Birds on Fire: Heavy disturbance by fireworks affecting wintering gulls, waterbirds and passerines

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Abstract

Fireworks are a global anthropogenic disturbance, yet their impacts on wildlife remain poorly understood. Despite frequent media coverage and growing public concern of mass bird disturbances around New Year, scientifically robust assessments of nocturnal behavioural responses on the ground are lacking. Here, I quantified immediate and mid-term responses of urban birds with a focus on Black-headed Gulls (*Chroicocephalus ridibundus*) to New Year's Eve fireworks over three winters (2020/21–2022/23). For gulls, I recorded nocturnal flight time (proportion of time gulls spent flying) and disturbance behaviours (roost displacement, flocking responses, high-altitude flights). During New Year's Eve, immediate reactions included substantial increases in flight time and disturbance behaviours, particularly around midnight. Flight time was directly related to nearby fireworks, whereas disturbance behaviours remained elevated throughout the night, indicating cumulative stress effects. In the following days, gull abundance at the roost first declined sharply (17–62%) with disturbance behaviours remaining elevated. Full recovery took several days, indicating mid-term impacts of stress. Waterbirds left the area after the first fireworks until the next day, while panicked flight reactions of passerines were recorded especially around midnight. The smallest behavioural disruptions occurred during the COVID-19 pandemic, when firework usage was lowest. These findings demonstrate both short- and mid-term behavioural disruptions caused by fireworks, highlighting the need for mitigation measures to minimise impacts on wildlife.

Keywords: Animal behaviour; birds; conservation; explosions; human disturbance; noise; roost; stress response; urban; wildlife

1 Introduction

Human disturbances shape the way animals move and rest (Frid & Dill, 2002; Tablado & Jenni, 2017; Tuomainen & Candolin, 2011). Predictable or regularly recurring disturbances lead to increased tolerance towards humans and their actions (Blumstein, 2016; Samia et al., 2015; Vincze et al., 2016), which can facilitate settlement near humans. Birds can seek such urbanized areas because of anthropogenic food sources, warmer microclimates, and abundant artificial structures for roosting and nesting (Chace & Walsh, 2006; Chamberlain et al., 2009). Behavioural adjustments to tolerate human presence may be beneficial (Sol et al., 2013), but unpredictable or rare disturbance events can still lead to temporarily abandoning of breeding, feeding and resting areas (Bernat-Ponce et al., 2021; Carney & Sydeman, 1999). Sudden loud explosive noises, such as fireworks, are especially disruptive, creating a disturbance *en masse* for wildlife, pets and livestock alike (Shamoun-Baranes et al., 2011; Stickroth, 2015). Although media frequently highlights mass bird disturbances or mortalities associated with fireworks (Sherriff, 2024; Stickroth, 2015), research on short- and midterm reaction of animals through ground-based behavioural observations remain limited, despite clear conservation implications at landscape scales (Shamoun-Baranes et al., 2011).

In birds, fireworks typically cause immediate and pronounced behavioural and physiological reactions (Kölzsch et al., 2023; Shamoun-Baranes et al., 2011; Wascher et al., 2022). The response can be triggered by noise or light, while environmental features such as water surfaces, forests, or buildings can amplify or dampen effects (Hoekstra et al., 2023; Stickroth, 2015). As a reaction, birds increase flight time, intensity, and altitude with thousands of birds abruptly ascending after fireworks and remaining airborne for hours (Hoekstra et al., 2023; Kölzsch et al., 2023). The main disturbance time is often reported between 45-60 minutes (Bosch & Lurz, 2019; Shamoun-Baranes et al., 2011). Birds also experience lack of rest, heightened heart rates, and significant physiological stress (Bögel et al., 1998; Wascher et al., 2022). While such flight and physiological responses have been documented, ground-based behavioural data after birds return to land is largely missing

Well beyond the immediate event, firework causes prolonged stress and behavioural responses. Disrupted sleep and prolonged flight causes birds to increase diurnal resting and foraging to compensate for lost energy (Kölzsch et al., 2023). Even single events can displace large numbers of waterbirds for several days with individual animals exhibiting notably severe responses, such as prolonged absence from breeding areas (Stickroth, 2015). These observations suggest mid-term impacts, but which behaviours persist and for how long has rarely been documented.

This study was motivated by behavioural changes observed in overwintering Black-headed Gulls (*Chroicocephalus ridibundus*) following New Year's Eve. While it is known that they may relocate in response to fireworks (Neub, 1974), nocturnal, multi-day time series linking flight activity, roost behaviour, and roost counts are lacking. To quantify the gulls' responses to firework, I recorded flight, disturbance responses and roosting numbers before, immediately during New Year's Eve and over subsequent days. Based on previous research, I expected strong flight responses immediately to fireworks (Shamoun-Baranes et al., 2011) with behavioural changes extending into the following days (Kölzsch et al., 2023). I also expected the number of birds at the roost to drop by at least 60 % (Stickroth, 2015).

2 Methods

While all bird encounters were recorded, our quantitative behavioural analyses focused on Black-headed Gulls (*Chroicocephalus ridibundus*) because they were by far the most abundant, consistently present, and easiest to track under artificial light due to their white bodies. Within the Black-headed Gull roost, a small number of Common Gulls (*Larus canus*; typically <10 individuals) were present but not analysed separately. The Black-headed Gull is a widespread Palearctic species that forms large winter roosts, often in urban areas, with individuals commuting between daytime foraging sites (waterways, cities, and nearby fields) and communal nocturnal roosts (Moser, Barbalat, et al., 2025). In the study area in Basel, the Black-headed Gull is a winter visitor, with most birds originating from North-Eastern Europe (e.g. Poland; Moser, de Titta, et al., 2025). In Switzerland, the species is a "national priority species" due to the total overwintering population of 40'000 exceeding 1.5 % in this flyway (Knaus et al., 2025; Moser, Barbalat, et al., 2025). The studied roost is situated in Basel, within the "border triangle" in Switzerland, France and Germany (47.589902, 7.589040, Figure 1). It is long-established and with 5000 roosting birds regionally important (Moser, Barbalat, et al., 2025; Moser, de Titta, et al., 2025). Gulls usually roost on water in the port area, but occasionally on the adjacent river Rhine between the Dreirosenbrücke and Dreiländerbrücke (Figure 1). Sleeping on the Rhine forces the birds to fly upriver regularly (about every 25 minutes), unusual for Black-headed Gull roosts normally located on open still waters (Moser, Barbalat, et al., 2025; Neub, 1974). On most nights, river-roosting birds eventually return to the port. The environment is urban and noisy with

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popular clubs right next to the roost. Port activities including ship-movements extend into the night and frequently displace the roost. There is a lot of artificial light, allowing for bird observation throughout the night.

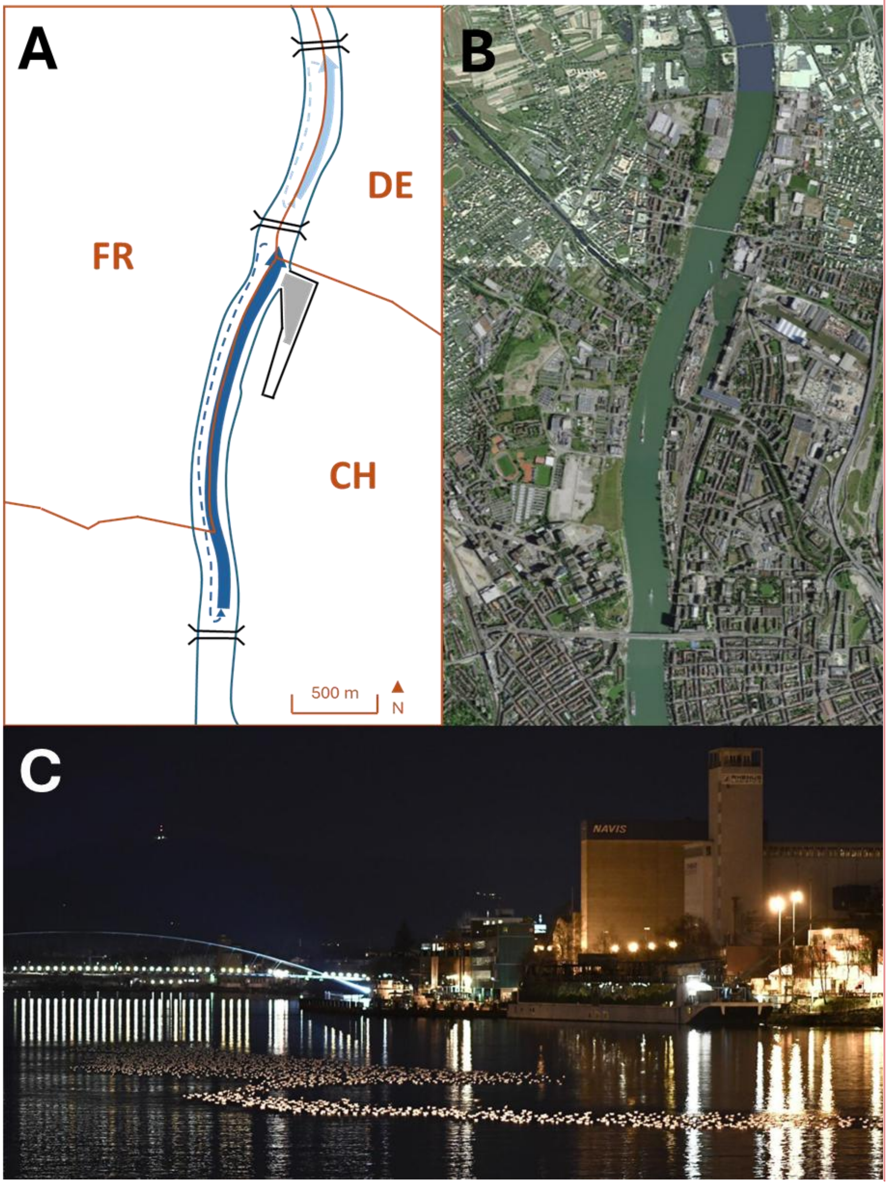

Figure 1 with A) Study area along the Rhine River flowing North at the tri-border region of Switzerland (CH), France (FR), and Germany (DE). The grey area marks the usual gull roost within the port basin. The dark blue area indicates the typical nocturnal roosting area along the river. The light blue area shows the extended roosting area used in winter 202021/2022, where gulls remained until at least

Commented [au1]: Add landscape picture, roosting picture, picture New Year firework *the night of 3rd January. Orange lines represent national borders. B) shows a satellite picture of the study area, ©swisstopo, while C) is made from the bridge in the South of the Study area towards the North, showing roosting Black-headed Gulls (representative of a control night), ©Jaro Schacht*

2.1 Counts of Black-headed Gulls

I counted the number of Black-headed Gulls present at the roost from 26th of December to the 24th of January. In winters 2020/2021 and 2021/2022, counts were conducted opportunistically throughout the winter (Supplementary Figure S1) to assess seasonal phenology of the roost and establish a behavioural baseline. Counts were done with a tally counter in groups of 10.

2.2 Bird behaviours around New Year's Eve

I recorded bird activity and fireworks for at least two full nights per winter. The control night (27.12. to 28.12.) was as close to New Year's Eve as possible without too much disturbance by early fireworks (Kölzsch et al., 2023), the second night was New Year's Eve (New Year, 31.12. to 01.01.). Observations started around sunset with Black-headed Gulls arriving at the roost in the port until half an hours' time of sunrise when most gulls left the area again (16:30-8:00). I additionally did visits in the following days and nights to document further mid-term changes until the Black-headed Gulls roosted at the port again.

All observations were made by a single observer, with the help of binoculars (Swarovski EL 10x32) and, only in the last winter, a thermal imager (Xeye E3 Max v2). Behaviours and fireworks were noted by hand in calm conditions, if frequency increased, voice recording was used. All bird species were observed. The presence of waterbirds and passerines (with a corvid roost located in the North off the study area) was recorded throughout the nights. For Black-headed Gulls, I additionally recorded flight time and bird disturbance behaviours (Table 1) in 15-minutes windows. These metrics complement each other by capturing short-term responses (flight proportion) and mid-term responses (disturbance score).

For the flight time, I noted the percentage of the flock taking flight and the time until half of the birds landed again after the disturbance, allowing calculation of individual mean flight time per disturbance. Individual flight times per disturbance was summed up over the 15-minutes interval (total flight time per 15 minutes), with flight time extending beyond an interval added to the next time window.

I also recorded disturbance behaviours per 15-minute intervals. At the end of each 16 -minute interval, I noted down all behaviours observed in the respective interval. For analysis, these disturbance behaviours within intervals were combined into a cumulative "disturbance score". The baseline (Table 1, not included in disturbance score) indicates gulls resting undisturbed in the port area. Mild disturbances (e.g. ship movements, noisy human activities) led gulls to relocate from the port to the river, with birds sometimes staying closer together or reducing flock length. Severe disturbances caused heightened stress responses, such as flying at high altitudes (> 50 m) or entirely abandoning the usual roosting areas. It is important to note that roost size declined throughout the New Year's Eve and could move within the study area. I stayed with the main flock present in the study area.

Table 1 A description of different categories of bird disturbance behaviour recorded at the roost.

Behaviour	Description	Reference
Baseline	No disturbance recorded during 15 min; observer present	None
Not in port	Gulls left the favoured roost in the port to rest on the river (Dreirosenbrücke–Dreiländerbrücke)	Mild roost displacement

Not in area	Entire flock abandoned usual roosting and sleeping areas	Severe roost displacement
Shortened length	Gulls occupy a shorter stretch of Rhine compared to their usual spread between the two bridges	Flocking response
Close together	Individual spacing reduced to less than half of usual minimum	Flocking response
Flying due to disturbance	Gulls flushed into flight due to a disturbance	Acute stress response
Flying high	Gulls fly > 50 m above ground	Acute stress response

2.3 Firework

Fireworks were recorded in two categories: “Close” and “Distant”. Close fireworks were explosions within ~ 100 m of the roost, either directly causing flight (category_1 in the raw data) or likely to do so (if gulls were already flying or displaced; category_2). All close fireworks were recorded with additionally noting the country of origin, using voice messages. For data analysis, close fireworks were summed up per 15-minutes irrespective of category or country, aligned with the intervals of the behavioural gull data. Distant fireworks (any audible explosion while walking) were recorded using a handheld tally counter individually if fewer than 10 explosions per minute occurred. When rates exceeded this, I estimated explosions per second or minute and extrapolated over the 15-minute intervals, using voice recordings to document the numbers. The COVID-19 pandemic affected firework usage with different firework and health restrictions in place. Despite restrictions, in all three winters, in all three countries, firework usage was recorded (Supplementary Figure S4).

2.4 Modelling

To analyse changes in gull behaviour, I fitted generalized additive mixed models (GAMMs) for disturbance score, flight time and firework influence. Models were fitted using the gamm() function from the mgcv package version 1.9.1 (Wood, 2017) in R version 4.4.1 (R Core Team, 2025). Both response variables were modelled using a quasibinomial distribution with a logit link function: Disturbance score was a scaled index (0-6), while flight time represented the proportion of maximum possible flight time per 15 minutes. The final models included a smooth interaction between time since sunset and observation day (27., 31.), a fixed effect of day, and a random intercept for winter (year) to account for inter-annual variation. To capture temporal autocorrelation within nights, an AR(1) correlation structure was added, nested within year and ordered by a time index starting at sunset. For visualization, predictions were generated from a model including only day and time, while statistical inference was based on a full model that additionally included both close and distant firework intensity. ChatGPT (version 4o, 18.04.- 03.07.2025, v5.2, 16-18.01.2026) was used to improve the clarity and flow of all the writing and as a coding assistant.

2.5 Ethical note

The data was collected with a purely observational monitoring of the gulls and other present birds. The observer remained passive and with sufficient distance to avoid interference with the behaviour of the gulls, which were therefore not influenced by the data collection.

Results

2.1 Black-headed Gulls: Counts

I recorded changes in the number of gulls at the roost across all three winters. Comparing the numbers of the 27th of December to the 1st of January (Figure 2), the strongest decrease was in winter 2022/2023 (-62.4%), with smaller drops in in 2020/2021 (-17.1%) and 2021/2022 (-37%).

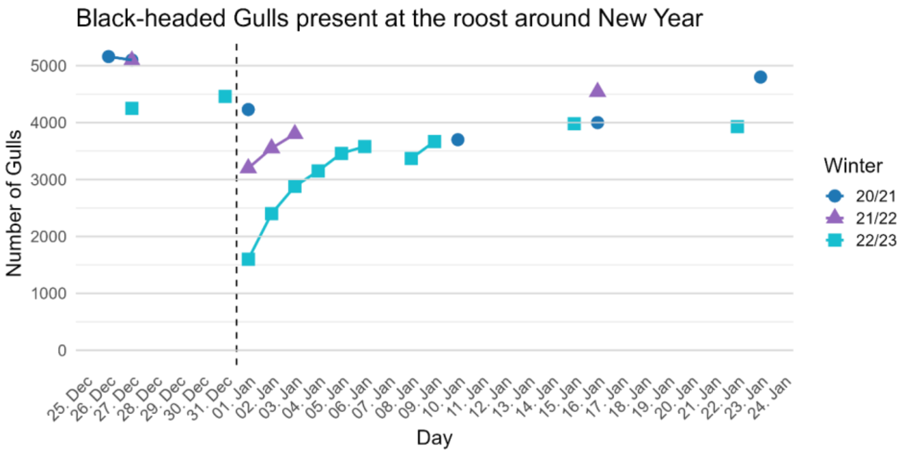

Figure 2 Presence of roosting gulls at Basel over the three winters around New Year. Number of gulls observed at the Basel roost site from 25th of December to the 24th of January across the winters 2020/2021, 2021/2022 and 2022/2023. Each point represents the total count on a given date. Colours and symbols distinguish between the three winters.

2.2 Black-headed Gulls: Behaviour

Both flight proportion and disturbance differed significantly, between the nights of 27th and 31st (Figure 3, Supplementary Figures S2 and S3). The flight model revealed a significant smooth term for the 31st (edf = 4.22, $p < 0.001$), but not for the 27th (edf = 1.00, $p = 0.29$), explaining a moderate amount of variance ($R^2 = 0.32$). The disturbance model showed a strong non-linear pattern on the 31st (edf = 7.47, $p < 0.001$), but no significant trend on the the 27th (edf = 2.22, $p = 0.14$), and explained 70% of variance (adj. $R^2 = 0.70$).

Gulls also showed increased flight time on January 1st in 2021/2022 and 2022/2023 (in latter as a response to close fireworks) and reacted to close fireworks on the 3rd and 4th of January in 2023. Elevated disturbance scores (vs. 27th December) persisted at least until 1st January (2020/21), 5th January (2021/22), and 6th January for the port area in 2022/23 (see Supplementary Figure S2 and S3 for longer time series up to 9th). Across all winters, gulls showed increased daytime resting behaviour (sitting, eyes closed, head tucked into feathers) in the days after New Year compared to before. Foraging gulls were more easily flushed and less inclined to approach humans for food, and their daytime roost locations and numbers shifted.

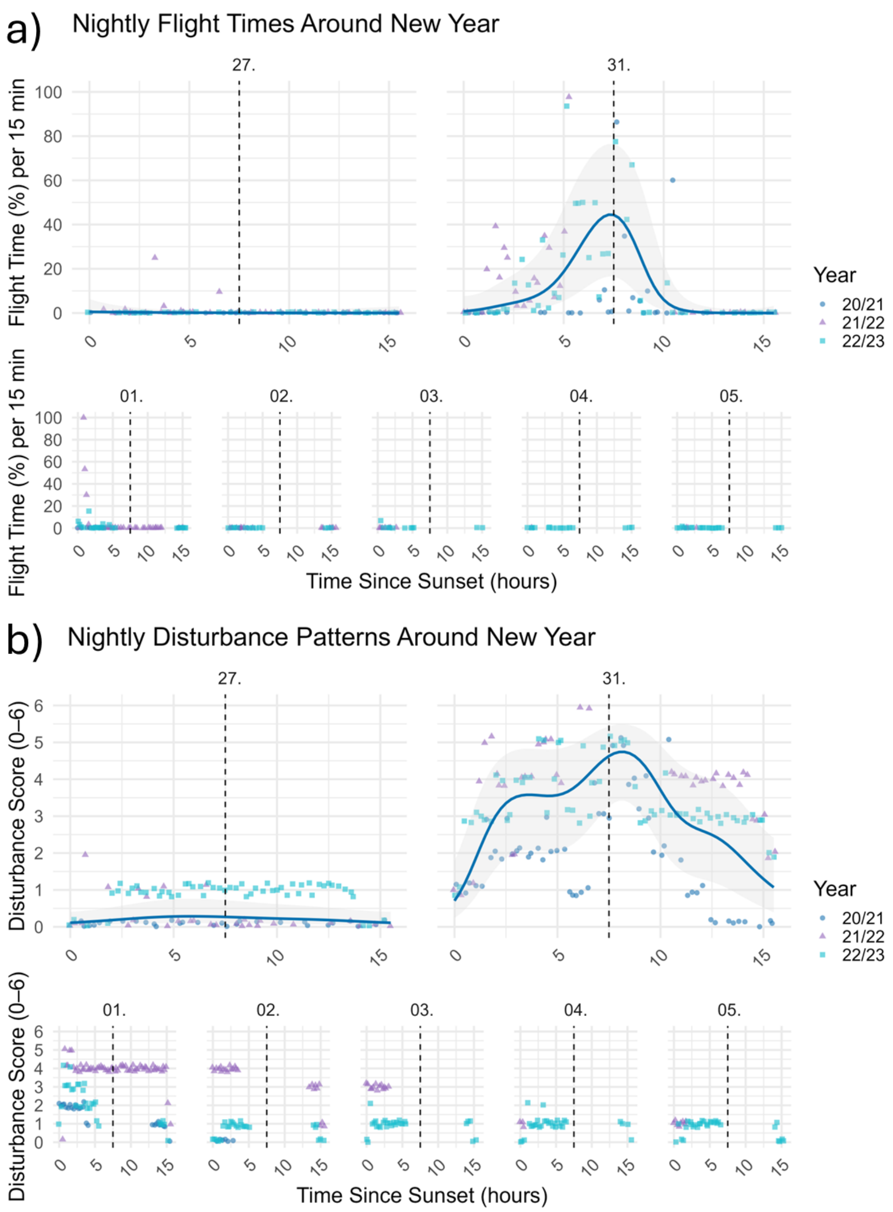

Figure 3 a) Nocturnal flight time and b) disturbance of Black-headed Gulls around New Year (27th –5th of January). Observed flight time (% per 15 min) and disturbance score (0-6) are shown as jittered points, coloured and shaped per winter (2020/2021, 2021/2022, 2022/2023). For the 27th and 31st, modelled GAMM predictions (solid lines) and 95% confidence intervals (grey ribbons) are shown. Midnight is marked by a dashed vertical line (7.5 hours after sunset).

2.3 Waterbirds excluding Black-headed Gulls

Other waterbirds present in the study area included Mallard (*Anas platyrhynchos*), Mute Swan (*Cygnus olor*), and Eurasian Coot (*Fulica atra*). In each of the three years, these species were present throughout the control night. They were also present at the start of each New Year's Eve, but numbers quickly reduced with the first close fireworks and at the latest after midnight no waterbirds were observed in the study area on the water, with most (more than 90%) staying absent until at least the early morning. Most waterbirds seemed to return during the day of the 1st of January. In the winter 2021/22, I temporarily lost the Black-headed Gull main flock; during the search by bike along the river, I visited two overwintering areas of Mallard, Mute Swan, Eurasian Coot, Common pochard (*Aythya farina*), Tufted Duck (*Aythya fuligul*) and Great Crested Grebe (*Podiceps cristatus*) 6 km up- and downstream of the study area in the two hours after midnight, finding no birds present, except Mute Swans, which moved to the most sheltered parts of the river. On the New Year's Eve of 2022/2023, I observed twice cormorants and one *Larus sp*. (likely Yellow-legged Gull), flying and seemingly disturbed by fireworks (Supplementary Table S1).

2.4 Passerines

Other species observed seemingly disturbed by fireworks include Rook (*Corvus frugilegus*), Carrion Crow (*Corvus corone*), Jackdaw (*Corvus monedula*), Feral Pidgeon (*Columbia livia*), European Robin (*Erithacus rubecula*), Common Blackbird (*Turdus merula*), and unidentified passerines. In the control nights, I observed passerines in two-time intervals, whereas on New Year's Eve nights, I observed passerines in 10 time intervals (Supplementary Table S1). Notably, with the thermal device only used in the last winter, I observed many passerines around midnight until at least 36 minutes past midnight flying in the air. Corvids also changed behaviour on New Year's Eve nights compared to control nights, with flying corvids recorded in all years after midnight on New Year's Eve nights. On the 1st of January 2022, 600 corvids were still flying in proximity of the usual roost at 17:50, at least half an hour later than the usual time when they settle in the trees compared to control nights.

2.5 Fireworks

Black-headed Gull flight time increased significantly on New Year and in response to close fireworks, while disturbance scores increased significantly with New Year but showed no significant links with firework themselves (Table 2). Firework intensity varied between winters, with additional fireworks recorded on nights after the 31st of December (Supplementary Figure S4).

Table 2 Summary of two Generalized Additive Mixed Models (GAMMs) analysing gull behaviour in response to fireworks and New Year (day). Both models include fixed effects for day, close fireworks (≤100 m), and distant fireworks (audible explosions while walking). Reported are the estimates, standard errors (SE), and p-values for all parametric terms. Asterisks indicate significance levels: $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***).

Model	Term	Estimate	Std_Error	p_value	
Flight proportion	Intercept	-6.96	1.16	< **0.001**	***
	Day	2.79	1.15	< **0.016**	*
	Close firework	0.06	0.02	**0.001**	***
	Distant firework	-0.0003	0.0002	0.135	
Disturbance score	Intercept	-3.37	0.53	< **0.001**	***
	Day	3.37	0.20	< **0.001**	***
	Close firework	0.0017	0.0019	0.365	
	Distant firework	-0.0001	0.0001	0.480	

4 Discussion

Over the three winters of the study, Black-headed Gulls, other waterbirds and passerines displayed significant behavioural changes in response to fireworks. Nocturnal flying and stress behaviours increased. For the Black-headed Gulls, numbers at the roost decreased through the night, and stress reactions continued into the following nights, indicating mid-term consequences. Previous studies have indicated extensive flight responses (Hoekstra et al., 2023; Kölzsch et al., 2023; Shamoun-Baranes et al., 2011), my findings highlight immediate disturbance behaviour with increased flight activity, roost tightening and displacements extending on the ground. The firework at New Year is likely the most severe and large-scale disturbance event of the winter for these birds and though of significant conservation relevance.

Birds reacted differently to fireworks. Many waterbirds already left with the first close fireworks and only returned on the next day, which has been described before (Stickroth, 2015). Passerines were mostly observed disturbed around midnight, with the biggest spatial and intensity peak of firework activity. However, due to their size and cryptic behaviour, most passerines beside the corvids were difficult to observe, allowing no quantitative assessment. The thermal imager used in the last year could provide more insights there. Black-headed Gulls, a species preferring to roost in big groups (Moser, Barbalat, et al., 2025), did not leave the area immediately, but were repeatedly flushed by fireworks through the night. Flying in this species was significantly correlated with close fireworks, reflecting immediate efforts to escape the perceived danger. Taking flight and flying high has been observed before and may be the most obvious and energy costly reaction to fireworks (Hoekstra et al., 2023; Kölzsch et al., 2023; Shamoun-Baranes et al., 2011). Consistent with previous findings (Shamoun-Baranes et al., 2011; Stickroth, 2015), at midnight all birds were in the air for up to 45 minutes. For Black-headed Gulls, the average airtime per night extended up to two hours. This would come with energetic consequences: The daily energy needed for a Black-headed Gull is around 500 kJ per animal, around 21 kJ per hour (Glutz von Blotzheim & Bauer, 1982). The basal metabolic rate is estimated to be 1.53 Watts or 5.5 kJ per hour (Shamoun-Baranes & Van Loon, 2006), with flight costs 5-10 the basal rate for small gulls, with Black-headed Gulls on the higher side (Källander, 2014; Tremblay et al., 2024). Two additional hours of flying would therefore result in 2.5 – 14 % more energy spend compared to the usual average per hour, values that align with geese disturbed by fireworks (Kölzsch et al., 2023). Likely, the energy spend is higher, as costs go beyond simply flying, given this study indicates that energy-costly stress behaviours continue throughout the night even when not flying.

Among the Black-headed Gulls, there seem to be large differences among individual birds in reaction to fireworks: Some were flushed with the slightest noise and stayed in the air longer, others were reluctant to fly and settled quicker. This could be a difference in experience between birds, resulting in individual differences in dealing with such disturbances (Kölzsch et al., 2023; Stickroth, 2015). The altitudes reached to escape the disturbance were very high, as in other studies (Kölzsch et al., 2023; Shamoun-Baranes et al., 2011). In 2021/22 I lost the gulls before midnight. First, I could not relocate any gulls on the ground six kilometres up- or downstream of the regular roost, even in relatively undisturbed areas. Later, I found the remaining gulls one bridge downriver of the regular roost (Figure 1). However, intermediately and as in all years, I did record multiple high-flying groups. As with geese (Kölzsch et al., 2023), these gulls might fly significant distances in the New Year Night, possibly traveling the 40 kilometres to the neighbouring roosts (Moser, Barbalat, et al., 2025). While flight time showed a significant and immediate response to fireworks, disturbance scores did not exhibit a statistically significant relationship with fireworks. This likely reflects the cumulative nature of the disturbance, which rose early in the night and remained elevated. Birds never fully relaxed, staying close together and outside of the preferred roosting area all night long. Disturbance thus becomes decoupled from momentary fireworks with behavioural changes persisting even in their absence.

The number of Black-headed Gulls present at the roost decreased following New Year, with the numbers slowly recovering over several days. Roost change is a common mid-term response to fireworks (Kölzsch et al., 2023; Stickroth, 2015). However, other behaviours such as roost shortening and tightening stayed in place at least in the first night, with up to five nights being required for the roosting behaviour to fully relax. This recovery time seems influenced by firework intensity, with the pandemic-induced reduction in 2020/21 clearly reducing disturbance, flight time and recovery, like in other studies (Bosch & Lurz, 2021; Kölzsch et al., 2023). However, higher disturbance is not always linked with higher firework intensity. In 2021/22 the birds had some particularly high disturbance rates, while in 2022/23, with the highest number of fireworks, the disturbance score was lower, but the gull roost was reduced the most (-62.4%). In 2021/22, changing roost area seemed to be especially disruptive on disturbance recovery. The remaining birds were driven to a less suitable stretch of the river (shorter, more frequent disturbance through ships) starting in New Year Night and for more than two further nights. Interestingly, this change of roosting area seemed to carry over to a corvid roost in the North of the study area, which took longer to settle for the night than usually, indicating that other birds might also experience mid-term behavioural disruptions. In 2022/23, a peak of firework early in the night may have already displaced a significant portion of the Black-headed Gulls, with only the most tolerant remaining at the roost. This possibly avoiding complete chaos induced by inexperienced birds later in the night.

Just as with geese (Kölzsch et al., 2023), the gulls changed their spatial and foraging behaviour in the days following New Year. The numbers of sleeping or resting gulls during the day seemed increased, characterized by birds sitting and not standing, as well as having their eyes closed or head tucked away. This behaviour I observed rarely during daylight otherwise, except after stormy nights. Also, the foraging behaviour changed, and the gulls seemed more easily flushed by people, sudden movement or noises and less prone to approaching humans for food. Finally, the gulls also changed their usual day roost area. These behavioural changes were also noticed by other local observers (pers. communication). These shifts away from their usual overwintering area and diurnal feeding place might be especially disruptive for Black-headed Gulls, as they show high site fidelity to in their overwintering area and may also have been driven to unfamiliar or lower quality habitat (Moser, de Titta, et al., 2025).

The result of this study highlights that the effect of fireworks on birds depends on distance, intensity, repetition, time and animal characteristics. For these birds, this night might be the most disturbing throughout their year, with the landscape-scale disturbance leaving few refuges. As such, firework deserves more attention in conservation and behavioural studies. Firework can be mitigated with minimal distances to roosts (Stickroth, 2015) with environmental circumstance mediating this distance (Hoekstra et al., 2023). Depending on the location of the fireworks, buildings seemed to reduce disturbance intensity by blocking emissions, but in other locations also increase disturbance through reflecting and possibly amplifying noise and light. Temporal and local restrictions may mitigate such effects: The results of the pandemic year suggest that with a shorter duration of the main disturbance, birds also recover more quickly. However, even isolated illegal fireworks recorded in this and other studies (Bosch & Lurz, 2021) disturbed the birds. Such single events seem particularly adverse when birds start to relax again. This highlights the importance, but also the challenges, of strict enforcement of such restriction measures.

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Declaration of Interest

None

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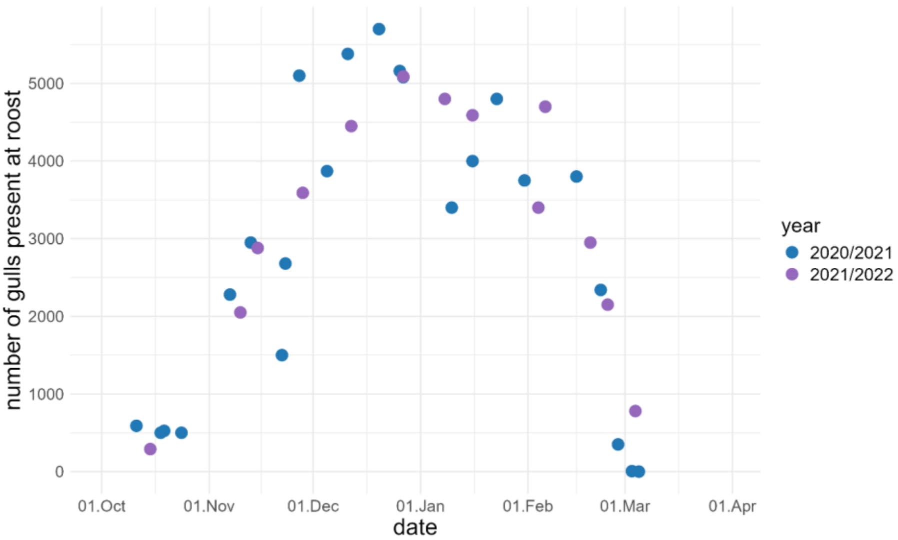
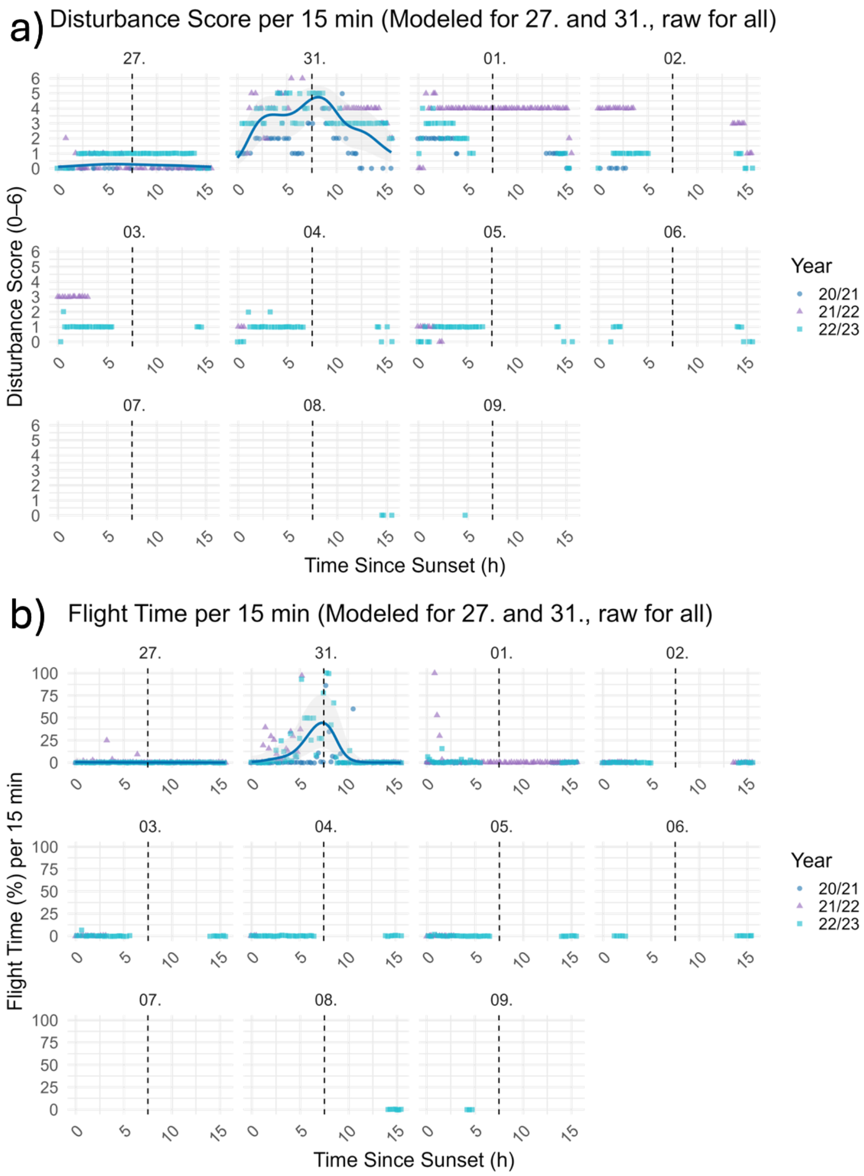
Supplementary material

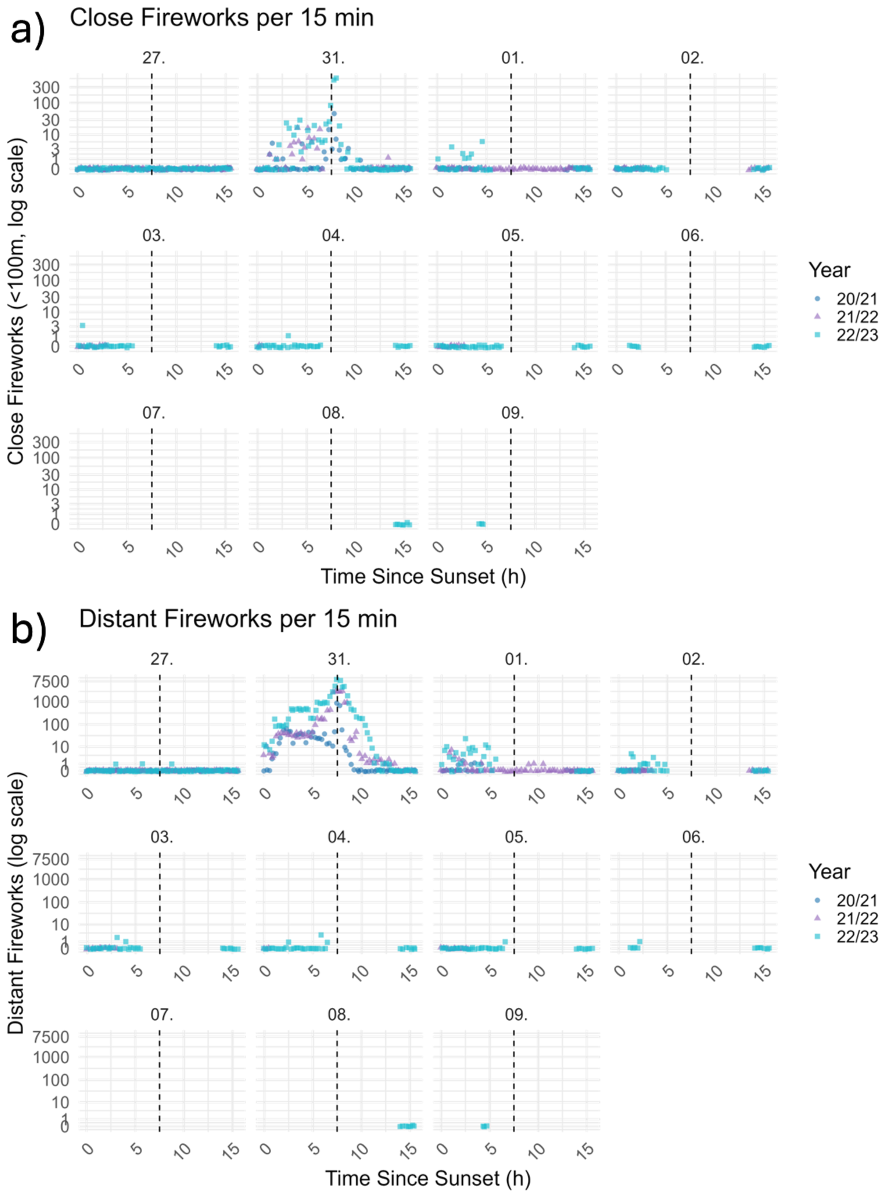


Supplementary Figure S1: Seasonal presence of roosting gulls at Basel over two winters. Number of gulls observed at the Basel roost site from October to April across the winters 2020/2021 and 2021/2022. Each point represents the total count on a given date. Colours and shapes distinguish between the two winters.



Supplementary Figure S2. Nocturnal disturbance score and flight time of gulls around New Year (December 27 – January 9). Observed individual-level flight time (% per 15 min) is shown as jittered points, coloured and shaped by winter (2020/2021, 2021/2022, 2022/2023). For December 27 and 31, modelled GAMM predictions (solid lines) and 95% confidence intervals (grey ribbons) are shown. Midnight is marked by a dashed vertical line (7.5 hours after sunset).

Supplementary Figure S3. Individual-level field observations of gull behaviour per 15-minute interval during nights around New Year. (a) Nights from December 27th to January 1st. (b) Nights from January 2nd to January 9th. Each row represents a specific behavioural or contextual category (e.g., "flying", "close together"), with color-coded presence (1), absence (0), or missing data. The x-axis shows time of night, aligned across all days. White indicates baseline (observer present, no event), while light grey indicates absence of observer. Days are split by columns; winters are shown by rows.



Supplementary Figure S4. Close and distant fireworks recorded every 15 minutes between sunset and morning during three New Year nights. (a) Close fireworks (≤100 m from the roost), summed per 15-minute interval. (b) Distant fireworks, summed per 15-minute interval. Points show individual records, jittered to reduce overplotting. Colour and shape denote the winter. The y-axis is log-transformed to improve visibility of variation at lower values. The dashed vertical line marks midnight (7.5 hours after sunset).

*Supplementary Table S1 Nocturnal observations of non-target bird species recorded in the study area. The corvids have a roost just North of the Dreiländerbrücke, mostly on German side. Common waterbirds such as Mallard (*Anas platyrhynchos*), Eurasian Coot (*Fulica atra*), and Mute Swan (*Cygnus olor*), which are frequently active in the night, are not listed here, even if they were observed to be displaced from their typical night-time location in all winters on New Year as well. "Winter" refers to the winter season. "Night" refers to the calendar date in December and only includes the first day (so 31 is the New Year from 31.12.-01.01.).*

Winter	**Night**	**Time**	**Species**	**Behaviour**
2021/2022	27	03:30	European Robin	foraging in artificial light, observed repeatedly in next 30 min
2021/2022	27	06:30	Black Redstart	foraging in artificial light
2020/2021	31	17:15	Rook, Carrion Crow, Western Jackdaw	Mixed corvid groups flying around, maybe also unrelated to fireworks, they are often later than the gulls
2020/2021	31	18:30	Feral Pigeon	disturbed by fireworks, flying
2020/2021	31	00:15	European Robin	disturbed by fireworks, flying
2020/2021	31	00:15	Common Blackbird	disturbed by fireworks, flying
2020/2021	31	00:30	Rook, Carrion Crow, Western Jackdaw	Multiple mixed corvid groups flying by with fireworks ongoing (60, 40, 40, 60, 80)
2021/2022	31	17:45	Rook, Carrion Crow, Western Jackdaw	Corvid flock also in the air
2021/2022	31	00:45	European Robin	disturbed by fireworks, flying
2021/2022	31	05:15	Common Blackbird	foraging in artificial light
2022/2023	31	17:30	Rook, Carrion Crow, Western Jackdaw	200 corvids flying towards Basel
2022/2023	31	20:30	European Robin	warning calls
2022/2023	31	22:15	Great Cormorant	flushed elsewhere, lands, but only until the next close explosion
2022/2023	31	22:45	*Larus sp*. (likely Yellow-legged Gull)	disturbed by fireworks, flying
2022/2023	31	23:45	European Robin	singing
2022/2023	31	00:15	several species	midnight: All gulls up, two cormorants, with thermal imager at least 10 other birds, including one probably Blackbird and Crow
2022/2023	31	00:30	Common Blackbird	warning calls
2022/2023	31	00:30	Passerine species	with the thermal imager passerines visible in the air 24 and 36 minutes after midnight
2021/2022	01	17:30	Rook, Carrion Crow, Western Jackdaw	Corvid flock in the air on CH side (800), together with 600 Black-headed Gulls. Never seen them together before, also usually the corvids stay on the German side as well
2021/2022	01	17:50	Rook, Carrion Crow, Western Jackdaw	Still 600 corvids with 200 gulls in the air, probably due to the chaos of gulls not roosting at usual spot
2021/2022	01	06:45	Common Chaffinch	Landing shortly on bridge, maybe a migrant