REDUCTION OF BIRD COLLISIONS

ON WINDOWS

TEST REPORT

BIRDPEN®

Tests according to ONR 191040 and WIN test procedure

in the Flight Tunnel II

at the Hohenau-Ringelsdorf Biological Station

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commissioned by

Vienna Ombuds Office for Environmental Protection (WUA)

Vienna, April 2015

Summary

Commissioned by the Vienna Ombuds Office for Environmental Protection, a float glass pane marked with *birdpen*[1] was examined in the Flight Tunnel II of the Hohenau-Ringelsdorf Biological Station according to ONR 191040 (reflection-free, transparent conditions) between 9 August and 2 September 2013, and according to the WIN test procedure (simulating windows in buildings) between 1 August and 15 September 2014. The ONR test did not produce a positive result – birds did not recognise the marked pane and did not fly toward it significantly less often than towards an unmarked reference pane. Three test series incorporating specular reflections (WIN 2014, WIN reference float glass versus mirror, WIN reference *birdpen* versus float glass) produced numbers of approach flights indicating a detectable though very weak effect. While the manufacturer advertises increased visibility to birds as UV-sensitive organisms, the product is no more conspicuous in the UV spectrum than in the spectral range visible to humans. Optical measurements showed only very weak contrasts in the UV range between 350 and 400 nm. Since the measured contrasts are also minimal in the spectrum visible to humans, *birdpen* is indeed – as stated by the manufacturer – more or less invisible. Based on these test and measurement results, there is no reason to expect the application of the tested product to lead to a reduction of bird collisions to the extent that would be desirable for bird conservation. Recommendation of the product, therefore, does not appear justifiable.

[1] The spelling of the product in this report has been matched with the exact product name on the website of Dr. Kolbe (www.*birdpen*.de, last accessed: 24 March 2015), but has been italicised throughout.

1 INTRODUCTION

1.1 Wording of the test assignment

"The Vienna Ombuds Office for Environmental Protection (WUA) is interested in evaluating a system to prevent bird collision, suitable for home users. The effectiveness of Dr. Kolbe's Bird Pen is to be tested in this regard." (*Vienna Ombuds Office for Environmental Protection*, 2013).

1.2 Test item

birdpen is a felt-tip pen, externally comparable with a highlighter, with a "tip" approx. 20 x 10 mm wide, with which a stored liquid can be applied to glass. The dried substance is supposed to produce contrasts in the UV spectral range (<400 nm), which should deter birds from colliding with the glass pane, while the marking remains invisible to humans. The test specimen is a conventional float glass window pane on which a *birdpen* stripe pattern has been applied according to the manufacturer's instructions.

1.2.1 Wording of product advertisement

"A stripe pattern applied to a glass surface with the birdpen is sufficient for birds to recognise the pane as an obstacle. The stripes are practically invisible to humans. According to a scientific study, the birdpen can reduce bird collisions on glass panes by around 66 percent. The pen is free of toxins and solvents. The markings applied with the birdpen are durable for approx. half a year and must be reapplied after window cleaning." (http://www.*birdpen*.de/product.php?id=1 – last accessed: 24 March 2015)

1.2.2 Retailer recommendations

The online stores of well-known nature conservation organisations such as BUND and NABU (BUND shop and NABU shop) offer the product online. On its website, the BUND store provides the following note (https://www.bundladen.de/Tierwelt/Voegel/Futter-Vogelschutz/*birdpen*-mit-Schaber.html – last accessed: 24 March 2015.)

[…] there is significant controversy regarding the effectiveness of treating windows to prevent bird collisions. An expert opinion of the product's effectiveness was obtained by the manufacturer. http://www.birdpen.de/pdf/gutachten.pdf
On the other hand, there are calls for more definitive solutions to prevent bird collisions. http://www.vogelglas.info/

1.2.3 Existing expert opinions

The link mentioned above, http://www.*birdpen*.de/pdf/gutachten.pdf, is currently inactive. The website of NABU-Münster (under http://www.nabu-muenster.de/app/download/5726129663/Gutachten+*birdpen*.pdf?t=1330455320 – last accessed 24 March 2015 provides an expert opinion of the Max Planck Institute for Ornithology, Radolfzell, but it is unclear whether this is the original opinion or the manufacturer's reproduction of an expert opinion. The scientifically incorrect interpretation of the choice experiment suggests that at least the assessment provided under "Conclusion" was not the work of the Max Planck Institute (see box on page 10: "Interpretation of choice experiments").

The full text of the published opinion:

"Experimental investigation of effectiveness of a birdpen-coated sheet glass sample against bird collision
Dr. Hans-Wilhelm Ley, Max Planck Institut for Ornithology, Radolfzell bird observatory,
Schloss Möggingen, D-78315 Radolfzell
December 2007

In a long-term study, the effectiveness of the sample sheet glass prototype "M2A" was tested under standardised conditions in the "flight tunnel". For experimental design and procedure as well as data analysis, see final report 2004 and Ley (2006): Ber. z. Vogelschutz 43. Results: Out of 102 flights, 67 were directed at the control pane and 35 at the test pane.

Conclusion: The experiments confirm an avoidance effect of approx. 66% based on the sample size under the given experimental conditions. Accordingly, 2/3 of potential glass collisions could be avoided as a result of obstacle perception.

Transference of this result to conditions in the open landscape (buildings, noise barriers, etc.) requires further testing under natural or near-natural conditions. Further studies and research projects are planned in this respect."

1.3 Key questions for the present study

The behavioural experiments with birds, intended to clarify whether *birdpen* is perceived and can significantly contribute to collision avoidance, address the following questions:

1) Under ideal conditions (exclusion of reflections), is glass marked with *birdpen* recognised by birds as an obstacle?

2) How effective is *birdpen* compared to (other) highly effective markings?

3) In situations comparable to windows (dark background, specular reflections on the glass surface), is glass marked with *birdpen* recognised by birds as an obstacle? Does the collision risk for *birdpen*-marked monolithic glass incorporating reflections (as in a window situation) differ from the collision risk for unmarked monolithic sheet glass?

4) Based on the experiment, is it safe to infer that collision avoidance is both extensive and satisfactory for bird protection in the long term, comparable with already known highly effective markings?

2 METHOD

2.1 Experimental principle: Choice experiment in a flight tunnel

Birds that find themselves in a dark room have a tendency to want to escape towards bright openings. In tunnels that open to one side, this behaviour can be exploited to test whether birds can detect obstacles made of transparent materials. Choice experiments following this design allow for quantification of the probability with which a bird distinguishes between a transparent reference body (e.g. unmarked float glass) and a test body (e.g. glass with UV markings).

In our choice experiment, birds fly towards a pair of panes of glass and make a directional choice for one of these two panes. The pair of panes is made up of a **marked test pane** and an **unmarked reference pane** that is invisible to birds (Rössler et al. 2007). The experimental setup is designed to ensure that the decisive parameters for the test birds' choices are focused as far as possible (ideally 100%) on the properties of the test panes; all other parameters (disturbances, distractions, light incidence angles, etc.) are kept constant. Thus, if identical test panes are mounted on the left and right side in the choice experiment (0 test), the result (if n is sufficiently large) must be equally distributed, i.e. 50:50. If, in the same test configuration, a marked pane is approached as frequently as an unmarked reference pane, this means that the tested marking is not recognised by birds. If multiple test series with different markings are compared, each tested against an unmarked reference pane, differences in the detectability of the different markings can be classified (see Rössler & Doppler 2014).

Basic concept:

- Tendency of birds to escape a dark room towards the light (light as an attractor)
- High efficiency when experiments on 1 m² glass surface (exchangeable test panes) are combined with mist-netting (bird ringing station, standardised ringing, 360 m² of mist nets)
- Choice experiment – test pane vs. unmarked float glass as reference pane
- Limited number of variables, large sampling frequency, statistically detectable differences in effectiveness between markings
- Wild birds, one-off experiments
- Large sample sizes – n>80
- Complete video documentation of all experimental flights
- No collisions, no casualties, birds are prevented from colliding by a mist net

2.2 Test methods

birdpen was tested according to two methods:

1) ONR test: choice experiment under reflection-free, transparent conditions at an approach angle of 90° in accordance with Normative Rule ONR 191040 (Austrian Standards Institute 2010)

2) WIN test: choice experiment simulating a "window" or "glass façade" application. The bright foreground and dim background produce high-contrast reflections on the panes; the approach angle is 55°.

2.2.1 ONR 191040 test

Test birds are released at the closed and dark end of a 7.50 m-long flight tunnel and fly at speeds of approx. 5 m/sec towards the light end of the tunnel (Fig. 1). The left and right half of the tunnel end are occupied by two different panes, an unmarked float glass reference pane on the one side and the test pane on the other (Fig. 2).

The background is made up of natural, largely homogeneous vegetation. After every three consecutive experimental flights, the order and position of the test panes is changed according to a randomised schedule. The flights and choice behaviour in the individual tests are recorded by video camera and later controlled and evaluated in slow motion or broken down into flight sequences.

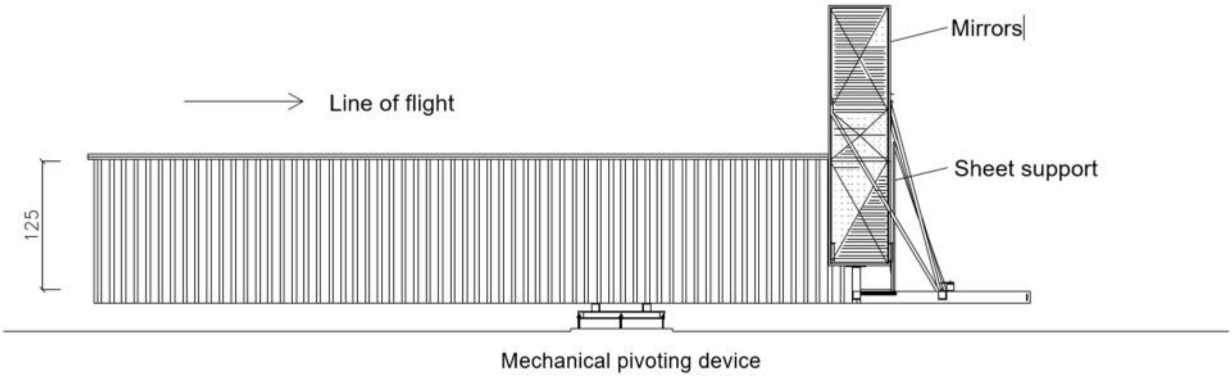

Figure 1: Flight Tunnel II of the Hohenau-Ringelsdorf Biological Station in the ONR test configuration with lateral mirrors.

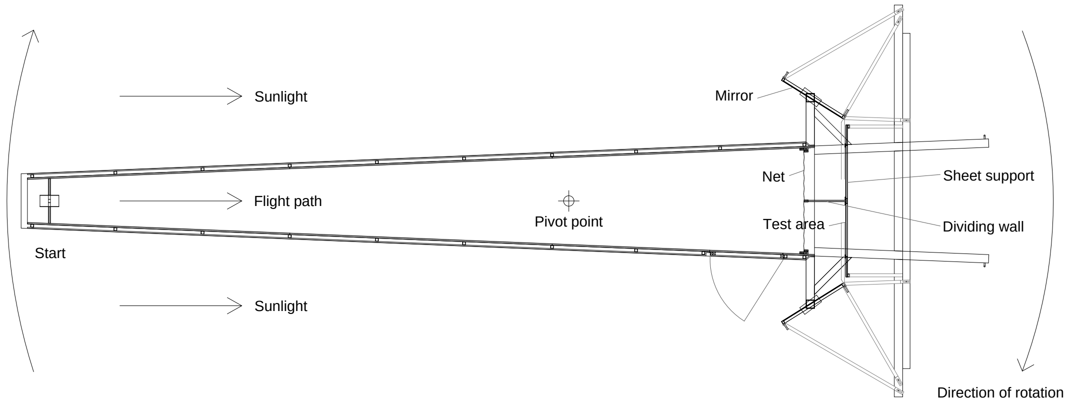

Figure 2: Horizontal section through the Flight Tunnel II in the ONR test configuration. The entire tunnel is mounted on a pivoting device and is turned clockwise to follow the position of the sun. Thus, the direction of sunlight is always parallel to the birds' line of flight. The test area is illuminated with natural (sun)light via two lateral mirrors.

Fig. 1 shows a lateral view of the Flight Tunnel in the ONR configuration. To achieve uniform illumination of the test panes, sunlight is directed parallel and symmetrically onto the test panes via two mirrors. The test panes are positioned at 90° to the flight axis of the test birds. Since the position of the sun changes constantly, the tunnel is mounted on a rotating ring and is continuously adjusted to follow the sun, thereby keeping the direction of sunlight parallel to the birds' line of flight (Fig. 2).

The test results are percentages of the birds' chosen direction of flight, either towards the marked test pane or towards the unmarked reference pane. A **low rate** of directional choices toward the marked test pane indicates **high effectiveness** of the marking.

Until 2010, the tunnel configuration described as the ONR test (Austrian Standards Institute, 2010) was the only method applied in Hohenau. In some cases, a critical limitation of the ONR test arises when assessing the effect of specular reflections on the panes. For example, reflected bright sky can lead to a reduction in contrast of white markings. Furthermore, markings on surface 2 (rear side) can be masked by reflections on surface 1 (front side), thereby cancelling out the markings' effect. Another test method was therefore developed to counteract these shortcomings.

2.2.2 WIN test

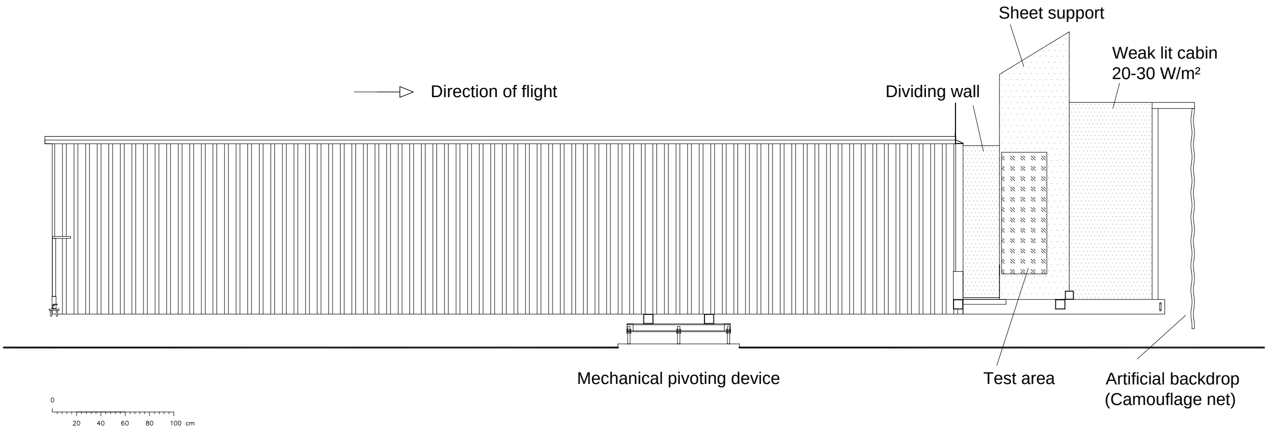

Figure 3: Flight Tunnel in the WIN test configuration. A ceiling, side walls and a partially translucent curtain create a weak-lit cabin behind the test panes. The trapezoidal sheet support prevents birds from seeing the sky and vegetation other than as reflections in the test area.

In order to also be able to investigate the significance of reflections, an adaptation of the ONR test configuration was implemented (Fig. 3). It is referred to as the “WIN test”, following its simulated application as *win*dows or façades. The experimental setup involves additional variables in order to incorporate specular reflections on the panes. For this purpose, the reference and test panes are not mounted perpendicularly to the flight axis, as in the ONR test, but at an angle of 55° (Fig. 4), thus creating reflections from the bird’s perspective, similar to side mirrors in a car. Illumination of the test area via the two mirrors, which are typical for the ONR test configuration (Fig. 2), is omitted in this case. The mirrors are removed and light falls directly on the test panes. As in the ONR test, the flight tunnel is continuously rotated to track the position of the sun and maintain symmetrical lighting conditions.

Since light intensities are lower behind glass façades or windows, clear specular reflections often occur on these glass surfaces. In the WIN test, these conditions are simulated through the addition of side walls, a ceiling and a white sheet in front of a camouflage net to create a closed and darkened background chamber in which the light intensity is limited to a target value of about 1-5 % of the daylight outside.

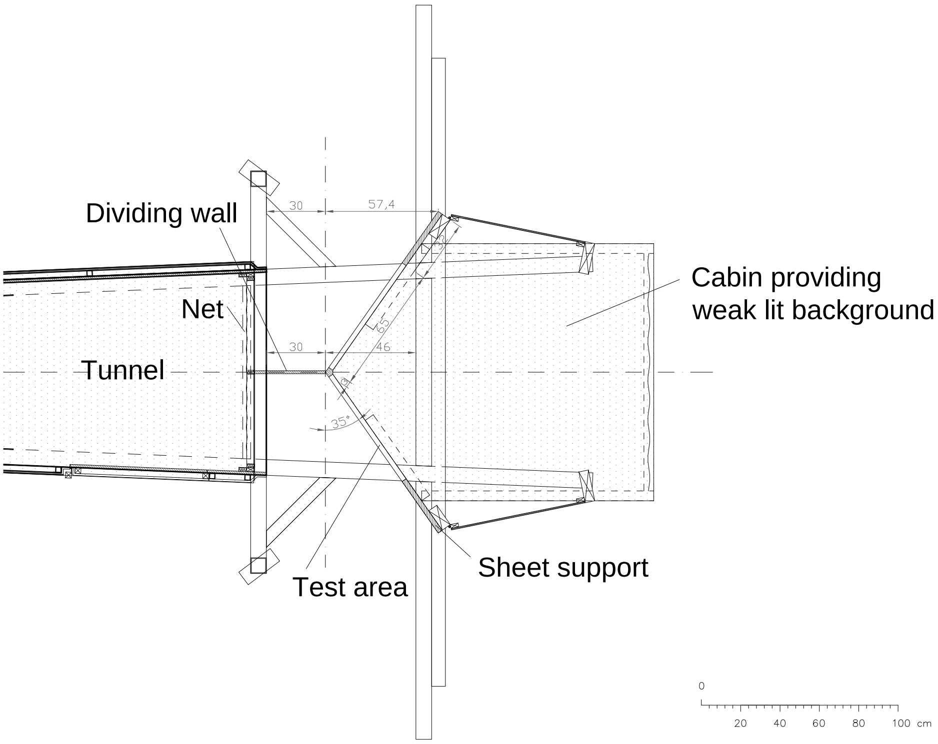

Figure 4: Horizontal section through the flight tunnel in the WIN test configuration with enclosed chamber (simulation of indoor rooms) behind the test panes positioned diagonally to the birds' flight axis.

As yet there is neither a standard for the WIN test, nor a "threshold value" defining the choice experiment result deemed necessary from the aspect of bird protection. Currently, however, it appears that highly effective markings can achieve values of less than 10% of flights towards the test pane.

2.3 Reference tests

For the ONR test no reference tests were necessary.

The *birdpen* WIN test, however, is one of a series of WIN tests of different products, each consisting of different types of glass such as monoliths, laminated glass or complex and high reflective multilayer glass units. To be able to compare the effectivity of markings with such different reflective properties, we required an "overall reference reflector" and decided on a conventional silver mirror. Two reference tests were carried out to complement and cross-check the results. Firstly, a limited sample size of float glass with *birdpen* application was tested versus unmarked, but otherwise identical, float glass (WIN reference *birdpen* vs float glass). Secondly, with a normal sample size, the "attractivity" of a silver mirror compared to unmarked float glass was examined (WIN reference float glass vs. mirror).

2.4 Documentation of individual tests

Documentation of tests comprises the recording of relevant data of each test bird (species, ring number for synchronisation with the ringing station database), time (for synchronisation with light measurement and video documentation), cloud cover, visually observed directional choice of the test bird and any results which may be relevant to the test's evaluation.

2.5 Video documentation

The test flights are recorded in "HQ" recording mode (9 Mbit/sec) with a digital video camera (Sony DCR-SX34E) mounted outside the tunnel and directed along the birds' flight path through a hole in the rear wall. The data is secured daily on an external PC.

2.6 Data analysis

Data analysis consists of consolidating the field sheets with the automatically recorded light measurements and video analysis. Only clear choices between two panes ("left" and "right") are taken into account, while "central" flights are discarded. Aborted flights, hesitant approaches and flights along the ceiling or the side walls cannot be counted. If it was already clear during a test that the test could not be counted, the test was repeated with another bird. Flights for which irregularities were not detected until the video analysis (asymmetrical light incidence, open doors, etc.) were subsequently discarded.

2.6.1 Video analysis

The visual observations recorded during the tests themselves are reviewed with the aid of video analysis (after the end of the season). Each test flight is examined in slow motion and/or broken down into sequences and is checked to see whether the test can be counted or must be discarded. The most common reason for discarding an individual test is refused or hesitant flight and landing on or in front of the net. The main purpose of the video analysis is to check and consider whether birds may have recognised the net and changed sides in an evasive manoeuvre related to the net. In order to standardise this decision, the following rule is applied: a sudden change of direction within the last five video frames (0.2 sec) before contact with the net means that the individual test is discarded.

2.6.2 Presentation of results

The results are easily analysed by determining the number of birds that flew to the reference pane and to the test pane, and relating them to each other. A significant difference between the determined numbers is generally confirmed with a binomial test. In our sample sizes of 80-100 individual experiments, a ratio of approx. 42:58 indicates a significant difference. Such a result indicates a sufficient difference between the reference pane and the test pane to be perceived by birds. For bird protection, however, we aim for far greater effects than a barely significant difference: according to ONR 191040, one can speak of bird protection glass if at least 90% of birds fly towards the reference pane in a choice experiment. A common misinterpretation of the choice experiment is to equate a certain flight approach ratio with the effectiveness of the marking (see box below: Interpretation of choice experiments). A valid form of presenting a result is the comparative positioning of the test result in a ranking of all previously tested markings. For the ONR test, the desired target is the 10:90 bird protection glass criterion. For the WIN test, a corresponding threshold value has not yet been established.

Interpretation of choice experiments

In a choice experiment, a random distribution (50:50) is expected for any two indistinguishable attributes. For this reason, in the case of an observed 50:50 ratio of flights, the following statement is

- false: “The test pane is 50% effective”
- false: “The product reduces bird collision by 50%”
- correct: “The test pane is ineffective”

Studies and product advertisements often imply that it is possible to infer the proportion of birds saved through use of the product based on the observed ratio of flights in choice experiments:

- false: "Relative flight ratios allow efficacy / potentially saved birds to be quantified”
- correct: "Standardised experimental tests can be used to compare different test panes against each other (high effectiveness, low effectiveness). They cannot predict how many potentially endangered birds will be saved in the wild”

Example of a misleading interpretation of a choice experiment: see 1.2.3 “Existing expert opinions” in this report.

„Result: Out of 102 flights, 67 were directed at the control pane and 35 at the test pane. Conclusion: The experiments confirm an avoidance effect of approx. 66% based on the sample size under the given experimental conditions. Accordingly, 2/3 of potential glass collisions could be avoided as a result of obstacle perception.

2.7 Measurement of light and optical characteristics

2.7.1 Radiation measurement (continuous)

To measure radiation, two silicon photovoltaic sensors (Environmental Measurement Systems EMS 11) were mounted on the tunnel. The sensors measure the total incident energy of radiation between 400 and 1,100 nm. The measurement interval is ten seconds and measurements are registered on a data logger (EMS Mini Cube) as mean minute values. They are retrieved every two weeks and saved on an external PC.

2.7.1.1 Measuring global radiation

To measure global radiation, a sensor with a horizontal measurement plane is placed roughly 2 m above the ground. The sum of diffuse sky radiation and direct solar radiation is measured (Fig. 5).

2.7.1.2. Measuring light intensity of pane background

To measure the light intensity of the background behind the panes – consisting of a combination of sky and vegetation in the ONR test and the reflection of an artificial background in the WIN test, as seen from the test bird's point of view – the sensor was fixed to the central axis of the tunnel at a height of approx. 50 cm and inclined 30° upwards (Fig. 6).

Figure 5: Photovoltaic sensor for measuring global radiation.

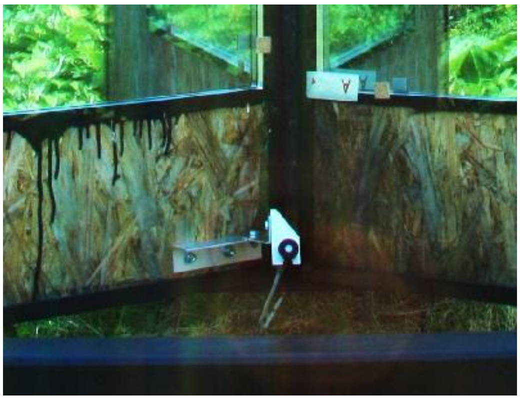

Figure 6: Photovoltaic sensor for measuring radiation behind the test panes.

2.7.2 Optical measurements of ***birdpen's*** reflection and absorption characteristics (light laboratory)

birdpen is advertised as a substance that is invisible to humans yet has a deterrent effect on birds due to the "special UV coating" (http://www.drkolbe.de/userfiles/files/pdf/Dr_Kolbe_Flyer.pdf – last accessed: 24 March 2015) that is formed. The product description leads one to expect a marked difference in reflection levels between 350-400 nm (the UV spectrum theoretically perceived by many songbirds) and 400-700 nm (light spectrum visible to humans), and that the optical behaviour, at least in the UV range, will differ significantly from that of an uncoated float glass pane.

In order to visualise the spectral effect of the special UV coating, a float glass pane identical to those used in the tunnel tests was marked with *birdpen* on two separate surfaces (coating 1 and 2) and spectrometrically measured in December 2013 in the light laboratory of the Institute of Meteorology at the University of Natural Resources and Applied Life Sciences.

The light source in this setup is a halogen lamp (HLX64625 100W) located in a case with a 10 x 10 mm opening towards the measuring device to avoid scattered light. The beam emitted by the light source hits a light guide (LI-J1010-SMA) with a forward-facing aperture. The light guide conducts light ranging from ultraviolet to long wavelengths to the measuring sensor with low loss.

The test object is mounted upright on a turntable which can adjust the angle between the test plane and light beam in 7200 steps using computer-controlled servomotors to suit the exact measurement requirements. The measuring surface is located in the axis of rotation. The light source can rotate independently around the common centre of rotation.

At the beginning and end of each measuring session, reference measurements of the light (direct and unobstructed) and the dark current (background noise of the spectrometer) are taken.

The Ocean Optics spectrometer (USB 2000+) measures wavelengths from 188.94 nm to 896.40 nm in 2048 steps. Each measurement is an average of 100 individual measurements. Only the spectral range between 350-700 nm is presented in this study, as other wavelengths are not relevant for bird eyes. The results are average values obtained from two to five individual measurements. For each of these measurements, the measured section was shifted slightly in order to capture and visualise the *birdpen* film, which is inevitably not perfectly homogeneous, as comprehensively as possible.

Figure 7: Spectral measurement, in this case of the transmission properties, of a large-surface *birdpen* coating. Right: light source, centre: illuminated *birdpen* coating, left: sensor of the spectrometer behind the pane. The test pane is oriented with computer-controlled servomotors.

2.8 Description of the test pane

Figure 8: Application on a work surface: stripes are barely visible and it is difficult to monitor the progress of work.

Figure 9: When turned into the light or backlit, adhesive residue-like streaks become visible.

A *birdpen* set was ordered in both years, on 19 June 2013 from NABU Natur-Shop and on 23 July 2014 from Dr. Martin Regner, which arrived on 28 June 2013 and 30 July 2014 respectively. On 6 August 2013 and 1 August 2014, 2 float glass panes each (length 100 cm, width 50 cm and 65 cm, thickness 4 mm) were marked with *birdpen* following the enclosed instructions for use. First, the panes were cleaned. Next, using templates, 2 cm-wide stripes of 100 cm length were applied in one go with a spacing of 5 cm as instructed. The panes were then briefly stood up to dry and were then stored in a dust-protected place until testing. This procedure was repeated on 1 September 2013 and 30

August 2014. This was necessary because we consistently work with cleaned panes in our tests and the removable *birdpen* coating does not allow constant cleaning.

Figure 10: *birdpen*, vertical stripes against natural background.

Figure 11: ONR test. Seen from the perspective of birds flying through the tunnel towards reference pane (left) and test pane (right).

The panes were placed on a work surface during *birdpen* application, with light coming from above. Under these lighting conditions it was almost impossible to monitor the progress of application, as there was practically no visible result and there was no way to rule out the possibility of the pen itself being defective (Fig. 8). In backlighting, however, the stripes became visible as adhesive residue-like streaks (Figs. 9 and 10). Fig. 11 shows the pair of panes consisting of the reference pane (left) and test pane (right) as seen by an approaching bird in the ONR test configuration. Fig. 12 shows the configuration for the standard WIN test with a mirror (left) and test pane (right), and Fig. 13 shows the configuration for the reference experiment *birdpen* vs. float glass with an unmarked float glass pane (left) and float glass with *birdpen* marking (right).

Figure 12: WIN test (WIN 2014). Mirror on the left (reference), test pane on the right (*birdpen* on float glass)

Figure 13: WIN reference test – *birdpen* vs. unmarked float glass Unmarked float glass on the left (reference), test pane on the right (*birdpen* on float glass).

2.9 Description of the reference panes

2.9.1 ONR test: unmarked float glass

The reference pane in the ONR test was an unmarked sheet of 4 mm float glass, which was identical to the pane on which *birdpen* was applied.

2.9.2 WIN test: "Overall reference reflector"

The WIN test examines the effectiveness of markings under reflective conditions. These reflections depend on the light conditions in front of and behind the panes and on the characteristics of the glass. The wide range of commercially available glass types, from conventional monolithic float glass, through glass with special "anti-reflective" coatings, to the large number of generally highly reflective insulating glass types, would necessitate the same wide range of "identical" reference panes. As a consequence, it would not be possible to produce a generalisable ranking of different and differently marked products. Instead, it would only be possible to state that a certain marking X on pane Y is more deterrent to collision to a certain extent than pane Y without the marking. The prospect of such limited conclusions implies the need for an "overall reflector" by means of which the different effectiveness of different marking types on different products can be related to each other.
The overall reflector chosen here is a silver mirror, similar to the one used to illuminate the panes in the ONR test (reflection values: Rössler et al. 2007), as its reflectivity is unlikely to be exceeded by any of the potential test panes.

2.9.3 Reference test: ***birdpen*** vs. unmarked float glass

In the reference test *birdpen* vs. float glass (see 2.3), the reference pane is an unmarked sheet of 4 mm float glass.

2.10. Test period and distribution of individual tests by time of day

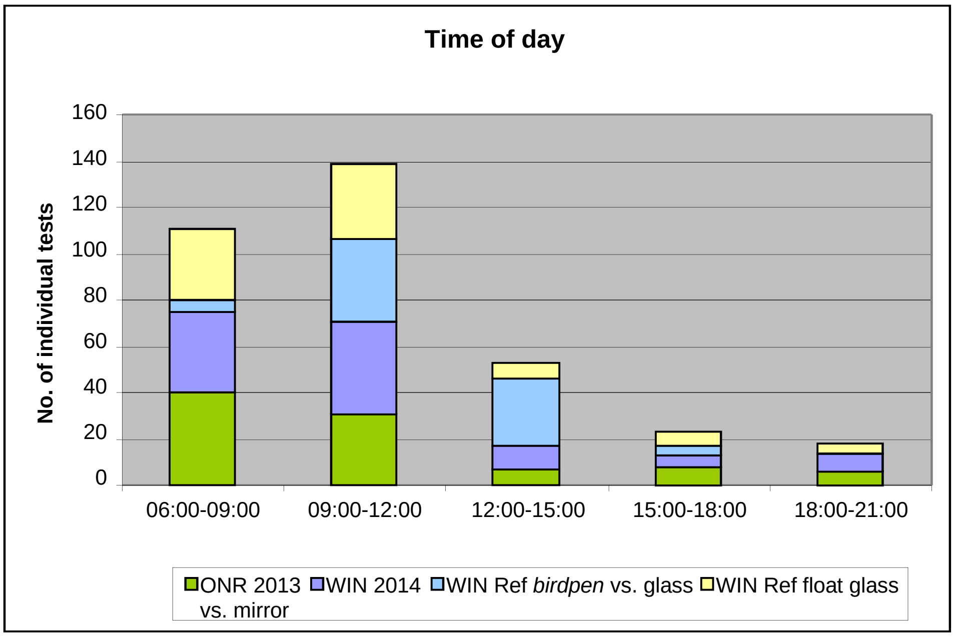

Figure 14: Distribution of tests by time of day. Green: ONR 2013 (ideal reflection-free transparency); purple: WIN 2014 (incorporation of specular reflections) *birdpen* applied to float glass vs. silver mirror; light blue: reference test *birdpen* on float glass vs. unmarked float glass; yellow: reference test unmarked float glass vs. silver mirror.

The tests were conducted between 9 August and 2 September 2013 (ONR test) and between 1 August and 15 September 2014 (WIN test and reference tests). The timing of the tests depended on the prevailing sunrise times, the respective lengths of day and on the distribution of net catches over the course of each day. The temporal distribution of the individual tests (Fig. 14) is in line with the daily activity distribution of birds in the field. Around three quarters of the tests took place in the early and late morning (before 12:00 CEST).

2.11 Number of valid and invalid individual tests

After completed video analysis, 344 individual tests (78%) could be used for evaluation. 107 birds (22%) refused to fly or flew only hesitantly, flew towards the centre or were discarded on the basis of video analysis owing to probable detection of the net.

2.12 Test birds

Table 1: Overview of test birds (30 species)

Bird species		**ONR 2013**	**WIN 2014**	**Reference tests 2014**		**Total**
		Transparency	Reflection	WIN reference *birdpen* vs. float glass	WIN reference float glass vs. silver mirror	
European Bee-eater	*Merops apiaster*	3				**3**
Wryneck	*Jynx torquilla*	3		1	2	**6**
Great Spotted Woodpecker	*Dendrocopos major*		1	1	1	**3**
Lesser Spotted Woodpecker	*Dendrocopos minor*	1				**1**
Barn Swallow	*Hirundo rustica*		1		1	**2**
Tree Pipit	*Anthus trivialis*				1	**1**
Dunnock	*Prunella modularis*				1	**1**
European Robin	*Erithacus rubecula*				1	**1**
Nightingale	*Luscinia megarhynchos*	1	2			**3**
Bluethroat	*Luscinia svecica*	1	1	1		**3**
Common Redstart	*Phoenicurus phoenicurus*		1			**1**
Whinchat	*Saxicola rubetra*	1				**1**
Sedge Warbler	*Acrocephalus schoenobaenus*	7	6	6	6	**25**
Marsh Warbler	*Acrocephalus palustris*	16	16	1	22	**55**
Eurasian Reed Warbler	*Acrocephalus scirpaceus*	4	2	2	1	**9**
Great Reed Warbler	*Acrocephalus arundinaceus*	9			3	**12**
Barred Warbler	*Sylvia nisoria*	1				**1**
Lesser Whitethroat	*Sylvia curruca*			2		**2**
Common Whitethroat	*Sylvia communis*	8	11	3	4	**26**
Garden Warbler	*Sylvia borin*	4	5	4	1	**14**
Blackcap	*Sylvia atricapilla*	2	18	7	2	**29**
Common Chiffchaff	*Phylloscopus collybita*				3	**3**
Willow Warbler	*Phylloscopus trochilus*	1	2		1	**4**
Spotted Flycatcher	*Ficedula hypoleuca*	1		1		**2**
Blue Tit	*Parus caeruleus*	1	11	5	3	**20**
Great Tit	*Parus major*	6	8	11	11	**36**
Red-backed Shrike	*Lanius collurio*	8	5	2		**15**
Great Grey Shrike	*Lanius excubitor*				1	**1**
Tree Sparrow	*Passer montanus*	4	5	20	14	**43**
Greenfinch	*Carduelis chloris*	1		1		**2**
Total		**92**	**98**	**73**	**81**	**344**

3 RESULTS

3.1 Optical measurements of ***birdpen*** coating on float glass

The manufacturer describes *birdpen* as invisible to humans but visible to birds and explains this difference with unspecified effects in the UV range. More detailed specifications regarding the optical properties of the substance are not available. The description of *birdpen's* mechanism of effect leads one to expect marked contrasts between uncoated and *birdpen*-coated float glass. These contrasts are mainly or entirely supposed to occur in the UV range which is invisible to humans.

3.1.1 Transmission

Fig. 15 shows the measured values of spectral luminous intensity as a percentage of the radiation emitted by the light source, when passing through uncoated 4 mm float glass (blue curve) and through a *birdpen* coating on 4 mm float glass (green curves). The transmission measurement clearly shows a stronger UV absorption (350-400 nm) of *birdpen* compared to uncoated float glass.

However, these contrasts only become relevant in practice if there is a UV source behind the pane – such as sun, blue sky, white clouds, water or snow – whereas interiors of houses and surfaces of plants, etc. more or less do not reflect UV. This characteristic is therefore irrelevant for *birdpen* applications on windows. In the ONR test, a contrast between the coated and unmarked sections of the glass surface can have an effect, since the sky occupies about one third of the birds' field of vision in the tunnel. This favours potentially better detectability under this scenario compared to applications on windows of buildings with UV-free background lighting.

3.1.2 Reflection at 90°

Regarding reflective behaviour, at an orthogonal view (90°) towards the glass and orthogonal incidence of light, the *birdpen* coating generally reflects less light than the float glass, which is due to scattering on the rougher surface (Fig. 16). This loss is stronger in the UV range than at wavelengths >400 nm. However, the resulting contrasts are very low. In the UV range between 350 and 400 nm glass reflects an average of 9.2% and *birdpen* 7.2% of the light, while in the spectral range >400 nm glass reflects 7.2% and *birdpen* 6.0% of the light.

3.1.3 Reflection at 35°

With incident light coming from the side (35° angle), reflection is generally somewhat higher, without any change in the overall result or in the contrasts themselves (Fig. 17). In the UV range between 350 and 400 nm glass reflects an average of 12.2% and *birdpen* 9.8%, while in the spectral range >400 nm glass reflects 8.4% and *birdpen* 6.4% of the light arriving from the light source.

3.1.4 Summary of results of the optical measurements

In summary, this means that 1) in the spectral range <400nm, which is not perceptible to humans, no strong contrasts are produced, 2) the one exception to this rule is the stronger absorption of UV from the background of the pane, which, however, has no practical relevance for windows of buildings (no UV behind the panes), and 3) given such low contrasts, there is no reason why *birdpen* should be more clearly perceptible in the UV spectrum than in the spectral range visible to humans.

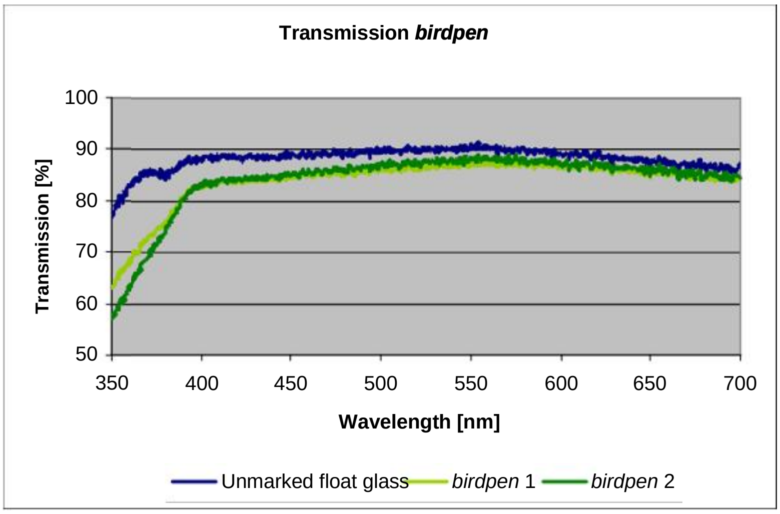

Figure 15: Spectral transmission through unmarked float glass (blue) and float glass with *birdpen* coating (greens). Stronger UV absorption of *birdpen* is clearly apparent. In the practical application as a window marking, however, UV absorption from background light is irrelevant, since UV is not emitted from inside buildings.

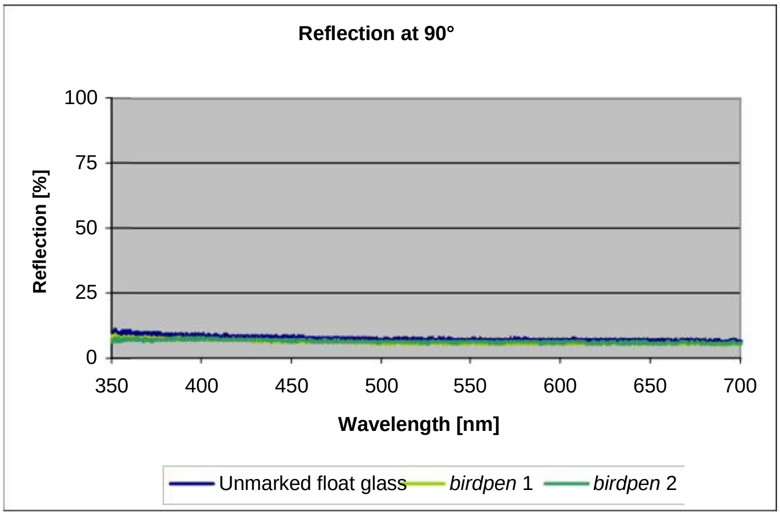

Figure 16: Spectral reflection on unmarked float glass (blue) and float glass with *birdpen* coating (greens). The measurement indicates generally low contrasts, which are slightly stronger in the UV spectrum than in the spectral range >400 nm

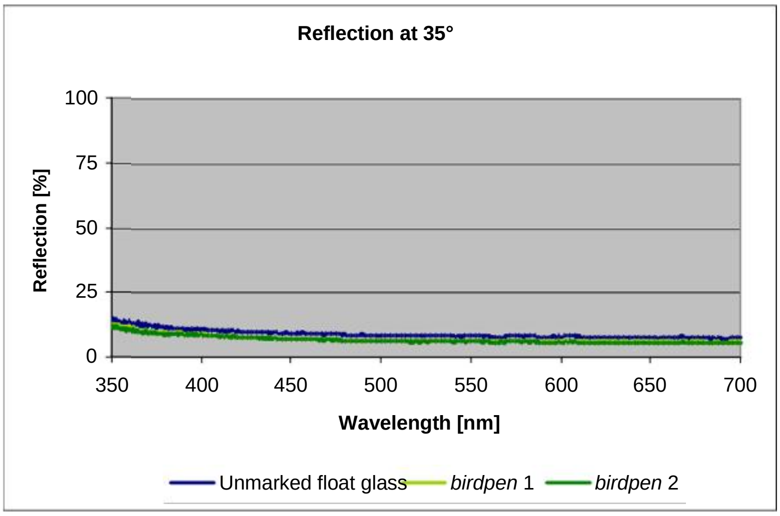

Figure 17: Spectral reflection on unmarked float glass (blue) and float glass with *birdpen* coating (greens). The measurement indicates generally low contrasts, which are slightly stronger in the UV spectrum than in the spectral range >400 nm

3.2 Measurements of light conditions during testing

3.2.1 ONR tests

The test panes are never exposed to direct sunlight to avoid harsh shadows on the markings. In sunlight, the test panes are strongly and homogeneously illuminated by the lateral mirrors. In cloudy conditions, illumination of the test panes decreases from top to bottom and from the outside to the inside. 95% of individual tests could be performed in sunlight (Tab. 2). Maximum global radiation was 908 Wm^{-2}. 38% of individual tests were performed at global radiation values above 400 Wm^{-2}. Radiation measured in the background of the panes was below 60 Wm^{-2} half of the time, and above that value the other half.

Table 2: Number of individual ONR tests depending on 1) light quality, 2) intensity of global radiation, 3) intensity of radiation of the background vegetation.

Light quality		**Light intensity [Wm^{-2}]**			
		Global radiation		**Background**	
Clouds (diffuse)	**Sun**	**< 400**	**> 400**	**< 60**	**> 60**
5	87	57	35	47	45
5,4%	94,6%	62,0%	38,0%	51,1%	48,9%

3.2.2 WIN tests

The WIN tests were largely conducted in sunny conditions. During the WIN reference test *birdpen* vs. float glass, however, conditions were more or less equally sunny and cloudy (Tab. 3). Around a third of the individual tests were conducted at global radiation levels above 400 Wm^{-2}.

Table 3: Number of individual WIN tests depending on light quality and different intensities of global radiation

	Light quality		**Global radiation [Wm^{-2}]**		
	Clouds (diffuse)	**Sun**	**< 400**	**> 400**	**Not measured**
WIN 2014	18	80	57	41	
WIN reference *birdpen* vs. float glass	39	34	54	18	1
WIN reference float glass vs. mirror	22	59	48	32	1
Total	**79**	**173**	**159**	**91**	**2**
Proportion	31,3%	68,7%	63,1%	36,1%	0,8%

3.3 Test results

3.3.1 Methodological integrity of the tests

A precondition for the tests' integrity is that the individual tests are carried out in random order and that the test panes' positions in the choice experiment (left or right) are equally distributed. If the test panes are positioned equally on the left and right sides, the flights should also be equally distributed. Even if flights to the unmarked reference pane and marked test pane are differentiated, each of these should also be equally distributed on the left and right sides. Tab. 4 shows that the observed distributions do not differ significantly from the expected equal distribution, and that the preconditions for methodological integrity are therefore fulfilled.

Table 4: Distribution to the left and right side in the choice experiment of 1) position of the test pane, 2) flights irrespective of the position of the test and reference panes, 3) flights toward the reference pane when it was positioned to the left or right, respectively. Distributions are equal in all cases (Pearson's chi²-test, not significant in all cases).

	Left	**Right**	**Total**	**p-value**
ONR 2013				
Position of test pane	45	47	92	
Flights in the individual tests	47	45	92	
Flights toward reference pane	22	20	42	0.921
WIN 2014				
Position of test pane	44	54	98	
Flights in the individual tests	57	41	98	
Flights toward reference pane	47	34	81	0.109
WIN reference *birdpen* vs. float glass				
Position of test pane	31	42	73	
Flights in the individual tests	36	37	73	
Flights toward reference pane	26	31	57	0.708
WIN reference float glass vs. mirror				
Position of test pane	38	43	81	
Flights in the individual tests	43	38	81	
Flights toward reference pane	32	27	59	0.629

3.3.2 Test result ONR 2013

The test according to ONR (2013) showed that the flights were distributed randomly between the left and right panes: 54.3% of birds flew to the pane marked with *birdpen*, 45.7% flew to the unmarked reference pane (Table 5). Thus, in reflection-free, transparent conditions, no effect emanating from the coating could be detected. An analysis of the flight ratios under different lighting conditions did not reveal significantly different results. No effect of light quality, nor global radiation, nor background light intensity could be determined.

Table 5: Test result ONR test: distribution of flights to test and reference panes.

No. of individual tests	**Flights towards**		
	Reference pane	**Test pane**	**Test pane [%]**
92	42	50	**54.3**

3.3.3 Test result WIN test

The results of the WIN tests are the most relevant for the main expected application area of *birdpen*, as these tests incorporate reflections and a dark pane background. In the standard WIN test (WIN 2014) 17.3% of birds flew to the *birdpen*-marked pane. Meanwhile, a completely unmarked float glass pane was approached by 27.2% of birds under comparable conditions. Thus, birds flew toward the pane marked with *birdpen* significantly less frequently than toward an unmarked pane (Fisher's Exact test p = 0.038). The extent of this effect, however, is slight. The reference test *birdpen* vs. float glass underscores this fact with a result of 35.6% of flights toward the pane marked with *birdpen* (binomial test: p = 0.019).

Table 6: Results of the reference test (WIN reference test float glass), the standard WIN test (WIN 2014), and a comparative test (WIN reference test *birdpen* vs. float glass).

Test	**Test pane**	**Reference pane**	**No. of individual tests**	**Flights toward**		
				Reference pane	**Test pane**	**Test pane [%]**
WIN 2014	*birdpen*	Silver mirror	98	81	17	**17.3**
WIN Reference test *birdpen* vs. float glass	*birdpen*	Unmarked float glass	73	47	26	**35.6**
WIN Reference test float glass vs. mirror	Unmarked float glass	Silver mirror	81	59	22	**27.2**
Total			**252**	**187**	**65**	

4 FINAL ASSESSMENT

The manufacturer cites contrasts in the UV spectral range (<400 nm) as the scientific justification for *birdpen's* effectiveness. Optical measurements of the *birdpen* coating show higher absorption but provide no evidence of higher reflection in the UV range. Therefore, UV contrasts between uncoated and *birdpen*-coated glass sections can be expected if UV sources are located behind the glass (sky, clouds, etc). If, however, the UV sources are located in front of the glass and reflected off its surface, no relevant optical characteristics could be measured in the UV range. Therefore, UV contrasts between uncoated and *birdpen* sections will be absent and possible reactions of birds can not be explained by UV contrasts.

The results of this experimental evaluation of *birdpen* do indeed show differences between reflection-free, transparent conditions and a window-like configuration with darkened background and commonly associated reflections. Under the ideal, reflection-free transparency conditions of the ONR test, contrary to expectations, *birdpen* is not detected by birds and proves to be ineffective. In 92 valid individual tests, the birds flew randomly toward the reference and test panes. In the WIN test with the darkened background creating specular reflections, a certain detectability of *birdpen* is shown: where the reference test with unmarked float glass vs. silver mirror (n = 81) scores a ratio of 27:73, *birdpen* vs. silver mirror (n = 81) scores 17:83 ($p<0.05$). Consistent with these results, a significant effect can be observed in the reference test *birdpen* vs. unmarked float glass (36:64, n = 73). This result is only just statistically significant, in other words only barely proving the product's detectability, although this detectability is likely not due to the product's (low) contrasts in the UV range. Under no circumstances does this permit the interpretation presented in 1.2.3 as a "conclusion" ("approx. 64% avoidance effect"; see 2.6.2).

The statistically (barely) significant result does not indicate any particular benefit of *birdpen* for bird protection, rather the result is to be interpreted as "very weak effectiveness" – very far, in any case, from the highly effective markings which have meanwhile also been tested under the WIN test procedure and achieve values of less than 10% of flights to the test pane. Thus, in the knowledge of other marking alternatives, a recommendation of *birdpen* is not justified.

5 LITERATURE

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