Disturbance effects of high-speed ferries on wintering sea ducks

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Human offshore activities are increasingly threatening waterbird conservation interests. The impacts of disturbance by high-speed ferries on Common Eiders *Somateria mollissima* and Common Scoters *Melanitta nigra* were studied at a wintering site in the Kattegat Sea, Denmark. Spatial patterns of winter site use, close-range distribution patterns relative to ferry passages and escape distances were examined using aerial surveys and ferry-based observations. For Common Eiders, there was a suggestion of major disturbance impacts, i.e. birds displacing in response to the passage of ferries, within 500–1,000 m of the ferry route: a considerable proportion of flocks (> 10%) located within 400 m took flight in response to a passing ferry, and distributional impacts, including birds responding by swimming, were occasionally suggested within a distance of 500–1,000 m. Although distributional impacts could not be demonstrated with statistical significance within the Hjelm area (partly because of an apparently limited food supply in the area around the ferry route), it is concluded that high-speed ferry disturbance, had the potential to reduce significantly habitat use within 500 m of the ferry route. Common Scoters tended to take flight further from the ferry route than Common Eiders, however, data were limited and no conclusions could be made on displacement distances or possible impacts on habitat use. The results show that high-speed ferries may be an important source of disturbance that should be given due attention when the cumulative effects of offshore activities on site use by sea ducks are considered.

Key Words: Common Eider, Common Scoter, displacement distance, disturbance, habitat use

Human offshore activities are increasing both in terms of types and overall intensity, and correspondingly may conflict with offshore nature conservation interests. The offshore waters of northwestern Europe are of vital importance to a large number of waterbird species that depend on the rich food resources for breeding, migration and wintering and the presence of remote, undisturbed areas for moulting (Delany & Scott 2002). To ensure that these waterbird populations are managed optimally, there is a pressing need for more knowledge on the possible impacts of human offshore activities.

One of the recent developments in offshore activities is the introduction of high-speed ferries. In Danish waters the number of routes operated by high-speed ferries has increased markedly within the last decade, from a few routes in the early 1990s to about 15 routes today. In most cases high-speed ferries have replaced or supplemented conventional ferries on existing routes, and some have been introduced on new routes. High-speed ferries are likely to constitute a more potent source of impacts on waterbirds than conventional ferries because of their markedly higher speeds (35–45 knots) and noise levels, their large wake and their potential to use relatively shallow waters. Knowledge of the impacts of boats on waterbirds stems mainly from studies conducted on lakes, fjords or shallow coastal waters (e.g. Burger 1998; Korschgen *et al.* 1985; Madsen 1998; Rodgers & Schwikert 2002), which relates to different range of boat types and waterbird species from those typically found on offshore waters, making the extrapolation of results difficult. Only a few studies have been conducted in offshore or open coastal waters (Ronconi & St. Clair 2002; Skov- og Naturstyrelsen 1997).

Sea ducks may be vulnerable to offshore activities, as they often occur in large concentrations in relatively restricted areas. The impacts of high-speed ferries on sea ducks may be divided into three main categories: i) changes in habitat, ii) disturbance and iii) collision risk. *Changes in habitat* caused by high-speed ferries may occur where the ferries pass through shallow waters, through the physical effect of the underwater waves generated, by the combined effect of the hull and the water jet, on the bottom substrate (Dahl & Kofoed-Hansen 2003). Changes in substrate composition may in turn affect the benthic fauna on which sea ducks depend. Sailing, like many other human activities, is a source of *disturbance* to birds. A boat passing through a sea-duck site will cause a temporary displacement of birds and a change in activity pattern within a corridor along the route travelled. Depending on the frequency of disturbance and the ability of birds to compensate for the resultant loss of feeding time, and the concomitant increase in energy expenditure, this may lead to a loss of feeding habitat. Finally, high-speed ferries may pose a *collision risk* to sea ducks. The speed at which a high-speed ferry travels leaves limited reaction time for sea ducks located in the ferry's immediate path, which might be especially critical during feeding bouts, when sea ducks spend much time underwater, or when visibility is reduced. Birds may collide with the ferry or, when attempting to escape by diving, become caught in the underwater turbulence.

The present study examines disturbance effects by high-speed ferries passing through a wintering site for Common Eiders *Somateria mollissima* and Common Scoters *Melanitta nigra*, with the objective of assessing the implications for habitat use (i.e. habitat loss).

Study area and ferries

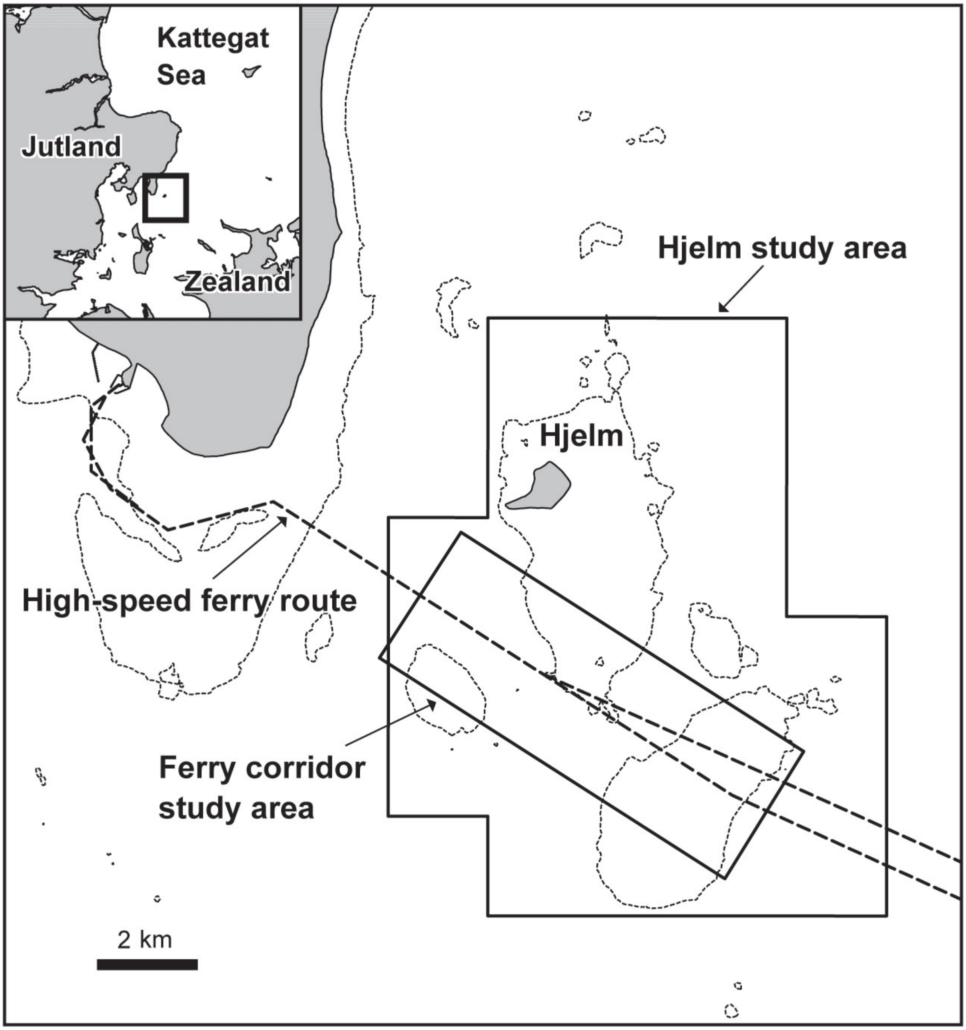
The main study area comprised a number of shallows close to the island of Hjelm in the southern Kattegat Sea, Denmark (56°7' N, 10°50' E; **Figure 1**). The Hjelm area is an important wintering site for Common Eiders and Common Scoters, regularly supporting internationally important numbers (Laursen *et al*. 1997; Skov- og Naturstyrelsen 1993). The high-speed ferry route from Ebeltoft on the Jutland side of the Kattegat Sea to Odden on the Zealand side passes through the southern part of the Hjelm area – the routes deviate to some extent depending on whether the ferries are travelling in an easterly or westerly direction (**Figure 1**). During the study, ferries departed at hourly intervals from each side of the Kattegat Sea, passing the study area twice every hour, between 0600 h and 2100 h on weekdays and 0700 h and 2200 h at weekends. The route was operated by two similar catamaran-type ferries, each powered by two gas turbines, with a normal speed of 36–37 knots. Ferry dimensions were length 76 m, width 23 m and height a.s.l. 9 m.

Methods

The data presented in this paper originate from an impact assessment study conducted during the winter of 1999–2000, as part of the process of obtaining environmental approval for the two high-speed ferries operating the Ebeltoft–Odden route. Danish legislation has demanded environmental approval of high-speed ferries since 1997, on all routes including a Danish harbour. Environmental approval entails, *inter alia*, that the applicant ferry company accounts for the noise and waves generated by the ferry, and, when deemed relevant, provides assessments of potential conflicts with nature conservation interests.

Investigations were directed at determining the distance from the ferry route at which major disturbance impacts occurred. Major disturbance impacts in the present context were defined as birds showing displacement behaviour, i.e. birds diving, flying or swimming away in response to a passing ferry. Three lines of investigation were undertaken, representing different approaches and levels of detail: 1) spatial pattern of distribution at site level for the entire winter period, 2) ferry exclusion experiment comparing numbers and distribution patterns relative to ferry crossings in a corridor around the ferry route, and 3) observations of birds' behavioural escape responses towards approaching ferries.

Figure 1. Location of study areas and high-speed ferry route, island of Hjelm, southern Kattegat Sea, Denmark. Also shown is the 10-m depth curve.



Overall pattern of site use

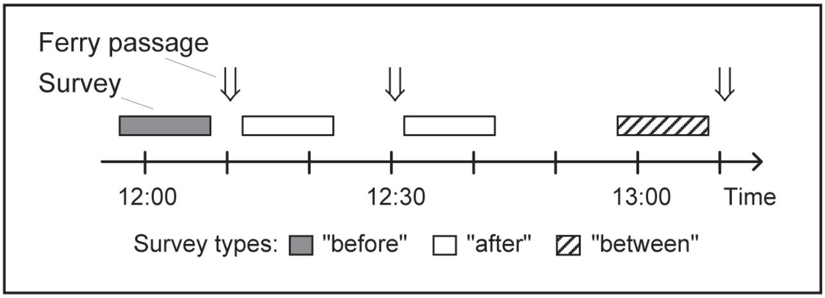
Overall numbers and distribution of Common Eiders and Common Scoters were investigated using aerial surveys. Between December 1999 and March 2000 five surveys were conducted using a Partenavia Observer, flying on fixed north–south oriented transects spaced at 2-km intervals throughout the study area. The transects were flown with an approximate speed of 100 knots and an altitude of 250 m. Observations were recorded continuously on a dictaphone by two people, each observing one side of the plane. For each flock, the time, species and numbers were recorded. Flock positions were deduced by relating the time of observation to a GPS-log of the route flown.

The spatial pattern of distribution was analysed based on mean numbers in 500-m intervals along aerial transects (n = 96). Serial dependency was considered sufficiently low at this interval length, mean autocorrelation on transects being 0.192 (range -0.030–0.436), in order not to critically violate the assumption of independency of sampling units. As the main predictor of sea duck distribution was assumed to be food availability, and this is typically depth related, data were analysed initially for patterns of depth use. The distribution of Common Eiders was highly related to water depth (one-way ANOVA, $F_{3,92} = 14.297$, $P < 0.001$): mean numbers compared to other depth intervals were significantly higher at a depth of 0–5 m and lower at a depth of 20–30 m, respectively, while numbers at depths of 5–10 m and 10–20 m did not differ significantly. Because the 0–5 m depth range was represented only at medium distances (1,000–4,000 m) from the ferry route and the 20–30 m depth range was clearly avoided, the influence of ferry route distance was analysed based on the combined data for the 5–10 and 10–20 m depth intervals, covering the full distance range and making up about 75% of the study area. A similar analysis was not attempted for the Common Scoter as this species did not occur in high numbers. For the purpose of analysis, transect intervals were assigned to ferry-route distance intervals of 0–500 m, 500–1,000 m, 1,000–1,500 m, 1,500–2,000 m, 2,000–3,000 m, 3,000–5,000 m and 5,000–8,000 m. Relationships were tested using one-way ANOVA on $\log_{10}(x+1)$-transformed numbers to approximate a normal distribution of test data. In case of significance, the Tukey-Kramer method, with unequal sample sizes, was applied to test for differences between means.

Numbers and distribution relative to ferry crossings

The use of distribution patterns to assess disturbance impacts may be confounded by spatial variation in food supply. In an attempt to control for this factor, a quasi-experimental approach was taken comparing distribution patterns of Common Eiders and Common Scoters within the ferry corridor (see **Figure 1**) relative to ferry crossings. During four trials carried out between January and March, aerial surveys were conducted immediately prior to the first crossing of the day, immediately after the first or second crossing and, finally, by the end of the longest time interval between two crossings (i.e. about 25 min after the last crossing), to see whether birds would return between crossings – below termed the 'before', 'after' and 'between' surveys (**Figure 2**). To increase the likelihood of the 'before' scenario's reflecting a distribution pattern in accordance with the food supply, ferries were excluded from the study area until midday on the day of observations, temporarily displacing the route about 10 km to the south. Common Eiders wintering in sub-littoral areas feed throughout the

Figure 2. Set-up of the ferry exclusion experiment, showing the timing of surveys (horizontal bars) relative to ferry crossings (vertical arrows). Each trial consisted of a 'before' survey, prior to the first passage of the day (at midday), an 'after' survey, following the first or second ferry passage, and a 'between' survey, by the end of the longest time interval between two passages.



day, with little segregation of feeding and resting areas (Guillemette 1998; unpublished data from the southern Kattegat Sea).

Numbers and distribution of Common Eiders and Common Scoters within the ferry corridor were determined by aerial surveys conducted along three fixed transects at 1-km intervals centred on and parallel to the ferry route. Transects were flown at an approximate speed of 100 knots and altitude of 300 m; the latter to minimise the aeroplane causing disturbance on neighbouring transects. Observations were recorded in the same way as for surveys of the general pattern of distribution in the Hjelm area (see above), with the modification that flocks were assigned to 250-m intervals relative to the transect. Distance intervals were determined with the use of an inclinometer (Silva CM-P).

The impact of ferry crossings was analysed based on the total numbers within each 250-m interval, combining data for similar intervals for the two sides of the ferry route. Statistical tests were conducted on $\log_{10}(x+1)$-transformed numbers. Patterns of changes in overall numbers during the trials were tested using ANOVA with correlated samples, and changes in numbers in different distance intervals during the trials using ordinary ANOVA, looking for interaction between distance and time of survey.

Distance of behavioural responses to passing ferries

The distance from the ferry route at which flocks responded by escape-diving or taking flight was observed from a travelling ferry. Observations were conducted along the entire length of the ferry route, i.e. including outside the Hjelm study area, during three full days in February. Two observers were situated in a small hide mounted 10-m a.s.l. and 5 m from the bow of the ferry. From this position the water surface in front of the ferry was scanned for sitting birds. Flocks were observed until at least 50% of the individuals had reacted by diving or taking flight, or the ferry had passed the flock, which remained on the water. At the point of reaction or when the ferry had passed, the distance and angle to the flock were measured using binoculars with a laser-based distance reading and a digital angular reading (Leica Vector IV). The measurements were accurate to 2 m and 0.6 degrees, respectively, and the operational range was 5–1,250 m for the species studied. For each flock, the perpendicular distance to the ferry route was determined based on the distance and angle measured. Results are presented as proportion of flocks with escape response in 100-m intervals, with day of observation as the sampling unit.

Results

Overall pattern of site use

Common Eider numbers ranged between 2,901 and 8,209 individuals in the Hjelm area during the study period. Common Eiders were found in most parts of the study area, with the largest concentrations immediately south of the island of Hjelm, on a small area of shallows to the southwest and in the eastern part of the area, respectively (**Figure 3**). Within the 5–20 m depth range, represented throughout the study area and commonly used by the Eiders (see Methods), there was no simple relationship between Common Eider numbers and distance from the ferry route, numbers being relatively low within 500 m, high at 500–2,000 m and low again beyond 2,000 m (one-way ANOVA, $F_{6,65}$ = 2.207, P = 0.053; **Figure 4**).

Common Scoter numbers ranged between 11 and 992 individuals, with the largest numbers present at the end of the study period. The major Common Scoter concentrations were found south of the island of Hjelm and in the central southern part of the area (**Figure 3**). The relatively few Common Scoter present during the study did not permit a detailed analyses of distribution patterns relative to the ferry route. It may be noted, however, that the largest concentration of Common Scoter was found at a distance of 1,000–2,000 m south of the ferry route.

Numbers and distribution relative to ferry crossings

Numbers and distribution of Common Eiders and Common Scoters in the ferry corridor relative to ferry crossings are illustrated in **Figure 5** for each of the four trials. For both species the possibility of discerning the impacts of ferry crossings was influenced by the fact that before the ferries resumed their normal routes larger numbers were more or less confined to the area 500–1,500 m to the south of the ferry route.

Common Eider The pattern of changes in numbers and distribution of Common Eiders from 'before', to immediately 'after' and 'between' crossings was not consistent between trials. On 25 January, when the highest numbers of Common Eiders were present, overall numbers more than halved after the first ferry had passed the area. The decrease in numbers was observed mainly in the 500–1,000-m interval, where the major concentrations were found, but a reduction was also seen within 250 m. In between crossings,

Figure 3. Overall distribution pattern of Common Eiders and Common Scoters in the Hjelm area, southern Kattegat Sea, Denmark, during the winter of 1999/2000. Mean numbers shown for 500-m aerial transect intervals, based on five surveys made during December 1999 –March 2000.

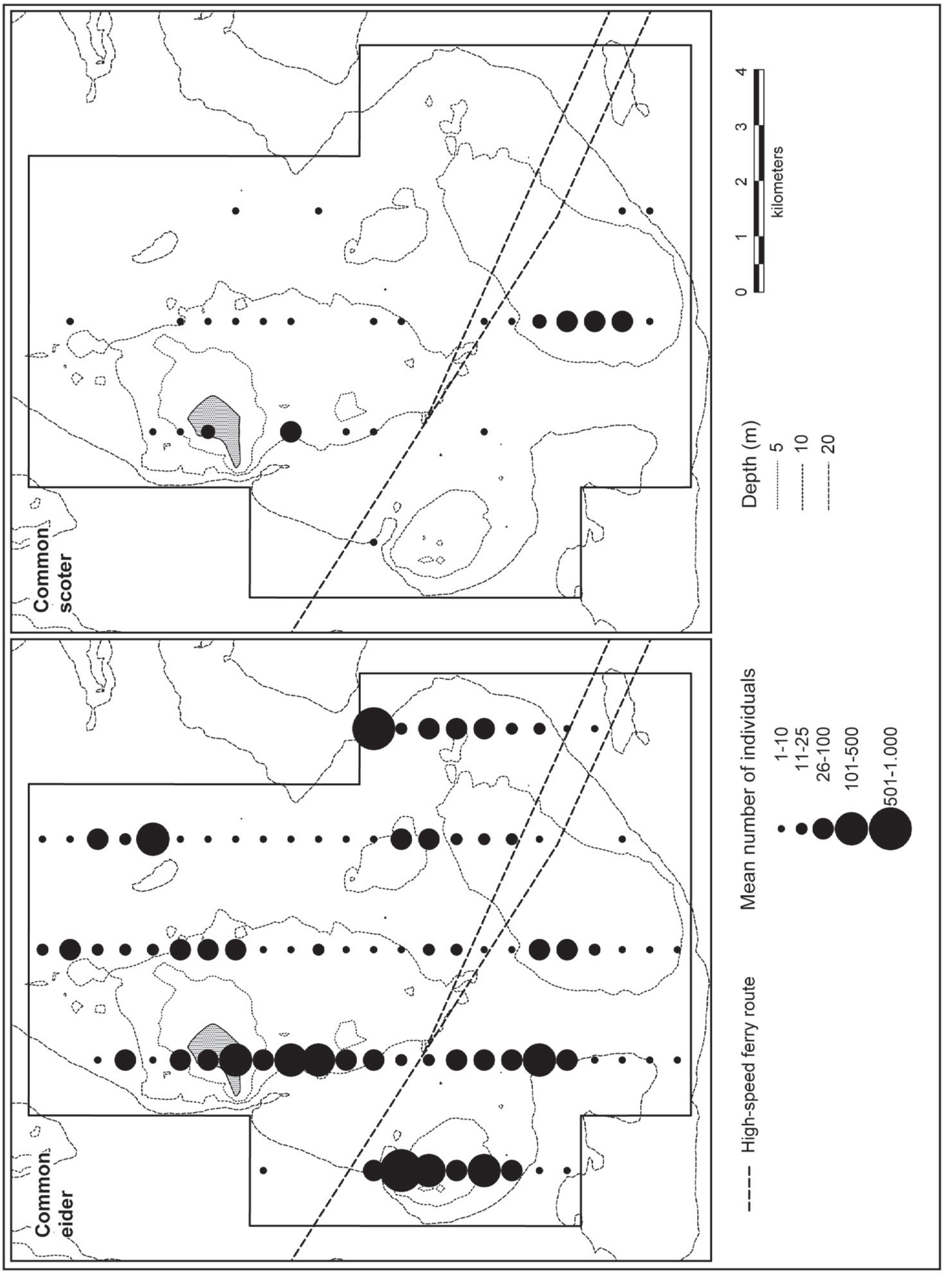
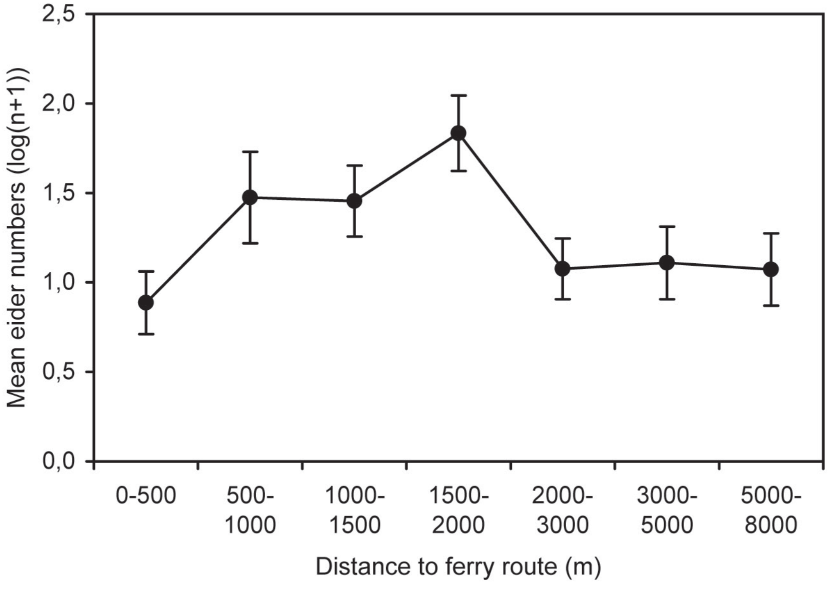


Figure. 4. Common Eider numbers in the Hjelm area, southern Kattegat Sea, Denmark, in relation to distance from the ferry route within the 5–20-m depth range, based on mean (± s.e.) numbers in 500-m aerial transect intervals (n = 8-14).



numbers partly recovered, and this was attributed to a full recovery of numbers 500–750 m from the route. On 11 February numbers of Common Eiders almost halved after the ferries resumed crossings, due to a decrease in numbers in the 500-750 m and 1,250-1,500 m distance intervals. Between crossings, numbers partly recovered within the 500–750 m distance interval. During the last two trials overall numbers remained constant, and apart from a decrease in numbers at a distance of 1,250–1,500 m on 21 February there was little indication of ferry-related impacts on distribution patterns. On 11 and 21 February several large flocks of Common Eiders were located over the southern border of the study area, making results for the 1,250–1,500 m interval susceptible to even small biases in correctly defining the interval boundaries.

Combining the data for all trials, overall numbers tended to decrease after the first crossing and then partly recover between crossings, mean 'after' numbers being 67% and 'between' numbers 82% of 'before' numbers. This pattern of change in numbers, however, was not statistically significant (ANOVA with correlated samples: $F_{2,11} = 2.230$, $P = 0.189$). Similarly, looking at changes in distribution patterns over all trials, the only consistent tendency for an impact of ferry crossings was found within 250 m of the route (**Figure 6**). Overall there was no statistically significant change in distribution patterns between surveys (two-way ANOVA, interaction

Figure 5. Numbers and distribution of Common Eiders and Common Scoters in the ferry corridor study area, southern Kattegat Sea, Denmark, before, immediately after and between ferry passages, respectively. For Common Scoters larger numbers were present during two trials only. Numbers are summed in 250-m distance intervals from each side of the ferry route (south indicated by negative distances), which is indicated by the dashed vertical line. Note that the scale of the y-axis differs between species.

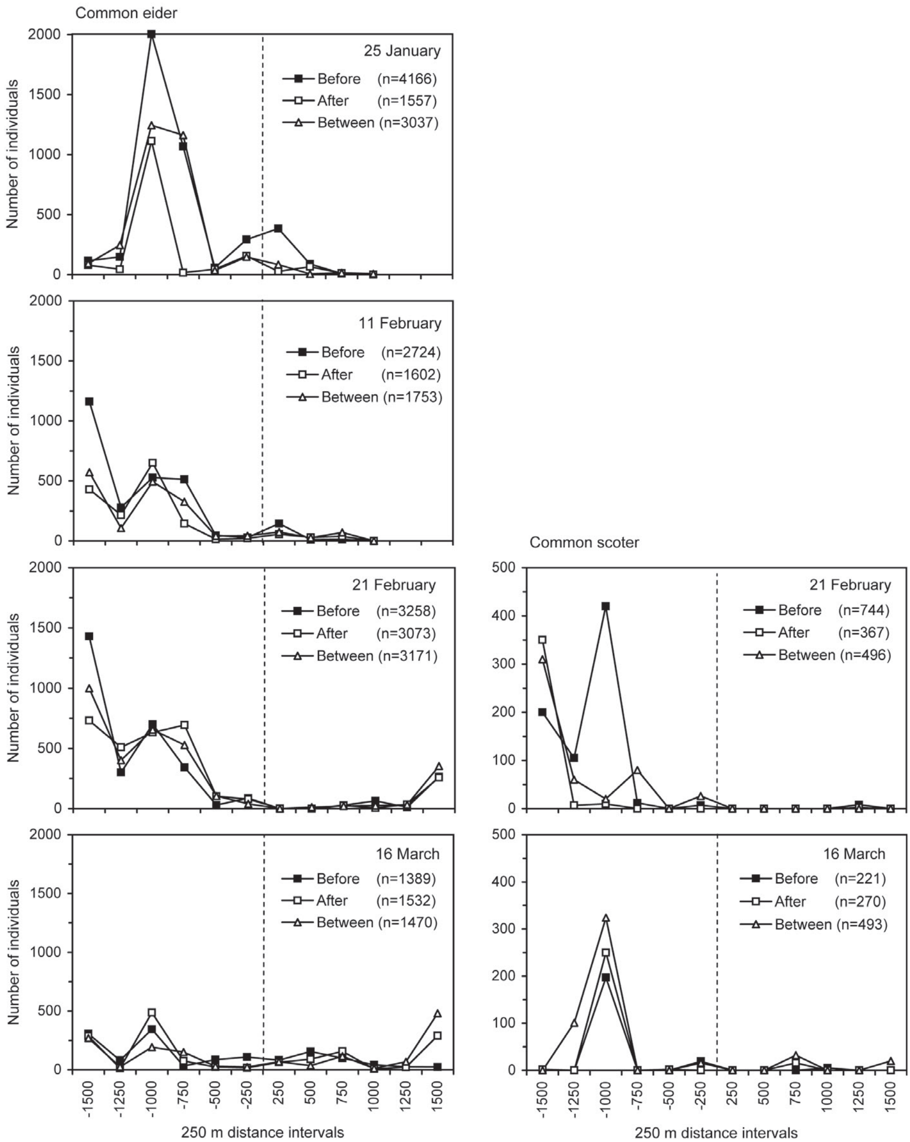
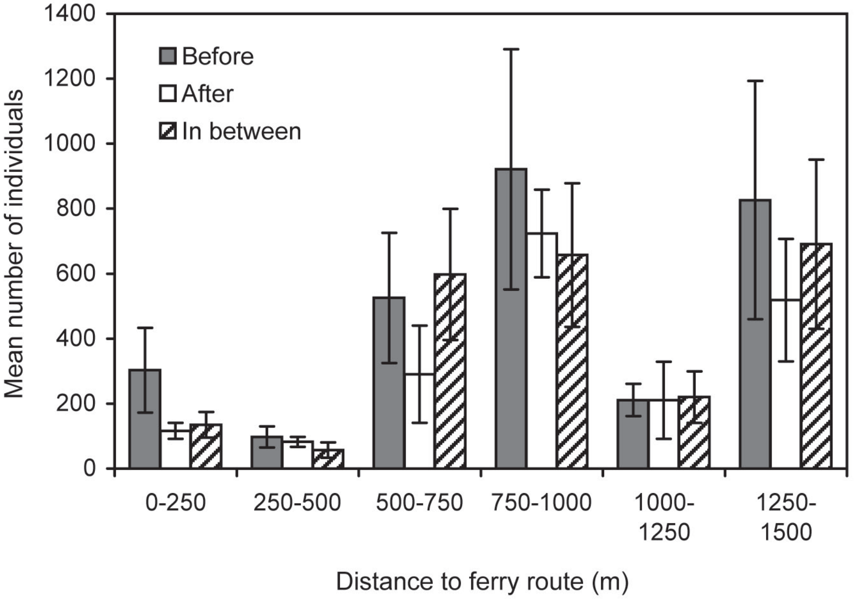


Figure 6. Mean (± s.e.) Common Eider numbers in the Hjelm area, southern Kattegat Sea, Denmark, in 250-m distance intervals relative to the ferry route before, after and between ferry passages, respectively, for all four trials. Numbers were summed for the two sides of the ferry route.



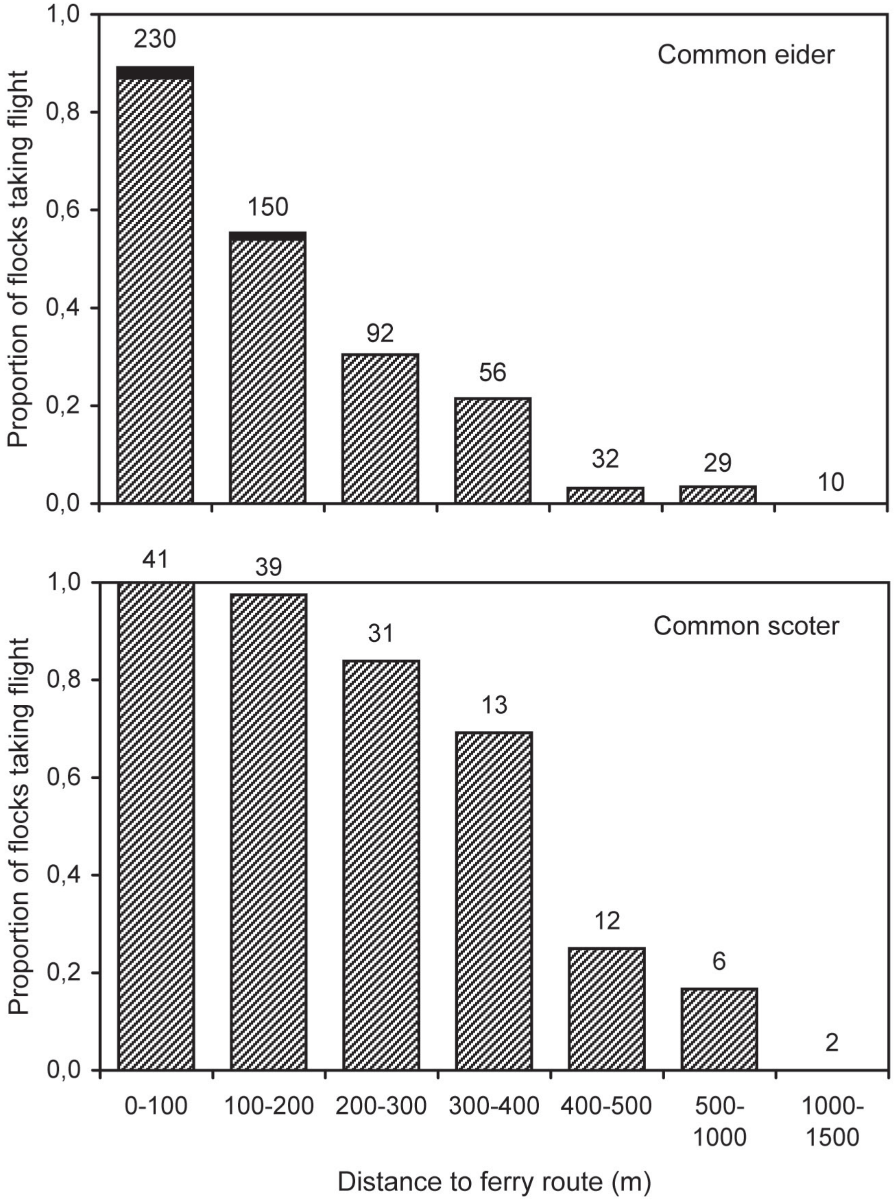
between distance and survey: $F_{10,54}$ = 0.567, P = 0.834).

Common Scoter Only during the last two trials were Common Scoters present in significant numbers. On 21 February, overall numbers halved after the first crossing, as the main concentration of birds 750-1,000 m south of the route largely disappeared. Between crossings numbers increased to about two thirds of the 'before' numbers, mainly due to an increase at 1,250–1,500 m and a partial recovery at 1,000–1,250 m. On 16 March, numbers in the main concentration 750–1,000 m from the route doubled during the trial. No statistical analysis was attempted for Common Scoters because of the limited sample size.

Distance of behavioural responses to passing ferries

During the three days of ferry-based observations, the reactions of 599 Common Eider flocks and 144 Common Scoter flocks were determined (**Figure 7**). For Common Eiders about 90% of flocks within 100 m of the ferry route took flight or dived in response to an approaching ferry. Escape-diving was observed mainly within 50 m of the ferry route. At longer distances the proportion of flocks taking flight gradually declined, and at a distance of 400–500 m less than 10% of flocks took flight. The largest distance perpendicular to the ferry route at which a Common Eider flock was observed to take flight was 587 m.

Figure 7. Proportion of Common Eider and Common Scoter flocks in the Hjelm area, southern Kattegat Sea, Denmark, taking flight (hatched) or diving (solid) in response to an approaching ferry at varying distances from the ferry route. Sample size for each distance interval is given above columns.



For Common Scoters virtually all flocks within 200 m of the ferry route took flight in response to a passing ferry. The proportion taking flight declined only slowly with increasing distance, with about a quarter of flocks still taking flight at a distance of 400–500 m from the route. The largest distance relative to the ferry route at which a flock was observed to take flight was 515 m. However, sample sizes were small at a distance of more than 500 m, and the results therefore uncertain beyond this range. Escape-diving was not observed among Common Scoters.

Discussion

Extent of major disturbance impacts

For Common Eiders the combined results suggests that major disturbance impacts, i.e. birds displacing in response to a high-speed ferry crossing, occurred up to 500–1,000 m from the ferry route. This finding is supported mainly by the observations of behavioural responses of flocks of Common Eiders towards approaching ferries, which showed that a considerable proportion of flocks (> 10%) located within 400 m of the ferry route took flight, and a small proportion took flight between 400 m and 600 m. These observations, however, did not address eider flocks responding by swimming, and therefore convey a minimum estimate of the extent of displacement impacts. Investigating patterns of Common Eider distribution within the Hjelm area (i.e. at the site level and close to the ferry route) gave less clear-cut results, but seems to corroborate the finding that major disturbance impacts could extend to a distance of 500–1,000 m from the ferry route. Analysing patterns of site use during winter could not establish the ferries as a major disturbance factor at the site level, although indications were found of less use of the area within 500 m of the ferry route. The limited presence of eiders within 500 m of the ferry route, however, was also found when ferries were excluded from the area, suggesting that other factors could be involved (see **Discussion** below). This, in combination with the limited number of trials, greatly hampered the potential for conclusions to be drawn from the ferry exclusion experiment about the existence of ferry-related disturbance impacts. Nevertheless, consistent indications of ferry-related impacts were found for the relatively small numbers of Common Eiders in the 0-250 m distance interval, while in the 500–1,000 distance zone, where larger numbers were present, impacts were indicated in two of four trials only (in two trials for the 500–750 m interval and one for the 750–1,000 m interval). It may be noted that the trial with the most pronounced indication of a ferry disturbance impact within the 500–1,000 m distance interval was characterised by the highest numbers of eiders in this range of all trials (about 3,000 individuals compared to about 500-1,000 in the other trials), suggesting a possible flock-size-related effect. Flock-size-related responses to disturbance have been found for other bird species, individuals in large flocks being disturbed at greater distances than individuals in small flocks (Burger & Gochfeld 1991; Mori *et al.* 2001). Distributional impacts possibly extending 500–1,000 m from the ferry route are similar to those suggested for wintering Common Eiders by an earlier Danish study of high-speed ferries (Skov- og Naturstyrelsen 1997).

For Common Scoters the statistical background from which to draw conclusions about disturbance impacts is weaker, the indication being an impact at least within the range suggested for Common Eiders. During the ferry-based observations a considerable proportion of Common Scoter flocks (> 10%) took flight to a distance of about 500 m from the ferry route – sample sizes beyond 500 m, however, were too small for it to be possible to follow the decline in the proportion of flocks taking flight in any detail. It may be noted that the largest Common Scoter concentrations within the Hjelm area were found at a distance of 1,000–2,000 m from the ferry route.

As the present study is an 'after' study (i.e. with the route already in operation by high-speed ferries) it does not address the situation of a high-speed ferry route vs. no high-speed ferry route. Possible overall depressing effects on sea duck numbers in the Hjelm area would not have been detected. Comparing maximum numbers recorded during the present study (Common Eider 8,200 individuals and Common Scoter 1,000 individuals) with maximum numbers recorded prior to the introduction of high-speed ferries (Common Eider 1,300–18,000 and Common Scoter 100–12,000 individuals, NERI aerial survey data 1987–1992), gives no indication of a marked overall decline in numbers. However, more years of 'after' data would be needed, given the high variability in 'before' numbers, to draw conclusions on this with more confidence.

Implications for habitat use

The conservation concern prompting the present study was whether high-speed ferries would affect the use of the Hjelm area by wintering sea ducks. Thus, the potential implications of the observed disturbance effects on habitat use have to be addressed. The fact that disturbance may be observed cannot by itself be taken as evidence that the birds' ability to exploit the available food resources is negatively affected (Gill *et al.* 1996; Gill *et al.* 2001). A crucial factor in this context is the ability of birds within the disturbance zone to compensate for the loss of foraging time and the increase in energy expenditure caused by the disturbance event, i.e. to maintain a positive energy balance. This ability will depend on a number of factors, notably frequency of disturbance and food abundance, and will be expected to increase with distance to the source of disturbance (i.e. the ferry route) as the intensity of the behavioural response diminishes. Common Eiders, which depend on benthic invertebrate prey of low energy density, spend the majority of daylight hours engaged in feeding or forage-related activities in winter (Guillemette 1998; Systad *et al.* 2000), and thus might be expected to be susceptible to disturbance. The results of a previous Danish high-speed ferry study suggest that Common Eiders took about 10 min to resume feeding after being displaced (by flying or swimming) by a passing ferry (Skov-og Naturstyrelsen 1997). Based on this result, with two ferry crossings each hour of daylight Common Eiders within the displacement distance would suffer a reduction in diurnal feeding time of about 30%. Meeting the increased energy expenditure caused by the disturbance under such circumstances would seem to be difficult, especially for eiders responding by taking flight. Common Eiders have high wing-loadings, and consequently flight is believed to be a relatively costly type of behaviour (Guillemette 1994). Thus, the authors suggest that the distance from the ferry route at which a large proportion of eider flocks were observed to take flight (i.e. 400 m), is likely to convey a minimum estimate of the extent of major habitat use impacts. As, conversely, the ferry exclusion experiment did not demonstrate consistent distributional effects on the major eider concentrations located 500–1,000 m from the ferry route, the authors conclude that major effects on eider habitat use would most probably occur within a distance range of 500 m.

Since food supplies in the Hjelm area were apparently limited within 500 m of the ferry route, it would seem that the actual impacts on eider habitat use were minor during the winter studied. Limited food supplies were suggested by the fact that even when ferries were excluded from the site few Common Eiders (or Common Scoters) were found within this distance range. Although somewhat higher numbers were observed in the 0-250 m distance interval without ferry crossings, overall numbers remained low compared to the concentrations found in neighbouring areas. Alternatively, eiders may deliberately have avoided this area because of its proximity to the ferry route. This seems unlikely, however, as eiders redistribute every morning, flying back after having drifted off the site during night, and because there are no visible indications of the location of the ferry route. Also, the eiders' depth preferences could not have produced this distribution pattern, as depth ranges were largely similar in all 250-m intervals within 1,000 m of the ferry route: there were no shallow areas of less than 5 m depth, 90% of the areas in this zone being 5–20 m in depth.

Could the apparently limited food supplies within 500 m of the ferry route possibly result from *changes in habitat* caused by the high-speed ferries? It has been shown that waves generated by large high-speed ferries at a depth of 10 m, which is similar to the mean depth along the ferry route in the present study area, can move stones of up to 600 g located directly below the ferry (Dahl & Kofoed-Hansen 2003). Thus, changes in the habitat would seem a possibility, especially in areas not exposed to wind-generated waves. The Hjelm area, however, is relatively exposed to the prevailing westerly and southwesterly winds, suggesting a minor potential for high-speed ferries effects on bottom habitats. Alternatively, the apparently limited food supply might have been a product of natural spatial variability in the benthic fauna. Large areas with comparably low eider numbers were found in adjacent areas to the north of the ferry route at a distance of 500–1000 m and further away at a distance of more than 2,000 m (see

Figure 3), the latter well beyond the probable lateral range of ferry-induced impacts on the bottom substrate.

It is not possible to assess habitat-use impacts for Common Scoters. The longer escape-flight distances might indicate that impacts on habitat use ranged further than for Common Eiders. However, this may as well reflect differences in escape strategies: Common Scoters are probably more inclined than Common Eiders to take flight, because of their lower wing-loading and the correspondingly lower costs of flight.

Implications and recommendations for future studies

Decreased habitat use within 500 m distance of the ferry route would, in the case of the Hjelm area, affect *c.* 15% of the area within the favoured depths (i.e. < 20 m). If food availability is a limiting factor, as has been suggested for a nearby wintering site (Larsen & Guillemette 2000), mean winter site use should be expected to be affected correspondingly. As food availability probably is variable both spatially and annually this may conceal the fact that there will be a high impact on site use in some years and no impact at all in others (as suggested for the specific study year). Although a reduced carrying capacity of the above magnitude may seem of relatively minor importance, care should be taken not to view possible high-speed ferry disturbance impacts in isolation. As offshore activities are intensifying, it is becoming increasingly relevant to consider the possible accumulation of impacts caused by different activities occurring within the same area. This will apply not only in relation to other kinds of boat traffic but also to different types of activities such as fishery, hunting, extraction of raw materials and wind farms. Indeed, there is a pressing need to investigate both the individual effects of such activities and the ways in which they interact to influence the use of offshore waterbird sites.

The suggested extent of the impacts of high-speed ferry disturbance on wintering Common Eiders should be applied with caution to other sites and other waterbird species. Evidently more studies are needed to establish the extent of habitat use impacts with more confidence. In particular, future studies should, when possible, sample food abundance and examine behaviour and disruption periods of focal flocks at varying distances from a ferry route. For sea ducks as a group, the suggested extent of habitat use impacts is probably not representative, as Common Eiders, judged by their general distribution patterns and behaviour, seem among the more robust species with respect to disturbance. Therefore, at the present level of knowledge, the authors suggest that, when planning new high-speed ferry routes, or converting conventional ferry routes to high-speed ferry routes, the authorities specify 1,000 m as the minimum distance that the route should take (the largest distance at which possible disturbance impacts were observed in the present study) from the larger sea-duck concentrations.

Finally, there may be other types of impacts related to high-speed ferries that deserve the attention of future studies, notably the risk of collision for high wing-loading species like the Common Eider; reluctance to take flight, and long time to do so, is evidently problematic characters when dealing with boats travelling with the speed of high speed ferries.

Acknowledgements

We thank the personnel on Mai and Mie Mols for their kind co-operation and assistance during the ferry exclusion experiment and the observations from Mie Mols. The study was financed by Mols-Linien A/S. The Department of Coastal Zone Ecology, NERI, is thanked for access to earlier count data from the study area. Thanks to Tony Fox, Stefan Pihl and an anonymous referee for comments on drafts of the manuscript.

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