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ABSTRACT

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Missile tests in the Meldorfer Bucht have been under debate for many years, especially since the test area has become part of the National Park Schleswig Holsteinisches Wattenmeer. Alterra Texel, as an independent institute involved in biological research in the Wadden Sea for many years, has been asked to quantify the effects of these tests by means of a brief field study. The results presented in this report are based on observations during a single observation day. Our results are combined with theoretical predictions and data from earlier studies. It appears that the use of helicopters for making clear range flights and for collecting the remains of the missile from the mudflats have the highest impact, especially because of disturbance of birds. Some thousands of waders and other waterbirds are disturbed briefly. The impact of these disturbances, expressed as extra energy expenditure for birds, can be classified as small. The number of macrobenthic animals (like worms and shellfish) killed by the missile landing on the tidal flats can be classified as very small. Although our study has been short and relatively superficial we believe that the results can be considered as a valid expert opinion on the most relevant implications of the impact of weapon technology trials in this area.

Keywords: Germany, disturbance; effects, helicopters; macrobenthos, Meldorfer Bucht, missile testing; Wadden Sea, waders

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Contents

Summary

Theoretically missile tests in the Meldorfer Bucht may be expected to have following effects:

1. disturbing effects on birds because of high sound levels during launching
2. disturbing effects on birds due to visual and/or acoustic stimuli during the missile flight
3. disturbing effects on birds due to helicopters making clear-range flights and for collecting the missile after landing
4. disturbing effects on birds and macrobenthos of people walking on the tidal flats when collecting remains of the missile
5. lethal effects on macrobenthic animals, being killed because of the missile hitting the tidal flat surface

Based upon a short field study, and taking into account some theoretical considerations, the following conclusions from the missile tests may be drawn:

1. Disturbing effects on birds because of high sound levels during launching

The launching of an Armiger missile on 21/11/01 has been registered by 2 observers in a helicopter which was situated approximately 100 m above and just behind the launching installation, as well as by 2 observers at 5-9 km distances. The launching itself had very limited effects, especially close to the lauching site. No obvious reactions were observed of birds present on the tidal flats, despite the fact that hundreds of Wigeon *Anas penelope* were present within 1 km from the sea wall at the time of launching. No effects at all have been noted in the Sommerkoog-Steert-Loch, north of the target area. The observer positioned on the sea wall south of the target area observed 2 types of reactions. About 10-15% of the birds present on the salt marshes around his location (975 Barnacle Goose *Branta leucopsis*, 25 Mallard, 14 Brent Goose *Branta bernicla,* 14 Shelduck were present) reacted by flying up briefly (<1-2 minutes). Birds feeding on the tidal flats (650 Shelduck, 250 Curlew, 550 Oystercatcher and 60 Dunlin were present) did not respond. The response was a direct reaction on the light-flash from the launching. As a result of the sound production from the launching 40% of the birds (i.e. 300 Barnacle Goose, 100 Wigeon, 75 Mallard) reacted by flying up for some minutes. It is not clear whether this reaction has been the general pattern for the whole salt marsh area on the southern border of the Meldorfer Bucht.

2. Disturbing effects on birds due to visual and/or acoustic stimuli during the missile flight

None of the observers registered specific effects of the missile on its way from the launching site to the target area. Although no reactions of birds have been noted when the missile landed we expect that birds within a 200 m radius will have been briefly disturbed. Given the mean densities of waders ($338/km^2$) and other waterbirds on the tidal flats of the Meldorfer Bucht in November this will mean that approximately $\pi.0.2^2.400 = 50$ waders, ducks and gulls will have been disturbed, most likely for less than a few minutes. Considering the rather low densities of birds

feeding on the tidal flats (with an approximate mean figure of 400 birds on 1 km², equalling 1 bird on 2500 m²) the chance that a bird is hit by the landing missile is extremely small.

3. *Disturbing effects on birds due to helicopters making clear-range flights and for collecting the missile after landing*

Helicopters are the most important source of disturbance during the missile tests. They are used for clear-range flights as well as for collecting the remains of the missile just been fired. Based upon observations during the clear-range flights, with helicopters flying at 1000-1100 ft, we have estimated that the helicopter making the northernmost clear-range flight has disturbed 1258 birds (ducks, waders as well as gulls) in 847 sec (1.48 birds/sec), the southernmost helicopter 5100 birds in 780 sec (6.54 birds/sec). The helicopter flight at 200-400 ft towards the Armiger landing site disturbed 1281 birds and lasted 300 sec (4.27 birds/sec). Based upon theoretical considerations and including bird densities in the Meldorfer Bucht in November, flight distances and the length of the flight path of a single helicopter making a clear-range flight at low altitude we have calculated that the disturbing effect of a low flying helicopter in the Meldorfer Bucht will disturb 6500 waders. This figure is somewhat higher than what has been observed from the helicopter. This may be due to the fact that the clear-range flights on 21/11/01 have been carried out at higher altitudes.

The observations from the helicopters indicate that part of the birds below the helicopter, and maximally a few hundreds of meters on both sides of the helicopter, fly up briefly. No panic reactions were observed. Fly-up time lasted for 10-15 sec to maximally 3 minutes. These data correspond to earlier findings in the same area. Assuming that waders have to fly up 3 min as a result of disturbance during a single tidal cycle such a disturbance is the equivalent of about 1% of the time available for foraging during a tidal cycle.

4. *Disturbing effects on birds and macrobenthos of people walking around on the tidal flats when collecting a missile*

Based on existing knowledge we may estimate that after landing of the missile an area of 5-50 ha is temporarily left by birds, because of the presence of people walking around, the exact size of this area being different between bird species. After the source of disturbance has gone the area will gradually fill up with birds again, the speed being dependant on the tidal situation and species involved.

5. *Lethal effects on macrobenthic animals, being killed because of the missile hitting the ground*

The missile landing on the mudflats in the Meldorfer Bucht produced a crater of approximately 3 m². Part of the animals that lived here will have been crushed, damaged or buried under a layer of sediment. Cockles belong to the common species found in the target are. They are known to be rather vulnerable, even when only slightly damaged. It may be expected that most of the Cockles that have lived here will all have died. The amount of Cockles being killed is the equivalent of the daily need of for food of 7-10 Oystercatchers. A relatively large part of *Hydrobia ulvae*, another common species in the target area, will have survived.

Effects of missile tests in the Meldorfer Bucht can be minimised by using only 1 helicopter during clear-range flights, and by keeping flight altitudes as high as possible. Our data show that some thousands of birds are briefly disturbed, even when helicopters fly at 1000 ft. Helicopters should try not to make sudden or unpredictable movements and avoid areas with high concentrations of birds, such as mussel beds. Additionally it is essential that periods with relatively high bird numbers are avoided. In order to minimise disturbances, the time-frame between November and February is highly preferred.

1 Introduction

After the 1962 storm floods which caused very considerable damage in many parts of the German Wadden Sea and Hamburg, embankments and dike strengthening projects have been carried out in various places in the area. One of these projects was the building of a new sea wall in the Meldorfer Bucht. The southern part of this reclamation has been completed in 1972, the northern part in 1978. Since then the southern part of this newly constructed “Speicherkoog Dithmarschen”, the so-called “Bundeswehrkoog", has been transformed into an area in which newly developed military equipment was going to be tested. This included the testing of fast underwater missiles (experiments which were carried out in freshwater channels in the Bundeswehrkoog), and the firing of experimental missiles from this Koog into the tidal flats of the Wadden Sea. These launching experiments in the Meldorfer Bucht have always been part of test programs of weapon technology. The Wadden Sea was considered an ideal target area because the missiles, packed with electronic equipment for the registration of flight patterns etc., could always be easily retrieved. Generally the missiles remained relatively undamaged because they landed in rather soft sediments. The launching of a missile has always been accompanied by various electronic registrations.

Especially since the target area has been designated as a special protection zone of the Nationalpark Schleswig Holsteinisches Wattenmeer the opposition against the weapon technology tests in the area and the political debate about its acceptability has increased. This applies especially for the launching of missiles into the Wadden Sea tidal flats. Nature conservation organisations argue that the tests and the many activities connected to the launching disturb large amounts of birds. Consequently, these activities should not be allowed in the National Park and should therefore be prohibited. In contrast, the German Ministry of Defence argues that their activities are carried out at a very low frequency, that sensitive periods of the year are avoided and that many precautions have been taken to minimise the negative effects on the Wadden Sea habitat and wildlife. This debate has been going on for several years now, both sides sometimes using inadequate information.

On 21/11/01 an Armiger missile was fired from a launching platform in the western part of the Bundeswehrkoog into the tidal flats of the Wadden Sea (Fig. 1). Alterra Texel, as an independent institute involved in biological research in the Wadden Sea for many years, has been asked to quantify the effects of these tests through field observations in order to determine the impact on Wadden Sea birds and other wildlife. Next to observations on the reactions of birds, sediment and macrobenthos samples (of animals living in the tidal flat sediments) have been taken which provide information on the biological significance of the predicted and actual missile target area. In this report the results of these observations and the analyses of the samples will be described. Due to the restricted time which was available our observations cannot be considered as a in-depth study of the biological implications of the missile launching. We believe, however, that the results of our observations can be considered as a valid expert opinion on the most relevant implications of the impact of weapon technology trials in this area.

Fig. 1. Launching of an Armiger missile from the Bundeswehrkoog into the tidal flats of the Meldorfer Bucht on 21/11/01. Photo: Wulf Pfeifer, Dithmarscher Landeszeitung

Acknowledgements

We thank Dick Schermer (name in this report abbreviated as DS) and Hans Verdaat (HV) for their valuable assistance in the field work at Meldorf. Grietje Zijlstra cheerfully carried out the analyses of the macrobenthos samples. She also determined the organic carbon content of the sediment samples which were collected during both our to trips to Schleswig Holstein. André Meijboom analysed the sediment samples collected during our second trip, using the facilities of the Netherlands Institute for Sea Research (NIOZ) at Het Horntje, Texel, the Netherlands. We especially thank the crew of vessel AM7 of the German marine for providing observation facilities for the second author on 20/11/01 and 21/11/01 and the staff of the "WTD71 camp" at Elpersbüttel for their hospitality and catering, in particular Mr. Günther, Mr. Hartnauer and Mrs. Petersen.

We greatly acknowledge the representatives of the authorities commissioning the assignment for our study, WTD71 in Eckernförde, Germany, in particular Dr. Uwe Vogel and Dipl.-Ing. Klaus Klaßen, for their pleasant support during our study and for all facilities supplied. We highly appreciated that we were given an entirely free-hand to carry out all activities we thought necessary.

2 Methods

The results presented in this report are based on 2 short visits to the study areas. During the first visit (on 17 and 18/10/01) potential observation locations have been selected. In target area A (in Fig. 2) sediment samples have been collected and preliminary arrangements for the observation session during the missile launch have been made. The visit has also been used for the development of ideas on which information was needed. In the initial target area (54°.5 35 N, 08 °.50 04 E) sediment samples of the upper 2 cm of the tidal flats were taken in 3 transects (Fig. 3), using small syringe cores. Sampling locations were approximately 50 m apart and were marked using a Garmin 12 XL GPS. The samples were stored in small glass tubes which have been kept as cool as possible and were analysed immediately after return in the Netherlands. Samples were dried for 48 hours at 60°C, weighed, and heated to 560°C in a well ventilated stove for 2 hours. The mass loss is considered to represent the organic carbon content of the sediment. This technique is a relatively quick and reliable method of determining the organic content of sediment (c.f. Leong & Tanner 1999). Because a strong and robust correlation has been found between total organic carbon (TOC) and sediment grain sizes the method is a quick and valid method for determining the silt content in the sediment (Wolff 1973, Zwarts 1988, Volkman *et al.* 2000).

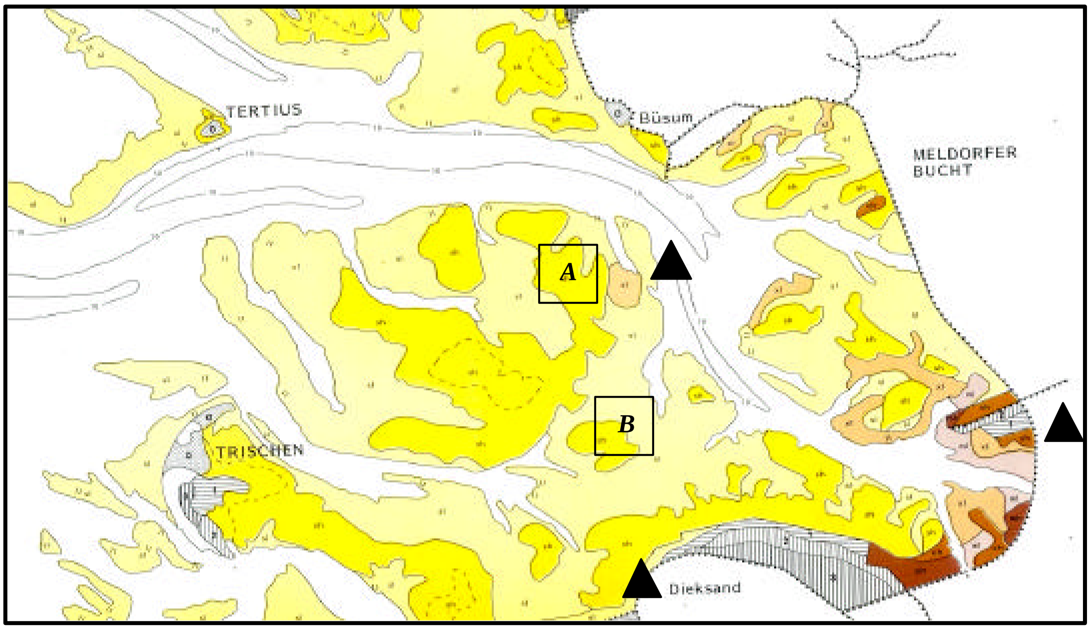

Fig. 2. Habitat map showing the initial target area where sediment samples have been collected on 18/10/01 (indicated by A) and the final target area where the Armiger missile hit the ground on 24/11/01 (indicated by B). In this location both sediment and macrobenthos samples have been collected. Black triangles denote the location where observers were positioned on the missile launching day. Map is based on Dijkema et al. 1989. Colours indicate habitat types; dark yellow: high sandy flats, pale yellow: low sandy flats, brown: muddy sediment types. Hatched areas denote salt marshes.

The first visit has also been used for getting a first impression of the densities and distribution of waders and other waterbirds in the study area. Since bird densities appeared to be high in some areas and low in other parts no attempts have been made to make any estimations of overall densities.

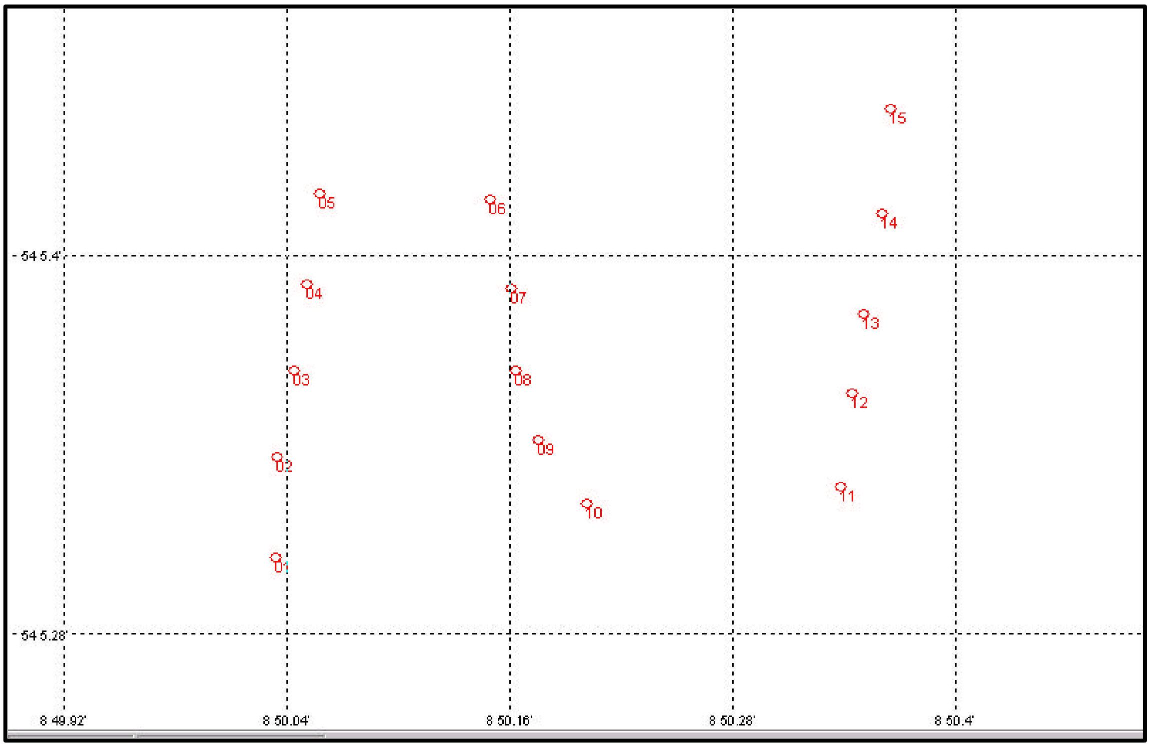

Fig. 3. Locations in study site A where sediment samples have been collected on 18/10/01

During our second visit the first observation day (20/11/01) could not be used due to dense fog. Hence, the missile launch had to be postponed to the following day. On 21/11/01 2 observers were distributed over the study area as indicated by triangles in Fig. 1, i.e. north and south of the proposed target area. The first observer has been positioned on marine vessel AM7, which had anchored in the Sommerkoog-Steert-Loch channel, close to buoy SL 113 at location 54°.06.347 N, 08 °.52.388 E. The second observer was situated close to one of the locations where track records of the launching were made. This location was situated on top of the sea wall, close to Edendorf. Both observers had been instructed to observe bird reactions after the missile firing in the area where they were positioned (numbers and species involved, response time, nature of the bird response) as detailed as possible. Both were equipped with 10*50 mm binoculars and 20-60* telescopes. They were both in direct radio-contact with the staff controlling the missile launching so that they were well aware in advance of the exact moment of the launching. Observers 3 and 4 took part in the clear-range flight of 2 helicopters (flight patterns shown in Fig. 4). During this clear range flight (at 1000-1100 ft) they studied the reactions of birds below and in the surroundings of the helicopters as detailed as possible. Bird reactions were recorded using small portable tape-recorders. Flight routes were continuously registered using Garmin 12 GPS's. After the clear-range flight both observers were positioned in the helicopter observing the missile-firing at about 300 ft altitude, close to the launching site. This helicopter followed the missile immediately after its launch.

After having retrieved the missile on the mudflats, observers 3 and 4 took sediment samples (duplicate samples on each location) and macrobenthos samples in 10 locations in study area B, the area surrounding the ultimate target area (54 °. 03.986 N, 08 °.51.036 E). Sampling locations were roughly 10 m apart, locations are depicted in Fig. 4. Macrobenthos samples were taken using a 10 cm wide corer, sampling depth amounted to 30 cm. On each location 1 sample was taken. Such cores are generally deep enough to catch all macrofauna, possibly except for some deep living adults of *Mya arenaria* and *Arenicola marina*. The cores were washed out in the field, using a 1 mm mesh sieve. The samples have been sorted out from the mixture of dead shells and large sediment particles in the Alterra-laboratory at Texel, the Netherlands, the day after our return from Meldorf. In the intervening period the samples were kept cool in a transportable cool-box and a refrigerator. All macrobenthos species were identified, the size of all shellfish species were measured to the nearest 0,1 mm. Sediment samples have been stored at –20°C until further analysis. Half of these samples have been analysed to determine organic carbon content, comparable to the technique applied to samples from location A. The remaining part of the duplicate samples have been analysed using the Coulter Laser Particle Size LS 230 Analyser from the Netherlands Institute for Sea Research at Texel. Grain size distribution was measured after sieving over 1 mm mesh. Hence, the analyses consisted of laser diffraction of particles < 1 mm, after removal of organic matter with 35% H_2O_2 at 80°C and carbonates with 0.5N HCl at 80°C. Results from both the total organic carbon content and the Coulter LS 230 analyses have been compared.

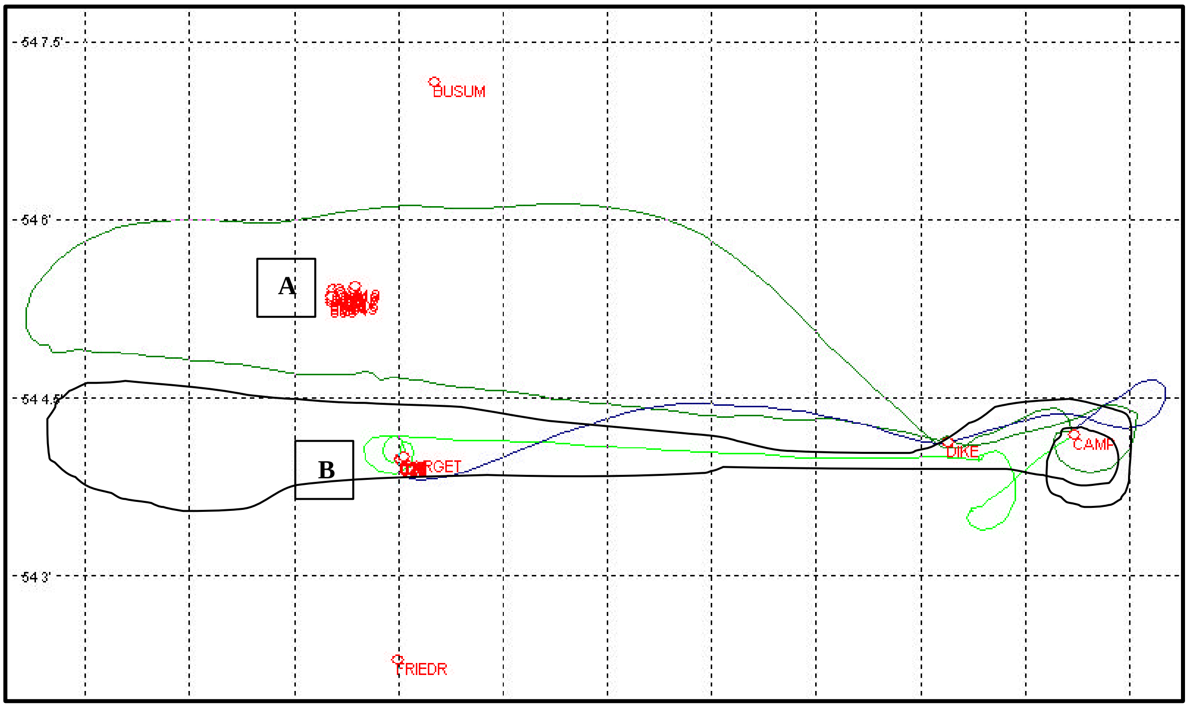

Fig. 4. GPS tracks of the flight routes of the 2 helicopters making the clear-range flight on 21/11/01, combined with the track of the helicopter heading for the Armiger landing site. Target areas A and B represent the same sites as in Fig. 1. Busum denotes Busum harbour, Friedr represents Friedrichskoogspitze

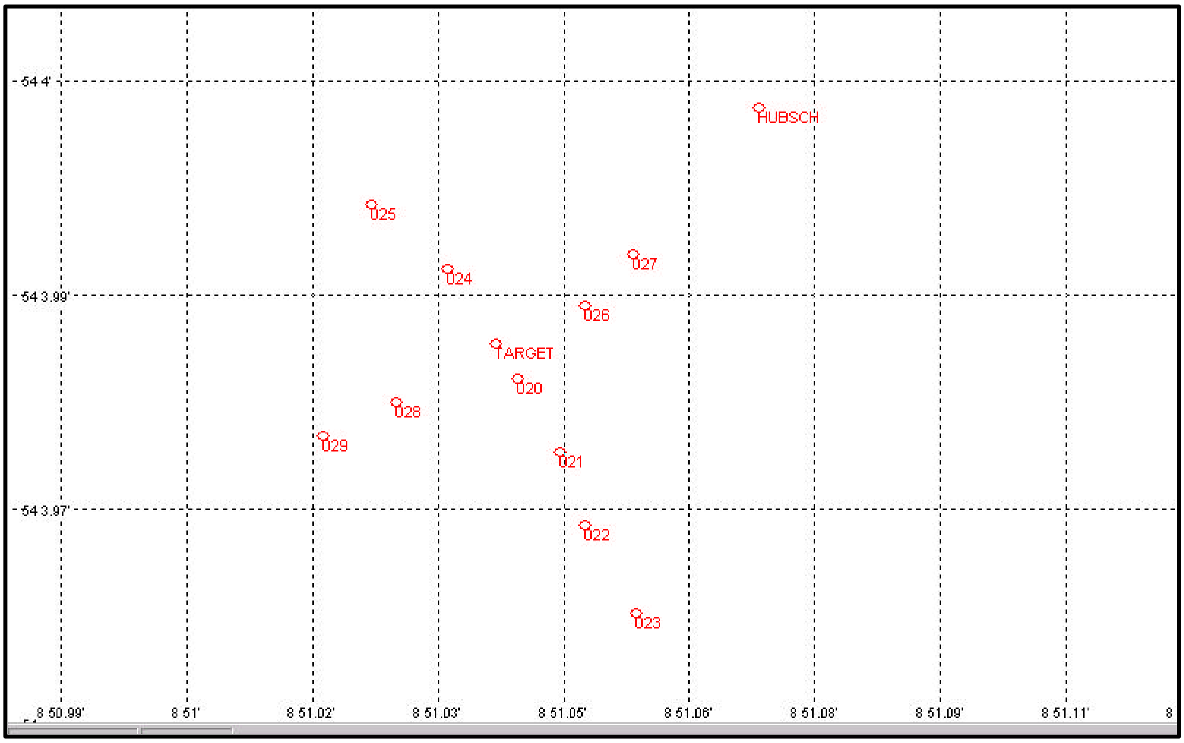

Fig. 5. Locations in target area B where sediment and macrobenthos samples have been collected on 21/11/01. Target denotes the location where the Armiger missile hit the mudflat surface, Hubsch indicates the location where the helicopter landed. Sampling locations are about 10 m apart

3 Theoretical considerations, based upon existing knowledge

3.1 Bird numbers in the Meldorfer Bucht

Like anywhere in the Wadden Sea the number of waders feeding on the tidal flats varies strongly in the course of the year (c.f. Meltofte *et al.* 1994). In winter the numbers of waders, ducks, geese and gulls in Schleswig Holstein and Denmark are relatively low as compared to Niedersachsen and the Netherlands, as well as in comparison to the numbers present in Schleswig Holstein from August-October and April-May. Based on frequent bird counts carried out during high tide from 1980 onwards we can estimate the average density of waders and other waterbirds in the area. The tidal flats in the Meldorfer Bucht measure 150 km^2. Based on the mean numbers per month in this area (Meltofte *et al.* 1994) and assuming that birds distribute randomly over the tidal flats, 650-850 waders per km^2 must be present in months when peak-numbers are present (Fig. 6). Depending on winter temperatures these numbers drop to 100-350/km^2 in the months following, somewhat more in mild winters and considerably less in severe winters. Under very cold conditions many birds leave the area for milder areas further south: in such a case only some hundreds of ducks, geese, waders and gulls stay behind in the Schleswig Holstein part of the Wadden Sea.

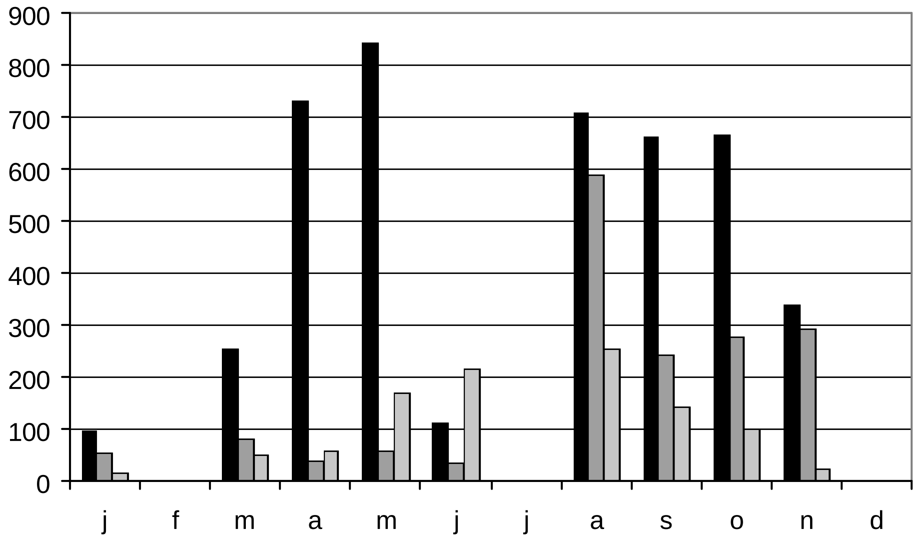

Fig. 6. Mean densities of waders (black), ducks and geese (hatched) and gulls + terns (double hatched) per month in the Meldorfer Bucht area, including the tidal flats around Trischen (counting unit SH-12 in Meltofte et al. 1994).

Such density calculations cannot be made for many ducks and geese, which frequently or almost exclusively forage inland (like Mallard *Anas platyrhynchos* and Barnacle Goose *Branta leucopsis*). These birds often distribute over the whole coastal region, sometimes they cluster in the salt-marshes of inland grassland areas close to the sea wall. Several of these species use the tidal flats or the open water of the Wadden Sea as a night-roosting place. Eiders *Somateria mollissima* are only partially included in these counts. Outside the breeding season they are generally present on open water, far away from the islands and the mainland coast from where they can be more or less easily counted. Eiders, and other seabirds, can only be properly counted using aerial surveys.

Fig. 2 indicates that the central part of the Meldorfer Bucht mainly consists of sandy tidal flats. The habitats on the leeward side of Trischen and especially close to the mainland coast are more varied. The data indicate that birds will not be distributed randomly over the tidal flats. Instead, they will occur patchy with low densities in some areas and relatively high densities in others. Cockle beds, with high quantities of readily available food for large shellfish eating birds and mussel beds especially attract high bird densities. Mussels create a habitat in their own. In fact mussel beds are complex ecosystems consisting of sometimes high ridges of mussels, which are clumped together with bissus threads. During high tide mussels continuously filter sea water. After having sieved out the organic particles from the water they deposit pseudo-faeces which consist of mud particles, glued together with a thin film of mucous. By doing so the area around mussel beds tends to increase in mud content. By moving on top of these newly deposited layers of mud mussels create a 3-dimensional habitat with ridges or hills of mussels, at low tide interspaced with pools of stagnant sea water, combined with flat and open areas of sand or mud. This much more varied habitat type not only attracts mussel eating birds, but also species preferring worms (like Redshank *Tringa totanus*) or crabs (like Curlew *Numenius arquata*). Hence, mussel beds attract high densities of different species of waders and gulls. Densities may go up to 40 Oystercatchers *Haematopus ostralegus*/ha (Zwarts & Drent 1981, Ens & Cayford 1996). Densities for other species are depicted in Fig. 7.

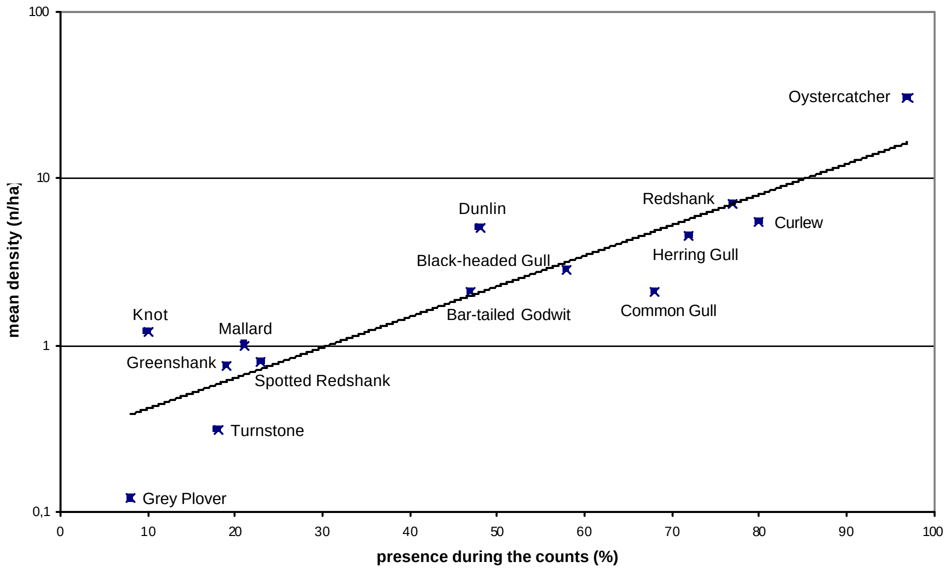

Fig. 7. Mean densities of Mallard, waders and gulls in late summer on mussel beds near Schiermonnikoog (Dutch Wadden Sea) and the frequency with which different species have been observed there. Data are based on many frequent counts (every 15 min) in 1971-1973 (data: Leo Zwarts, after van de Kam et al. 1999).

Eiders moult and spend the winter in the Meldorfer Bucht/Trischen area. During the moulting season (July-mid September) up to 19.000 Eiders may be found here, concentrating in the area around Trischen and east of the Sommerkoog-Steert-Loch area. In winter even higher numbers have been recorded in the same area. Maximum numbers then amount to about 40.000 (Nehls 1995). Another bird concentrating in relatively high numbers is Shelduck *Tadorna tadorna*. Especially the area around Trischen is famous because of its moulting Shelduck which then have lost their flight feathers altogether. Shelduck from all over western Europe assemble here from early June onwards, as well as in the area around Großer Knechtsand (Cramp & Simmons 1977, Smit & Wolff 1981). Although flightless adult Shelduck may still be present in October, juvenile Shelduck disperse again from August-September onwards. In the peak period (August) up to 82.000 Shelduck have been counted in the Meldorfer Bucht/Trischen area. In October numbers may still amount to 4000-8000. Numbers have dropped to 1400-1800 from November onwards (all data from Meltofte *et al.* 1994).

3.2 Bird reactions caused by fast flying objects and helicopters

Little is known about the disturbing effects on birds of missiles flying at a speed of those being tested in the Bundeswehrkoog (approximately Mach 2-3). The only study which has been carried out on the effects of missile testing activities in the Meldorfer Bucht comes from Van Raden (1990). He calculated that 0.1-10% of the waders in the area had been disturbed by the firing of a missile. In many cases the disturbance lasted some seconds, in extreme cases some birds were disturbed for up to 4 minutes. He noted considerable differences between species, waders and Black-headed Gulls *Larus ridibundus* reacting at a distance of 100-250 m from the launching installation. Ducks and Shelduck sometimes reacted at distances of up to 400-1000 m. Birds generally flew up: sometimes for only a few seconds, sometimes for up to 3 minutes.

Military jets, although larger, probably have rather comparable effects as missiles such as Armiger or the Hochgeschwindigkeits-Flugkörper (HFK), under study here. In general birds do not react strongly on fast and sometimes low flying jet planes (Gladwin *et al.* 1988, Harrington & Veitch 1992, Trimper *et al.* 1998). Locally stronger effects have been noted (c.f. Grubb & Bowerman 1997), indicating that a generalisation of research results is not well possible. Aircraft producing relatively much noise are more disturbing than “silent” planes (Burger 1981, 1983, Ward *et al.* 1999). Brent Geese, ducks and waders moved away from the study area in the Königshafen, Sylt, where military jets passed by at very low altitudes, probably as a result of the very high sound pressure. After some days a certain degree of habituation could be noted (fewer birds reacted and they could be observed at closer distances to the training area) but also the opposite phenomenon has been recorded (birds reacting more strongly on each following jet flying over). In general, the behaviour remained rather unpredictable. Reactions strongly depended on the tidal situation (high or low water) and the presence of other disturbing objects in the same area (Küsters & van Raden 1986, 1987). Sonic booms disturb birds as well, especially in places where the phenomenon is not common. The effects are generally limited and short lasting (Cottereau 1978, Ellis *et al.* 1991, Kempf & Hüppop 1996).

Helicopters tend to have relatively strong disturbing effects (Mosbech & Glahder 1991, Holm 1997, Ward *et al.* 1999), especially in areas where this type of aircraft occurs infrequently (Anderson *et al.* 1989, Smit 2000). Such disturbances have not only been noted in birds but also in mammals (Bleich *et al.* 1994, Coté 1996). Helicopters may cause birds to fly up. If such disturbances occur frequently it may shorten the time available for feeding or lead to extra energetic costs because the birds often have to fly up. It may also cause birds to leave an area altogether.

The reaction of birds when being approached by an aircraft are highly dependent on many different variables. Birds will react differently when they are feeding on the tidal flats, as compared to when they are gathered at high tide roosts. Bird assembled in large flocks again react differently than birds concentrated in small flocks and how intensive they react again is dependent on whether they are being hunted in the same area (Owens 1977). Birds that have "planned" to leave the high tide roosts (because the tidal flats are emerging) will tend to leave these roosts after a small disturbance, whereas birds that have just assembled there tend to remain there under those circumstances. Birds that have just arrived on the tidal flats after having spent 6 hours on a high tide roost (in a situation in which they are still hungry) will tend to be more tolerant towards disturbance as compared to those that have just finished a meal, after having spent 5-6 hours on the feeding grounds. Additionally, birds that have been disturbed by (for instance) a predator will react differently on a helicopter than in a situation without preceding predator disturbance (c.f. Smit & Visser 1993). There are also considerable differences between species and the type of helicopter being used. Large helicopters tend to have stronger effects (e.g. Miller 1994), possibly because they produce more noise. Ward & Stehn (1989) found a linear relation between the sound production and the response of Brent Geese in the breeding areas, the threshold of flying up being 58 dB(A). In general, low flying helicopters disturb more severely as compared to helicopters flying at more than 300 m (Sossinka & Nieman 1994). But there are also studies indicating that intermediate altitudes (305-760 m) are the most disturbing (Ward *et al.* 1999). Several literature references come up with comparable data: rather intensive disturbance of at least part of the birds up to 200-500 m and milder disturbances within an area of sometimes as large as 2.5 km (e.g. Barry & Spences 1976, Ward & Stehn 1989, Smit & Visser 1993). The Australian Antarctic Division has used 1000 m as an operational guideline of for helicopter activities in Antarctica for a long time but this altitude did not fully exclude disturbing effects on penguin chicks (Giese & Riddle 1999). Since then a more conservative guideline of 1500 m (5000 ft) has been advocated as a minimum overflight altitude for helicopter operations around breeding localities of penguins. In situations where birds are habituated to helicopters with a highly predictable behaviour often no visible effects may be noted at all (Smit 2000).

A summarising conclusion from the observations mentioned above may be that reactions of birds on helicopters are difficult to predict but mostly cover a distance of 300-500m. The intensity of the reactions, however, is dependent on many different variables and can, in fact, only be determined adequately by studying the birds in the area itself. Such a study has been carried out by the “Amt für Wehrgeophysik“ in October 1988 (Van Raden 1990). He concluded that helicopters disturb at vertical and lateral distances of up to 300 m (1000 ft). Seals were not affected by the missile firing activities because the target areas are several km’s away from the haul-out areas. Seals have not been seen to be disturbed by helicopters if flight-altitudes exceed 150 m. Approximately 90% of the waders feeding on the tidal flats in October were disturbed when helicopters flew over at of 50 m, 10% reacted at a flight altitude of 250 m. Van Raden’s also noted that helicopters flying at an altitude <30 m disturbed fewer birds and during a shorter time than helicopters flying between 30-300 m. Altitudes >300 m again yielded less disturbance. These observations, however, were carried out during the breeding season. Hence, habituation effects of birds staying for a relatively long time in the Helmsand Insel area (where the observations were carried out) should not be excluded. Comparable findings have not been described in literature elsewhere.

Theoretically one would expect a situation as shown in Fig. 8. In this case very low altitudes have the largest lateral effects, whereas altitudes exceeding 300 m do not lead to any disturbance. Obviously, given all observations that are mentioned in this paragraph, this situation will be different from locality to locality and vary between seasons and between species.

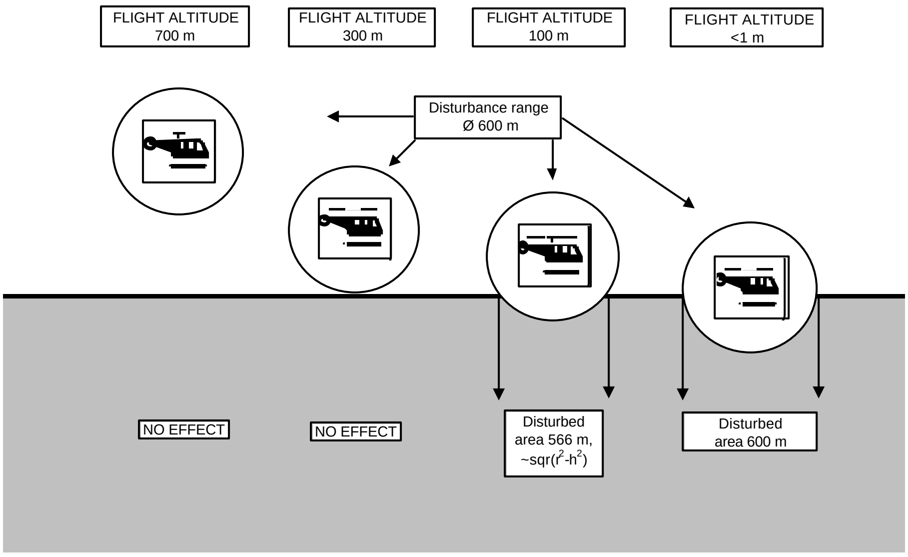

Fig. 8. Theoretical effects of a helicopter at various altitudes, having a disturbing effect on birds of 300 m on both sides (which equals a range of 600 m).

3.3 Theoretical estimate on the disturbance of birds

Because of the relatively strong disturbing effects of helicopters our field observations on the effects of the missile launching at Meldorf focussed primarily on the effects of the helicopters. These are used for making clear-range flights and for collecting the remains of the missile after landing. The bird densities mentioned in chapter 3.1 allow for some theoretical calculations on the number of birds being disturbed. Assuming that:

- birds distribute randomly over the tidal flats
- only helicopters have disturbing effects during a missile launching (and not the missile itself)
- low flying helicopters disturb birds at a 300 m distance on each side (c.f. chapter 3.2),
- the number of waders being disturbed as a result of a single helicopter passing at low altitudes over the tidal flats will be:

$$0.6 * \text{distance flown} * 338$$

in which 0.6 is the disturbance distance in km and 338 is the mean density of waders on the Meldorfer Bucht tidal flats in November. If, for instance, a helicopter moves to a target area at 16 km from the sea wall, and back again, in total some 6500 waders (0.6 * 32 * 338) might be disturbed. This calculation applies for November. In a month in which bird densities are higher the numbers will be proportionally larger, in mid-winter they can be expected to be lower than this figure. Additionally a smaller number of ducks of various species, gulls and an unknown number of inland feeding birds (geese, Lapwing *Vanellus vanellus* or Golden Plover *Pluvialis apricaria)* may be disturbed.

4 The habitat in the target areas

4.1 Habitat characteristics in target area A

Target area A has been visited on 18/10/01. The results of the sediment samples taken at target area A show that the sediment can be characterised as sandy, holding an organic content ranging from 0.21 – 0.37% (Table 1). Such a habitat is common in the eastern part of the Meldorfer Bucht (Gast *et al.* 1984, Dijkema *et al.* 1989). The habitat in all 15 sampling stations can be described as firm, sandy and flat, with 0.5-2 cm high micro-ripples. In most places the tidal flat was covered with 1-2 cm of water, in the easternmost locations 12-15 small pools of stagnant water were present. The westernmost transects of sampling stations were partly covered with small patches of macro-algae and *Ulva*. A superficial inspection of the upper sediment layer revealed that locations 1-10 all consisted of cockle *(Cerastoderma edule)* bed, with densities ranging from 500-1000/m², all of these small and only 1-2 years old. Locations 10-15 had lower densities, up to 200/m². *Hydrobia ulvae* was numerous in all of these locations (in densities of approximately 1000/m²). Lugworm *Arenicola marina* occurred in low densities, ranging from 0-12/m². Locations 11-15 were somewhat more muddy. This appears from directly visible characteristics (like depth of a footprint) but also from the somewhat higher organic carbon contents in the easternmost transect. This location is situated close to and partly within a large mussel bed stretching out along the Sommerkoog-Steert-Loch channel. Georg Nehls (*in litt.*) estimated the size of this mussel bed at 100 ha in 2000. Based upon the information presented in Fig. 7 and assuming that the mussel bed had the same size as in 2000, the number of birds feeding on the mussel bed in late summer can be estimated. The most numerous species will be Oystercatcher (approx. 3000 present), Redshank (800), Curlew (700), Dunlin *Calidris alpina* (700) and Herring Gull *Larus argentatus* (600). It may be expected that during high tide the mussel bed area also acts as an important feeding habitat for Eiders. During low tide Eiders will be resting on the edges of the tidal channels in the surroundings. It should be stressed that these figures on bird numbers can merely be a rough guesstimate of the numbers present. Not only the time of the year is different than in the observation period from Fig. 7, also the locality is different. The data do indicate, however, that this mussel bed alone should host several thousands of birds. This is also what we observed when visiting the area. The general impression of the tidal flats in target area A was that they were sandy and relatively rich in macrobenthic fauna as well as in terms of birds. The distribution of the birds over the area appeared to be rather patchy, with high densities in some areas and low densities in others.

Table 1. Habitat characteristics of 15 sampling stations in target area A, visited on 18/10/01 (c.f. Fig. 3). We have determined sediment types (S for sand, MS for muddy sand), organic carbon content (expressed as weight %, data are based on laboratory analyses), the height of micro-ripples, water coverage of the tidal flats (as a film or as small pools, Yes/No), the presence of macro-algae and Ulva (Yes/No), the numbers of macrobenthic animals (roughly estimated in case of cockles by sieving out 0.25 m², the other species counted by eye), the presence of "Streusiedlungen" of mussels or as a mussel bed (with approx. 3000 mussels/m², most of these 0-1 year old), the presence of a diatoms film, the depth of a footprint, and the depth of the anaerobic layer under the tidal flat surface

Sampling location, target area A	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Sediment type	S	S	S	S	S	S	S	S	S	S	MS	MS	MS	MS	MS
Org. content (%)	0,22	0,24	0,23	0,22	0,21	0,24	0,25	0,24	0,27	0,33	0,36	0,38	0,35	0,33	0,21
Micro-ripples (cm)	2	2	2	1	1	1	1	1	1	1	0.5	0.5	0.5	0.5	0.5
Water layer (cm)	1-2	1-2	2	2	2	-	1	1	1	2	0	0	0	0	0
Pools (Y/N)	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Macro-algae (Y/N)	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Ulva (Y/N)	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Cockles/m²	1000	1000	200	500	750	500	750	750	750	1000	+	200	+	20	+
Lanice/m²	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arenicola/m²	0	0	12	8	4	4	0	0	0	4	0	0	0	0	0
Heteromastus/m²	+	+	+	1200	200	+	0	0	0	0	+	800	80	400	2000
Mussels	-	-	-	-	-	-	+	-	-	-	bed	bed	bed	bed	bed
Diatoms Y/N	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Footprint (cm)	1	1	1	1	1	1	1	1	1	1	3	2	2	1	2
Anaerobic layer (cm)	4	4	2	1	3	2	2	2	3	3	3	2	2	4	2

4.2 Habitat characteristics and macrobenthos in target area B

Quite opposite to our expectations the Armiger missile landed on a location about 3 km south of target area A (see Fig. 2). After the landing of the missile the area around the landing site has been sampled, both for sediment and for macrobenthic animals. Target area B was situated about 30 m north of a small channel ("Priel") The mudflat area was covered with 1-2 cm micro-ripples and the tidal flats were considerable more muddy than target area A, already at first sight. Although part of target area B was rather sandy, sampling stations 20-23 and 26-27 could be characterised as muddy (c.f. Fig. 5). In these places footprints went down as deep as 10-20 cm. Cockles were rather abundant all over the area, Lugworm was present in low densities in only few places, the flats were covered with high densities of *Hydrobia ulvae*. Locally patches of *Ulva* were present. As in target area A Cockles were rather small, the great majority being 1-2 years old. The average size amounted to only 11.55 mm (n=68). Slow growth of Cockles is a common phenomenon in muddy areas (Zwarts 1988).

According to Table 2 the sediment in target area B can be classified as muddy sand (c.f. Flemming 2000). This habitat ("sandiger Schlicksand') is relatively common in the eastern parts of the Meldorfer Bucht (Gast *et al.* 1984). A comparison of the organic carbon content data from Tables 1 and 2 shows that target area B holds a considerably higher organic carbon content, indicating that the sediment in this location contains a relatively large amount of particles <63 µm. It is surprising that, although the sediment in the field seemed highly variable, with parts being rather firm and sandy and others muddy, the median grain sizes, as well as the other sediment characteristics, are rather uniform.

Table 2. Sediment parameters and macrobenthos densities in target area B, visited on 21/11/01. Macrobenthos data are expressed as n/m². Sampling locations correspond to those presented in Fig. 5.

Sampling location target area B	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**
median grain size (D_0)	91.45	91.79	93.05	94.72	92.15	90.69	88.44	91.09	90.86	89.20
fraction < 2 µm (volume %)	1.80	1.57	1.63	1.79	1.63	1.67	1.59	1.79	1.82	1.87
fraction < 63 µm (volume %)	15.9	14.7	14.2	13.2	15.0	15.9	16.9	15.6	17.3	17.4
organic carbon content (weight %)	0.498	0.539	0.561	0.478	0.493	0.721	0.464	0.489	0.603	0.582
Cockle, Cerastoderma edule	1200	600	1080	1920	720	600	480	600	600	240
Hydrobia ulvae	3900	1980	24000	38400	14400	15600	23400	12000	13200	25200
Mussel, *Mytilus edulis*	120	-	-	-	-	-	120	-	-	-
Retusa alba	120	-	-	-	-	120	120	-	360	120
Macoma balthica	120	-	120	-	-	-	-	120	-	-
Mya arenaria	-	-	120	-	-	-	-	-	-	-
Nereis diversicolor	-	-	-	-	120	-	-	-	120	-
Scoloplos armiger	-	-	-	120	-	-	-	-	-	120

5 Visible effects of the Armiger missile launching on birds and macrobenthos

Missile tests in the Meldorfer Bucht may be expected to have following effects:

- disturbing effects on birds because of high sound levels during launching
- disturbing effects on birds due to visual and/or acoustic stimuli during the missile flight
- disturbing effects on birds due to helicopters making clear-range flights and for collecting the missile after landing
- disturbing effects on birds and macrobenthos of people walking on the tidal flats when collecting remains of the missile
- lethal effects on macrobenthic animals, being killed because of the missile hitting the tidal flat surface

All aspects have been considered as detailed as possible. In this chapter only visible effects of the Armiger missile launching will be discussed. It should be stressed that we have only been able to study visible effects, whereas it is known that birds may react on disturbances without showing any sign of disturbance at all. The fact that they are disturbed can be deduced from higher heart rates (Jungius & Hirsch 1979, Hüppop & Hagen 1990, Wilson *et al.* 1991) or the production of stress hormones (e.g. Sapolsky 1990, Engelhard *et al.* 2001). Obviously, such observations have not been possible within the framework of our study. We have considered "disturbance" as birds responding to external stimuli, expressed as the number of birds in the air as well as birds showing a type of behaviour which is different from the behaviour prior to disturbance. We have quantified the effects by quantifying disturbed and undisturbed bird numbers, species, disturbance time and flight distances. These parameters are often used in behavioural research as part of studies on the effects of disturbance.

On the observation day weather conditions were not optimal. There was 5-6 km visibility, which was not enough for detecting bird behaviour at the Armiger landing site from the AM7, located at approximately 5 km distance. There was a cloud cover at 400-500 m, locally even at 300 m. Temperature was about 7° C, wind force was 5-6 B, direction SW.

5.1 Disturbing effects on birds because of high sound levels from the launching

The launching of the Armiger could only be registered by 2 observers in the helicopter which was situated approximately 100 m above and just behind the launching installation. These observers (DS, CS) only saw 4 Shelduck fly up, as a result of the launching. These birds were present in the inland area of the Bundeswehrkoog, in between the launching installation and the sea wall. No obvious reactions were observed of birds present on the tidal flats, despite the fact that hundreds of Wigeon *Anas penelope* were present within 1 km from the sea wall at the time of launching. It is, however, possible that these birds reacted briefly as a result of the missile launching. These reactions could not be seen because the birds were hidden behind the sea wall. These birds certainly did not fly up high enough to become visible for the observers in the helicopter.

Observer 3 (MdJ) was positioned at approximately 9 km from the launching site. He did not register any reaction of birds in his study area. Observer 4 (HV), positioned on the sea wall south of target area B, observed 2 types of reactions. About 10-15% of the birds present on the salt marshes around his location (975 Barnacle Goose *Branta leucopsis*, 25 Mallard, 14 Brent Goose *Branta bernicla*, 14 Shelduck were present) reacted by flying up briefly (<1-2 minutes). Birds feeding on the tidal flats (650 Shelduck, 250 Curlew, 550 Oystercatcher and 60 Dunlin were present) did not respond. The response was a direct reaction on the light-flash from the rising missile. As a result of the sound production from the launching (arriving approximately 25 sec later) 40% of the birds (i.e. 300 Barnacle Goose, 100 Wigeon, 75 Mallard) reacted by flying up. This reaction lasted for several minutes and was seriously prolonged because of the presence of a Peregrine *Falco peregrinus*, that flew up as a result of the noise as well. Part of the Barnacle Geese and the small flock of Brent Geese continued flying around until 4-7 minutes after launching.

No reactions were observed of birds present in the inland area (Bundeswehrkoog). It is well possible that due to human activities in the area around the launching site, already several days prior to the launching (helicopters flying over, cars driving around, people making preparations for the launching), most birds temporarily had left the area around the launching area.

5.2 Disturbing effects of the missile under way

The 2 observers in the helicopter were not in a proper situation to register the effects of the missile flying over the tidal flats. Observer 3 at AM7 (MdJ) was situated 5-9 km away from the track followed by the missile. Due to rather poor visibility conditions (limited to 4-5 km because of haze) and the fact that the Armiger landed in target area B, approximately 2.8 km further south than anticipated, he was unable to observe any reactions. The birds within 3 km from his location did not react on the missile flight. Observer 4 (HV) was situated much closer to the target area. He only observed reactions as a direct result of the launching. No specific reactions of birds were registered when the missile was under way or as a result of the landing.

5.3 Disturbing effects on birds due to helicopters making clear-range flights and flights for collecting a missile after landing

Observations during the clear-range flight, with the helicopter flying at 1000-1100 ft, are presented in Tables 3a and 3b. Observations from the helicopter on its way to recover parts of the Armiger are presented in Table 3c. The data shown in these tables can be used to calculate the number of birds that have been disturbed by the helicopter flights on 21/11/01. Because 2 observers have been distributed over 2 different helicopters the number of birds seen being disturbed has to be multiplied by 2 (one observer only being able to observe reactions of birds on one side of the helicopter). The data from Tables 3a and 3b show considerable differences, the helicopter passing over the southern part of the tidal flat area disturbed considerably more birds. This may be due to the fact that bird densities were higher in the area where the second helicopter was flying. Overall, the helicopter making the northernmost clear-range flight disturbed 1258 birds (ducks, waders a well as gulls) in 847 sec (1.48 birds/sec), the southernmost helicopter 5100 birds in 780 sec (6.54 birds/sec), taking into consideration that an individual observer only registered birds on one side of the helicopter. The helicopter flight at 200-400 ft towards the Armiger landing site disturbed 1281 birds and lasted 300 sec (4.27 birds/sec). These data do not clearly indicate that flights at a higher altitude disturb fewer birds. It should be kept in mind, however, that the data are not independent. Birds that have been disturbed by the second helicopter flight already have been disturbed by the first flight and that, as a result, some habituation may have occurred. One should, therefore, not to conclude from these data that flight altitude does not influence birds reactions.

Table 3a. Observations from a Bo-105 M helicopter during the northernmost clear-range flight on 21/11/01 at 1000-1100 ft altitude. Birds registered represent half of the birds being present below the helicopter (1 observer present in each helicopter). Time was read from a GPS registering the helicopter's flight path. Observer: CS

time	species	n	Behaviour, remarks
9.06.58			departure from camp
9.07.59			900 ft, flying W
9.09.29			1100 ft
9.09.45			passage over sea wall, no disturbance of birds inland and in salt marshes
9.10.45	gulls	flock	no reaction
9.11.34	shelduck	1	flying up
9.11.35	black-headed gull	1	flying up
9.12.13	black-headed gull	2	flying up
9.13.01			passage Sommerkoog-Steert-Loch; no birds present
9.13.33	black-headed gull	1	no reaction, 1000 ft
9.13.54	black-headed gull	1	150 m S of helic.; flying up
9.15.24	oystercatcher	20	flying up
9.16.05	black-headed gull	100	about 1/3 flying up, 100 m S of helic.
9.16.10	oystercatcher	50	right below helic., all flying up and landing after 15 sec., 50 m to the S
9.18.55			passing over area with small channels; no birds present
9.19.30			turn to N and E; no birds present
9.20.15	black-headed gull	40	right below helic., all flying up
9.20.18	eider	10	flying up
9.20.20	black-headed gull	150	right below helic., all flying up
9.20.30	eider	100	flying up and immediately landing
9.20.54	eider	50	flying up
9.22.06	black-headed gull	30	flying up and immediately landing
9.22.15	eider	50	remain seated along channel border
9.23.19	shelduck	50	flying up and landing after 30 sec.
9.23.25			going down to 800 ft
9.23.30	black-headed gull	30	flying up
9.23.52			passage sea wall
9.24.30	lapwing/golden plover	400	inland; right below helic., flying up., altitude 400 ft
9.25.06			100 ft
9.26.20			landing

Table 3b. Observations from a Bo-105 M helicopter during the southernmost clear-range flight on21/11/01 at 1000-1100 ft altitude. Birds registered represent half of the birds being present below the helicopter (1 observer present in each helicopter). Observer: DS

time	species	n	Behaviour, remarks
9.07			departure
9.11			passing Helmsand Insel
9.11	shelduck	115	at 100 S of helic. flying up
9.11	dunlin	100	flying up
9.12	shelduck	20	at 100 S of helic. flying up; 100 no reaction
9.12	curlew	50	flying up
9.12	dunlin	100	flying up
9.13			passage Sommerkoog-Steert-Loch; no birds present
9.14	eider	15	no reaction
9.14	oystercatcher	30	flying up
9.15	oystercatcher	20	flying up
9.15	dunlin	100	flying up
9.15	shelduck	150	flying up
9.15	eider	200	no reaction
9.16	oystercatcher	100	flying up
9.16	'wader'	100	flying up at 150 S of helic.
9.16	eider	15	flying up
9.18	'wader'	50	flying up
9.18	shelduck	50	flying up
9.18	oystercatcher	175	flying up at 150 m S of helic.
9.19			helic. Turns E again
9.19	oystercatcher	150	flying up
9.19	oystercatcher.	75	flying up at 100 S of helic.
9.20	black-headed gull	200	flying up and immediately landing
9.20	shelduck	50	no reaction
9.20	black-headed gull	150	flying up
9.21	oystercatcher	20	flying up
9.22	dunlin	100	flying up
9.23	shelduck	700	50% flying up, 50% no reaction
9.23	redshank	100	flying up
9.23	bar-tailed godwit	100	flying up
9.23	wigeon	150	flying up and crossing the sea wall
9.24			landing

Helicopter flights have also been registered by observers 3 and 4. Observer 4 did not register any visible effects, neither on birds close to the helicopter, nor in his own study area. Observer 3 registered 3000 Dunlin *Calidris alpina* in the air close to the landing site of the first helicopter collecting Armiger remains. Probably these birds flew up as a result of the landing helicopter. These birds have not been seen by the observers in the helicopter itself.

The observations from the helicopter indicate that part of the birds below the helicopter, and to some extent also those within maximally a few hundreds of meters on both sides of the helicopter, fly up briefly. No panic reactions were observed. In general fly-up time lasted for 10-15 sec, but it is possible that observers in a helicopter get a biased picture of what really happens in the field. Part of the (smaller?) birds may have already left before they can be registered from the helicopter. It is likely that the same is true for estimates on how long the fly-up time lasts. The birds can have been in the air for some time before they can be observed from the helicopter. The general impression during our first visit to the Meldorfer

Bucht in October 2001 was that birds that were disturbed by a helicopter, remained in the air for <1-3 minutes.

Table 3c. Observations from a Bo-105 M helicopter on 21/11/01 on its way for collecting Armiger remains at 200-400 ft. Observers (CS & DS) were present on both sides of the helicopter

Time	species	n	Behaviour, remarks
10.15.00			launching of Armiger
10.15.45	wigeon	50	flying up, close to sea wall, 45 sec. After launching of missile
10.15.45	wigeon	250	no reaction, close to sea wall, 45 sec. after launching of missile
10.15.45	wigeon	400	flying up, and immediate landing
10.15.45	shelduck	10	flying up, and immediate landing
10.16.13	shelduck	5	flying up
10.16.30	shelduck	40	flying up
10.16.23	shelduck	30	flying up, 200 m S of helic.
10.16.50	shelduck & eider	50	no reaction on helic. at 200 distance
10.16.55	shelduck	15	flying up, just below helic.
10.17.10	shelduck	50	flying up, just below helic.
10.17.10	oystercatcher	30	flying up, just below helic.
10.17.10	oystercatcher	40	flying up
10.17.25	shelduck	35	flying up
10.17.30	shelduck	25	flying up
10.18.00	eider	20	flying up
10.18.05	oystercatcher	40	flying up
10.18.00	oystercatcher	10	no reaction
10.18.14	eider	2	no reaction, passing over W shore of Sommerkoog-Steert-Loch,
10.18.43	herring gull	1	flying up, at 100 m S of helic.; landing after 10-15 sec.
10.18.43	oystercatcher	50	flying up, at 100 m S of helic.; landing after 10-15 sec.
10.19.00	oystercatcher	400	flying up at 200 distance from helic.
10.19.00	oystercatcher	50	no reaction of oystercatchers at 250 m
10.19.43	black-headed gull	40	flying up due to helic. decreasing altitude for landing
10.19.43	black-headed gull	100	no reaction, despite helic. decreasing altitude for landing
10.21.00			landing at target area

5.4 Disturbing effects on birds and macrobenthos of people walking around on the tidal flats when collecting a missile

Because of other obligations (sampling) the effects of people walking around on mudflats has not been studied. Based on existing knowledge (c.f. Smit & Visser 1993, Spaans *et al.* 1996) we may estimate that an area of 5-50 ha is temporarily left by birds, the size of this area being largely dependant upon bird species. After the disturbance source has gone such areas gradually fill up with birds again, the speed being dependant on the tidal situation and, once again, the species involved. Walking on tidal flats may kill organisms living in the tidal flats, Cockles being the most vulnerable species to trampling (Wolff *et al.* 1982). These phenomena especially occur especially in areas which are used intensively by people, such as well-fixed routes used for mudflat walking. Areas which are used extensively will hardly suffer.

5.5 Lethal effects on macrobenthic animals, being killed because of the missile hitting the ground

The missile landing on the mudflats in the Meldorfer Bucht produced a crater of approximately 3 m². Based on the information from Table 2 it is possible to calculate mean densities of macrobenthic animals in the target area and thus calculate the number of animals possibly killed by the landing. The results from these considerations are presented in Table 4. Cockles are known to be rather vulnerable, even when only slightly damaged. This applies for cold temperatures (Beukema 1985) as well as for somewhat more than superficial touching (Wolff *et al.* 1982). Hence, it may be expected that Cockles that have been hit or plowed under the tidal flat surface by the missile will all have died. This does not apply for the other species, possibly with the exception of *Mya arenaria*. A relatively large part of *Hydrobia ulvae* will have survived. It may be expected that only those being crushed by the missile and those being covered by a thick layer of sediment will have succumbed. The amount of Cockles being killed may seem large. In fact it is not. Cockles of the size as those that have been found in the target area (mean size 11.55 mm) contain the equivalent of approximately 150 mg of dry flesh (Zwarts & Blomert 1992). The daily need of an Oystercatcher amounts to 36-50 g dry flesh (Zwarts *et al*. 1996), or 240-333 small Cockles of the size found in the study area. The amount of Cockles killed by the landing of the missile represents the equivalent of the daily need for food of 7-10 Oystercatchers.

Table 4. Mean densities of macrobenthic animals living in the tidal flat in target area B and the numbers potentially hit on 3 m² of tidal flats. Data are calculated from Table 2

	mean density/m²	numbers on 3 m²
Cockle, *Cerastoderma edule*	800	2400
Hydrobia ulvae	22502	67506
Mussel, *Mitylus edulis*	24	72
Retusa alba	84	252
Baltic Tellin, *Macoma balthica*	36	108
Sand Gaper, *Mya arenaria*	12	36
Ragworm, *Nereis diversicolor*	24	72
Scoloplos armiger	24	72

6 Conclusions

The launching of a missile in the Meldorfer Bucht had rather small effects on birds using the nearby tidal flats as a feeding area. The observers present in the helicopter did not observe any strong reactions of birds present on the mudflats. The observer positioned on a ship north of the landing site did not observe any response to the launching and missile flight at all. The observer on the southern border of the Meldorfer Bucht did not observe reactions of birds foraging on the tidal flats but 40% of the birds present on the salt marshes did respond by flying up. It is not clear whether this has been the general pattern for the whole salt marsh area on the southern border of the Meldorfer Bucht. If so, several thousands of waterbirds, mainly ducks and geese feeding east on the salt marshes east of the observation point, must have reacted. In normal situations (i.e. without the presence of a Peregrine, c.f. Chapter 5.1) we may assume that such a disturbance lasts from some seconds to up to a few minutes. Such figures on disturbance duration have also been found by Van Raden (1990). It is, however, somewhat surprising that the missile firing had effects over such a large distance, a much larger distance than found by Van Raden (1990). The respons from waders was rather comparable: whereas we observed no reactions, Van Raden noted brief disturbances in a small area of tidal flats close to the launching site. It should be mentioned once more that we have not been able to study the effects close to this site in detail. If, however, a severe disturbance had occurred, we would have seen it. Neither did we observe strong reactions from ducks close to the launching site, whereas at a distance of 9 km part of the ducks and geese did show a response. Most likely, Van Raden did not observe birds at such a large distance as we did. We have no explanations for why we experienced relatively mild reactions of ducks and geese close by the launching site and stronger reactions at a large distance.

Although none of our observers has been able to document the effects of the landing of the missile on the tidal flats we expect that only birds within a 200 m radius will have been briefly disturbed. Given the mean densities of waders (338/km²) and other waterbirds on the tidal flats of the Meldorfer Bucht in November this will mean that approximately $\pi.0.2^2.400 = 50$ waders, ducks and gulls will have been disturbed, most likely for less than a few minutes.

Considering the rather low densities of birds feeding on the tidal flats (with an approximate mean figure of 400 birds on 1 km², equalling 1 bird on 2500 m²) the chance that a bird is being hit by a landing missile is extremely small.

Based on earlier observations (van Raden 1990) it is unlikely that seals will have been affected in some way or another, because they are mainly found in the western part of the Meldorfer Bucht, away from the impact area.

The effect of the missile landing on animals living in the tidal flats has been calculated, using the samples that have been taken in the target area. It is estimated that 2400 Cockles have succumbed. This amount is the equivalent of the daily food requirement of 7-10 Oystercatchers. Given the densities in which macrobenthic animals occur on the tidal flats and the relatively small number that has been affected, the effect of the missile landing on these animals has to be considered as small.

Helicopters are the main sources of disturbance during the missile tests. They are used for clear-range flights as well as for collecting the remains of the missile just been fired. Based on theoretical considerations (Chapter 3.3) we have calculated that a low flying helicopter crossing the tidal flats of the Meldorfer Bucht disturbs 6500 birds. Based on our own observations on 21/11/01, made from helicopters flying at an altitude of 1000-1000 ft (Chapter 5.3), we arrived at 1258 (for the helicopter flying the northern track) and 5100 (for the helicopter flying the southern track) birds. The theoretical and empirical approach start from the same flight distance. Therefore, the results may be compared: they show that the estimate of the number of disturbed birds are in the same order of magnitude. To some extent this is a surprise: based upon experiences elsewhere one would expect that helicopters flying at 1000-1100 would disturb fewer birds. It is possible that the observers in the helicopters have missed some of the small *Calidris* waders and possibly also some of the relatively shy Curlew (because they had disappeared already in front of the approaching helicopter). The observer based at AM7 found some evidence for the fact that some small waders may have been overlooked when the helicopter landed, but not for having missed Curlew. It also became obvious that the helicopters only affected birds some hundreds of meters beneath and on each side of the helicopter. The observers at some km's distance from the helicopter pathways did not observe any reaction of birds in their study areas. These observations are confirmed by Van Raden (1990) who determined disturbance distances of 50-250 m, the distance being rather different from season to season. Especially in May he noted much higher flight distances. As far as we have been able to see the effects of the helicopters generally lasted less than 1 min. Van Raden arrived at a 10-60 sec for waders, 10-20 sec for gulls, 10 sec for Eiders, and 5-15 sec for Shelduck, in all cases as an effect of helicopters flying at altitudes < 1000 ft.

Assuming that waders fly up maximally 3 min as a result of disturbance by helicopters during one tidal cycle the amount of disturbance equals about 1% of the time available during a full tidal cycle of approximately 5 hours (or 300 min). In most cases the fly-up time will be more limited. Flying is a costly activity in terms of energetics (Jehl 1994, Kersten 1996). Flying-up because of disturbance is even worse, because instead of gaining energy through foraging the birds have to spend energy for flying. It may not be expected, however, that the energetic deficit the birds have to face as a result of disturbances from missile firing in the Meldorfer Bucht, if practised on a scale as is currently being done, exceeds more than 1 to a few percent of their daily intake. Based upon our findings we may expect that some thousands of birds have to cope with such extra costs. The rather small scale of the disturbances in the Meldorfer Bucht will allow them to compensate for lost feeding time by longer or more intensive foraging.

Recommendations

Waders feeding in tidal flat areas which are frequently visited by humans may show habituation. Flight distances of birds in remote areas tend to be higher as compared to areas where birds frequently meet people (Spaans *et al.* 1996). The opposite can also occur: human activities leading to an avoidance of a particular area for a longer time. This phenomenon has been documented for high-tide roosts which face a relatively high pressure from recreation in parts of the year (Mitchell *et al.* 1988). It may happen in feeding areas as well. Such reactions do not occur after a single disturbance. Instead, birds may gradually avoid areas where they are frequently disturbed. There are indications that such behaviour has developed in some intensively used military training areas close to some of the Dutch Wadden Sea islands (Smit 1984). Considering the intensity of human activities in the Meldorfer Bucht it is not likely that birds in the area show such behaviour. In order to avoid the risk that such behaviour develops the missile-firing tests and helicopter flights in the area should be kept to a frequency as limited as possible.

One way of minimising the effects of activities connected to missile-firing in the Meldorfer Bucht is the use of 1 helicopter during clear-range flights, instead of the 2 which have been used in November 2001. It simply reduces the disturbance of birds with 50%. It is also recommended that flight altitudes are kept as high as possible. Our data show that some thousands of birds are disturbed, even when helicopters fly at 1000 ft. For this reason even higher altitudes than that are recommended. Helicopters preferably should start and land according to a flight path as depicted below:

```
  →→→→→→→→→→→→→→→→
↑                                ↓
↑   flight altitude over the tidal flats   ↓
↑          at >1000 ft                ↓
↑                                ↓
↑                                ↓
camp                            camp
```

Helicopters should also avoid to make sudden or unpredictable movements, since these often cause strong reactions in birds (Smit 2000). Preferably they should also try to avoid areas with high concentrations of birds, such as mussel beds.

It is essential that periods with relatively high bird numbers are avoided. The strong decrease in wader and waterbird numbers in the area in winter (as shown in Fig. 6) obviously has immediate consequences for the number of birds which is disturbed. This implies that, in order to minimise disturbances, a time-frame between November and February is highly preferred.

References

Anderson, D.E., O.J. Rongstad & W.R. Mytton, 1989. Response of nesting Red-tailed Hawks to helicopter overflights. Condor 91: 296-299.

Barry, T.W. & R. Spencer, 1976. Wildlife response to oil well drilling. Can. Wildl. Service, Prog. Notes 67: 15 p.

Beukema, J.J., 1985. Zoobenthos survival during severe winters on high and low tidal flats in the Dutch Wadden Sea. In: J.S. Gray & M.E. Christiansen (eds.), Marine biology of polar regions and effects of stress on marine organisms: 351-361. Wiley, Chichester.

Bleich, V.C., R.T. Bowyer, A.M. Pauli, M.C. Nicholson & R.W. Anthes, 1994. Mountain sheep Ovis canadensis and helicopter surveys: ramifications for the conservation of large mammals. Biol. Cons. 70: 1-7.

Burger, J., 1981. Behavioural responses of Herring Gulls Larus argentatus to aircraft noise. Environm. Poll. (Series A) 24: 177-184.

Burger, J., 1983. Jet aircraft noise and bird strikes: why more birds are being hit. Environm. Poll. (Ser. A) 30: 143-152.

Côté, S.D., 1996. Mountain goat responses to helicopter disturbance. Wildl. Soc. Bull. 24: 681-685.

Cottereau, P., 1978. Effect of sonic boom from aircraft on wildlife and animal husbandry. In: J.L. Fletcher & R.G. Busnel (eds.). Effects of noise on wildlife: 63-79. Academic Press, New York.

Cramp, S. & K.E.L. Simmons (eds.), 1977. Handbook of the birds of Europe, the Middle East and North Africa, Vol. I.. Oxford Univ. Press, Oxford: 722 p.

Dijkema, K.S., G. van Tienen & J.G. van Beek, 1989. Habitats of the Netherlands, German and Danish Wadden Sea 1:100 000. RIN Texel/ Veth Foundation, Leiden: 24 habitat maps.

Ellis, D.H., C.H. Ellis & D.P. Mindell, 1991. Raptor responses to low-level jet aircraft and sonic booms. Environm. Poll. 74: 53-84.

Engelhard, G.H., J. van den Hoff, M. Broekman, A.N.J. Baarspul, I. Field, H.R. Burton & P.J.H. Reijnders , 2001. Mass of weaned elephant seal pups in areas of low and high human presence. Polar Biol. 24: 244-251.

Ens, B.J. & J.T. Cayford, 1996. Feeding with other Oystercatchers. In: J.C. Goss-Custard (ed.), The Oystercatcher. From Individuals to Populations: 77-104. Oxford University Press, Oxford.

Flemming, B.W., 2000. A revised textural classification of gravel-free muddy sediments on the basis of ternary diagrams. Cont. Shelf Res. 20: 1125-1137.

Gast, R., R. Köster & K.-H. Runte, 1984. Die Wattsedimente in der nördlichen und mittleren Meldorfer Bucht. Untersuchungen zu Fragen der Sedimentverteilung und der Schlicksedimentation. Die Küste 40: 165-257.

Giese, M. & M. Riddle, 1999. Disturbance of emperor penguin Aptenodytes forsteri chicks by helicopters. Polar Biol. 22: 366-371.

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. Report 88/30, U.S. Fish and Wildlife Serv./NERC, Fort Collins: 20 p.

Grubb, T.G. & W.W. Bowerman, 1997. Variations in breeding Bald Eagle responses to jets, light planes and helicopters. Journal of Raptor Research 31: 213-222.

Harrington, F.H. & A.M. Veitch, 1992. Calving success of Woodland Caribou exposed to low-level jet fighter overflights. Arctic 45: 213-218.

Holm, C., 1997. Disturbance of dark-bellied Brent geese by helicopters in a spring staging area. Dansk Ornitologisk Forenings Tidsskrift 91: 69-73.

Hüppop, O. & K. Hagen, 1990. Der Einfluss von Störungen auf Wildtiere am Beispiel der Herzschlagrate Brütender Austernfischer (Haematopus ostralegus). Vogelwarte 35: 301-310.

Jehl, J.R., 1994. Field estimates of energetics in migrating and downed Black-necked Grebes. J. Avian Biology 25: 63-68.

Jungius, H. & U. Hirsch, 1979. Herzfrequenzänderungen bei Brutvögeln in Galapagos als Folge von Störungen durch Besucher. Journal für Ornithol. 120: 299-310.

Kam, J. van de, B. Ens, T. Piersma & L. Zwarts, 1999. Ecologische Atlas van de Nederlandse wadvogels. Schuyt & Co, Haarlem: 368 p.

Kempf, N. & O. Hüppop, 1996. Auswirkungen von Fluglärm auf Wildtiere: ein kommentierter Überblick. Journal für Ornithol. 137: 101-113.

Kersten, M., 1996. Time and energy budgets of Oystercatchers Haematopus ostralegus occupying territories of different quality. Ardea 84A, Special Issue: 291-310.

Küsters, E. & H. van Raden, 1986. Zum Einfluss von Tiefflug, Schiessbetrieb und anderen anthropogenen Störungen auf Vögel im Wattenmeer bei Lyst/Sylt. Teil 1. Untersuchungen an Ringelgänsen. Vogel und Luftverkehr 6-2: 75-89.

Küsters, E. & H. van Raden, 1987. Zum Einfluss von Tiefflug, Schiessbetrieb und anderen anthropogenen Störungen auf Vögel im Wattenmeer bei Lyst/Sylt. Teil 2. Anatiden und Limikolen. Vogel und Luftverkehr 7-1: 15-24.

Leong L.S. & P.A. Tanner, 1999. Comparison of methods for determination of organic carbon in marine sediment. Mar. Poll. Bull. 38: 875-879.

Meltofte, H., J. Blew, J. Frikke, H.-U. Rösner & C.J. Smit, 1994. Numbers and distribution of waterbirds in the Wadden Sea. IWRB Spec. Publ. 34/ Wader Study Group Bull. 74, Special Issue: 192 p.

Mitchell, J.R., M.E. Moser & J.S. Kirby, 1988. Declines in midwinter counts of waders roosting on the Dee estuary. Bird Study 35: 191-198.

Mosbech, A. & C. Glahder, 1991. Assessment of the impact of helicopter disturbance on moulting Pink-footed Geese Anser brachyrhynchus and Barnacle Geese Branta leucopsis in Jameson Land, Greenland. Ardea 79: 233-237.

Nehls, G., 1995. Stategien der Ernährung und ihre Bedeutung für Energiehaushalt und Ökologie der Eiderente (Somateria mollissima (L., 1758). Thesis Christian Albrechts University, Kiel, 177 p.

Owens, N.W., 1977. Responses of wintering Brent Geese to human disturbance. Wildfowl 28: 5-14.

Raden, van H., 1990. Untersuchung zu speziellen Auswirkungen des Erprobungsbetriebes der Wehrtechnischen Dienstelle 71 auf Vögel und Seehunde in der Meldorfer Bucht. Abschlußbericht. Report Amt für Wehrgeophysik, Traben-Trarbach: 25 p.

Sapolski, R.M., 1990. Stress in the wild. Scientific American Jan. 1990: 106-113.

Smit, C.J. & W.J. Wolff (eds.), 1981. Birds of the Wadden Sea. Balkema, Rotterdam: 308 p.

Smit, C.J., 1986. Oriënterend onderzoek naar veranderingen in gedrag en aantallen van wadvogels onder invloed van schietoefeningen. RIN report 86/18, Texel: 28 p.

Smit, C.J. & G.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 Bull. 68, Special Issue: 6-19.

Smit, C.J., 2000. Bouwstenen voor een beheersvisie van de Texelse Mokbaai. Alterra report 146, Wageningen: 97 p.

Sossinka, R. & J. Niemann, 1994. Störungen von Entenvögeln durch Hubschrauber nach Untersuchungen an der Weserstaustufe Schlüsselburg. Artenschutzreport Vol. 4: 19-21.

Spaans, B., L. Bruinzeel & C.J. Smit, 1996. Effecten van verstoring door mensen op wadvogels in de Waddenzee en de Oosterschelde. IBN report 202, Wageningen: 134 p.

Trimper, P.G., N.M. Standen, L.M. Lye, D. Lemon, T.E. Chubbs & G.W. Humphries, 1998. Effects of low-level jet aircraft noise on the behaviour of nesting Osprey. J. Appl. Ecol. 35: 122-130.

Volkman, J.K., D. Rohjans, J. Rullkotter, B.M. Scholz-Bottcher & G. Liebezeit, 2000. Sources and diagenesis of organic matter in tidal flat sediments from the German Wadden Sea. Continental Shelf Res. 20: 1139-1158.

Ward, D.H. & R.A. Stehn, 1989. Responses of Brant and other geese to aircraft disturbances at Izembek Lagoon, Alaska. Report U.S. Fish and Wildlife Service, Anchorage: 193 p.

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. J. Wildlife Managm. 63: 373-381.

Wilson, R.P., B. Culik, R. Danfeld & D. Adelung, 1991. People in Antarctica: How much do Adelie penguins Pygoscelis adeliae care? Polar Biol. 11: 363-370.

Wolff, W.J., P.J.H. Reijnders & C.J. Smit, 1982. The effects of recreation on the Wadden Sea ecosystem: many questions but few answers. In: G. Luck & H. Michaelis (eds.), Schriftenreihe M.E.L.F., Reihe A: Angew. Wissensch. Nr. 275: 85-107.

Wolff, W.J., 1973. The estuary as a habitat. An analysis of data on the soft-bottom macrofauna of the estuarine area of the rivers Rhine, Meuse, and Scheldt. Zoologische Verhandelingen, Leiden 126: 1-242.

Zwarts, L., 1988. De bodemfauna van de Fries-Groningse waddenkust. Flevobericht 294, Lelystad: 195 p.

Zwarts, L. & R.H. Drent, 1981. Prey depletion and the regulation of predator density: Oystercatchers (Haematopus ostralegus) feeding on Mussels (Mytilus edulis). In: N.V. Jones & W.J. Wolff (eds.), Feeding and survival strategies of estuarine organisms: 193-216. Marine Science 15. Plenum, New York.

Zwarts, L. & A.M. Blomert, 1992. Why Knot Calidris canutus take medium-sized Macoma balthica when six prey species are available. Mar. Ecol. Progr. Ser. 83: 113-128.

Zwarts, L., J.T. Cayford, J.B. Hulscher, M. Kersten, P.M. Meire & P. Triplet, 1996. Prey size selection and intake rate. In: J.C. Goss-Custard (ed.), The Oystercatcher. From Individuals to Populations: Pp. 30-55. Oxford University Press, Oxford.