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Monitoring of birds and studies of disturbance sensitivity in relation to mosquito control on flood plains along River Dalälven, central Sweden

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Abstract

This four years study collected data on birds and analysed the risk of disturbance because of helicopter activity for mosquito control in temporarily flooded wetlands along lower River Dalälven, Sweden. A maximum of 13 622 ha were surveyed every year between 2005 and 2008 with special focus on five species: White-tailed Eagle *Haliaeetus albicilla*, Osprey *Pandion haliaetus*, Crane *Grus grus*, Whooper Swan *Cygnus cygnus* and Black-throated Diver *Gavia arctica*. The numbers of pairs of each species were very low which indicate little overlap between presence of sensitive bird species and areas pointed out as possible mosquito control areas. A power analysis showed that if the percentage of number of affected breeding pairs, due to low-flying helicopter is very low, but at the same time considered serious (e.g. if zero tolerance is claimed), the study will not be able to detect that unless the number of pairs is considerably increased.

Introduction

The flood-plains of River Dalälven, central Sweden, are subjected to recurrent but irregular floods of variable amplitude and duration. Although water flow regulations of River Dalälven have reduced the amplitude and duration of floods in most of the flood-plains floods during May to September induce massive emergence of the flood-water mosquito *Aedes sticticus*, a species causing massive nuisance problems within large areas around the wetlands (Schäfer et al., 2008). After decades of complaints, mosquito control operations were commenced in the summer of 2002, using the biological mosquito larvicide VectoBac G©, with protein crystals produced by *Bacillus thuringiensis* var. *israelensis* (*Bti*) as active ingredient, to reduce populations of mosquito species. The mosquito control is carried out from helicopter.

Mosquito control programmes using *Bti* have been extensively discussed including possible non-target effects (UNEP, ILO & WMO 1999, Boisvert & Boisvert 2000, Becker et al 2003). The issue has recently also been debated in Sweden (Svenska Naturskyddsföreningen 2002, Ehnström 2003, Goedkoop 2003, Länsstyrelsen Gävleborg 2007), but six years of field studies have not shown any undesired non-target effects on insects in the River Dalälven flood-plains (Brodin & Petersson 2008, Lundström et al 2009).

In Sweden the control of mosquitoes on a wider and somewhat regular basis started only recently and until now has it included fairly restricted areas around lower River Dalälven (Nedre Dalälven) in central-east Sweden. The lower parts of River Dalälven are known for temporary mass development of floodwater mosquitoes resulting in enormous numbers of individuals with up to 62 100 individuals captured in one trap and night (Schäfer et al. 2008). The area is characterised also for very high nature conservation values and large parts include both several Natura 2000 sites and a national park. The area consists of many different habitats, representing a biologically rich zone where northern and southern species meet (Holmstedt 2006).

As part of a scientific control program to follow up any possible secondary effects a surveillance program on birds was initiated in 2005 and ended in 2008, on demand of county administrative boards and national authorities. The aim was to study possible disturbance on birds caused by helicopter used for BTI-application in mosquito control areas. At an early stage concern was expressed by nature authorities and conservationists, among other environmental issues connected to the mosquito control program, that low-flying helicopter may cause disturbance to some sensitive and rare bird species in the area. After consultation with several local bird experts' and involved local authorities, five bird species known to occur in the area was pointed out as generally particularly sensitive to disturbance. These species were White-tailed Eagle *Haliaeetus albicilla*, Osprey *Pandion haliaetus*, Crane *Grus grus*, Whooper Swan *Cygnus cygnus* and Black-throated Diver *Gavia arctica*. They all occur on the flood plain of River Dalälven and may breed in areas of interest for mosquito control. The five bird species have in common that they lay their eggs in open nests and if disturbed they may leave the nests and eggs may be predated upon, or cooled, which may cause breeding failure. Furthermore, all the species are on the EU Birds Directive Annex 1 and the White-tailed Eagle is also on the Swedish Red list classified as Near Threatened (Gärdefors *et al.* 2005).

Two main questions were raised: where and how many pairs of White-tailed Eagle, Osprey, Crane, Whooper Swan and Black-throated Diver breed in areas pointed out as possible mosquito control areas including buffer zones? Along with the search for possible presence of those birds also other bird species of conservation concern were documented although no species specific censuses for these species were carried out. Secondly, would it be possible to carry out an experimental study and measure the strength and extent of possible disturbance connected to the use of helicopter for mosquito control and does it differ between the species?

<u>Methods</u>

Area: The areas surveyed for birds included temporarily flooded wetlands along lower River Dalälven between the cities of Avesta and Söderfors (Figure 1). The areas were identified and pointed out as potential mosquito mass development areas (based on measured abundance of mosquitoes) by the project Biological Mosquito Control (http://www.mygg.se/). To get an idea on the extent of mosquito control the following example can be presented: In 2008 permission to use BTI for mosquito control was granted for 2 434 ha and a maximum of 1 037 ha were in fact controlled. During the course of this study successively more potential mosquito mass development areas were identified and subsequently these were also included in this study (Table 1). The total area surveyed including buffer zones covered 13 622 ha contained seven human population centres (Avesta, Österfärnebo, Gysinge, Tärnsjö, Huddunge, Hedesunda and Söderfors). Buffer zones included an extra 300 m around pointed out areas for White-tailed Eagle and Osprey. This because the generally particularly high conservation value of large birds of prey (see below for more information).

Bird censuses were carried out with a standardised procedure similar to territory mapping (Sutherland 2000). Territory mapping can shortly be described as identification of territories or nest sites compared to other techniques, e.g. line transects, which gives data on relative abundance. Each area was searched both by foot and from the air. When visiting an area for the first time the survey was particularly thoroughly and included documentation also of other bird species of interest, although the main focus was on the five target species. The census was carried out by slowly walking through the area using binocular and telescope while documenting the presence of birds. Special effort was put on areas with habitats known to be used by any of the five target species. People engaged in species projects that regularly count and follow up populations of Osprey and White-tailed Eagle did also participate. If needed some areas were visited more than once and at different occasions during the breeding period. In addition, all areas were surveyed also from the air by the use of helicopter at one time per year (2007-2008) and two times per year (2005-2006). This enabled us to get a good overview, and for some areas which were difficult to get access and overview from the ground this was in fact the only reliable method. Helicopter search was carried out from a height of 100-150 m above ground level. Speed was about 25 knots and when more detailed observations were required the speed was slowed down or stopped which made observing more efficient. Observations from the air were always carried out by two experienced field ornithologists. The rather high flight height was chosen deliberately to be on the safe side and avoid any possible risk to disturb birds. GPS positions were taken for raptor nests. The inventories were carried out mostly in the mornings between 05 and 09 from early May to mid June, 2005-2008.

Experimental study: Mathematical modelling was used to give guidance on what grounds added disturbance (here simulated helicopter disturbance) could be studied. The normal variation in breeding success, i.e. the variation related primarily not to human disturbance, can normally be consider the most important factor in terms of influencing the sample size (see discussion for more information). A hypothetical example was used to study the prerequisites to evaluate the required sample size to be able to run an experimental study with statistically sound results. A power analysis was used to test the numbers of fledge young, of a particular species, that would be needed to study to detect added disturbance and to verify it statistically.

Results

The surveyed habitats subjected to possible mosquito control can be characterised as mostly open areas covered with tufted grass and sedges (Figure 2). Also common are open areas covered with more or less dense willow stands and reed belts. Present but less common are areas with wet deciduous forest. The bird communities, based on present censuses, can be seen as typical for the different habitats and bio-geographical area. Most species are common and more rarely species of special conservation concern was found.

Of the five target species the Whooper Swan was most abundant with between 2-4 breeding pairs per year (Total=13 pairs, 2005-2008), followed by Crane 0-6 pairs/year (Tot=12p), Osprey 0-1 breeding pairs/year (+ 2 nesting sites within 200m from area-border) and White-tailed Eagle 1 pair (Table 2).

In addition to the target species a complete count of Black-throated Diver was carried out in three out of four years showing 4-9 pairs per year (Table 2). Although, the exact locations for breeding Black-throated Divers were not identified, no signs, nor the habitat, indicated breeding within or in close proximity of any of the surveyed areas and the species was excluded from the further studies.

The distribution of breeding pairs of the target species varied and for some species some areas were more frequently used than others. This was particularly pronounced for the Osprey which showed strong fidelity year after year to some particular nests and sites. For example, two nests were occupied during three out of four years and a third nest was occupied for two years. The Whooper Swan also showed strong fidelity to certain locations whereas the Crane regularly switched locations. The numbers of observations were not enough to allow for a statistical analysis of differences in presence or breeding of the target birds in wetlands used for BTI-treatment and reference wetlands.

The time period, four years, is too short to make studies of any possible long-term trends really meaningful. However, for Whooper Swan and Crane, of which data are most abundant, a rough look at the data indicate a small upward trend for Whooper Swan and for Crane numbers fluctuated strongly with two initially good years followed by two years with no or almost no breeding (Table 2).

Data on breeding performance was collected when possible. For Osprey data is available from two nests/pairs and both successfully raised chicks all years when breeding was initiated. The single pair of White-tailed Eagle, which bred in one year, successfully raised one young. For Whooper Swan, 10-12 pairs successfully produced young out of 13 breeding attempts. For the Crane figures are difficult to interpret since pairs with chicks sometimes move away from breeding grounds rather quickly after hatching and then became difficult to find, or if found difficult to know from where they come. Nevertheless, data indicate that between 6 and 9 pairs succeeded with their breeding out of 12 breeding attempts.

Other bird species, interesting from a conservation perspective (Birds Directive Annex 1 or Swedish Red list) observed breeding or with indications of breeding include: Bittern *Botaurus stellaris* (two males at two sites), March Harrier *Circus aeruginosus* (three sites, 3-4 pairs), Wood Sandpiper *Tringa glareola* (one site), Corncrake *Crex crex* (one site), Curlew *Numenius arquata* (two sites, 4-5 pairs), Lesser Spotted Woodpecker *Dendrocopus minor* (one site, ≤3 pairs), Grasshopper Warbler *Locustella naevia* (max c. 10 pairs), March Tit *Parus palustris* (occasional pairs), Scarlet Rosefinch *Carpodacus erythrinus* (one site) and Red-backed Shrike *Lanius collurio* (two sites).

Bird inventories included also observations that could be used to say something about habitat use other than solely for breeding. The Crane was the most observed species and frequently used the open parts of the wetlands. Also in years with poor breeding, pairs spent extended periods of time out on the open areas including both feeding and resting. Whooper Swans were never seen directly on land and only observed there when those were flooded. The Osprey was frequently seen bypassing wetlands but obviously do not use it for foraging unless it is flooded for extended periods of time and fish get access to it. However, popular watch-outs, e.g. some trees or electricity pools, in connection to wetlands were sometimes important. The White-tailed Eagle, both juveniles and adults, were now and then seen in or near wetlands. Since diet in this region probably mostly consists of fish the wetlands are probably of less importance for foraging.

Experimental study: As a first step to explore the conditions to undertake an experimental study a hypothetical example was modelled, using power analysis (Figure 3). We choose the Osprey as model species. The Osprey lay on average 2.6 eggs/pair (Cramp & Simmons 1977) and in the studied area an earlier study (Persson 2007) estimated the number of fledge young 0.9 ± 0.2 /pair and year (mean value achieved by bootstrapping procedure). The range was 0.5 – 1.3 fledge young/pair and year. This mean value and standard deviation were used in the calculations. If the number of produced chicks, at low ("normal") disturbance, is 0.9, 83 pairs of each category (test and control) would be needed to detect a 10 % reduction of numbers of fledge young (at the 5-% significance level; the power being 80 %); a 50% reduction requires in total 10 pairs.

Discussion

Shown by this study the bird communities of areas pointed out as possible mosquito control areas, of the River Dalälven flood plain, hold mostly common bird species and more rarely species of special conservation concern. This was to some degree unexpected because of the known generally high bird values of the Nedre Dalälven region (Holmstedt 2006). In particularly the open grassy areas it was striking how few species and numbers that were observed, which, however, requires more detailed studies to validate. Historically many of the wetlands were used for hay production (Maria Sandvik Widemo pers. comm.). This land use was abandoned in the 1950thies and has led to that many former open wetland areas in later decades have became overgrown by bushes (mainly *Salix ssp.*) and their biological values have probably gradually diminished. Changes in vegetation are also due to water regulation for hydroelectric power purposes (Länsstyrelsen Gävleborg 2009). In recent years some areas have been subjected to vegetation clearing to improve conditions for some animals and plants (Länsstyrelsen Gävleborg 2009). The temporary and large water fluctuations typical for these areas must be challenging for birds that breed on ground. A couple of examples can reflect this: A pair of Whooper Swan started breeding on flooded shallow grassy wetland. A couple of weeks later the water had retreated and the nest became connected to land. Remnants from egg shells were found on the nest indicating predation, and apparently the birds abandoned the breeding. The same fate, under similar conditions, met at least two pairs of Crane in one year. The unpredictable and sometimes rapid changes in water level obviously may strongly hamper breeding success of ground breeding birds, including also the Black-throated Diver. It is likely that those unpredictable changes in water levels may affect the breeding success more than the disturbance from helicopters for these three species.

Only one pair each of Osprey and White-tailed Eagle were found in potential mosquito mass development areas which indicate little risk of conflicting interests. Both species prefer to build their nests in mature trees, often pine, which usually stand on less wet ground and at somewhat higher elevation. The Osprey, which is a typical species of the lower River Dalälven, every year breed with between 12 and 23 pairs (1998-2007) only in Färnebofjärden National park, in the heart of lower River Dalälven (Inga-Britt Persson pers. comm.). Obviously the areas pointed out as possible mosquito control areas are not the preferred breeding habitat of the species. The White-tailed Eagle is steadily increasing in numbers in recent decades, both in the lower River Dalälven area and elsewhere in Sweden (Ottvall *et al.* 2008). The only nest was found in 2008 after strong indications of breeding in that area in the years before.

The modelling approach shows that if the percentage of number of pairs affected by helicopter disturbance is low, but at the same time considered serious (e.g. when zero tolerance is claimed), the present study will not be able to detect this impact unless the number of studied pairs are considerably increased. This would in fact be impossible because the whole populations around River Daläven are far below that (Holmstedt 2006, Tjernberg 2009). According to the calculation an overall reduction of fully grown chicks of 10 % requires 166 pairs to be detected by an ordinary parametric test (oneway ANOVA). Or to illustrate the problem in another way; a large number of breeding pairs have to fail at mosquito control if it should be possible to couple those losses with overflying helicopters.

To make a discussion on possible disturbance caused by helicopter used for mosquito control meaningful, it is important to analyse what disturbance in fact means. To make it relevant from a conservation point of view the disturbance should cause significant negative consequences on a population level (Gill et al. 1996). This means that the disturbance should be of that important it causes increased mortality, decreased reproductive success, and unfavourable redistribution of active pairs from high ranking territories to low ranking territories, reduced inflow of individuals to the population, or other factors that lead to a decrease in population size. For different reasons many of these factors are difficult to quantify and the prerequisites to carry out an experiment were not met in this study. Moreover, with no indications or explicit suspicion of disturbance the actual need of an experimental study became less relevant. The risk of disturbance should also be viewed in proportion to the method used for mosquito control. In short a mosquito control can be described as follows: The helicopter moves forward and back in long sweeps at a height of about 40 m above ground level. Spreading of VectoBac is done from a container placed underneath the helicopter. The speed while spreading is about 60 knots and it takes about two minutes per ha. Mosquito control has been carried out between zero and two times per year on any single area. With the lack of an experimental study the behaviours of birds, and individual variations, could not be studied. However a single pair of Whooper Swan was observed at time of mosquito control. At the time when the helicopter passed the female was incubating while the male was foraging at close distance from the nest (Figure 4). The swans seemed not to react to the helicopter and obviously the pair was not disturbed. This example does however not provide enough evidence to state that negative impact does not exist. Examples from the literature with relevance to this study are few but indicate small if any disturbance to large birds due by low-flying helicopter or aircrafts (Delaney et al., 1999; Watson, 1993; Cook & Anderson, 1990; Andersen et al., 1989). Presence of humans is generally a larger disturbance factor (Swenson, 1979; Holmes et al., 1993; Klein, 1993; Rodgers & Smith, 1995; Stalmaster & Kaiser, 1998). The type of aircraft also affects the reactions of birds and helicopters are considered to cause generally more disturbance than aircrafts with non-movable wings (Grubb & Bowerman, 1997; Ward et al., 1999). Furthermore, birds are generally more sensitive to disturbance early, than later in the breeding cycle (Tremblay & Ellison, 1979; Götmark et al., 1989; Bolduc & Guillemette, 2003). Except for scientific studies extensive knowledge is also available from different projects on large birds of prey in Sweden (e.g. White-tailed Eagle, Gyrfalcon *Falco rusticolus* and Peregrine *Falco peregrinus*) where small aeroplanes and helicopters regularly are used for breeding inventories.

Inventories can some times be carried out at distances as close as 30-50 meters from the nests without any detectable negative disturbance observed (Björn Helander, Peter Lindberg, Johan Ekenstedt pers. comm.).

Strong demands of nature conservation authorities to prevent any kind of disturbance for the target species or other bird species of high conservation values in relation to a small but yet possible risk that disturbance after all will occur at mosquito control, justifies some kind of protective measures, in particular so for the raptors. Therefore we suggest that protection zones should be established around active nests of Osprey (200±50m) and White-tailed Eagle (300±50m). These suggestions are based on international experiences (e.g. Storstad 2002, Helander & Stjernberg 2003, Ruddock & Whitfield 2007) and the discussion with experienced bird experts Björn Helander (Swedish Project White-tailed Eagle project), Martin Tjernberg (Swedish Species Information Centre) and Per Aspenberg (local bird expert). Periods should include the time of incubation until when young leave their nests. The most sensitive period is likely to be in the early phase of the breeding and special attention and care should be paid at this time of the year. For Whooper Swan and Crane there seem to be no need for the time being and according to available information to suggest protective zones around active nests.

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Uppföljningsprogram för fåglar och undersökning av störningskänslighet i samband med helikopterbekämpning av stickmyggor vid Nedre Dalälven

Sedan 2002 genomförs vid behov myggbekämpning vid ett antal översvämningsvåtmarker vid Nedre Dalälven. Myggbekämpningen genomförs från helikopter genom spridning av VectoBac, ett så kallad biologiskt bekämpningsmedel, innehållande BTI som aktiv substans. Myggbekämpningen sker i samband med kraftig översvämning och efter bedömning av förekomsten av larver av gruppen översvämningsmygg. Gruppen omfattar sju arter och i Nedre Dalälvsområdet dominerar *Aedes sticticus*. Då myggbekämpningsverksamheten sker i områden som förknippas med generellt mycket höga naturvärden ledde bekämpningsverksamheten tidigt till stark oro från naturvårdsmyndigheter, naturvårdsorganisationer och allmänheten. För att utröna om ev. negativa sidoeffekter förekommer av verksamheten har under ett antal år pågått en omfattande kontrollverksamhet av vilka denna fågelstudie är en. Syftet med denna studie var att identifiera vilka känsliga fågelarter som häckar och nyttjar övervämningsvåtmarker identifierade som potentiella myggbekämpningsområden. En andra fråga var att studera förutsättningarna att genomföra experimentella studier för att analysera eventuella effekter av lågflygande helikopter i samband med bekämpning, och på vilket sätt och i vilken omfattning flygningarna i så fall stör känsliga arter.

Fågelfaunan i området kring Nedre Dalälven är sedan tidigare allmänt väl beskriven (Holmstedt 2006 och referenser däri) men det saknades mer exakt kunskap om vilka arter som häckar i områden identifierade som potentiella myggbekämpningsområden. Efter diskussion med lokala fågelexperter och naturvårdsmyndigheter beslutades att genomföra fågelinventeringar med särskild fokus på havsörn, fiskgjuse, trana, sångsvan och storlom vilka bedömdes som generellt särskilt störningskänsliga. Samtliga arterna är upptagna på lista 1 i Fågeldirektivet och havsörnen är dessutom rödlistad under kategorin sårbar. I samband med inventeringarna noterades också andra arter med särskild fokus på rödlistade arter. Inventeringarna utfördes både från marken och luften och pågick under perioden 2005 till 2008. Markinventeringarna skedde genom att långsamt vandra genom områdena spanandes och lyssnandes. Habitat som bedömdes som särskilt passande för någon av de fem storfåglarna studerades mera grundligt, mindre lämpliga habitat inventerades mera övergripande. Inventeringar genomfördes vid minst ett tillfälle per år men i särskilt intressanta områden gjordes upp till tre besök per säsong. Inventeringar företogs också en gång per år från helikopter från en höjd av 100-150 meter över omgivande mark. Den relativt höga höjden, att jämföra med ca 40 meter vid bekämpning, valdes avsiktligt för att eliminera eventuell risk för störning. Inventering från helikopter var effektivt i uttalat våta marken och områden som var svåra att överblicka från marken. Totalt inventerades som mest 13 622 ha (2008) och med något mindre ytor under de första årens studier.

Av de fem arterna var sångsvan mest vanlig med mellan 2 och 4 häckande par per år (Totalt=13 par, 2005-2008), följt av trana 0-6 par per år (Totalt 12p), Fiskgjuse 1 par (+2 häckningar inom 200 m från områdesgräns, se huvudtexten för säkerhetszoner runt rovfågelhäckningar) och 1 par havsörn. Storlommen inventerades komplett tre av fyra år och sammanlagt påträffades 4-9 par per år. Var exakt paren häckade identifierades inte men inget tyder på att de häckade på de inventerade ytorna, då habitaten är olämpliga, utan på små öar i närheten. En bedömning av inventeringseffektiviteten antyder att tranan kan ha underskattats något, och enstaka par missats, då de ibland häckar i tät och fuktig terräng som kan vara mycket svår att inventera, i en del fall även från luften.

Det är viktigt att veta på vilket sätt fåglarna reagerar på störning vid helikopteröverflygning i samband med bekämpning. Om fåglarna reagerar kraftigt bör olika åtgärder vidtas för att minska störningarna. En genomgång av litteraturen med avseende på störningskänslighet hos häckande fåglar på olika luftfarkoster pekar i allmänhet på små eller försumbara störningar. Mänsklig närvaro är generellt ett större störningsmoment. Studierna pekar också på att det knappast är möjligt att mer exakt kunna avgöra störningskänsligheten hos en viss art i ett specifikt område utan att där också genomföra experimentella studier. Praktiskt och resursmässigt kan dock experiment visa sig svåra, och i vissa fall omöjliga att genomföra. I denna studie gjordes en poweranalys för att studera förutsättningarna att genomföra experimentella studier och bedöma vilka krav som ställs på stickprovstorlek för att med statisk signifikans kunna säkerställa resultaten.

Den ”normala” variationen i häckningsframgång, d v s den som i det här fallet inte beror av mänsklig störning, bedöms vara den variation som påverkar stickprovsstorleken mest. En slutsats från räkneexemplet (Figur 3) är att om det procentuella antalet påverkade häckningar orsakade av överflygningarna är lågt, men ändå bedöms som allvarliga (t.ex. vid krav på nolltolerans) så förmår studien inte att upptäcka denna påverkan om inte antalet studerade häckningar utvidgas betydligt. Problemet kan också uttryckas som att ett stort antal häckningar måste misslyckas vid test för att dessa med statisk säkerhet ska kunna bindas till helikopteröverflygningarna.

Resultaten från denna studie visar att antalet störningskänsliga och ovanliga arter var fåtaliga på de översvämningsvåtmarker som pekats ut som potentiella myggbekämpningsområden. I flera fall var det påfallande hur få häckande eller födosökande fåglar som överhuvudtaget uppehöll sig i dessa områden. Undantag utgjordes av vissa områden (t.ex. Nordmyran) som under vissa perioder i samband med fåglarnas flyttning besöktes av ett större antal vadare (främst grönbena) och i viss mån änder (kricka och bläsand). Ett skäl till låg förekomst av häckande fåglar kan vara att de översvämningar som periodvis förekommer gör områdena direkt olämpliga för markhäckande arter, och ägg och ungar riskerar att dränkas vid högvatten. På motsvarande sätt kan arter som häckar på blöt mark påverkas och häckningarna spolieras då vattnet drar sig undan och bona blir stående på torra land. Två exempel kan belysa detta och vid kraftig vårflod ett år påbörjade ett sångsvanpar och två tranpar häckning som senare avbröts efter att vattnet dragit sig tillbaka och bona fått landförbindelse.

De resultat som framkommit i denna studie pekar på generellt begränsade fågelvärden i områden utpekade som potentiella myggbekämpningsområden. Annan dokumentation (se Holmstedt 2006) visar dock på mycket höga fågelvärden i angränsade områden utmed Nedre Dalälven, och då framför allt skogslevande arter. Det finns idag inga bevis eller indikationer på att enstaka överflygningar på låg höjd med helikopter påtagligt skulle kunna leda till störning hos ens normalt störningskänsliga arter. Sedan myggbekämpningsverksamheten vid Nedre Dalälven startade (år 2002) har mellan noll och två bekämpningar utförts per år och som mest inkluderat 1 037 ha. De höga krav på artskydd som ställs från naturvårdens sida idag, och den lilla men trots allt befintliga risk att störning uppkommer, motiverar någon form av försiktighetsskapande åtgärder för de mest känsliga arterna. För aktiva bon av fiskgjuse och havsörn föreslår vi därför att skyddszoner inrättas om vardera 200±50 m och 300±50 m. Myggbekämpning från helikopter bör inte vara tillåtet innanför dessa gränser och bör omfatta perioden 1 februari till 30 juli för havsörn, och 1 april till 30 augusti för fiskgjuse.

Figure/table legends:

Figure 1. Map showing locations, along the lower parts of River Daläven, Central Sweden, covered by bird inventories and with permission to control mosquitoes (map: Martina Schäfer, Biological Mosquito Control).

Kartan visar områden utmed Nedre Dalälven som fågelinventerats och områden där tillstånd till myggbekämpning finns.

Figure 2. Flood-plains at Nordmyrasjön, Tärnsjö (2007-05-24) subjected to recurrent but irregular floods. When flooded, and at water temperatures above 8ºC, this type of habitat may induce massive emergence of the flood-water mosquito *Aedes sticticus*, a species causing large nuisance problems (© Henri Engström).

Översvämningsvåtmark Nordmyrasjön, Tärnsjö (2007-05-24). Vid översvämning och vattentemperatur över 8ºC finns förutsättning för massutveckling av översvämningsmyggor, framför allt arten Aedes sticticus, som orsakar stor olägenhet hos människor i området.

Table 1. The table shows size of areas covered by bird inventories and areas subjected to mosquito control divided upon years.

Tabellen visar ytor inventerade på fåglar och ytor som myggbekämpats uppdelat på år.

Year *År*	Areas surveyed for birds *Ytor inventerade på fåglar*	Areas subjected to mosquito control *Ytor där myggkämpning bedrivits*
2005	8 812 ha	729 ha
2006	12 785 ha	840 ha
2007	13 662 ha	40 ha
2008	13 198 ha	1 471 ha

Table 2. Number of pairs found of each of the five focal species subjected to special attention within this study. For Osprey figures within brackets are nests found within 200 m from area boarder (see text for more information). Pairs of Black-throated Diver were found close to mosquito control areas but did most likely not breed there.

Tabellen visar antalet aktiva häckningar funna inom utpekade områden av de fem målarterna. För fiskgjuse är siffror markerade med klamrar bon funna inom 200 m från områdesgräns (se text för ytterligare information). För storlom fanns samtliga par i närheten av utpekade områden men häckade sannolikt inte där.

	Osprey *Fiskgjuse*	White-tailed Eagle *Havsörn*	Whooper Swan *Sångsvan*	Crane *Trana*	Black-throated Diver *Storlom*
2005	0	0	2	5	8
2006	3(2)	0	3	6	2*
2007	3(2)	0	4	0	8
2008	1(1)	1	4	1	4

*no complete count/*ej komplett inventering*

Figure 3. This figure presents the outcome of the power analyses. The base for the calculations is that Ospreys in undisturbed nests are able to produce on average 0.9 fully grown chicks (standard deviation = 0.2) and the reduction on nests being disturbed were 10 – 50% (see numbers in the figure). Yet another assumption is that the numbers of nests in undisturbed and disturbed areas are equal. The x-axis gives the significant level, the dotted line indicate the 5% level; the y-axis gives the total number of nests that are needed to give a certain significance level. The power equals 80% in all cases.

Figuren visar resultat av poweranalys. Beräkningarna utgår från att fiskgjusen under ostörda förhållanden producerar i snitt 0.9 flygga ungar (standaravvikelse=0.2). Bon i störda områden antogs ha 10-50% minskning (angivet i figuren). Antalet bon antogs vara lika många i störda och ostörda områden. Den horisontella axeln (x-axeln) anger signifikansnivån, 5 %-nivån är markerad med den prickade linjen. Den vertikala axeln (y-axeln) anger det totala antalet bon som krävs för att en viss signifikansnivå. Power i samtliga fall är 80 %.

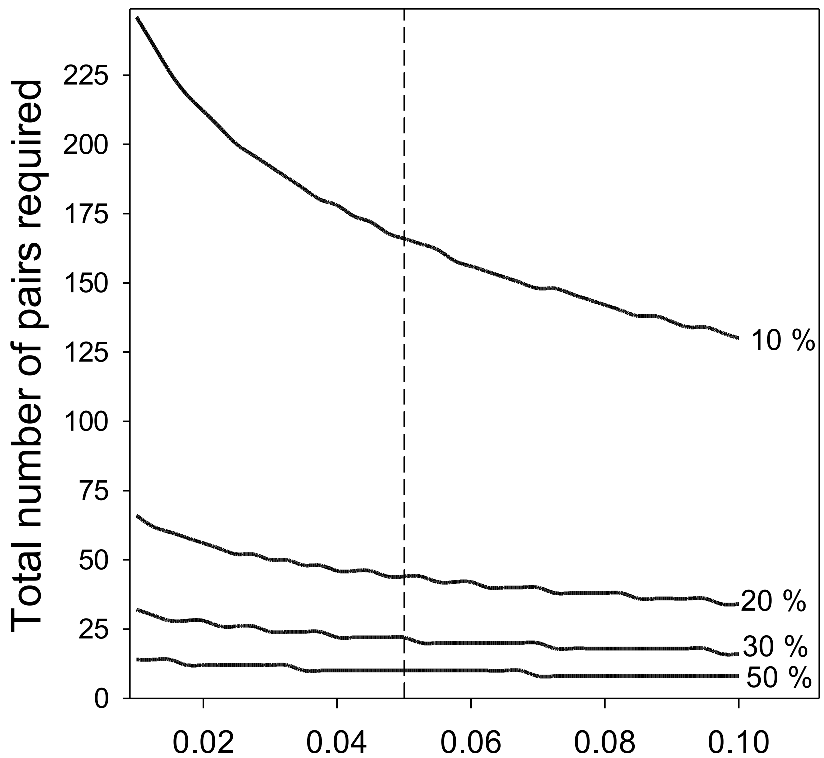

Figure 4. The picture shows a pair of Whooper Swan over-flown by helicopter at mosquito control, Laggarboån, Österfärnebo, 2006-05-11. The female is seen incubating (red arrow), the male laying nearby (black arrow). No reaction can be seen from the birds to the passage of the helicopter. (© Henri Engström).

Myggbekämpning från helikopter av översvämmad våtmark vid Laggarboån, Österfärnebo, 2006-05-11. Upptill till vänster syns bo med ruvande sångsvan (röd pil) och ett stycke åt höger ligger hanen (svart pil). Helikoptern har just passerat fåglarna utan synlig reaktion.