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Research article

Farmers' tolerance for crop damage caused by wildlife: the role of compensation

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Compensation is a common strategy to alleviate financial losses caused by wildlife, but its effects on farmers' tolerance towards damage to crops caused by wildlife are poorly understood. To address this knowledge gap, we conducted semi-structured interviews in three areas in and around biosphere reserves in Sweden and Germany to examine farmers' appraisals of wildlife-related crop damage and their evaluation of financial compensation in relation to crop damage prevention measures. We found that tolerated yield loss was higher and more variable with compensation compared to a scenario without compensation. Yet, also under a scenario of full financial compensation, farmers tolerated a median of less than 10% yield loss. Using an environmental stress model, our analysis revealed that farmers' perception of crop damage risk was influenced by their experience with wildlife and crop damage, their coping appraisals (e.g. accessibility of prevention measures and compensation), and individual motivations. Our results indicate that while compensation can be effective, its success to increase tolerance to crop damage varies most likely based on farmers' values and how they perceive administrative challenges. Effective management of wildlife-related crop damage near and within protected areas should thus combine compensation schemes with tailored communication and crop damage prevention strategies involving governmental authorities, farmers, and other stakeholders.

Keywords: *Anser*, *Branta*, *Cervus elaphus*, *Grus grus*, coexistence, conflict, human–wildlife interaction, *Sus scrofa*

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Introduction

Rising global demand for food has led to rapid expansion of agricultural land (Grassini et al. 2013, Laurance et al. 2014), which is a primary cause of biodiversity loss (Dobrovolski et al. 2011, Balmford et al. 2012). However, this expansion also increases interactions between wildlife and people, often resulting in crop damage caused by foraging wildlife (Seoraj-Pillai and Pillay 2017, König et al. 2020). In Europe, the growing populations of ungulates, several goose species (*Anser, Branta* spp.), and common cranes *Grus grus* have further increased the prevalence of wildlife-related crop damage, making it a frequent and contentious issue in agricultural landscapes (Massei et al. 2015, Carpio et al. 2021). While the associated yield losses are generally minor compared to overall agricultural earnings (Montràs-Janer et al. 2019), damage is often concentrated in specific areas (Montràs-Janer et al. 2020), leading to disproportionately severe impact on individual farms (Düttmann et al. 2023). This is particularly true for farms situated near or inside protected areas, where damage pressure is elevated due to favorable environmental conditions for wildlife (Nilsson et al. 2019, Branco et al. 2020). In such areas, there is an urgent need for strategies that facilitate coexistence between wildlife and people to mitigate conservation conflicts related to the protected areas (Kremen and Merenlender 2018, Pooley et al. 2022).

In many circumstances, damage prevention methods are insufficient to fully protect against wildlife-related crop damage (Månsson 2017, Kiffner et al. 2021). This is why compensation schemes reimbursing farmers for the financial losses incurred are frequently implemented (Bielza et al. 2007, Dickman et al. 2011). The aim of compensation is to reduce the financial burden for affected individuals, increase their ability to cope with damage, and thereby decrease possible conflicts between objectives of agricultural production and wildlife conservation (Nyhus et al. 2005). A recent review on this topic found that crop damage was the second most common reason for compensation payments, yet less than 5% of the reviewed articles (n = 288) measured success of compensation schemes (Ravenelle and Nyhus 2017). Among these articles, the measurements of success varied and included reduction of wildlife scaring by farmers (Tombre et al. 2013), reduced animal killing (Dickman et al. 2011), or recovery of wildlife populations (Klenke et al. 2013). However, none of the reviewed studies assessed the impact of compensation on levels of tolerance for crop damage, highlighting an important research gap.

Theoretical framework

Human–wildlife coexistence is defined as the persistence of humans and wildlife in shared spaces, maintaining 'tolerable levels' of risk for both (Carter and Linnell 2016, Pooley 2021). The concept thus builds on the psychological concept of 'tolerance' (Slagle and Bruskotter 2019). But what exactly are 'tolerable levels of risk'? And how far are they influenced by actual damage levels on the one hand and the individual stakeholders´subjective perception of damage on the other hand?

Human tolerance of wildlife is often viewed as an attitude separate from the actual costs involved (Kansky et al. 2014, 2016). However, there are calls to create a common definition of tolerance to wildlife that incorporates damage thresholds rated acceptable by stakeholders (Brenner and Metcalf 2020). The discussion also includes how damage levels affect stakeholder tolerance and the best management strategies to encourage it. As promoting wildlife tolerance is crucial for human–wildlife coexistence, a better understanding of how damage and tolerance relate is needed. Evidence from multiple studies suggests that this association is not linear. For example, farmers may overestimate and overstate actual damage levels to express discontent rooted in underlying social conflicts (Zimmermann et al. 2020). Thus, a more nuanced understanding of tolerance for wildlife is needed to guide coexistence strategies (Dickman 2013, Hill 2018).

To provide a structure for farmers' decision making process regarding their response to crop damage and the option of compensation, we draw on an environmental stress model developed by Reser and Swim (2011) (Fig. 1). Direct experiences of wildlife, such as viewing, hunting, or the experience of wildlife-related crop damage and resulting yield and productivity losses, as well as indirect experiences (e.g. via media or interpersonal interactions), underlie their threat appraisals, i.e. how farmers perceive the likelihood and severity of crop damage. Farmers' responses are also determined by their appraisals of potential ways of coping with damage. These coping appraisals may address the availability of resources, their strategies, abilities, and individual skills. Interpretative and motivational processes including attribution processes and emotions are important for threat and coping appraisals. Additionally, individual factors, such as past experiences and the physical and community characteristics, are significant factors. In turn, these subjective appraisal processes are important for how farmers respond to the risk of crop damage and the option of compensation (i.e. coping responses). These responses are likely to play a role in future appraisals via interpretative and motivational processes. For example, highly effective prevention methods may reduce perceived risk during individual risk assessments in the future and can contribute to a lowered perceived risk at the community level. On the other hand, greater perceived risk in the community may increase levels of concern at the individual level.

Objectives

The aim of this study was to gain a better understanding of farmers' tolerance to wildlife-induced crop damage within and surrounding biosphere reserves. Biosphere reserves, implemented under the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Man and the Biosphere Program, serve as model regions for reconciling biodiversity conservation and sustainable land use, including

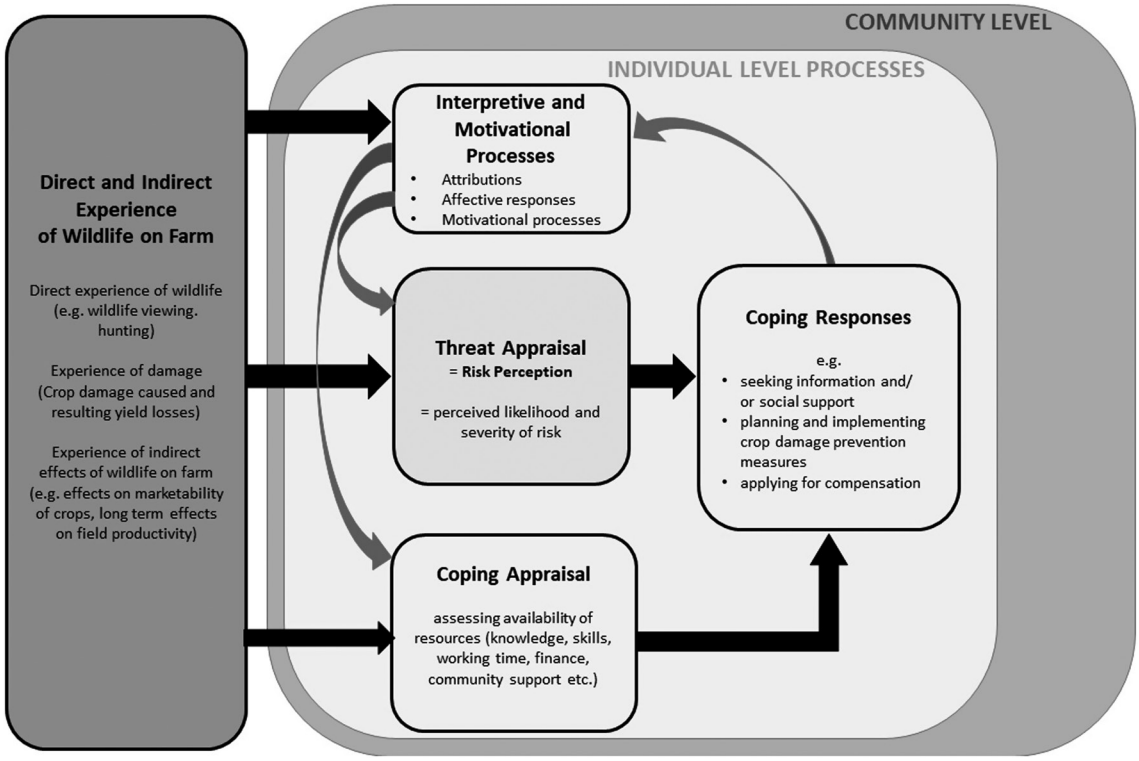

Figure 1. Psychological processes that influence farmers' adaptation to and coping with wildlife-related crop damage and their decision to apply for compensation payments (adapted from Reser and Swim 2011).

agriculture (van Cuong et al. 2017). To this end, we study the reasoning of farmers regarding increased wildlife pressure in and around these protected areas to inform targeted policy interventions for human–wildlife coexistence. By interviewing farmers embedded in one study area in Sweden and two areas in Germany, we were able to explore farmers' reasoning in two countries representing different governance settings (Baxter and Jack 2015).

We conducted semi-structured interviews and analyzed them quantitatively and qualitatively (Bryman 2016) to uncover farmers' appraisals of wildlife-related crop damage and their evaluation of financial compensation in relation to various crop damage prevention measures. Our analysis addressed the following research questions:

1) What experiences and appraisals of wildlife crop damage are evident among farmers in and around the biosphere reserves?
2) How does the option of financial compensation influence farmers' tolerance levels?
3) What coping appraisals underlie tolerance and reactions to compensation?

In the result section, we first present findings on respondents' experiences and appraisals of crop damage by wildlife. Next, we present quantitative results of the farmers' response to the option of full financial compensation. Finally, we qualitatively analyze views on tolerance and compensation by relating to the farmers' coping appraisals of crop damage more generally.

Material and methods

Study areas

The selected case study areas were two sites in northern Germany and one site in southern Sweden (Fig. 2). The German sites are located at the western and eastern shore of Lake Schaalsee. The study area at the eastern shore is located within the Biosphere Reserve Schaalsee in the federal state Mecklenburg–Western Pomerania (hereafter S-MV). The study area at the western shore is situated in the federal state Schleswig–Holstein and not part of the biosphere reserve (hereafter S-SH). Until 1990, Lake Schaalsee was part of the inner-German border and the effects of land consolidation during GDR times are still evident in significantly larger farm sizes in Mecklenburg–Western Pomerania (average farm size = 275 ha; (MLU MV 2020)) compared to Schleswig–Holstein (78 ha; (MELUND SH 2022)). Lake Schaalsee is used by common cranes and several goose species for staging and breeding, and its surrounding areas provide habitats for ungulates, including roe deer *Capreolus capreolus*, wild boar *Sus scrofa*, red deer *Cervus elaphus*, and fallow deer *Dama dama* (Middelschulte et al. 2021, Reinke et al. 2021). In 2000, a group of rhea *Rhea americana* escaped from an

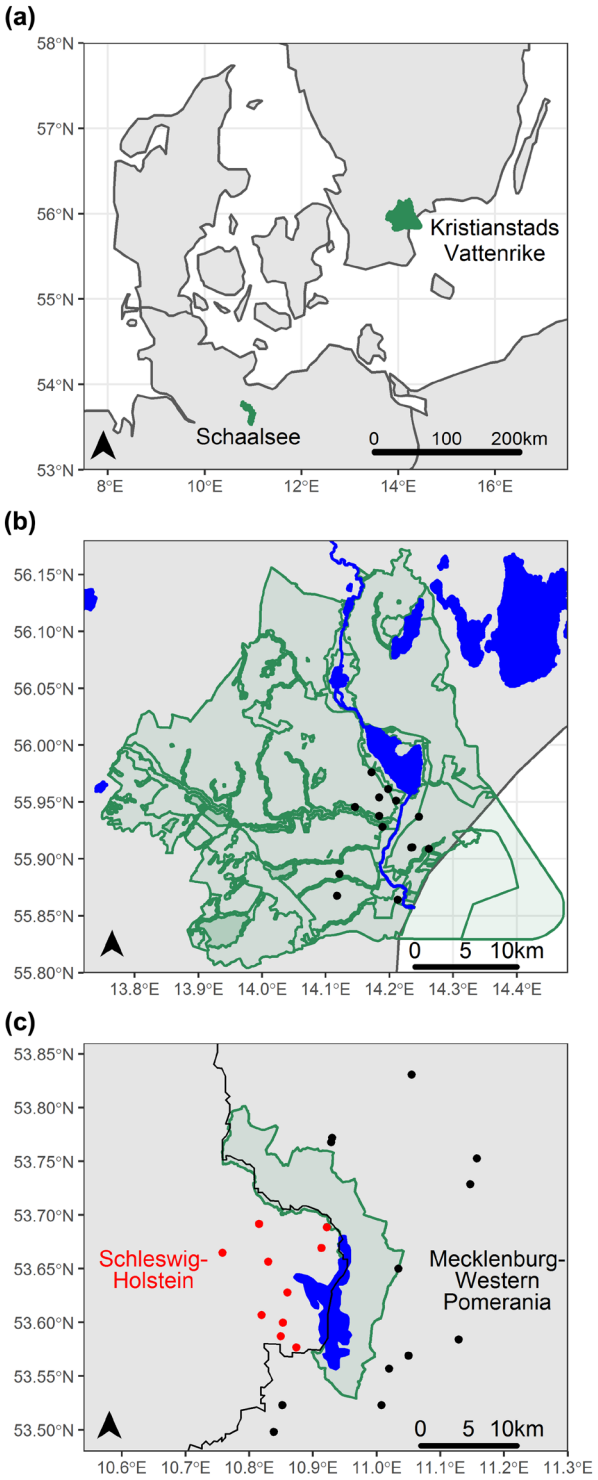

Figure 2. Maps of the case study areas: (a) location of the Biosphere Area Kristianstad Vattenrike and the Biosphere Reserve Schaalsee in Sweden and Germany. (b) Location of farms operated by the respondents (black dots) within the Biosphere Area Kristianstad Vattenrike. (c) Location of farms operated by the respondents outside Biosphere Reserve Schaalsee in Schleswig–Holstein (red dots) and location of farms operated by respondents in Mecklenburg–Western Pomerania (black dots). For orientation, we included major lakes (blue) in (b) and (c).

enclosure north of the lake, and a population of > 100 individuals established in the area (Korthals and Philipp 2010).

In Germany, crop damage caused by protected species is regulated at the federal state level. In Mecklenburg–Western Pomerania (S-MV), the state offers compensation payments for damage caused by protected species, and farmers can apply to the Biosphere Reserve administration for these funds (B. Gebhard, unpubl.). In Schleswig–Holstein (S-SH), compensation is not available, but farmers can apply for financial support for cultivating fields for goose grazing within agro-environmental schemes. Crop damage caused by huntable species is compensated by the holder of the area's hunting permit in agreement with the landowner (BMEL 2020).

The Biosphere Area Kristianstad Vattenrike (hereafter KV) covers a river basin of 1040 km² within Kristianstad municipality in Skåne County, Sweden. KV provides suitable habitats for ungulates, including roe deer, fallow deer, red deer, wild boar, and moose *Alces alces*. Its lakes serve as breeding sites for greylag geese *Anser anser* in summer and as staging and wintering sites for seven goose species. Common cranes use the area for spring and autumn staging. This seasonal bird presence leads to varying degrees of crop damage depending on the season and location (Schultz et al. 2015, Tuvendal and Elmberg 2015). To prevent cranes from foraging on newly sown summer grain during spring staging, a diversionary feeding site, where barley is spread to provide alternative food, was established in 2011 by the county administrative board. The amount of used barley has increased from 14 tons per year in 2011 to almost 70 tons in 2022 to accommodate the rising crane population (over 10 000 individuals in 2022) (A. Hallengren, unpubl.; Cronert and Svensson 2012). Additionally, the county administrative board offers consultancy services to support farmers in preventing crop damage caused by cranes, geese, and whooper swans *Cygnus cygnus*. In Sweden, a national financial compensation system is available to farmers for damage caused by the protected species common crane, barnacle goose *Branta leucopsis*, whooper swan, and for species with open hunting season such as greylag goose and bean goose *Anser fabalis* close to protected wetlands. Trained inspectors estimate the yield loss when farmers report damage, and compensation is paid accordingly. Crop damage caused by ungulates should primarily be prevented by hunting.

Respondents and procedure

In January and March 2019, we conducted 37 semi-structured face-to-face interviews: 11 interviews in S-SH, 12 in S-MV, and 14 in KV. Our initial focus was on common cranes, which typically roost in the wetlands and feed on surrounding fields within a 10 km radius from the roost during the day, posing a prevalent damage risk (Nilsson 2016). Therefore, we defined our respondent recruitment areas within a 10 km radius around major roosting sites. However, during the interviews, we discovered that the respondents' perceptions of crop damage were not influenced by the specific damage-causing species. Consequently, we expanded

the scope of the study to include all species of cranes, geese, swans, and ungulates that cause crop damage.

Once the interview protocol was approved by three experienced agronomists, it was pre-tested with two farmers and adapted based on their comments. After these adjustments, we contacted potential respondents. For the study areas in Germany, the first author created a complete list of farms in the defined areas based on publicly available data of receivers of area payments from the EU agricultural funds (S-SH: 152 farms; S-MV: 145 farms) and called a random sample of farmers to ask for interviews. In KV, co-author AH called a random sample of farmers among the 225 registered farms. With a total of 37 farmers agreeing to do an interview, we enrolled 6.5% of registered farms in the study area S-SH, 8.0% in S-MV, and 6.0% in KV. Each interview was carried out at the respondent's farm homestead and lasted approximately 60 minutes. The first author conducted 30 interviews, four interviews in S-SH were conducted by a co-author (HK), and two interviews in KV were conducted by another (AH). In Germany, interviews were conducted in German, while in Sweden, interviews were held in English (n = 12) or Swedish (n = 2), depending on the preference of the respondents. Before the start of each interview, the respondents were handed a written consent form and the interviewers explained the purpose of the study, and how their responses would be utilized. All respondents signed the form. Of the 37 respondents, 22 agreed to have their interview audio-recorded, which limited the number of transcripts we could use for the qualitative analysis. The total area farmed by respondents was approximately 4800 ha in KV and S-SH, and exceeded 10 000 ha in S-MV (Table 1). The respondents' average age was 50 (range 30–75). Two out of 37 respondents were female, 18 of the respondents held a university degree, and 16 had completed vocational training.

Survey questions

The interview guideline contained both closed and open-ended questions, covering topics such as the respondent's perception of financial losses caused by wildlife damage, perceived positive and negative effects of wildlife, and actions taken by the respondent in response to wildlife damage. We operationalized the tolerance level for wildlife-related crop damage as behavioral intention (Bruskotter et al. 2015) using the questions given in Table 2. Thirty-six out of 37 respondents answered these questions. In case the respondents commented or explained their answers to closed questions, these answers were also recorded and analyzed.

Data analysis

Data were analyzed using quantitative and qualitative methods. To evaluate the univariate relationships between stated tolerance levels with and without compensation, we performed non-parametric tests using the statistical software R (ver. 4.1.3; www.r-project.org). The 22 audio-recorded interviews were transcribed in full and then coded using MAXQDA 24. The first author performed an initial coding of the transcribed material using deductive thematic analysis based on the environmental stress model by Reser and Swim (conceptual framework) (Braun and Clarke 2006). In a first step, the first author identified the common themes of how respondents think about crop damage by wildlife and their options for compensation. The codes were sorted in two thematic levels: thematic level 1, comprising respondents' appraisal of wildlife presence on their farm and severity of crop damage; and thematic level 2, comprising respondents' appraisal of compensation in relation to crop damage prevention methods. In a second step, the results were discussed with the group of co-authors and analyzed according to the environmental stress model to identify three main categories: 1) appraisals of crop damage (risk perception), 2) appraisals of coping with crop damage (coping appraisals), and 3) coping with crop damage (coping responses).

Results

Experience and appraisals of wildlife and crop damage

The majority of respondents in KV mentioned geese as a damage-causing species, followed by common cranes, wild boar, and crows *Corvus* spp. In S-SH and S-MV, most respondents mentioned wild boar as a damage-causing species, followed by red deer and common cranes. The experience of crop damage by wildlife differed greatly among respondents. While the majority of respondents had experienced crop damage by wildlife in the year preceding the interview, the extent of damage estimated by the respondents varied widely (< 1–20% loss of the farm's total yield). Approximately half of the respondents reported crop damage by wildlife as one of five major financial challenges for their enterprise. Moreover, half of the respondents considered the extent of

Table 1. Average size and location of the farms operated by the respondents in the three study areas.

Name of study area	Kristianstad Vattenrike (KV)	Schaalsee (S-SH)	Schaalsee (S-MV)
Region/state (country)	Skåne (Sweden)	Schleswig–Holstein (Germany)	Mecklenburg–Western Pomerania (Germany)
Biosphere reserve	Inside Biosphere Area 'Kristianstad Vattenrike'	Adjacent to Biosphere Reserve 'Schaalsee'	Inside and adjacent to Biosphere Reserve 'Schaalsee'
Farm size (average of the interview sample; range)	342.5 ha (50–1000 ha)	481.4 ha (90–1385 ha)	835.5 ha (7–2251 ha)
Number of organic farms/ sample	1/14	4/10	4/14

Table 2. Survey questions used to gauge tolerance for wildlife-related crop damage in and around biosphere reserves in Germany and Sweden.

Variable name	Question	Possible answers
Tolerance without compensation	How much proportional yield losses do you tolerate before implementing additional preventive measures?	Percentage loss of entire farm yield
Tolerance with compensation	What proportion of yield losses caused by wildlife would you accept if financial losses were completely reimbursed?	Percentage loss of entire farm yield

damage acceptable, while the other half deemed it unacceptable. Results suggest not only experience but also the respondents' appraisals of damage varied. Respondents mentioned livestock losses by crows attacking piglets, and yield losses caused by wildlife trampling or foraging on crops or newly sown seeds among the negative impacts of wildlife. Apart from the direct effect of such damage on the current yield, respondents also mentioned indirect effects of wildlife for their farm – such as the dispersal of weed seeds, disturbance of soil surfaces, or the inability to fulfill contracts with wholesalers. They explained that these indirect effects may lead to long-term financial losses that are not covered by the financial compensation. However, the respondents also expressed positive impacts of wildlife, e.g. hunting, as a fulfilling activity; or selling permits as financial revenue for their farm. Positive effects of wildlife for their farm–ecosystem were also mentioned, such as regulation of rodent pests by foxes or birds of prey, soil- and crop-enhancing effects by wild boar rooting the ground, and geese feeding on the shoots of canola. These diverse experiences and appraisals of wildlife and wildlife damage provide a baseline when attempting to understand the respondents' reaction to financial compensation.

Effect of compensation

The median level of wildlife-related crop damage that respondents considered tolerable was 2% (SE: ± 0.6%) of the total yield. Given the scenario of full compensation, the tolerance for damage was significantly greater among the majority of interviewed farmers (paired Mann–Whitney U-test, $U = 210$, $p < 0.001$, $n = 36$). The median level of tolerated damage was 7.5% (SE: ± 5.6%) of total yield. While the prospect of compensation did not change tolerance levels for some respondents, some stated they would tolerate up to 100% yield loss if they were fully compensated (Fig. 3).

Coping appraisals and compensation scheme

To better understand the diversity in farmers' responses to compensation schemes, we considered coping appraisals, and associated interpretative and motivational processes. Notably, not only individual processes, but also community characteristics and relations with the responsible government are relevant.

Tolerance and the compensation scheme

A common sentiment for tolerating wildlife-related crop damage was the value placed on wildlife as an integral part of the agricultural landscape, and that seeing wildlife made them feel happy, an illustrative quote being '*but for me, as a nature lover and also a wildlife enthusiast, it is simply beautiful to observe the animals in the wild and to take joy in that*' (S-MV-12). Respondents also articulated their desire to support wildlife: '*and that [presence of wildlife on the farm] is a sign that we are not so far off with our work, that we also give the animals a chance through our way of management. [...] For me, it's a symbol that things are as they should be*' (S-MV13). This motivation was further illustrated by respondents who found it easier to tolerate crop damage caused by wildlife foraging rather than trampling.

Some respondents stated that receiving compensation would not increase their tolerance for damage, because they have a motivation to achieve good yields regardless of the financial revenue. This view is well illustrated by the following quote: '*If you work with something, if you are a farmer and you work hard, you do everything you can to get a nice yield, a big yield. [...] It's like, [...] a football player [...], he is playing football and of course if you say "okay you'll get the same salary but you have to lose this championship" – of course you want to win. You want to do a good job as a football player*' (KV 7). Similarly, some respondents also stressed that they preferred to generate their own income instead of being dependent

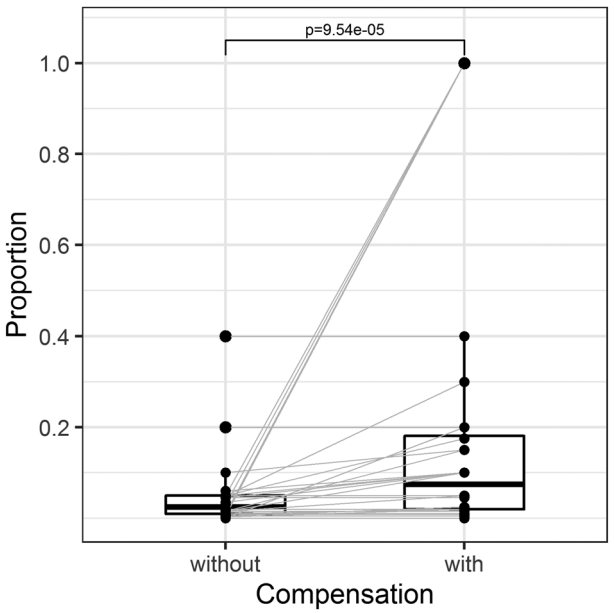

Figure 3. Tolerance for crop damage by wildlife in proportion of total yield stated by interviewed farmers (n = 36) under a scenario without and with full financial compensation. The p-value is based on a paired Mann–Whitney U-test.

on compensation provided by the government. In contrast, other respondents explained that wildlife damage was only a problem because of the income losses, and receiving compensation would allow them to be more tolerant. The majority of respondents emphasized the importance of being able to control and prevent wildlife damage. Yet, while some expressed that wildlife damage could be effectively controlled, others felt that levels of wildlife damage exceeded their capacity to successfully manage them. Different reactions to compensation may be rooted in these diverse perspectives on farming and income as well as the perceived ability to control wildlife damage.

Some of the reasoning underlying tolerance may be sought in the reasons for wildlife-related crop damage acknowledged by the respondents. Some stated they felt that wildlife damage was unavoidable in farming, Characteristic quotes for this were: '*[wildlife damage] is a part of agriculture*' (KV13) and '*farmers have had to deal with this for centuries*' (S-MV8). Other farmers stated that crop damage by wildlife would only become a problem when wildlife numbers increased beyond the '*natural balance*' (MV12), and certain species underwent disproportionate growth compared to other species; this was mentioned for rabbits, crows, cranes, geese, and wild boar. While some respondents attributed shifting levels of wildlife damage to ecological factors, e.g. changes in migration patterns of geese or higher frequency of wildlife foraging on fields due to reduced forage availability in forests due to droughts, others felt that the proximity of the biosphere reserves contributed to higher abundance of wildlife and thus increased crop damage risk.

Moreover, it is also relevant to consider farmers' appraisal of the compensation scheme's characteristics. Respondents criticized the limited availability of compensation, noting that it applies only to certain species, while considerable damage is also caused by other species, such as crows and wild boar. Additionally, respondents in S-MV reported that state funds for financial compensation were insufficient to cover all applicants, resulting in instances where farmers completed the application process but did not receive any compensation.

The process of applying for compensation

Respondents also criticized the process of applying for compensation, particularly due to the time effort required: they noted the difficulty in assessing and documenting the impact of wildlife damage on yield loss in relation to other inhibiting factors, which discouraged them from reporting damage for compensation acquisition. Nevertheless, time and operational constraints also impacted the respondents' ability to prevent wildlife damage since it is just one of many factors challenging crop management (e.g. weed and disease control, soil quality, and market prices, often hindering them from choosing farming practices with limited risk for wildlife damage). Moreover respondents said it was difficult to dedicate sufficient labour time to preventive measures, as illustrated by this quote: '*So you have to be alert and you have to be home to [scare cranes from the fields]. When? I have two jobs. It's really hard to be in two places at the same time. And if you miss one day, a lot of your work can be ruined in a couple of hours*' (KV 9). Adding to these challenges, respondents noted the high seasonal variability of wildlife damage, making it difficult to plan preventive measures. Moreover, respondents mentioned that habituation of certain species to scaring methods (such as crows, geese, and cranes) made effective damage prevention very difficult, as illustrated by the following quote: *'[..] But the birds are the big problem, because I can scare them off with the car, I can put gas [propane cannons] [...] and it helps a little bit. And later they come again and they come again. And so this is continuing' (KV2).*

The community and responsible government agency

Responses to compensation schemes should also be seen in light of farmers' relationships with the responsible government agency. Respondents in KV commended the cooperation with the county administrative board. They appreciated that the county administrative board was responsive to the farmers' suggestions and praised the experience and ease of contact of the person in charge of scaring consultancy services for geese and cranes. The farmers' high level of satisfaction is illustrated by the quote: '*I think that farmers in this area wouldn't be as quiet and less concerned if it wasn't for [the scaring consultant]*' (KV9). Respondents in KV were also satisfied with the diversionary feeding of cranes. They perceived the feeding to be effective in preventing crop damage by cranes and appreciated the close cooperation between the county administrative board, the biosphere reserve, and the farmers themselves: e.g. the start of feeding is coordinated with the time of barley seeding each spring and the farmers´ union provides part of the grain for feeding, while the county administrative board pays the person in charge for distributing the grain at the feeding site. Yet, some respondents also recounted negative experiences of cooperating with hunters and the biosphere reserve administration. Hunters were criticized for adhering to their interests of increasing wildlife numbers without considering potential effects on crop damage. Concerns raised regarding the biosphere reserve administration included that respondents felt overregulated and some disagreed with leaving protected areas entirely unmanaged. They felt this approach was leading to problems such as the spread of common ragwort *Senecio jacobaea* in grasslands being toxic for grazing domestic animals, or increased wildlife use of farmland due to wetland flooding. Respondents also criticized the restrictions of hunting in the biosphere reserve's core zones: '*we need to hunt again in protected areas and we also need to go into the dense areas, [...]. And if we don't do that, then such factors will come back to haunt us*' (S-SH9). Respondents in S-SH, located outside the biosphere reserve, explicitly stated that they did not know whom to approach in the case of wildlife damage.

Coping responses

Respondents explained that they would only go through the application for compensation if they had experienced significant economic losses. Possible reasons explaining this position

are the factors summarized above, namely the view that farmers should tolerate some damage, and negative expectations regarding the process of application, as well as relationships with the responsible government agency. In contrast, the respondents engaged in continuous and proactive efforts to avoid major losses from wildlife. To find effective methods, they read management advice and exchanged information with other farmers to develop innovative solutions. For example, respondents in KV placed old cars in their fields to prevent cranes from landing, while respondents in S-SH used blue plastic barrels as a scaring device. In addition to scaring methods, respondents adapted their crop management practices to limit wildlife damage.

Discussion

Wildlife species frequently cross the boundaries of designated protected areas (Nightingale et al. 2023), making farmers' tolerance of wildlife presence on surrounding agricultural lands essential for fostering human–wildlife coexistence. To achieve this, it is crucial to manage wildlife-induced damage at tolerable levels, either by reducing damage pressures or by increasing farmers' tolerance. Considering the following arguments, we propose that a combination of both approaches is necessary.

Minor yield losses are tolerable among farmers

We analyzed semi-structured interviews with farmers operating in and in the vicinity of biosphere reserves to enhance our understanding of their tolerance for wildlife-induced crop damage and their coping responses. Despite the relatively small sample size (n = 37), we identified patterns in farmers' decision making regarding wildlife crop damage, and gained a nuanced understanding of their motives. By explicitly asking respondents what amount of wildlife-related yield losses they are willing to tolerate, we identified that respondents tolerated median yield losses of 2.0 ± 0.6% of their total harvest. This range is comparable to the demands of the Swedish farmers' union, which stated tolerance levels of 4% for individual farms and 2% for crop damage at the national level (Wigertoft 2022). Given the large differences in experiences with wildlife and individual motivational factors described above, it is notable that respondents expressed remarkably consistent tolerance for crop damage, with a standard deviation of 0.6%, under a scenario of no compensation.

The effect of financial compensation is limited and varies between individuals

The option of compensation increased tolerated levels of yield loss for some, but not for all respondents. Our results show that respondents' tolerance increased to a median of 7.5 ± 5.6% wildlife-related yield loss of the total harvest under the assumption of full financial compensation. It is notable that even under a scenario of full financial compensation, respondents tolerated less than 10% of yield loss. While previous research has reported positive outcomes from compensation with regards to perceived alleviation of conflict (Tombre et al. 2013, Eythórsson et al. 2017), recovered wildlife populations (Klenke et al. 2013) or improved relationships among stakeholders (Anthony and Swemmer 2015), we did not find another assessment on the effect of compensation on tolerated yield loss by farmers, highlighting the need for further studies on this topic. Our results reveal variation between individual respondents with large effects of the option of compensation for some respondents but little to no effects for other respondents. It is furthermore important to emphasize the small variation in tolerance levels without the option of compensation, whereas a large variation in tolerance levels is observed given the option of full financial compensation.

Possible reasons for varying effect of compensation

From our qualitative analysis, we outline several possible reasons for the variation in how farmers respond to compensation schemes. First, it may be associated with how farmers reason around financial compensation, such as the positive value of being compensated for yield losses or appreciation for being able to support wildlife on their lands which may underlie increased tolerance following compensation for yield losses caused by wildlife. On the negative side, some respondents favored crop damage prevention over compensation, because they would not only work to achieve good economic returns, but had an intrinsic motivation to achieve high yields and sustain good productivity in their farmland. These findings challenge previous critique of compensation to potentially incentivize farmers to neglect crop damage prevention efforts or abandon farming in economically non-viable areas (Ravenelle and Nyhus 2017). Finally, respondents also expressed very diverse views on their support from the community and the government agency. Some praised effective cooperation with the hunting community or the support provided by the county administrative board, while others criticized that cooperation with hunters was difficult, or that biosphere reserve administration was overly regulating, without offering support in managing wildlife damage. While our sample size of respondents does not allow for comparisons between study areas, part of these differences may reflect contrasting governance approaches between our study areas and the two countries. In the Biosphere Area Kristianstad Vattenrike, cooperation with stakeholders is founded on over 20 years of trust building. In the early 1990s, prior to the biosphere area's implementation, the local administration initiated an informal advisory group – comprising landowners and other stakeholders – to discuss and manage crop damage caused by cranes, later extending its focus to geese-related issues. Despite lacking legal authority, the group proved to be a sustainable management solution by creating a collaborative arena for sharing experiences and addressing problems (Tuvendal and Elmberg 2015). In contrast, the designation of the Schaalsee Biosphere Reserve was associated

with several challenges. The original plan was to establish the biosphere reserve on both shores of the lake. However, no majority for this plan was reached in the state of Schleswig–Holstein during votes in the counties for which the reserve was proposed (Biosphärenreservat Schaalsee 2011). Hence, the discontent among respondents in Schleswig–Holstein regarding the management of wildlife-related crop damages may originate from historical opposition to the biosphere reserve. Nevertheless, differences in how well respondents felt supported by the community or authorities may also stem from varying individual attribution processes. For example, farmers who perceive wildlife damage as a natural part of farming may feel more responsible to manage damage proactively; whereas farmers who attribute high wildlife damage pressure to mismanagement by the biosphere reserve, or by other authorities, could be more likely to expect the government agency to implement effective damage prevention or compensate them financially.

Methodological considerations

The environmental stress model (Reser and Swim 2011) provides a suitable framework for exploring the farmers' decision making process around crop damage by wildlife, and underscores that their responses to compensation is likely connected both to the experiences and appraisals of crop damage and diverse coping strategies. However, to reliably assess the importance of the factors that may influence farmers' responses to wildlife damage, there is a need for a more comprehensive study with a larger sample of farmers. Nevertheless, this study provides insights from a rare sample of farmers operating within or in the vicinity of biosphere reserves, a key stakeholder group for the development of compensation schemes for wildlife damage. In addition to a small sample to quantitatively analyze tolerance levels, we did not alternate the order of the questions. This could potentially have introduced a bias favoring the positive effect of compensation. Yet, neither the small sample size nor using the same question order can explain the small variation in tolerance without compensation but large variation in tolerance with compensation, indicating that the main results are relatively robust.

Conclusions

In this study, we examined farmers' appraisals of wildlife and wildlife-related crop damage in and around biosphere reserves. We found that their experiences and appraisals were highly diverse, reflecting the spatial heterogeneity of wildlife movement and damage pressure, as well as the varied individual motivational factors among respondents.

This suggests that financial compensation could serve as an important measure, particularly for farms experiencing substantial wildlife-related crop damage. However, for some respondents, we found limited or no effect of compensation, while substantial effects were observed for others. This variation is likely due to differences in the respondents' motivation for farming, the perceived time-consuming nature of damage inspections and compensation applications, and the fact that compensation does not cover indirect costs of wildlife damage to crops. Even under a scenario of full financial compensation, the median tolerated yield loss remained below 10%, highlighting the necessity of incorporating effective crop damage prevention methods into coexistence strategies.

The importance of preventive measures was also emphasized by our respondents, who reported actively engaging in crop damage prevention measures. The system of diversionary feeding, combined with consultancy services on scaring methods in one of the study areas was particularly well received by the respondents. Thus, tailored strategies that integrate both prevention and compensation measures – coupled with effective communication between farmers, governance authorities, and other stakeholders – appear essential for managing crop damage at 'tolerable levels' and thereby sustain human–wildlife coexistence.

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Author contributions

Karoline Hemminger: Conceptualization (equal); Data curation (lead); Formal analysis (lead); Investigation (lead); Methodology (equal); Visualization (equal); Writing - original draft (lead); Writing - review and editing (lead). **Louise Eriksson**: Conceptualization (equal); Methodology (equal); Visualization (equal); Writing - review and editing (equal). **Lovisa Nilsson**: Conceptualization (equal); Supervision (equal); Writing - review and editing (equal). **Johan Månsson**: Conceptualization (equal); Supervision (equal); Writing - review and editing (equal). **Hannes König**: Conceptualization (supporting); Funding acquisition (lead); Investigation (equal); Project administration (equal); Supervision (equal). **Sonoko Bellingrath-Kimura**: Supervision (equal). **Anders Hallengren**: Investigation (equal); Resources (equal). **Emu-Felicitas Ostermann-Myashita**: Methodology (supporting); Writing - review and editing (supporting). **Christian Kiffner**: Conceptualization (equal); Formal analysis (supporting); Methodology (supporting); Writing - review and editing (equal).

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Data availability statement

Data are available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.kwh70rz6v (Hemminger et al. 2025).

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