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USE OF DRONES IN THE MONITORING OF THE EUROPEAN POND TURTLE *EMYS ORBICULARIS* IN HABITATS OF THE POLESKI NATIONAL PARK (POLAND)

The study tested the suitability of consumer drones for monitoring the abundance of the European pond turtle Emys orbicularis, an endangered species whose reliable monitoring is crucial for active species conservation. The widely available semi-professional DJI Mavic Air2 model was used, as it can be used to obtain 48 Mpix images or 4K videos. Until now, the species has been monitored visually with binoculars, but this method only works well in specific habitats, such as ponds and drainage ditches. It has been shown that the best method in inaccessible habitats, such as tall rushes, sedges, etc., is to plan a drone flight along a specific trajectory and take a series of photos. In addition, the size of the area can be accurately assessed, and animal density can be calculated. The research is essential for retardation of negative changes in the state of biodiversity in Poland.

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

I. INTRODUCTION

In recent years, drones have been increasingly used to observe wild animals in their natural habitats, especially those inaccessible and challenging to use ground-based inventory methods. Using drones for turtle inventories offers far greater opportunities than monitoring by traditional approaches based on direct observation. Drone flights make it possible to verify the presence of turtles in places that are entirely inaccessible to observers while at the same time not scaring them away. Using drones with optical and thermal imaging cameras, combined with deep learning, allows automatic processing and recognition of images [Chamoso et al. 2014, Kallenberger et al. 2018, Rančić et al. 2023, Prosekov et al. 2020, Ezat et al.2018, Rey et al. 2017].

The European pond turtle is the only native representative of turtles in the Polish fauna. It is a very high-risk, endangered species, listed in the Polish Red Book of Animals and the Red List of Dying and Endangered Animals in Poland [Głowaciński 2001, 2002] with EN (endangered) status. It is subject to the Habitats Directive 92/43/EEC (Annexes II and IV) and the Bern Convention. It is strictly protected in Poland and requires active protection (Regulation of the Minister of Environment of 16 December 2016). In Poland, it occurs indigenously, most abundantly in Polesie Lubelskie. Poleski National Park was established

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mainly to protect wetland and peatland ecosystems. In the case of reptiles, the most spectacular and best-studied species in the Polesie National Park is the European pond turtle [Dziedzic 2002, Kosik et al. 2013]. There are 11 nesting sites in the park and its buffer zone. The population size is estimated at 350-450 adults. Estimates are based on assessing the number of adult females laying eggs in a given year. The number of males is usually unknown, as is the number of juveniles. The species is found in various available habitats over much of the park area. It inhabits peat bogs, sedges, alders, ponds, drainage ditches and canals [Mitrus 2006].

As a ectothermic species, the turtle depends on warm, easily-heated places in its habitat. However, changes in the last few decades, including land reclamation and afforestation of the so-called wastelands (often nesting grounds), have caused turtles in Poland to increasingly frequent forest habitats. Also, in the area of the Poleski National Park, it can be observed that some individuals use aquatic habitats in forest areas. These are mainly mid-forest drainage ditches, sedges, and ponds.

The aim of the study was: to assess the suitability of low-cost consumer drones for European pond turtle monitoring, to compare classical and drone monitoring, and to assess habitat preference by European pond turtles in Poleski National Park.

II. MATERIALS AND METHODS

Preliminary field inventory made it possible to select 51 likely turtle habitats. The size of the monitored areas varied, usually limited by natural features, such as a group of mid-forest peat ponds, sedges bounded by drainage ditches, ponds, etc. The flights were repeated six times a season (from April to September 2023). Considering the repetition of flights in subsequent control dates, the area covered by drone monitoring amounted to 190.20ha.

Drone flights

The DJI Mavic Air 2 drone features a 1/2″ Quad Bayer sensor with 48 megapixels for high-resolution images. All images are geotagged, i.e. they are assigned a geographical location. We found that the best altitude for flying the Mavic Air 2 drone is between 17 and 22 m, as this allows for a photo resolution of 0.3-0.4 cm/pixel without scaring the turtles. The turtles' reaction to the drone's presence was tested on other surfaces before proceeding. The hovering drone gradually descended. The first alarm signs (head lifting) appeared only when the drone was below 15 m in height, but the turtles rarely fled into the water. At heights above 15 m, we observed no escape.

The work began by determining the routes to fly the drone over the various surfaces with the designation of the waypoints where the photographs would be taken. For this purpose, the Grid Waypoint Mission Tool for Litchi (https://ancient.land) was used, allowing the initial flight parameters to be determined. The flight template prepared this way was imported into the Litchi Mision Hub (*https://flylitchi.com/*). In the Hub, we make adjustments to the flight parameters, e.g. adding or removing individual points, moving them, and correcting the direction or altitude of the flight (Fig. 1). A field trips were made between 16 April to 12 September. Aerial inspections of a smaller number of areas were supplemented by visual monitoring using binoculars.

Fig. 1. Drone flight plan - screenshot of Litchi Mission Hub software
Rys. 1. *Plan lotu drona - zrzut ekranu z oprogramowania Litchi Mission Hub*

Statistical analysis

The normality of distributions of the analysed parameters was assessed with the Shapiro-Wilk test. Since the distributions of the dependent variables significantly diverged from normality, nonparametric (rank) tests were employed to analyse the significance of the differences between these distributions. The Man Whitney U test was used to compare two groups (the results of two inventory methods). The description of the distributions was based on the measures of the position of the mean value, i.e. the median and quartiles. In comparing groups and significant differences between these groups, the results of the multiple comparison tests have the so-called letter marking. Groups denoted with the same letter are not significantly different from each other (they represent the same homogeneous group), whereas groups that are not marked with the same letter differ significantly for $p \leq 0.05$. Statistical analysis of the research results was done using the Statistica 13.1 package

III. RESULTS AND DISCUSSION

A total of 656 turtle observations were made during inspections. Depending on the date and location, 3 to 71 individuals were found during each inspection. An example photo of the turtles observed from a drone in the habitat from a height of 22 meters is shown in Fig. 2.

The number of turtle sightings was strongly influenced by location due to the type of habitat, which is related to the biology and behaviour of the species. To lay eggs, female freshwater turtles usually migrate a distance of tens, rarely hundreds or more meters from a body of water [Burke et al. 1998, Zufi and Rovina 2006]. Drainage ditches and water channels can be used as a route for movement to lairs and wintering sites, which can be explained by the fact that in our study, they were not found in drainage ditches during the breeding months (V, VI). Only after the breeding season (VII, VIII) is there a marked increase in the number of turtle sightings in the ditches due to dispersal in search of habitats with the best resources [Burke and Gibbons 1995, Burke et al. 1998, Zuffi and Rovina 2006, Cadi et al. 2004] and to hibernation sites [Novotny et al. 2004]. At the same time, in the park, the water level usually decreases during the season; hence, the extensive sedge habitats become less suitable, and turtles congregate in places with deeper water, including drainage ditches, mid-forest ponds and ponds

Fig. 2. Photo of turtles from a drone on one of the surfaces
Rys. 2. *Zdjęcie żółwi z drona na jednej z powierzchni*

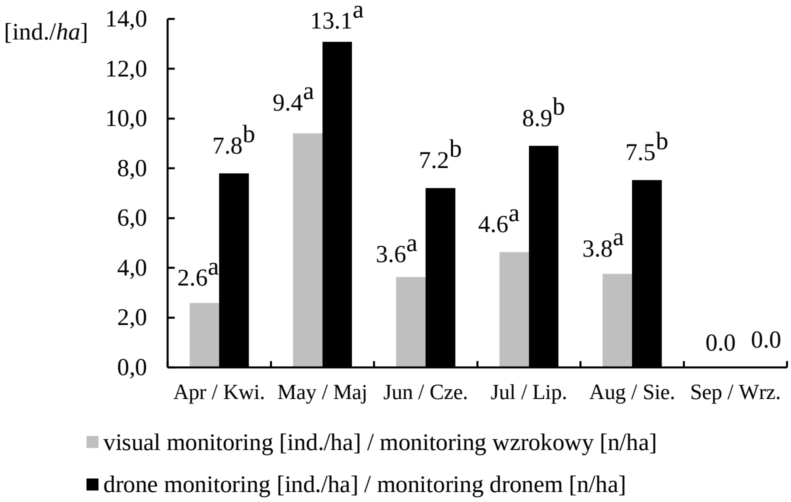
Comparing the results of turtle inventories made by the two methods, in terms of density (ind./ha), there was a higher precision of the inventory using drones (tab. 1). The average density of turtles obtained with drones was twice as high as the density of turtles using the traditional (visual) method, and this difference was statistically significant (Mann-Whitney U test: Z=5.1163; p=0.0001). Comparison of parameters for the two inventory methods over the entire study period (without dividing by habitat or month) Mann-Whitney U test: Z=5.1163; p=0.0001.

Table 1- ***Tabela 1***

Comparison of parameters for the two inventory methods over the entire study periods / *Porównanie parametrów dla dwóch metod inwentaryzacji w całym okresie badan*

Parameter / *Parametr*	Visual monitoring [ind./ha] *Monitoring wzrokowy [os./ha]*	Drone monitoring [ind./ha] *Monitoring dronem [os./ha]*
Average / *Średnia*	4.2	8.2
Range / *Zakres*	0.0-73.6	0.0-112.4
SD	11.3	15.9
Median / *Mediana*	0.0	2.0
Q25-Q75	0.0-2.0	0.0-6.9

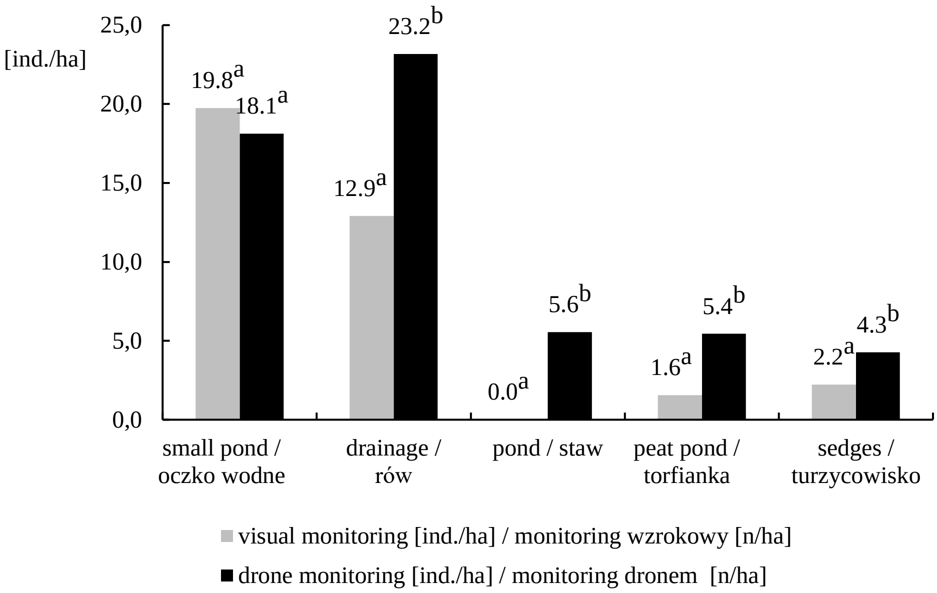
In each month of observation, the average density of turtles obtained using drones was significantly higher than the visual inventory results (Fig.3). In all months except May, the difference in results (average density ind./ha) between the compared methods was statistically significant.



[a, b]averages marked with different letters between the two inventory methods (in each month) differ significantly for p≤0.05 (Mann-Whitney U test) / *[a, b] średnie oznaczone różnymi literami między dwiema metodami inwentaryzacji (w każdym miesiącu) różnią się istotnie dla p≤0,05 (test U Manna-Whitneya)*

Fig. 3. Comparison of turtles inventory results (ind./ha) obtained by drone and visual methods by month
Ryc. 3. *Porównanie wyników inwentaryzacji żółwi (os./ha) uzyskanych metodą dronową i wizualną w poszczególnych miesiącach*

Comparing the average densities of turtles obtained by two inventory methods in different habitat types, statistically significant differences were found in all habitat types except ponds (Fig.4). Due to their small size, their areas are easy to verify using the visual method, while in other cases, the visual method is less effective than drone flights. It was found that the highest number of turtles observed was in May, while no individual was found in the last month of observation. These observations coincide with European pond turtle activity, which lasts for about six months, beginning in late March/early April (depending on weather conditions) and ending in late summer, usually in late August/early September [Lebboroni and Chelazzi 1991]. According to the literature [Ficetola et al. 2004, Maciantowicz and Najbar 2004, Cadi et al. 2008], two periods can be distinguished in the annual cycle of turtles: an active period from April to October and a lethargic hibernation period from November to March.



[a, b]averages marked with different letters between the two inventory methods (in each habitat) differ significantly for p≤0.05 (Mann-Whitney U test) / *[a, b] średnie oznaczone różnymi literami między dwiema metodami inwentaryzacji (w każdym siedlisku) różnią się istotnie dla p≤0,05 (test U Manna-Whitneya)*

Fig. 4. Comparison of turtles inventory results (ind./ha) obtained by drone and visual methods on different habitats
Ryc. 4.*Porównanie wyników inwentaryzacji żółwi (os./ha) uzyskanych metodą dronową i wizualną w różnych siedliskach*

IV. CONCLUSIONS

The use of drones for turtle inventories provides the opportunity to accurately locate individual turtles by geotagging photos taken with a drone, making it possible to determine the degree of habitat use, the spatial distribution of the population, and changes in these parameters during the species' season of activity. The monitoring results obtained with the drone are higher in every case, and the differences are statistically significant. Using drones to inventory species such as the European pond turtle creates many new opportunities. It is possible to conduct inventories in habitats that are difficult to access or inaccessible to classical methods (deep marshes, the spit zone on lakes, etc.), thus obtaining more complete results from habitats inaccessible to classical methods.

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WYKORZYSTANIE DRONÓW DO MONITORINGU ŻÓŁWIA BŁOTNEGO *EMYS ORBICULARIS* W SIEDLISKACH POLESKIEGO PARKU NARODOWEGO (POLSKA)

Streszczenie

W pracy przetestowano przydatność dronów konsumenckich do monitorowania liczebności żółwia błotnego Emys orbicularis, gatunku zagrożonego, którego rzetelny monitoring jest niezwykle ważny w czynnej ochronie gatunkowej. Użyto powszechnie dostępnego półprofesjonalnego modelu DJI Mavic Air2, ponieważ można go wykorzystać do uzyskania zdjęć 48 Mpix lub filmów 4K. Do tej pory gatunek ten był monitorowany wizualnie za pomocą lornetki, ale ta metoda sprawdza się tylko w określonych siedliskach, takich jak stawy i rowy melioracyjne. Wykazano, że najlepszą metodą w siedliskach niedostępnych takich jak np. szuwary wysokie, turzycowiska itp. jest zaplanowanie lotu dronem wzdłuż określonej trajektorii i wykonanie serii zdjęć. Ponadto można dokładnie ocenić wielkość obszaru i obliczyć zagęszczenie zwierząt. Badania mają znaczenie dla retardacji negatywnych zmian stanu różnorodności biologicznej w Polsce.

Słowa kluczowe: żółw błotny, *Emys orbicularis*, monitoring z użyciem drona, siedliska podmokłe, retardacja