ADAPTING THE SPECTRAL COMPOSITION OF ARTIFICIAL LIGHTING TO SAFEGUARD THE ENVIRONMENT

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Abstract - Over 60 million birds, of many species, cross the North Sea each year, twice. Light has a significant impact on migratory birds at sea, as it can attract and trap birds at large illuminated structures, such as off shore platforms. We first studied the behaviour of birds around offshore platforms and secondly tested the effect of the presence of lighting, the intensity and type of lights and the light colour on bird behaviour. As a conclusion, about 10% of the North Sea migrating bird populations are impacted by offshore installations. We developed a light spectrum that can be applied off shore, offering safety to both humans and birds. A field demonstration test, involving the exchange of lights to the new colour on a gas production platform has demonstrated a reduction of bird reaction of at least 50 to 90 %. Finally, the compliance to explosion safety requirements has been demonstrated. It is expected that the bird-friendly lighting will become the new standard for any installation situated in areas with bird migration.

Index Terms — Migrating birds, lighting, off shore platforms, fatal light attraction, ecology.

I. INTRODUCTION

The North Sea is an important migration route for a large number of bird species (songbirds, waders, birds of prey and other bird species). Over 50 million birds may cross the North Sea each year twice, with peaks in spring and autumn. Appendix 1 gives an overview of migration intensity and direction above the North Sea in different months. This route is normally indicated as the Atlantic flyway. Several more of such flyways exist around the globe.

At the same time, these bird populations are worldwide under pressure. Their environment is subject to rapid change by multiple factors (land-use, climate change, exploitation of natural resources, etc.). In order to protect endangered and vulnerable species and to enhance resilience of the ecosystems, measures are taken worldwide. For EU countries this results in the further implementation of the habitats and Bird directives, developing environmental legislation and the creation of a network of interconnected protected areas (Natura2000). This recently also includes the North Sea. Several international treaties have been signed to protect migratory species including the Migratory Bird Treaty Act (US) and the African-Eurasian Migratory Waterbird Agreement (Lenten, B. 2006).

The investigations were initiated because of observations that large flocks of migratory birds occasionally may enter flares. It was found, however, that also without flaring, large flocks of birds accumulated around illuminated installations at open sea at night. The reason was not fully understood, but it was estimated that North Sea wide, about 10% of the migrating bird population (6 million birds) could be significantly affected (delay, wasting energy resources, exhaustion, enhanced predation, etc.) by the installations. The impact could worldwide even be magnitudes greater.

In the period 1992-2002 we experimentally proved that artificial light was the reason that these birds accumulated and what were the conditions that triggered this behaviour. In the following period we revealed that only a part of the spectral light was responsible for the bird's reactions.

Finally we developed and tested a spectrum for different light sources as are mostly used offshore that is electrically safe, allows safe and comfortable working conditions and does no longer disorient birds.

Our paper will cover three major topics:

1) Migration in the ecology of birds and the response to artificial lighting;
2) The development of light sources for safe working, while being bird-friendly;
3) The electric safety of replacement light sources.

II. MIGRATION IN THE ECOLOGY OF BIRDS AND THEIR REACTION TO ARTIFICIAL LIGHTING

Many bird species migrate long distances. The most common pattern involves flying north to breed in the temperate or Arctic summer and returning to wintering grounds in warmer regions in the south.

There are many reasons to migrate. One reason is to avoid predation, other reasons involve essential food reserves and the longer day length. The longer days of the northern summer provide greater opportunities for breeding birds to feed their young. Most species developed their own optimum for migrating, most go north as soon as possible, some return immedialtely after the first clutch, some stay till the bitter end of season. Species that breed extremely north, like many wader birds, have a very limited window. If they come to early, there might still be snow, if they come too late, their offspring might not make it.

Migration is often concentrated along well established routes known as flyways. These routes typically follow mountain ranges or coastlines, and may take advantage of updrafts and other wind patterns or avoid geographical barriers such as large stretches of open water. Much information about flyways can be found in a recent series of web publications: www.jncc.gov.uk/worldwaterbirds. The altitude at which birds fly during migration varies. Most bird migration is in the range of 150 m (500 ft) to 600 m (2000 ft), but occasionally up to 6 km (20.000 ft) to cross mountain ridges. Bird hit records from the US show

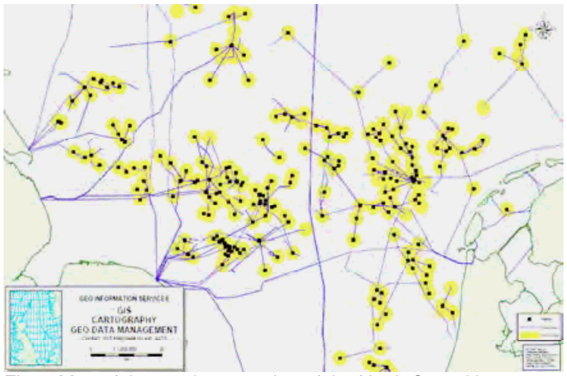

Fig. 1 Map of the southern section of the North Sea with existing production platforms (2007).
Also indicated the potential impact zone of 5 km (in yellow)

most collisions below 600 m (2000 ft) and almost none above 1800 m (6000 ft).

Reactions to artificial lights are known for a long time. Clarke (1912) was the first to record the impacts of lighthouses in his extensive studies on bird migration. Many bird watchers became obsessed by the phenomenon of large flocks of birds circling around lighthouses in incredible high concentrations and species diversity, often resulting in the death of many. The "problem" was solved, by applying floodlights around the lighthouse, enabling the birds to orient themselves on the surroundings. Marquenie and Van der Laar (2004) identified the same phenomenon around gas and oil production installations at sea. Their systematic approach let to the conclusion that the majority is song and wader birds and that the milling behaviour around platforms only occurs during cloudy or foggy nights during the broad front migration. In addition, the milling in high concentrations of birds only occurred between midnight and dawn.

The role of the platform lighting was assessed by turning lights off and on and sequential testing groups of lighting. A typical outcome for the on-off experiment is shown in table 1 and for the impact of different groups of lighting in table 2.

TABLE I
TYPICAL REACTION RATE OF BIRDS TO LIGHT AT SEA DURING CLOUDY NIGHT MIGRATION (ALL LIGHTS ON, INCLUDING MAIN DECK LIGHTS; 30 kWh)

Time in minutes after light-on	Number of birds
7	200-250
12	1000
20	1500
25	2000
30	4000-5000
Time in minutes after lights off	
3	Significant decrease
15	Gone

The results prove that the artificial lighting is responsible for the disorientation of birds during periods of cloudy skies. They also prove that the response is dose related: the more light, the stronger the effect. Upward directed TL floodlights have an increased effect as well as the sodium flood lights of the cranes. The impact was estimated to reach between 3 and 5 km. Maximum lighting (TL and Sodium floodlight) gives the strongest impact. The estimated residence time of bird flocks is about 20 minutes, but some solitary and therefore specific recognisable birds (like a solitary Woodcock, etc) have been observed to circle for several hours.

From an analysis of the spatial distribution of platforms in the southern North Sea (Fig. 1) in relation to migration routes, the reach of the impact and the frequency of cloudy conditions during periods of migration, it was concluded that about 10% (6 million birds) of the migrating population is impacted every year.

The solution to switch off lights appeared not workable due to costs of redesign of the electrical scheme and costs of installation. Moreover, light is essential for safety reasons.

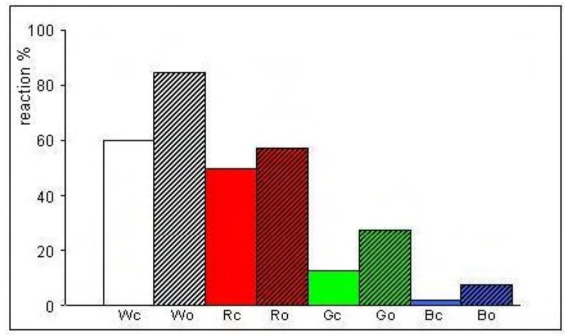

Fig. 2 Bird responses to different light conditions: white (W), red (R), green (G) and blue (B) under clear (c) and overcast (o) conditions.

III. BIRD FRIENDLY LIGHT SOURCES FOR SAFE WORKING CONDITIONS

Eager to find a solution, a novel experimental approach was chosen and the sensitivity of birds in field conditions was tested towards primary colours blue, green and red, and a "white" spectrum. The experiments were performed using a HPI 1000 W light source directed to the sea in a nature conservation area at 10 km distance from the nearest light point. The spectrum was manipulated with filters and the response parameter was change of original flight direction of migrating birds coming freshly from sea. Bird's reactions were registered as solitary birds or as groups. The results are shown in figure 2. This shows a clear trend of increasing bird's reaction going from red to green, blue, to white light. The reaction under cloudy conditions also proved to be stronger as under clear skies.

This outcome led to the hypothesis that the reaction of birds to change flight direction is mainly due to the red component in the spectrum. This red part of the spectrum, is known to interact with the bird's internal compass (Wiltschko, W., Munro, U., Ford, H. & Wiltschko, 1993). This also explains the observations during the previous 10 years that birds only reacted during overcast nights or fog and disappeared at the onset of dawn or breaking of clouds, whereas moonlight did not make a difference. We speculated that lighting in general attracts birds, but the reason for accumulation and circling around is loss of direction due to a disturbance of their compass by red light.

To put this result in practice, a number of other factors had to be taken into account. A light source without any red light would not be acceptable from safety considerations, as any colour, which is not present in the available light will not be visible. A certain minimum level of red is therefore necessary for a sufficient visibility of important safety equipment such as fire extinguishers and emergency buttons and safety signs.

To ensure that helicopter pilots can locate the helicopter deck easily, a new standard for helicopter deck lighting is being put in place, defining the perimeter lighting to be green and excluding the use of green lighting on other parts of the platform. The ICAO definition of green is shown in figure 3.

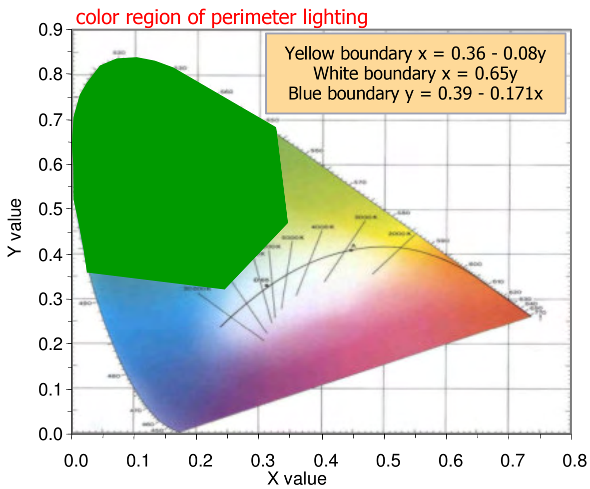

Fig. 3 x,y CIE colour triangle, showing ICAO definition of green.

Fig. 4. Off shore platform equipped with low-red exterior lighting.

The following two years, similar tests were performed during autumn migration, now using specially developed lamps with adapted spectra. A detailed analysis of all data, has shown that the best description of the relation between the spectrum and the bird reaction is given by the parameter *B* which we defined as the fraction of the light (radiation with a wavelength between 380 and 780 nm) which has a wavelength between 575 and 650 nm:

$$B = \frac{\int_{575}^{650} E(\lambda)d\lambda}{\int_{380}^{780} E(\lambda)d\lambda} \qquad (1)$$

The correlation of the bird reaction to this parameter is shown in figure 5. This has been the basis for our further lamp development.

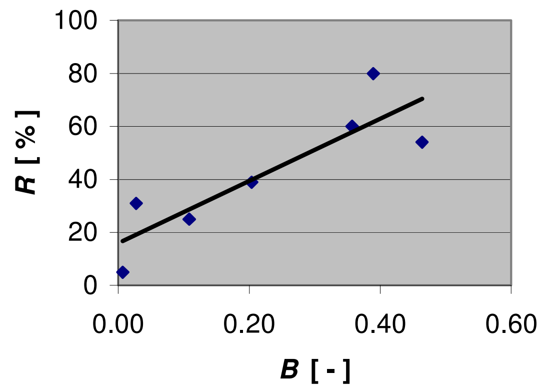

Fig. 5 Reaction percentage, *R*, versus parameter, *B*, for seven tested spectra.

In order to confirm that a light source as this would not disorient birds when used at a large scale, a test was needed offshore. To ensure safe working conditions, perception and functional tests were first done at on shore test facilities under the guidance of lighting application specialists. These tests were performed both with off shore personnel and randomly selected members of the public and showed that safety was indeed guaranteed. The new light was applied on an off shore platform 20 km north of the Dutch island of Vlieland. In May 2007 almost all of the exterior 400 TL and 20 floodlights were replaced with lamps with the new spectrum. A photo of the platform is shown in figure 4.

Autumn 2007 the reaction of birds off shore was assessed following the techniques that were applied during the offshore inventory phase. The observations were compared with observations in previous years, taking into account the weather conditions and aligning with bird intensive counts all along the shore. The results are shown in table 3.

It was concluded that the period of observation fell with in the top of the period of migration (based on coastal bird counts and radar observations) and that the circumstances for disorientation were optimum (cloudy weather). Taking this into account, the disturbance of birds declined with 50-90%. It has to be noted that at the time of this test not all white lamps had been replaced. Much of the remaining bird reactions were concentrated around the remaining white lamps. Therefore, the total effect is assumed to be even more positive.

TABLE 2
INFLUENCE OF BRIGHTNESS AND LAMPTYPES ON BIRDS

Intensity of light	Number of birds	Remarks
Beacon and obstruction lights (300 W)	None	This level of brightness is inconsequential
Light in crane (1500 W) Light in crane, beacon and obstruction lights	Small number	Bright lights shining outward, albeit to a limited extent, has some influence on birds
Light in crane, on helicopter landing platform (160 W) and beacon and obstruction lights	Limited numbers	Lights in a place clearly visible to birds has a marked, but limited influence
All lights on the helicopter landing platform (incl. landing lights: 480 W)	Numbers clearly increase	Quite a lot of light in a place conspicuous to birds has quite a considerable influence
All lights switched on (30 kWh)	During intensive migration, large to very large numbers	Standard lighting of a location has a marked, considerable and prolonged influence

TABLE 3
RESULTS OF THERMAL MEASUREMENTS FOR \840 AND LOW-RED LAMPTYPES

	driver				lamp		reflector		protective bowl			enclosure
Lamp type	above L3	above L3 in furrow	at side of L3	above L22	near filament No. 1	No. 2	under lamp 1 near filaments	under lamp 2 near driver	above the filaments lamp 1	lamp 2	above lamp 2 near driver	above driver
/840	57	62	66	57	69	67	53	64	34	33	37	41
Low-red	57	61	66	56	70	68	52	64	34	34	37	41

TABLE 4
RESULTS OF ELECTRICAL MEASUREMENTS FOR \840 AND LOW-RED LAMP TYPES

	main			lamp 1			lamp 2			total power
Lamp type	I [mA]	P [W]	cos φ	I [mA]	P [W]	U [V]	I [mA]	P [W]	U [V]	Dissipation [W]
/840	285	62.5	0.95	300	27.8	93.2	288	27.4	95.8	7.3
Low red	287	63.1	0.96	299	28.2	94.9	287	27.6	96.5	7.3

IV. ELECTRIC SAFETY OF RETROFIT TL LAMPS

The process area lighting of the relamped platform is in majority of a double bi-pin TL type. All the production / process areas are classified zone 1 and zone 2 for explosion protection, meaning all lighting equipment is certified for use in these areas. However for standardization reasons the luminaries are all EX"e" (zone 1 luminaries). Replacement of the platform luminaries, to conduct the test, was not seen as an option. Replacement of the "white lighting tubes" by "bird-friendly" ones was the most efficient way to do the testing. The light output of the tubes is 16% lower as the normal 36W/840 tubes. It is remarked however that this not resulted in an increase of safety risk, as the perceived brightness is higher due to the higher colour temperature of this light.

The installation owner is responsible to operate the lighting within the certification boundaries. A risk assessment on the new lighting was done by the manufacturer of the luminaries by assessing the influence of the "bird-friendly" tubes on the existing lighting certification. The impact investigation of the lamp change with respect to Ex requirements was done by the luminaries' original manufacturer. The first luminary, with an electronic ballast, used for the investigation was manufactured after 2003. The luminary, 2x36W, was rated for a voltage range of 110 V to 254 V and a frequency range of 50 Hz to 60 Hz. The working temperature range is from –20° C and 70°C.

Compared were the Master TLD 36/840 lamp with the same lamp type but with a new phosphor composition producing the new light color.

On request of the installation owner two additional luminaries were tested too, an older one of the same manufacturer (manufactured in the nineties) and a luminary of another manufacturer.

Test results of the first test are given in attachment x (number to be given). The test results of the additional test were equal to the ones of the first test.

The test program consisted of:

1) Temperature measurement with both types of tubes at normal ambient temperature,
2) Electrical measurements (voltage, current) including signal analysis at the tubes,
3) Light output measurement with both types of tubes.

The executed measurements on the fixture show nearly the same results for the “white” tubes as well as for the new “low-red” tubes.
“Nearly” means that the results of the thermal and electrical measurements are within the estimated variances of different tubes of the standard “white” tubes.

Based on these results and the fact that the structural design of the “white light” and “low red” lamps are identical the “low-red” fluorescent lamps could be used for replacement of “white light” lamps in installed luminaries in hazardous areas. This statement is to our opinion valid for luminaries with electronic ballasts of different make and type. However it is advised to check this with the original manufacturer of the luminaries in use.

CONCLUSION

Lighting is the main factor in attracting migrating birds to off shore platforms. In many cases, lighting is needed to give safe working conditions. A new light colour has been designed which can reduce the distraction of migrating birds with a factor of up to 90 %. In separate experiments, the safety of these new lamps with respect to human working conditions and explosion safety has been demonstrated.

NOMENCLATURE

B	Bird parameter (-).
I	Current (A).
P	Power (W).
R	Reaction percentage (%).
U	Voltage (V).

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VITA

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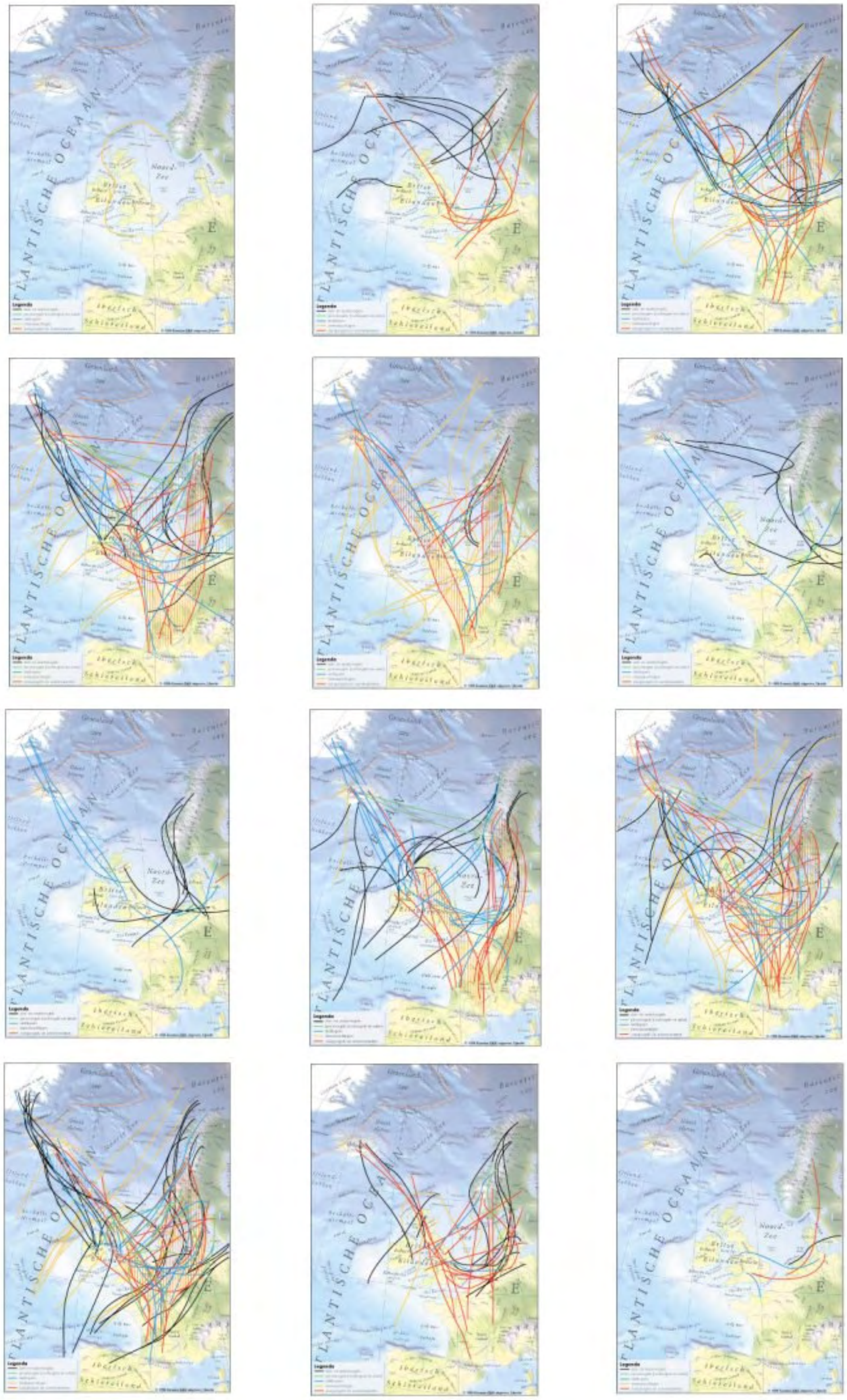
Appendix

Migration intensity and direction in different months (January through December) above the North Sea.
In spring species migrate to northerly breeding grounds.



Legenda

Black	**=**	**Sea birds**
Green	**=**	**Birds of prey**
Red	**=**	**Songbirds**
Bleu	**=**	**Waders**
Yellow	**=**	**Gulls**