Altenburg & Wymenga ECOLOGISCH ONDERZOEK

A&W-rapport 1227

THE IMPACT OF CONVENTIONAL ILLUMINATION OF OFFSHORE PLATFORMS IN THE NORTH SEA ON MIGRATORY BIRD POPULATIONS

Final Report

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In coöperation with Frank van de Laar

Altenburg & Wymenga ECOLOGISCH ONDERZOEK BV
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PHOTO FRONT PAGE
Wim Maatje. Chaffinch *Fringilla coelebs* victim found dead on an offshore platform.

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CONTENTS

1. CONSIDERATIONS AND CONCLUSIONS

Considering that:
The North Sea has an important function in the ecology of migratory bird species. It was estimated that circa 50 million birds, consisting of at least 120 different species, migrate through the area as part of their annual migration cycle.

Most nocturnally migrant birds in the North Sea are susceptible to artificial lights on offshore platforms. They can circle for prolonged periods of time (clockwise) around illuminated platforms, resulting in energy loss or death.

Scientific results unequivocally prove that conventional broad-spectrum illumination on platforms leads to attraction and disorientation of birds. By temporarily switching the lights on and off, it was shown that the lights were the key-factor. Additional experiments in which the spectral composition of the lights were manipulated, showed that the harmful part of the spectrum consists of the long wave (red light) fraction.

Of all the 120 species observed (in one autumn at one point in the North Sea), 72 species have been recorded as attracted to an illuminated platform at night, and of these 58 species are prone to collision risks with illuminated platforms.

The direct effect of platform lighting on mortality of bird species cannot be assessed directly in the field, since this requires a reliable registration of all the victims. This is not possible because carcasses are hard to find at sea and disappear rapidly due to consumption by scavengers.

There is a gap in our understanding of nocturnal bird migration in the North Sea, it is therefore hard to link species specific casulaties with geographically separated breeding sites.

It is possible, generally accepted and ecologically sound to compare estimated additional mortality due to illuminated platforms with 1% of the background mortality for the species concerned. This approach is based on an EU 'rule of thumb' used to define exploitation of 'small numbers' of birds in the context of the EU Bird directive. This estimate is not dependent on a given population size.

Patterns of bird movements across the North Sea suggest that there are seven different main migration routes and the probability of encountering an illuminated platform varies with the followed migration route. The probability to encounter a platform with a sphere of influence of 1 km varies between 0.27 and 0.85 for the seven different routes. The encounter probability increases non-linear with an increased sphere of influence.

For a worst case scenario, it was estimated that 49 bird species are affected and subjected to mortality levels exceeding the threshold level of 1% of the annual mortality. Of these, 11 species are heavily affected and subjected to elevated mortality, exceeding the threshold by more than a factor 20. A total of 13 species surpass the threshold by a factor 10-20 times.

The worst case scenario suggests that the most common species migrating across the North Sea (Redwing *Turdus iliacus*, Common Blackbird *Turdus merula*, Song Thrush *Turdus philomelos*, Fieldfare *Turdus pilaris*, European Robin *Erithacus rubecula*, Skylark *Aluada arvensis*, Common Eider *Somateria molissima* and Common Starling *Sturnus vulgaris*) all show high collision risks and all exceed the threshold by more than a factor 10.

The worst case scenario suggests that seven species make up for the majority of all victims. The species group that is numerical mostly affected are the trushes: 75% of all victims are Redwings, Common Blackbirds, Song Thrushes and Fieldfares. The remaining 25% are mainly European Robins, Skylarks and the Common Starling. Only a small fraction of the total number of victims (3%) is divided over 40 other species.

This study relies heavily on calculations that are based on assumptions. Future work should be focused on providing detailed empirical estimates.

Concluding:

Conventional broad spectrum lights causes attraction and disorientation of birds and if this can be avoided this will result in

- A Very likely improvement of the populations of 49 bird species that migrate through the North Sea, their annual survival changes will improve, in some cases possibly to a large extent.
- Annual reduction of the number of individual bird casualties North Sea wide.
- Reduction of the ecological footprint of offshore platforms in the North Sea.

2. INTRODUCTION

The North Sea has an important function in the ecology of migratory bird species. It was estimated that that over 50 million birds, consisting of at least 120 different species, migrate through the area as part of their annual migration cycle (Marquenie & van der Laar 2004). Large numbers of birds can circle around illuminated objects at night in the North Sea. This phenomenon has become a common sight around platforms, especially during the time period when migration intensity is reaching peak levels. This is most profound at clouded nights (Marquenie & van der Laar 2004) when the birds can no longer rely on celestial cues (stars) for their navigation. Detailed studies on the orientation mechanism of birds (Wiltschko *et al.* 1993) and additional field trials (Poot *et al.* 2008) have irrefutably demonstrated that the red part of the emission spectrum of lights is responsible for disruption of the internal compass in birds (Poot *et al.* 2008). This causes birds to circle (clockwise) for prolonged periods of time around the light source, leading to energy loss and sometimes death.

2.1. SERVICES REQUESTED

OSPAR is the mechanism by which fifteen governments of the western coasts and catchments of Europe, together with the European Community, cooperate to protect the marine environment of the North-East Atlantic. A report addressing the issue of bird friendly lighting has been presented to two separate committees of OSPAR, they concluded that although there is sufficient evidence with regard to the impact of conventional lighting on individual birds, there is uncertainty whether alternatives would result in an improvement at the population level. It is possible that a shift to bird friendly lighting on platforms will improve the survival changes of only a few individual birds, and this may result in negligible effects on the population dynamics of the species concerned. In that case this measure, although sympathetic, will not lead to an improvement of the ecological quality of North Sea.

The Dutch government is comitted to investigate this uncertainty and the Ministry of Public works (Rijkswaterstaat, Waterdienst) commissioned Altenburg and Wymenga ecological consultants to investigate the effect of conventional lighting of offshore platforms in the North Sea on migratory bird populations. The main question as commissioned was phrased as: *Is there a possible significant effect of conventional lights on platforms on birds at a population level?*
Unfortunately, the magnitude of this effect cannot be assessed directly in the field, since this requires a detailed analysis of vitims found and carcasses are hard to find at sea and disappear rapidly due to consumption by scavengers. Therefore, the first step in this approach would be a worst case scenario at the individual level. In other words, circling around a platform will inevitably be fatal for an individual bird. A scenario should take into consideration the migration route, the number of platforms

encountered along the route, the sphere of influence around the light source, the probability of encountering specific weather along the route that is known to be associated with a high number of collisions, and ultimately the effects on a population level. The worst case analysis will result in a list of species for which a significant effect at population level can not be excluded. For these species a more detailed analysis is necessary. This detailed analysis should be focused on the assumptions that underlie the worst case scenario.

3. CONCEPTUAL FRAMEWORK

3.1. ESTIMATING MORTALITY

In order to arrive at a reliable estimate of the number of birds that die on a platform, the first suggestion that comes to mind is to investigate the actual numbers of victims directly. However, analyses of the number of dead birds found on a platform will always produce a highly underestimated number. Firstly, because the chance of finding a carcass on the platform is very small and most victims do not end up on the platform itself but in the sea, where they cannot be found. Secondly, many carcasses rapidly find their way back into the food chain due to consumption by scavengers and raptors.

Our approach to come to a reliable estimate of species specific mortality at a platform is depicted in figure 1. The traditional approach is to quantify the total number of birds that pass through the area. The next step would be to break this total number down by species, based on species composition usually obtained for one or a few locations. This figure then should be combined with the probability of having a fatal collision with a platform. This probability depends on the spatial orientation of the platforms in the North Sea, the migration route that this species takes and the timing of migration. The timing of migration will affect the probability of encountering risk prone weather (for instance in November, the probability of bad weather is higher than in September).

Figure 1: Estimation of species specific mortality

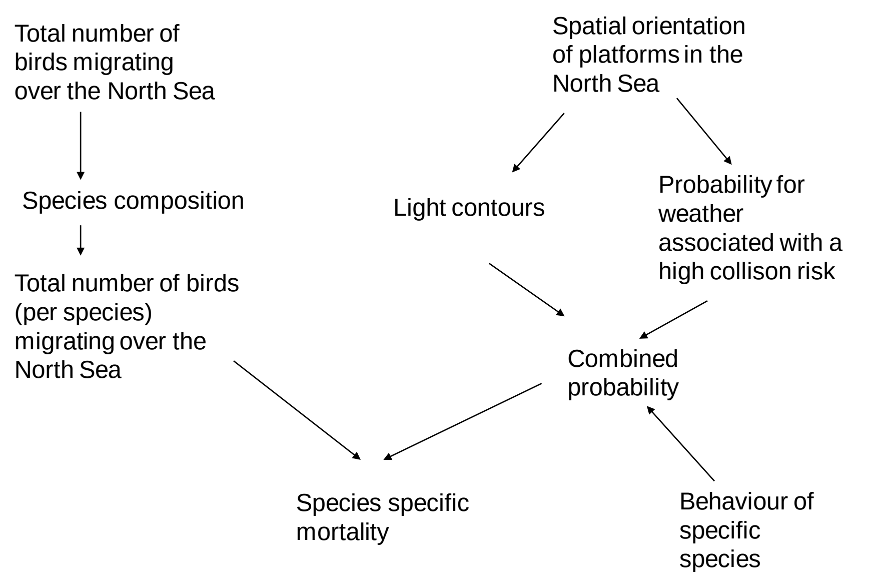


Figure 1. Estimation of species specific mortality

3.2. INTERPRETATION OF MORTALITY IN A POPULATION CONTEXT

Once the species specific mortality is known, a comparison with the breeding population seems straightforward. However, for most species it is difficult to find a satisfactory geographic population for comparison. Finding a proper biogeographic population as reference is important, since this is the level on which compensation for additional unnatural mortality might occur. For instance for the population of Chaffinches *Fringilla coelebs* it is important to decide beforehand which breeding population size to adhere to: the world population with an estimated number 370 million birds? the European population with an estimated population size of 260 million birds? or the Norwegian population size with an estimated 3 million breeding birds? If platform collisions would each year take a toll of 500,000 Chaffinches, this would result in a negligible effect if projected on a global or European scale (respectively 0.14% and 0.19%), but would result in a significant effect if all individuals originate from the Norwegian population (it would result in an annual loss of 17% of the population). This scale problem can be avoided by using the population that uses the North Sea as a migration route as the biogeographic population.

We compare the species specific mortality around platforms, with the population size of the species concerned that is actually using the North Sea annually as a migration route (Figure 2).

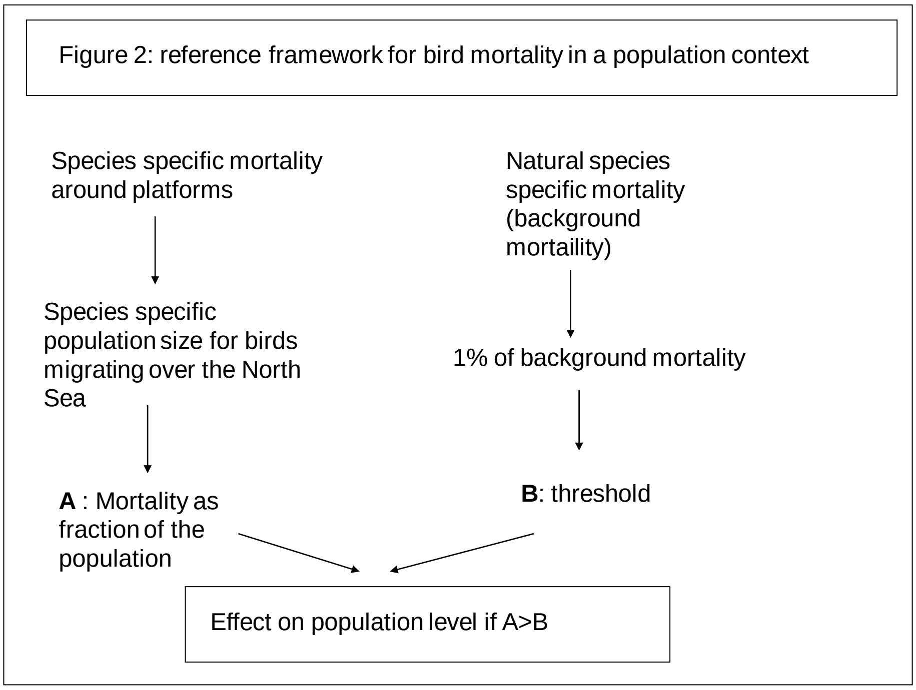


Figure 2. Reference framework for bird mortality in a population context

The mortality due to collisions with platforms is then compared with the background mortality. We use the background or natural mortality as the mortality that a normal population is experiencing. The EU adheres to an arbitrarily level of 1% of the natural/background mortality as a threshold. A given value below this level corresponds to a relatively small number, with a negligible effect. For a given value above this level the effect is no longer negligible. This approach follows from jurisprudence from the EU Birds Directive (see section 4.8). The strength of this approach is that relatively short-lived species are not weighed equally compared to relatively long-lived species and this makes sense from a ecological/demographic viewpoint. Relatively short-lived species have a natural low annual survival rates (and high annual mortality rates). In the natural situation they are adapted to relative high levels of mortality (and variation in mortality), and naturally compensate for this these by having a higher annual reproductive output.
Another positive side effect of this approach is that in the final judgment of the impact of conventional illumination on bird populations, our estimates become independent of the (inaccurate) actual size of the bird populations in the North Sea. The mortality as a fraction of the population that is making use of the North Sea has both the total number of birds (N) and the fraction of the species concerned (Fx) in the nominator and denominator (Figure 3), therefore is of no use in the final interpretation. In other words: estimating the species specific impact becomes independent of the population size.

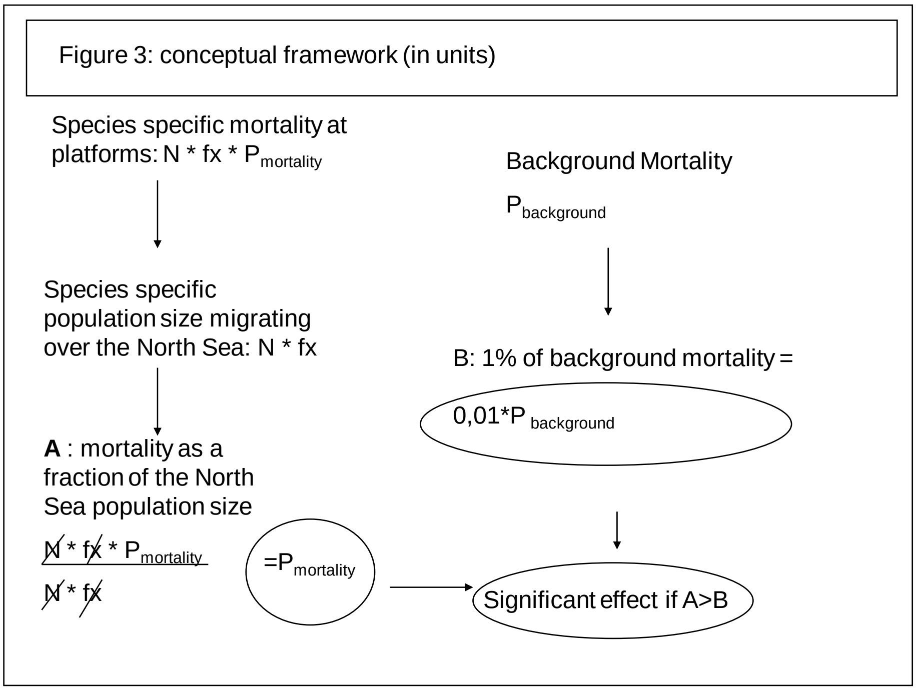


Figure 3. The conceptual framework in units

4. METHODS

4.1. BIRD SPECIES, NUMBERS AND REACTIONS TO PLATFORMS

Data were used that were collected by Frank van de Laar who counted and categorized all species that he observed during his ten year research for the NAM (based on a total of circa 90 observation days and nights, on various platforms located at various distances from the mainland in the Dutch sector of the North Sea in various times of the year). We used estimates derived by Frank van de Laar and those are appropriate for one point in the North Sea for one autumn. For small birds (the size up to Common Blackbird) these estimates are valid for a distance up to 100m from the platform. Larger species (from Common Blackbird to Curlew) could be reliably estimated up to a distance of 250m, and larger species up to a distance of 2500m. The majority of these birds (circa 80%) were observed at night. Most seabirds, ducks and grebes were observed during the day.

Fundamentally, each animal can react on a stimulus (an illuminated platform) in three different ways: by tolerance, avoidance and attraction.

Avoidance
Birds that show avoidance in general change their flight paths during the day in response to the platform. During the day they never come in the proximity of a platform and at night they were never seen circling around the platform. Birds that avoid a platform can be indirectly negatively affected. For instance their migration route can be blocked, on the other hand a part of the marine habitat becomes unsuitable for them to forage (seabirds). However, in comparison with the direct impact that illuminated platforms can have, this effect will be small, but this might affect species that are not considered in this study.

Tolerance
Birds that showed tolerance to the platform, reacted as if there was no platform at all. They usually migrate in a straight line, sometimes passing the platform at close range. However at night they were never observed to circle around the platform.

Attraction
Birds that were attracted to the platform change their flight path towards the platform at day or rest on the platform, and regularly circle around the platform at night.

4.2. ATTRACTED BIRDS : POSITIVE AND NEGATIVE IMPACT

Birds can become attracted or trapped at a platform because they are caught in the lightbeam at night. Without exception this has a negative impact on the birds, because they can not forage at or around the platform. However, some species are attracted to platforms for its resources. For instance the carcasses of passerines can be a meal for raptors, owls, and scavengers like gulls or Jackdaws. We will focus on the first group, for which attraction is solely negative, throughout this report.

High and low risk group

The group of bird species that show attraction to a platform with a negative impact was further broken down in two categories. Species that often circle for prolonged periods (1 hour up to the whole night) of time around a platform and/or are regularly found dead as victim, these species are categorized as birds with a high collision risk (high risk group). On the other hand, some species only circle for relatively short periods of times (less than one hour) and/or are not often found dead are categorized as having a (relatively) low collision risk (low risk group).

Example of a species that is negatively attracted to a platform. This chaffinch Fringilla coelebs probably has spend the last energy reserves circling around the platform, and there are no options available on the platform to refuel (photo: Wim Maatje)

Example of a species that can be positively attracted to a platform. This Jackdaw Corvus mondula can refuel at the platform and continue its migratory journey (phot:o Wim Maatje)

4.3. MIGRATION

For each individual species we analyzed the migration in space and time over the North Sea. As a starting point we used the breeding distribution of birds in Europe (Hagemeijer & Blair 1997) and the Migration atlas (Wernham *et al.* 2002). For mainly nocturnal migrants, these sources were supplemented with information from a coastal ringing station in the western part of the Netherlands (Levering & Keijl 2008) and two ringing stations in the northern part of the Netherlands (VRS Schiermonnikoog and VRS Vlieland, data published on www.trektellen.nl). For the timing and flight directions of diurnal migrants we also relied on information published in LWVT/SOVON (2002). For each species we made a preliminary map with the migration routes. Based on these maps we distinguished seven main migration routes (arbitrarily named A to G). For all the species we deduced the migration pattern to one (or more than one, up to 3) of the migration routes.

4.4. ANNUAL SURVIVAL RATE

We used published information regarding the annual survival of species. The main sources were Arriero and Møller (2008) and BTO-birdfacts. For waterrail *Rallus aquaticus* we used a value similar to the value used for Moorhen *Gallinula chloropus.*
Throughout this report when refering to 'mortalitity' we refer to the annual mortality, this value is one minus the annual survival rate.

4.5. PROBABILITY OF ENCOUNTERING PLATFORMS DURING MIGRATION

For each of the seven migration routes (A-G) we calculated the probability of encountering a platform along the route. For each route we projected all platforms on one imaginary line (cross-section) that intersects the flyway at a 90 degree angle. Around each platform we projected a sphere of influence of respectively 1, 2 and 3 kilometer. This imaginary line can thus be broken down by parts that give unobstructed passage for a migrant and a parts that reflect the flight path where at least one platform is encountered. By knowing the summed length of all the parts where at least one platform is encountered and dividing by the total length of the cross-section, we can estimate the probability of encountering a platform.

4.6. PROBABILITY OF ENCOUNTERING BAD WEATHER DURING MIGRATION

Clouded weather is one of the main determinants in explaining bird attractions to light sources (Poot *et al.* 2008). For this study we used weather data available online (www.knmi.nl). Based on climatic data (1998-2008) for one coastal station in the Netherlands (De Kooy, Den Helder) we calculated for each month the probability of a certain cloud coverage. The cloud cover is registered every hour on a scale from 0 (no clouds cover) to 8 (sky fully covered in clouds). These hourly values were averaged (and rounded) in order to arrive at one point estimate per day. The daily values were averaged per month and over the years. The probability of encountering full cloud cover (score 8) was used as indicator of the probability of risk prone weather in the calculations.

***Table 1** Probability to encounter a day with a specific average cloud cover(scale 0-8) as a function of the month of the year. Based on 10 years of data for one station (de Kooy, source KNMI.nl).*

	cloud cover index (monthly average)								
Month	0	1	2	3	4	5	6	7	8
Jan	0.006	0.023	0.023	0.065	0.079	0.138	0.208	0.240	0.217
Feb	0.026	0.058	0.045	0.035	0.077	0.135	0.213	0.213	0.197
Mar	0.027	0.044	0.035	0.065	0.088	0.133	0.209	0.198	0.201
Apr	0.067	0.064	0.061	0.076	0.106	0.167	0.194	0.173	0.094
May	0.033	0.105	0.090	0.075	0.108	0.127	0.181	0.187	0.093
Jun	0.024	0.055	0.061	0.088	0.127	0.152	0.176	0.233	0.085
Jul	0.029	0.068	0.059	0.100	0.100	0.130	0.206	0.192	0.115
Aug	0.018	0.044	0.059	0.085	0.118	0.174	0.235	0.200	0.068
Sep	0.034	0.055	0.061	0.098	0.073	0.162	0.187	0.239	0.092
Oct	0.029	0.056	0.059	0.056	0.103	0.138	0.194	0.252	0.114
Nov	0.003	0.015	0.012	0.030	0.082	0.185	0.248	0.245	0.179
Dec	0.015	0.032	0.023	0.041	0.059	0.188	0.194	0.199	0.249

4.7. THRESHOLDS FOR A SIGNIFCANT EFFECT AT POPULATION LEVEL

In this report we choose to compare the probability that a bird species will have a fatal encounter with an illuminated platform with a fraction of the background or natural mortality of the species involved. The EU adheres to an arbitrarley level of 1% of the natural mortality as a threshold. A given value below this level corresponds to a small number, with a negligible effect. For a given value above this level the effect is no longer negligible. This approach follows from jurisprudence from the EU bird directive (see box).

Box: Interpretation of the term 'small numbers' in the EU bird directive used by the European Commission.

EU com2000/180, com 2002/146'.

....There can be no exemption either from the formal requirements laid down by the Directive (79/409 EEC on the conservation of wild birds) for maintaining bird populations at levels corresponding to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements, or from the requirements to maintain habitats and to avoid pollution.

Strict conditions are set for the granting of these derogations, including that there must be no satisfactory alternative and there must always be strict supervision. In the case of the third reasons there is also the limitation to 'small numbers'. This is of course a relative concept and, when the derogation concerns exploitation, is best expressed by a comparison between the losses due to these activities and the annual death rate of the populations concerned by the derogation. A derogation involving a loss amounting to less than 1% of the annual death rate for these populations may be considered mathematically as affecting a "small number", since its impact is less than the uncertainty attaching to the population dynamics...

5. RESULTS

5.1. SPECIES PRONE TO COLLIDE WITH PLATFORMS

In appendix 1 we summed all the species that were observed. A total of six species always avoided the platforms, a total of 42 species always tolerated the platform and a total of 72 species were in some way affected in their behavior by the platforms (appendix 1). The species attracted to platforms can further be broken down in a category where the attraction has negative consequences (58 species) and a category where attraction has a positive effect (14 species, raptors and gulls that rest and forage on a platform and some seabirds that forage in the shelter of the platform, or rest on it) (appendix 1).

In table 2 we summed the main species specific information that we used in our risk assessment. For all bird species that are attracted to a platform and when this attraction has negative consequences (see appendix 1) we collected information regarding their survival rate, numbers, risk category and the route and timing of migration.

Table 2

Bird species that migrate across the North Sea and are negatively affected by illumination of platforms. For these species the annual survival rate is given, the average number that pass in one autumn (on one site in the North Sea, collected by F van de Laar), the risk category (high risk: species showing prolonged circling and sometimes found dead, low risk: species showing circling for only a limited period of time and not frequently found dead. For each species the main migration routes are given (A-G). In addition the main migration period is given. Species are ordered by risk category and numerical occurrence.

						migration period											
Species	survival rate	Estimated number for one place (in one autumn) in the North Sea	Risk: High	Risk: Low	flyway	J	F	M	A	M	J	J	A	S	O	N	D
Redwing	0,42	250,000	X		ACE										1	1	
Common Blackbird	0,56	150,000	X		ACE										1	1	
Song Thrush	0,46	150,000	X		ACE									1	1		
Fieldfare	0,35	100,000	x		ACE										1	1	
European Robin	0,38	90,000	x		ACE									1	1		
Skylark	0,66	50,000	x		C										1		
Common Eider	0,94	30,000	x		D			1	1	1			1	1	1	1	1
Common Starling	0,47	25,000	x		AE			1							1	1	
Hedge Accentor (Dunnock)	0,49	5,000	x		BC								1	1	1		
Goldcrest	0,22	5,000	x		AEF										1		
Eurasian Curlew	0,74	3,000	x		AEG			1	1			1	1	1	1		
Chaffinch	0,64	3,000	x		EF		1	1	1						1		
Red Knot	0,68	2,500	x		E					1				1	1	1	
Brambling	0,64	2,500	x		AEF			1	1						1	1	
Eurasian siskin	0,39	2,500	x		AEG		1	1	1						1		
Barnacle Goose	0,90	1,500	x		AB		1	1							1	1	
Dunlin	0,75	1,500	x		B												
Blackcap	0,46	1,500	x		F									1	1		
Eurasian Wigeon	0,53	500	x		AEB		1	1							1	1	
Eurasian Teal	0,46	500	x		BE			1	1							1	
Ruddy Turnstone	0,78	500	x		AE				1	1						1	
Meadow Pipit	0,54	500	x		BF										1		
Reed Bunting	0,52	500	x		AEG			1							1		
Wheatear	0,55	300	x		F									1			
Firecrest	0,22	250	x		AEF										1		
Common Goldeneye	0,63	200	x		AD		1	1	1							1	1
Sanderling	0,56	200	x		E			1	1	1					1	1	1
Northern Pintail	0,52	150	x		BE		1	1							1	1	
Gadwall	0,58	100	x		B		1	1							1	1	
Water Rail	0,62	100	x		BE				1						1	1	

Woodcock	0,61	100	x		AEG				1						1		
Ring Ouzel	0,50	50	x		B									1	1		
Little Stint	0,50	10	x		B					1			1	1			
Grey Heron	0,69	5	x		AEG			1	1			1	1				
Great Bittern	0,70	2	x		E				1						1		
European Golden Plover	0,61	1,500		x	BE		1	1							1	1	1
Black Redstart	0,55	1,500		x	B									1	1		
Mistle Thrush	0,52	1,500		x	F										1		
Grey Plover	0,80	1,000		x	E				1	1				1	1		
Common Snipe	0,48	750		x	BEF		1	1	1				1	1	1		
Common Chiffchaff	0,33	750		x	EF								1	1	1		
Mallard	0,52	250		x	AEB		1	1	1					1	1	1	
Common Whitethroat	0,39	250		x	F								1	1			
Ringed Plover	0,58	200		x	AE			1	1				1	1			
Willow Warbler	0,33	150		x	F							1	1	1			
Greenfinch	0,43	150		x	ACB				1						1		
Common Redpoll	0,42	150		x	F		1	1	1							1	
Lesser Whitethroat	0,49	50		x	E								1	1			
Great Tit	0,49	50		x	EG										1		
Yellowhammer	0,53	25		x	B				1						1		
Goldfinch	0,35	25		x	B				1	1					1		
Horned Lark (Shore Lark)	0,66	10		x	BF										1	1	
Winter Wren	0,37	5		x													
Common Bullfinch	0,44	5		x													
Jack Snipe	0,45	2		x													
Whinchat	0,46	2		x													
Eurasian Collared dove	0,61	1		x													
Dusky warbler	0,33	1		x													

5.2. PROBABILITY OF ENCOUNTERING A PLATFORM

The plethora of migration routes used by the different bird species that belong to the risk prone category (table 2) where reduced to (a combination of) seven main migration routes. These routes are depicted in the graphs on page 22 and 23. As expected, the probability of encountering a platform (table 3, Figure 4) depends on the migration route. Migration routes differ largely in the number of platforms that can be encountered. In addition the probability of encountering a platform increases with an increased sphere of influence, but not proportional. This was also expected and this is caused by the fact that when the sphere around platforms increase, also the probability that those spheres overlap will increase and this will not result in an increased risk. Perfectly overlapping spheres will not increase the encounter probability, since we assume that the first encounter is already fatal.

Table 3a. Migratory flyway (scenario A-G), length of the imaginary line that intersects the flyway (km) and the probability (in %) of encountering a platform with a sphere of influence of respectively 1km, 2km and 3 km. All assuming each encounter is fatal (single encounter model). The notation P(s1) refers to the chance of encountering a platform under the single encounter approach, for a sphere of influence of 1km.

scenario	length (km)	P(s1)	P(s2)	P(s3)
A	520	27.03%	44.97%	59.31%
B	188	84.85%	89.78%	91.08%
C	363	77.05%	88.44%	92.11%
D	354	46.41%	55.94%	63.10%
E	219	74.75%	78.49%	80.17%
F	234	72.27%	77.34%	80.55%
G	534	40.79%	55.22%	63.69%

In order to give an indication of the the least tolerable 'sphere of influence' we also calculated the change of encountering a platform for spheres that range in magnitude between 50 and 500m (see table 3b). We used these figure to illustrate for the Redwing the maximum sphere of influence that is tolerable (see box).

Table 3b. Migratory flyway (scenario A-G), length of the imaginary line that intersects the flyway (km) and the probability (in %) of encountering a platform with a sphere of influence of respectively 50m to 500m. All assuming each encounter is fatal (single encounter model). The notation P(s50m) refers to the chance of encountering a platform under the single encounter approach, for a sphere of influence of 50m.

scenario	P(s50m)	P(s100m)	P(s150m)	P(s200m)	P(s250m)
A	1,0%	1,6%	2,3%	3,1%	3,9%
B	3,0%	4,8%	7,3%	9,7%	12,1%
C	3,8%	5,7%	8,5%	11,4%	14,2%
D	0,7%	1,1%	1,7%	2,3%	2,8%
E	4,0%	4,8%	7,1%	9,5%	11,9%
F	2,2%	3,5%	5,3%	7,0%	8,8%
G	2,6%	3,6%	5,4%	7,2%	9,0%
scenario	P(s300m)	P(s350m)	P(s400m)	P(s450m)	P(s500m)
A	4,7%	5,4%	6,2%	7,0%	7,8%
B	14,5%	17,0%	19,4%	21,8%	24,2%
C	17,0%	19,9%	22,7%	25,6%	28,4%
D	3,4%	4,0%	4,5%	5,1%	5,7%
E	14,3%	16,6%	19,0%	21,4%	23,8%
F	10,6%	12,3%	14,1%	15,8%	17,6%
G	10,8%	12,6%	14,4%	16,2%	18,1%

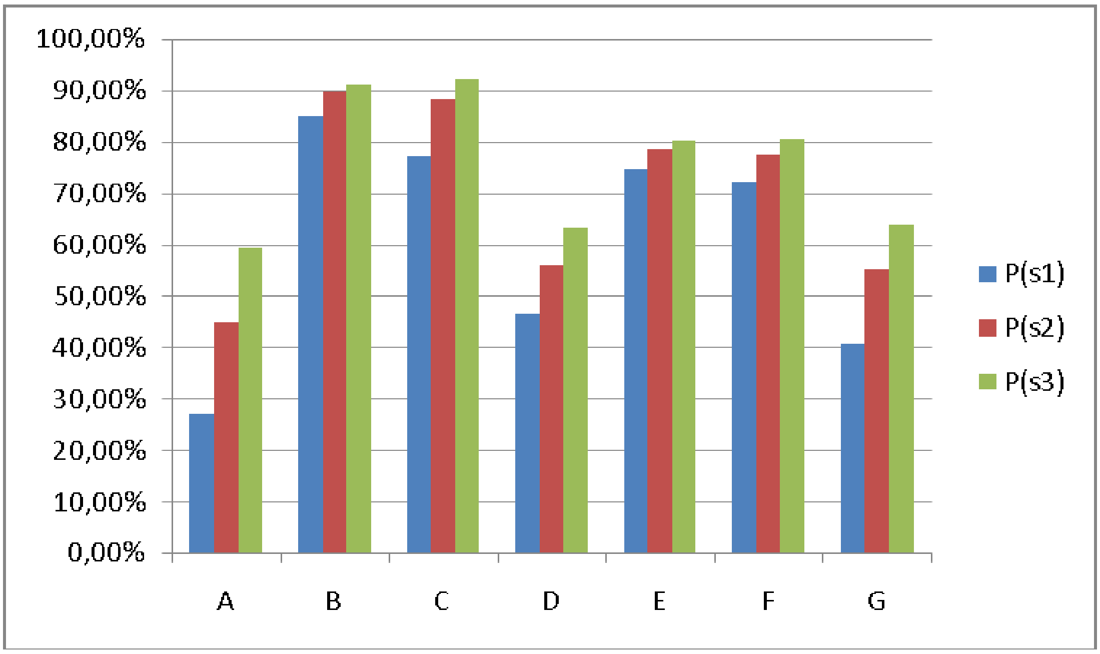
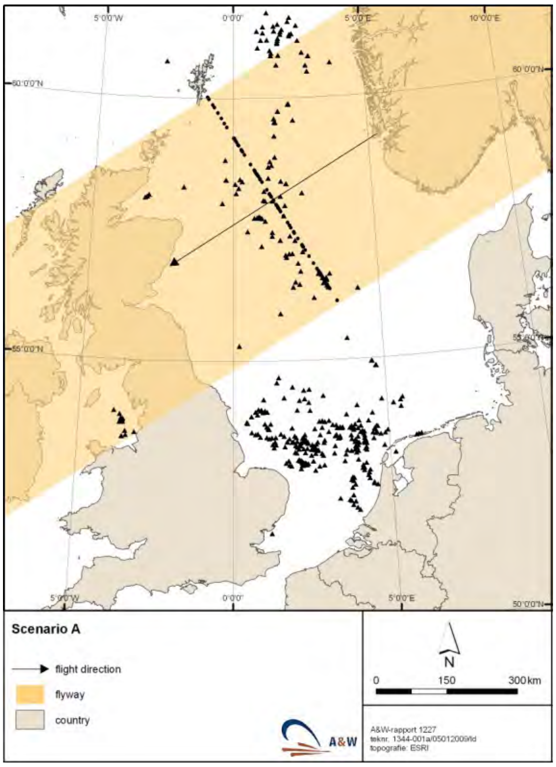
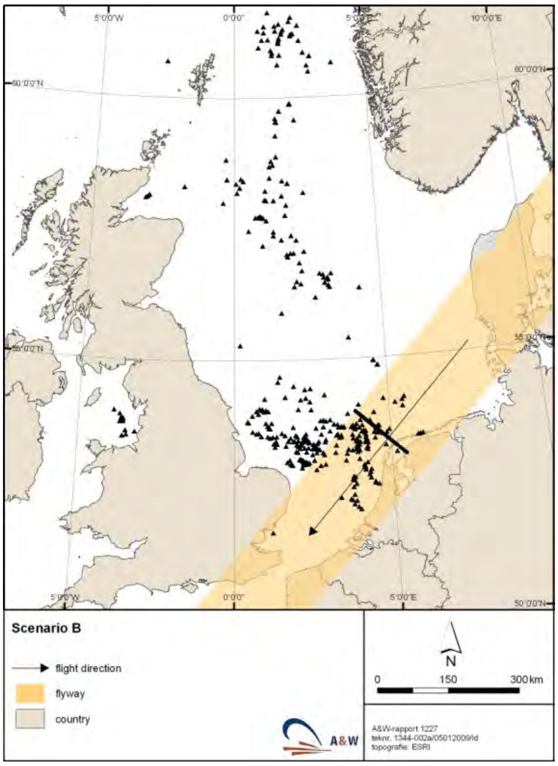


Figure 4 *The probabilitye of getting into contact with a platform as a function of migration scenario (A-G) and the sphere of influence around a platform (arbitrarily set at 1,2 and 3 kilometres).*


Scenario A
flight direction
flyway
country
N
0 150 300 km
A&W
A&W-rapport 1227
teknr. 1344-001a/05012009/ld
topografie: ESRI


Scenario B
flight direction
flyway
country
N
0 150 300 km
A&W
A&W-rapport 1227
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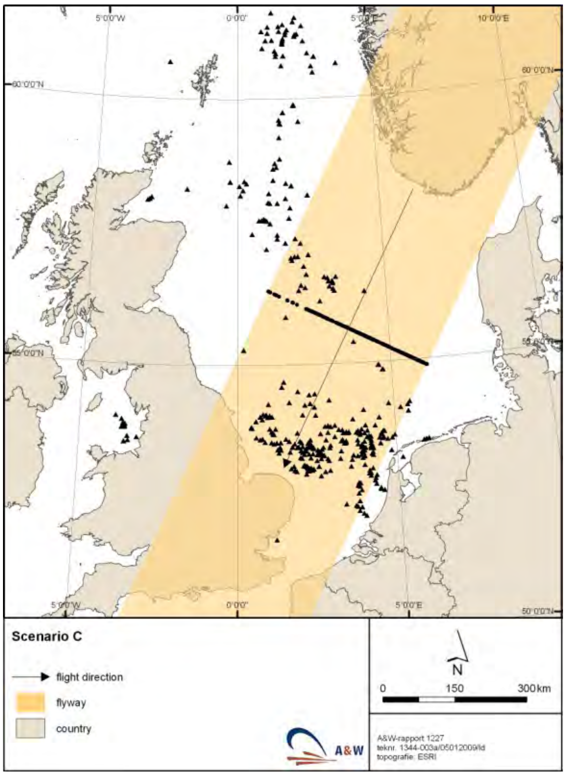
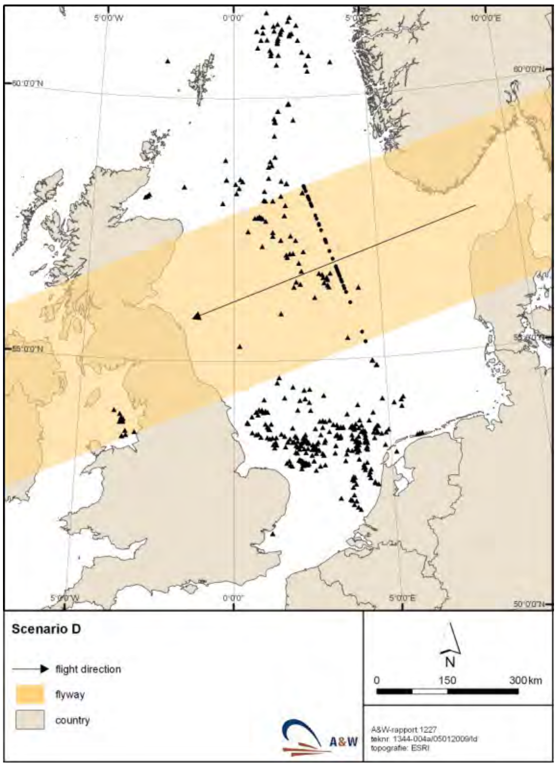
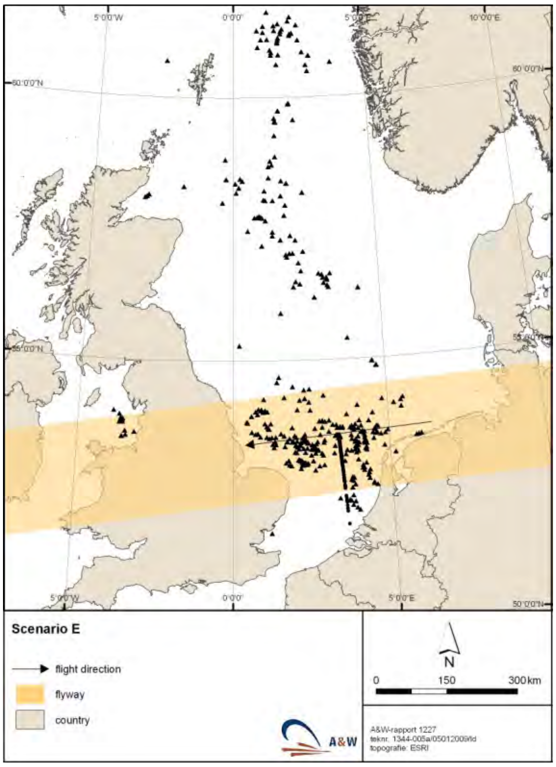
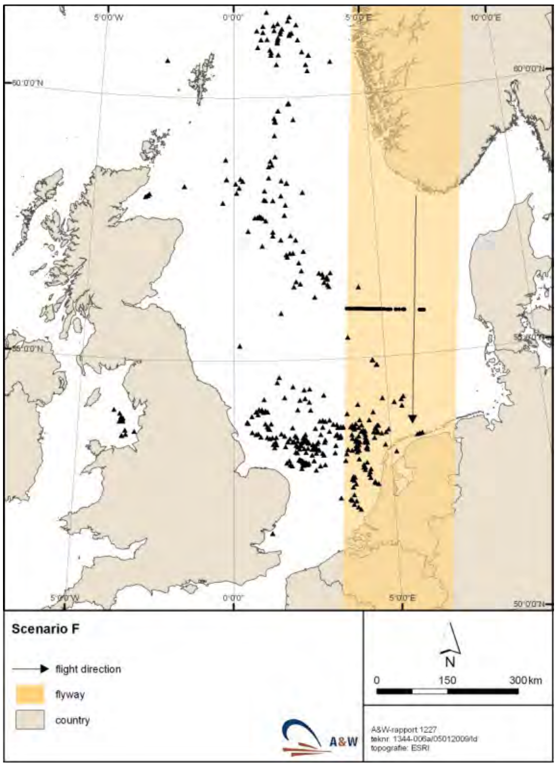
topografie: ESRI


Scenario C
flight direction
flyway
country
N
0 150 300 km
A&W
A&W-rapport 1227
teknr. 1344-003a/05012009/ld
topografie: ESRI


Scenario D
flight direction
flyway
country
N
0 150 300 km
A&W
A&W-rapport 1227
teknr. 1344-004a/05012009/ld
topografie: ESRI





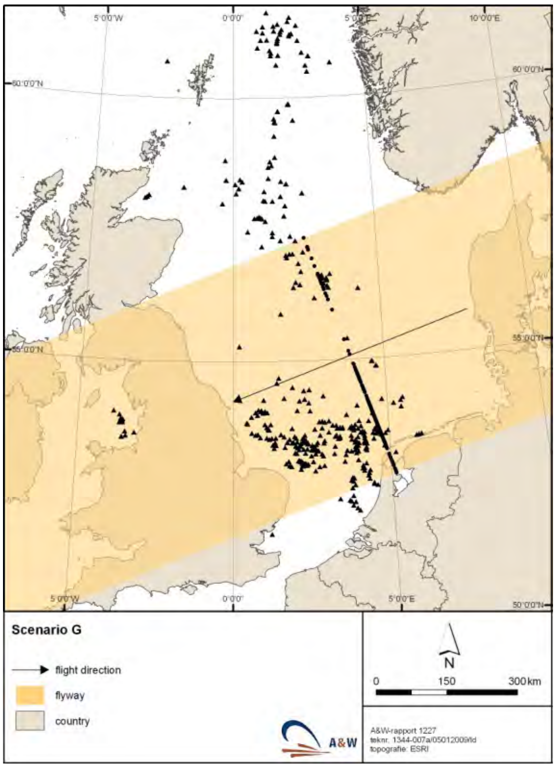


Figure 5. Main migration routes (A-G) used by birds that migrate across the North Sea. The arrows depict the main flight direction. The panels indicate the area that was used to calculate the encounter probability. Each symbol indicate a platform. The position of each platform is duplicated on an axis perependicular to the flight direction to visualize the probability of encountering a platform.

5.3. WORST CASE SCENARIO: EVERY ILLUMINATED PLATFORM ENCOUNTERED DURING BAD WEATHER IS LETHAL

In appendix 2 we tabulate the main parameters underlying the worst case scenario. For each species (from table 2) we estimated the probability of encountering a fully clouded sky during the migration period (a combined function of the timing of migration in table 2 and the cloud cover in table 1). In addition we tabulate the probability of encountering a platform assuming a sphere of influence around a platform of respectively 1, 2 and 3 km.. In addition we incorporated the incidence that a bird is attracted to a platform. For birds that were always attracted to a platform (only two species) we used the value of 1, for species that are 'mostly' attracted we used a value of 0.9 (assuming that 90% of the birds are attracted) and for birds showing some attraction we used the value of 0.1 (assuming that 10% is attracted). We did not incorporate the behaviour of the bird. In the worst case approach we assume that all collisions are fatal. Therefore this parameter was fixed at a value of 1.

Main conclusion

Under the assumptions of a worst case scenario we estimated that conventional illumination has a large effect on the annual survival rate of birds that migrate through the North Sea. A total of 49 species exceeds the 1% mortality threshold (table 4). A total of eleven species surpass this threshold by a factor larger than 20, indicating that for these species at least 20% of the annual mortality could be attributed to collisions with illuminated platforms. A total of 16 species is subjected to elevated mortality levels that surpass the 1% background mortality by a factor 10 to 20 times, and 21 species surpass the threshold by a factor of 1-10 times.

Table 4 *List of species* exceeding the 1% mortality threshold. The combined collision risk for a platform with a sphere of respectively 1, 2 and 3km and the magnitude by which the threshold (N-times exceeding the 1% of mortality) is surpassed**. Species are arranged by the magnitude of the impact, and colour coded in categories (>20 times exceeding the limit, between 20 and 10 times exceeding the limit, between 10 and 1 time exceeding the limit, and similar to the limit.*

Species	combined risk (1km)	combined risk (2km)	combined risk (3km)	exceeding limit N-times (1 km)	exceeding limit N-times (2 km)	exceeding limit N-times (3 km)
Chaffinch	0.100	0.106	0.110	28	30	30
Great Bittern	0.078	0.082	0.083	26	27	28
Northern Pintail	0.124	0.131	0.133	26	27	28
Ruddy Turnstone	0.056	0.068	0.077	25	31	35
Water Rail	0.093	0.098	0.099	24	26	26
Skylark	0.079	0.091	0.095	23	27	28
Brambling	0.077	0.089	0.097	21	25	27
Eurasian Teal	0.113	0.120	0.122	21	22	23
Eurasian Wigeon	0.097	0.111	0.119	21	24	25
Grey Heron	0.057	0.071	0.081	18	23	26
Common Blackbird	0.079	0.093	0.102	18	21	23
Meadow Pipit	0.081	0.086	0.088	18	19	19
Ring Ouzel	0.079	0.083	0.084	16	17	17
Common Starling	0.075	0.091	0.103	14	17	20
Reed Bunting	0.067	0.084	0.096	14	18	20
Redwing	0.079	0.093	0.102	14	16	18
Wheatear	0.060	0.064	0.067	13	14	15
Hedge Accentor (Dunnock)	0.067	0.073	0.075	13	14	15
Blackcap	0.067	0.072	0.075	12	13	14
Fieldfare	0.079	0.093	0.102	12	14	16
Eurasian siskin	0.065	0.081	0.092	11	13	15
Common Eider	0.006	0.008	0.009	11	13	14
Song Thrush	0.055	0.065	0.072	10	12	13
Barnacle Goose	0.010	0.012	0.013	10	12	13
Common Chiffchaff	0.060	0.064	0.066	9	10	10
European Robin	0.055	0.065	0.072	9	11	12

Willow Warbler	0.060	0.064	0.066	9	10	10
Firecrest	0.060	0.069	0.075	8	9	10
Goldcrest	0.060	0.069	0.075	8	9	10
Dunlin	0.012	0.013	0.013	5	5	5
European Golden Plover	0.015	0.016	0.016	4	4	4
Grey Plover	0.007	0.008	0.008	4	4	4
Gadwall	0.015	0.016	0.016	3	4	4
Horned Lark (Shore Lark)	0.012	0.012	0.013	3	4	4
Red Knot	0.009	0.009	0.010	3	3	3
Sanderling	0.012	0.012	0.012	3	3	3
Common Redpoll	0.012	0.013	0.014	2	2	2
Eurasian Curlew	0.005	0.007	0.008	2	3	3
Black Redstart	0.009	0.009	0.009	2	2	2
Common Snipe	0.010	0.010	0.011	2	2	2
Mallard	0.009	0.010	0.011	2	2	2
Yellowhammer	0.009	0.009	0.009	2	2	2
Common Goldeneye	0.007	0.009	0.011	2	3	3
Mistle Thrush	0.008	0.009	0.009	2	2	2
Little Stint	0.007	0.008	0.008	1	2	2
Ringed Plover	0.006	0.007	0.008	1	2	2
Goldfinch	0.009	0.009	0.009	1	1	1
Great Tit	0.007	0.008	0.008	1	1	2
Woodcock	0.005	0.006	0.007	1	2	2
Lesser Whitethroat	0.006	0.006	0.006	1	1	1
Greenfinch	0.007	0.008	0.008	1	1	1
Common Whitethroat	0.006	0.006	0.006	1	1	1

*species in bold are numerical important species (see discussion)
** the magnitude by which the threshold is surpassed (calculated as: P mortality/(0.01 * P background mortality) is similar to the percentage of the total mortality that is caused by illuminated platform (that is Pmortality/P background *100%).

BOX
Interpretation example: Redwing

For the Redwing we know that large numbers migrate across the North Sea. For one point in the North Sea it was estimated that 250,000 individuals (table 2) can pass in one season. These birds show in most of the cases (90%) a negative attraction to the platform (and only in 10% of the cases the birds react to the platform as if it was not there, appendix 1). The birds that are attracted to the platform belong to the high risk group; they can circle around the platform for prolonged periods of time (appendix 1). However, since this analysis is focused on a worst case approach we assume that all birds that are negatively affected all have the same survival change regardless of the risk category (e.g. they all die). The migration routes that Redwings follow (table 2) are graphically presented in figure 5A, 5C and 5E. We assume that Redwings proportionally use the three flyways (33% takes route A and similar for B and C). The probability of encountering a platform is given in table 3 (for three different spheres of influence). Migration takes place in October and November (table 2) and in this time of year we can expect a probability of encountering clouded conditions of respectively 11% and 18% of the time (table 1), combining these two leads to a species specific weather risk (appendix 2). With these parameters we can estimated the mortality (combined risk) for this species for platforms with a sphere of influence of 1, 2 and 3 km. For the redwing this results in a mortality of 8%, 9% or 10% (table 7). The natural (or background) mortality is around 0.58 (calculated as one minus the survival rate=0.42, table 2). The EU rule of thumb suggests that 1% of the natural mortality is acceptable as a 'small number'. So a mortality that exceeds 0.0058 (that is 0.01*0.58) is regarded as having an influence on the population. The Redwing mortality on platforms exceeds this limit by 14-18 times (depending on the sphere of influence of the platform). Based on these figure we conclude that the number of Redwings that, according to our model calculations, collide with illuminated platforms cannot be ignored.

Allowing for a mortality that equals the threshold, we arrive at a combined risk of 0,46 for the combined use of migration route (A, C and E). For a sphere of influence measuring 500m (or less), the risk of encountering a platform is 19.9% (or less) (based on values in table 3b). Platforms that have a sphere of influence between 500 and 1000m will result in a mortality around the threshold level, if the sphere of influence exceeds 1km, there is a significant effect for the redwing, if the sphere of influence is less than 500m there will be no significant effect. These cut-off values will be species dependent.

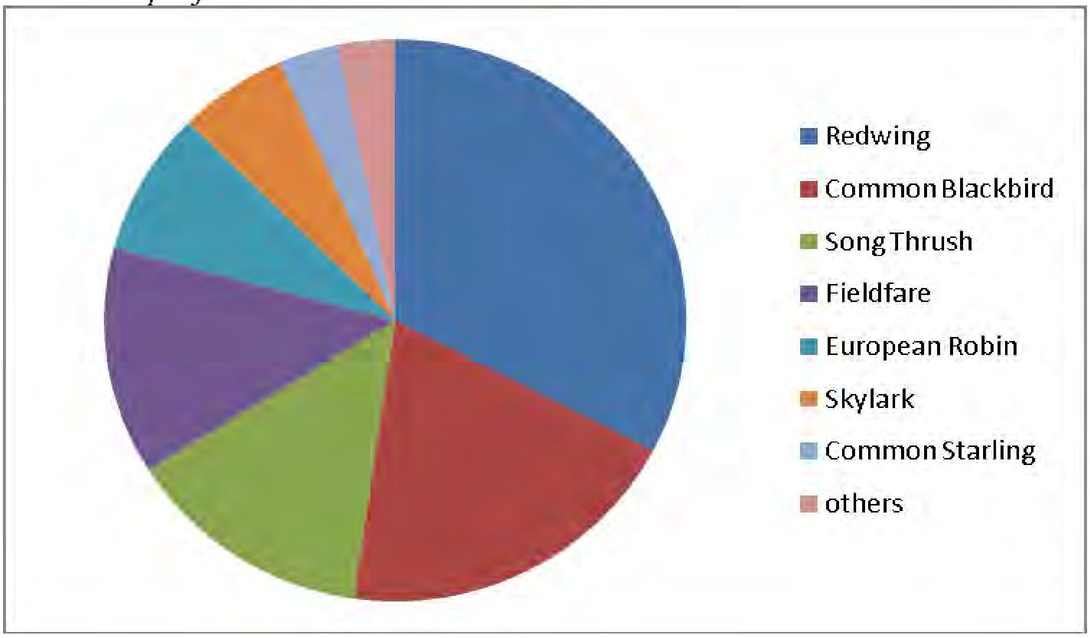
Redwing photographed on a platform in the North Sea (photo; Wim Maatje)

6. DISCUSSION

We conclude that under the assumptions of a worst case scenario we estimated that 49 bird species that migrate across the North Sea are significantly affected by conventional illumination of platforms. This was largely based on empirical observations collected over a ten year period in Dutch waters and a theoretical modeling approach. Empirical observations collected in British waters by the North Sea Bird Club (Barton & Pollock 2008) underline our findings that substantial numbers of birds are affected

It has has been estimated that over 50 million birds of many different species cross the North Sea twice each year on migration (Hüppop 2007, van de Laar 2007, Marquenie *et al.* 2008). Our worst case analysis suggest that one platform can annually take a toll of 60,000 individual birds, and that a total of 100 platforms might take a toll of 6 million birds annually. The species mostly affected (in numerical terms) are depicted in the graph below.

Figure 6. Graphic representation of the species composition of the casualties due to illuminated platforms



According to our estimations the majority of victims belong to only seven species. The species group that is mostly affected in numbers are the thrushes. 75% of all victims belong to the four thrushes: Redwing, Common Blackbird, Song thrush and Fieldfare. In addition of the remaining 25%, 22% percent belongs to the European Robin, the Skylark and the Common Starling. Only a tiny fraction of 3% is divided over a total of 40 other species.

Since this is worst case scenario approach, the real figures are probably less than the values presented. In our model, we compare the mortality risk of a certain species, with the natural or background mortality. The rationale behind this is not only a practical one (e.g. our estimates are independent from the population size of the species concerned), but is a more ecological sound way of dealing with mortality. In this way we scale mortality in relation to the natural or background mortality. Species that have a natural high mortality (such as Goldcrest *regulus regulus*, where only 1 in 5 birds makes it to the next breeding season) are weighed differently compared to species with a low mortality. Each species is subjected to basic life history trade-offs and the most important life history trade-off is between survival and reproduction. Short lived species are much better adapted to cope with variation in annual survival compared to long-lived species.

Assumptions and future directions

Our worst case model contains a lot of assumptions. The assumption that circling will always result in death is probably not realistic. More realistic is to investigate the circling duration of individual birds in detail, and estimate the consequences in terms of energy loss and mortality. In that case, it must be taken into account that along some migration routes bird statistically encounter more than one platform (see appendix 3). The sphere of influence chosen in this study is arbitrarily. In reality the sphere of influence might be larger. Especially the relation between clouded conditions and the effective sphere around a platform under these conditions needs investigation.

The knowledge of bird movements across the North Sea is poorly developed, and largely relies on anecdotic evidence. A better description of the species composition and the distribution in space and time is needed to quantify the effects that man made objects can have. Radar based surveys, and studies with light intensifiers can make a large step forward towards understanding the migration system in the North Sea. In addition, we need to collect more information from ringing research supplemented with detailed studies (such as transmitters, stable isotopes and radar) to connect breeding areas, via migration routes, with wintering areas in the North Sea basin.

This study raises two other important points. Cumulation is the fact that the influence of man made systems that interfere with natural values should not only be investigated in relation to the focal disturbing factor, but should be analyzed in conjunction with other factors that potentially can interfere with natural values. In the case of migrant birds, it is important that the effects of conventional illumination are investigated in conjunction with the ongoing development of large scale windfarms.

Another important issue is that our model suggest that birds that only pass through the area as migrant are seriously affected, while those that show an ecological relation with the area (gulls, storm-petrels, *alcidae*, divers, grebes, ducks etc.) generally tend to avoid illuminated structures. This was also noted by Wiese *et al.* (2001) and this tends to play a role especially in the North Sea. This is in contast to the Atlantic (especially off eastern Canada) where mainly storm-petrels and other seabirds were affected by illuminated platforms (Wiese *et al.* 2001). Birds that avoid illuminated objects, will not be directly affected in terms of survival prospects. However, habitat loss or loss of foraging grounds might be a serious factor for these birds.

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APPENDIX 1

All species observed and the species specific reactions on encountering a platform. Birds can react on a platform by avoidance (change flight path), tolerance (no observed reaction) or attraction (found at higher density around platform compared to the surrounding area). The effect of the attraction can either by positive (no negative consequences for the bird) or negative (the result of disorientation).Species are ordered according to taxonomy. (Data collected by Frank van de Laar)

Species	***scientific***	**avoidance**	**tolerance**	**attraction**	**effect**
Black-throated diver	*Gavia arctica*	always			
Red-throated diver	*Gavia stellata*	always			
Great Crested Grebe	*Podiceps cristatus*		always		
Red-necked Grebe	*Podiceps grisegena*		always		
Slavonian Grebe	*Podiceps auritus*		always		
Black-necked Grebe	*Podiceps nigricollis*		always		
Northern Fulmar	*Fulmarus glacialis*		always		
Manx Shearwater	*Puffinus puffinus*		always		
Sooty Shearwater	*Puffinus griseus*		always		
Balearic shearwater	*Puffinus mauretanicus*		always		
European Storm-petrel	*Hydrobates pelagicus*		mostly	some	pos
Leach's Storm-Petrel	*Oceanodroma leurcorhoa*		mostly	some	pos
Northern Gannet	*Morus bassanus*		always		
European Shag	*Phalacrocorax aristotelis*		mostly	some	pos
Great Cormorant	*Phalacrocorax carbo*		mostly	some	pos
Grey Heron	*Ardea cinerea*			always	neg
Great Bittern	*Botaurus stellaris*			always	neg
Mute Swan	*Cygnus olor*		always		
Whooper Swan	*Cygnus cygnus*		always		
Tundra Swan (Bewick's Swan)	*Cygnus columbianus*		always		
Greylag Goose	*Anser anser*		always		
White-fronted Goose	*Anser albifrons*		always		
Brent Goose	*Branta bernicla*		always		
Barnacle Goose	*Branta leucopsis*		mostly	some	neg
Common Shelduck	*Tadorna tadorna*		always		
Mallard	*Anas platyrhynchos*		mostly	some	neg
Gadwall	*Anas strepera*		mostly	some	neg
Eurasian Wigeon	*Anas penelope*		some	mostly	neg
Eurasian Teal	*Anas crecca*		some	mostly	neg
Northern Pintail	*Anas acuta*		some	mostly	neg
Tufted Duck	*Aythya fuligula*		always		
Common Pochard	*Aythya ferina*		always		

Common Eider	*Somateria mollissima*		mostly	some	neg
Black Scoter (Common Scoter)	*Melanitta nigra*	always			
Velver Scoter	*Melanitta fusca*	always			
Common Goldeneye	*Bucephala clangula*		mostly	some	neg
Long-tailed Duck	*Clangula hyemalis*		always		
Goosander	*Mergus merganser*		always		
Red-breasted Merganser	*Mergus serrator*		always		
Smew	*Mergus albellus*		always		
Eurasian Sparrowhawk	*Accipiter nisus*		mostly	some	pos
Peregrine Falcon	*Falco peregrinus*		mostly	some	pos
Common Kestrel	*Falco tinnunculus*		mostly	some	pos
Water Rail	*Rallus aquaticus*		some	mostly	neg
Common Moorhen	*Gallinula chloropus*		always		
Common Coot	*Fulica atra*		always		
Eurasian Oystercatcher	*Haematopus ostralegus*		always		
Pied Avocet	*Recuvirostra avosetta*		always		
Ringed Plover	*Charadrius hiaticula*		mostly	some	neg
European Golden Plover	*Pluvialis apricaria*		mostly	some	neg
Grey Plover	*Pluvialis squatarola*		mostly	some	neg
Ruddy Turnstone	*Arenaria interpres*		some	mostly	neg
Northern Lapwing	*Vanellus vanellus*		always		
Dunlin	*Calidris alpina*		mostly	some	neg
Little Stint	*Calidris minuta*		mostly	some	neg
Red Knot	*Calidris canutus*		mostly	some	neg
Sanderling	*Calidris alba*		mostly	some	neg
Common Redshank	*Tringa totanus*		always		
Common Greenshank	*Tringa nebularia*		always		
Wood Sandpiper	*Tringa glareola*		always		
Green Sandpiper	*Tringa ochropus*		always		
Eurasian Curlew	*Numenius arquata*		mostly	some	neg
Whimbrel	*Numenius phaeopus*		always		
Woodcock	*Scolopax rusticola*		mostly	some	neg
Jack Snipe	*Lymnocryptus minimus*		mostly	some	neg
Common Snipe	*Gallinago gallinago*		mostly	some	neg
Great Skua	*Stercorarius skua*		always		
Arctic Skua	*Stercorarius parasiticus*		always		
Pomarine Skua	*Stercorarius pomarinus*		always		
Long-tailed Skua	*Stercorarius longicaudus*		always		
Black-headed Gull	*Larus ridibundus*		always		
Little Gull	*Larus minutus*		always		
Herring Gull	*Larus argentatus*		mostly	some	pos
Lesser Black-backed Gull	*Larus fuscus*		mostly	some	pos
Great Black-backed Gull	*Larus marinus*		mostly	some	pos
Mew Gull (Common Gull)	*Larus canus*		mostly	some	pos

Black-legged Kiitiwake	*Rissa tridactyla*		mostly	some	pos
Common Tern	*Sterna hirundo*		always		
Arctic Tern	*Sterna paradisea*		always		
Razorbill	*Alca torda*	always			
Common Guillemot	*Uria aalge*	always			
Atlantic Puffin	*Fratercula arctica*		always		
Little Auk	*Alle alle*		always		
Eurasian Collared dove	*Streptopelia decaocto*		mostly	some	neg
Long-eared Owl	*Asio otus*		mostly	some	pos
Short-eared Owl	*Asio flammeus*		mostly	some	pos
Horned Lark (Shore Lark)	*Eremophila alpestris*		mostly	some	neg
Skylark	*Alauda arvensis*		some	mostly	neg
Meadow Pipit	*Anthus pratensis*		some	mostly	neg
Hedge Accentor (Dunnock)	*Prunella modularis*		some	mostly	neg
Common Whitethroat	*Sylvia communis*		mostly	some	neg
Lesser Whitethroat	*Sylvia curruca*		mostly	some	neg
Blackcap	*Sylvia atricapilla*		some	mostly	neg
Willow Warbler	*Phylloscopus trochilus*		some	mostly	neg
Common Chiffchaff	*Phylloscopus collybita*		some	mostly	neg
Dusky warbler	*Phylloscopus fuscatus*		some	mostly	neg
Goldcrest	*Regulus regulus*		some	mostly	neg
Firecrest	*Regulus ignicapillus*		some	mostly	neg
Whinchat	*Saxicola rubetra*		mostly	some	neg
Wheatear	*Oenanthe oenanthe*		some	mostly	neg
Black Redstart	*Phoenicurus ochruros*		mostly	some	neg
European Robin	*Erithacus rubecula*		some	mostly	neg
Common Blackbird	*Turdus merula*		some	mostly	neg
Ring Ouzel	*Turdus torquatus*		some	mostly	neg
Fieldfare	*Turdus pilaris*		some	mostly	neg
Redwing	*Turdus iliacus*		some	mostly	neg
Song Thrush	*Turdus philomelos*		some	mostly	neg
Mistle Thrush	*Turdus viscivorus*		mostly	some	neg
Great Tit	*Parus major*		mostly	some	neg
Winter Wren	*Troglodytus troglodytus*		mostly	some	neg
Yellowhammer	*Emberiza citrinella*		mostly	some	neg
Reed Bunting	*Emberiza schoeniclus*		some	mostly	neg
Brambling	*Fringilla montifringilla*		some	mostly	neg
Chaffinch	*Fringilla coelebs*		some	mostly	neg
Eurasian siskin	*Carduelis spinus*		some	mostly	neg
Goldfinch	*Carduelis carduelis*		mostly	some	neg
Greenfinch	*Carduelis chloris*		mostly	some	neg
Common Bullfinch	*Pyrrhula pyrrhula*		mostly	some	neg
Common Redpoll	*Carduelis flammea*		mostly	some	neg
Common Starling	*Strunus vulgaris*		some	mostly	neg

APPENDIX 2

Main parameters underlying the worst case scenario: the probability of encountering a fully clouded sky during migration (species specific weather risk: a function of the timing of migration in table 2 and the cloud cover in table 1). In addition we tabulated the probability of encountering a platform assuming a sphere of influence of respectively 1, 2 and 3 km. In addition we incorporated the incidence that a bird is attracted to a platform. For birds that were always attracted to a platform (only two species) we used the value of 1, for species that are 'mostly' attracted we used a value of 0.9 (assuming that 90% of the birds are attracted) and for birds showing some attraction we used the value of 0.1 (assuming that 10% is attracted)(see appendix 1). The risk behavior score was fixed at a value of 1. Species are arranged in alphabetical order.

Species	species specific weather risk	single encounter risk (1km)	single encounter risk (2km)	single encounter risk (3km)	incidence behaviour score	risk behaviour score (set at 1)
Barnacle Goose	0,173	0,56	0,67	0,75	0,1	1
Black Redstart	0,103	0,85	0,90	0,91	0,1	1
Blackcap	0,103	0,72	0,77	0,81	0,9	1
Brambling	0,147	0,58	0,67	0,73	0,9	1
Chaffinch	0,152	0,74	0,78	0,80	0,9	1
Common Blackbird	0,147	0,60	0,71	0,77	0,9	1
Common Chiffchaff	0,091	0,74	0,78	0,80	0,9	1
Common Eider	0,136	0,46	0,56	0,63	0,1	1
Common Goldeneye	0,184	0,37	0,50	0,61	0,1	1
Common Redpoll	0,168	0,72	0,77	0,81	0,1	1
Common Snipe	0,128	0,77	0,82	0,84	0,1	1
Common Starling	0,165	0,51	0,62	0,70	0,9	1
Common Whitethroat	0,080	0,72	0,77	0,81	0,1	1
Dunlin	0,142	0,85	0,90	0,91	0,1	1
Eurasian Curlew	0,114	0,48	0,60	0,68	0,1	1
Eurasian siskin	0,152	0,48	0,60	0,68	0,9	1
Eurasian Teal	0,158	0,80	0,84	0,86	0,9	1
Eurasian Wigeon	0,173	0,62	0,71	0,77	0,9	1
European Golden Plover	0,188	0,80	0,84	0,86	0,1	1
European Robin	0,103	0,60	0,71	0,77	0,9	1
Fieldfare	0,147	0,60	0,71	0,77	0,9	1
Firecrest	0,114	0,58	0,67	0,73	0,9	1
Gadwall	0,173	0,85	0,90	0,91	0,1	1
Goldcrest	0,114	0,58	0,67	0,73	0,9	1

Goldfinch	0,100	0,85	0,90	0,91	0,1	1
Great Bittern	0,104	0,75	0,78	0,80	1	1
Great Tit	0,114	0,58	0,67	0,72	0,1	1
Greenfinch	0,104	0,63	0,74	0,81	0,1	1
Grey Heron	0,120	0,48	0,60	0,68	1	1
Grey Plover	0,098	0,75	0,78	0,80	0,1	1
Hedge Accentor (Dunnock)	0,091	0,81	0,89	0,92	0,9	1
Horned Lark (Shore Lark)	0,147	0,79	0,84	0,86	0,1	1
Lesser Whitethroat	0,080	0,75	0,78	0,80	0,1	1
Little Stint	0,084	0,85	0,90	0,91	0,1	1
Mallard	0,146	0,62	0,71	0,77	0,1	1
Meadow Pipit	0,114	0,79	0,84	0,86	0,9	1
Mistle Thrush	0,114	0,72	0,77	0,81	0,1	1
Northern Pintail	0,173	0,80	0,84	0,86	0,9	1
Red Knot	0,120	0,75	0,78	0,80	0,1	1
Redwing	0,147	0,60	0,71	0,77	0,9	1
Reed Bunting	0,158	0,48	0,60	0,68	0,9	1
Ring Ouzel	0,103	0,85	0,90	0,91	0,9	1
Ringed Plover	0,114	0,51	0,62	0,70	0,1	1
Ruddy Turnstone	0,122	0,51	0,62	0,70	0,9	1
Sanderling	0,155	0,75	0,78	0,80	0,1	1
Skylark	0,114	0,77	0,88	0,92	0,9	1
Song Thrush	0,103	0,60	0,71	0,77	0,9	1
Water Rail	0,129	0,80	0,84	0,86	0,9	1
Wheatear	0,092	0,72	0,77	0,81	0,9	1
Willow Warbler	0,092	0,72	0,77	0,81	0,9	1
Woodcock	0,104	0,48	0,60	0,68	0,1	1
Yellowhammer	0,104	0,85	0,90	0,91	0,1	1

APPENDIX 3

Towards a multiple encounter model..

In the description of the single encounter model, we assume that every contact that a bird has with a platform to be fatal. However, if we want to make the model (in the future) more realistic, (for instance by assuming that an encounter with a platform will not always result in instantaneous death, but will result in energy loss) we need to develop also a model that allows individuals to encounter more than one platform along the route. Therefore we projected all platforms on one imaginary line that intersects the flyway at a 90 degree angle. Around each platform we projected a sphere of influence of respectively 1, 2 And 3 kilometer. In addition we separated the imaginary line in separate segments of 500m length. For each segment we summed the number of platforms.

Migratory flyway (scenario A-G) and the probability of encountering no platforms (P0), one platform (P1), two platforms (P2) up to 9 platforms (P9) all calculated for a sphere of influence of 500m.

scenario (500M)	P0	P1	P2	P3	P4	P5	P6	P7	P8	P9
A	92,31%	5,87%	1,35%	0,19%	0,19%	0,10%	0,00%	0,00%	0,00%	0,00%
B	76,39%	18,57%	3,45%	1,06%	0,00%	0,27%	0,27%	0,00%	0,00%	0,00%
C	72,35%	18,16%	6,19%	1,65%	1,24%	0,41%	0,00%	0,00%	0,00%	0,00%
D	93,35%	6,22%	0,28%	0,14%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
E	77,68%	12,30%	5,24%	2,28%	1,59%	0,23%	0,00%	0,68%	0,00%	0,00%
F	84,40%	10,47%	2,99%	1,50%	0,43%	0,00%	0,21%	0,00%	0,00%	0,00%
G	82,10%	11,62%	3,84%	1,22%	0,47%	0,47%	0,00%	0,19%	0,00%	0,09%

APPENDIX 4

Beached corpses of Redwings in the Netherlands and Belgium, indicative for an elevated mortality due to platforms?

Bird corpses on the beach might give a glimpse of the mortality that occurs at sea. The vast majority of passerines that die at sea are swallowed whole by gulls. The passerines found dead on the beach are just a tiny tip of the iceberg. However, if Redwing mortality due to illuminated platforms is significant, we might expect to find a difference in beached carcasses between the central part of the southern north sea (the dutch part) and the southern part the southern north sea (the Belgium part), since platforms are absent in the southern part of the north sea.

Redwing carcasses found in the Netherlands (an area with platforms) and Belgium (where platforms are absent)

	Netherlands (1965-2007)[1]	Belgium (1962-2008)[2]
Total number of Redwings found dead	3484	88
Total number of birds found dead	261,602	19,405
Redwing percentage of total	1.33 %	0.45%

The fraction of beached redwing carcasses (expressed as a percentage of all birds found dead) is 3 times higher in the Netherlands compared to Belgium (table x). This might be caused by an artifact in the denominator, however the redwings corpses expressed for instance in relation to two other species (random picked from the list of species) show a similar pattern. For instance in relation to the numbers of dead guillemots found (Netherlands 3484/45357=8% versus Belgium 88/4876=2%) or expressed in relation to the number of dead black headed gulls found (Netherlands 3484/7577=46% versus Belgium 88/100=9%) reveals a similar difference in magnitude of an order of 4 to 5 times higher). There is a plethora of options that could explain this difference, however the difference is in the direction we expect and could be an indication that mortality for the Redwing in the Dutch part of the North Sea, with illuminated platforms is substantially higher than for the Belgium part of the north sea. During the month of October the Redwing is among the most common birds found dead on the beach in the Netherlands. About 17,7% off all bird corpses belong to this species and the densities of dead birds on the beach typically fluctuate around 2.56 birds/km (Data collected by Cees Camphuysen NZG/NSO, http://home.planet.nl/~camphuys/NZGNSO.html). The total coastline of the Netherlands is 523km. This would indicate a total of 1339 Redwings that wash on the coast. However the big question remains, how large is the fraction that does not wash on the beach?...

[1] Data collected by Cees Camphuysen NZG/NSO, http://home.planet.nl/~camphuys/NZGNSO.html

[2] Verstraete, H., E.W.M. Stienen & M. Van de Walle 2008. Monitoring Vlaamse stranden, winter 2007/08. INBO.R.2008.38. D/2008/3241/306.