Quick-scan: Effects of low-flying aircraft on wildlife

Appendix: Literature Review

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ABSTRACT

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1 Review: Birds and low-flying (military) aircraft

1.1 Birds of Prey

Table 1.1. Effects of low-flying (military) aircraft on Bald eagle (Haliaeetus leucocephalus).

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Stalmaster et al. 1997 [USA/Washington]	*Objective: assessment of flushing responses of wintering Bald eagles to military firing activity, helicopter overflights, and boating on river and a creek on the Fort Lewis Army Reservation.* • The birds in the Fort Lewis Army Reservation are regularly exposed to disturbance and might be expected to have become used to this. • The helicopters used were UH-1 Huey and OH-58 Bell, flying at 60-120 m altitude and 35-55 km/h speed.	• It is recommended to restrict air traffic to a minimum 300 m above ground level.
	• 47% of 919 Bald eagles flushed in response to 48 **helicopter** overflights, 37% on the river (n=14) and 53% on the narrower creek (n=34). • Subadults flushed more often than adults (43% and 54%, respectively). • Eagles feeding or standing on the ground flushed more often than those perching in trees. • Few eagles were observed flushing to high-altitude (>330 m) helicopter traffic in the same area.	
Watson 1993 [USA/Washington]	*Objective: to determine nest success, including assessment of responses of nesting Bald eagles to helicopter overflights.* • The birds were regularly exposed to aircraft activities (military aircraft and float planes) throughout the area and might be expected to have become used to this. • The **helicopters** used were turbine-engine Hiller/Soloy UH-12E and Bell 206-BIII (which are quieter than comparable piston-driven helicopters).	• Helicopter surveys should maintain a flight approach distances of ≥60 m from nests. • Hovering rather than moving approaches may increase agitation responses but adults

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Eagles were disturbed in 53% of the encounters (n=142). • Disturbed eagles either flushed (68%) or were agitated but did not flush (32%). • Disturbance rates and flush distances from survey helicopters were affected by encounter distance and nest tenacity. • Disturbance rates varied significantly with encounter distance. • Eagles were disturbed at higher rates when there were no young in the nest, when they were perched <60 m from the nest, or when the helicopter hovered rather than moved towards the nest. • Flushed eagles (n=97) circled and soared (56%), evaded the helicopter (21%), returned to their nests (12%), or approached the helicopter to attack (11%). • Agitated eagles (n=45) vocalized (57%), crouched (25%), or perched at flight-attention (18%). • Nestlings rarely displayed behavioral changes on approach of the helicopter; none were flushed, trampled by adults, or known to have been bumped from nests by flushing adults. • Flush distance was on average 102 m (SE=7.7, n=97).	may allow closer approaches before flushing.
Grubb & King 1991 [USA/Arizona]	*Objective: to present a hierarchical classification tree model (CART) for evaluating human activities potentially disturbing breeding Bald eagle.* • Level of overflights above ground are not mentioned.	• Exclusion of aircraft within 625 m and permitting only short duration flights within 1,100 m

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Parameter ranking in CART ranks distance as the most important classifier or splitting variable for determining if aircraft overflights (n=2,849) were disturbing. • The overall ranking was: distance > duration > visibility > number > position > sound. • Aircraft had a response frequency of 42% within 625 m distance, what increased to 65% within 172 m distance. • A response was observed in 33% of the events of potentially disturbing aircraft activity (n=2,849) within 2000 m of breeding Bald eagles; i.e. alert 29%, flight 3%, departure 1%; median distance 550 m. • For light planes the response was 27% (n=1,543; alert, flight, departure: 25%, 1% and 1%), median distance 700 m. • For helicopters the response was 47% (n=718; alert, flight, departure: 36%, 9% and 2%), median distance 400 m. • For jets (Grubb & Bowerman 1997: = military jet fighters) the response was 30% (n=588; alert, flight, departure: 28%, 1% and 1%), median distance 500 m.	should minimize disturbance of breeding Bald eagles. To be most effecttive, management of bald eagle breeding areas should also address habitat and behaviour for each site specifically.
Grubb et al. 1992 [USA/Michigan]	*Objective: to evaluate human–breeding Bald eagle interacttions by applying the parameter ranking in CART classification tree model.* • Level of overflights above ground are not mentioned. • Adults responded (alert and/or flight) more frequently than nestlings. • Adults responded (alert and/or flight) at greater distances-to-disturbance when perched away from the nest. • Distance from eagle to aircraft, duration of overflight and number of aircraft and/or passes were the most important characterristics influencing eagle responses. • A response of breeding eagles was observed in 29 % of the events of potentially disturbing **aircraft** activity within 2000 m of breeding Bald eagles (n=341); median distance 500 m. • For **light planes** the response was 15% (n=52), median response distance 800 m. • For **helicopters** the response was 29% (n=48), median distance 700 m.	• Management of human activities for the protection of breeding Bald eagles should begin with a no-activity primary zone at 500-600 m from nest sites, followed by a secondary zone at 1000-1200 m.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• For **jets** (Grubb & Bowerman 1997: = **military jet fighters**) the response was 31% (n=241), median distance 500 m.	
Grubb & Bowerman 1997 [USA/Arizona & Michigan]	*Objective: to evaluate the combined results of Grubb & King 1991/Grubb et al. 1992.* • Level of overflights above ground are not mentioned. • **Helicopters** elicited the geatest frequency of response (47%), followed by **military jet fighters** (31%) and **light fixed-wing planes** (26%). • Frequency of response (23-61%) and frequency of flight (2-13%) both increased through the nesting season from February to June. • The analysis indicates a categorical exclusion of aircraft within 600 m of nest sites would limit bald eagle response frequency to 19%. • CART modeling verified distance as the most critical determinant between response and no-response associated with aircraft. Duration-of-overflight was a consistent second and number-of-units-per-event third.	• Management plans for Bald eagles should categorically exclude aircraft from within 600 m of nest sites and key habitat areas during the breeding season.
Fraser et al. 1985 [USA/Minnesota]	*Objective: to document the effect of disturbance on the behaviour of breeding Bald eagle.* • **Fixed-wing aircraft** (Cessna) passing 20-200 m from the nests for weekly observations did not flush incubating or brooding eagles.	• None.

Table 1.2. Effects of low-flying (military) aircraft on Osprey (Pandion haliaetus).

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Trimper et al. 1998 [Canada/Labrador]	*Objective: to examine the 2.5 nautical miles (nm) radius exclusion area of active nest sites of osprey from low-level overflights (defined as 100-500 ft, or 30-150 m above ground) for the duration of the breeding season.* • Military CF-18 Hornet **fighter**, flying near five nests at distances ranging from 2.5 nm to directly overhead (as low as 30 m above ground) at speeds of 400-440 knots. Experimental design: seven nesting pairs (five treatment; two control). • Osprey in the study area may have habituated to overflights during exposures in previous years.	• None.
	• Osprey behaviour did not differ significantly between pre- and post-overflight periods. Adult ospreys did not appear agitated from overflights at 0.75, 1.25 or 2.5 nm. • The reaction of adults varied from alertness, focused observation of the aircraft, to adjustment in incubation posture. Adult ospreys often stared in the direction of the approaching aircraft before it was audible (to the observers). • No observed Adverse Effects Levels: 1.39 km horizontal distance, 30 m altitude, 100 dB maximum sound pressure levels.	

Table 1.3. Effects of low-flying (military) aircraft on Peregrine falcon (Falco peregrinus).

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Palmer et al. 2003 [USA/Alaska]	*Objective: to examine the hypothesis that low-altitude* **jet aircraft** *overflights affect parental care, i.e. nest attendance, time-activity budgets and provisioning rates, by Peregrine falcons.* • Previous exposure of nesting Peregrine falcons to overflights was not known, though some exposure was likely.	• None.
	• Subtle effects of low-altitude jet aircraft overflights (at or below 150 m) on parental behaviour were detected, but no evidence was found that overall parental attendance patterns differed depending on exposure to overflights. • Differences depended on stage of the nesting cycle and gender. • During incubation and brooding stages, males attended the nest ledge significantly less when overflights occurred than did males from reference nests. Females attended the nest ledge significantly more during overflown periods compared to females from reference nests. • While females were still brooding nestlings, they were less likely to be absent from the nest area during periods when overflights occurred than females from reference nests. • There were differences in nest attendance and time-activity budgets between overflown and reference nests, but no differrences between periods with overflights and periods without overflights at the same nests. • There was no significant relationship between nest attendance and the number of overflights occurring within a given time period, the cumulative number of above-threshold noise events at each nest, or the average sound-exposure level of overflights. • There was no evidence that nestling provisioning rates were affected by overflights.	

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Ellis et al. 1991 [USA/Arizona]	*Objective: to determine which, if any, of the possible adverse responses listed below were operative in the case of raptors: (1) interruption of parental behaviour (leading to exposure of eggs or young to inclement weather), (2) physiological stress of parents or young (leading to reduced reproductive performance), (3) eyrie abandonment (immediate and long term), (4) accidental death due to premature fledging or startled young, and (5) loss of eggs or small chicks from the eyrie by startled adults (as observed in response to gunshots).* • About 1100 exposures to aircraft (F-4s, F-7s, F-10s, F-104s) passes within 500 m from the birds or nests, and sonic booms (real and simulated: 118).	• None.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Responses to **(military) jet aircraft**: 1. Small (downy) nestlings did not respond noticeably. 2. Large nestlings in exposed nests (e.g. stick nests in trees) were alerted by, and sometimes cowered below, the closest aircraft (100 m or less). 3. Large nestlings in cavity nests often fled into the cavity and cowered in response to the closest aircraft. 4. Large nestlings were alerted by distant aircraft (>500 m), but showed no alarm. 5. Adults ignored or casually watched craft >500 m distant. 6. Adults were normally alerted or alarmed by craft <300 m. Occasionally, adults ignored but some fled from the closest aircraft. 7. Non-breeding or pre-breeding prairie falcons were more likely to flush and/or flee in response to test stimuli than pairs attending eggs or nestlings. 8. Adult behaviour suggesting that site abandonment was imminent was not observed. 9. Nestling behaviour suggesting that premature fledging was imminent was not observed. • Responses to **booms**: 1. Small nestlings did not respond noticeably. 2. Large nestlings were alerted or alarmed or, less often, they cowered. 3. Adults were frequently alerted or alarmed by extreme booms. Occasionally, adults gave no apparent response to very loud booms, however, some birds briefly fled in response to loud booms. 4. Adult behaviour indicative of offspring endangerment or site abandonment was not observed. • Long term behavioral responses: 1. The reproductive rates for test eyries in 1980 and 1981 were at or above normal. 2. The reoccupancy rates for sites experimentally disturbed in 1980 were at or above normal.	

Table 1.4. Effects of low-flying (military) aircraft on Red-tailed hawk (Buteo jamaicensis).

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Andersen et al. 1989 [USA/Colorado]	• Hawks nesting where low-level air traffic was non-existent prior to the study period exhibited stronger avoidance behavior than did hawks nesting where helicopter activity had occurred since long. • 53% of the birds in the first area flushed from the nest while 8% flushed in the second area. • Age of nestlings did not influence avoidance behavior. • Overflights did not appear to influence nesting success. • The results suggest the hawks habituate to low-level overflights of helicopters during the nesting period.	• None.

1.2 Owls

Table 1.5. Effects of low-flying (military) aircraft on Mexican spotted owl (Strix occidentalis lucida).

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Delaney et al. 1999 [USA/New Mexico]	*Objective: (1) record, characterize, and quantify* ***helicopter*** *overflights at Spotted owl roost sites during a post- or non-nesting season and at active nest sites during the nesting season, (2) develop a dose-response threshold relation for quantifying Spotted owl behavioral responses to variation in noise levels and stimulus distances, (3) determine if helicopter overflights affect Spotted owl reproductive success (successful nests) or productivity (young fledged), and (4) develop disturbance-specific management guidelines to minimize potential effects from helicopter overflights on the Lincoln National Forest.* • 161 manipulations = overflights of helicopters (Sikorski HH-60G, Pave Hawk, twin-jet helicopters), 15, 30 and 60 m above ground level, speed 150-170 km/h.	• A 105 m radius, hemispherical protection zone should eliminate Spotted owl flush response to helicopter overflights in the study area. • Helicopter overflights between 3 hours past sunset and 3 hours preceding dawn should minimize effects on Spotted owl behaviour.
	• Manipulated and non-manipulated nest sites did not differ in reproductive success or the number of young fledged. • As the distance from helicopters to owls decreased, the severity of owl responses increased. • The proportion of owls flushing in response to a manipulation was negatively related to stimulus. • The proportion of owls flushing in response to a manipulation was positively related to noise level. • Flush responses were minimal when the helicopters were >105 m away. Spotted owls did not flush when helicopter SEL (sound exposure level) noise levels were $\leq$102 dBO (92 dBA). • Adult owls were more likely to flush in response to manipulations later in the reproductive season. Female owls only flushed after their chicks had left the nest. • Spotted owls exhibited alert responses when helicopters were an average of 304 ± 148 m away, but showed no response when helicopters were >660 m distant.	

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Prey delivery rates were highly and positively correlated with stimulus distance. Thus, manipulations in close proximity to owl territories may affect delivery rates. • The estimated threshold for detrimentally affecting prey deliveries (96 m) indicates a subflushing response. • The results suggest that Spotted owls may have been habituating to manipulation testing. • Distance was a better predictor of Spotted owl flush response to helicopter flights than noise levels as the helicopter noise varies with a series of conditions of use, topography, weather.	
Johnson & Reynolds 2002 [USA/Colorado]	*Objective: to investigate the effects of military fixed-wing aircraft training on the behavior of the endangered Mexican spotted owl during breeding.* • Fixed-wing **military jet aircraft (F-16)** overflights near or at a minimum height of 660 to 760 m (i.e. minimum height of 460 m for training flights + 200-300 m distance from owl roost site in canyon to canyon rim).	• None.
	• Five (23.8%) of the 21 fly-bys produced no response, nine (42.8%) produced low responses (slow head turn), and seven (33.3%) produced intermediate responses (sudden head turn towards origin of the sound); none produced high responses (flush). • The behavior of the owls during the pre- and post-flyby periods of the sequentially louder fly-bys, showed that the birds that responded at the second or third levels all very quickly returned to normal day-roosting behavior.	

1.3 Waterfowl

Table 1.6. Effects of low-flying (military) aircraft on Whooper swan (Cygnus c. cygnus).

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Rees et al. 2005 [Scotland]	*Objective: analysis of the current variation in the behaviour of wintering Whooper swans to determine whether their susceptibility to human activity changes with time, location and the type of disturbance.* • The birds in the area are regularly exposed to disturbance and might be expected to have become used to this.	• None.
	• **Helicopters** and **other aircraft** alerted the swans at a mean distance of 1355 ± 227 m. • The birds were alert for disturbance by aircraft for 1.71 ± 0.31 min (n=53). The length of time that the birds remained alert was much shorter than for disturbances by other sources. • Disturbance levels are higher for smaller flocks than for larger flocks. • The negative correlation between field size and disturbance distance suggests that the openness of the landscape may be important. • Evidence for habituation to human activity was avoided by a negative correlation between disturbance distance and the number of previous disturbances recorded in the day, but any increase in tolerance did not appear to be maintained over longer periods.	

Table 1.7. Effects of low-flying (military) aircraft on Trumpeter swan (Cygnus buccinators).

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Henson & Grant 1991 [USA/Alaska]	*Objective: attempt to quantify effects of human disturbance, including* **air traffic** *when passing below 615 m above the ground, on breeding Trumpeter swans.* • There is regular air traffic over much of the Copper River Delta consisting primarily of small, fixed-wing airplanes, with smaller numbers of helicopters and large commercial jets. The birds might be expected to have become used to this disturbance.	• Restrict use of sources of loud noises on or near Trumpeter swan breeding grounds during the breeding season.
	• .No differences in response to **helicopters**, **small single propeller airplanes** or **large commercial jets** were noted. • Birds frequently reacted to the sound of the approaching aircraft before it became visible. • Regular aircraft overflights alerted birds but did not cause incubating females to leave the nest. • The typical response was for a bird to cease its current activity, assume a head-up (HU) posture for a few seconds to several minutes, and then to resume previous behaviour once the disturbance was no longer heard or seen. • One or both adult swans at 4 nesting territories reacted to aircraft on 19 of 21 overflights (commercial airliner 4, fixed-wing 10, helicopter 5). • There was little difference in the response-no response ratio between male and female swans, but the response time for females was almost double the response time of males. • Incubating females on two occasions took disturbance recess when the nest were circled in a **survey plane** at an altitude of about 60 m. On another occasion a male assumed a hiding posture as a fixed-wing plane passed directly over the wetland. One swan pair nesting within 1.3 km of the main runway of the Cordova Airport were not disturbed by airport traffic.	

Table 1.8. Effects of low-flying (military) aircraft on Brant goose (Branta bernicla nigricans).

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Ward et al. 1994 [USA/Alaska]	*Objective: to measure current disturbance levels and to determine the extent to which disturbance affects the behavior of Brant at the Izembek Lagoon when over 90% of their Pacific Flyway population stages there for 4 to 10 weeks.* • The birds in the lagoon are regularly exposed to disturbance and might be expected to have become used to this.	• None.
	• In response to **helicopters** (n=6), 83% of the flocks left the study area. • Helicopters elicited a mean response of ≥3.4 minutes/disturbance. • Flocks of Brant were disturbed by 49% of **fixed-wing aircraft** overflights and took flight in response to 26% of them. • The proportion of Brant flocks that flew in response to overflight varied with aircraft altitude and lateral distance to the flock. One half of 279 flocks took flight when lateral distance to the aircraft was ≤0.8 km but only 13% of the flocks took flight in response to more distant aircraft. • Within a lateral distance of 0.8 km to the aircraft, Brant flocks were >2 times more likely to respond to fixed-wing aircraft at an altitude of ≤610 m (68%; n=142) than to overflights at >610 m (33%; n=137). • Brant first became alert in response to aircraft at a mean distance of 2.6 km (n=346).	
Miller et al. 1994 [USA/Alaska]	*Objective: Description of a simulation model designed to study the effects of* **helicopter** *disturbance on moulting Pacific brant near Teshepuk Lake, Alaska. The model determined the behavioral and energetic response of every bird encountered by the aircraft during an overflight, then calculating the weight of these birds at the end of wing moult The effects were classified into five risk categories.*	• Weight loss along a given flight line can be reduced by (1) flying at altitudes greater than 1,065 m, (2) flying only when most brants are in their second week of moult, (3) minimizing flight frequency, (4) avoiding use of the larger Bell 412 (instead of the Bell 206) when possible.
	• Model: route/flight line + flock location → lateral distance, lateral distance + altitude → position of helicopter relative to birds, position of helicopter relative to birds + flock size + helicopter type → behaviour, behaviour + productive energy + maintainance energy → total energy → weight/weight loss. • The model can reveal slight changes that result in significant decreases in disturbance.	

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Application of model results in recommendations for mitigation of helicopter disturbance on moulting Pacific brant near Teshepuk Lake, Alaska.	
Ward et al. 1999 [USA/Alaska]	*Objective: to measure behavioral response of staging Brant [and Canada geese] to* **fixed- and rotary-wing aircraft**, *using planned aircraft overflights with control of aircraft type, noise, altitude, and lateral distance to flock, to develop predictive models of the relation between aircraft type, noise, altitude, and lateral distance and the response of geese, and to determine if response declines with sequential cumulative days of exposure to aircraft overflights.*	• Managers of areas with large concentrations of waterfowl should consider lateral distance from the birds as the primary criterion for establishing local flight restrictions, especially for helicopters.
	• Overall, 75% of Brant flocks flew in response to overflights at 30 to 1,219 m altitude and 0.0 to 8.0 km lateral distance. • Tests of accommodation to helicopter* overflights were inconclusive, although there was some evidence for a reduction in response of Brant. • Mean flight and alert responses were greater for fixed-wing aircraft than for rotary-wing aircraft** and for high noise than for low-noise aircraft***. • Increased lateral distance between an aircraft and a flock was the most consistent predictive parameter associated with lower probability of a response by geese. • Altitude was a less reliable predictor because of interaction with aircraft type and noise. • Although mean response of Brant goose generally was inversely proportional to aircraft altitude, greatest response occurred at intermediate (305-760 m) altitudes. • More flocks flew in response to rotary-wing (51%) than fixed-wing (33%) aircraft, and to high-noise (49%) than low-noise (40%) aircraft. • Responses to overflights occurred up to 1,219 m altitude and 4.8 km lateral distance. • Mean flight response decreased with increasing lateral distances, regardless of aircraft type or noise. • Flight response to aircraft at different altitudes was inconsistent: response generally decreased with increased altitude of fixed-wing and low noise aircraft but tended to remain the same or increase with rotary-wing and high noise aircraft. • There was weak evidence for a reduction in mean flight response to rotary-wing aircraft over the 3-6-day exposure period.	

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	* Bell 205, Bell 206-B, Hughes 500-D, Sikorsky HH-3F ** Fixed-wing aircraft = Arctic Tern, Piper 150, Cessna 180, Cessna 206, Piper Navajo, Grumman Goose, Twin Otter; Rotary-wing aircraft = Hughes 500-D, Bell 206-B, Bell 205, Sikorsky HH-3F. *** High noise aircraft = Cessna 206, Piper Navajo, Grumman Goose, Twin Otter, Bell 205, Sikorsky HH-3F, low-noise aircraft = Arctic Tern, Piper 150, Cessna 180, Hughes 500-D, Bell 206-B.	

Table 1.9. Effects of low-flying (military) aircraft on Dark-bellied brent goose (Branta b. Bernicla).

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Holm 1997 [Denmark]	*Objective: to descripe reactions of Brent geese to* **helicopter** *traffic during spring staging.* • The island was since the early 1980s exposed to overflights of helicopters (Super Puma MK1 and Bell 212) at a speed of ca. 250 km/h and 185 km/h, respectively, following one or two fixed routes at 300 to 650 m elevation 4-6 times a day on working days and Saturdays. In addition, nonscheduled, pilot training flights and military traffic occurred.	• None.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Low flying helicopters disturbed the geese more often and caused greater alertness in flocks than helicopters at normal flying height. • There was no statistical significant correlation between uplift or vigilance and flock size. • Overflights following the most frequently used route evoked relatively little disturbance. • Low overflights caused comparatively frequent disturbance. • Overflights following unusual routes caused comparatively frequent disturbance. • In 25 (21%) out of 120 occurrences, helicopters put almost two thirds of the Brent goose flocks to flight. On average, 62% (SE=7.3%, n=25) of the flock took flight in these cases. • When helicopters did not cause upflights, they caused increased vigilance with 66%, about twice as many geese to be vigilant as in undisturbed situations. • During all helicopter flights, an average of 23% of the Brent flock (SE=2.6%, n=111) assumed the vigilance posture, significantly more than the average vigilance posture of 10.3% (SE=0.26%, n=1526) in undisturbed flocks.	
Riddington et al. 1996 [UK]	*Objective: identification of the sources of current disturbance of wintering Brent geese in a coastal area and assessment of their effects.* • The birds in the area are regularly exposed to disturbance and might be expected to have become used to this.	• On goose refuges, regulating disturbance from high-impact sources, not only within the refuge but also on adjacent areas, may be far more effective in providing an undisturbed site than restricting human access well away from grazing areas. • Imposing a minimum height for aircraft, possibly no lower than 500 m.
	• A total of 160 disturbance events were observed on pastures, the most frequent source being pedestrians (31.9%), followed by **not specified aircraft** (19.4%). • Flight duration in response to aircraft and gunshots was much higher than that in response to other human sources (pedestrians, vehicles)	

Table 1.10. Effects of low-flying (military) aircraft on Canada goose (Branta canadensis tavereri).

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Ward et al. 1999 [USA/Alaska]	*Objective: to measure behavioral response of staging [Brant] and Canada geese to* **fixed- and rotary-wing aircraft**, *using planned aircraft overflights with control of aircraft type, noise, altitude, and lateral distance to flock, to develop predictive models of the relation between aircraft type, noise, altitude, and lateral distance and the response of geese, and to determine if response declines with sequential cumulative days of exposure to aircraft overflights*	• Managers of areas with large concentrations of waterfowl should consider lateral distance from the birds as the primary criterion for establishing local flight restrictions, especially for helicopters.
	• Overall, 9% of Canada goose flocks flew in response to overflights at 30 to 1,219 m altitude and 0.0 to 8.0 km lateral distance. • Tests of accommodation to helicopter* overflights were inconclusive. • Mean flight and alert responses were greater for fixed-wing aircraft than for rotary-wing aircraft** and for high noise than for low-noise aircraft**. • Increased lateral distance between an aircraft and a flock was the most consistent predictive parameter associated with lower probability of a response by geese. • Altitude was a less reliable predictor because of interaction with aircraft type and noise. • Although mean response of Canada goose generally was inversely proportional to aircraft altitude, greatest response occurred at intermediate (305-760 m) altitudes. • The mean percentage of flocks that responded was greater for rotary-wing (41%) than fixed-wing (20%) aircraft, and for high noise (43%) than low noise (31%) aircraft. • Mean flight response decreased with increasing lateral distances, regardless of aircraft type or noise. • Flocks rarely flew in response to fixed-wing (5% of flocks responded) or rotary-wing (11% of flocks responded) aircraft. • Mean response decreased or remained the same as altitude increased for fixed-wing aircraft and high-noise and low-noise aircraft, but mean response increased for rotary-wing aircraft.	

	* Bell 205, Bell 206-B, Hughes 500-D, Sikorsky HH-3F ** Fixed-wing aircraft = Arctic Tern, Piper 150, Cessna 180, Cessna 206, Piper Navajo, Grumman Goose, Twin Otter; Rotary-wing aircraft = Hughes 500-D, Bell 206-B, Bell 205, Sikorsky HH-3F. *** High noise aircraft = Cessna 206, Piper Navajo, Grumman Goose, Twin Otter, Bell 205, Sikorsky HH-3F, low-noise aircraft = Arctic Tern, Piper 150, Cessna 180, Hughes 500-D, Bell 206-B.	

Table 1.11. Effects of low-flying (military) aircraft on Greater snow goose (Chen caerulescens atlantica).

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Bélanger & Bédard 1989 [Canada/Quebec]	*Objective: establish the effects of current human disturbance on staging Greater snow geese during spring and fall in the Montmagny bird sanctuary.* • Non-specified, transport related activities, particularly low-flying aircraft (e.g., **planes, helicopters**), caused ≥45% of all human disturbances (652) in spring and fall on staging geese. • Study recorded only disturbances severe enough to cause geese to take flight. • Geese spent more time flying after transport-related disturbances than they did after any other type of disturbance. • Geese often stopped feeding following overflights at an unquantified slant distance. Loss of feeding time was always at least 15 min per disturbance. • Time to resume feeding was not influenced by the type of human disturbance but was generally greater in fall than in spring and that, for most disturbance types, mainly for aircraft. • When the mean hourly disturbance rate was greater than 2 per hour, the numbers of geese were lower the next day.	• Flights below 500 m should be prohibited.

Table 1.12. Effects of low-flying (military) aircraft on King eider (Somateria spectabilis) and Pacific eider (Somateria mollisima v-nigra).

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Mosbech & Boertmann 1999 [Greenland]	*Objective: to identify locations and numbers of moulting and post-breeding King eiders by aerial survey. Secondary to this aim, the King eider response to the approaching* ***survey plane*** *was studied.* • King eiders exhibit avoidance behavior in response to an approaching aircraft. • Flocks of King eiders dispersed by diving in different directions when the plane was still a kilometer away. This behavior was more pronounced in areas with more disturbance (hunting), and also when the survey aircraft was flying at high altitudes (2000 feet). In remote areas, avoidance diving was reduced. • Flocks began responding to the approaching aircraft by either alert behaviour or swimming away from the coast at distances between 500 m and 5 km. • For mid-day overflights, the reaction distance for the first reaction was found to be significantly greater at 400 feet than at 250 feet altitude. For approaches at 400-1800 feet, however, the distance for the first reaction was found to be negatively correlated with flying altitude. • The intermediate reaction of avoidance swimming and spreading out started up to 3 km from the approaching airplane. This was not observed in all flocks or in approaches at an altitude of 250 feet. • The strongest reaction of avoidance diving was observed approximately 1 km from the approaching plane, at an altitude of 250 feet, but not at approaches at higher altitudes. • Avoidance reaction was less in the morning when King eiders forage, than at mid-day when most King eiders rest.	• None.
Johnson et al. 1987 [USA/Alaska]	*Objective: To test the hypothesis that industrial activities on Thetis Island in 1983 would have no measurable negative effect on the number of nests or the of Pacific eiders on either island during the 1983 breeding season, as compared to historical data.* • Potential sources of disturbance included all **aircraft** flights in the vicinity, with special attention being given to the two twin-engine helicopters (Bell 212 and Messerschmitt Bolkov BO-105CBS). • Pacific eiders did not appear to react to the routine flights of the **helicopters** as they flew to and from Thetis Island outside the 1.8 km buffer zone.	• None.

*Table 1.13. Effects of low-flying (military) aircraft on American black duck (Anas rubripes) and Wood duck (Aix sponsa) and Harlequin duck (*Histrionicus histrionicus*).*

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Conomy et al. 1998 [USA/North Carolina]	• In experiments, initial exposure to **jet aircraft** noise elicits behavioral responses from Black ducks and wood ducks. • With continued exposure to aircraft noise, Black ducks may become habituated, but Wood ducks did not exhibit the same pattern of response. • The results suggest that the ability of waterfowl to habituate to jet aircraft noise may be species specific. • In the experiment, the proportion of times Black ducks reacted to visual and auditory aircraft activity decreased from 38 to 6% during the first 17 days of confinement. • Response rates remained stable at 5.8% thereafter. • The proportion of times Black ducks reacted to exposure to 6 different recordings of jet noise decreased significantly from first day of exposure (25%) to last (i.e., day 4; 8%). • Wood duck responses to jet noise did not significantly decrease uniformly among experimental groups following initial exposure to noise.	• None.
Harms et al. 1997 [USA]	*Objective: Development of a technique for heart rate biotelemetry transmitter implantation to monitor heart rate fluctuations of Black ducks in response to simulated aircraft noise in a large outdoor enclosure. Aircraft noise was computer generated, replicating an* **FB-111 jet** *flying 70 m above ground level.*	• None.
	• Acute responses to noise events were not evident consistently. • When present, heart rate increases in response to noise events were short-lived and only evident during the first day of the noise events. Habituation to frequent loud aircraft noises occurred rapidly in a few days. • A behavioral response often accompanied a heart rate response. • Outside disturbances sometimes influenced heart rates when a programmed noise did not. • A light single-engine (fixed-wing) plane that happened to fly over the flight pen less than 1 min prior to a noise event caused the ducks to raise their heads and to track the plane visually, while spiking a brief increase in heart rate, where after the ducks showed neither	

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	behavioral nor heart rate response to the ensuing noise broadcast.	
Goudie & Jones 2004 [Canada/Labrador]	*Objective: to experimentally quantify the dose-response relationship between* **military jet** *noise and avian behaviour, i.e. on behaviour of breeding pairs of Harlequin ducks.* • Design of the experiment: before-after-control-impact (BACI). • Low-level passes (30-100 m above ground level), noise generated >100 dBA, background sound levels 40-70 dBA. • Harlequin ducks reacted to noise from military jets with alert behavior, showing a positive dose-response that especially intensified when noise exceeded 80 dBA. • Direct behavioural responses to military jet overflights were of short duration (generally <1 min), and were unlikely to affect critical behaviors such as feeding and resting in the overall time-activity budgets of breeding pairs. • Residual effects, in other words, deviations from normal behavior patterns after initial responses, were decreased courtship behavior for up to 1.5 h after, and increased agonistic behavior for up to 2 h after military jet overflights. The presence of residual effects on behavior implied whole-body stress response that is potentially more serious.	• A precautionary approach to mitigation and, in Labrador, military aircraft overflights should be modified to reduce the exposure of habitats used by Harlequin ducks to aircraft noise levels >80 dBA. This could, for example, involve avoiding river valleys or defining minimum altitudes for overflights that assure noise levels remain below this threshold, or is less sudden in onset.

Table 1.14. Effects of low-flying (military) aircraft on a variety of waterfowl.

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Robinson & Pollitt 2002 [UK]	*Objective: Wetland Bird Survey (WeBS) data were reviewed to investigate the sources and scale of current potential disturbances to waterbirds in the UK.* • The birds in the WeBS-areas are regularly exposed to disturbance and might be expected to have become used to this. • Coastal waterbirds were more likely to be disturbed by walkers, shooters and **large aircraft** whereas those inland were more likely to be disturbed by motor-driven machines and unpowered boats.	• None.
Komenda-Zehnder et al. 2003 [Switzerland]	*Objective: to analyse at which minimum crossing altitude waterbirds do not show any visible reaction to overflying aircraft (**small fixed-wing** and **helicopters**), and in addition to examine the differences in the bird's behaviour depending on the type of aircraft and the amount of noise.* • Variety of wintering waterfowl, in concentrations between appr. 50 to 1000 birds. Mainly: Tufted duck (*Aythia fuligula*), Coot (*Fulica atra*) and Pochard (*Aythia ferina*). • 326 experimental overflights at lakes situated in three different areas of the Swiss lowland, with Small fixed-wing aircraft (Bonanza (F33A, A36) and Robin (DR400/500, DR400-180R)) and small helicopters (Ecureuil (AS-350B2) and Alouette 3 (SA-316B)). • Aircraft made one series of overflights per site per half-day, each series consisting of four to six overflights in 15 min intervals at successively decreasing altitudes (600-450-300-150-80 m, or 450-300-150-80 m) or at varying altitudes (150 or 80 m). • The proportion of birds showing stressed behaviours depended significantly on the type of aircraft (helicopter or fixed-wing plane) and the flight altitude. • No other variable (noise level, type of fixed-wing plane and type of helicopter) could explain further variance. • The proportion of birds with stressed behaviours was significantly higher during the overflights below 300 m for fixed-wing planes and below 450 m for helicopters, than on days without flights. • There was no statistical evidence for short term habituation, nor sensibilisation.	• None.

1.4 Shorebirds and seabirds

Table 1.15. Effects of low-flying (military) aircraft on shorebirds and seabirds.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Dunnet 1977 [Scotland]	*Objective: to obtain data on which to base advice on the risks to seabird colonies of overflying commercial* ***helicopters*** *and* ***twin-engine fixed-wing aircraft****.* • Mixed colony of: Fulmar *(Fulmarus glacialis)*, Shag *(Phalacrocorax aristotelis)*, Herring gull *(Larus argentatus)*, Kittiwake *(Rissa tridactyla)*, Guillemot *(Uria aalge)*, Razorbill *(Alca torda)*, Puffin *(Fratercula arcti)*. • Two sets (days) of observations, with a Sikorsky S61 passing once at 150 m and a Piper Aztec passing five times at 150 m. • The bird cliffs are on the normal route of helicopters flying from Aberdeen to rigs and platforms in the North Sea, and it may be that the birds have become accustomed to the passage of these aircraft. • No evidence was found to suggest that aircraft (helicopters and fixed-wing aircraft) flying at heights of about 150 m (= 100 m above the cliff-top) affected the attendance of incubating and brooding birds.	• None.
Burger 1981 [USA/New York]	*Objective: to examine the effects of airplane noise on incubating and brooding Herring gulls (Larus argentatus) within 2 km of Kennedy Int. Airport.* • Supersonic (Concorde) vs subsonic(Boeing 707, 727, 747) vs average ambient background noise in Herring gull colony. • No effects of subsonic aircraft, passing over every 2-3 min, on nesting gulls were noted. • When supersonic transport flew over once a day, significantly more nesting gulls flew from their nests, and they engaged in more fights when they landed compared with the other conditions. Many eggs were broken during these fights, and subsequently eggs were eaten by intruders. • At the end of the incubation period there were lower mean clutch sizes in dense sections (more potential for fights) of the colony compared with solitary nesting pairs of gulls.	• None.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• For loafing gulls, significantly more birds flushed when planes flew over compared with immediately before and after such plane noises.	
Heinen 1986 [Germany]	*Objective: not specified.* • Aircraft: small fixed-wing aircraft, military jet aircraft, helicopters. • Note: no overflight altitudes given.	• None.
	• Redshank reacted comparatively strong (disturbance in 74% of the overflights). • Oystercatcher reacted comparatively weak (disturbance in 32% of the overflights). • Shelduck and lapwing were intermediate (disturbance in 37-42% and 46% of the overflights, respectively). • Brent goose, Shelduck and Oystercatcher reacted significant to the intensity of the sound of the airplanes.	
Fjeld et al. 1988 Olsson & Gabriel-sen 1990 [Spitsbergen]	*Objective: to obtain data on the risks to remote seabird colonies, especially breeding Brunnich's guillemot (Uria lomvia), of overflying* ***helicopters****.*	• None.
	• In colonies where aircraft overflights are frequent, guillemots do not usually react to them, which is attributed to habituation. • In an ambitious experiment, in colonies where aircraft overflights were virtually absent, guillemots sometimes responded to an approaching helicopter (Bell 212) at a distance of 6 km and always by a distance of 2.5 km. Reactions were correlated primarily with the sound levels from the helicopter, only secondarily with its distance. • In an ambitious experiment, in colonies where aircraft overflights were virtually absent, eggs or chicks were not lost as a result of the flybys. • In an ambitious experiment, in colonies where aircraft overflights were virtually absent, no indication of habituation to the helicopter was seen in these infrequently-repeated experiments.	
Brown 1990 [Australia]	*Objective: to quantify the responses of nesting sea birds in the wild to acoustic stimuli simulating aircraft overflights by exposure to tape recordings of a* ***small fixed-wing aircraft*** *(DHC-2 Beaver floatplane).* • The colonies had no chronic exposure to aircraft overflights or to other human disturbance. • Mixed colony of breeding Crested tern (*Sterna bergii*) and Bridled tern (*Sterna naethetus*).	• None.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Maximum responses observed, preparing to fly or flying off, were restricted to exposures greater than 85 dB(A). • The minimum response, i.e. a scanning behavior involving head-turning, or a more intense response, was observed in nearly all birds at all levels of exposure (peak fly-over levels at 5 dB intervals from 65 dB(A) to 95 dB(A)). • An intermediate response, an alert behavior, demonstrated a strong positive relationship with increasing exposure. • Short to medium term habituation/sensibilisation (within one day, and over successive days up to four days) did not occur in the observed responses. • For Bridled tern escape behaviors (flying up) were observed at much lower noise exposures than were observed for Crested tern. • A preliminary observation of responses of the colonies to balloon overflights suggests that visual stimulus is likely to be an important component of aircraft disturbance.	
Nijland 1997 [Netherlands]	*Objective: to present a survey of all present knowledge, from literature as well as from unpublished sources, on the effects of* ***aircraft*** *on wildlife, and to recommend on mitigating measures and on further research.*	• Aircraft should avoid concentration-areas altogether. • The minimum flight altitude of small aircraft should be raised from 150 m to 300 m AGL.
	• General: 1. The visual appearance of aircraft is an important stimulus generally inducing flight response in birds. 2. Bird species differ greatly in vulnerability for disturbance by small aircraft. 3. Habituation may develop if aircraft passes by regularly along the same route at the same height. 4. Staging areas, where migrating birds stop over for a shorter or longer period, are very vulnerable. 5. Birds are often very vulnerable for disturbance in the stage of nest site choice. Breeding birds are generally less easily disturbed than birds in other conditions. 6. Geese and spoonbills are very vulnerable. 7. Overflights at <600 m AGL causes disturbance (flight reaction) in >80% of the incidences.	

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Small fixed-wing aircraft: 1. Disturbance (flushing response) of shore birds by low-flying aircraft >500 m AGL, disturbance decreases above appr. 350 m AGL (n=366, Rottummerplaat 1986-1996). 2. Disturbance (flushing response) of shore birds by low-flying aircraft >450 m altitude, disturbance decreases above appr. 300 m AGL (n=2756, Boschplaat 1992-1996). • Motorgliders and ULVs: elicits relatively much disturbance, 50% of the overflights caused disturbance (flushing reaction). • Helicopters: Cause little disturbance (flushing response) at >500 m AGL and when flying over the beach. Otherwise very disturbing (flushing, flight response). • Military jets: Overflights at <600 m AGL caused disturbance (flushing reaction) in >80% of the incidences. Sonic booms always caused mass panic-flight reaction.	
Smit & De Jong 2002 [Germany]	*Objective: not specified.* • During several flights with **helicopters** at ca. 300 m AGL, 81% of the birds responded by flushing; usually over short distance.	• None.
Smit 2004 [Netherlands]	*Objective: not specified.* Resting and foraging shorebirds; Waddenzee. • Responses to noise aircraft are (somewhat) larger than those to less noise aircraft. • Aircraft types that fly over incidentally, disturb more, stronger and longer than aircraft types that pass over regularly (habituation). • Unussual military air traffic results in most disturbance, followed by (in decreasing order) militairy helicopter flights, civil fixed-wing aircraft flights and civil helicopter traffic. • The behavior of the passing aircrafts determines to a great extent the responses of the birds. Circling or accelerating aircraft cause a relatively high response, passing aircraft without any special maneouvers a relative low response. • The time of overflight in relation to high or low tide determines to a great extent the	• None.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	response of birds. Over-flights during low tide, when birds are spread out over the tidal sands may have a significant different response than when the birds are concentrated on a few high tide tidal sand. • Responses of Bar-tailed godwit (*Limosa lapponica*) and Grey plover (*Pluvialis squatarola*) are stronger in May than in other months, probably as a result of their recent arrival from undisturbed tropical wintering areas. This possibly also occurs when they return from their relative undisturbed Arctic breeding areas in August-September. • If the number of over-flights increases the number of responses decreases: many disturbances result in relatively low number of responses, little disturbances result in relatively high number of responses (habituation).	
	Resting and foraging shorebirds; Balgzand, Van Ewijcksluis. • Over-flights of civil helicopters (n=5) and militairy helicopters (mainly Lynx)(n=3) at >200 m AGL (usually around 300 m AGL) caused in 40% and 67% respectively a light response. • About 50% of over-flights is estimated to be disturbing for birds.	
	Foraging geese, shorebirds, gulls; Texel, Mokbaai. • 2.3% of all over-flights of militairy and civil helicopters (n=2,322) caused disturbance of birds. 1.8% was due to low-flying militairy helicopters. • Habituation is assumed. • No relation was found between season and the frequency of responses in birds. • Note: Flight altitudes are not specifically mentioned but assumed to be usually around 300 m AGL.	
	Foraging shorebirds and gulls; Balgzand – Kooijhoekschor. • Over-flights (<200 m AGL) of civil helicopters and militairy helicopters (mainly Lynx) caused a response in, respectively, 0% (n=2) and 8% (n=25) of the cases. • Over-flights (>200 m AGL, usually 300 m AGL) of civil helicopters and militairy helicopters (mainly Lynx) caused a response in, respectively, 0% (n=17) and 8% (n=8) of the cases.	

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• About 25% of all over-flights with civil helicopters is believed to cause low to reasonable disturbance.	
	Resting and foraging geese and shorebirds. Balgzand – Kuitje. • Over-flights (<200 m AGL) of civil helicopters and militairy helicopters (mainly Lynx) caused a response in, respectively, 21% (n=39) and 27% (n=11) of the cases.	

1.5 Songbirds

Table 1.16. Effects of low-flying (military) aircraft on songbirds.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Canaday & Rivade-neyra 2001 [Ecuador]	*Objective: to evaluate the impacts on terrestrial insectivorous songbirds that have taken place during a petroleum operation by comparing the avifauna of sites at different distances from roads and oil wells, and to test the usefulness of species richness within foraging guilds as an index of impact.* • The birds in the study area were by and large not seriously exposed to other sources of disturbance. • Responses to road traffic and **helicopter** over-flights are not separately treated.	• None.
	• Significantly more species of terrestrial insectivores were registered at interior forest sites than at road-edge sites. Arboreal granivores (i.e. parrots) constituted the next most important group. The responses of other guilds were much more variable. • The statistics indicate that the terrestrial insectivores as a group tended to increase in frequency with distance from roads, to beyond 1.5 km. • The degree to which each species was affected by the construction of roads was significantly correlated to body mass. • Noise appears to be the factor that most affected terrestrial insectivorous birds.	
Larkin et al. 1975 [USA]	*Objective: In relation to the risk of bird-aircraft collisions, to establish the response of nocturnal migrants to approaching* ***small fixed-wing aircraft****.*	• None.
	• Birds often react, by taking evasive maneuvres, to the approach of aircraft. • Small fixed-wing twin-engine aircraft (Piper Commanche) with its landing lights on was observed to encounter four birds, which took evasive maneuvers at 70, 100, 280 and 360 m distance. • The bird with the shortest response distance was approached from below and behind, the two birds with the longest response distance were approached from the front flying at roughly the same altitude as the aircraft.	
Hilgerloh 1990	*Objective: none - unexpected observation during the radar observation of spring migration of nocturnal songbids.*	• None.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
[Gibraltar]	• An unusual behaviour of passerine migrants could be observed during spring migration in Gibraltar. Birds having rested during the day on the rock of Gilbraltar, at dawn did not start to migrate towards northerly directions, but at first flew from the rocks towards all directions and then turned south. This was interpreted as escape behavior, attributed to the much intensified frequency of flight of **military jet planes** around the rock which occurred in the course of preparations of international military training exercises.	

1.6 Penguins and albatrosses

*Table 1.17. Effects of low-flying (*military*) aircraft on Emperor penguin (*Aptenodytes forsteri*), King penguin (*Aptenodytes patagonicus*), Gentoo penguin (*Pygoscelis papua*), Adélie penguin (*Pygoscelis adeliae*) and Wandering albatross (*Diomedea exulans*).*

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Giese & Riddle 1999 [Antarctica]	*Objective: quantitative assessment of the effects of* **helicopter** *overflights on the behaviour of creching Emperor penguin chicks.* • Chicks were exposed to two overflights, on the same day, by a Sikorski S76 (twin-engine helicopter) at 1000 m. • There were no significant differences in the way the chicks responded between the morning and the afternoon flight, in spite of different wind conditions. • All chicks (n=81) became more vigilant when the helicopter approached and 85% maintained this higher level of vigilance for the 5 min of post-flight recordings. • 69% of the chicks either walked or ran, generally moving less than 10 m towards other chicks (i.e. not scattering). • Most chicks (83%) displayed flipper-flapping, probably indicating nervous apprehension. This behaviour was seldom displayed in the absence of disturbance (i.e. by less than 2%). • All effects were relatively transitory, lasting as long as the helicopter was in the range of the birds.	• None other than stressing the importance of operational guidelines based on rigorous experimental studies which exercise careful control over disturbance stimuli.
Cooper et al. 1994 [Antarctica]	*Objective: observation of responses in penguins.* Lockheed C-130 Hercules passing twice at 100 to 300 m above ground level, between 0 to 500 m from the colonies at Archway Bay. • King penguin adults and post-brood chicks were alerted by the sound of the approaching aircraft. As the plane passed by, the birds commenced to run to the back of the colony, where some accumulated against a steep cliff. Some birds moved up to 10 m. Each time the aircraft had passed by, the birds moved back into the colony and	• All visits by fixed-wing aircraft not for the purpose of airdrops should not approach closer than appr. 5 km and/or should not fly lower than approximately 1000 m while in the island's vicinity. • Every attempt should be made to

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	spaced themselves out. The period of panic lasted less than a minute on each pass. • A small group (appr. 10 individuals) of non-breeding Gentoo penguins showed signs of being alerted during the first pass, and fled inland in different directions during the second pass. These birds had left the area before the third overflight. • A nearby group of breeding Gentoo penguins guarding large chicks did not flee, remaining at their nest sites.	avoid airdrops in the period December to March, when King penguins are incubating or brooding small chicks. • Flights should not pass within 2 km of King penguin breeding colonies. • All passes in which no airdrops are made, should not be lower than 500 m. • Helicopters should not fly at low altitudes in the vicinity of, or approach or land within 500 m of King penguin breeding colonies.
	Lockheed C-130 Hercules passing twice at 100 to 300 m above ground level, between 250 to 500 m from the colonies at King Penguin Bay. • Birds were first alerted by the aircraft noise, then ran inland with some birds packing against colony banks, but no pile-ups or mortalities occurred, and after the panic, which lasted no more than a minute, moved back into the colony.	
	Lockheed C-130 Hercules passing appr. 300 m out to sea and at an altitude of 300 m. • One-quarter of the King penguins present moved inland a short distance as the aircraft passed by, but none was seen to stumble or fall over. • Five low-level fly pasts by Lockheed C-130 Hercules caused no discernible reactions from brooding and guarding Wandering albatrosses and their chicks. • Wandering albatrosses seem to take very little notice of helicopters: in several years a pair has bred successfully within 50 m of the helicopter platform at Marion Island, brooding adults and chicks being wind-blasted without apparent deleterious effects during aircraft movements.	
	Puma helicopter over-flights. • King penguins at two breeding colonies were alerted by the sound of an approaching Aerospatiale Puma helicopter before it came into view. As it came into view and passed at least 500 m out to sea, adults and chicks milled around for less than a minute but no panicked rushes occurred and the colonies soon quietened down.	
Wilson et al. 1991 [Antarctica]	*Objective: to document the effect of disturbance by (humans and)* ***aircraft*** *on the behaviour and physiology of breeding Adélie penguins.* • Penguins in the area are regularly (about once every two weeks) exposed to aircraft	• Any work conducted during the austral summer that is likely to disturb penguins should be

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	flights in the vicinity during the summer. The birds might be expected to have become used to this disturbance. Helicopter: • Penguins commuting between the sea and the colonies did not react to the Super Puma helicopter until it was closer than 600 m. By the time it was 400 m away, all birds were moving away. • Reaction stopped quickly with 90% of all birds still moving away when the helicopter had flown to 1.25 km distance, but virtually all fleeing had stopped by the time it was at 1.5 km. • There is no evidence of habituation of the commuting birds. On the contrary, the number of commuters increasingly dropped during three days of intensive helicopter flying to 49%, to raise afterwards again to 106%. • The number of birds arriving or departing was directly related to local helicopter activity. • Three days of helicopter flights caused numbers of birds to decrease by 12%, but former numbers were regained 24 h after the flights were stopped. • During the three days of helicopter flights, the total number of active nests in all 11 surveyed colonies dropped from 505 to 466, a nest mortality of 8%. • Implanted birds brooding chicks did not desert their nests even when approached by a helicopter to 25 m. • Heart rate values of birds brooding chicks rose significantly from pre-helicopter mean resting values of 83.4 bpm (SD 6.7, n=10 from 4 birds) to a maximum value of 286 bpm, and were accompanied by 'Head Waving'. • Heart rate was inversely proportional to helicopter-penguin distance. • Heart rate decreased as a function of exposure time. Penguins showed no change in heart rate when approached by the helicopter to 200 m after an exposure time of 300 min, although birds still reacted with less vigorous 'Head Waving'.	carried out after chicks have fledged, otherwise when birds are incubating and have been incubating for at least 10 days. • Potentially disturbing work should be carried out around mid-day. • Aircraft should use the same flight path for serial drops and Super Puma helicopters should not approach a colony closer than 1,000 m horizontally and 200 m vertically.

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
	Hercules airplane: • First reaction to Hercules occurred when the aircraft was 1.1 km away. • By the time the plane had approached to 500 m, all birds were moving away and when it was 350 m away 75% of all birds were tobogganing. • When the aircraft receded, 50% of the birds were still moving away when the distance was 2.3 km. Completely normal activity had resumed by the time the Hercules was 2.8 km away. Twin Otter: • First reaction to Twin Otter occurred when the aircraft was 1 km away. • Most birds stopped all movement until the Twin Otter was at a distance of ca 500 m, when they began moving away; 10% tobogganed. • By the time the aircraft had retreated to 600 m, all unusual behavior had ceased.	
Southwell 2005 [Antarctica]	*Objective: to assess the extent of response behaviour by [seals and] Adélie penguin (Pygoscelis adeliae) and Emperor penguin (Aptenodytes forsteri) observed in aerial survey and their implications of such behaviour on survey assumptions.* • Sikorski S76 (twin-engine **helicopter**) flying at 130 m altitude and 90 knots speed along straight-line transects. • Close to the flight path (101-200 m), 64% of the penguin groups (n=1148) moved, 6% displayed alertness, and 30% remained still. • At distances >400 m, the percentages dropped to <25% of the penguin groups moving. • Distance moved was $\leq$20 m, mean distance was $\leq$3 m.	• None.

1.7 Pheasants

Table 1.18. Effects of low-flying (military) aircraft on Eastern wild turkey (Meleagris gallopavo silvestris).

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Lynch & Speake 1978 [USA/Alabama]	*Objective: to establish the effect of sonic boom on brooding hens and hens with chickens.* • The results of the study indicate that sonic booms do not initiate abnormal behaviour in wild turkey that would result in decreased productivity.	• None.

1.8 Different bird groups

Table 1.19. Effects of low-flying (military) aircraft on birds: surveys/reviews/annotate bibliographies.

Reference	Subject	Responses to low-flying aircraft
Gladwin et al. 1988	Inventory of observed incidents, especially in U.S. Fish and Wildlife Service refuges.	• Helicopters caused disturbance at 70% of the installations (U.S. F&WS refuges), small jets at 59%, small propeller aircraft at 50% and large jets at 31%. • Helicopters engender a greater flight/fright response than other, fixed-wing aircraft. • Waterfowl are by far the most frequently reported animal group disturbed by aircraft – especially colonial nesting species. Several installations reported that some species of waterfowl were completely driven off refuges by frequent aircraft activity. • Impacts to all wildlife range from minor behavioral responses to severe changes in the use of an area. • Stresses e.g. the need for better relations with the FAA, airport operators, and military bases such that discussions of the effects of aircraft operations on wildlife could be openly and productively pursued.
Manci et al. 1988	Broad literature study concerning wildlife.	• Behavioral responses depend on the characteristics of the noise and vary between species and within a species due to a variety of factors such as age, sex, natural history, health at the time, prior exposure, etc. • Field studies indicate that the reproduction of wild populations may be more affected by noise disturbance than domestic populations (particularly poultry). The reproductive effects have primarily been the result of disturbance of the animal's behavior during the reproduction cycle. • Aircraft can be particularly disturbing to waterfowl, particularly geese. • Geese tend to flush at greater distances [than ducks] when the aircraft is under 1,000 ft above ground level. After severe disturbance Snow goose flock sizes reduce, with a consequent increase in the number of flocks. • Nonbreeding waterfowl and seabirds appear to be more susceptible to disturbance by aircraft (fixed-wing and helicopter) than are nesting birds. Birds are more susceptible to disturbance while they are roosting or courting, than during nets-building, incubation, or rearing young,

Reference	Subject	Responses to low-flying aircraft
		when their tendency to remain at their nest site is strong. • Behavioral responses of wading bird colonies to low overflights by military jets and helicopters are limited and short lasting. • The high-frequency whine made by some of the jet-engine helicopters seems to be much less disturbing to nesting raptors than the low-frequency piston-powered helicopters.
National Park Service 1994 (Report to Congress 1994, Chapter 5)	Broad literature study concerning wildlife.	• Behavioral responses depend on the characteristics of the noise and vary between species and within a species due to a variety of factors such as age, sex, natural history, health at the time, prior exposure, etc. • Behavioral responses reflect a variety of states, from indifference and mild annoyance to escape behavior and extreme panic. • Such responses are manifestations of stress, but the effects of stress from overflights are not well documented. • Excessive stimulation of the nervous system can amount to chronic stress, and continuous exposure to aircraft overflights can be harmful for the health, growth, and reproductive fitness. • Of high concern is the possibility of habitat avoidance and abandonment by species whose high-quality habitat is already scarce. • Problems with detecting long-term effects of aircraft disturbance is due both to the limitations of ecological research and to the nature of long-term responses. • Such long-term responses may include permanent changes in habitat use, increased mortality of birds during migration (due to lower weight gains during staging), or population effects due to reduced reproductive success (due to egg loss, altered patterns of attendance to yound, etc.). • Recommends to develop impact criteria meant to help agencies in determining the severity of impacts.
Kempf & Hüppop 1996	Effects of airplane noise on wildlife.	• Especially the noise of aircraft can scarcely be assessed separately from its optical appearance. Optical or acoustical stimuli taken separately have only minor effect with the optical stimulus evoking the stronger reaction; even soundless paragliders can cause panic flights.
Larkin 1996	Effects on wildlife of noise associated with military training activities, esp. vehicle	• General: Several studies report on the effects of aircraft noise/overflights on reproduction in various birds. The observed effects varied from none to fleeing from the nest. • Raptors: Literature reveals variability of response by raptors to disturbance. Whereas some

Reference	Subject	Responses to low-flying aircraft
	noise, artillery, small-arms and other blast noise, and helicopter noise.	medium-sized diurnal raptors flee from approaching helicopters, others refuse to be flushed from the nest, and larger ones sometimes attack helicopters, presumably in defense against a flying intruder. • Seabirds (mainly Brunnich's Guillemot): In colonies where helicopter overflights are frequent, guillemots do not usually react to them, which is attributed to habituation. No indication of habituation was observed in colonies where helicopter overflights were infrequent.
Efroymson et al. 2000	Ecological risk assess-ment framework for low-altitude overflights by fixed-wing and rotary-wing military aircraft	• Major stressors are (1) sound, and (2) sound and visual stressors, combined. Raptors: • "Lowest Observed Adverse Effects Level LOAEL": Mean slant distance associated with flight is between 250 and 300 m (Awbrey & Bowles 1989). • The sound level associated with flight is 97 dBA. • Threshold distance for a negative impact on prey delivery in owls is 69 m (Delaney et al. 1999). • "No Observed Adverse Effect Level NOAEL" ranges from about 150 to 1000 m slant distance. • Based on the threshold models, there is no apparent difference in raptor sensitivity to rotary-wing or fixed-wing aircraft. • Habituation of raptors has been observed in owls and red-tailed hawks. Waterfowl: • "Lowest Observed Adverse Effects Level LOAEL" ranges from about 300 m to about 20 km. A conservative distance effects level is 15 km. • The compiled information suggests that shorebirds and other waterfowl are the most sensitive endpoints to overflights, at least in terms of flight behavior. • "No Observed Adverse Effect Level NOAEL": few are available for waterfowl. NOAELs that have been measured at 2 km are shorter slant distances than some of the LOAELs, which suggests that a reliable NOAEL for waterfowl in general is not available. • Evidence regarding the habituation of waterfowl is mixed.
Krijgsveld et al. 2004	Vulnerability of birds related to recreational activities.	• Flight altitude and slant distance determine, among others, the level of noise a bird is exposed to. • Distance bird-aircraft is the most important predictor of responses in birds, as shown in a

Reference	Subject	Responses to low-flying aircraft
		variety of studies. • Flight speed affects the visual part of the disturbance but also determines the duration of the disturbance, which can be considered an essential part of the disturbance. • Small fixed-wing aircraft can disturb birds even at large distances and flight levels. Maximum distance at which responses were recorded in literature is 3200 m. Maximum flight level at which responses were recorded in literature is 3100 m.
Harris 2005	Vulnerability of birds in Antarctica.	• Development of practical guidelines for aircraft operations near concentrations of birds (mainly penguins) in Antarctica.

2 Review: Mammals and low-flying (militairy) aircraft

2.1 Ungulates

Table 2.1. Effects of low-flying (military) aircraft on Moose (Alces alces).

Helicopter

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Andersen et al. 1996 [Norway]	• During military maneuvers (including helicopter overflights) home range size of moose (n = 9) increased. • One of the moose made a significant home range shift. • No flight response was recorded when helicopters were >400 m away from the moose (n = 4). • When helicopters approached the moose a flush distance was recorded of 40-50 m (n = 2). The flight distance in these cases was 1000-1500 m. Heart rates went up from 80 (before disturbance) to 205 beats/min (during disturbance). The time needed for heart rates to return to normal was 8-11 min.	• None.

Military jet aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Andersen et al. 1996 [Norway]	• During military maneuvers (including jet overflights) home range size of moose (n = 9) increased. • One of the moose made a significant home range shift. • No flight response or change in heart rate was recorded when a jet passed at 150 m from the moose (n = 1).	• None.

Table 2.2. Effects of low-flying (military) aircraft on Roe deer (Capreolus capreolus).

(Light/small) Fixed-wing aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Mrlik 1987 [Czech Republic]	• Aircraft overflights (50-100 m above ground level) induced flight of deer in 25% of observations (n=63). In 5% of observations deer responded by taking an alerted posture. • Flight distance was 50-70 m. • Mean distance ran by disturbed deer was ~250 m. • The deer were believed to be habituated to the frequent disturbances by low-flying agriculture aircraft.	• None.

Table 2.3. Effects of low-flying (military) aircraft on Mule deer (Odocoileus hemionus) and Desert mule deer (Odocoileus hemionus crooki).

Militairy helicopter & jet aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Stephenson et al. 1996 [USA/Colorado]	• Mule deer increased their home range size in response to military training activity, including helicopter and jet fighter overflights.	• None.

(Light/small) Fixed-wing aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Krausman et al. 1986 [USA, Arizona]	• Fixed-wing overflights <100 m above ground level rarely (3% of observations; n=70) caused desert mule deer to change habitats. • Of the adult deer that changed habitats they did so only during the first overflight. • The mule deer appear to have habituated to low-flying aircraft in the area as it receives regular air traffic.	• None.

Table 2.4. Effects of low-flying (military) aircraft on Barren-ground caribou (Rangifer tarandus), Woodland caribou (Rangifer tarandus caribou), Peary caribou (Rangifer tarandus pearyi), and Grant's caribou (Rangifer tarandus granti).

Helicopter

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Calef et al. 1976 [Canada/Yukon] [USA/Alaska]	• During spring and fall migration about 80% of the barren-ground caribou groups (n = 736) exhibited panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes of less than 30 m. • During spring and fall migration about 20% of the caribou groups (n = 736) exhibited panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes of 30-60 m. • During spring and fall migration 10-20% of the caribou groups (n = 736) exhibited panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes of 60-150 m. • During spring and fall migration none of the caribou groups (n = 736) exhibited panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes above 150 m. • During spring and fall migration 10-30% of the caribou groups (n = 736) exhibited mild escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes above 150 m. • During calving and in early winter 50-85% of the caribou groups (n = 736) exhibited panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes of less than 150 m. • The activity of caribou at the time of overflights (fixed-wing aircraft and helicopter combined) influenced their response. Caribou at river crossings were most reactive. Resting caribou were least reactive. Travelling and feeding caribou took an intermediary position in their level of response. • The size of the group of caribou did not affect their response to aircraft (fixed-wing aircraft and helicopter combined). • The terrain and vegetation type in which caribou were observed did not affect their	• Minimum aircraft altitude of 150 m during spring and fall migrations. • Minimum aircraft altitude of 300 m at other periods.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	response to aircraft (fixed-wing aircraft and helicopter combined). • Aircraft overflights (fixed-wing aircraft and helicopter combined) did not cause cows to abandon calves (n = 5). • Cows with calves were no more sensitive to aircraft (fixed-wing aircraft and helicopter combined) than other caribou in fall.	
Miller & Gunn 1981 [Canada/North-west Territories]	• Play in Peary caribou calves was proportionately most frequent during helicopter overflights (harassment phase), least frequent before helicopter overflights (undisturbed phase), and occurred slightly less than expected after helicopter overflights (recovery phase). • It is hypothesized that calves become more excited because of helicopter overflight (overhead passes, 200-400 m altitude), this higher excitement led to a general readiness to be active, and in the absence of social signals from adults, the readiness of the calves to be active was released as play. Play should therefore not be used as an indication of well-being.	• None.
Gunn et al. 1983*	• Helicopter overflights, followed by landings up to 2 km from post-calving aggregations of barren-ground caribou elicited behavioral responses leading to displacements of at least 1-3 km.	• None.

(Light/small) Fixed-wing aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Calef et al. 1976 [Canada/Yukon] [USA/Alaska]	• During spring and fall migration about 80% of the barren-ground caribou groups (n = 736) exhibited panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes of less than 30 m. • During spring and fall migration about 20% of the caribou groups (n = 736) exhibited panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes of 30-60 m. • During spring and fall migration 10-20% of the caribou groups (n = 736) exhibited	• Minimum aircraft altitude of 150 m during spring and fall migrations. • Minimum aircraft altitude of 300 m at other periods.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes of 60-150 m. • During spring and fall migration none of the caribou groups (n = 736) exhibited panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes above 150 m. • During spring and fall migration 10-30% of the caribou groups (n = 736) exhibited mild escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes above 150 m. • During calving and in early winter 50-85% of the caribou groups (n = 736) exhibited panic or strong escape responses during overflights (fixed-wing aircraft and helicopter combined) at altitudes of less than 150 m. • The activity of caribou at the time of overflights (fixed-wing aircraft and helicopter combined) influenced their response. Caribou at river crossings were most reactive. Resting caribou were least reactive. Travelling and feeding caribou took an intermediary position in their level of response. • The size of the group of caribou did not affect their response to aircraft (fixed-wing aircraft and helicopter combined). • The terrain and vegetation type in which caribou were observed did not affect their response to aircraft (fixed-wing aircraft and helicopter combined). • Aircraft overflights (fixed-wing aircraft and helicopter combined) did not cause cows to abandon calves (n = 5). • Cows with calves were no more sensitive to aircraft (fixed-wing aircraft and helicopter combined) than other caribou in fall.	

Military jet aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Harrington & Veitch 1991* [Canada/Labrador]	• Sound rather than the appearance of the low-flying aircraft was responsible for startling of woodland caribou.	• None.
Harrington & Veitch 1992 [Canada/Labrador]	• Woodland caribou calf survival was negatively correlated with the female's (n=9 in 1987; n=8 in 1988) exposure to low-level jet overflights (overflight at altitudes below 300 m, within 1 km of caribou location) during the calving and immediate post-calving period (end May-half June). • Calf survival was negatively correlated with the female's exposure to low-level jet overflights during the period of insect harassment during summer (early July-half September). • No significant relationship between calf survival and exposure to low-level jet overflights was seen during the pre-calving period (half April-end May), during the late post-calving period prior to insect harassment (end June-early July) and during fall (half September-end October).	• No low-level overflights in caribou calving range during the last week of May and the first three weeks of June.
Maier et al. 1998 [USA/Alaska]	• Barren-ground caribou subjected to low-level overflights (<33 m above ground) in late winter interrupted resting bouts more often than caribou not subjected to overflights. • Caribou subjected to low-level overflights (<33 m above ground) during postcalving were more active and moved farther than caribou not subjected to overflights. • Caribou subjected to low-level overflights (<33 m above ground) during the insect season were more active than caribou not subjected to overflights. • Responses of caribou to aircraft were mild in late winter, intermediate in the insect season, and strongest during postcalving. • Females with young exhibited the most sensitive response.	• Training activities should be curtailed in areas where caribou are concentrated during calving and postcalving (May-June). • Nutritional aspects should be included in decisions upon mitigation strategies.
Trimper & Chubbs 2003 [Canada/Labrador, Québec]	• -	• Spatial separation of military training aircraft from woodland caribou, by (1) reconfiguration of the boundaries of low-level

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
		military training area, (2) implementation of a monitoring program of satellite collared caribou to indicate herd movements and distribution, and (3) establishment of (temporary) closure areas based on the actual locations of the collared caribou. • Closure areas based on the location of satellite collars and directions of movement, were found to enclose the majority of caribou within the low-level military training area. This was done by correlating collar presence with visual observations of groups of animals.
Otto et al. 2003 [Canada/Labrador]	• -	• Providing a sample of woodland caribou with satellite collars for spatial and temporal avoidance by low-level jet fighter training activities. • Assessment (per season) of number of collars required for different probability levels to ensure adequate mitigation.
Lawler et al. 2005 [USA/Alaska]	• Military jet overflights did not cause deaths of Grant's caribou calves during the calving period.	• A-10s can operate as low as 457 m above ground level during the

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Caribou responses to overflights were variable, with greater responses as slant distances decreased and jet speeds increased. • Differences in responses were found between jet type, with A-10 jets causing less reaction than F-15s and F-16s.	calving period if the jets maintain low speed and avoid maneuvers that require changes to higher power settings. • F-16s should be restricted to elevations >610 m above ground level during the calving period.

Table 2.5. Effects of low-flying (military) aircraft on Alpine ibex (Capra ibex ibex).

Helicopter

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Szemkus et al. 1998 [Switzerland]	• In ~15% (n = 5) of all helicopter overflights (n = 35) within a range up to 1200 m ibex showed a flight response. • Median flight distance of ibex to helicopter overflights was 20 m (n = 5). • Covered median difference of altitude by ibex in response to helicopter overflights was 0 m (n = 5).	• None.

(Light/small) Fixed-wing aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Szemkus et al. 1998 [Switzerland]	• In ~3.5% (n = 3) of all fixed-wing aircraft overflights (n = 85) within a range up to 1200 m ibex showed a flight response. • Median flight distance of ibex to fixed-wing aircraft overflights was 20 m (n = 3). • Covered median difference of altitude by ibex in response to fixed-wing aircraft overflights was 0 m (n = 3).	• None.

Military jet aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Szemkus et al. 1998 [Switzerland]	• In ~5.5% (n = 1) of all jet overflights (n = 18) within a range up to 1200 m ibex showed a flight response. • Median flight distance of ibex to jet overflights was 20 m (n = 1). • Covered median difference of altitude by ibex in response to jet overflights was 0 m (n = 1).	• None.

Sailplane

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Szemkus et al. 1998 [Switzerland]	• In ~17% (n = 3) of all sailplane overflights (n = 18) within a range up to 1200 m ibex showed a flight response. • Median flight distance of ibex to sailplane overflights was 200 m (n = 3). • Covered median difference of altitude by ibex in response to sailplane overflights was 50 m (n = 3).	• None.

Paraglider

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Szemkus et al. 1998 [Switzerland]	• In 100% of paraglider overflights (n = 13) within a range up to 1200 m ibex showed a flight response. • Median flight distance of ibex to paraglider overflights was 650 m (n = 13; range 30-1200 m). • Covered median difference of altitude by ibex in response to paraglider overflights was 200 m (n = 13; range 20-500 m). • On days with encounters with paragliders groups of ibex walked significantly further (median 1600 m) and covered more altitude (475 m) than on days without paragliders	• Regulation of paragliding.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	(800 m/110 m). • Many escape flights went out of the home range normally used by the observed male ibexes. • Flight altitude of the paraglider, activity of the group members before the encounter, and group size showed no significant effect on the flight response of ibex to paragliders.	

Table 2.6. Effects of low-flying (military) aircraft on Alpine chamois (Rupicapra rupicapra).

Helicopter

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Boldt & Ingold 2005 [Switzerland]	• The first aircraft of the day (low-flying paragliders and helicopters combined) induced a downward movement of chamois. • A high intensity of aircraft affected the altitudinal difference that was covered during the whole day. • Additional altitudinal movement was 7.5 m with mean intensity of air traffic, 122 m with high intensity of air traffic. • Daily energy costs of altitudinal locomotion were not considerably increased: 0.1% of the field metabolic rate (FMR) with mean intensity of air traffic, 1.2% of FMR with high intensity of air traffic.	• None.

Paraglider

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Ingold et al. 1993 [Switzerland]	• Experimental paraglider overflights (150-200 m above ground level) provoked strong reactions in chamois. The animals started a flight reaction towards the woods (800 m) when the paragliders were at distance of 600-700 m.	• None.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• It is unknown whether habituation occurs as paragliding is a relative novel outdoor activity.	
Schnidrig-Petrig & Ingold 2001 [Switzerland]	• Female chamois showed strong reactions to paragliders, becoming alert at distances of up to 1280 m and taking flight at distances of up to 900 m. • Chamois sought refuge within forest cover after paragliders appeared. • Escape distances were larger when paragliders appeared over the animals than when they appeared at about the same height. • Escape distances were shorter when the animals were closer to forest cover than when they were in open alpine meadows above the timberline. • Colour of the paragliders, distance to rocks, and group size did not affect the reactions of chamois. • In areas with regular paragliding, chamois moved away from the air traffic and eventually disappeared into the forest, and did so earlier with increasing flying activity. • Chamois stayed within forest cover longer wth increased duration of paragliding off the normal flight path. • In an area with only sporadic paragliding, chamois sought refuge within the forest for up to four hours after single paraglider fly-overs.	• Paragliding should be controlled, including the designation of no-fly zones, standard flight paths and limitation of the number of take-off points. • No-fly zones can be permanent or temporarily, e.g. during calving season. • Paragliding pilots should be educated about the effects on wildlife.
Boldt & Ingold 2005 [Switzerland]	• The first aircraft of the day (low-flying paragliders and helicopters combined) induced a downward movement of chamois. • A high intensity of aircraft affected the altitudinal difference that was covered during the whole day. • Additional altitudinal movement was 7.5 m with mean intensity of air traffic, 122 m with high intensity of air traffic. • Daily energy costs of altitudinal locomotion were not considerably increased: 0.1% of the field metabolic rate (FMR) with mean intensity of air traffic, 1.2% of FMR with high intensity of air traffic.	• None.

Table 2.7. Effects of low-flying (military) aircraft on Mountain goat (Oreamnos americanus).

Helicopter

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Foster & Rahs 1983 [Canada/British Columbia]	• Mountain goats were equally nervous and as highly excitable in response to helicopter, airplane, and other human activity (e.g. drilling). • More than 80% (n = 667) of observed goats elicited some form of behavioral stress-response, with 33% (n = 265) displaying a severe flight response to local rock or plant cover, 16% (n = 129) displaying a moderate alarm, and 34% (n = 273) displaying increased alertness. • Goat responses were independent of the time of year, type of disturbance (including helicopters and fixed-wing aircraft), vertical orientation of disturbance (above, level, below) and group size. • Goat responses were dependent of the distance of disturbance, geographic area, cover availability (exposed versus protected), and degree of disturbance awareness (anticipated versus surprised). • At a disturbance distance of >1600 m 43% of the goat display no-response, 57% display increased alertness, 0% display a moderate flight response, and 0% display a severe flight response. • At a disturbance distance of 400-1600 m 38% of the goat display no-response, 40% display increased alertness, 10% display a moderate flight response, and 12% display a severe flight response. • At a disturbance distance of 100-400 m 14% of the goat display no-response, 34% display increased alertness, 24% display a moderate flight response, and 28% display a severe flight response. • At a disturbance distance of <100 m 3% of the goat display no-response, 29% display increased alertness, 11% display a moderate flight response, and 57% display a severe flight response. • Disturbances resulted in temporary range abandonment.	• Appointment of buffer areas around mountain goat habitat with a minimum radius of 2 km.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Disturbances resulted in changes in habitat use and activity patterns. • Mountain goats did not habituate to the disturbance.	
Côté 1996 [Canada/Alberta]	• Mountain goats were disturbed by 58% of all helicopter overflights (n = 81; range >500 to >1500 m). • Overflights <500 m from the goats caused 85% of the goats to move >100 m. • Overflights 500-1500 m from the goats caused 57% of the goats to move >100 m. • Overflights >1500 m from the goats caused 9% of the goats to move >100 m. • Only in case of overflights at >1500 m distance a part of the goats (63% of all responses) were classified as not or lightly disturbed. • Helicopter visibility, height above ground, group size, group type (bachelor or nursery), and behavior of groups just prior to helicopter overflights did not appear to influence reactions of goats to helicopters. • Helicopters caused the disintegration of social groups on 5 occasions (7%). • Helicopter flights caused severe injury to an adult female on 1 occasion. • There was no difference between goat reaction to the first flight of the day and subsequent flights.	• Restriction of helicopter flights within 2 km of alpine areas and cliffs that support mountain goat populations.
Goldstein et al. 2005 [USA/Alaska]	• The probability of a mountain goat group being disturbed was inversely related to distance of the helicopter from the group. • The probability of a mountain goat group being disturbed increased by a factor 1.25 for every 100-m reduction in approach distance. • Where mountain goats had received more prior exposure to helicopters approach distances resulting in >90% probability of no response were significantly smaller: >991 m versus >1730 m in the areas with most and least helicopter traffic respectively. • The probability of any mountain goat in a group becoming disturbed at 500 m was 25-62%, depending on prior exposure to helicopters. • The probability of any mountain goat in a group becoming disturbed at 1000 m was 10-45%, depending on prior exposure to helicopters.	• Defining no-fly zones. • Developing guidelines for the minimum distance between aircraft and mountain goats.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• The length of time that a goat remained in a disturbed state following overflight did not depend upon the distance of the helicopter: mountain goats remained in a disturbed state for an average of 31 seconds.	

(Light/small) Fixed-wing aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Foster & Rahs 1983 [Canada/British Columbia]	• Mountain goats were equally nervous and as highly excitable in response to helicopter, airplane, and other human activity (e.g. drilling). • More than 80% (n = 667) of observed goats elicited some form of behavioral stress-response, with 33% (n = 265) displaying a severe flight response to local rock or plant cover, 16% (n = 129) displaying a moderate alarm, and 34% (n = 273) displaying increased alertness. • Goat responses were independent of the time of year, type of disturbance (including helicopters and fixed-wing aircraft), vertical orientation of disturbance (above, level, below) and group size. • Goat responses were dependent of the distance of disturbance, geographic area, cover availability (exposed versus protected), and degree of disturbance awareness (anticipated versus surprised). • At a disturbance distance of >1600 m 43% of the goat display no-response, 57% display increased alertness, 0% display a moderate flight response, and 0% display a severe flight response. • At a disturbance distance of 400-1600 m 38% of the goat display no-response, 40% display increased alertness, 10% display a moderate flight response, and 12% display a severe flight response. • At a disturbance distance of 100-400 m 14% of the goat display no-response, 34% display increased alertness, 24% display a moderate flight response, and 28% display a severe flight response.	• Appointment of buffer areas around mountain goat habitat with a minimum radius of 2 km.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• At a disturbance distance of <100 m 3% of the goat display no-response, 29% display increased alertness, 11% display a moderate flight response, and 57% display a severe flight response. • Disturbances resulted in temporary range abandonment. • Disturbances resulted in changes in habitat use and activity patterns. • Mountain goats did not habituate to the disturbance.	

Commercial jet aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Foster & Rahs 1983 [Canada/British Columbia]	• No overt reactions were displayed by the goats to daily noise levels from overhead flights of Boeing 747 aircraft (altitude: 9 km).	• None.

Table 2.8. Effects of low-flying (military) aircraft on Muskox (Ovibos moschatus).

Helicopter

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Miller & Gunn 1980 [Canada/North-west Territories]	• Of all observed responses (n = 2626) to helicopter overflights (>180 m) in three muskox herds 54-80% remained bedded or foraging; 13-23% alerted or walked; and 7-24% cantered or galloped or formed group defense formations., • Flight distance differed from about 3000 m during the first pass to a few metres during the last pass within one set of passes. • There was a trend towards decreasing responsiveness within a series of overflights on one day (short-term habituation). • One of the three studied herds exhibited also a long-term habituation response (overflights at beginning and end of summer compared). • The helicopter overflights did not cause injuries, splinter herds or force the herds to abandon the range.	• Adaptation of helicopter operating schedules. • Avoidance of low-level (<200 m) flights overhead muskox herds, circling or following the animals, and landings closeby the animals with on-foot approaches.
Miller et al. 1986 [Canada/North-west Territories]	• The frequency of suckling by young calves increased in response to helicopter overflights (240-400 m). • Observations of nursing, however, cannot easily be employed with any confidence as a monitoring indicator of muskox response to helicopters due to variation within and between muskox herds.	• None.

*Table 2.9. Effects of low-flying (*military*) aircraft on Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*), Desert bighorn sheep (*Ovis canadensis nelsoni*), Mexican bighorn sheep (*Ovis Canadensis Mexicana*) and California bighorn sheep (*Ovis canadensis californiana*).*

Helicopter

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
MacArthur et al. 1979 [Canada/Alberta]	• A low overflight (150-200 m above ground level) of a helicopter over one Rocky Mountain bighorn ewe caused running and resulted in a 3.5-fold rise in heart rate. • No behavioural reactions or changes in heart rates to helicopter overflights (n=4) were observed at distances 500-1500 m from sheep (n=2).	• None.
MacArthur et al. 1982 [Canada/Alberta]	• Low overflights (90-250 m above ground level) of helicopters (n=5) caused fleeing of Rocky Mountain bighorn sheep and increased sheep heart rate 2-3.5 times, with recovery times of 20-65 s. • No reactions to helicopters were observed at distances exceeding 400 m from sheep.	• None.
Bleich et al. 1990 [USA/California]	• Helicopters (50-200 m above ground) affect distribution and movements of California bighorn sheep. • Adult sheep (males/females) moved about 2.5 times farther the day following helicopter surveys (April and June) than on the day before such surveys. • 35-52% of the sheep changed polygons (i.e. subdivisions of the study area, delimited by roads and natural breaks in topography) following sampling from a helicopter, whereas only 11% did so on the day prior to the survey. • Sampling intensity (0.8 min/km2 vs. 2.0 min/km2) and terrain type (steep vs. rolling) had little effect on sheep movements.	• None.
Stockwell et al. 1991 [USA/Arizona]	• Reduction in foraging efficiency in Desert bighorn sheep during winter. • No reduction in foraging efficiency in spring, probably because of larger distances between helicopters and sheep after spring migration of sheep to lower elevations in the canyon. • No difference in response between the sexes and age classes • No differences in response with group size. • No difference in response due to differences in weather conditions (precipitation).	• Restricting number of flights in seasons with high responses in bighorn sheep. • Restricting flights to specified periods of the day. • Regulating flight altitudes: a minimum distance to bighorn

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	• Disturbance distance threshold of 250-450 m.	habitat of 500 m.
Bleich et al. 1994 [USA/California]	• Habitat shifts for California bighorn sheep in all seasons with flight altitude of ~100 m. • Change in vegetation type in spring. • Sheep continued to move during the day. • No difference in response between the sexes. • No habituation to repeated helicopter overflights.	• None.

(Light/small) Fixed-wing aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
MacArthur et al. 1982 [Canada/Alberta]	• No reactions to fixed-wing aircraft were observed at distances exceeding 400 m from Rocky Mountain bighorn sheep.	• None.
Krausman & Hervert 1983 [USA/Arizona]	• 41% of sheep were disturbed by overflights (n=32; 30-300 m agl) and >19% of the sheep moved >100 m into different habitats. • At a flight level of <50 m agl all responses were extreme, involving habitat shifts of >1 km from the areas of observation. • At a flight level of 50-100 m agl responses were mixed, some (13%) extreme, more (27%) mild, and most (60%) sheep showed no overt reaction. • At a flight level of >100 m agl responses ranged from mild (23%) to no overt reaction (77%). • Different sex and age classes reacted similarly. • Airplanes flying at >100 m above ground cause minimal disturbance.	• Flight altitude should be >100 m agl to minimize disturbance.

Military jet aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Weisenberger et al. 1996 [USA/Arizona]	• Heart rates of Desert bighorn sheep (n=5) increased related to dB levels during simulated overflights. Heart rates returned to pre-disturbance levels in 60-180 seconds. • Sheep behavior changed during simulated overflights (i.e. alerted and alarmed responses). Behavior returned to pre-disturbance conditions in <252 seconds. • All responses decreased with increased exposure suggesting that the sheep habituated to simulated sound levels of low-altitude aircraft.	• None.
Krausman et al. 1998 [USA/Nevada]	• F-16 aircraft overflights (n=149; 125 m above ground level) did not alter use of habitat of semi free-ranging Desert bighorn sheep (n=3), or increase heart rates. • Limited responses in behavior were observed, e.g. an increase in foraging and decrease in bedding after overflights. • On 54 occasions (12% of overflights), overflights caused animals to run. Sheep ran short distances (<10 m) in all cases but one (40 m). • The study suggests sheep habituated to aircraft and the noise they created.	• None.
Sayre et al. 2002 [USA/North Dakota]	• Responses occurred more frequently when jets passed within 200 m of California bighorn sheep compared to more than 200 m away. • Sheep fled marginally further in response to jets within 200 m compared to more than 200 m away. • Bighorn sheep shifted habitats more frequently when jets approached within 200 m compared to more than 200 m away. • Response duration was not different when jets approached within 200 m compared to more than 200 m away. • Season (post-lambing, fall) and group size did not affect distances fled by bighorn sheep. • The disturbance from military jets did not result in a shift to escape terrain. • No difference in frequency of strong responses in bighorn sheep to bomber and fighter jets. • Bighorn sheep did not appear to habituate to jets that flew within 200 m.	• Alteration of flight routes: >200 m away from areas frequently used by bighorn sheep. • Alteration of flight altitude.

Commercial jet aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
MacArthur et al. 1979 [Canada/Alberta]	• No reactions were observed in Rocky Mountain bighorn sheep to the sound of high-flying commercial jet aircraft.	• None.

Table 2.10. Effects of low-flying (military) aircraft on Dall sheep (Ovis dalli dalli).

Helicopter

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Frid 2003 [Canada/Yukon]	• Sheep groups fled during 77% of all overflights. • Sheep ran dring 86% of all fleeing events. • Most group members fled synchronously. • Fleeing probability decreased as minimum distance from aircraft trajectory increased. • Fleeing probability decreased at a higher rate when sheep were on rocky slopes than when sheep were 5-20 m from rocky slopes. Sheep >20 m from rocky slopes always fled, regardless of minimum distance to from trajectory (within a 2-km range). • Distance fled ranged from 15 m to 1.5 km (median: 100 m). Distance fled increased as distance to rocky slopes increased. • Flight initiation distance ranged from 100 m to 3 km (median: 900 m). • More direct approaches were likely to elicit fleeing or to disrupt resting. • No differences in response between female-young groups and male groups. • No difference in the proportion of groups fleeing between groups in which all sheep were resting and groups in which some to all sheep were active. • Sheep far from rocky slopes were much more likely to flee than sheep on rocky slopes during indirect approaches. • Sheep that had been resting prior to overflights tended to switch to feeding after they	• Spatial restrictions to aircraft: Defining setback distances and elevations that limit or even eliminate direct approaches. Design flying pathways which use ridges to block the line of sight between aircraft and areas of high sheep density. • Temporal restrictions to aircraft: Seasonal and diurnal restrictions that correspond with (predictive) variability in sheep's fleeing probability. • Encouragement of the use of fixed-wing aircraft rather than helicopters in roadless sheep ranges.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	stopped fleeing. Sheep that had been feeding prior to overflights tended to resume feeding shortly after settling down. • The proportion of sheep fleeing did not decrease with the number of cumulative weeks of disturbance.	

(Light/small) Fixed-wing aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Frid 2003 [Canada/Yukon]	• Active sheep fled during 37% of all overflights. • Resting sheep interrupted resting during 47% of all overflights. • Active Sheep ran during 84% of all fleeing events. • Fleeing probability of active sheep decreased as minimum distance from aircraft trajectory increased. Fleeing probability was 50% when the aircraft flew directly to the sheep (minimum distance = 0). No animals fled when minimal distance from trajectory was >700 m. • The probability of interrupting rest decreased as minimum distance from aircraft trajectory and relative elevation increased. The probability of interrupting rest was >80% when the aircraft was ≤80 m above the sheep and approached directly. • Flight initiation distance for active sheep ranged from 0.2 to 4.6 km (median: 1.2 km). • The distance at which sheep interrupt rest ranged from 0.4 to 6.1 km (median: 1.6 km). • More direct approaches extended latency to resume feeding or begin resting in active sheep. Sheep that interrupted resting during overflights took an almost three times longer period to begin feeding or resume resting than active sheep. • No differences in the proportion of active sheep fleeing during overflights between females with young and adult females without young. • No differences in the proportion of resting sheep interrupting rest during overflights between females with young and adult females without young. • Sheep that had been resting prior to overflights tended to switch to feeding after they	• Spatial restrictions to aircraft: Defining setback distances and elevations that limit or even eliminate direct approaches. Design flying pathways which use ridges to block the line of sight between aircraft and areas of high sheep density. • Temporal restrictions to aircraft: Seasonal and diurnal restrictions that correspond with (predictive) variability in sheep's fleeing probability. • Encouragement of the use of fixed-wing aircraft rather than helicopters in roadless sheep ranges.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
	stopped fleeing. Sheep that had been feeding prior to overflights tended to resume feeding shortly after settling down. • The proportion of sheep fleeing did not decrease with the number of cumulative weeks of disturbance.	

Table 2.11. Effects of low-flying (military) aircraft on horse (Equus caballus).

Helicopter

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Linklater & Cameron 2002 [New Zealand]	• Helicopter overflights (~60 m above the ground) induced running and changes in group size and composition in all observed horse groups (n=17). • Fleeing horse groups ran from 0.1 to 2.75 km before leaving the observers view.	• None.

Table 2.12. Effects of low-flying (military) aircraft on Pronghorn (Antilocapra americana) and Sonoran pronghorn (Antilocapra americana sonoriensis).

Helicopter

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Luz & Smith 1976 [USA/New Mexico]	• No reactions in pronghorn when the helicopter was at an altitude of 120 m and a slant range from the herd (17 individuals) of 900 m (noise level ~66 dBA) (n = 1). • Strong reactions (running) when the helicopter was at an altitude of 45 m and a slant range from the herd (17 individuals) of 150 m (noise level ~77 dBA) (n = 1).	• None.

Military jet aircraft

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Krausman & Harris 2002 [USA/Arizona]	• Military jet aircraft overflights (n = 363, of which 109 were direct overflights, i.e. <100 m to side of animal, but only 6 were <305 m above ground level) did not cause significant changes on Sonoran pronghorn behaviour. • During direct overflights, 3.7% of all observed behaviour changes (n = 45; 41% of overflights) was from any other activity to trotting or running. • During indirect overflights, 1.6% of all observed behaviour changes (n = 105; 34% of overflights) was from any other activity to trotting or running.	• None.

"Military aircraft"

Reference [Country/State]	**Responses to low-flying aircraft**	**Proposed mitigation**
Landon et al. 2003 [USA/Arizona]	• Sonoron pronghorn used areas with lower levels of noise (<45 dB) more than expected and areas with high levels (>55 dB) less than expected.	• Planning military activities in time and space. • Better placement of water catchments in relation to military (training) sites.
Krausman et al.	• Sonoran pronghorn exposed to military activity bedded the same amount of time,	• None.

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
2004 [USA/Arizona]	foraged less and stood and traveled more than pronghorn not exposed to military activity. • Pronghorn rarely responded to military aircraft. • Note: the study focused on a variety of military activities, including overflights of military and non-military aircraft. Military overflights occurred 363 times and non-military overflights occurred 77 times. Of these only 6 military and 7 non-military overflights occurred at <300 m above ground level.	

2.2 Carnivores

Table 2.13. Effects of low-flying (military) aircraft on Coyote (Canis latrans).

Military helicopter/jet aircraft

Reference [Country/State]	Responses to low-flying aircraft	Proposed mitigation
Gese et al. 1989 [USA/Colorado]	• Coyotes altered their behavior in response to military activity. • Coyotes responded to military activity, including helicopter and jet fighter overflights, by expanding, contracting, abandoning, or not changing their home range during militairy maneuvers compared to before and after maneuvers. • Of the 16 studied coyotes 2 abandoned their home range permanently and 1 abandondeded its home range temporarily. • Responses were related to the amount of available cover, topography and intensity of military activity. • Animals contracting their home range typically contracted their activity into dense vegetation, canyons and hills: places too rough for military maneuvers. • Coyote activity patterns during the day increased.	• Restricting activities during critical time periods (i.e. denning). • Revegetation of disturbed areas to provide cover.