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Research article

Fearfulness of geese and swans on cropland in winter: a multi-species flight initiation distance approach

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Geese and swans are focal species in conservation and in management aimed at reducing crop damage. In the former disturbance should be minimized, and in the latter it is important to know how different species react to scaring activities. Previous research about trade-off between predation risk and foraging in birds often uses 'flight initiation distance' (FID) as a proxy to compare fearfulness under different circumstances and among species. We studied variation in FID in geese and swans by species, flock size and composition, time of day, and body size (408 scaring trials on agricultural land in the winters 2018–2021). In single-species flocks mean FID decreased in the order: bean goose (171 m) > greylag goose (104 m) > whooper swan (102 m) > Canada goose (92 m) > barnacle goose (77 m). In line with predictions based on body mass, the lightest species (barnacle goose) was the least fearful, but contrary to prediction neither of the two heaviest species (whooper swan, Canada goose) was the most fearful. FID was negatively correlated with flock size in bean goose. Flock size and FID did not correlate in greylag, Canada, and barnacle geese. FID did not differ between morning and afternoon in the four species with a sample of > 20 single-species trials. When in multi-species flocks, FID differed less among species, converging in the 108–138 m range. Accordingly, bean goose FID decreased significantly whereas it increased significantly in barnacle and greylag geese. Barnacle goose (protected from hunting by the EU Birds Directive) was less fearful than species with an open hunting season in the EU, implying that exposure to hunting affects species-specific FID. We show that the level of fearfulness varied among swan and goose species, making it necessary to adopt diverse strategies in conservation as well as crop protection.

Key words: *Anser*, anti-predator, *Branta*, crop protection, *Cygnus*, disturbance, FID, scaring

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Introduction

Staying alive to breed and transmit genes to future generations is a basic tenet of evolutionary ecology. Natural selection is presumed to favor behaviors that reduce individual predation risk, and the scientific literature on anti-predator adaptations is vast. In most animals the logical primary action is to flee from predators, but this behavior depends on an array of circumstances in the prey–-predator interaction (c.f. Fig. 1 in Lima and Dill 1990). To cite Ydenberg and Dill (1986): "Animals faced with approaching predators must decide at which distance to initiate their flight, and they are expected to do so in way that maximizes their fitness". This quote contains two important messages; flight response is preceded by predator detection and hence occurs after a decision process, and secondly, flight has benefits and costs that need to be traded off. The obvious benefit is reduced predation risk, whereas costs may be lost feeding opportunities, increased energy expenditure, and losing contact with a foraging group or a familiar site. Consequently, spatiotemporal variation in predation risk and resource availability can result in inter- as well as intraspecific variation in anti-predator behavior, depending on site, season, and situation, for example (Berger 1978, Ripple and Beschta 2004, Li et al. 2012).

Measuring 'fear' in animals is far from straightforward, but a widely used proxy and metric is 'flight initiation distance' (hereafter: FID; in some studies instead called 'escape flight distance' – EFD (Fox and Madsen 1997)). FID can be seen as representing the risk an individual is willing to take before fleeing (Ydenberg and Dill 1986, Dill and Houtman 1989, Stankowich and Blumstein 2005). Since its inception, FID has rarely been viewed as a constant, but rather as something that can vary with circumstances and individual traits, for example sex, age, personality (e.g. boldness), distance to safe cover, flock size, and feeding needs (Laursen et al. 2005, Carrete and Tella 2010, Morelli et al. 2019). The FID concept easily lends itself to experiments, in which focal individuals (or flocks) are approached by a threat under conditions that can be varied and repeated in a more or less controlled way. As a result, the scientific literature using the FID concept is also large. Weston et al. (2012) reviewed FID data for 250 Australian bird species, Blumstein (2006) reviewed FID in 150 bird species, and Livezey et al. (2016) compiled a database for non-nesting birds containing 34 775 FIDs from 50 studies representing 650 species.

In many FID studies an approaching human is the proxy predator. This is partly for practical reasons, but also because FID has frequently been used to define 'safety distances' (also called 'set-back' or 'buffer zones') between animals and human presence in reserves, parks, and similar settings (Rodgers and Smith 1995, Fox and Madsen 1997, Livezey et al. 2016). The rationale is to avoid human disturbance impacting feeding rate, survival, reproductive success, or presence of focal species in a certain area (Livezey et al. 2016). With time, interest in FIDs has grown also for the opposite purpose; when there is a need to scare away animals from parks, beaches, airports or growing crops, how much effort this will take and, when doing so, does FID vary by season, time of day or crop type?

Goose Anserini and swan Cygnini management embraces both these uses of the FID proxy. Some species are globally threatened (e.g. lesser white-fronted goose *Anser erythropus* and red-breasted goose *Branta ruficollis*) and ideally need to be managed to avoid any kind of disturbance, year around. Other species have become super-abundant (e.g. greylag goose *Anser anser* and barnacle goose *Branta leucopsis* in Europe, and Canada goose *Branta canadensis* and snow goose *Anser (Chen) caerulescens* in North America), creating conflict with human interests such as agriculture, biodiversity conservation, and airport safety (Bradbeer et al. 2017, Fox and Madsen 2017, Bakker et al. 2018). Population growth in combination with reduced migration distance in some species, and a large-scale shift from foraging on natural food plants to agricultural crops, have made the conflict between geese and agriculture grow steadily during recent decades (Fox and Abraham 2017, Fox and Madsen 2017, Fox et al. 2017). For example, abundant goose populations are causing increased costs through crop damage, and cases of up to 50% harvest loss have been recorded in Europe (Fox and Madsen 2017, Montràs-Janer et al. 2019, Düttmann et al. 2023). Scaring geese off agricultural crops is now a commonly used countermeasure in management, and FID is a means of quantifying responses to scaring as well as its overall utility (Månsson 2017, Heim et al. 2022, Robai et al. 2024).

Geese and swans are obligate herbivores and highly gregarious outside the breeding season. They usually aggregate in large flocks during migration and on wintering grounds. Moreover, they often mix with other goose species in the latter seasons. Escape flight for predator avoidance by geese is energetically very costly (Mooij 1992, Kahlert 2006). Thus, assessment of predation risk is crucial for individuals to avoid unnecessary loss of energy and feeding opportunities. Reflecting the widened scope of goose management from

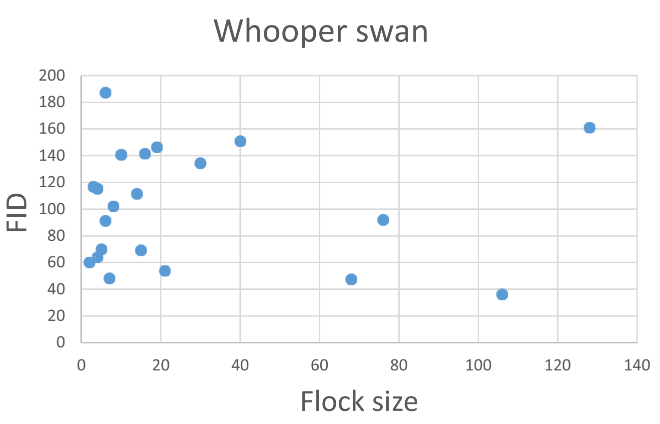

Figure 1. Scatter plot of flock size versus flight initiation distance (FID) in single-species flocks of whooper swan *Cygnus cygnus*. Pearson $r = -0.02$, $p > 0.05$, $n = 21$.

chiefly conservation to also include crop damage reduction, studies of FID have displayed broadened objectives over time. Accordingly, the first studies of FID in geese were aimed at quantifying disturbance response (not explicitly to scare geese off crops): Owens (1977) found that wintering brent geese *Branta bernicla* in England had short FIDs, generally in the 50–100 m range. Madsen (1985), on the other hand, who studied wintering pink-footed geese (*Anser brachyrhynchus)* in Denmark found very long FIDs (200–500 m). Livezey et al. (2016) presented FIDs for many species. Of these, one concerned white-fronted geese *Anser albifrons* (FID 47 m) and another brent geese (FID 105 m). Taken together, these values indicate a large variation in fearfulness among species and settings.

Suitable strategies to mitigate crop damage may thus vary by culprit species and by species composition in flocks causing damage. Other factors, such as flock size, experience of hunting, and body condition have also been shown to affect the response to scaring (Fox and Madsen 1997). Previous studies of FID in geese and swans tend to be one-site one-species approaches, and those from Europe are moreover rather old and were carried out at a time when populations, farming practices, and possibly diets and fearfulness were quite different from today. By studying FID in geese and swans by a multi-species approach in today's agricultural landscape, it may be possible to provide more specific recommendations to farmers and managers about when scaring will be successful and when it needs to be combined with other measures, such as diversionary fields with sacrificial crops, local culling, or population reduction.

We studied FID in geese and swans in a multi-species context in landscapes characterized by intensive agriculture and a wide variety of crops. Based on previous research we predicted that:

- FID should be longer in large-bodied (body mass) than in smaller-bodied (lighter) species (case studies and reviews indicate a taxonomically wide spread pattern that larger species initiate flight at greater distance than do smaller species; Laursen et al. 2005, Blumstein 2006, Morelli et al. 2019).
- FID in a given species differs between single-species flocks and when occurring in mixed flocks with other species (c.f. Deboelpaep et al. 2018, Mai et al. 2022).
- FID should be longer in hunted species than in those protected from hunting by the EU Birds Directive (c.f. Laursen et al. 2005).
- FID should increase as flock size increases in single-species flocks (Owens 1977, Madsen 1985, Kahlert 2006, Mayer et al. 2019, Morelli et al. 2019). Stankowich and Blumstein 2005 found such a general positive correlation in a review of a wide range of avian taxa.
- FID should display an intraspecific diel pattern; shorter in hungry geese (morning) than in those that have fed (afternoon), indicative of hungry geese being willing to take higher risk (shorter FID).

Material and methods

Study area, seasons, and crop availability

This study was carried out in southernmost Sweden (Scania province (Skåne); 55–56°N, 12–15°E) in open landscapes characterized by intensive agriculture. Cereals (wheat, barley, oats, rye), potatoes, sugar beet, oil rape seed (canola), and ley/hay are the main crops. However, also corn (maize), lettuce, broccoli, cale, carrots, beetroot, parsnip, cabbage, quinoa, green peas, yellow peas, yellow onion, red onion, leek, beans, spice herbs, and sileage crops such as alfalfa and grass–legume mixtures are cultivated in the study area.

Scaring trials were conducted by walking towards a flock of geese and/or swans (see Scaring trials for details) and were only carried out on agricultural land, including pastures and hayfields. Since sampling was done from November through March, geese were encountered on growing crops (fall-sown cereals and oil rapeseed (canola), or sugar beets or carrots yet to be harvested) as well as in harvested fields. In early and mid-winter, some fields had fall-sown (growing) intercrops such as grasses, legumes, or oil radish. The seasons of study in the winters of 2018–2021 were typical for recent decades in the area when it comes to weather; snow cover was rare, thin, and lasted a few days or a week at the most. Temperatures were above the monthly means for the meteorological reference period 1991–2020 in 14 out of 15 study months (Supporting information). Consequently, fall-sown (winter-green) crops and spill from harvested cereals and root crops (mainly potatoes, sugar beets, and carrots) were available to grazing birds throughout the winter.

Study species and species-specific predictions

Greylag goose is a common breeder in wetlands near agricultural land throughout the study area, whereas Canada goose and barnacle goose are scarce breeders. All three breeding species are resident, thus occurring throughout winter. Residents of these species are reinforced in numbers by conspecifics arriving from the northeast to spend the winter in the study area. Bean goose (*Anser fabalis* (taxa *fabalis* and *serrirostris/rossicus*)) is an abundant non-breeding visitor from November through March. Pink-footed goose and greater white-fronted goose are regular in fall, winter, and spring, but are not as abundant as the aforementioned species. Lesser white-fronted goose and red-breasted goose are very rare but annually occurring in the study area in the non-breeding season. Whooper swan *Cygnus cygnus* and mute swan *Cygnus olor* are scarce but widespread local breeders, being more numerous in winter. In other words, the study area has a speciose set of large grazing avian herbivores present on agricultural land throughout winter, making it well suited for studies of the present type.

With respect to the species later observed during the course of the study, two of the general predictions listed in the introduction can be made species-specific:

- FID should be longer in large-bodied than in smaller-bodied species. Prediction: FID mute swan > whooper swan > Canada goose > greylag goose > bean goose > pink-footed goose > white-fronted goose > barnacle goose) (c.f. Blumstein 2006; body mass data from Cramp and Simmons 1977).
- FID should be longer in species hunted in the EU. Prediction: FID longer in greylag, bean, pink-footed, white-fronted, and Canada geese than in barnacle goose and whooper swan.

Scaring trials

We drove rural roads slowly by car with the purpose of spotting flocks of geese and/or swans foraging in agricultural fields. Days with very strong winds and reduced visibility due to rain, fog, or snowfall were avoided. Whenever geese and/or swans were sighted, we stopped at a discreet distance before they were alarmed (stretched necks, wing-flapping, walking away) and made sure that there were no obvious ongoing external disturbances. Next, we ensured that sight was free between the observer and the majority of the individuals in the flock (c.f. Mayer et al. 2019). The distance between the car and the flock ('detection distance' sensu Weston et al. 2012) varied and the primary goal was to park the car so that its presence did not initiate agitation in the flock.

From immediately outside the car, we counted and identified geese and/or swans in the flock using a spotting scope. Next, the scaring person started walking slowly, calmly, and silently towards the flock, in a straight direction whenever possible. We used plain clothing and left the spotting scope behind. When the first birds in the flock took off, we stopped to record the observer's GPS position (first GPS fix), while at the same time noting the spot from which the first birds had left. Next, we walked to the latter spot to obtain a second GPS fix. FID is the distance between the first and second GPS fixes.

When a flock was scared off a field, we used binoculars to note its flight direction and, if possible, where it landed. We did this to avoid scaring the same birds more than once the same day. We regard the risk of repeated scaring (and hence habituation) as very small. For example, the study area typically hosts hundreds of thousands of geese during the winter months (Haas and Nilsson 2019), and we tried to visit new areas from day to day. When possible, we recorded the flight order of the different species in multi-species flocks.

We discarded cases during which geese or swans were disturbed by something else after the start of our approach (e.g. cars, airplanes, dogs, noises). We also discarded three trials for which a totally unrealistic FID was obtained, most likely due to handwriting errors when filling out the field protocol. This left us with a total of 408 successful scaring trials, of which 146 were carried out before noon and 262 in the afternoon (Table 1).

To test the last of the hypotheses (Introduction), scaring trials were grouped as either 'morning' (before 12:00) or 'afternoon trials' (after 12:00) (Table 1). Although geese may forage at night under some circumstances, most if not all geese in our study area in winter spend nights in roost sites where they cannot forage much (lakes, iced-over wetlands, sheltered sea bays; Olsson et al. unpubl.).

Table 1. Number of scaring trials of geese and swans 2018–2021 per month and part of the day.

Month	Morning	Afternoon	Monthly total
November	13	3	16
December	19	14	33
January	24	25	49
February	36	119	155
March	54	101	155
Total	146	262	408

We also noted crop stage and crop type in fields from which geese were scared, but due to sample size restrictions it was not possible to analyze these data statistically when broken down by species, flock type, flock size, and time of day. Data from all three winters of study were pooled before subsequent analyses, as they were all benign for geese weather-wise.

Restrictions: bean geese, pink-footed goose, and mute swan

Although the two bean goose taxa *fabalis* and *serrirostris* (here regarded as subspecies) can be identified when seen well, the latter is not always the case. During our field work there were individuals that could not be identified to subspecies in 41 of the 102 trials involving bean geese. Out of the 102 bean goose trials there were 53 that positively had *fabalis* in the flock and 41 that had *serrirostris*. In many cases flocks contained both subspecies. For these reasons we subsequently did not treat the two subspecies separately; hence all trials involving bean geese are termed as concerning bean goose in the wide sense (*Anser fabalis* sensu latu) (Table 2). Mute swan and pink-footed goose were recorded in just one trial each and were excluded from further analyses.

Statistical methods

A one-way ANOVA and pair-wise Student's t-tests were used to evaluate differences in FID among single-species flocks. Similarly, t-tests were used to compare FID between single-species and mixed flocks, as well as between morning and afternoon trials. We used the Pearson's correlation test to explore co-variation between FID and flock śize. All tests were carried out using software in either SYSTAT (SPSS Inc.) or EXCEL.

Results

In single-species flocks the order of decreasing fearfulness (FID) was bean goose > greylag goose > whooper swan > Canada goose > barnacle goose (Table 2). A one-way ANOVA revealed a significant among-species variation in FID ($F=12.76$, $p < 0.0001$, $df=4, 521$). The species that really stood out was bean goose with its significantly much

Table 2. Scaring trials and flight initiation distance (FID, mean and SD) per species in single-species and mixed-species flocks. t-tests contrasting single-species and mixed flocks have a two-tailed probability level. Data for '*Anser fabalis* sensu latu' concern subspecies *fabalis* and *serrirostris*, as well as bean geese that were not identified to subspecies. Cut-off for calculating means was set at > 6 trials. N/A = 'not applicable'.

Species	No. Scaring trials per species			Mean (SD) FID in single-species flocks	Mean (SD) FID in mixed flocks	t-test
	Total	Single-species flocks	Mixed flocks			
Anser fabalis sensu latu	102	26	76	171.3 (54.9)	138.4 (77.7)	p = 0.023
Anser anser	318	182	136	103.6 (50.1)	126.2 (65.4)	p < 0.001
Cygnus cygnus	45	21	24	101.9 (42.4)	107.5 (54.8)	p = 0.710
Branta canadensis	42	7	35	92.1 (62.5)	114.8 (49.4)	p = 0.430
Branta leucopsis	76	20	56	77.1 (41.3)	117.1 (60.9)	p = 0.002
Anser albifrons	31	1	30	N/A	119.0 (59.8)	N/A

longer FID than all other species (t-test bean goose versus greylag goose (closest contender): p < 0.00001). FID in barnacle goose was significantly shorter than in greylag goose and whooper swan (t-tests, p < 0.05, one-sided probabilities). Greylag goose, whooper swan, and Canada goose had rather similar FIDs when in single-species flocks (t-tests, p > 0.33 in all cases of pairwise comparison).

Mean FID was longer in mixed than in single-species flocks in all species except bean goose (Table 2). Recorded FIDs were more varied among species when in single-species flocks but tended to converge in the 108–138 m span when occurring in mixed flocks compared to single species flocks (77–171 m; Table 2). The difference in FID between single-species and mixed flocks was statistically significant in three species; greylag and barnacle geese became more fearful and took flight at a longer distance when in mixed flocks, whereas bean goose was less fearful when in mixed flocks (shorter FID). The fact that mean FID for some species generally differed so much between single-species and mixed flocks prompted us to address the remaining predictions using only data from trials involving single-species flocks.

FID was negatively correlated with flock size in bean goose (single-species), meaning that they were less fearful in larger flocks (p < 0.01, Fig. 2). There was no significant correlation between FID and flock size in whooper swan, greylag goose, and barnacle goose (p > 0.05 in all cases, Fig. 1, 3–4).

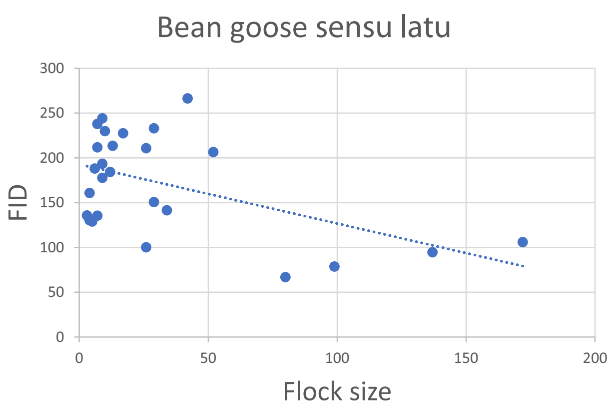

Figure 2. Scatter plot of flock size versus FID in single-species flocks of bean goose (*Anser fabalis* sensu latu). Pearson r = − 0.509, p < 0.01, n = 26. The dashed line shows the linear trend.

FID did not differ between morning and afternoon, that is, between presumed 'hungry' versus 'satiated' birds, in the four species with data from > 20 single-species trials (Table 3).

Discussion

Considering that we studied several species in the same setting and seasons with consistent methods, our data strongly support the notion that FID (hence fearfulness) in geese and swans differs among species when occurring in single-species flocks. Consequently, different species appear to make consistently different trade-offs with respect to predation risk and feeding opportunity. Previous research, though, does not offer much opportunity for comparison of FID in single-species flocks of geese and swans. Madsen et al. (2009) studied pink-footed geese, brent geese, and barnacle geese, but did so in summer on breeding grounds in Svalbard. They found generally much longer FIDs (1717, 620, and 330 m, respectively) than in the present and other studies on the same species in winter (Owens 1977, Madsen 1985), and it is also expected that nesting and/or flightless birds should be more wary than they are in winter. Deboelpaep et al. (2018) found rather short FIDs in Canada geese in Belgium in winter (single-species and mixed flocks), but that study was partly carried out in near-urban park-like settings where geese are probably strongly habituated to human presence. Another

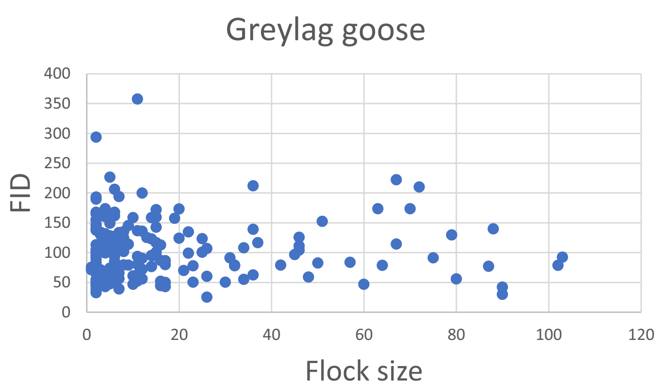

Figure 3. Scatter plot of flock size versus FID in single-species flocks of greylag goose *Anser anser*. Pearson r = − 0.003, p > 0.05, n = 182.

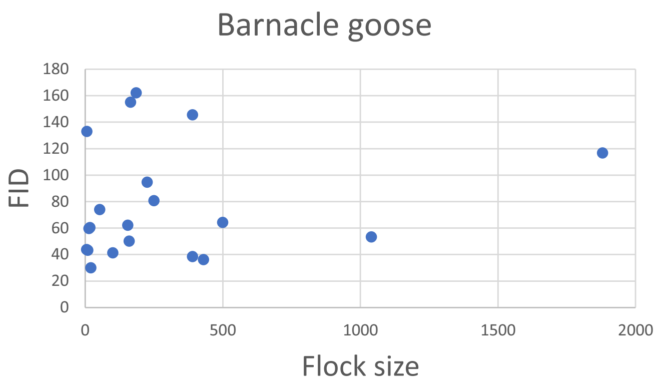

Figure 4. Scatter plot of flock size versus FID in single-species flocks of barnacle goose *Branta leucopsis*. Pearson $r = 0.160$, $p > 0.05$, $n = 20$.

study reporting very short FID values in urban settings is Mai et al. (2022), who studied greylag geese over a year in both urban and rural settings.

The prediction that FID differs intraspecifically between single-species and mixed flocks was supported in the three species for which we obtained the largest sample. This pattern seems logical if the level of fearfulness is 'averaged out' in mixed flocks comprising species that in isolation would differ in their risk trade-off. Our data support this notion also in the sense that FID tended to converge among species when they mixed; bean goose FID (the most fearful species) decreased 19% whereas barnacle goose FID (the least fearful) increased 52% when occurring in mixed flocks. As bean goose was the only species in which FID was correlated to flock size (negative relationship), it may behave less fearfully in mixed flocks due to the larger flock size when mixed, and/or due to perceived safety when together with more confiding species. Nevertheless, our data imply that bean geese increase feeding opportunities by associating with other species, whereas barnacle geese lose feeding opportunities by associating with more fearful species. In other words, associating with other species is a gain for bean geese but a cost for barnacle geese, at least in proximate terms. Finally, it should be noted that the general interval in which specific FIDs converged when mixing with other species was higher than the single-species FID of the respective species in all species except barnacle goose. In general terms, thus, most species lose feeding opportunities by associating with other species.

Studying flight order in mixed flocks was not part of the core protocol in this study but was nevertheless noted in approximately one-quarter of the scaring trials. These data imply that fearfulness also differs somewhat among species in mixed flocks. There were 13 trials involving flocks of three or more species, in which barnacle goose was the last species to take flight in 11. The short FID in pure barnacle goose flocks is thus reflected as a lower fearfulness relative to other species also when in mixed flocks. Bean goose, which had the longest FID in single-species flocks (the most fearful species) was the first to take flight in six out of twelve flocks containing three or more species and the second in five, corroborating its status as a more fearful species also when in mixed flocks.

The prediction that FID should increase with body mass (single-species flocks) was not unequivocally supported by our data (c.f. Blumstein 2006). The smallest species (barnacle goose) did indeed have the shortest FID, but neither the heaviest (whooper swan) nor the second heaviest (Canada goose) had the longest FID. By and large, species in our study were not ordered in increasing FID by increasing body mass. This suggests that other variables also affect FID and potentially interact in a complex fashion. For example, hunting has been shown to increase wariness in several waterfowl species (reviewed by Fox and Madsen 1997). Exposure to and experience of hunting vary among the species included in this study, as some (barnacle goose and whooper swan) are protected according to the EU Birds Directive, whereas the others have an open hunting season. Yet, the prediction that FID should be positively related to hunting pressure was not unequivocally supported in our sample as a whole (c.f. Table 2). If whooper swan (protected from hunting) is excluded, though, and we consider geese only, FID was shorter in the protected species (barnacle goose) than in those for which hunting is permitted in the EU (greylag, Canada, and bean goose). In other words, with respect to geese, 'the hunting hypothesis' for differences in FID is to some extent supported by our data.

We found little support for the prediction that FID increases with increasing flock size. Whooper swan, greylag goose, and barnacle goose showed no correlation between these variables in single-species flocks (Fig. 1, 3, 4), whereas bean geese were less fearful when occurring in large flocks. The latter observation is contrary to prediction, and opposite to the results in Madsen's (1985) study of pink-footed geese in Denmark. It is also contrary to general patterns in gregarious passerines, as described by Morelli et al. (2019), but fits well with the classical 'safety by numbers' argument (Pulliam 1973). We see no obvious reasons why our results differ among species but conclude that flock size had little effect on FID in our study setting.

Table 3. Number of scaring trials of single-species flocks before noon and in the afternoon, respectively. Flight initiation distance (FID) with mean and SD. t-tests contrasting morning and afternoon FIDs have two-tailed probability levels.

Species	n before noon	n afternoon	FID before noon	FID afternoon	t-test
Cygnus cygnus	4	17	130.8 (37.6)	95.1 (40.6)	$p = 0.20$
Anser anser	61	121	106.6 (43.8)	102.0 (53.0)	$p = 0.55$
Anser fabalis sensu latu	12	14	175.2 (50.7)	167.9 (58.0)	$p = 0.75$
Branta leucopsis	8	12	68.1 (35.9)	83.2 (43.6)	$p = 0.44$

This study was carried out during three benign winters in an area dominated by agriculture and high goose abundance. Due to differences in abundance among the goose species present, most of our results pertain to single-species flocks. The main reasons for the high number of single-species flocks of greylag geese are that they are numerous in general but mainly that they are local and very early breeders. In other words, small flocks of this species in February—March are the result of larger winter flocks disintegrating as birds spread out over agricultural land close to nesting sites.

Finally, the prediction that hungry morning geese/swans take higher risks while foraging (shorter FID) than satiated afternoon conspecifics was not supported at all by our data. All four species with a fair sample size concurred in not showing a significant difference in FID between morning and afternoon scaring trials. This result may seem counter-intuitive for foraging geese in winter experiencing a short light photoperiod, but if foraging efficiency is high (abundant high-quality food and few episodes of inclement weather), as may have been the case during the benign winters of our study, these large avian herbivores were perhaps not in any nutritional bottleneck and the prediction was perhaps not warranted in the first place.

Several implications for management emanate from this study. Firstly, it is obvious that fearfulness in swans and geese differs among species, which may call for different approaches in conservation as well as in crop protection. Secondly, fearfulness often depends on whether a species occurs in pure flocks or mixes with other species. At the species level, FIDs reported here can serve as contemporary baseline values for management decisions, but also for future comparison to gauge changes in fearfulness over time. Further, it is important to consider that behavioral responses like FID may depend on hormonal and other seasonally varying conditions, related to nutritional needs or reproductive cycle. Consequently, if FIDs are used to delineate 'buffer zones' to avoid human disturbance, such recommendations should ideally be based on values documented for the season and species in question.

Several previous studies have shown that it is difficult to fully succeed in crop protection solely by means of scaring. Geese habituate to some extent and scaring probably often merely moves the problem locally rather than solve it (Månsson et al. unpubl.). The present study does not address these aspects but shows that there are differences in how fearful species are, implying that scaring can be effective to a different degree depending on species. Consequently, the need for alternative methods of crop protection, beyond mere scaring, may vary among species. The bean goose appears to be the one that is easiest to scare, while both the present and other studies show that barnacle goose is generally harder to scare (Heim et al. 2022). In other words, it may be that other measures than scaring are more suitable for species like barnacle goose. Even though not conclusive, our study supports previous studies demonstrating that hunting pressure can affect fearfulness (Fox and Madsen 1997). Hunting, therefore, can serve as a strategy to amplify the fearfulness of geese towards other scaring measures.

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Author contributions

Johan Elmberg: Conceptualization (equal); Data curation (equal); Formal analysis (lead); Funding acquisition (equal); Investigation (supporting); Methodology (lead); Project administration (lead); Resources (lead); Supervision (lead); Validation (equal); Writing – original draft (lead); Writing – review and editing (lead). **Elin Svensson**: Data curation (lead); Formal analysis (supporting); Investigation (supporting); Writing – review and editing (supporting). **Elias Kvarnbäck**: Data curation (lead); Formal analysis (equal); Investigation (lead); Writing – review and editing (supporting). **Camilla Olsson**: Data curation (supporting); Investigation (equal); Methodology (supporting); Writing – review and editing (equal). **Johan Månsson**: Conceptualization (equal); Funding acquisition (equal); Methodology (equal); Project administration (supporting); Supervision (equal); Writing – original draft (equal); Writing - review and editing (supporting).

Transparent peer review

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Data availability statement

Data are available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.z8w9ghxq4 (Elmberg et al. 2024).

Supporting information

The Supporting information associated with this article is available with the online version.

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