ABSTRACT: The number of ground-nesting bird species in meadows, one of the most vulnerable habitats in the ornithological reserve of Vrana Lake Nature Park has decreased in recent decades. Nest survival rates were investigated in meadows and reed beds using nest predation experiments in late March and in May 2005. Predators damaged 18% of the 50 artificial nests placed in the pasture meadow habitat in March and 22% in May. Daily survival rate of nests were found to be similar in March (97%) and May (96%). In May, 64% of 25 nests located in the reed bed were discovered by the predators, with the daily survival rate of nests (90%) being significantly lower than that of nests in the nearby meadow. The results suggest that the reasons for the decreasing number of nesting bird species may be – instead of the pronounced presence and activity of predators in the area – the shrinkage of meadow area, the lack of buffer zone, the proximity of agricultural lands, and disturbance caused by intensive grazing.

KEY WORDS: artificial nest, predation, survival rate, threats, Vransko jezero

Habitat loss causes losses of biodiversity world-wide (Fahring 2003). During the last decades, agricultural intensification has modified the hydrology of Mediterranean wetlands (Robledano et al. 2010). The importance of wetlands is increasingly recognised as systems supporting specific and valuable biodiversity (Gibbs 2000). The biodiversity of the Mediterranean region is particularly vulnerable (Underwood et al. 2009), indicated by a number of examples in Croatia as well (e.g. Mužinić 1995, Cvitanić and Mužinić 1999, Radović et al. 2005, Barun et al. 2010, Purger and Mužinić 2010). In the ornithological reserve Vrana Lake Nature Park, meadows are the most degraded habitats and have recently shrunken to the narrow zone between reed beds and agricultural fields which areas inside the reserve have expanded from the beginning of 1980s (Radović et al. 2004). The meadows are often flooded in early spring, allowing ground-nesting birds to start their breeding cycle only after the water has receded. However, as the water level drops, predation pressure can increase (Purger and Mészáros 2006). Due to intensive grazing and other forms of human disturbance, several ground-nesting bird species (e.g. Corncrake Crex crex (L.)) have become extinct in the meadow habitats (Radović et al. 2004), but the role of predation in this cannot be excluded either. Artificial bird nests have become popular as subjects for testing various ecological and behavioural hypotheses of predation theory (Major and Kendall 1996).
The aim of this study was to find out about predation pressure on ground-nesting birds in the remaining meadow habitats and the neighbouring reed beds under the prevailing conditions, after the water cover has withdrawn.

Vrana Lake (Vransko jezero) is one of Croatia’s largest freshwater lakes (30.3 km²), situated south-east from Biograd (Radović 2005). The lake is 13.6 km long and 1.4–3.5 km wide, stretching only a couple of hundred meters from the Adriatic Sea, parallel with its coastline, and forming part of the 56.1 km² large Vrana Lake Nature Park. The ornithological reserve (6.6 km²) is located in the north-western periphery of the lake in an intensive flood zone with marshland vegetation, mostly reed and sedge communities (e.g. Ass. Phragmitetum australis Soó 1927, Ass. Scirpetum maritimi (Br.-Bl. 1931) R. Tx. 1937, Ass. Scirpetum lacustris Schmale 1939) (Stančić and Kamenjarin 2007). Stands dominated by Eleocharis palustris or Alopecurus utriculatus occur on flooded or wet soil. There are also amphibious plant communities of the class Isoëto-Nanojuncetea Br.-Bl. et R. Tx. ex Westhoff et al. 1956. Between the reed beds and agricultural lands wet meadows belonging to the Trifolio-Hordeetalia H-ić 1963, a widespread vegetation type in the Sub-Mediterranean area can be found. Meadows are considered to be the most significant habitats of the Nature Park, and are used as pastures (Radović 2005). In early spring the major part of the meadow becomes flooded by water. After the water has receded, vegetation remains mostly low due to intensive grazing, except small insular patches formed by few mainly unpalatable plant species (e.g. Bolboschoenus maritimus, Carex vulpina, Eleocharis palustris, Juncus articulatus, Scirpoides holoschoenus).

Nest predation experiments were done in March and in May 2005. On 20th March altogether 50 artificial nests were created in the vegetation patches of the meadow. Ground nests were formed by creating a depression in the soil using our heel (Marini et al. 1995, Fenske-Crawford and Niemi 1997). Nests were separated for more than 20 meters from each other (Major and Kendal 1996, Bayne and Hobson 1999), than 3 brown chicken eggs and one plasticine egg were placed into each of the nests. Plasticine eggs were half the size of the chicken eggs, and used for predator identification from tooth and bill imprints (Niehaus et al. 2003). Both plasticine and chicken eggs were stored outdoors for one week before the start of the experiment (Báldi 1999). The nests were checked after their instalment, on days 1 (21 March), 2 (22 March), 4 (24 March) and 7 (27 March), between 10h00 and 12h00 each time. The investigations were repeated in May. The positioning and content of the nests in the meadow in May were the same as in March. The water has receded allowing us to set up artificial ground nests in the reed bed only in May. The content of the 25 ground nests in the reed bed and the times of checkings were

![Fig. 1. Differences in the proportions of depredated artificial ground nests (+1SE).](image-url)
identical with those in the meadow. Nests were created on 1st May, followed by a series of checkings on 2nd, 3rd, 5th and 8th of May. Also, care was taken not to make any change to the nests during the process of checking (Brua 1999). A nest was considered to be predated when at least one egg was damaged or missing (Clark and Wobeser 1997). Survival rates of nests were calculated with the Mayfield (1975) method and compared using the test proposed by Johnson (1979). For comparisons, the freeware “J-test” developed by K. Halupka was used. For comparing predation rates of plasticine eggs, 2 × 2 contingency tables with Yates correction were used (Zar 1999). A minimum probability level of P < 0.05 was accepted for all the statistics.

Predators damaged 18% of the 50 artificial nests placed in the pasture meadow habitat in late March 2005 and 22% in May (Fig. 1). Daily survival rate of nests in March (97%, SE = 0.009, 95% confidence limits: 95.62–99.10) were similar (z = 0.610 P = 0.542) to data obtained in May (96%, SE = 0.010 95% c. l.: 94.49–98.59). In May, 64% of nests located in the reed bed were discovered by the predators (Fig. 1). The daily survival rate of nests in the reed bed (90%, SE = 0.023 95% c. l.: 85.44–94.81) were significantly lower (z = 2.509 P = 0.012) than that of nests in the nearby meadow in the same period.

In March, chicken eggs were damaged in only 6 of the 50 nests. Based on the signs, damage was caused by treading in one case, as suggested by hoof imprints on the ground. One nest was depredated by Eurasian Otter Lutra lutra L., concluded from fish remains and sprains left at the nest. In the case of four nests, the predators managed to break only one or two of the three chicken eggs. In May, in meadow habitat chicken eggs were damaged in 7 nests, but all three eggs were broken up and eaten in only one of these cases. In the reed bed, predators managed to break up one or two eggs in only 6 of the 25 nests.

The proportions of intact vs. damaged or removed plasticine eggs in the case of nests in the meadow were similar (c² = 0.61 df = 1 P = 0.43) in March (43 vs. 7) and May (39 vs. 11). In March, 14% of the plasticine eggs had marks from small beak (4 cases) or teeth (3 cases) (Fig. 2). In May, 22% of plasticine eggs were damaged. In 6 cases, evidences from bird attack, in 1 case marks from small mammals were found on them, whereas in four cases the plasticine eggs were missing from the nests. Beak marks were left behind by small-sized birds, apart from a single case. In nests located in the reed bed, 60% of the plasticine eggs had marks left behind by small birds (3 cases) or mammals (12 cases).

The daily survival rate of artificial ground nests in the meadow was found to be substantially high in March as well as May. In this area only Mallards Anas platyrhynchos L. start their breeding cycle in early spring (Radović et al. 2004). Bird predators active in the beginning of the breeding season are replaced only gradually by the more efficient mammal species (Opermanis et al. 2001). In March, Yellow-legged Gull Larus michahellis J.F. Naum. and Hooded Crow Corvus cornix L. (Radović et al. 2004), both bird species being common throughout the year, did not cause any damage to the experimental nests located in the open area. Until May, water normally withdraws from the entire area, allowing the majority of ground-nesting species (e.g. Comon Quail Coturnix coturnix L., Spotted Crane Porzana porzana L., Northern Lapwing Vanellus vanellus L., Eurasian Skylark Alauda arvensis L., Yellow Wagtail Motacilla flava L., Corn Bunting Emberiza calandra L.) to start breeding (Radović et al. 2004). In May, Western Marsh-harriers Circaus aeruginosus L.), too, arrive at Vrana Lake (Purger and Mužinić 2005). Both bird species being common throughout the year, did not cause any damage to the experimental nests. However, predation pressure represented by larger-sized bird species did not change significantly. Similar results were obtained in our earlier experiment at Lake Kuti (delta of the river Neretva, Croatia), where the daily survival rate of nests in the open pasture area were also found to be high, whereas predation pressure caused by large-sized predator birds was found to be insignificant (Purger and Mužinić 2010). The scent of plasticine eggs in the artificial nests can be attractive in many cases for mammalian predators having sensitive smelling (Purger et al. 2008). Nevertheless, there was only one case in our investigation when we had evidence about nest...
predation by a large-sized mammal. From this it could be concluded that either there are few large-sized mammal predators in the area or they stay away from the meadow where the amount of breeding birds has decreased substantially in recent years and anthropogenic disturbance has reached a considerable level (Radović et al. 2004). Also, it is not large-sized predators that are responsible for higher predation rates recorded for the reed bed habitat. The reed bed provides better protection for smaller birds and mammals. In this habitat, they more easily discovered the exposed ground nests and could depredate them, as suggested by tooth and beak marks left behind on the plasticine eggs.

Chicken eggs are larger and have stronger shell, making it difficult for smaller predators to break them open (Zegers et al. 2000, Maier and DeGraaf 2001), as is supported by our finding that they could break up one or maximum two of the three chicken eggs found in one nest. In the case of real scenarios and true nests, the role of small-sized bird and mammalian predators in damaging the clutches is probably even smaller, because the parent birds stay on the nest, sometimes even protecting their brood (MacIvor et al. 1990).

Despite Vrana Lake being part of the “National ecological network – areas important for birds in Croatia”, birds are threatened by mainly illegal constructions, agricultural intensification, drainage, excessive or illegal hunting in the surrounding areas and excessive water extraction from lake tributaries (Radović et al. 2005). The Vrana valley is a significant vegetable production area (Borošić et al. 1998). Even lands that remain water-covered until early spring are ploughed (Mužinić and Purger 2005). Due to the lack of buffer zones, conflicts are quite common between the managing authority of the protected areas and agricultural land users (e.g. burning the reed bed), the interest conflicts being particularly sharp in the periods of bird migration and breeding. Certain species migrate in enormous numbers to feed in the nearby agricultural lands where the peak human activity is in the same period (gardening, irrigation, grazing), meaning also disturbance to potential breeding sites, resting or feeding grounds (Beale and Monaghan 2004). The only solution for ensuring safe breeding is the creation of a buffer zone. To preserve this valuable habitat in the Ornithological reserve the only way is to replace intensive agriculture with traditional husbandry (Radović et al. 2004), which could lead to recolonisation and breeding by bird species that have become absent from the area.

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Fig. 2. Rate of damage to plasticine eggs (white bars – taken away from nest, black bars – mammals gnawing, hatched bars – pecking by birds).
REFERENCES


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