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EFFECTS OF DISTURBANCE BY AIRCRAFT OVERFLIGHT ON WATERBIRDS – AN EXPERIMENTAL APPROACH

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Abstract

The hazards of bird strikes are not the only conflict between aircraft and birds. From the point of view of the birds, aircraft overflights can be an important source of disturbance. Such disturbances are especially problematic in nature protection areas. Negative effects are loss of usable habitat, increased energy consumption, lower food intake and resting time and in consequence an impaired body condition. Reliable data about minimum flight altitudes that would guarantee a negligible influence of aircraft are largely lacking. Therefore, we were commissioned by the Swiss Federal Office for Civil Aviation and by the Swiss Agency for the Environment, Forests and Landscape to investigate the behaviour of birds in relation to the overflight altitude of helicopters and aeroplanes.

During winter 2001/02 we performed 326 experimental overflights at lakes situated in three different areas of the Swiss lowlands. The behaviour of waterbirds was observed before, during and after the overflights. We analysed the influence of type of aircraft and crossing altitude on the proportion of waterbirds showing a stressed behaviour (alarm posture, swimming, flying). The birds returned to a relaxed behaviour (resting, preening, feeding) within 5 min after the overflights. No short-term habituation or sensitisation was observed. The disturbance effect of helicopters was higher than of aeroplanes and increased with decreasing flight altitude. The behaviour of the birds was not significantly influenced if the aeroplanes flew at 300 m above ground level (AGL) and if the helicopter flew at 450 m AGL or higher.

Our study indicates that disturbance by aircraft can be reduced significantly if minimum flight altitudes of 450 m AGL are implemented. Furthermore, the probability of aircraft provoking a take off of waterbirds is minimised, which decreases bird strike hazard over lakes.

Key words: disturbance, waterbirds, aeroplane, helicopter, flight altitude

Introduction

The conflict between air traffic and birds has been followed for several decades from the point of view of flight safety, thus with the aim of reducing the risk of bird strikes. In the context of nature conservation, however, collisions, in which birds are killed, are a minor problem. More important may be the effects of disturbance by aircraft overflights which under certain circumstances can lead to the loss of usable habitat, increase the energy expenditure of birds due to escape reactions, lower the food intake due to interruptions, reduce the breeding success and as a long term effect, reduce population sizes of a certain species (KEMPF & HÜPPOP, 1998). The extent of such negative impacts depends strongly on the distance between aircraft and birds. However, minimum flight altitudes are established primarily to ensure the flight safety and to prevent excessive noise emission in populated areas. Only recently have minimum flight altitudes been suggested as a nature conservation measure.

Several studies have shown that the vertical or horizontal distances at which birds first react to an aircraft approach, depend on the type of aircraft, the bird species, topographical features, habituation and other factors (BRUDERER & KOMENDA-ZEHNDER, 2002). Consequently, conclusions based on observations made elsewhere can only be applied with great caution to a specific site. In order to develop criteria for an effective protection of sensitive areas against disturbance by aircraft in Switzerland, the Federal Office for Civil Aviation (FOCA) and the Swiss Agency for Environment Forest and Landscape (SAEFL) commissioned the Swiss Ornithological Institute to carry out a study on the influence of air traffic on birds. As one approach, we performed experimental overflights with aeroplanes and helicopters in the Swiss Lowlands during the winter 2001/02. The main aim was to analyse at which minimum crossing altitude waterbirds do not show any visible reaction to overflying aircraft overflight. In addition, we examined the differences in the birds' behaviour depending on the type of aircraft and the amount of noise. The influence of the sites, size of concentrations of waterbirds and species will be presented elsewhere.

Study sites and methods

We performed the experimental overflights in three different regions of the Swiss Lowlands with different levels of concentrations of wintering waterbirds [*Figure 1*]. In each area, we selected two sites where waterbirds are known to winter regularly. In the region of Bern and in central Switzerland the sites were located at different waterbodies, whereas the sites at the Untersee were selected at a distance that guaranteed independent reactions of the birds. We fixed the observation sites at points on the shore from where the observer could survey the open water and to which the aircraft had free access.

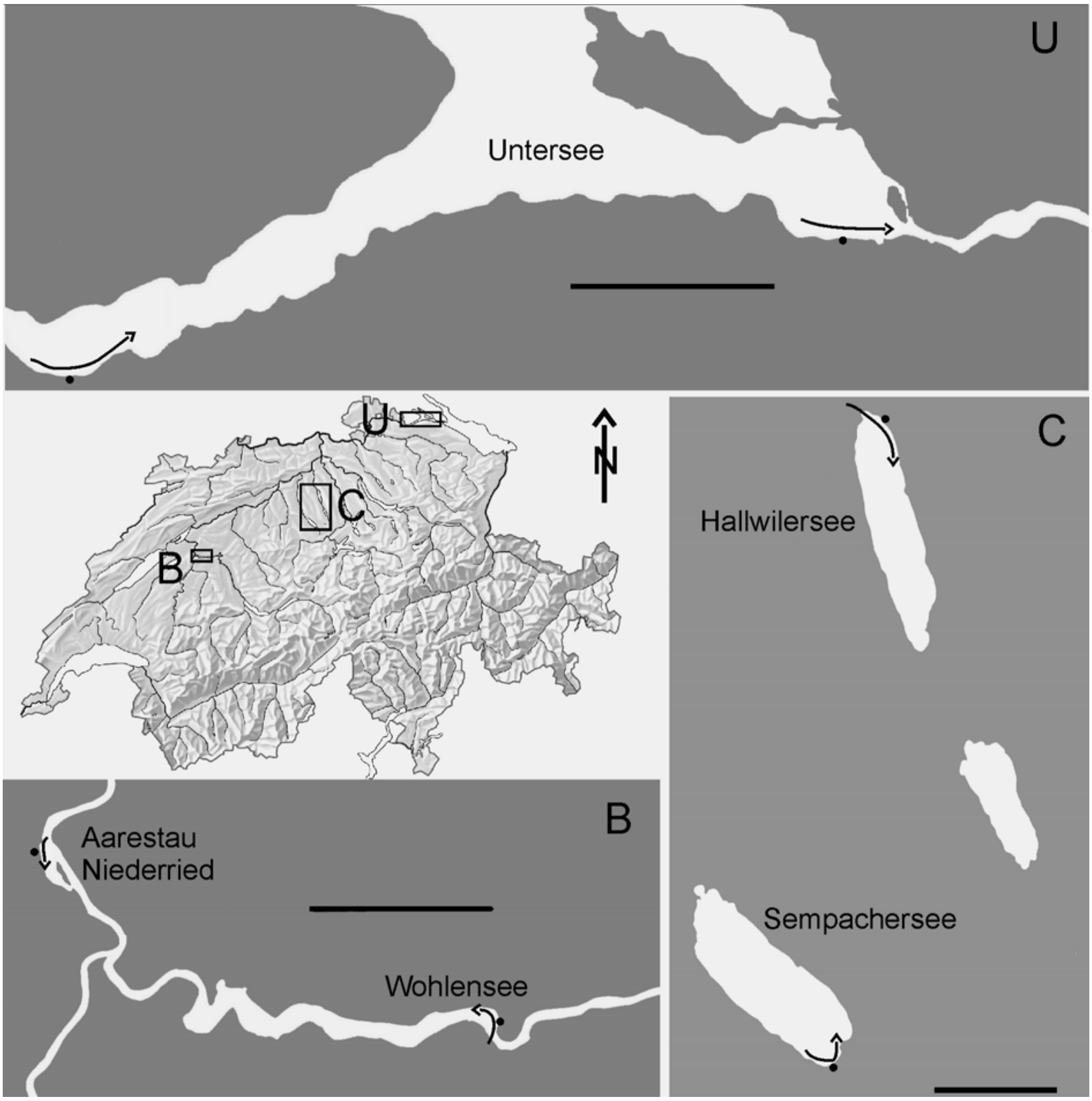

Figure 1. *Regions in Switzerland where the experimental flights were performed. The rectangles in the map delimit the enlarged areas (U Untersee, B Bern, C Central Switzerland), where the white parts illustrate the waterbodies. The dots mark the observations sites and the arrows the flight routes. The black bars illustrate a distance of 4 km.*

We used aeroplanes of the type “Bonanza” and “Robin” and helicopters of the type “Ecureuil” and “Alouette 3” [*Table 1*], owned by the FOCA. The pilots followed an imaginary line at a lateral distance of 100 m from the shore and flew directly over the observed group of waterbirds at an altitude of 600 m, 450 m, 300 m, 150 m or 80 m AGL.

Table 1. *Aircraft used for the experimental over flights*

Aircraft	Type		Length (m)	Wing span, diameter of rotor, rsp. (m)
Aeroplane	Bonanza	F33 A	8.12	10.20
		A 36	8.38	10.20
	Robin	DR 400/500	7.22	8.72
		DR 400-180 R	7.22	8.72
Helicopter	Ecureuil	AS-350B2	10.93	10.69
	Alouette 3	SA-316B	10.20	11.00

If the weather conditions remained favourable, the aircraft performed four to six overflights in 15 min intervals either at successively decreasing altitudes [*Table 2*] (series type 1), at a constant altitude (series type 2) or at varying altitudes (series type 3). The aircraft alternated between the two observation sites of one region. Only one series of overflights was accomplished per site and half-day in order to prevent excessive stress to the birds.

Table 2. *Description of three procedures of overflights. A series consisted of four to six overflights over the same area in intervalls of 15 min*

Series type	Characteristic	Flight altitudes (m AGL)	Comments
1	decreasing altitude	600 – 450 – 300 – 150 – 80	At the Wohlensee flights at 80 m AGL were not possible
2	constant altitude	150 or 80	
3	varying altitude	450 – 300 – 150 – 80	partially repeating the same altitude

Waterbirds on the water surface were censused before the first and after the last overflight of a series. For the study of bird behaviour, a sample of birds (mean = 51 individuals, sd ± 175) was selected according to the field of vision of the observer’s binoculars (x8 magnification). The observer recorded the percentage of birds showing a relaxed or stressed behaviour. A relaxed behaviour was attributed to resting, preening and feeding, whereas a stressed behaviour was attributed to alarm posture, swimming, diving or flying. Observations of the birds’ behaviour started 5 min before the first overflight of a series and were repeated at 5 min intervals. Thus, the second observation and every third of the subsequent observations coincided with an aircraft overflight. The last observations were made 5 min after the last overflights of a series. We used an integrating sound level meter (Type 2225, BRÜEL & KJAER) to record the peak of sound impulse level in dB. Since only one device was available, the measurements were done only at one site per half-day and region. Measurements were performed at all sites except for the Hallwilersee. This site is very similar to the observation site at the Sempachersee and therefore we can assume that the measurements were representative for all regions.

The experimental overflights could only be performed on days with weather conditions that were in agreement with visual flight rules. In order to show that the birds' behaviour was not different on days with worse weather conditions, we performed control observations on days without flights, following the same method.

Descriptive and analytic statistics were calculated with the software package STATISTICA 5.0 (STATSOFT, Inc. 1995). We analysed the data with t-tests and ANOVA (Type I Sums of Squares).

Results

The experimental overflights were carried out during 29 days between late October 2001 and February 2002. We performed 83 series of totalling 326 overflights, 42 series (179 overflights) of which were with aeroplane and 41 (147) with helicopter [*Table 3*]. A total of 30 control observations took place over 20 days.

Table 3. *Number of series per type and region, separately for aeroplanes and helicopters*

Series type		**1**	**2**	**3**
Aeroplane				
	Bern	10	6	2
	Central Switzerland	6	10	0
	Untersee	4	3	1
Total		*20*	*19*	*3*
Helicopter				
	Bern	6	6	2
	Central Switzerland	2	3	0
	Untersee	0	6	16
Total		*8*	*15*	*18*

The censuses of waterbirds performed before the first overflight of a series revealed relatively high numbers for the observation sites at the Untersee (Mean = 1081, SD ± 1531). There were relatively low numbers at the two lakes in the area of Bern (Mean = 193, SD ± 189) and the two lakes in central Switzerland (Mean = 48, SD ± 38). The number of birds before and after a series of overflights did not differ significantly (all series types included; paired t-test; t-value = -1.39, df = 82, p = 0.168).

The most frequent species were tufted duck (*Aythia fuligula*; 40 %), coot (*Fulica atra*; 31 %) and pochard (*A. ferina*; 18 %). The other 29 species had frequencies ≤ 2 % and were representatives of the families of Anatidae, Podicipedidae, Phalacrocroracidae, Ardeidae and Laridae.

In order to exclude confounding effects of habituation or sensitisation after consecutive overflights, we first analysed the data of the series with flights at a constant altitude (series type 2). The aeroplane overflights at 80 m (9 series) and at 150 m (10 series) showed that the proportion of birds with a stressed behaviour remained constant during the overflights [*Figure 2*; ANOVA: $F_{3, 32} = 0.445$, n.s.; $F_{3, 36} = 0.599$, n.s.; for 80 m AGL and 150 m AGL overflights, respectively). For the helicopter, the differences between successive overflight were also not significant (ANOVA: $F_{3, 8} = 1.00$, n.s.; $F_{3, 36} = 1.474$, n.s.; for 80 m AGL and 150 m AGL overflights, respectively).

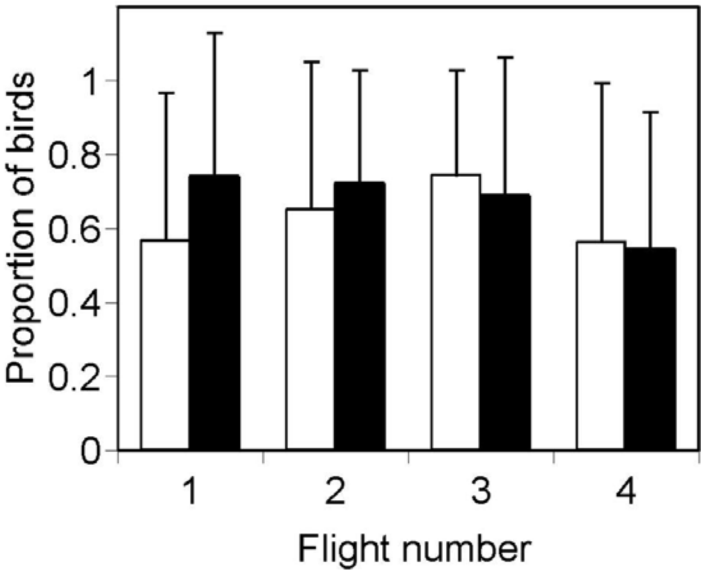

Figure 2. *Mean proportion of birds with a stressed behaviour during four consecutive aeroplane overflights at a constant altitude (series type 2); the results from the flights at 80 m AGL are illustrated by the white columns and 150 m AGL by the black columns. The error bars denote the standard deviation.*

The behaviour of the birds before and after each overflight was investigated based on the data of the flight procedure series type 1 (decreasing altitude) in order to base the analyses on comparable conditions [*Figure 3*]. The proportion of birds with a stressed behaviour 5 min before or 5 min after an overflight did not differ significantly, neither for the aeroplane nor for the helicopter overflights (paired t-test; Aeroplanes: t-value = - 0.961, df = 59, p = 0.340; Helicopters: t-value = 0.991, df = 21, p = 0.333). For both types of aircraft, the proportions do also not differ significantly from the control observations (ANOVA; Aeroplanes: before overflight $F_{5, 93} = 0.515$, n.s., after overflight: $F_{5,83} = 0.612$, n.s.; Helicopters: before overflight: $F_{5,47} = 1.545$, n.s., after overflight: $F_{5,47} = 0.919$, n.s.).

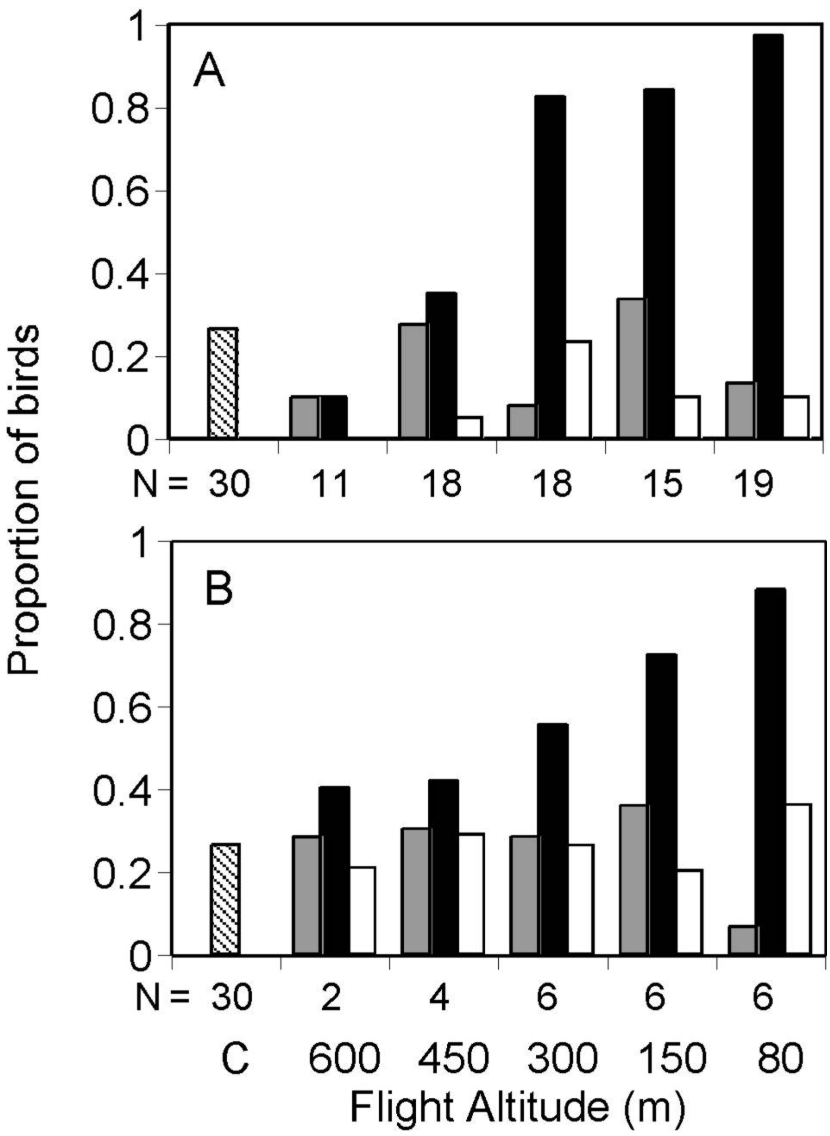

Figure 3. *Comparison of the mean proportion of waterbirds with stressed behaviours during the series of overflights with decreasing altitudes (from 600 to 80 m AGL) with the behaviour at days without flights (C control, hatched columns) for aeroplanes (A) and for helicopters (B). The white columns illustrate the behaviour five minutes before, the black during and the grey five min. after the overflights.*

The fact that there was no evident habituation nor sensitisation, the fast return to behaviours that occur under normal conditions and the constant number of birds present legitimise the assumption of independent observations during each overflight. Therefore, for the further analyses all overflights were included.

The proportion of birds showing stressed behaviours depended significantly on the type of aircraft (helicopter or aeroplane) and the flight altitude [*Table 4*]. The interaction was not significant. No other variable (noise level, type of aeroplane and type of helicopter) could explain further variance.

Table 4. *Analysis of variance of the proportion of birds with a stressed behaviour (ANOVA, Type I SS). The overflights of all series were included*

	df	**MS**	**F**	**p-level**
Type (aeroplane or aircraft)	1	2.983	29.041	< 0.001
Altitude	4	0.927	9.024	< 0.001
Residuals	320	0.103		

We compared the proportion of birds with stressed behaviours during overflights at different altitudes with the control observations on days without flights. [*Figure 4;* ANOVA: $F_{5, 203}$ = 9.538, $p < 0.001$; $F_{5, 171}$ = 31.652, $p < 0.001$; for aeroplanes and helicopters, respectively). The proportion of birds with stressed behaviours was significantly higher during the overflights below 300 m for aeroplanes and below 450 m for helicopters, than on days without flights [*Table 5*].

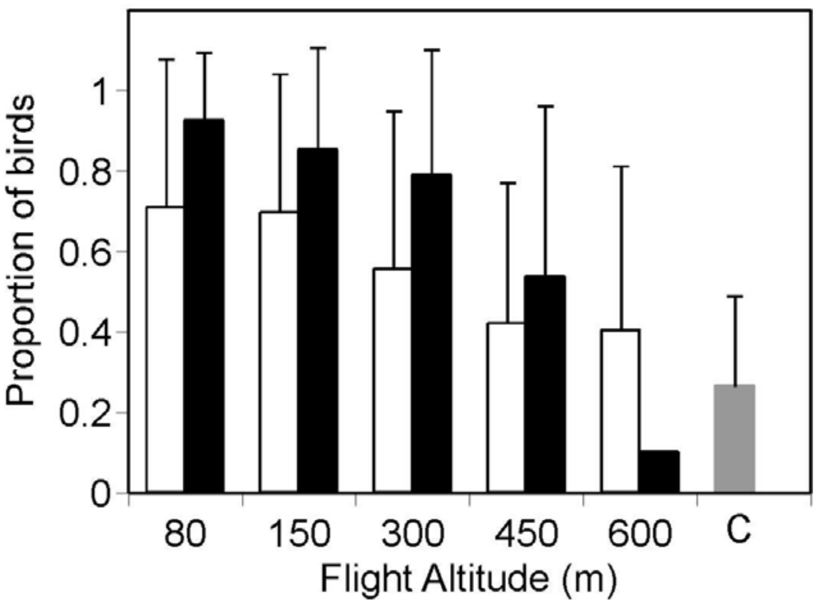

Figure 4. *Comparison of the proportion of waterbirds with stressed behaviours during overflights of aeroplanes (white columns) and helicopters (black columns) with the control observations of days without flights (C; grey column). All data are included. The error bars denote the standard deviation. The sample sizes are given in Table 4.*

Table 5. *Probabilities of the post hoc test (Tukey HSD for unequal N) of the comparison of the proportions of waterbirds with stressed behaviours during control observations (C) and aircraft overflights at different altitudes above ground level. The values for the aeroplane overflights are given in the unshaded part of the table and for the helicopter overflights in the shaded part. N denotes the sample size.*

Altitude (m)		C	80	150	300	450	600
	N	30	66	66	18	18	11
C	30		< 0.001	< 0.001	0.123	0.762	0.939
80	36	< 0.001		1.000	0.772	0.128	0.306
150	75	< 0.001	0.828		0.830	0.164	0.354
300	27	< 0.001	0.359	0.942		0.854	0.908
450	7	0.339	0.046	0.178	0.419		1.000
600	2	0.987	0.014	0.035	0.070	0.515	

The peak noise level was measured at only one of the two observation sites per region and thus the dataset is reduced substantially. However, it depended significantly on the type of aircraft and the flight altitude [*Figure 5;* ANOVA: $F_{5,116} = 124.05$, $p < 0.001$].

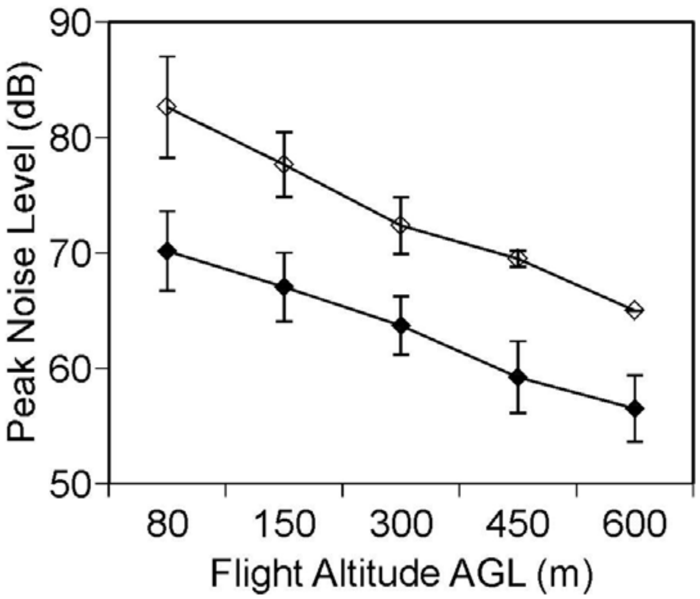

Figure 5. *Mean peak noise level of helicopters (open symbols) and aeroplanes (black symbols) during overflights at different altitudes*

Flights at 150 m AGL performed by the “Robin” type aeroplane resulted in a higher proportion of birds showing stressed behaviours than did the “Bonanza” type aeroplane [*Table 6*]. The “Robin” flew significantly faster than the “Bonanza” but there was no significant difference between the noise emission of the two types. The two types of helicopters, “Alouette” and “Ecureuil”, caused a similar proportion of birds with stressed behaviour, although the “Alouette” flew significantly faster and was noisier than the “Ecureuil”.

Table 6. *Comparison of the proportion of birds with a stressed behaviour, speed and noise level between the two types of aeroplanes and helicopters at the 150 m overflights*

	Means (sd)		**t-value**	**df**	**p**
Aeroplanes	**Bonanza**	**Robin**			
Proportion of birds	0.78 (0.27)	0.60 (0.40)	2.144	64	0.036
Speed (km/h)	95 (25)	112 (26)	-7.824	59	< 0.001
Noise (dB)	66.44 (3.28)	67.86 (2.25)	-1.378	30	n.s.
Helicopters	**Alouette**	**Ecureuil**			
Proportion of birds	0.89 (0.22)	0.82 (0.28)	1.309	73	n.s.
Speed (km/h)	115 (23)	62 (6)	14.037	73	< 0.001
Noise (dB)	78.94 (1.73)	75.08 (3.23)	4.257	28	< 0.001

Discussion

This is the first time that birds’ reactions have been investigated with the aim of determining a minimum flight altitude at which the negative influence of aircraft on the birds is negligible. Our analyses showed that helicopters have a higher potential for disturbance than fixed-wing aeroplanes, which confirms the results of many earlier studies that investigated disturbances caused by existing air traffic (e.g. OWENS, 1977; KEMPF & HÜPPOP, 1995; SÉRIOT & BLANCHON, 1996; GLADWIN et al. 1988; WARD et al. 1999). The helicopters used in this study were larger and louder than the aeroplanes, which makes it impossible to determine which of the two factors, the visual or acoustic cues, was responsible for the differences.

The minimum flight altitude that did not cause a change in behaviour was 450 m above ground level (AGL) for helicopters and 300 m AGL for aeroplanes. It is important to note that these findings, which are valid for wintering waterbirds (mainly ducks) in concentrations between approximately 50 to 1000 individuals, cannot be extrapolated easily to other conditions. All waterbodies in Switzerland are exposed throughout the year regularly to disturbances such as people walking on the shore, motorboats and air traffic, which probably entail some habituation. The distances given in the literature indicate that birds can be more sensitive in undisturbed regions (e.g. WARD et al. 1994), or when in very high concentrations (e.g. DAVIS et al. 1974), when moulting (DERKSEN et al. 1982) or when breeding in colonies (ZONFRILLO, 1992). Moreover, the reactions differ strongly between bird species groups, such as waders, geese, raptors or passerine (KEMPF & HÜPPOP, 1998).

Although a basal level of habituation to disturbances must be assumed for birds wintering in Switzerland, no short term habituation to a series of four aircraft overflights was observed. The birds were consistent in their reactions and did not become more sensitive. They returned within less than five minutes to a similar behaviour as before and although there were regularly birds taking off, the numbers of birds in the surveyed area remained constant. This indicates that the disturbances had only a very short term effect. In February 2002, many smaller lakes were frozen which may have made the birds reluctant to leave the remaining open water surfaces. Although it may be argued that the additional energy consumption caused by our overflights probably was small, it is very obvious that aircraft overflights at low altitudes are at odds with nature protection policies. Minimum flight altitudes must be adopted accordingly over protected areas.

The larger type of aeroplane “Bonanza” used in this study, which had a slower crossing speed, had a significantly stronger effect than the smaller “Robin”. This is consistent with the finding that crossings at a very high speed as of military jets, are less disturbing than overflights at slower speeds (SMIT & VISSER, 1993). However, the differences in speed and noise of the two similarly sized helicopter types did not cause different effects on the behaviour of birds. This shows the complexity of visual and acoustical cues which does not allow simple predictions.

We conclude that only an experimental approach can provide reliable information about disturbance effects of aircraft over a specific area. Flights at a minimum flight altitude of 600 m AGL as recommended by the European Union (Council Directive 92/14/EWG of 2 March 1992 on the limitations of the operation of aeroplanes covered by Part II Chapter 2 Volume 1 of Annex 16 to the Convention on International Civil Aviation, second Edition 1998) will very probably avoid large-scale disturbances.

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Literature

DAVIS, R.A. & A.N. WISELEY, 1974. Normal behavior of snow geese on the Yukon-Alaska North Slope and the effects of aircraft-induced disturbance on this behaviour, September 1973. - In: Gunn, W.W.H. (ed.), Studies on snow geese and waterfowl in the Northwest Territories, Yukon Territory, and Alaska, 1973.

DERKSEN, D.V., W.D. ELDRIDGE & M.W. WELLER, 1982. Habitat ecology of pacific black brant and other geese moulting near Teshekpuk Lake, Alaska. - Wildfowl 33: 39-57.

GLADWIN, D.N., D.A. ASHERIN & K.M. MANCI, 1988. Effects of aircraft noise and sonic booms on fish and wildlife: Results of a survey of U.S. Fish and Wildlife Service Endangered Species and Ecological Services Field Offices, Refuges, Hatcheries, and Research Centers. - U.S.Fish and Wildl.Serv., National Ecol. Research Center.

KEMPF, N. & O. HÜPPOP, 1995. Behaviour of meadow birds towards aircraft close to an airport. - Wader Study Group Bulletin 76: 21.

KEMPF, N. & O. HÜPPOP, 1998. Wie wirken Flugzeuge auf Vögel? Eine bewertende Übersicht. – Naturschutz und Landschaftsplanung 30: 17-28.

KOMENDA-ZEHNDER, S. & B. BRUDERER, 2002. Einfluss des Flugverkehrs auf die Avifauna - Literaturstudie. Schriftenreihe Umwelt Nr, 344. Bundesamt für Umwelt Wald und Landschaft. Bern.

LUGERT, J. 1988. Militär und Tourismus als Störfaktor für Enten und Gänse (Anatidae) in dem Naturschutzgebiet "Geltinger Birk". - Seevögel 9: 44-47.

OWENS, N.W. 1977. Responses of wintering brent geese to human disturbance. - Wildfowl 28: 5-14.

SÉRIOT, J. & J.-J. BLANCHON, 1996. Étude relative à l'impact sur l'avifaune du survol des réserves naturelles de montagne par des aéronefs. Rapport de fin de contrat rédigé à la demande de Ministère de l'Environnement – Direction de la Nature et des Paysages.

SMIT, C.J. & J.M. VISSER, 1993. Effects of disturbance on shorebirds: a summary of existing knowledge from the Dutch Wadden Sea and Delta area. - Wader Study Group Bulletin 68: 6-19.

STATSOFT, Inc. 1995. STATISTICA [5.0]. Tulsa, Oklahoma.

WARD, D.H., R.A. STEHN & D.V. DERKSEN, 1994. Response of staging brant to disturbance at the Izembek Lagoon, Alaska. - Wildlife Society Bulletin 22: 220-228.

WARD, D.H., R.A. STEHN, W.P. ERICKSON & D.V. DERKSEN, 1999. Response of fall-staging Brant and Canada geese to aircraft overflights in southwestern Alaska. - Journal of Wildlife Management 63: 373-381.

ZONFRILLO, B. 1992. The menace of low-flying aircraft to seabirds on Ailsa Craig. - Scottish Bird News 28: 4.