reduced their activity and moved to deeper, more stable aquatic habitats or hidden under vegetation. The increase in sightings in ditches and reservoirs in June and July, coinciding with the drought period, results from migration to areas where water lasted longest. Ditches act as migration corridors, while permanent water bodies provide the last refugia during the dry season. Short-term desiccation of water bodies does not significantly affect turtle survival or the rate of movement between habitats [Owen-Jones et al. 2016]. However, long-term desiccation, e.g. due to habitat reclamation, significantly reduces the survival of the species. According to Ficetola et al. [2004], the annual probability of a turtle leaving one water body in favour of a neighbouring one does not exceed 15% and declines sharply with increasing distance. Most of these movements are limited to within 1 km, while occasional movements up to 2 km probably corresponded to male dispersal behaviour. The connectivity between ponds influenced movements. This highlights the importance of aquatic corridors, such as ditches, drainage lines and culverts for supporting natural intra-population exchange, as turtles tend to follow these when available [Rees et al. 2009].

Preferred habitat types where turtles were recorded most frequently were sedge meadows and drainage ditches (35.4% and 25.2% observed turtles). Turtles were most abundantly recorded in sedge meadows (Fig. 3), which in spring turned into floodplains with overhanging, tufted vegetation on which turtles can bask, and the presence of water facilitated their movements, especially during the breeding season. Similar habitat preferences have been confirmed in studies from other European countries [Segurado and Araújo 2004, Thienpont et al. 2004, Drechsler et al. 2018]. However, the local sedge meadows are being overgrown by willow or alder thickets as a result of succession. Drainage ditches in the park area currently act as water storage reservoirs, so as water levels drop in shallower habitats, turtles use them as migration routes and permanent habitats. Like the sedge meadows, the ditches are also subject to overgrowth and shallowing.

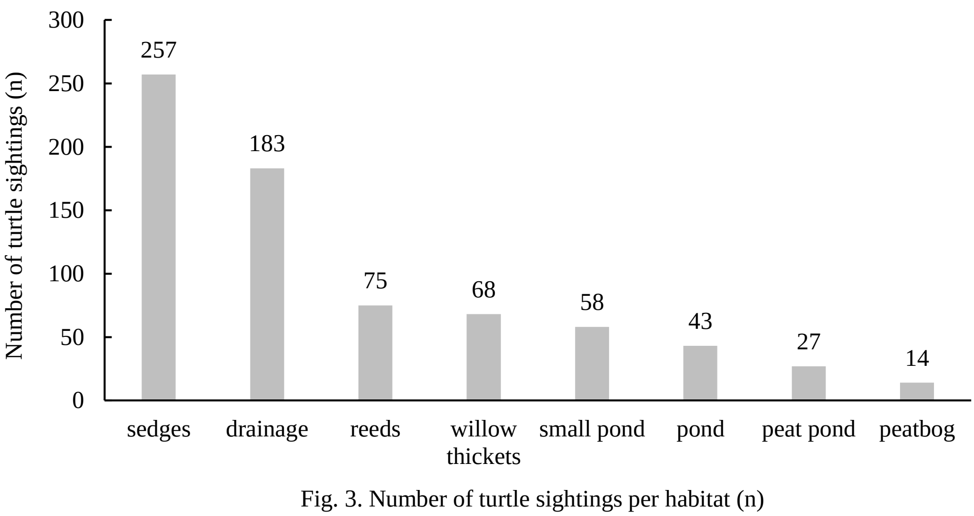

Fig. 3. Number of turtle sightings per habitat (n)

Spring is a critical period in the life cycle of turtles, particularly for breeding. At moderate temperatures of 16 to 25°C, the highest number of individuals was observed on sedge meadows, suggesting that this habitat plays a vital role during this time (Fig. 4). Their shallow waters warm up more quickly, enhancing food availability, providing suitable resting sites , and offering conditions conducive to mating. Statistical analysis confirmed the relationship, with Pearson's χ^2 test showing a statistically significant relationship between habitat type and air temperature range for the number of turtles observed ($\chi^2 = 255.77$; df = 21; $p < 0.0001$). At cooler temperatures below 5°C, the number of turtles in the sedge habitats was much lower, indicating that their activity was still much reduced in early spring. As the air warmed, they became more active, and sedges became their primary habitat. However, as temperatures exceeded 25°C, the sightings decreased again, which may indicate that on hot days, the turtles do not leave the water or choose more sheltered environments. On hot summer days, the turtles are often submerged in the water with only their heads protruding above the surface, a behaviour visible through binoculars but undetectable by drones. At air temperatures above 25°C most individuals were found near drainage ditches in the study area. In a study by Marchand et al. [2021], conducted using temperature recording sensors, it was observed that the activity of mud turtles significantly increased in the morning, decreased at midday and peaked in the evening. At midday, turtles were more likely to rest than to bask, suggesting a strategy of avoiding exposure to excessive heat during the period of maximum sunshine.

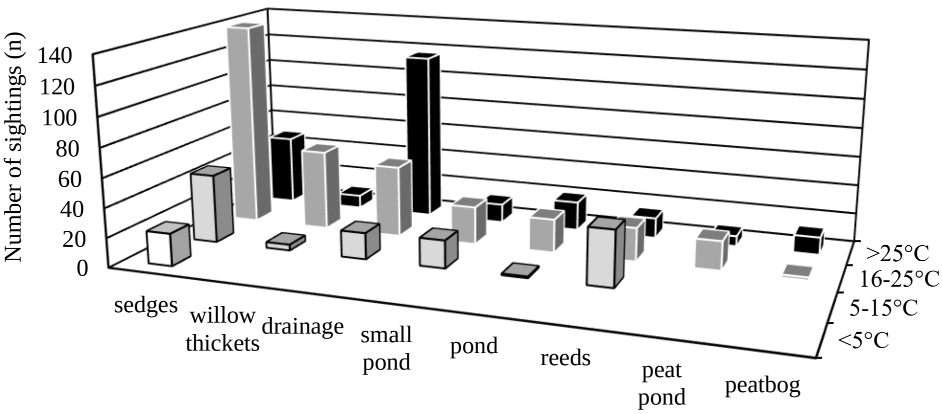

Fig. 4. Number of turtle sightings (n) in each habitat according to the range of air temperature

However, it is important to note that the observed patterns of turtle activity may largely reflect the specific weather conditions during the study period. The highest number of individuals observed was recorded in periodically drying habitats (mainly sedge meadows) during spring with the lowest mean minimum air temperatures (Fig. 5). As the temperature increased in successive monitoring periods, the number of turtles observed in shallow water bodies declined, likely due to desiccation, in favour of drainage ditches. Pearson's χ^2 test confirmed a statistically significant relationship between the number of turtles observed and the interaction between observation date and habitat type ($\chi^2 = 195.94$, df = 10, $p = 0.001$). Similar patterns were reported by researchers in other central European countries,who also observed high basking activity of pond turtles in spring [Novotený et al. 2008, Vamberger and Kos 2011, Erdélyi et al. 2019].

After emerging from hibernation in March or April, depending on weather conditions, turtles gradually increase their activity while remaining relatively close to the nesting ground and water bodies where they overwinter. Early in the spring season, turtles are more sedentary and restrict their movements to familiar habitats, staying close to bodies of water where they mate. Males become more mobile from April to May, searching for females to copulate, whereas female turtles move most extensively from May to June to lay eggs [Cadi et al. 2004, Mignet et al. 2014]. During the egg-laying period, females undertake migrations to locate suitable nest sites. They choose well-known sites for nesting, often those where they hatched, with adequate sunlight. Research indicates strong nest site fidelity [Mitrus 2006, Najbar and Szuszkiewicz 2007]. Turtles migrate by water and land, travelling various distances, often reaching several hundred metres or even several kilometres [Paul and Andreas 1998, Zufi and Rovina 2006, Liuzzo et al. 2023].

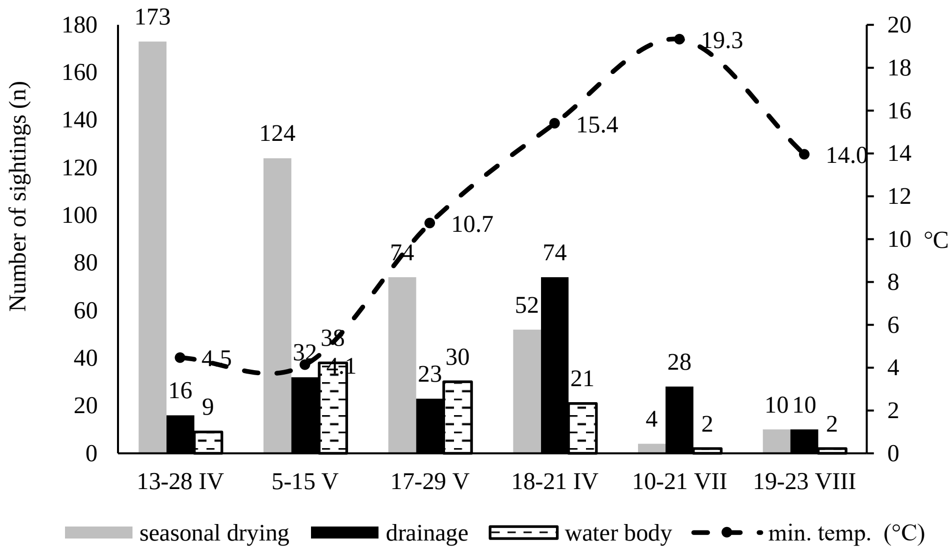

Fig. 5. Number of turtle sightings (n) according to the presence of water in the habitat on successive survey dates

Towards the end of summer and into autumn, turtles may once again increase their movement range, particularly evident on the sixth observation period (August), when a sharp increase in distance from nesting sites was recorded. This may be related to migration to overwintering sites, where they select suitable hibernation habitats, often distant from summer foraging sites [Owen-Jones et al. 2016] (Fig 6). Alternatively, this movement may be a response to environmental stress and a defence strategy against habitat drying [Cash and Holberton 2005].

While adult turtles are well-adapted to overland movement and, contrary to popular belief, are not slow, as they can easily cover several hundred metres during a single day, land migration poses greater challenges for juveniles. It not only requires more physical effort but is also associated with the threat of land-based predators. Proximity to water is beneficial, and the closer the site is to a water source, the more juveniles are observed (Fig. 7). In contrast, more remote sites are typically inhabited only by adults. As confirmed by previous studies [Escoriza et al. 2020], juvenile turtles, unlike adults, restrict their movements to a small area. After leaving the nest, young turtles move over land until they reach the nearest body of water and remain there for several years – these habitats are characterised by low water levels and dense vegetation [Vignoli et al. 2015].

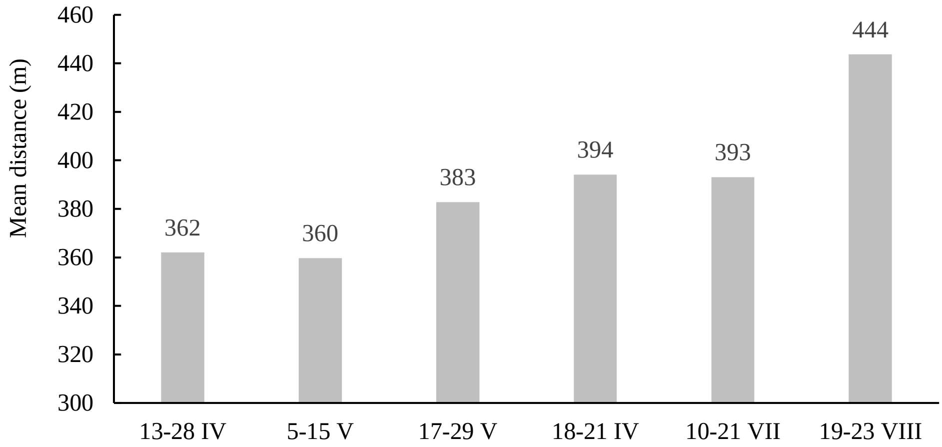

Fig. 6. Mean distance (m) of turtles observed from the nesting site across successive survey periods

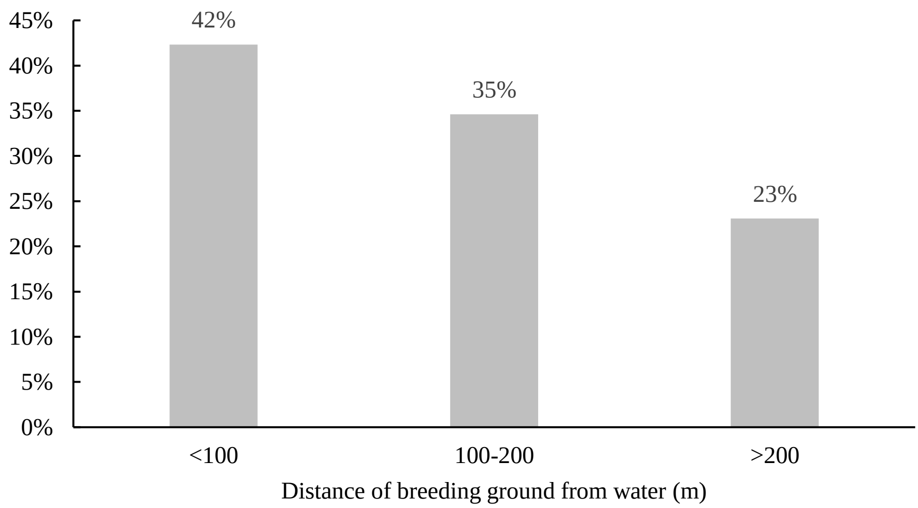

Fig. 7. The proportion of sites (%) where juvenile turtles were observed depending on the distance of the bed from the water body

Considering the size of the plots monitored relative to the number of turtles, the highest densities, above 40 individuals/ha, occurred in the Bubnów study plots (Fig. 8). This may have been attributed to the fact that turtles concentrated in selected locations, such as drainage ditches and peat bogs. Surprisingly, although the Zbójno area is known for its numerous nesting sites and high turtle abundance, the vastness of the area makes their population density low. The distribution of individuals is also the most distant from the nesting sites (Fig. 9). The Nowiny area supports only a few turtles, hence the lowest observed densities (Fig. 10). These findings confirm previous observations of the strong dependence of pond turtles on specific habitat types, especially canal habitats, which have been identified, among others in Italy, as critical nesting sites [Zuffi and Rovina 2006]. The observed distribution of individuals in relation to known breeding sites may indicate the existence of established migratory routes and high fidelity to breeding grounds, as previously noted by Rovero and Chelazzi [1996], among others.

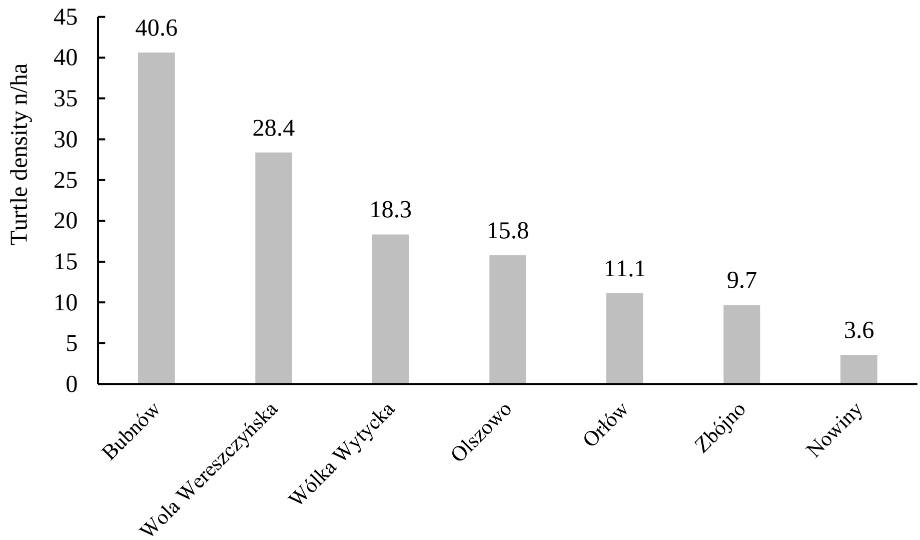

Fig. 8. Density (n/ha) of individuals observed at individual study sites in conservation districts

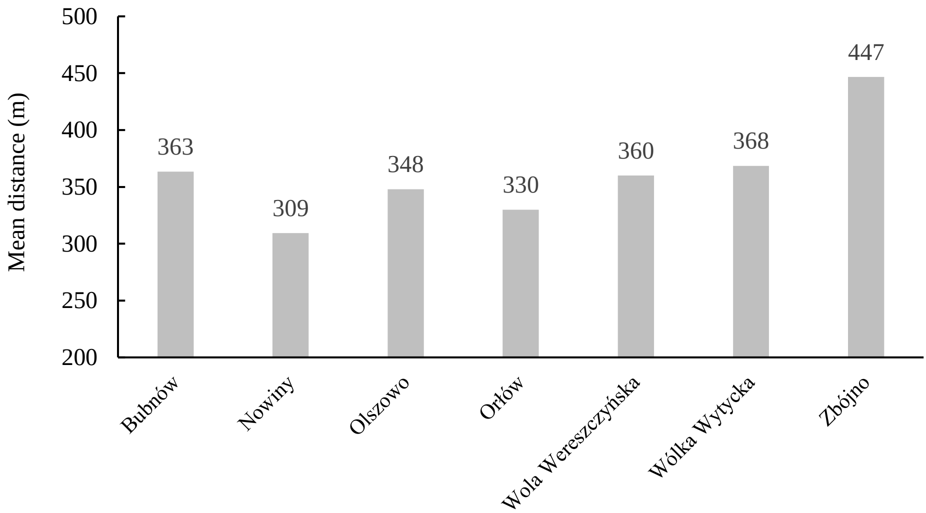

Fig. 9. Average distance (m) of observed turtles from the breeding ground in individual areas (protective perimeters)

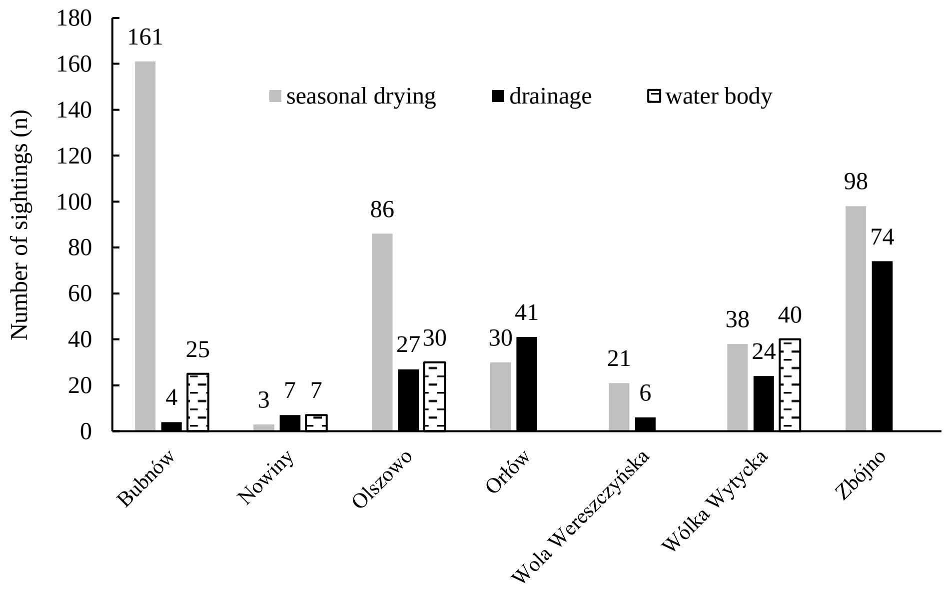

Fig. 10. Number of turtle observations (n) depending on the presence of water in a given habitat in individual protection areas

SUMMARY AND CONCLUSIONS

The study confirms the high value of drone technology in protected species monitoring. The use of drones has proved highly effective – it has made it possible to monitor hard-to-reach habitats without disturbing the animals and to document the presence of turtles precisely. However, certain environmental and climatic factors limit its effectiveness. Dense, tall forests can obstruct visibility, and during hot summers, turtles often submerge in warm water or restivate beneath silt or vegetation, making detection more difficult.

Turtle activity was closely related to weather conditions – the number of observations decreased with rising temperatures and intensifying drought. Research on the occurrence of the pond turtle in the Polesie National Park has shown that the most significant activity of these reptiles occurs in spring.

The preferred habitat types are sedge meadows and drainage ditches, which accounted for 60.7% of all recorded observations. Their exposed surfaces provide access to the sun, vital for thermoregulation. However, sedge meadows are increasingly being replaced by willow or alder thickets due to succession. Drainage ditches in the park area act as water storage reservoirs, so as the water level drops in the shallower habitats, turtles use them as migration routes and permanent habitats. These ditches, however, are also subject to overgrowth and shallowing. Seasonal migrations were observed, resulting from reproductive needs, foraging and preparations for wintering.

The conservation of semi-aquatic species such as the European pond turtle requires a comprehensive understanding of their habitat requirements and the need to protect periodically flooded habitats, which play a key role in the life cycle of the turtle. Maintaining connectivity between water bodies, such as through drainage ditches, facilitates natural migrations and increases the chances of population survival. In the context of climate change and increasing drought frequency, it is especially important to implement conservation measures aimed at maintaining stable water sources within the species' habitats.

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M.W. https://orcid.org/0000-0002-9561-8852
S.B. https://orcid.org/0000-0003-4569-8273
P.C. https://orcid.org/0000-0002-8587-246X

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