BIRD STRIKES ON GLASS SURFACES

TEST REPORT

ORNILUX MIKADO

Test in Flight Tunnel II
at the Hohenau-Ringelsdorf Biological Station

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on behalf of the

Vienna Ombuds Office for Environmental Protection

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AURING
BIOLOGISCHE STATION
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TABLE OF CONTENTS

SUMMARY

Ornilux Mikado, described by the manufacturer as ‘bird protection glass’, was tested in three standardised test series. The aim was to ascertain whether birds are sufficiently able to perceiving the pane – which according to the manufacturer is provided with a UV-effective coating – as an impediment, and whether the special glass can effectively reduce bird strikes. The panes were tested in three ways: in addition to the test procedure regulated by Austrian technical regulation ONR 191040, two further experimental steps were carried out to investigate the potential influence of reflections on the pane. Alongside the Ornilux tests, reference tests were carried out with a visible marking that had been thoroughly tested and classified as highly effective. On the basis of the present tests, it is not possible to understand how the description ‘bird protective glass’ can be justified. According to the present results, Ornilux Mikado has a slight effect if reflections from the natural background are excluded. However, the results come nowhere near those attained by highly effective markings. If reflections from sky and vegetation are integrated into the test, it is no longer possible to discern any effectiveness: birds cannot distinguish the Ornilux pane from unmarked window glass.

1 SCOPE OF PROJECT

Wording of contract: The Vienna Ombuds Office for Environmental Protection (WUA) commissioned the Hohenau-Ringelsdorf Biological Station ‘to test the effectiveness of Ornilux Mikado laminated glass (manufacturer: Glaswerke Arnold), described as ”bird protection glass”. Since the results of earlier tests are not publicly available, and since Ornilux Mikado is marketed and used in environmentally sensitive areas, a test of the glass should be carried out at Hohenau independently of the manufacturer’ (WUA, June 2011).

In the following, ‘effectiveness’ is understood to mean the effectiveness of markings in reducing bird strikes. In the case of Ornilux Mikado, the marking is a special coating in the interior of the insulating glass.

Wording of product advertisement: According to the manufacturer’s description, ‘birds can recognise this coating because they can see in the ultra-violet range. For human beings, however, it is transparent or, as in the case of Ornilux Mikado, almost undetectable. Moreover, the coating is not applied to the entire surface but only partially, for example in the form of a filigree ‘Mikado structure’ (Glaswerke Arnold, October 2010: http://www.isolar.de/media/ORNILUX_03- 2010.pdf – accessed 06/02/2012).

Ornilux Mikado was launched in 2009. The glass is provided with a special coating.

Bird protection glass: Ornilux is advertised as ‘bird protection glass’. In Austria, technical regulation ONR 191040 states that, in the meaning of the regulation, the term ‘bird protection glass’ is applicable if no more than 10% of test birds fly towards the marked pane in a dichotomous choice experiment conforming to the technical regulation (Austrian Standards Institute, 2010).

Questions for the present investigation:

1) Do birds recognise Ornilux Mikado as an obstacle if specular reflections are excluded?
2) In a dichotomous choice experiment conforming to ONR 191040, do no more than 10% of the test birds fly towards Ornilux Mikado?
3) How effective is Ornilux Mikado in comparison with (other) highly effective markings?
4) Is Ornilux Mikado distinguished from unmarked glass surfaces if reflections are included?

    Case 1: in front of a bright, natural background – application case: open countryside (e.g. noise barrier)

    Case 2: in front of a weakly illuminated background – application case: buildings (windows, façades)

Samples tested: customary Ornilux Mikado insulating glass (Ornilux Neutralux 1.1) – as at: June 2011.

2 METHOD

2.1 Test principle: Dichotomous choice experiment in flight tunnel

Birds that find themselves in a dark space tend to escape in the direction of bright openings. In tunnels that are open on one side, this behaviour can be exploited to test whether birds can detect obstacles consisting of transparent materials. Dichotomous choice experiments corresponding to this design make it possible to quantify the probability with which a bird will decide between a transparent reference object (e.g. unmarked float glass) and a test object (e.g. glass with UV markings).

The present choice experiment is designed so that the parameters determining the test birds' decisions are focused on the properties of the test panes as far as possible (ideally 100%); all other parameters (disturbances, distractions, incidence of light etc.) are kept constant. Thus, if identical test panes are installed on the left and right in the choice experiment (0 test), the result (if n is sufficiently large) should be evenly distributed, i.e. 50:50.

For example, if it is known that, in a given test scenario, birds fly towards float glass as frequently as towards a free opening (even distribution), it may be stated that in this test scenario birds do not perceive the glass (cf. Rössler et al. 2007: unmarked float glass is not perceptible for birds). If, in the same test scenario, birds fly towards a marked pane as frequently as towards an unmarked glass pane, it may be stated that the marking being tested is not recognised by birds. If several series of tests involving different markings are compared, each of which having been tested against an unmarked glass pane, differences in the detectability of the markings (effectiveness in preventing bird strikes) can be classified.

Basic concept:

- Tendency of birds to fly out of a dark space into the light (light attraction)
- High level of efficiency involving a combination of net capturing (bird ringing scheme, 360m² of mist net) and tests on 1m² glass surface (exchangeable test panes)
- Dichotomous choice experiment – test pane versus unmarked float glass as reference pane
- Limited number of variables, high sample size, statistically quantifiable differences of effectiveness between markings
- Wild birds, one-off tests
- Large sample sizes – n>80
- Complete video recording of all test flights
- No collisions, no fatalities, birds are caught by mist net prior to collision

2.2 Tunnel tests at Hohenau-Ringelsdorf

Test birds are released at the closed end of a 7.5 metre long flight tunnel and fly at a speed of around 5 m/sec in the direction of the forward open end of the tunnel (see Figure 1). The left and right halves of the tunnel's open end are occupied by two different panes – an unmarked float glass reference pane on one side and the test pane on the other (see Figure 2). The backdrop is natural vegetation, as homogenous as possible. The sequence of the test panes, and the sides on which they are installed, are randomised. The test panes are changed after every three individual tests. The flights and the preferences shown in individual tests are recorded by a video camera, and checked and analysed either in slow motion or segmented into flight sequences.

The birds used are supplied by the bird-trapping programme at the Hohenau-Ringelsdorf bird ringing station. The birds are used for the tests once only, are not subjected to harm thanks to safety precautions (nets), and are immediately released after their flight through the tunnel.

Interpretation of choice experiments

Observed ratio of flights: 50:50

- False: Test pane is 50% effective
- True: Test pane is ineffective

Note: In the dichotomous choice experiment, random distribution (50:50) is to be expected for two indistinguishable objects.

- False: The product reduces bird strikes by 50%
- True: Different test panes can be compared with one another by means of standardised experimental tests. It is impossible to predict how many potentially endangered birds can be saved.

2.3 Different test scenarios to answer different questions

The Hohenau flight tunnel ('Flight Tunnel II') has been in operation since 2006. Until 2009, only standardised tests excluding specular reflections on the panes were carried out, to avoid extra variables. These reflection-free tests comply with ONR 191040 and are known as **'**ONR tests'. Between 2010 and 2011, the tunnel was rebuilt to address more specific questions – for example, Ornilux is coated on the inside of the insulation glass, which means that reflections on the surface can reduce its effectiveness. Since 2011, it has been possible to carry out experimental investigations that help to measure the **influence of specular reflections on the effectiveness of marking patterns** (marking materials, application surface...). Therefore, in the present investigation, the test panes were examined in three ways (cf. Table 1):

1) 'Ideal' situation without specular reflections (according to ONR 191040);

2) Incorporating specular reflections, with a view through the glass to a bright background (e.g. **noise barriers**);

3) Incorporating specular reflections, in front of a dark background (e.g. **windows**).

Using the same test scenario, **reference tests** were carried out with markings whose effectiveness had already been tested. In this way, it is possible to compare the results obtained with Ornilux with highly effective markings whose effectiveness might also be diminished to an unknown degree as a result of reflections.

Table 1: Characteristics of the three test scenarios in the present study.

Test scenario	Specular reflections	Background
‘ONR’	no	natural vegetation, natural light
‘Noise barrier’	yes (usually with poor contrast)	natural vegetation, natural light
‘Window’	yes (usually with strong contrast)	camouflage net, space behind test pane darkened to about 10% of surroundings (<25W/m²)

Control tests with identical, unmarked glass panes were used to check the facility and were carried out in conjunction with all the test scenarios.

Reflections on glass

1.) How do mirror images occur?

- Reflections appear on smooth surfaces, such as glass, as a matter of principle.

2.) Perceived ‘intensity’ of mirror images:

- Depends on the light conditions in front of and behind the pane.

The brighter the foreground, and the darker the background, the stronger the contrast of the reflections will appear.

- Depends on perception and focusing

Mirror image and background can be superimposed over one another. Through focusing, it is possible to switch back and forth visually between reflection and background.

3.) How can mirror images influence the effectiveness of markings?

- Markings that are applied to the rear side of the glass pane can lose contrast and effectiveness as a result of reflections that appear on the front side of the pane.
- Bright (e.g. white) markings can lose contrast and effectiveness compared to reflections of a bright sky on the glass pane.

2.3.1 Test according to ONR 191040 ('ONR test')

Figure 1 depicts a view of the ONR flight tunnel. In order to illuminate the test panes evenly, sunlight is directed by means of two mirrors onto the test panes, which are placed at 90° to the flight path of the test birds. Since the position of the sun changes continuously, a mechanical pivoting device allows rotation and thus constant adjustment of the tunnel's orientation relative to the position of the sun, resulting in parallel, uniform and symmetrical lighting at all times during testing (Fig. 2).

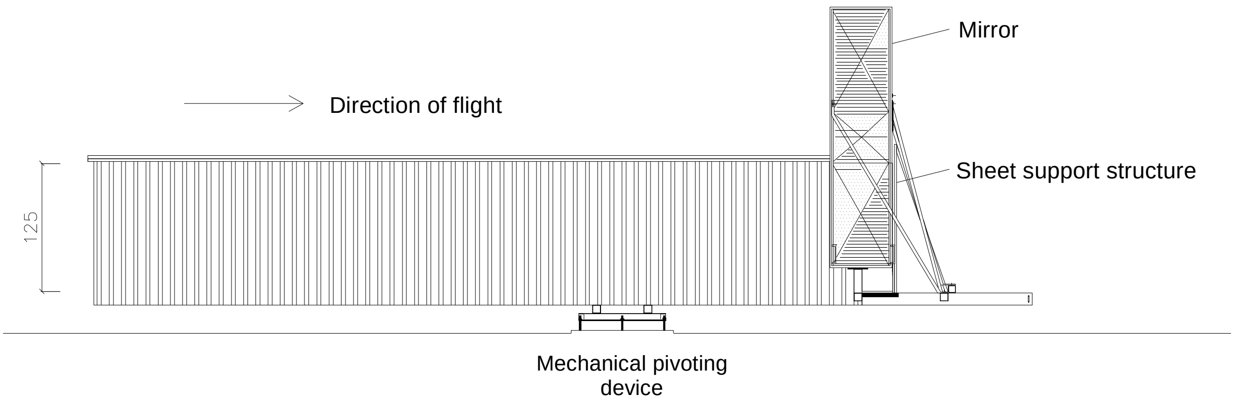

Figure 1: ONR testing with side mirrors at Flight Tunnel II of Biologische Station Hohenau-Ringelsdorf, Austria.

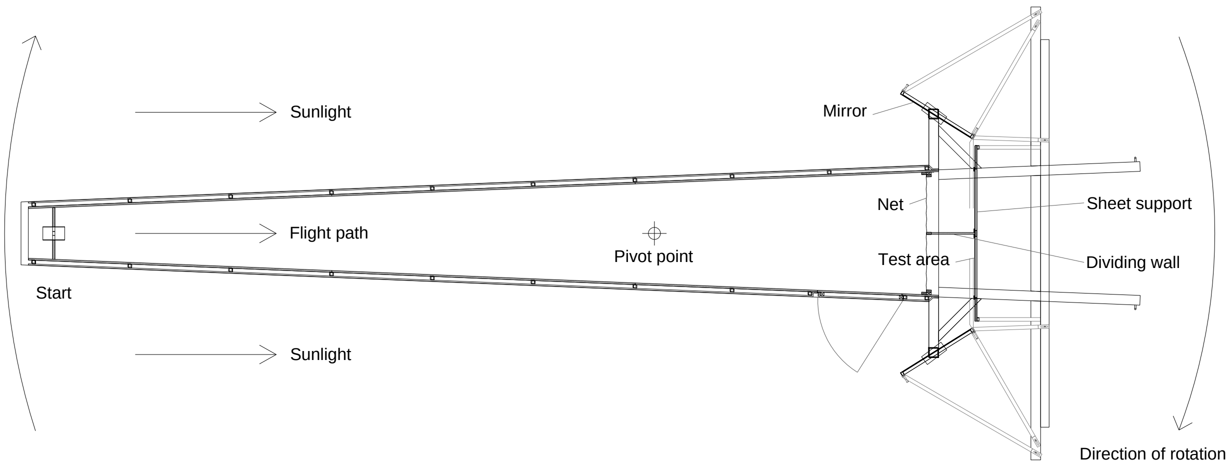

Figure 2: Horizontal profile of the Flight Tunnel in ONR tests. The entire tunnel is installed on a mechanical pivoting device and is turned clockwise with the movement of the sun. The direction of the sunlight is always parallel to the flight path of the birds. Lateral mirrors illuminate the test area with natural sunlight.

2.3.2 ‘Noise barrier test’

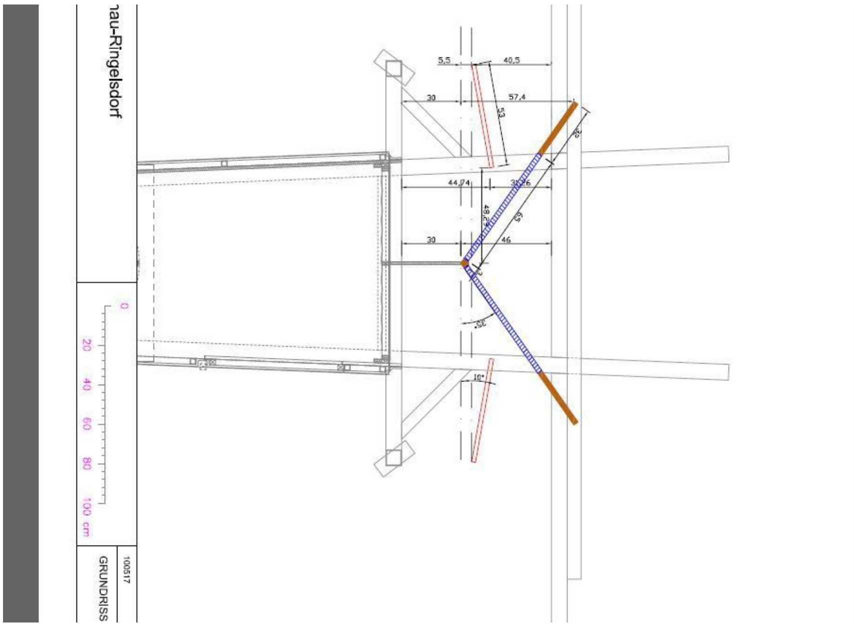

Figure 3: Horizontal section through Flight Tunnel II, modified for noise barrier test. Blue: test panes and reference panes; brown: pane holder, screen for background and sky; red: lateral screen

One of the limitations of the ONR test, which is critical in many cases, emerges when assessing the effect of specular reflections on the panes. For example, the reflection of a bright sky can result in a reduction of contrast of white markings. Additionally, markings on surface 2 (rear side of a pane) can become superimposed by specular reflections on surface 1 and lose their effect. The ‘noise barrier’ test scenario admits additional variables in order to incorporate reflections on the panes into the test scenario. For this purpose, the reference pane and test pane are mounted at an angle of 35° to the flight axis. Similar to rear mirrors in vehicles, from a bird’s perspective this arrangement produces (usually weak) mirror images which can be superimposed over parts of the background. Rotation with the sun’s position is also maintained in the ‘noise barrier’ test scenario, in order to keep the angle of light incidence constant. Screens prevent the birds from seeing the sky and vegetation beside the panes, which would uncontrollably influence their decisions. There had been no comparative results for this test scenario. Reference tests were therefore carried out with well-researched markings (cf. 3.3).

2.3.3 ‘Window test’

Since the prevailing light intensity behind building façades or windows is usually weak, distinct reflections frequently appear on their glass surfaces. As a result of low irradiation, these reflections are more clearly visible than those on free-standing panes in front of a bright background (cf. ‘noise barrier test’). For birds, this produces the illusion of unobstructed habitat. In the test according to ONR 191040 (‘ONR test’), mirror reflections are excluded. The ‘window test’, a modification of the ONR test to answer specific questions, admits reflections on the panes as added variables. Reference pane and test pane are mounted at an angle of 35° to the flight axis. Darkening the space behind the test panes produces contrast-rich reflections similar to those which appear on windows. In order to darken the background, an enclosed chamber is assembled from side walls, a roof and a camouflage net, inside which the light intensity is limited to a target value of <25W/m² by indirect light incidence. Fig. 4 shows the flight tunnel with rotating assembly and rearward structures. Fig. 5 shows the rearward structures in more detail.

In order to prevent the test birds from seeing past the panes (placed at an angle to their flight axis) towards the vegetation and sky beyond, thus making their decision independently of the test panes, screens must be mounted corresponding to the birds' visual axes (Figs. 3 and 5). The lateral screens, both positioned in front of the test panes, necessarily create reflections on the test panes. These disturbing reflections are minimised by optimising alignment. Rotation and alignment of the tunnel according to the position of the sun are maintained, in order to avoid asymmetrical light incidence. Direct sunlight never falls on the test panes.

Fig. 4: Flight tunnel with screening and shading construction at the rearward end. The foundation of the rotation assembly can be seen to the right of the image centre.

Fig. 5: Screens (black plates) restrict the birds' view to the extent of the glass panes. The side walls (white plate) and camouflage net (green curtain) reduce the light intensity in the background of the tunnel to $\leq$25W/m².

Figs. 6 and 7 show the mounted test panes from a bird's point of view, shortly before it is caught by the net. In Fig. 6, the left side has been left free and the background is visible without obstruction. In Fig. 7, the unmarked reference pane is on the left, and the Ornilux Mikado test pane on the right. Vegetation and sky from areas on each side of the tunnel are reflected on both panes. Additionally, light spots can be detected in the mirror images, which are created by the background light falling through the camouflage net.

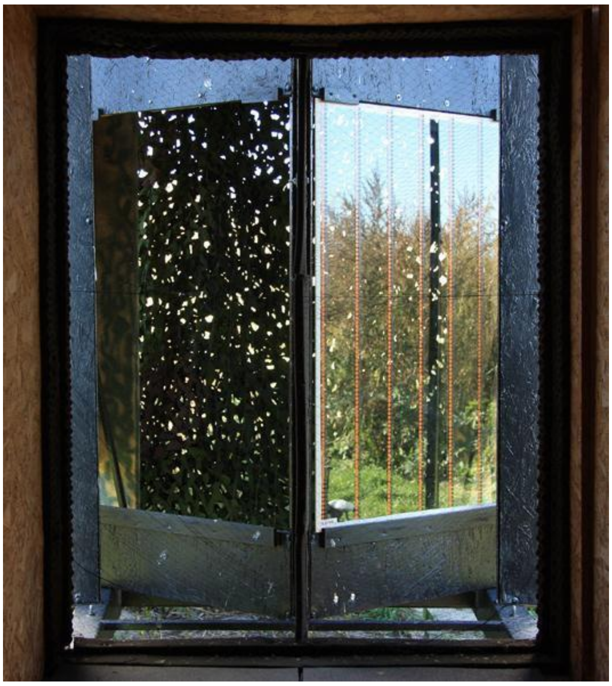

Figure 6: End of tunnel with pane holder and darkened area in the background of the panes. Left: no pane, unobstructed view of camouflage net (artificial background with light spots); right: black and orange reference test pane, reflection of vegetation outside right. The vertical black line is the reflection of the right screen, projected into the image from the right.

Figure 7: End of tunnel with pane holder and test pane. Left: float glass reference pane; right: Ornilux Mikado test pane. Vegetation and sky are reflected on both panes. The background of the panes can only be seen in the form of individual spots of light. The contrasts on the test pane (R.) are weaker than those on the reference pane (L.) The possible influence of different heights of vegetation is cancelled out by the continuous rotation of the tunnel and the equal frequency with which the test panes are positioned on the left and right side.

2.4. Control tests and reference tests

Testing of the Ornilux panes was accompanied by control and reference tests. The purpose of control tests is to check the test facility. Reference tests allow the test results to be better assessed and interpreted.

2.4.1 Control tests

The purpose of control tests is to identify undetected, systematic disturbances of the symmetry of the facility during the test period. The control tests, which are randomly distributed throughout the test period, are carried out with an identical pair of panes (two unmarked float glass panes). According to ONR 191040, the number of control tests should amount to at least 10% of the regular tests. Equal distribution is expected.

2.4.2 Reference tests

Since the 'noise barrier' and 'window' test assemblies were being used for the first time this year, it was necessary to carry out reference tests with at least one known marking pattern, and to document whether, and to what extent, reflections influenced the effectiveness of known, highly effective markings.

We carried out the reference tests with the 'black and orange dots' printed pattern. 'Black and orange dots' was tested in 2009 (cf. Rössler 2010: 'Punkte schwarz-orange R2'). In the ONR test, only 2.4% of birds flew towards the test pane. The marking was used as a reference for the 'noise barrier' and 'windows' tests, both in the version using a printed float glass pane and in the version using an insulated glass pane printed on the inner side. The printed float glass pane was investigated in two series of tests, with printing both on the front side (level 1) and the reverse side (level 2), in order to compare the effect of reflections. The markings are described in 2.7.2 (Fig. 11).

2.5. Test measurements, record keeping and video recording

2.5.1 Radiation measurement

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 was ten seconds. The measurements were registered on a data logger (EMS Mini Cube) as mean minute values, retrieved every two weeks, and saved on an external PC.

2.5.1.1 Measurement of global radiation

A sensor was placed roughly 2 m above the floor to measure the global radiation. The measurement plane is horizontal. The measurement taken is the sum of diffuse sky radiation and direct solar radiation (Fig. 8).

2.5.1.2. Measurement of light intensity in pane background

To measure the light intensity of the pane background, the sensor was fixed to the central axis of the tunnel at a height of approx. 50 cm and inclined 30° upwards (Fig. 9).

Figure 8: Photovoltaic sensor for measuring global radiation

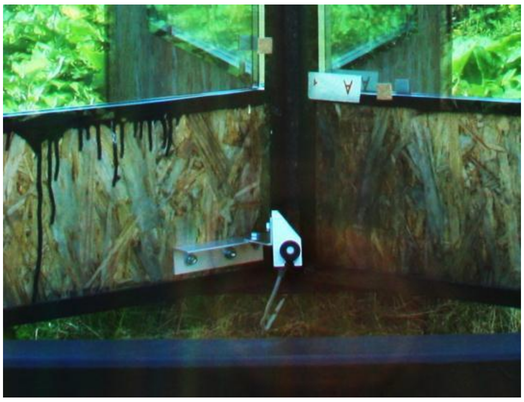

Figure 9: Photovoltaic sensor for measuring radiation behind the test panes.

2.5.2 Record keeping

Record keeping for the tests comprises recording the relevant data of each test bird (species, ring number for synchronising with the ringing station database), time of day (for synchronising with light measurement and video documentation), cloud cover, the visually observed decisions of the test bird and any results which could be relevant to the assessment of the test.

2.5.3 Video recording

The test flights were recorded in ‘HQ’ recording mode (9 Mbit/sec) with a digital video camera (Sony DCR-SX34E) mounted outside the tunnel and aligned towards the birds’ flight path through a hole in the rear wall. The data were secured daily on an external PC.

2.6. Data analysis

The analysis of the data consists of consolidating the field reports with the automatically recorded light measurements and video analysis. Only unambiguous decisions between two panes ('left' and 'right') were taken into account; flights into the 'middle' were disregarded. Aborted flights, hesitant approaches and flights along the ceiling or the side walls cannot be assessed. If it already became clear during the test that the test could not be assessed, the test was repeated with another bird. Flights in which irregularities were not established until the video analysis (asymmetrical light incidence, open doors etc.) were subsequently disregarded.

2.6.1 Video analysis

The visual observations recorded during the tests themselves are cross-checked with the aid of the video analysis (after the end of the season). Each test flight is examined in slow motion and/or segmented into sequences, and is checked to see whether the test can be assessed or must be discarded. The most frequent cause of discarded individual tests is delayed or hesitant flight and landing on or in front of the net. The main purpose of the video analysis is to check and decide whether it is necessary to take into account the fact that the bird has detected the net and changed sides in a manoeuvre designed to avoid it. 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.

2.7 Test panes and reference panes

2.7.1 Ornilux Mikado

Fig. 10 shows the Ornilux Mikado test pane. It consists of insulating glass, on the inside of which special coatings have been applied to different surface layers. These are as largely transparent, absorb UV radiation and – according to the manufacturer's specifications – reflect UV. The coating does not cover the entire surface. A geometrical pattern, consisting of straight lines running over the surface in a chaotic design that recalls Mikado pick-up sticks, is not coated. Contrasts visible to birds are supposed to emerge between the uncoated areas and coated surfaces. The coating can be made out with the naked eye.

Figure 10: The Ornilux Mikado test pane.

2.7.2 Marked panes for reference tests – black and orange dots

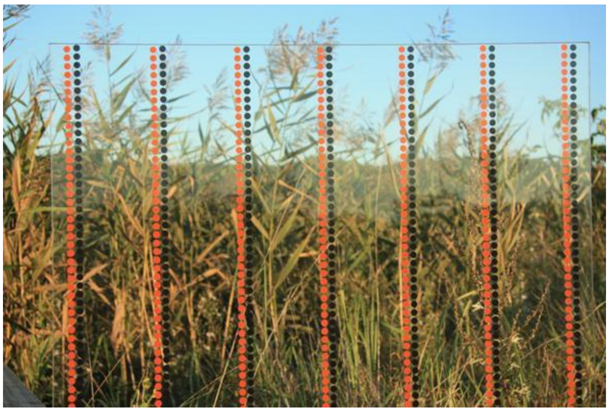

Figure 11: Only 2.4% of the birds in the ONR test flew towards the ‘black and orange dots’ pattern, which was therefore well suited for use as a reference pane in the ‘noise barrier’ and ‘window’ tests. Test cases involving the printed surface on both the front and reverse sides were investigated.

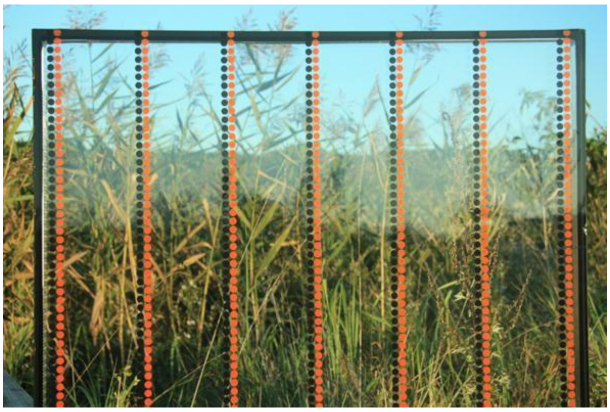

Figure 12: ‘Black and orange dots’ pattern applied to an insulation glass pane (printed surface on the inside, surface 2), tested in the ‘noise barrier test’).

‘Black and orange dots’ was selected as the pattern for the reference tests owing to its high level of effectiveness (Rössler 2010, cf. 2.4.2). The marking consists of columns of dots arranged in vertical pairs. The dots are black and orange and have a diameter of 8 mm. The distance between the twin rows of dots is 10 cm. The (silk-screen) printing takes up 9% of the total surface. The test panes were investigated in the form of printed float glass (Fig. 11) and 2-layer insulation glass printed on the inside (Fig. 12).

2.7.3 Reference panes – unmarked float glass

The outcome of the choice experiment is influenced to a certain extent by the choice of the reference pane. The following options are available: comparison of the test pane with (1) an open, unglazed comparison field; (2) unmarked float glass with reflective properties comparable to conventional windows; (3) glass of identical construction to that of the test pane but without bird protective markings.

In the series of tests described here, the reference panes consist of unmarked 8 mm float glass. It must be emphasised that the role of the float glass reference pane in the ONR test is different from its role in the tests involving reflections (‘noise barrier’ and ‘window’). In the case of the first scenario, the basis for comparison is the proven invisibility of the glass for birds (Rössler et al. 2007) in the absence of reflections. The question in the ONR test is: ‘Do birds perceive the markings?’ In the other two scenarios, the optical behaviour of an unmarked pane provides the basis for comparison. The question in the ‘noise barrier’ and ‘window’ tests is:
‘Do the birds detect the marked pane better than an unmarked float glass pane?’ Since reflections on glass panes are a major cause of collisions, it is legitimate to take a comparable situation as a reference and to test whether a specific test pane demonstrates (significantly) improved perceptibility.

2.8 Test procedure

2.8.1 Test period and data compilation

Out of a total of 268 test flights between 15 July – 18 September 2011, 226 individual tests (84.3%) could be used for assessment after the concluding video analysis (Table 2). 32 birds (11.9%) refused to fly or flew only hesitantly towards the net. 5 test birds (1.9%) flew towards the centre and 5 flights (1.9%) were discarded on the basis of the video analysis owing to probable detection of the net.

Table 2: Test periods, the number of valid individual tests with Ornilux Mikado, and the number of tests discarded as invalid.

Test design	Testing period	valid	invalid	Total
ONR	21/08 – 05/09	**86**	11	97
Noise barrier	15/07 – 23/07	**59**	15	74
Window	29/08 – 13/09 16/09 – 18/09	**81**	16	97
Total		**226**	**42**	**268**

2.8.2 Temporal distribution of individual tests

The timing of the tests depended on the time of sunrise and length of each day, as well as on the distribution of net catches over the course of each day. The temporal distribution of the individual tests corresponds quite well to the daily distribution of birds' activity in the wild (Fig. 13). Roughly 60% of the tests took place in the early and late morning (up to 12:00 CET).

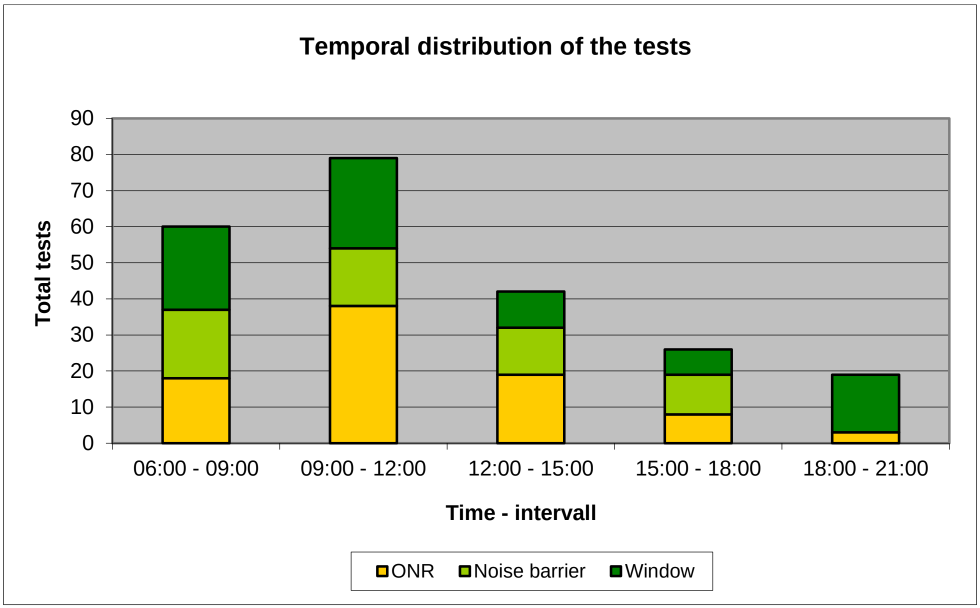

Figure 13: Temporal distribution of valid individual tests of Ornilux Mikado.

2.8.3 Light conditions

Table 3 shows the number of tests carried out under sunlight or diffuse light, lower or higher global radiation, and lower or higher light intensity in the background behind the panes. The threshold values of 400W/m² for global radiation and 60 or 70W/m² for the background of the panes are based on the distribution of light values over the entire season, so that half of all the tests carried out in this year were above this value, and half below it.

The test panes were never exposed to direct solar radiation, to avoid sharp shadows on the markings. However, diffuse light or sunlight on surrounding vegetation do influence the reflections on the test panes. A fifth (20%) of the tests took place under diffuse light (cloud shadow), the majority under direct sunlight. The distribution of more weakly and more intensely illuminated backgrounds, as well as the distribution of weaker and higher global radiation, should ideally be the same. With global radiation, this was the case overall; in the case of background light intensity, 57% fell into the weaker light category (threshold values of 70 W/m² having been applied for the ONR test and 60 W/m² for the 'noise barrier' test). In the case of the 'window test', stating background illumination is meaningless, since very weak light conditions (< 25W/m²) were created artificially.

Table 3: Number of experiments under (1) diffuse light or direct solar radiation, (2) intensity of global radiation, (3) light intensity of background vegetation

Test scenario	**Light**		**Light intensity [Wm^{-2}]**			
			Global radiation		**Background**	
	diffuse	**sunlight**	**< 400**	**> 400**		
ONR					**< 70**	**> 70**
	0	86	28	58	56	30
Noise barrier					**< 60**	**> 60**
	21	38	25	34	26	33
Window					**artificially reduced to < 25W**	
	26	55	61	20		
Total	47	179	114	112		

2.8.4 Test birds

The test birds used comprised all birds that were captured and ringed or checked at the Hohenau-Ringelsdorf ringing station during the test period, and which were suitable for the test. This yields a range of bird species characteristic of the local conditions, and a sequence of test birds determined by the ringing procedure. Table 4 lists the species of test birds for the 226 evaluated tests. A total of 20 bird species were used for the tests.

Table 4: Distribution of the test birds (20 species) among the individual tests with different test panes.

Test design	**ONR**	**Noise barrier**	**Window**	**Total**
Common Nightingale	1			**1**
Bluethroat			2	**2**
Common Redstart			1	**1**
Savi’s Warbler	1	1		**2**
Sedge Warbler	15	8	9	**32**
Marsh Warbler	17	22	29	**68**
Reed Warbler	4	1	1	**6**
Great Reed Warbler	4	9	3	**16**
Common Whitethroat	2	2	2	**6**
Garden Warbler	1		1	**2**
Eurasian Blackcap	3		6	**9**
Common Chiffchaff	3	2		**5**
Willow Warbler	1			**1**
Eurasian Blue Tit	1	1		**2**
Great Tit			8	**8**
Eurasian Penduline Tit		3		**3**
Red-backed Shrike			3	**3**
Common Starling			2	**2**
Eurasian Tree Sparrow	28		11	**39**
Common Reed Bunting	5	10	3	**18**
Total	**86**	**59**	**81**	**226**

3 RESULTS

3.1 Methodological integrity of the tests

An essential condition for the integrity of the tests is the random sequence of individual tests and the equal frequency with which the test panes are mounted on the left or right side. The crucial questions are:

- Were the test panes mounted on the left and right with equal frequency?
- Are the flights towards the left or right side evenly distributed in the control tests?
- Are the flights towards the left or right side evenly distributed in the actual tests?
- Are the results of the tests (flights towards the reference pane/test pane) equally distributed between the left and right side?

All data indicate a satisfactory degree of integrity for the tests. The results of the tests are presented in the following sections.

3.1.1 Distribution of test pane on left and right side

It is possible to compensate for any irregularities in the tunnel symmetry and potential systematic preferences for one of the two sides (left or right) by mounting the panes to be tested on the left or right with equal frequency. Table 5 shows the distribution of the test panes to the left and right positions in the 226 tests. The test panes were evenly distributed (Pearson-Chi² = 0.25, $p = 0.88$).

Table 5: Position of the marked panes in 226 dichotomous choice experiments

Test scenario	**Mounted left**	**Mounted right**	**Total**
ONR	38	43	81
Noise barrier	30	29	59
Window	43	43	86
Total	111	115	226

3.1.2 Distribution of flights towards left or right side

As long as the test assembly does not result in a systematic preference for the left or right side, the control tests (two identical unmarked float glass panes) should yield a random distribution of flights towards the left and right. Provided that the test panes are mounted on the left and right with equal frequency, and that the random temporal distribution of the tests has eliminated any dependence on disturbance variables, the totality of assessed tests should also demonstrate an equal distribution of flight trajectories. Neither the control tests nor the assessed tests revealed any divergence from an equal distribution of flights towards the left and right side (Table 6, Pearson-Chi² = 0.77, $p = 0.38$).

Table 6: Distribution of flight trajectories in 111 control tests (unmarked vs. unmarked) and 226 assessed dichotomous choice experiments for Ornilux Mikado.

	Flight trajectory		
	Left	**Right**	**Total**
Control tests with two unmarked float glass panes	57	54	111
Ornilux Mikado	103	123	226
Total	160	177	337

3.1.3 Distribution of preferences for the reference pane/test pane on left and right side

The distribution of flights towards the Ornilux pane and the unmarked reference pane revealed no difference from equal distribution (Table 7, Pearson-Chi² = 0.06, p = 0.81).

Table 7: Distribution of flights (left/right) towards Ornilux Mikado and towards the reference pane.

	Flight trajectory		
Flight towards	**Left**	**Right**	**Total**
Ornilux Mikado	46 (44.2%)	58 (55.8%)	104
Reference pane	57 (46.7%)	65 (53.3%)	122
Total	**103 (45.6%)**	**123 (54.4%)**	**226**

3.2. Test results

3.2.1. What results are expected?

3.2.1.1 ONR test

For panes that cannot be recognised as an obstacle or distinguished from unmarked window glass, a random distribution is to be expected (50% of the test birds fly towards the test pane). For panes that can be very clearly recognised as an obstacle or distinguished from unmarked window glass, flight trajectory ratios of between 2:98 and 10:90 were observed in numerous cases in the ONR test (WUA 2011). According to ONR 191040, 'bird protection glass' is understood to mean a (marked) pane towards which no more than 10% of birds fly in a dichotomous choice experiment. A result of 0 flights towards the test pane was achieved with an opaque pane in the ONR test, the best-possible result that can thus be expected is 0% (personal data, unpubl.).

3.2.1.2 Tests with reflections

In the tests that incorporated reflections on the panes ('noise barrier' and 'window'), there are as yet no comparative figures from previous years. In the case of the test design using panes inclined at an angle to the flight axis which also reflect part of the construction, a higher proportion of random preference decisions was expected in advance, compared with the highly accurate ONR test. The 'best possible result' will only become apparent over the course of future years of testing under these new test conditions. There are as yet no equivalent reference tests for the tests involving reflections. Therefore, reference tests were carried out (cf. 2.4.2, 2.7.2), and the results are presented in this report.

3.2.2 General results for Ornilux Mikado

Table 8 shows the test results. 1) In the ONR test without reflections, 37.2% of the birds flew towards the test pane and 62.8% towards the reference pane. The birds therefore distinguished the Ornilux Mikado test pane from an unmarked pane that was invisible to birds, and avoided it to a minor extent. 2.) In the 'noise barrier' test scenario, 45.8% of the birds flew towards the Ornilux pane. This result does not differ significantly from a random distribution of flight trajectories – no avoidance. 3.) In the 'window' test scenario, 55.6% of the birds flew towards the Ornilux pane. The test pane was not distinguished from an unmarked float glass pane – no avoidance.

Table 8: Distribution of flights towards test and reference panes, Exact Binomial Test for equal distribution.

Test design	Total	Flights towards			Binomial test
		Reference pane	**Test pane**	**Test pane [%]**	**p**
ONR (no reflections, bright natural background)	86	54	32	**37.2**	**0.02**
Noise barrier (reflections, bright natural background)	59	32	27	**45.8**	0.60 (n.s.)
Window (reflections, background <25W/m²)	81	36	45	**55.6**	0.37 (n.s.)
Total	**226**	**122**	**104**		

3.2.3 Results for Ornilux differentiated according to light conditions

An analysis according to different light conditions can possibly provide further insights into the way test patterns function. It is important to bear in mind that the low sample sizes resulting from splitting up the total results may in some cases prohibit a clear result.

3.2.3.1 Influence of diffuse light and direct sunlight

The ONR tests (21/08 to 05/09/2011) coincided with a period of dry weather and only took place under sunny conditions. In this case, therefore, it is not possible to differentiate more precisely according to diffuse light conditions vs. direct sunlight. In the tests involving reflections, these differences could be tested. In these tests, the test panes are screened against the incidence of direct sunlight. However, overcast sky with diffuse light and sunny days with direct sunlighthave a major impact on the brightness and contrast of the vegetation which is reflected on the panes under the chosen test conditions. In the 'noise barrier' test scenario, no detectable effect is observed with small sample values: 42.9% and 47.4% of the birds flew towards the test pane, respectively. In the 'window' test scenario using a weakly illuminated background, 38.5% of the birds flew towards the test pane under diffuse light, and 63.6% flew towards the Ornilux pane under sunny conditions (Tab. 9, Pearson Chi² = 3.57, p=0.059).

Table 9: Flights towards the test pane under diffuse light and solar radiation

Test pane	**Light conditions**				**Total**	
	diffuse		**sunlight**			
	n	**Flights towards test pane [%]**	**n**	**Flights towards test pane [%]**	n	Flights towards test pane [%]
ONR			86	**37.2**	86	37.2
Noise barrier	21	**42.9**	38	**47.4**	59	45.8
Window	26	**38.5**	55	**63.6**	81	55.6
Total	47		179		226	

3.2.3.2 Influence of global radiation

Table 10: Distribution of flights towards test pane under different levels of brightness (global radiation measured on horizontal plane).

Test pane	**Global radiation**				**Total**	
	< 400 Wm^{-2}		**> 400 Wm^{-2}**			
	n	**Flights towards test pane [%]**	**n**	**Flights towards test pane [%]**	n	Flights towards test pane [%]
ONR	28	**53.6**	58	**29.3**	86	37.2
Noise barrier	25	**44.0**	34	**47.1**	59	45.8
Window	61	**53.3**	20	**65.0**	81	56.3
Total	114		112		226	

The influence of global radiation on the test results is presented in Table 10 (see 2.8.4 for setting of threshold values). With values below 400W/m², in none of the cases is there any indication that the test pane is recognised as an obstacle or distinguished from an unmarked float glass pane. With radiation values above 400W/m², 29.1% of the birds in the ONR test flew to the test pane. In this case the difference to the result with low global radiation is significant (Fisher's Exact Test, n=86, p=0.0348). In the tests which examine the effect of reflections occurring under outdoor conditions ('noise barrier', 'window'), no difference related to radiation conditions can be detected.

3.2.3.3 Influence of light intensity in pane background

The influence of the light intensity in the pane background is shown in Table 11 (see 2.8.4 for setting of threshold values). In the ONR test, 42.9% of the birds flew towards the test pane with values below 70W/m², and 6.7% with radiation values above 70W/m². Here too, higher levels of global radiation seem to improve the visibility of the test pane, although it is not possible to support this statistically owing to the small sample values (Pearson Chi²=1.55; p=0.21). Where reflections are possible ('noise barrier test'), the result is not influenced by the light intensity in the background (Pearson Chi²=0.04; p=0.83).

Table 11: Distribution of flights towards the test pane under different levels of light intensity in the pane background

Test pane	Light intensity in pane background				Total result	
	n	**Flights towards test pane [%]**	**n**	**Flights towards test pane [%]**	n	Flights towards test pane [%]
	< 70 Wm^{-2}		**> 70 Wm^{-2}**			
ONR	56	**42.9**	30	**26.7**	86	37.2
	< 60 Wm^{-2}		**> 60 Wm^{-2}**			
Noise barrier	26	**46.2**	33	**45.5**	59	45.8
Window	**<25 W/m² – no differentiation possible**					

3.3 Results of reference tests

Table 12: Reference tests with ‘black and orange dot’ markings. Distribution of flights towards test and reference panes in the ‘ONR’, ‘noise barrier’ and ‘window’ test scenarios and with different printed surfaces (front and rear side).

Test design	Total	Flights towards		
		Reference pane	**Test pane**	**test pane [%]**
ONR (Rössler 2010)				
Printed on front	85	83	2	**2.4**
Noise barrier				
Printed on front	103	89	14	**13.6**
Printed on rear	113	95	18	**15.9**
Insulating glass, printed on the inside	100	85	15	**15.0**
Window (reflections, background <25W/m²)				
Printed on front	76	67	9	**11.8**
Printed on rear	73	58	15	**20.5**
	550	**477**	**73**	

Alongside the Ornilux tests, reference tests were carried out with a visible marking that had been thoroughly tested and classified as highly effective. This was a high-contrast, screen-printed pattern with black and orange coloration (see 2.7.2). In an ONR test from 2009 (Rössler 2010), this pattern with a printed surface area of 9% achieved the best result of all tested markings to date since tests began in 2006. The effectiveness of this pattern is also expected to be diminished when reflections occur, compared to the ONR test. The markings were tested in both the ‘noise barrier’ and ‘window’ tests with printing (1) on the side facing the bird and (2) on the side facing away from the bird, and (3) in the ‘noise barrier test’ additionally with printing on the inside of an insulating glass pane. Here too, the markings were tested against an unmarked float glass pane. The results are presented in Table 12.

In every case, birds flew towards the reference panes to a significantly greater extent than towards the test panes (exact binomial tests for all tests: $p<0.001$). In the ‘noise barrier test’, no difference between the results with different marking surfaces (front/back) could be observed statistically (Pearson $Chi^2=0.23$, $p=0.89$). There is no statistical difference in the case of the ‘window test’ either (Pearson $Chi^2=1.49$, $p=0.22$), although in this case the data suggest that the markings clearly have a lesser effect on the rear side of the pane (surface 2). Further experiments are necessary before a conclusive statement can be made in this regard.

4 DISCUSSION AND FINAL ASSESSMENT

4.1 What was tested?

The test object was off-the-shelf Ornilux Mikado insulating glass (Ornilux Neutralux 1.1, as at: June 2011).

It is not known whether there are different types of Ornilux Mikado glass or different coatings with different optical properties, which might possibly have an effect on the visibility of the coatings (cf. Ley 2006). Without access to the manufacturing companies, the key data concerning pane thickness, distance between panes, thickness of coatings etc. are difficult to assess. To date, nothing concrete is known about the coating of Ornilux Mikado and its optical properties. Since UV properties cannot be assessed with the human eye, in the absence of any disclosures regarding the transmission and reflection properties of the coatings and of the panes as a whole, a degree of uncertainty prevails.

4.2 How should previous tests be assessed?

Of the tests to date, the series of tests by Ley (2006) and the outdoor tests by Ley and Fiedler (2007) have been published. Ley (2006) tested various prototypes of Ornilux using choice experiments in a flight tunnel. The first flight tunnel at the Hohenau-Ringelsdorf Biological Station (Rössler & Zuna-Kratky 2004) was also oriented along this design. In some respects, Ley’s investigations can be compared with the ONR test. However, there are major differences regarding the lighting of the panes (artificial in Ley’s case, by sunlight at Hohenau-Ringelsdorf) and adaptation of the birds to brightness (in Ley’s case adapted to darkness, at Hohenau-Ringelsdorf to the light outside the tunnel). The question addressed by the outdoor tests by Ley and Fiedler (2007), which used large-format panes mounted alongside one another with natural vegetation in the background, was closer to that of our ‘noise barrier’ test method.

Ornilux Mikado is marketed as insulation glass for enclosed structures. The investigations available before this study gave little information about Ornilux Mikado, for the following reasons:

1) All published test results did not pertain specifically to Ornilux Mikado as it is currently available on the market, but to predecessors (patterns with vertical bars).

2) Owing to a lack of suitable methods, Ornilux was never tested for its main application case, as modelled in the ‘window test’. Since the markings of Ornilux Mikado are on the inside of the insulation glass pane, it was urgently necessary to determine whether any potential effectiveness of the coating under transparent conditions was not completely cancelled out by the high-contrast reflections which frequently and inevitably appear on a pane’s surface.

3) On the basis of our test results, a methodological weakness in Ley’s tests (2006) must also be considered. As is explained in the following section, it was possible to reproduce the results obtained by Ley under one specific light condition. This light condition might represent a special case.

4.3 Reassessment of tunnel tests by Ley

A closer look at our test results may indicate the need for a reassessment of the tunnel tests by Ley (2006). The frequently cited result obtained by Ley was 24% of birds flying towards the test pane (stated by Ley with v_{ei} = 0.76, n=108).

In the ONR test without reflections, which is most closely comparable to Ley's test scenario, and when the sample was divided into two halves (brightness classes), very similar values to those obtained by Ley could be established for the tests under strong illumination (see Table 13). 25.6% (n=43) of the birds flew towards the test pane in the case of high global radiation, and 27.9% (n=43) when the light intensity in the pane background was high. By contrast, at lower levels of light intensity, an approximately equal distribution of flight trajectories predominated, and the test pane therefore had no effect. There is a significant difference between the results under higher and lower global radiation (Pearson $Chi^2=4.03$, $p=0.04$).

Table 13: Differentiation of the ONR test results for Ornilux Mikado into two brightness classes of equal size.

Light intensity		**Flights towards reference pane**	**Flights towards test pane**	**[%]**
Global radiation	intense	32	11	25.6
	weak	22	21	48.8
Background	very bright	31	12	27.9
	less bright	23	20	46.5

A discussion of the exact circumstances of Ley's tests cannot be given here, since too little is known about the distribution of light on the panes by the Osram Ultra Vitalux lamp that Ley used to illuminate them, or about the light intensity in the background of the panes. However, one cannot rule out the possibility that Ley's results apply to a special case (high light intensity, no reflections), and not to the totality of light conditions that may be expected.

4.4 Interpretation of reference tests

In the tests involving reflections on the panes, the highly contrasting test pane with black and orange markings was less well distinguished from an unmarked float test pane in every case compared with the ONR test. As far as the printed side is concerned, no differences are detectable with a bright background, regardless of whether the markings are printed on the front side (surface 1) or rear (surface 2), or inside an insulation glass pane. If the printing is applied to the front side, in the case of the high-contrast markings investigated, it makes no difference whether the background is bright or dark, i.e. whether the pane is placed outdoors or is part of a glass façade with a dark background. However, a striking difference – albeit not statistically significant in the case of the present sample – occurs with a weakly illuminated background (window or glass pane) if the markings are applied to the rear side of the pane (or inside the insulation glass).

To date it is not possible to make any statements regarding the influence of reflections on less contrasting markings (e.g. white markings when bright skies are reflected in the panes).

4.5 Assessment of Ornilux Mikado

In the ONR test, Ornilux Mikado demonstrated a weak level of effectiveness. On the basis of the ONR test, the pane must be classed as not very suitable from the point of view of bird protection. In the 'noise barrier' and 'window' tests it was not possible to establish any effectiveness at all. Birds cannot distinguish the pane from an unmarked float glass pane. Even if the results of the Ornilux tests across different scenarios show a similar pattern to those of the reference tests, there is a wide gap between the results of the black and orange markings and those of the Ornilux markings. The black and orange markings are still fairly well recognised and avoided by birds under difficult light conditions, including reflections, whereas there is no reason to expect that Ornilux markings would reduce the risk of bird strikes to any significant degree compared with normal unmarked window glass.

The argument is frequently put forward that even a marginal improvement of visibility in comparison with unmarked window glass represents an improvement of the total situation. At best, this argument is only valid in cases where existing glazing is replaced. Newly fitted glass surfaces generally mean an aggravation of the risk of collision for birds. From the point of view of conservation, it is fundamentally impossible to speak of an improvement, but only of a more or less promising cushioning against additional risks. Austria takes account of this fact by recommending only highly effective markings wherever the risk of bird strikes must be considered. However, to date it has not been possible to make such a recommendation for markings that are almost completely transparent.

5 LITERATURE

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