Avocet *Recurvirostra avosetta* responses to predator activity at Newport Wetland Nature Reserve

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Keywords

Abstract

The Newport Wetlands National Nature Reserve holds Wales' only breeding colony of Pied Avocets *Recurvirostra avosetta*. However, colony productivity is consistently low due to predation of eggs and chicks by both avian and mammalian predators. Here we describe predator activity, mobbing activity and predation events during the 2019 breeding season using a combination of scan sampling (avian predators and interactions) and camera traps (mammalian predators). Carrion Crow *Corvus corone* was the most sighted avian predator with 151 (53%) of total sightings and the only species directly depredating Avocet chicks. Carrion Crows elicited a mobbing response 52% of the time, often by individual Avocets. In contrast, six Common Buzzard *Buteo buteo* were detected all of which were mobbed by multiple Avocets. Brown Rat *Rattus norvegicus* was the most commonly detected mammal predator, accounting for 84% of total sightings. Mobbing activity was more common at lower temperatures, likely a result of increased predator activity.

Introduction

Avian populations are affected by a range of biotic and abiotic factors, including temperature and precipitation (Doyle et al., 2020), habitat (Kentie et al., 2018), anthropogenic impacts (e.g. Verga et al., 2017; Caravaggi et al., 2019a; da Silva et al., 2020) and predation (Roos et al., 2018). Many of these factors have particular relevance during the breeding season, when consistently high mortality among breeding adults, eggs or chicks can result in substantial and prolonged population declines (Grüebler et al., 2008; Caravaggi et al., 2019b)

 Wading birds (Order Charadriiformes; 'waders' hereafter) are commonly found along shorelines and mudflats where they forage for food, such as crustaceans and invertebrates. Many waders are ground-nesting species that occupy low-lying habitats such as wetland, mudflat saline lagoon and saltmarsh ecosystems for breeding and feeding (Smart, et al., 2006). Such habitats are relatively rare due to destructive coastal processes and anthropogenic impacts (Klemas, et al., 2004). As a result, ground-nesting wader colonies may be restricted to narrow strips or small patches of suitable habitat (e.g. Lavers & Haines Young, 1996). Further, many waders are colonial breeders, a system that is thought to confer considerable benefits in terms of enhancing foraging efficiency (Beauchamp, 1999), obtaining extra-pair copulations (Drachmann et al., 2002), and minimising individual depredation risk (e.g. Cresswell, 1994; Hernández-Matías et al., 2003; but see Varela et al.,

2007). Certainly, such wader populations often exhibit considerable between-year variation in breeding success due to depredation by a range of species (Evans & Pienkowski, 1984; Frederick & Collopy, 1989).

The Pied Avocet *Recurvirostra avosetta ('avocet', hereafter)* is a medium-sized (260-290 g)wader with a distinctive, long, up-curved bill that is used to forage in waters heavy with sediment (Moreira, 1995). It is widespread, with a patchy breeding distribution that includes northern Africa, central and eastern Asia, and Europe, including the UK where it is a species of conservation concern (Eaton et al., 2015). The breeding season in the UK extends between April and August. A typical clutch contains 3-4 eggs, incubation lasts for 23-25 days, and chicks fledge 35-42 days after hatching. Like many prey bird species, Avocets often respond to a perceived avian threat by performing a variety of diversionary displays or 'mobbing' potential predators. In contrast, responses to mammalian predators are comparatively weak, involving mostly aerial circling and terrestrial distraction displays (Sordahl, 2004). Potential predators in the UK include the red fox *Vulpes vulpes,* brown rat *Rattus norvegicus* (Seymour, et al., 2003), Carrion Crow *Corvus corone* (MacDonald & Bolton, 2008), Western Raven *Corvus corax* (Ewins et al., 1986), and Common Buzzard *Buteo buteo* (Swann & Etheridge, 1995).

The only breeding Avocet colony in Wales is located at Goldcliff Lagoons, a site that is part of Newport Wetlands National Nature Reserve (NNR; Dalrymple, 2020). This population has experienced extremely low breeding success in recent years, with some years seeing up to one hundred percent egg and chick mortality, despite active management. In this study we focus on the anti-predator behavior of the Goldcliff population, exploring associations with predator occurrence and weather that will increase our understanding of relevant community dynamics.

Methods

The study took place at Goldcliff lagoons, part of the Newport Wetlands NNR (OS ST 37183 82542); a site that was created in 1998 as compensation the for the destruction of the then Cardiff Bay SSSI. The reserve is owned and managed by Natural Resource Wales (NRW), with a visitor and education center run by the Royal Society for the Protection of Birds (RSPB). A full description and history of the Newport Wetlands National Nature Reserve (NNR) is provided by Dalrymple (2020). Goldcliff lagoons is situated to the east of the NNR and comprises three saline lagoons, each of which contains a single islet, and is surrounded by fencing designed to exclude mammalian predators. Avocet breed on two of the islets along with Lapwing *Vanellus vanellus* and Redshank *Tringa totanus* (Fig. 1). Avian predators found in the wider landscape include Common Buzzard, Herring Gull *Larus argentatus*, Great Black-backed Gull *Larus marinus,* Western Raven and Carrion Crows, Grey Heron *Ardea cinerea* and Common Crane *Grus grus*; mammalian predators include stoat *Mustela erminea,* brown rat, red fox, and Eurasian otter *Lutra lutra*.

The study took place between 23rd of March and 7th of June 2019, i.e., during the Avocet breeding season. Avian predator activity was surveyed from a bird hide located in the South-West of the lagoons (Fig. 1), by a single observer with binoculars (Bushnell H20 10x42 mm roof prism) and a telescope (Swarovski ATS/STS 80). Three surveys were conducted each

week; one at the start of the week (Monday-Tuesday), one mid-week (Wednesday-Thursday) and one at the end of the week (Friday-Sunday), depending on the observer's availability (n = 22). Environmental data, including temperature, wind direction and speed, precipitation (0-3, where 0 = none and 3 = heavy rainfall) and cloud cover on the okta scale (Smith et al., 2017) were recorded at the start of each survey period. Avian data were collected using a scan sampling method (Simpson & Simpson, 1977) and by a single observer. Observations began at 08:30 and concluded at 10:30, during which time all avian predators observed, their interactions with Avocets (if any) and Avocet reactions (if any) were recorded. Mobbing was defined as two or more Avocets taking to the air to surround or attack potential threats. An assessment of the strength and consistency of the mobbing response was made, based on the number of Avocets involved, both at the start and end of the activity, and the duration of the mobbing activity. Herring Gulls, Lesser Black-backed Gulls and Great Black-backed Gulls were grouped for the purposes of this study ('gulls' from hereon), due to difficulties in discriminating between species at a distance or in sub-optimal conditions.

Four remote-sensing camera traps (Bushnell HD) were deployed at sluices around the reserve, inside the perimeter fence, to survey predatory mammal activity (Fig. 1). Vegetation height and density precluded the use of camera traps elsewhere on the site. Cameras had normal sensitivity and were set to capture still images, with a 30-second delay. Each camera trap was set 2 m away from a ¾ inch, wire mesh cage measuring approximately 30 cm^2, at a height of 30 cm and with a slight downward tilt. Cages were fixed in placed and baited with mackerel that was refreshed opportunistically by the reserve management team. Scan sampling data were analysed using Pearson's r t to explore temporal variation in predator count and Avocet mobbing activity. A General Linear Model (GLM) with a binomial distribution and log-link function was used to explore the influence of predator occurrence, weather and climate on mobbing behavior, ensuring that Variance Inflation Factors (VIF) were <5. Avocet response was fitted as the response variable and temperature, cloud cover, precipitation and avian predator count were fit as explanatory variables. A General Linear Mixed Model (GLMM) framework was explored, with survey day and species as random variables but models failed to converge. No interaction terms were included as they prevented model convergence. Post-hoc examination of GLM results led to the exploration of a potential relationship between temperature and predator count via Pearson's r. Statistical analyses were conducted in R 3.5.3 (R Core Team, 2019).

Results

A total of 255 individual avian predators were recorded across 44 hours of scan sampling during this study. Carrion Crows were the most common avian predator recorded (n = 151), followed by gulls (n = 47) and Grey Herons *Ardea cinerea* (n = 25). Additional avian predators recorded included Western Raven (n = 21), Common Buzzard (n = 6) and Magpie *Pica pica* (n = 5). Carrion Crows were mobbed on 80 occasions (53% of all crow observations), gulls were mobbed 21 times (47%) and Common Buzzards were mobbed six times (100%). Magpies did not elicit a mobbing response. Direct depredation of an Avocet chick was observed on two occasions, by a Carrion Crow in each instance.

Avocet mobbing activity increased with decreasing temperatures (GLM; β = -0.255 ± 0.062,

P < 0.0001). Post-hoc correlative analysis of the association between temperature and predator count resulted in a significant association (t_{211} = -2.303, P = 0.022), i.e. more individual avian predators were recorded during colder weather. Temperature was strongly associated with survey date (R^2 = 0.80); colder temperatures were recorded earlier in the breeding season (Fig. 2). There was no significant increase observed in mobbing activity over time.

A total of 25 individual mammalian predators were detected across 300 camera days. Brown rats were the most commonly detected species (n = 21). Additional species included stoats (n = 3; Fig. 3) and red fox (n = 1). A total of 17 detections were recorded between 22:00 – 02:00.

Discussion

The results of this study show that, given the explanatory variables detailed herein, temperature was the only relevant factor explaining temporal variation in the frequency of mobbing behavior of breeding Avocets. Given the observed trends in both predator number and temperature, it may be that our data simply reflect greater predation pressure earlier in the season, when mean daily temperature is lower. Further, it should be noted that no Avocet chicks were observed later than early May, which coincides with a decline in predator observations. However, while the number of individual predators was not a significant predictor of mobbing behavior, responses to predators were not equal. For example, while Carrion Crows were the most frequently recorded predator (n = 151), eliciting a mobbing response 53% of the time, and were seen in active depredation of Avocet chicks, they nevertheless elicited a weak community response (i.e. mobbing by a small number of adults; Nicholas Bishop, *pers. comm.*). In contrast, Common Buzzards were rarely recorded (n = 6) and were not observed depredating chicks during the study but nevertheless elicited a strong communal response on each occasion, with adult Avocets mobbing in great numbers (NB, *pers. comm.*). Avocets typically mob potential threats that are larger than themselves (Sordahl, 1986) and, indeed, Common Buzzards were observed to elicit a stronger and more consistent response than any other avian predator.

The high abundance of crows may be partially due to the surrounding habitat; the reserve occurs in an agricultural landscape that may provide enhanced foraging opportunities for the species when compared to other habitats (Mastubara, 2003). Opportunistic observations by site wardens suggest that Buzzards are also particularly abundant in the area, despite the lack of records reported herein, and have been observed depredating Avocet chicks (TD, *pers. comm.*). It is unlikely that Avocets represent a substantial proportion of the diet for either species (Graham et al., 1994; Miller et al., 2014). However, video evidence from the Netherlands suggests that Carrion Crows and Buzzards can be important predators of wader chicks and eggs, with Buzzards being among the most frequently recorded (Teunissen, et al., 2008).

Mammalian predators were infrequently detected by camera traps during the study (n = 25). This is likely to be an artefact of camera number and placement, rather than a true reflection of predatory mammal activity (Kolowski & Forrester, 2017). The most frequently detected mammalian predator, the Brown Rat, is a common threat to breeding birds worldwide (e.g.

Major, 1991; Moors et al., 1992; Angelici, et al., 2012), including Avocets (Norman, 1975). Brown Rats are extremely capable swimmers (Brown, et al., 2000), able to reach the islets of Goldcliff Lagoons with ease. It is therefore likely that depredation by Brown Rats contributes to overall Avocet egg and chick mortality rates at Goldcliff. It is important to note, however, that, due to the placement of camera traps, there is no direct evidence of Brown Rats accessing breeding Avocet colonies nor attacking eggs or chicks. Further studies are required to quantify the nature of the threat posed by Brown Rats to breeding Avocets at Goldcliff.

The observation of Stoats inside the protective fencing is also of considerable concern. Stoats regularly consume birds and their eggs (e.g. Green et al., 1987; King et al., 2001; Macdonald & Bolton, 2008) and are capable of depredating a whole clutch in a single attempt (Barlow & Choquenot, 2002). Moreover, they are flexible opportunists, able to rapidly shift to alternative sources of food when normal prey become scarce or suitable alternative prey become abundant (King et al., 2001). As with rats, Stoats were not observed directly accessing breeding Avocet colonies. However, the potential remains and, indeed, both rats and Stoats pose a threat to other ground-nesting breeding birds at Goldcliff. Monitoring the activity patterns and direct threat posed by these predators poses logistical difficulties in terms of direct or remote observation. During the breeding season, vegetation growth ensures that any terrestrial cameras have a limited field of view and frequently capture moving vegetation. Intervention in terms of cutting vegetation is not currently seen to be a viable option. Further, while cameras might be placed adjacent to active nests by reserve staff, it is currently impossible to position cameras so that they are not triggered by moving vegetation, birds, water, or weather. The issue is exacerbated by the fact that access to the islands is strictly limited during the breeding season and regular camera maintenance is rarely possible and would be less so when alongside active nests. Hence, while cameras ostensibly offer the best method for determining the impact of mammalian predators, there are limited opportunities for deployment at present. However, such data would be of substantial value in providing a more complete understanding of the factors affecting breeding Avocets at Newport Wetlands. Hence, considered and focused deployment of camera traps is recommended, ensuring a more complete coverage than was attempted in the current study.

Localised and relatively isolated breeding bird colonies represent a concentration of readily available resources for predators (*sensu* Manton et al., 2019). Heavy depredation of such locations can be anticipated, particularly where predator species are common breeders. Certainly, if a breeding raptor nest, rookery, mammal den or other predator refuge is nearby, it is probably that one or more individuals would indeed visit the same pool of resources multiple times (Bonal & Aparicio, 2008). However, predators can exhibit considerable temporal and spatial unpredictability in their movements (e.g. Roth & Lima, 2006). Given the lack of suitable explanatory data, we recommend further study into the abundance and diversity of potential wader predators and prey availability in the wider landscape.

Conclusions

The frequency of avian predator sightings and the presence of mammalian predators within

the perimeter fence described in this study are of considerable concern. Our results highlight the persistence of threats faced by the small, breeding Avocet population at Newport Wetlands NNR. The results of this study, coupled with further research will help the development of existing and new management processes to assist the colony to persist in the long-term.

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Table 1. The results of a General Linear Model (GLM) exploring factors affecting Avocet mobbing behavior. Variables are ranked according to P value; significant variables are highlighted.

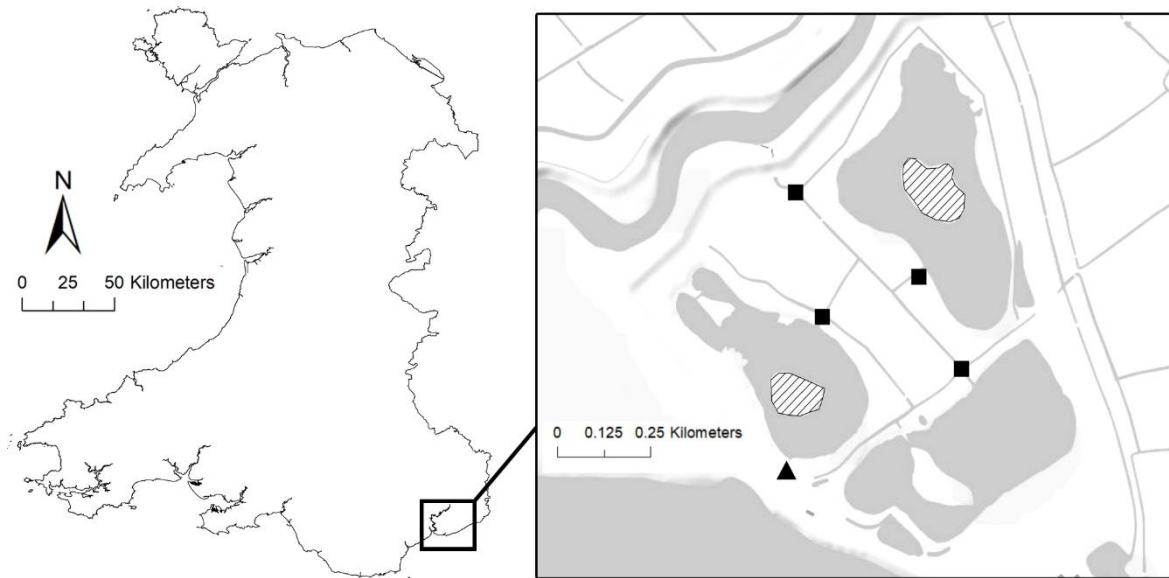| Variable	β coefficient (± Standard Deviation)	P value
Temperature	-0.255 (0.062)	<0.0001
Cloud cover	-0.178 (0.119)	0.136
Precipitation	0.102 (0.264)	0.697
Predator count	-0.006 (0.266)	0.979

Figure 1. The position of camera traps (■), the point of observation (▲) and breeding Avocet sub-colonies (hatched areas) at Goldcliff Lagoons.
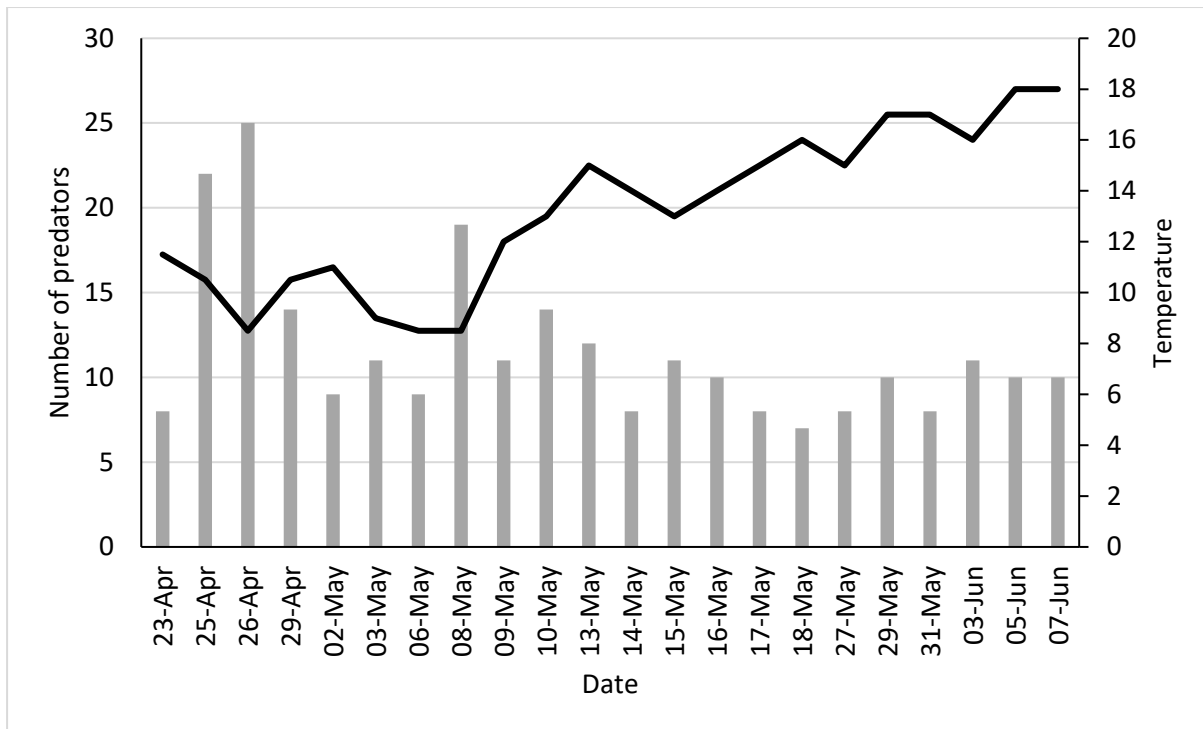
Figure 2. The total number of avian predators observed during morning surveys (bars) and the recorded temperature for each survey period (black line).

Figure 3. A stoat *Mustela erminea* recorded by a camera trap at Goldcliff Lagoons, Newport.