SHORT COMMUNICATIONS

SEX-BIASED MORTALITY OF COMMON TERNS IN WIND FARM COLLISIONS

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Abstract. We studied sex differences in collision mortality in adult Common Terns (*Sterna hirundo*) at a wind farm in the direct vicinity of a breeding site in Zeebrugge, Belgium in 2005–2007. In total, 64 fatalities were collected and sexed, of which 64% were males. Uneven sex ratio among these birds was most pronounced during the period of incubation and early chick feeding (15 May–15 June), when 78% of the 28 mortalities were male. During prelaying and feeding of young, the sex ratio of mortalities did not differ from equality. We argue that sex-biased collision mortality in Common Terns does not result from morphological differences between the sexes, but rather reflects differences in foraging frequency between males and females during egg-laying and incubation.

Key words: Belgium, Common Tern, mortality, sex differences, Sterna hirundo, *wind turbine.*

Mortalidad Diferencial entre Sexos de *Sterna hirundo* por Colisiones en Fincas de Producción de Energía Eólica

Resumen. Estudiamos las diferencias entre sexos en la mortalidad por colisión en adultos de *Sterna hirundo* en una finca de producción de energía eólica vecina a un sitio de cría en Zeebrugge, Bélgica entre 2005 y 2007. En total, colectamos y determinamos el sexo de 64 individuos muertos, de los cuales el 64% eran machos. El desequilibrio en el cociente de sexos en estas aves fue más pronunciado durante el período de incubación y durante el inicio de la alimentación de los pichones (15 Mayo–15 Junio), cuando el 78% de los 28 individuos colectados fueron machos. Durante el período previo a la puesta de los huevos y el período de alimentación de los pichones, el cociente de sexos de los individuos muertos fue parejo. Argumentamos que el sesgo dado por la mortalidad diferencial entre sexos de los individuos que murieron por colisión en *S. hirundo* no resulta de las diferencias morfológicas entre los sexos, sino más bien refleja diferencias en la frecuencia de forrajeo entre los machos y las hembras durante la puesta de los huevos y la incubación.

The enormous growth of the wind energy sector in recent decades has accordingly generated study of its impact on birdlife. Various scientific studies address avian collision risks and disturbance of birds during the nonbreeding period, especially during migration (Winkelman 1992a, Larsen and Madsen 2000, Osborn et al. 2000, Thelander et al. 2003, Barrios and Rodríguez 2004). Scientific literature on the effects of wind turbines preceding or during the breeding season is, however, scarce (Winkelman 1992b, Leddy et al. 1999, de Lucas et al. 2004). Everaert and Stienen (2007) showed that the adverse impacts on colony-breeding birds can be substantial in terms of increased mortality. Here we report on the sex-biased collision risks of Common Terns (*Sterna hirundo*) during pair formation and breeding. The study was conducted in Zeebrugge, Belgium (51°22′N, 3°13′W), where in 2000, a breeding peninsula for terns and plovers was created in the outer port. The site was meant as a compensation measure for the loss of breeding habitat in the western part of the port and was raised along the eastern port breakwater. During the next few years, the peninsula was enlarged in several steps and had an area of approximately 8.5 ha during the breeding season in 2005. Despite the fact that 25 small- to medium-sized wind turbines (10 turbines of 200 kW, 12 turbines of 400 kW, and 3 turbines of 600 kW) stand in the vicinity of the colony site, the peninsula has proved to be very successful in attracting terns (Stienen et al. 2005). In 2005, 2006, and 2007, respectively 1475, 2043 and 2791 pairs of Common Terns nested on the peninsula. This success, however, has been tempered by the high risk of tern collision with the wind turbine rotor blades (Everaert et al. 2002, Everaert and Stienen 2007). The great majority (90%) of the mortalities in 2005–2007 were found at four 400 kW wind turbines (tip height 50 m) situated closest to the colony site. The nearest Common Terns were nesting 30 m from those turbines, but most nests were located ≥100 m from the turbines (Everaert and Stienen 2007).

Hitherto, there has been no study investigating sex-biased differences in avian collision mortality. Still, such differences may be expected, either because of substantial size differences between the sexes (e.g. raptors) or because of behavioral differences between males and females (e.g. in migration routes and wintering areas). Several studies on avian collision found an effect of bird size on the ability to avoid wind turbines (Winkelman 1992a, Everaert 2003), and wing length is an important parameter in

statistical models in order to derive a probability of collision (Chamberlain et al. 2006). The Common Tern is a seabird with a very low degree of sexual dimorphism and considerable overlap in all external body measurements between the sexes (Becker and Ludwigs 2004). Therefore potential, differences in collision rates between males and females probably reflect behavioral differences between the sexes rather than differences in size. Here we report a skewed sex ratio among adult Common Tern collision fatalities at Zeebrugge. We discuss this finding in light of behavioral differences and the sex ratio in the breeding population.

METHODS

During the breeding seasons 2005, 2006, and 2007, the vicinity of the wind turbines on the eastern port breakwater of Zeebrugge was searched for Common Tern fatalities. Searches (occurring at least four times a week) were most frequent during the terns' incubation and early chick-rearing periods, 1 May–15 July. In April and after 15 July, searches were performed less frequently but still at least once a week. Of 104 adult casualties collected in the period from 24 April to 11 August, 64 were reasonably recent and had undamaged sex organs such that their sex could be determined by internal examination. Exposed culmen length, head-plus-bill length, tarsus length, and bill depth at the gonys were measured to the nearest 0.1 mm using vernier calipers, while stretched wing chord was measured to the nearest 1 mm. Not all body parts were found of some birds; therefore, only the remaining parts could be measured. Hence, sample sizes may differ among the various biometric data. One bird was sexed, but no biometrics taken; of 21 of the remaining 40 unsexed individuals, at least some kind of biometrics were taken. Biometrics of collision fatalities were compared to the biometrics of 103 adults that were caught on the nest in 2005–2007. Additionally, 12 adults found dead without obvious signs of collision (i.e., no wounds or fractures found after external and internal examination, or obvious other cause of death) were sexed as well.

STATISTICAL ANALYSES

We used chi-square analysis to test for unequal sex ratios and three independent t-tests with Bonferroni adjustment to detect differences in biometric measurements between the sexes using $P = 0.05$ as the threshold for significance. To examine effects of breeding period on the sex ratio, we pooled data into three periods that roughly delimit three breeding phases, namely the period prior to egg laying (i.e., before 16 May; in all years the first clutches were found thereafter); the period of egg laying, incubation, and feeding of early chicks (16 May–15 June, when the majority of clutches were produced); and the period of feeding young or fledglings (after 15 June, when almost all clutches had hatched young). For convenience, these periods are hereafter called the prelaying, incubation, and chick-rearing periods.

RESULTS

Pooled data on sexed individuals (collision fatalities and birds otherwise found dead) show that all head characteristics (exposed culmen length, head-plus-bill length, and bill depth at the gonys) averaged larger in male than in female Common Terns (t-test: all $t \geq 4.7$, all $P < 0.001$). These differences were still significant after Bonferroni correction. Exposed culmen length, head-plus-bill length, and bill depth at the gonys averaged respectively 5.5%,
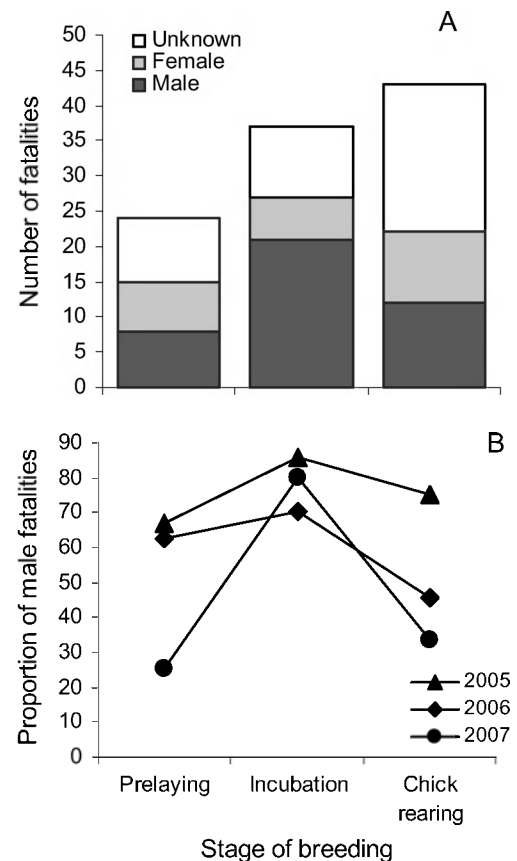

FIGURE 1. (A) Number of sexed and unsexed collision fatalities of Common Terns found during prelaying, incubation, and chick rearing in Zeebrugge, Belgium in 2005–2007. (B) Among the sexed individuals, the proportion of male fatalities changed through the breeding season, peaking in each year during the incubation period.

3.8%, and 8.0% larger in males than in females. In contrast to this, we found no morphological differences between turbine-struck Common Terns and adults caught on the nest (t-test: all $t \leq 1.4$, all $P > 0.10$), although significantly more male casualties were found (64% of 64 wind turbine casualties were males; $\chi^2{}_1 = 5.1$, $P < 0.03$). In 2005, the bias toward males among the wind turbine mortalities was more pronounced (78% of 18 birds) than in 2006 (59% of 29 birds) and 2007 (59% of 17 birds). When treating the years separately, only the 2005 sex ratio among collision fatalities significantly differed from equality ($\chi^2{}_1 = 5.6$, $P < 0.05$). Among birds found dead of other causes, proportionally more females were found (75% females out of 12 dead birds); sex ratio differed significantly between birds whose deaths did and did not results from wind turbine collisions ($\chi^2{}_1 = 6.3$, $P < 0.05$).

During the prelaying period and during chick rearing, sex ratio among collision fatalities was slightly biased towards males (53% and 55% males, respectively; Fig. 1) but did not differ statistically from equality (both periods: $\chi^2{}_1 < 2.7$, $P > 0.10$). During the incubation period, sex ratio was strongly biased towards males (78% of 27 mortalities, $\chi^2{}_1 = 8.3$, $P < 0.01$). A very similar seasonal pattern appeared in each of the three study years (Fig. 1),

but sample sizes were insufficient for statistical testing within years.

DISCUSSION

Our study provides strong evidence for male bias among Common Tern collision fatalities. Male Common Terns are on average slightly larger than females, but only bill measurements differ significantly between the sexes (Coulter 1986, Craik 1999, Fletcher and Hamer 2003). One would expect collision fatalities to have larger bills and heads than birds caught on the nest because males predominated the group of turbine-struck terns, but these small differences were likely obscured by the large overlap in body measurements and the low sample size in this study. Alternative explanations for the lack of difference between the groups—that males are easier to catch on the nest or that males with larger bills are less susceptible to collision with wind turbines—seem unlikely.

In the nearly monomorphic Common Tern, male bias among individuals struck by wind turbines most probably results from behavioral differences between males and females. It is known that female Common Terns spend more time in their territories defending their nests against avian intruders and kleptoparasites (Sorokaité 2005), while males allocate more time to foraging and more frequently deliver food to their mates and chicks (Nisbet 1973, Wiggins and Morris 1987, Gonzalés-Solís et al. 2001). In fact, a male bias was found only when most pairs on the peninsula were engaged in egg laying and incubation. During this period, male flight activity is higher than that of females because males catch fish for females, the latter of which spend most of their time near their nest sites defending territory or incubating eggs (Nisbet 1973, Gonzalés-Solís et al. 2001). In Zeebrugge, the wind turbines stand between the colony site and some of the Common Tern feeding grounds (Everaert and Stienen 2007); the higher foraging activity of males thus increases their collision risk. Other behaviors may also increase males' susceptibility to collision with wind turbines. For example, they return longer fish to the colony than females do (Wagner and Safina 1989; Fasola and Saino 1995) and select larger fish to feed to females for courtship (Taylor 1979). Therefore, males might be engaged in kleptoparasitic chases more frequently (Ratcliffe et al. 1997, Stienen et al. 2001), and prey-carrying males may circle the immediate surroundings of the colony for longer than females before they can actually deliver the fish to the nest.

Early in the season, Common Terns often engage in aerial displays (either with or without fish). Although these displays are often interpreted as courtship displays between individuals of a pair, high flights are occasionally performed by single males. Also, what appear to be sexual partners in low flights can sometimes be two males (but never two females; Tinbergen 1931, 1938, Cullen 1960, Becker and Ludwigs 2004). Given the equal sex ratio among collision fatalities found during the prebreeding season, male aerial display does not seem responsible for the uneven collision rate found in our study. Alternatively, an unequal sex ratio in the Zeebrugge colony may underlie the male bias among the fatalities. Since body measurements of Common Terns that were caught on the nest were smaller (though not significantly so) than those of collision mortalities, the male proportion among the breeding population was probably lower than the ratio found in terns that had collided with wind turbines. Other studies suggest that the sex ratio in Common Tern colonies is equal or even slightly female biased (Ezard et al. 2006). Later in the season, when young nonbreeding prospectors visit the colony, the sex ratio may shift toward a male bias, since male prospectors visit the colony more intensively than do females (Dittmann et al. 2005). However, we found that toward the end of the breeding season, the male bias among the wind turbine fatalities disappeared. This suggests that adults were most susceptible to collision when crossing the row of wind turbines during feeding flights. In agreement with this, we found very few juvenile collision fatalities (in total, five in the three study years), whereas the reproductive output of the studied colony varied between 0.7 and 2.2 fledglings per pair (EWMS, unpubl. data).

Although most wind farms do not appear to have large effects on bird populations (Van den Bergh et al. 2002, de Lucas et al. 2004), some that are positioned along major migratory routes or in other sensitive locations may cause substantial mortality (Leddy et al. 1999), even among threatened bird species (Langston and Pullan 2003, Barrios and Rodríguez 2004, Everaert and Stienen 2007). The wind turbines in Zeebrugge pose a particular threat to Common Terns but also strike Little Terns (*S. albifrons*) and Sandwich Terns (*S. sandvicensis*; Everaert and Stienen 2007). These species (particularly Common Terns) are site-faithful, long-lived, have delayed maturity, and lay small clutches. Species with these life-history strategies are especially vulnerable because a small increase in adult mortality can result in a substantial decrease in population size (Dierschke et al. 2003). This is the first study to investigate sexual differences in mortality rate at wind turbines, but similar results may be expected in sexually dimorphic species (e.g., collision risk may depend on wing size) and in bird species that exhibit sexual differences in breeding behavior, migration routes, or staging areas. The results of this study suggest that the number of individuals crossing the wind turbines probably is decisive for collision risk. Generally, wind farms may have minor effects on birds, but our findings underline that great caution must be taken in placing wind turbines in areas with important bird populations.

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