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Assessing the efficiency of time-lapse cameras in collecting data on various life-history traits of two sympatric-nesting pelican species

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Abstract

Time-lapse cameras have been widely used in wildlife research in recent years to assist in data collection. Seven time-lapse cameras were installed on four Dalmatian pelican *Pelecanus crispus* and Great white pelican *P. onocrotalus* nesting islets at the Lake Lesser Prespa colony, NW Greece, during the 2015-2016 breeding period. The objectives were to assess the efficiency of this method in collecting data related to breeding phenology and breeding success, the seasonal and daily variation in attendance of adults of both species during the breeding season, the use of the islets by other bird species and mammals, and to document predation instances. We used Bushnell motion-triggered cameras, activated 24 hours a day, which also operated as time-lapse cameras, taking photos every half an hour during the daytime. At the end of the period, about 13,000 photos per camera were retrieved. Phenology dates documented with this method confirmed or enhanced results obtained with other methods. The attempt to estimate breeding success was not accomplished, due to the crèching behaviour of pelican chicks, combined with the inability to fully cover the nesting islets. Attendance of adult Dalmatian pelicans peaked from early February to early April. Respectively, attendance of adult Great white pelicans peaked from early April to early June. No significant differences were observed between day and night in attendance of either species. The islets also serve as a haven for Greylag geese *Anser anser*, mainly during the night for roosting and before the arrival of pelicans. At least four predatory mammals use the pelican nesting islets, but only prior to pelican arrival. The method is laborious and has various limitations and, although it provided some satisfactory results to our research questions, the effort involved is deemed excessive compared to other methods used for the same objectives at the Lesser Prespa Lake pelican colony.

Keywords: pelican colony, time-lapse cameras, nesting islands, Lake Lesser Prespa

Introduction

Time-lapse cameras and camera traps are increasingly being used in a wide array of ecological research and avian ecology studies (Pietz & Granfors 2000; Booms & Fuller 2003; Black et al. 2018). With regard to wild birds, they have been used primarily to investigate nest predation and behavioural aspects of nesting ecology (Thompson & Burhans 2003; O' Brien & Kinnaird 2008), as well as to document breeding phenology and estimate breeding success in both solitary nesting (Booms & Fuller 2003) and colonially nesting species (Merkel et al. 2016; Black et al. 2018; Hinke et al. 2018). It is a particularly efficient method when studying species sensitive to human presence, while it can provide information on previously 'unseen behaviour' such as activity at night and during harsh weather conditions (Black 2018).

In contrast to solitary nesting birds, the large and inaccessible colonies of ground nesting seabirds/waterbirds can present researchers with serious logistical and other challenges when using time-lapse cameras for the intensive collection of representative ecological data over large parts of the annual cycle (Black 2018).

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The focal species of this study was the Dalmatian pelican *Pelecanus crispus* (hereafter DP), but data were also acquired for the Great white pelican *P. onocrotalus* (hereafter GWP), two ground-nesting species reproducing side by side on the same nesting islets at the Lesser Prespa Lake colony, in a challenging setting for research and monitoring. The mixed pelican colony of Lake Lesser Prespa consists of around 1,300 DP and 600 GWP nests (Catsadorakis et al. 2015) and it is situated on many small, spongy and unstable islets formed of common reed *Phragmites australis* rhizomes (Catsadorakis & Crivelli 2001) lying in the strictly protected zone of a protected area (Catsadorakis et al. 2022) and spread over two areas of ca 25 ha each (Figure 1). In addition to the fact that both species are intolerant to close human presence, building observation towers overlooking large parts of the colony would be impossible. Visits to the colony to collect scientific data creates much disturbance and is avoided. Thus, in order to collect important data on life history traits we are left with three non-invasive methods in practice: direct observation from a distance, drone photos and time-lapse cameras on the nesting islets.

The objectives of the study were to evaluate the efficiency of time-lapse cameras in assessing the seasonal and daily variation of adult pelican attendance on their nesting islets during the breeding period; documenting the use of the islets by other birds and mammals; and collecting evidence for instances of predation of pelican eggs and young. Most of all, we aimed to assess whether this method could be used effectively to collect data on breeding phenology and to estimate breeding success in a representative subtotal of the colony, as well as whether it could provide comparable or superior results in a more efficient way compared to other methods used at the Lesser Prespa pelican colony in recent years, namely direct observation from distant vantage points and the use of drone photos. Both these methods have several weaknesses and limitations; namely, direct observations are performed from a large distance, and they may be lacking in accuracy, while sometimes they do not provide full coverage of the nesting islets, because of their orientation, or the aquatic vegetation hindering visibility. On the other hand, drone flights executed during the last decade at the Lesser Prespa pelican colony have provided rather satisfactory estimations of the number of nests and breeding success, yet this method has some limitations too, mainly originating from the limited number of flights during the breeding period, combined with the asynchronous nesting of DPs and their renesting attempts (Crivelli 1987).

Study area

Lesser Prespa Lake and (Great) Prespa Lake are two adjacent lakes in the Western Balkans, shared between three countries, Albania, Greece and North Macedonia (Figure 1). They are situated in a closed mountain basin between 830 and 845 m asl. Lesser Prespa Lake (ca. 47 km^2) is eutrophic with a maximum depth of 8.4 m. Prespa Lake is mesotrophic (ca. 254 km^2) and has a maximum depth of 50-58 m (Hollis & Stevenson 1997; Matzinger et al. 2006). The two lakes comprise one functional ecosystem, as they are only separated by a narrow, alluvial land strip and are connected hydrologically. Two hyper-eutrophic ponds of ca. 50 ha in area, the largest of which is known as 'Viro' (Figure 1), lie within the alluvial strip and are surrounded by marshes on peaty and sandy soils. Both lakes are cyprinid dominated, with Prespa bleak *Alburnus belvica* and Prespa roach *Rutilus prespensis* being the most abundant species. Lesser Prespa, the largest part of which lies in Greece, hosts a mixed colony of DP and GWP, whereas the adjacent Prespa Lake is used as the main foraging grounds for these fish-eating birds (Crivelli et al. 1998; Catsadorakis et al. 2015). The breeding avifauna of the two Prespa Lakes is of international importance, both due to its high species richness and the important populations of rare species, among them several waterbirds (Catsadorakis 1997; Catsadorakis et al. 2016). The Greek part of the Prespa basin, where the pelican colony is located, is sparsely inhabited, with a total population of 1,500 people who are primarily occupied in agriculture, stockbreeding and, to a much lesser degree, in fishing activities (Society for the Protection of Prespa et al. 2005).

Materials and methods

Camera deployment

We used digital wildlife observation cameras (Bushnell NatureView HD Cam), which were motion-triggered, while also operating as time-lapse cameras. When the motion sensor was activated, the cameras recorded individual, instantaneous events 24 hours a day. They were equipped with infrared LED flashes that produce black and white photographs at night but have the advantage of being almost invisible and silent and thus do not cause disturbance. A 60-min triggering interval was set to reduce demand on data storage and battery life. At the same time, the 'time-lapse' feature operated independently, forcing the camera to take photos at a pre-selected 30-min interval, and only during the daytime, i.e., 07:00-21:00. Hence, the cameras captured a maximum of 53 photographs per day (24 + 29), and to do so they were deployed with 12 lithium AA batteries that endured throughout a 7-month operation period. The cameras were placed inside wooden marine plywood boxes with a pointed cap to prevent birds from using them as perches, and they were positioned at about two metres above ground level on metal poles, which were anchored in the unstable substratum of the nesting islets, using a metal three-legged base construction. A total of seven cameras were deployed respectively on seven sites, on four different nesting islets, with the aim of representing the variability of the colony as much as possible. Two smaller nesting islets (coded TR76 and TR79) were equipped with a single camera, while three cameras were placed on the colony's largest islet, TR61 (TR61A, TR61B, TR61C), and two cameras on TR21 (TR21A, TR21B), a nesting islet in the inner Viro Pond (Figure 1). Three of the nesting islets (TR21, TR76 and TR79) are located at the margins of the reedbed, while TR61 is situated in open water, though less than 100 m from the reedbed edges. Cameras were placed before the start of the breeding period in late December 2015 (TR21A and TR21B) and early January 2016 (all the rest) and were removed towards the end of the breeding season, in late July 2016. They were placed close to the edges of the nesting islets facing towards their centre, to ensure capturing images of clusters or nesting assemblages of at least 10-15 nests.

Each photograph was stamped with a time and date, providing accurate records of the sequence and timing of events, and a custom name was set for each camera for identification purposes, as multiple cameras were used.

Photograph analysis

We visually examined every single photograph to assess the use of nesting islets by other bird species and mammals, as well as for the documentation of phenological dates. However, for assessing seasonal and daily variation of pelican numbers, we only examined a predetermined number of photos, namely three daytime photos (early morning, noon, before dusk), and two nighttime photos, resulting in five photos/day/camera checked. Likewise, for estimating breeding success, we used sample analysis. We calculated breeding success as the number of fledged or almost fledged young per pair. We also made an effort to estimate clutch size and hatching success, calculated as the number of young hatched relative to the number of eggs present in a

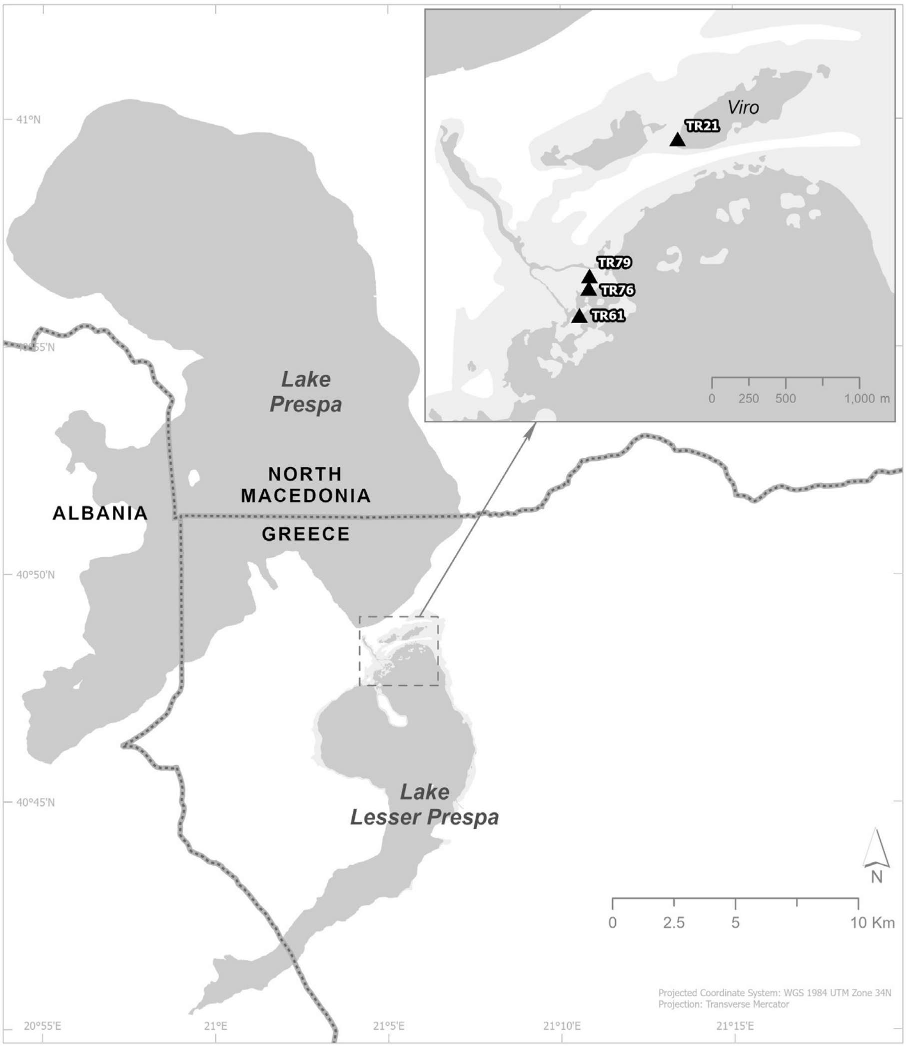

Figure 1. Map of the study area, the northern part of Lake Lesser Prespa where the mixed Dalmatian pelican and great white pelican colony is located and the four nesting islets where time-lapse cameras were deployed.

clutch. We recorded the following phenological dates per pelican species for each camera site: arrival of the first ten adult individuals, clutch initiation (first egg observed) and hatching of the first chick.

Results

In total, nearly 90,000 photographs (ca. 13,000 per camera) were produced during the breeding period. DPs occupied all seven camera sites, whereas GWPs only three (TR21A, TR21B, and TR61B). The estimation of individuals present on TR61B was challenging, as the very large aggregations on that site after May did not allow for precise counts, and it was decided not to include it in the analysis, with respect to seasonal and daily variation of attendance, as well as for phenological dates.

Phenology

The first ten adult DPs were observed on the seven camera sites from 27/1 to 12/2/2016, with the sites at the inner Viro Pond being occupied 5-16 days later than the sites on Lesser Prespa Lake. The first eggs were observed from 5/2 to 27/2, the more delayed clutch initiation taking place in Viro sites. Finally, the first chicks were observed from 7/3 to 1/4. DPs took 9.5 ± 4 days (n = 6 camera sites) between arriving at a site and laying eggs.

Regarding GWPs, the first 10 adults were observed from 18/3 to 9/4/2016, and, contrary to DPs, the earlier arrivals were documented at Viro sites, 21-22 days earlier than at Lesser Prespa Lake sites. The first eggs were observed on 29/3 and 4/4, and the first chicks on 28/4 and 7/5.

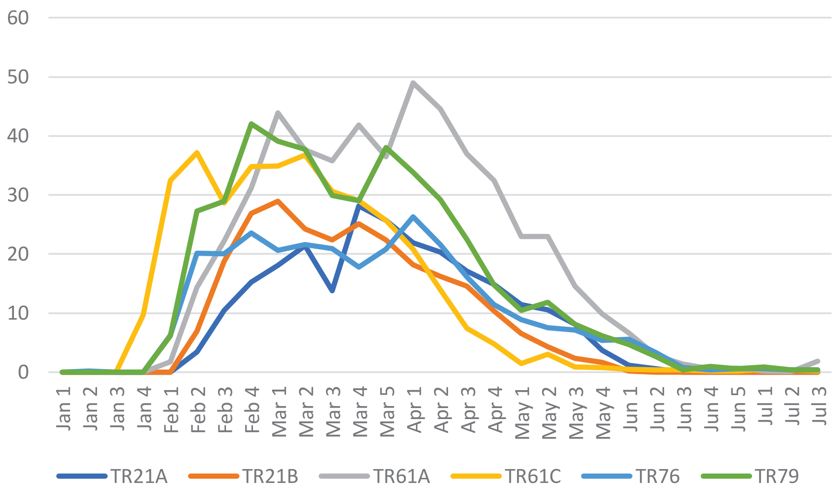

Figure 2. Seasonal variation of attendance (number of individuals) of adult Dalmatian pelicans on six camera sites of four nesting islets equipped with cameras at the Lesser Prespa Lake colony.

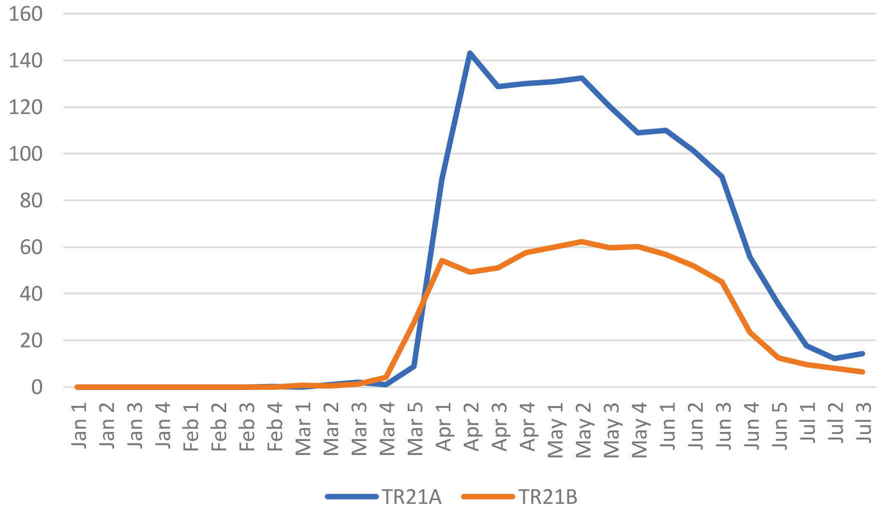

Figure 3. Seasonal variation of attendance (number of individuals) of adult Great white pelicans on two camera sites of a nesting islet equipped with cameras at the Lesser Prespa Lake colony.

Seasonal and daily variation of attendance

During the 2016 breeding period, numbers of adult DPs occupying the seven camera sites peaked from early February to early April with moderate fluctuations, and then decreased gradually until mid-June, when adults practically stopped visiting their nesting sites (Figure 2). Adult GWPs' attendance, on the other hand, peaked from early April to early June, and then decreased considerably until late July, when adults stopped being present for long periods on the nesting islets (Figure 3).

No significant differences were documented between day and night numbers of present individuals of either species, although night records were generally somewhat lower (Figure 4). Nevertheless, night counts are treated with caution, taking in account visibility limitations, especially towards the photos' edges, that can lead to some underestimation. Interestingly, when the first GWPs arrived in mid-March, they were more abundant during nighttime (Figure 5), suggesting limited use of the nesting islets in the very early stages, and mainly for roosting.

Usage of pelican nesting islets by predatory mammals

Four mammal species were recorded on the pelican nesting islets, namely the Eurasian otter *Lutra lutra*, the Wildcat *Felis silvestris*, the Red fox *Vulpes vulpes* and the Beech marten *Martes foina*. Every site was used by all four mammal species, except for nesting islet TR61, where the Otter was absent. The site most heavily used by mammals was TR21 in Viro Pond. Mammals were observed on the nesting islets only prior to the arrival of pelicans (Table 1 and Figure 6).

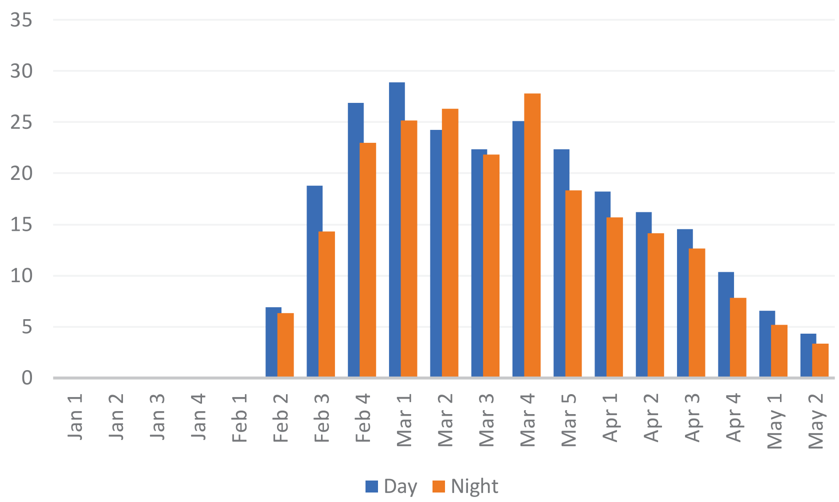

Figure 4. Day and night attendance (number of individuals) of Dalmatian pelicans on camera site TR21B.

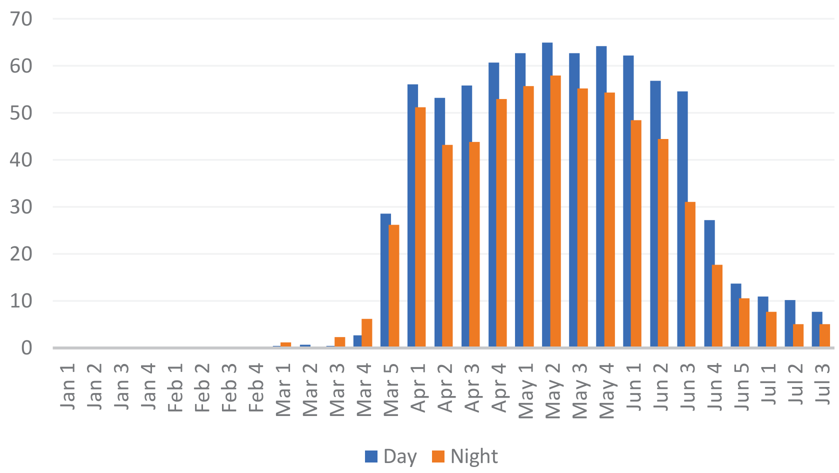

Figure 5. Day and night attendance (number of individuals) of Great white pelicans on camera site TR21B.

Table 1. Presence of predatory mammals on the camera sites (O: Eurasian otter, F: Red fox, M: Beech marten, W: Wildcat, n/a: not applicable, as cameras at these sites were placed in January).

MONTH/SITE	TR21A	TR21B	TR61A	TR61B	TR61C	TR76	TR79
DEC	O	-	n/a	n/a	n/a	n/a	n/a
JAN	O,F,M,W	O,F,M,W	F,M,W	F,W	F,M,W	O,F,M,W	O,F,M,W
FEB	O	O	-	-	-	-	-

Figure 6. Predatory mammals on snow-covered pelican nesting islets, recorded prior to the arrival of pelicans at the colony. A Eurasian otter on TR21A (left), a Wildcat on TR79 (middle), and a Red fox on TR76 (right).

Usage of pelican nesting sites by other bird species

Greylag geese *Anser anser* used all sites, but the Viro sites (TR21A and TR21B) in the northern part of the lake, were heavily used. All large aggregations of geese were recorded on night photos, and the islets were used only sparsely during daytime. As many as 32 individuals were recorded within picture frames on TR21A in mid-February, when DPs started occupying this islet, but significant numbers of up to 20 individuals were also recorded in March and April. Several other waterbird species were recorded using the islets, in small numbers, but only before pelican arrival: Grey herons *Ardea cinerea*, Great cormorants *Phalacrocorax carbo*, Pygmy cormorants *Microcarbo pygmaeus*, Mute swans *Cygnus olor*, Great white egrets *Ardea alba*, Mallards *Anas platyrhynchos* and Yellow-legged gulls *Larus michahellis*. Also, a few raptors were recorded, namely the Eagle owl *Bubo bubo*, the Common buzzard *Buteo buteo*, and the Goshawk *Accipiter gentilis*, while corvids, such as the Magpie *Pica pica* and the Jackdaw *Corvus monedula* were also documented using the islets. Unlike geese, these species used the islets primarily during the daytime, and as with geese, the most used site was the Viro Pond islet (TR21). Interestingly, Yellow-legged gulls' presence coincided in several cases with the presence of dead pelican nestlings. In one case, we recorded a crushed eggshell with a dead DP chick just outside a

Figure 7. A Yellow-legged gull approaching a crushed eggshell with a dead Dalmatian pelican chick just outside a nest on nesting islet TR76.

nest and a Yellow legged gull standing near the carcass (Figure 7). In one of the following photos of this series, both the eggshell and the chick had disappeared, and the Yellow-legged gull had left.

Breeding success

The attempt to estimate breeding success was not accomplished because a high level of uncertainty was ascertained during the image analysis. The primary cause for this uncertainty was the crèching behaviour of pelican chicks after three weeks of age, combined with the inability of cameras to fully cover the nesting islets. Crèching behaviour, the aggregating of chicks from different nests, is common in several colonial seabird species, among them pelicans (Evans 1984), and it is a function serving anti-predator defence and thermoregulation as suggested by researchers (e.g., Johnsgard 1993). This behaviour was occasionally recorded occurring towards the edges of the image frames, while there were cases when it was apparent that some nestlings were systematically crèching outside the image frame (Figure 8A-D). Thus, no reliable breeding success estimation could be achieved, as even on the smaller nesting islets, such as TR76 and TR79, a full coverage of the islet was not possible. Furthermore, the growing aquatic vegetation during the breeding period acted as a wall in some sites, severely hindering visibility. In addition, we were not able to estimate clutch size and hatching success, as very few incubating females were photo-captured in a standing pose, that would allow a good view of the nest content.

Discussion

In this the study we evaluated the efficiency of time-lapse cameras in collecting primarily breeding data from the Lesser Prespa Lake pelican colony. The high volume of photographs which needed to be analysed made this method laborious and time-consuming, especially for tackling study questions for which the full examination of the photographic material was required. Black et al. (2018) argue that even as few as six photographs daily can provide enough information to observe accurate phenological dates and examine temporal trends. The huge number of photographs produced in this study is partially explained by the wide array of study objectives.

Phenology dates documented with time-lapse photography generally confirmed and, in some cases, enhanced the results obtained from systematic direct observations from vantage points using a telescope (performed three times a week during the breeding

Figure 8. Examples of time-lapse camera images of the Prespa pelican colony. A-upper left: a breeding unit of Dalmatian pelicans incubating on nesting islet TR61. B-upper right: crèching young from the same unit, some of them at the edges of the image frame. C-lower right: a breeding unit of Great white pelicans incubating on nesting islet TR21. D-lower left: the same unit with crèching young.

period). As expected, the discussed method was in general more accurate, as cameras can provide more frequent observations, yet the estimates of the two methods were generally comparable (Table 2). A similar finding is discussed in a relevant study on colonial pygoscelid penguins *Pygoscelis sp.* (Hinke et al. 2018). Environmental conditions affect timing of phenological events causing inter-annual and spatial variation, but the intervals between phenological events are more fixed. The period estimated between the arrival of the first DPs and egg-laying in this study generally agrees with the results from a previous study (9 ± 1.4 days, versus 9.5 ± 4 days, this study) which was carried out in the late 1980s at the Lesser Prespa colony and involved colony visits (Crivelli et al. 1998).

We conclude that the need to sufficiently understand phenology traits of the Lesser Prespa pelican population and to inform management activities is sufficiently covered by direct observations from vantage points with much less effort. Moreover, despite the more detailed results of the camera method, we noticed that direct observations proved superior in some cases, detecting earlier the onset of breeding (Table 2). This is attributed to the fact that, as the cameras' range of view did not include the entire islet, despite optimal placement, parts of the nesting assemblages (breeding units) on the same islet remained undetected, being outside the cameras' ranges. In some cases, these nesting assemblages had started earlier due to asynchronous laying initiation. Hence, the inability of the method to fully cover the islets, which host asynchronous breeding units, proved to be a major limitation of the study. Similar placement practicalities and limitations of this method have been discussed in other studies too (e.g., Black 2018).

The seasonal variation of attendance of adult pelicans on the nesting islets is associated with nest attendance and parental care. The number of present DP adults dropped significantly by late April when most chicks had reached 3 weeks of age. At this age, chicks are no longer constantly guarded by their parents (Crivelli et al. 1998; Dentressangle et al. 2008), so parents seem to only occasionally visit the nesting sites to feed their young, whereas late in the breeding season when the young are more than 2 months old, the adults are completely absent from the nesting sites, apparently roosting and resting elsewhere, as our results show. Like DPs, the attendance of adult GWPs peaked during the early stages of chick-rearing and then gradually decreased to zero. Notably, peak numbers and the presence pattern of DPs were chronologically more variable between camera sites compared to that of GWPs, who seem to occupy the nesting islets more synchronously, with peak numbers observed much more aggregated chronologically. This is probably an effect of the more synchronous arrival of the long-distance migrant GWPs, which arrive in large groups at their breeding sites in Europe in spring (Hatzilacou 1992; Boyla 2011). On the contrary, the short-distance migrant DPs arrive at the Lesser Prespa colony more asynchronously and in several waves, consisting of smaller groups (Crivelli 1987).

The large temporal differences in attendance between DPs and GWPs are explained by the fact that the two species do not arrive simultaneously at their breeding grounds at Lesser Prespa, with the long-distance GWP arriving later (Doxa et al. 2012).

This is the first time that the activity patterns of pelicans on the nesting islets during nighttime have been documented. Even though there were visibility limitations in the night photos, it seems that fluctuations in numbers of pelicans present during the day and at night follow the same pattern, apparently dictated by the breeding stage, as discussed earlier.

Although the documentation of immature individuals' presence was not one of the main objectives of the study, it is worth noting that the attendance of immatures was also recorded, as their numbers were low for both species. Immature individuals were essentially observed only early in the breeding period, though later than the first arrivals of adults, and they were completely absent from the nesting islets after most nests had been established. The absence of immatures from nesting grounds at the Lesser Prespa colony has been documented before for both species (Crivelli 1987; Hatzilacou 1992).

Pelican nesting islets seem to act as a haven for the resident Greylag goose population, which is the largest breeding population in Greece (Catsadorakis 1997) and

Table 2. Comparison of basic phenology dates acquired through two different methods: direct observations from vantage points, and the method discussed here (time-lapse cameras).

Nesting islet	First 10 DPs (vantage points)	First 10 DPs (cameras)	First nests (vantage points)	First nests (cameras)
TR61	21/1	27/1	8/2	5/2
TR76	8/2	4/2	11/2	8/2
TR79	4/2	2/2	11/2	10/2
TR21	11/2	11/2	15/2	23/2

among the southernmost populations of the species in Europe (Scott & Rose 1996). Geese apparently use pelican nesting islets mainly before pelicans arrive in the area, while the most preferred site was TR21 in Viro Pond, which lies in the heart of the species' major nesting area in Lesser Prespa (Boleti et al. 2015). In general, the method provided original results about the use of pelican nesting islets by other waterbirds, and also gave an important insight into the interactions between pelicans and Yellow-legged gulls in the area. At Lesser Prespa Lake the latter species has its only inland colony in Greece (Catsadorakis 1997), while skilful predation of DP newly hatched chicks from the nest, despite the presence of the parent, has been documented in an older study in the area (Hatzilacou 1992). Furthermore, Yellow-legged gulls' presence on and around pelican nesting islets, especially during hatching, has been systematically recorded (G. Catsadorakis pers. obs.).

The presence of predatory mammals on pelican nesting islets before pelican arrival may be associated with feeding opportunities, and particularly probably scavenging on carcasses of pelican chicks and adults or unhatched eggs from the previous breeding period. Moreover, pelican nesting islets, especially the one in Viro Pond, which is not as isolated from the mainland as other nesting islets, could be forming part of the foraging habitat of various mammals. Nevertheless, no disturbance incidents or predation were observed, and the presence of mammals was restricted in the period before pelican arrival on the nesting islets. Negative impacts of predatory mammals on pelican nesting colonies have been documented at Prespa in extreme drought years (predation by foxes, Catsadorakis et al. 1996), while the presence of otters on pelican nesting islets during the breeding period has been associated with occasional predation of very young GWP nestlings (Hatzilacou 1992). Predation by mammals has been recorded in other pelican colonies; namely, Simeonov (2011) documented Wild boar *Sus scrofa* and Golden jackal *Canis aureus* disturbance and destruction of eggs at the Srebarna DP colony, Bulgaria, while invasive Racoon dogs *Nyctereutes procyonoides* were recorded causing disturbance and forcing DPs to abandon part of the same colony in Bulgaria through a video-monitoring system (Koshev et al. 2020). In Australia, introduced European foxes were responsible for nesting failure and nest abandonment in an Australian pelican *Pelecanus conspicillatus* colony (Johnston 2016).

For the objective of estimating breeding success at the Prespa colony, this method demonstrated several weaknesses. On one hand, natural vegetation growing during the breeding period was obstructing visibility, and on the other hand, full coverage of the nesting islets, especially of the larger ones, was not possible, a limitation aggravated by the crèching behaviour of the young, as discussed earlier. Constraints posed by terrain, vegetation and crèching behaviour that may limit the efficacy of camera systems are also discussed in Hinke et al. (2018).

Overall, it may be said that this method provided some original and interesting results, yet the effort involved is deemed excessive in comparison to other methods used for similar objectives at the Lesser Prespa pelican colony. Nevertheless, the use of artificial intelligence for processing camera-trap data is on the rise in recent years (e.g. Vélez et al. 2023) and it could provide substantial help in relevant studies. Regarding the estimation of breeding success, we conclude that time-lapse photography may produce more reliable results if used in pelican colonies on artificial nesting structures, with limited surface area, much more controlled conditions and lack of vegetation.

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