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INFORMATION NOTE

Disturbance effects of aircraft on birds

Introduction

The purpose of this note is to examine the evidence of impacts on bird populations resulting from disturbance caused by aircraft. This includes an assessment of the effects of different aircraft types and their proximity, altitude and frequency of flight. Other important factors discussed are differences in sensitivity shown by different species and flock sizes and behavioural responses such as habituation and facilitation. The evidence for harmful disturbance caused by aircraft is then presented under a number of categories of impacts including: increased energy expenditure, reduced foraging rates, reduced breeding success and increased predation. Finally, a number of measures that may reduce disturbance impacts are described, including changes to flight altitudes and the use of no-fly zones.

Before discussing the impact of disturbance caused by aircraft, it is important to define the meaning of disturbance in this context. Disturbance can be defined as 'any situation in which a bird behaves differently from its preferred behaviour' or 'any situation in which human activities cause a bird to behave differently from the behaviour it would exhibit without the presence of that activity'. Here we are concerned mainly with the latter definition, although natural causes of disturbance (weather, predators) will always play an important role and may result in even greater impacts when combined with disturbance caused by human activities.

A gradient or hierarchy of behavioural responses to disturbance shown by birds is described by much of the work presented below. For example, the lowest detectable response is for a bird to briefly look in the direction of the source of disturbance before resuming its previous activity. The other extreme would be for a flock of birds to fly away from an area and to not return for several hours, or even days. Such high levels of disturbance resulting in flushing or escape behaviour are quite likely to have an effect, for example, by increasing the energy expenditure of wintering birds. The more difficult question to answer is at what point along the lower end of the gradient does the disturbance result in an impact on a population. For example, repeated exposure to lower levels of disturbance may result in increased stress which, in turn, may cause lower breeding success.

Useful introductions to bird disturbance and further information on the above issues can be found in Davidson & Rothwell (1993) and Hill *et al* (1997).

Disturbance caused by aircraft

The degree of disturbance caused by aircraft relative to other sources of disturbance varies greatly. For example, Grubb & Bowerman (1997) cite results from research on the human disturbance of Bald Eagles where aircraft caused the lowest frequency of behavioural response of the five disturbance groups evaluated (vehicle, pedestrian, aquatic, noise, aircraft). By contrast, small aircraft and pedestrians were the most important sources of disturbance in a study of waders at a high-tide roost on Terschelling, the Netherlands, summarised by Smit & Visser (1993). Bélanger & Bédard (1989) also concluded that the time spent in flight and the time taken to resume feeding by staging Snow Geese in the Montmagny bird sanctuary, Québec, were greater after disturbance by aircraft than after any other type of disturbance encountered in their study.

Disturbance caused by different types of aircraft

Differences in response to different types of aircraft have also been identified. The work on Bald Eagles by Grubb & Bowerman (1997) established that the eagles in their study showed a much greater response to helicopters (47% of all potential disturbance events) than to jets (31%) and light planes (26%). This is consistent with Platt (1977) who recorded that helicopter flights at 160 m altitude or less disturbed all adult Gyrfalcons being tested. Visser (1986) also compared the effects of jets and helicopters on roosting waders on Terschelling and found that helicopters disturbed birds more frequently and over longer distances than jets, even though the activities from jets were accompanied by weapon testing and high sound levels. Similar results were found in a study of small aircraft flying over wader roosts in the German Wadden Sea (Heinen 1986). In this study helicopters disturbed most often (in 100% of all potentially disturbing situations), followed by jets (84%), small civil aircraft (56%) and motor-gliders (50%). These data confirm the widely accepted view that helicopters are the most disturbing type of aircraft (Watson 1993).

The effects of ultra light aircraft are briefly described by Smit & Visser (1993). Although very little research on the effects of ultra lights has been carried out so far, there is evidence that they can cause significant disturbance, probably because of the low altitude at which they operate and the noise they produce. For example, the numbers of roosting and foraging Bewick's Swans close to an ultra light air strip in the Delta area of the Netherlands dropped from 1,400-4,300 in 1986-88 to only a few birds in 1989, after the strip has been used for one year (Smit & Visser 1989). However, this must be compared with the results of a study on the effects of microlights on wintering Pink-footed Geese near the Ribble Estuary (Evans 1994). Although only based on six observations during January to March, this study concluded that birds rapidly habituated to the presence of microlights landing and taking off from an air-strip only 250 m from their feeding areas.

Effects of proximity and frequency of aircraft flights

The altitude and lateral distance of aircraft have been shown to be important factors affecting bird disturbance. In a model of helicopter disturbance of moulting Black Brant geese it was shown that altitude strongly influenced the results, as measured by the number of birds disturbed and by weight loss. At an altitude of 1220-1830 m (depending on helicopter size) there was no predicted weight loss. However, helicopters at 915-1065 m disturbed most birds along all the flight routes. The greatest weight loss was predicted to occur with helicopters at 305-460 m (Miller 1994). Work carried out by Ward *et al* (1994) also confirms an effect of aircraft altitude for staging Black Brant on the Izembeck Lagoon, Alaska. It was found that large planes flying above 610 m had little effect, causing only brief responses by relatively few birds. Fixed-wing aircraft caused the greatest flight response when passing at less than 610 m and less than 0.8 km lateral distance to the flock. Similarly, Owens (1977) reported that wintering Black Brant showed a greater response to fixed-wing aircraft at less than 500 m altitude and less than 1.5 km lateral distance. Aircraft disturbed Black Brant at greater distance than other disturbance types and affected more geese over a larger area than other stimuli. Again, helicopters caused the greatest response duration of all aircraft types. Jensen (1990) found that helicopters had to fly at over 1070 m to avoid disturbing moulting Black Brant. Mosbech & Glahder (1991) suggest that *distant* helicopters are less disturbing when at low altitudes as they are likely to transmit less noise than helicopters at a higher flying level.

Observations of cliff-nesting seabirds on the coast of Aberdeenshire by Dunnet (1977) showed that helicopters and fixed-wing aircraft flying at 150 m above sea level and 100 m above the cliff top caused no detectable effect on the attendance of breeding Kittiwakes and Guillemots at their nests during egg-laying and hatching. However, it was noted that the cliffs are on the normal route of air traffic and thus the birds may have become habituated. No observations were made of aircraft at less than 100 m above the cliff top. Very different responses by seabirds, presumably not habituated, have been recorded on Ailsa Craig in the Firth of Clyde. During one incident a Hercules transport aircraft made successive flights about 200 m above the summit of the island. This caused an entire gannet colony to scatter for about an hour, leaving eggs and small chicks exposed to predation (Zonfrillo 1992).

Smit & Visser (1993) cite further information on the effects of small civil aircraft on roosting shorebirds at different altitudes:

- Aircraft at an altitude of more than 300 m at various sites in the German Wadden Sea disturbed birds in 8% of all potentially disturbing situations, with those flying at 150-300 m in 66% of the cases and those flying at less than 150 m in 70% (Heinen 1986).
- Disturbance in another study was always registered at 150 m altitude and, at a height of 300 m, there was still disturbance within a radius of 1,000 m (Baptist & Meininger 1984). It has been estimated that an aircraft passing over at 150 m creates a disturbed area of more than 15,000 ha (Meer 1985).
- Disturbance can still be detected when aircraft pass at 1000 m altitude (Werkgroep Waddenzee 1975).
- In addition to altitude, the behaviour of aircraft also influences disturbance levels. Flying high in a straight line leads to smaller effects than flying low or with unpredictable curves (Boer *et al* 1970).

Experimental studies of the effects of microlights on Pink-footed Geese (Evans 1994) indicated that they caused no detectable disturbance of geese, Lapwing, Curlew or Golden Plover when over 1000 ft. Signs of disturbance were first noted at around 500 ft.

Turning to the effect of lateral distance of aircraft, a study of the effects of low level jets on nesting Osprey in Labrador, Canada, could not identify any significant disturbance to birds from over-flights as close as 0.75 nautical miles (Trimper *et al* 1998). However, the Ospreys in this study may have habituated to aircraft during exposures in previous years. Visser (1986) detected the disturbance of roosting waders on Terschelling by jets flying up to 1000 m away. Brent Geese on the Essex coast were put to flight by any aircraft up to 1.5 km away when at altitudes below 500 m (Owens 1977).

Research has also been carried out to assess the effect of the frequency of aircraft flights on birds. For example, a study of staging Snow Geese in the Montmagny bird sanctuary, Québec, found that a rate of greater than two disturbances per hour during a single day could reduce the numbers of geese present on the site the following day (Bélanger & Bédard, 1989). Simulations of the effects of over-flights on moulting Black Brant also showed that increasing flight frequency usually caused greater impact on the birds through increased weight loss (Miller 1994). Similarly, experiments on feeding waders on tidal flats on Terschelling showed that 10 minutes after a single disturbance by a small plane at 360 m altitude bird numbers had returned to the same level as prior to disturbance. However, a plane passing twice, at 450 and 360 m respectively, caused a stronger effect, with only 67% of original number of Oystercatcher and 87% of the Curlew returning after 45 minutes (Glimmerveen & Went 1984).

Effect of noise

There has been little work on the effects of aircraft noise on birds. Busnel (1978) states that some species, such as gulls on airfields, breed close to extremely loud man-made noises without ill effects. Birds are assumed to habituate to the frequent loud noises of landing and departing aircraft, and only unusually loud noises are known to cause a reaction of alarm in these circumstances. Similarly, during the study by Owens (1977), Brent Geese quickly became habituated to most sounds, including extremely loud but regular bangs made during weapon testing. In another study of the effects of pre-recorded aircraft noise on nesting seabirds on Australia's Great Barrier Reef it was found that Crested Terns showed the maximum response of preparing to fly or flying off at exposures of greater than 85 dB(A). However, a scanning behaviour involving head-turning was observed in nearly all birds at all levels of exposure down to 65 dB(A), a level only just above that of the background noise (Brown 1990). It is not known what effect repeated exposure to lower noise levels can have on birds, although Fletcher (1988) found that low level jet and helicopter over-flights can cause physiological changes in domestic animals that may represent symptoms of stress.

Work by Mosbech & Glahder (1991) found that moulting geese in north-eastern Greenland showed signs of disturbance before helicopters were visible and that, typically, the noise stimuli alone disturbed the geese. Trimper *et al* (1998) found that nesting Osprey exhibited a similar response, staring at an approaching aircraft before it was audible to observers. There is also circumstantial evidence associating a near total hatching failure of Sooty Terns nesting on the Dry Tortugas Islands with sonic booms produced by low-flying military jets (reviewed in Bell 1972). However, Schreiber & Schreiber (1980) investigated sonic boom effects on colonial nesting gulls and cormorants and concluded that, compared to a human walking into a colony, a sonic boom had a minimal effect. Further work is needed to examine the combined effects of visual and acoustical stimuli. For example, trial balloon flights during a study by Brown (1990) indicated additional or interactive effects from the visual stimulus. In situations where background noise from natural sources is continually high the visual stimulus may have a greater effect.

Sensitivity of different species and effect of flock size

Significant variations in the sensitivity of different species have been observed during studies of the effects of aircraft on birds. For example, during observations of roosting waders on Terschelling, the Netherlands, it was found that Oystercatchers were rather tolerant of aircraft disturbance and Bar-tailed Godwits and Curlews were less so (Visser 1986). Different responses were also found during a study of coastal waterfowl in the German Wadden Sea. Brent Geese were amongst the most strongly reacting species (being disturbed in 64-92% of all potentially disturbing situations), together with Curlew (42-86%) and Redshank (70%), with Shelduck (42%) and Bar-tailed Godwit (38%) reacting less often (Heinen 1986). However, identifying consistent trends within species is difficult, as shown by another study of waders on Terschelling by Glimmerveen & Went (1984) where the recovery time following disturbance caused by a small air plane was greater for Oystercatcher (30 minutes before feeding resumed) than Curlew (7 minutes).

The relationship between flock size and disturbance was noted by Bélanger & Bédard (1989) when disturbance rates for staging Snow Geese were higher when more birds were present. Similarly, Owen (1977) observed that larger flocks of Black Brant geese took flight at a greater distance than did smaller flocks when approached by people, and Madsen (1985) observed the same reaction in staging Pink-footed Geese in Denmark. Disturbance behaviour of flocks is largely determined by the behaviour of the most nervous members of the group. Take-off of only a few birds may cause the entire flock to take flight, and the larger the flock the more chance of it containing a higher number of especially susceptible individuals. Thus, species that form large flocks may be more vulnerable to disturbance from aircraft.

Habituation and facilitation

The absence of any visible response of some species to aircraft suggests that, under certain circumstances, habituation may take place. The process of 'learning' that a particular stimulus is not associated with risk is probably encouraged by a more or less constant and predictable exposure to that stimulus. This may be the reason for the presence of Lapwings, gulls and Starlings at airfields where the movements and sound levels of planes are very predictable (Burger 1981). Similarly the habituation of nesting Ospreys to human activity has been shown to vary depending on the frequency and type of disturbance (Daele & Daele 1982). Ospreys nesting near humans, highways and the approach corridors for aircraft habituated to those activities, whereas others nesting farther from humans were less tolerant (Mullen 1985).

The importance of 'predictable' stimuli is illustrated in a study of feeding and roosting waders at Texel, the Netherlands, where it was found that a high degree of habituation had occurred to helicopters passing over at a frequency of 2-3 per hour at 100-300 m altitude. However, 'unusual' types of plane, which show up at low frequencies, still had strong effects (Smit & Visser 1993). This study suggests that birds are able to distinguish between types of plane as they do between aerial predators. Koolhaas *et al* (1993) note that habituation is only likely to develop in those individuals that are persistent in using an area throughout the season. Furthermore it is likely that birds never habituate to some types of disturbance. For example, studies of the effects of shooting ranges on roosting waders on Vlieland, the Netherlands, suggest that certain species could not habituate and, as a result, moved to alternative sites (Tanis 1962). Similarly, in a study of wintering Dark-bellied Brent Geese it was noted that, although birds quickly became habituated to most sounds, they never habituated to small, low-flying aircraft (Owens 1977). Jensen (1990) also found that moulting Black Brant geese did not habituate to over-flights.

The opposite to habituation, referred to as facilitation, may also occur when a combination of disturbing stimuli leads to an impact that far exceeds the effect that each activity alone would have had. For example, a study by Smit & Visser (1993) at Texel showed that, following exposure to an unusual aircraft type, otherwise habituated birds became more vulnerable to other forms of disturbance. Thus, an over-flying Grey Heron could cause a panic reaction much greater than would occur under normal conditions. A similar effect was found by Küsters & Raden (1986) on Sylt, Germany, where over-flying jets appeared to have greater effects when wind surfers had previously been in the area. Thus, the effect of facilitation is that birds become much more sensitive to relatively low levels of disturbance.

Impacts of aircraft disturbance on bird populations

As described above, the response of birds to disturbing events depends on a wide range of factors. These include the level of disturbance, reactions of other birds nearby, flock size and knowledge from earlier experiences (habituation and facilitation). Additional factors determine either their willingness to remain in the same place (scarcity of food, adverse weather, physiological condition of individual birds) or their motivation to leave for another place (daily and annual patterns of movement related to time of year and tidal level, or the presence of alternative sites). For this reason it is difficult to accurately predict the response of birds to different sources of disturbance. However there is evidence that, under certain circumstances, disturbance can have serious consequences for bird populations. The evidence of disturbance-related effects on bird populations is presented under the following categories of impacts.

Reduced food intake rates

There is general evidence that disturbance can significantly reduce food intake rates. For example, Beliën & Brummen (1985) found that birds forced out from preferred feeding areas may often simply wait until the source of disturbance has disappeared before resuming feeding. This was shown by the experimental disturbance of a single Oystercatcher. The bird was forced out from its preferred feeding site to another area where, despite the presence of other feeding birds, its intake rate dropped to almost zero. These results are confirmed by Hooijmeijer (1991) during similar work on Oystercatcher at Texel, the Netherlands. This showed that resting and walking during disturbance become the more dominant behaviour than feeding. Also, the food intake rate during the recovery period following disturbance was much higher than normal, presumably a result of birds trying to compensate for the loss of feeding time. Similarly, in response to frequent helicopter disturbance, the amount of time spent grazing by Pink-footed Geese in Northeast Greenland was decreased (Mosbech & Glahder 1991). Instead, the geese spent more time on the water and resting on ice floes. It was concluded that helicopter disturbance had a drastic impact on the time budget of Pink-footed Geese in this area.

Obviously, the impact of reduced intake rates will depend on other factors, including the physiological condition of the disturbed birds and their ability to compensate, for example, by feeding at night. This is illustrated by a simulation of the impact of helicopter flights on staging Black Brant geese which indicated that disturbance could result in significant weight loss (Miller 1994). Taylor (1993) found that Black Brant nearing the completion of wing moult are 'nutritionally emaciated' and that, for birds already in such poor condition, the additional loss of weight resulting from disturbance could result in abnormal or incomplete moult, if not decreased survival. Concerning compensation for reduced intake rates, Jensen (1990) suggested that gut capacity and passage rates and forage digestibility might limit the ability of Black Brant to compensate for lost feeding.

Increased energy expenditure

A potentially serious consequence of the extra flights needed to escape sources of disturbance is that energy expenditure will increase. The energetic costs of man-induced disturbance to staging Snow Geese in the Montmagny bird sanctuary, Québec, have been estimated by Bélanger & Bédard (1989). Human activities here accounted for over 80% of all disturbances recorded, with hunting and over-flying aircraft ranked highest. Two responses of birds to disturbance were considered: birds fly away but promptly resume feeding; and birds interrupt feeding altogether. The average rate of disturbance (1.46/hr) for the first response was estimated to result in a 5.3% increase in hourly energy expenditure combined with a 1.6% reduction of energy intake. The disturbance for the second, more prolonged, response was estimated to result in a 3.4% increase in hourly energy expenditure and a 2.9% reduction of energy intake. A conclusion from this study is that high levels of disturbance may have harmful energetic consequences for Snow Geese in Québec. More than two disturbances per hour may cause an energy deficit that no behavioural compensatory mechanism (such as night feeding) can counterbalance. Davis & Wiseley (1974) carried out similar work and claimed that an average seasonal disturbance rate of one event every two hours would cause a reduction of 20.4% in the energy reserves of staging Snow Geese. White-Robinson (1982) noted that wintering Black Brant geese increased their energy expenditure by 15% because of flights in response to disturbance.

Decreased breeding productivity

Disturbance caused by aircraft can have a range of impacts on breeding birds. Harmful effects include interference with courtship and initial nesting activities, the loss of eggs and chicks as a result of predation or exposure to adverse weather, and greater chick mortality due to starvation or premature fledging. However, the linkage between disturbance and decreased breeding productivity is not always clear and often it is not possible to conclusively show adverse effect. For example, the study by Dunnet (1977) of cliff-nesting seabirds found no evidence that aircraft affected incubating and brooding Kittiwakes, though habituation may have influenced the results. Some of the most dramatic evidence comes from 'catastrophic' incidents of the type described at Ailsa Craig (Zonfrillo 1992) where a low over-flight by a Hercules transport aircraft resulted in the estimated loss of 2000 Gannet eggs or chicks to gull predation. Another incident at the same location caused young auks, mostly Guillemots, to panic and fall from their ledges, resulting in the death of at least 123 birds. A similar panic response has been recorded for species of heron where, because of flimsy nest construction and vulnerable locations, rapid flights from the nest can result in the loss of eggs or young (reviewed in Bell 1972).

More subtle effects were suggested by Burger (1981) in a study of Herring Gulls nesting near Kennedy International Airport. These birds had a lower mean clutch size than expected and it was proposed that this was an indirect result of aircraft disturbance. Significantly more gulls flew up and engaged in more fights when aircraft flew overhead than under normal conditions and it was observed that eggs were broken during these fights. Under normal conditions fights between gulls do not occur because adults return to their nests at different times. However, the aircraft disturbance synchronized the landings of close nesting pairs thus increasing the likelihood of territorial disputes. Chick mortality as a result of aircraft disturbance is also cited by Grubb & Bowerman (1997) where the death of a nestling Bald Eagle was attributed to frequent helicopter flights less than 30 m from the nest which significantly reduced prey deliveries by the adults.

Birds are particularly sensitive to disturbance early in the breeding season. For example, Palmer (1976) and Myerriecks (1960) discuss the sensitivity of Great Blue Herons to startle effects during the early stages of courtship and nesting. Similarly, in a review by Vana-Miller (1987), sporadic activity following the initiation of nesting has been found to have severe effects on Osprey reproduction.

Physiological changes

There has been much experimental work on the effect of noise on the physiology of animals, both wild and domestic (Bell 1972, Fletcher 1988). For example, research on heart-beat rates of breeding Adélie Penguins has shown that rates increase as helicopters fly in the vicinity of their colonies, even when birds remained on their nest and showed no other signs of stress (Culik 1990). This work suggests that unusually loud noises can result in physiological changes that can be equated with increased stress. It has been speculated that continual exposure to disturbance of this nature, although having little visible effect, may reduce reproductive success. A similar effect has been suggested for Black Brant geese in Alaska where stress from aircraft over-flights might inhibit their ability to complete their moult while maintaining or acquiring the body condition necessary for migration (Taylor 1993).

Habitat loss

Frequent and high levels of disturbance can effectively result in habitat loss. This may be in the form of decreased carrying capacity where an area becomes less used by birds or, at its most extreme, it can occur when birds move away from a disturbed site permanently. An example of the latter is cited by Grubb & Bowerman (1997) where aircraft disturbance caused Bald Eagles to depart an area entirely. Consequently, displaced birds may have to feed at higher densities elsewhere, which may effect food intake due to increased competitive interactions between birds.

Mitigation of aircraft disturbance

Any attempt to reduce the effects of aircraft disturbance, for example by setting tolerance distances or disturbance-free zones, is complicated by the large variation in vulnerability to disturbance. This variability occurs across species and within species, across habitat types and between sites, and where exposure to disturbance causes varying amounts of habituation or facilitation. However, there are certain general principles which may help reduce disturbance in most circumstances. Also, a small number of case histories exist that may provide useful examples of effective mitigation measures under certain circumstances.

Timing

The potentially damaging effects of disturbance are greater for birds at particular times of the year. For example, disturbance is most likely to result in greater mortality of wintering birds in conditions of severe weather when food intake rates are reduced and fat and energy reserves are low. As illustrated above, birds are also very vulnerable to disturbance during the breeding season. Thus if aircraft disturbance can be removed or reduced at these critical times then overall impacts may be greatly reduced. Birds are also more vulnerable to 'unusual' disturbance events, for example unfamiliar aircraft types or unpredictable flight behaviour, and these should be avoided at critical times of the year.

Aircraft type

Certain types of aircraft create more disturbance than others. The existing research suggests that the use of helicopters in particular should be avoided in areas of importance for birds. There is also some evidence that ultra-lights are especially disturbing.

Flight distance, altitude and frequency

In some circumstances the use of zones around sensitive bird areas to restrict aircraft movements may be appropriate. Both lateral and altitudinal restrictions may be beneficial, although distances will vary with species and site. For example management plans for Bald Eagles in North America typically include restrictive buffer zones limiting human activity around nest sites and other key habitat areas such as foraging sites. Grubb & Bowerman (1997) suggest that aircraft would best be excluded from within 600 m of nest sites and key habitat areas during the breeding season. Work by Visser (1986) suggests that an exclusion zone of 1000 m may be required to prevent disturbance of roosting waders and Owens (1977) reports disturbance of Brent Geese up to 1.5 km distance. Turning to altitudinal restrictions, the results of the studies of Snow Geese in Québec and Brent Geese in Essex suggested that flights below 500 m over sanctuaries should be prohibited (Bélanger & Bedard 1990, Owens 1977). The work on Black Brant geese by Ward *et al* (1994) indicates that a flying altitude of at least 610 m is necessary to minimise disturbance. The simulation of helicopter disturbance of Black Brant geese by Miller (1994) predicted that the impact of helicopters could be greatly reduced by flying over 1065 m, minimizing flight frequency and by avoiding the use of larger (and thus noisier) helicopter. Similarly, in relation to flight frequency, Bélanger & Bedard (1990) recommended that human disturbance, particularly aircraft over-flights, should be reduced to less than one event per hour.

No-fly zones

There are two mechanisms for identifying such no-fly zones in the UK. The Civil Aviation Authority (CAA) publishes information on 'Bird Sanctuaries' and the MoD identifies national 'Avoidance Areas'. Both rely on map-based information to warn pilots of the location of large numbers of birds in order to reduce the risk of bird strike. The CAA defines a Bird Sanctuary as an *airspace of defined dimensions within which large colonies of birds are known to breed.* The location of these sanctuaries are listed in the UK Aeronautical Information Publication (AIP), an important reference for all civil pilots, giving details of location, avoidance distances (up to 3 nm) and heights (up to 4000 ft). Pilots are requested to avoid the Bird Sanctuaries during a particular period or during the breeding season. They are also advised to avoid flying at less than 1500 ft above surface level over areas where birds are likely to concentrate, such as offshore islands, headlands, cliffs, inland waters and shallow estuaries. The AIP recognizes that, apart from the danger to flying aircraft, the practice of flying close to breeding birds should be avoided for conservation reasons. However, these warning are only advisory for civil pilots.

The MoD can designate permanent and seasonal Low Flying Avoidance Areas to restrict the use of low-flying military aircraft. These are part of the UK Low Flying System (UKFLS) which aims to spread low-flying activity as widely as possible in order to reduce the burden of disturbance in any one area. Military aircraft are deemed to be low-flying when, in the case of fixed wing aircraft, they are less than 2000 ft above the surface, and for propeller-driven light aircraft and helicopters, when they are less than 500 ft. Avoidance areas include civil airspace around airports, airfields and glider sites, industrial sites, major built-up areas, stud farms and hospitals. Some bird reserves and sanctuaries are also included, although the list is far from comprehensive and requires a review.

Reducing other sources of disturbance

Finally, in circumstances where it is not possible to reduce or eliminate aircraft disturbance, it may be beneficial to reduce other sources of disturbance present on the site. This requires an integrated approach to controlling disturbing activities such as wildfowling, sailing and public access through temporal and spatial zoning. For example, the designation of refuges from wildfowling disturbance may help reduce the effects of facilitation and thus lessen the impacts of aircraft activity.

Conclusion

As with all forms of disturbance, it is often difficult to identify the effects of aircraft on birds, especially at the lower levels of potentially disturbing activities. Detecting effects is further complicated by the great variation in response of birds to aircraft, depending on a whole range of factors including aircraft type, proximity and frequency of flights and noise levels. Add to this variation the additional factors of flock size, habituation and facilitation, and it quickly becomes apparent that simple generalisations regarding the effects of aircraft cannot be made. This is especially so when consideration is given to the host of other variables that influence bird populations, including food availability, habitat change, competition, predation and weather. However, from the current information on aircraft disturbance the following general points can be made:

- Low-flying helicopters and ultra-lights cause the greatest level of disturbance.
- Low flight altitudes cause most disturbance; flights over sensitive bird areas should be at least 500 m above surface levels, and preferably over 1000 m (especially for helicopters).
- Unpredictable, curving flight lines are more disturbing than predictable, straight flight lines; birds can often habituate to regular and predictable events.
- The impact of aircraft disturbance may be increased if other sources of disturbance effect the same area.
- Cliff-nesting and other colonial seabirds during the breeding season and flocks of waterfowl during the winter are most vulnerable, especially during severe weather conditions.
- No-fly zones should be sought if serious disturbance is apparent.

Any future studies of the effects of aircraft disturbance, as with all forms of potentially disturbing activity, should take into account a range of factors: the intensity, duration and frequency of disturbance; proximity of source; seasonal variation in sensitivity of affected species; whether birds move away and return after disturbance ceases; whether there are alternative habitats nearby; and whether there are additional forms of disturbance. Ideally work on disturbance effects should include before-and-after studies and experimental controls. However, the flexibility for before-and-after studies rarely exists and often the disturbance is established and on-going. In these circumstances several sites should be studied and as many variables as possible should be measured in order to identify reliable correlations between bird activity and disturbance.

Once an effect has been identified, it is rarely possible to establish an impact on population dynamics and survival without extensive research into the behavioural responses of individual birds. As research of this nature requires significant time and resources it is not always practicable. Where time or resources are constraining it will be necessary to rely on existing research results as presented here to indicate *potential* impacts. Thus, for examples of higher levels of disturbance where an effect has been established, the existing research literature that identifies impacts on populations should be used to reinforce the precautionary approach. However, the evidence for impacts at the lower levels of disturbance is less strong and this requires further research.

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