

VISUAL ECOLOGICAL IMPACT OF A PECULIAR WASTE OIL LAKE ON THE AVIFAUNA: DUAL-CHOICE FIELD EXPERIMENTS WITH WATER-SEEKING BIRDS USING HUGE SHINY BLACK AND WHITE PLASTIC SHEETS

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Since 1951 there has existed a waste oil lake in Budapest (Hungary). This oil lake acted as a huge bird trap for 50 years. Prior to its removal, from August, 1997 to March, 1998, a monitoring was performed to observe and document the carcasses of the birds trapped by the oil. This oil lake is an analogy of the crude oil lakes in the desert of Kuwait and the ancient/recent natural asphalt seeps and tar pits that acted/act as massive animal traps. To study the visual attractiveness of shiny oil surfaces to birds, we performed dual-choice field experiments in every August from 1997 to 1999. We imitated the oil by means of a huge, shiny, black plastic sheet laid onto the ground, while the brighter surface of certain natural water bodies was mimicked by means of a huge, shiny, white plastic sheet. We observed the birds and their reactions to these plastic sheets.

Water-seeking birds could be visually deceived by and attracted to shiny plastic sheets. They apparently mistook the shiny surface of these plastic sheets for water or a wet muddy surface. At the plastic sheets the deceived birds showed quite a similar behaviour as at natural water bodies or muddy areas. A black kite tried to drink from the white plastic sheet. A great white egret preferred the white plastic sheet to the black one. Swallows considered the plastic sheets as water, or feeding, or mire-gathering place. During flight or after landing, they tried to drink mainly from the white plastic sheet. They hunted the attracted insects more frequently above the black plastic sheet. The behaviour of wagtails at and on the plastic sheets was the same as that at real water bodies or wet muddy surfaces. Wagtails preferred the black plastic sheet. The black plastic sheet was three times as attractive to white storks as the white plastic. The

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storks made such movements with their bills as it is observable at the birds searching in the mud. Starlings avoided the plastic sheets if they landed directly close to them in the grass.

Our field experiments showed that the optical cues of the shiny surface of open-air oil reservoirs may be so strong that water-seeking birds are visually compelled to remain in the immediate vicinity of the oil in spite of the fact that other senses signal that it is not water. Thus, the deceived birds try to drink from the oil, or land directly on the oil surface, or wade into the oil, or try to catch the insects attracted to the oil surface. The consequence of all these reactions is, at least, a single contact with the sticky oil, which is enough to be trapped or to become oiled, the necessary aftermath of which is death. That is why the open-air oil reservoirs are so extremely dangerous for water-seeking birds. Birds of prey are also in danger of being trapped by the oil when they try to feed on the carcasses of other trapped birds. Also insectivorous birds are endangered to be trapped, which try to catch the insects attracted to the oil surface.

The study of the visual ecological impact of oil lakes on the avifauna is the prerequisite of the necessary environmental protective arrangements that should be urgently taken in order to eliminate any man-made oil spills and open-air oil reservoirs. The dangerous impact of these oil lakes to birds is demonstrated by the estimation that the waste oil lake in Budapest trapped about 13–17 thousands birds during the 50 years of its existence.

Keywords: Birds; Avifauna; Bird trap; Waste oil lakes; Plastic sheets; Visual deception; Water detection; Water imitation

INTRODUCTION

Since 1951 there has existed an open-air oil reservoir, the so-called “waste oil lake” (Fig. 1) in a suburb of Budapest (the capital of Hungary), which is being removed at present (Horváth *et al.*, 1998). Before the Second World War this area was a mine of pebble. During the war the mining operations were stopped, then, from 1951 the remained pits were used to store waste, spent and refused oil. The pebble pits were separated by hindrances resulting in the lakes. After appropriate recycling the oil was consumed as fuel, but according to the decrease of demand the plant was closed. At warm weather the surface of the oil lakes, tar pits or asphalt seeps is flat, shiny and acts as an efficient reflector of sunlight and skylight, like a water surface. We observed that this waste oil lake deceives, lures and traps birds *en masse* (Fig. 2). Prior to the removal of this lake, from August, 1997 to March, 1998, we performed a monitoring in order to observe and document the carcasses of the birds trapped by the oil. The first aim of this work is to report on the results of this monitoring.

The waste oil lake in Budapest acted as a huge bird trap for 50 years. It is an interesting visual ecological question which birds and why are deceived by and lured to such a shiny oil surface. The uniqueness of this oil lake is that it has existed for half a century in a densely populated suburb of a city (Fig. 1A), where there was no any natural water surface (neither lake, nor streamlet,

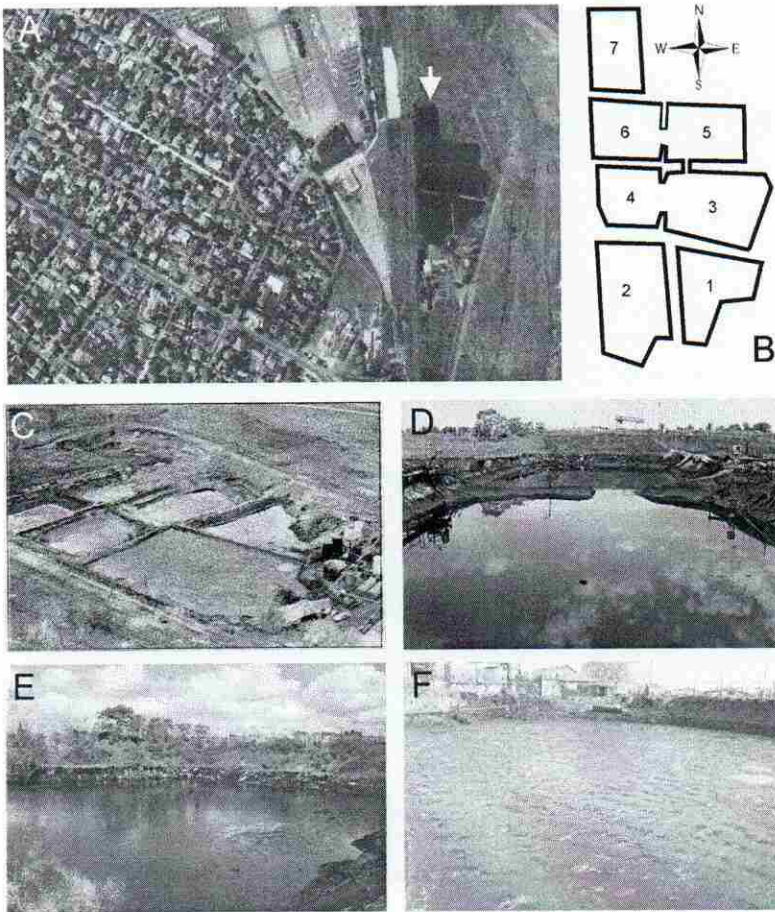


FIGURE 1 The waste oil lake in Budapest. (A) On this satellite photograph the oil lake is the black polygonal patch at the right-hand side marked with a white arrow. (B) Schematic map of the waste oil lake composed of seven oil reservoirs. (C) Aerial photograph of the waste oil lake. (D) In summer (July, 1997) the surface of the oil lake is flat and shiny. (E) In Autumn (September, 1997) the surface of the lake becomes gradually dull as the air temperature decreases. (F) In Winter (December, 1997) the surface of the oil lake becomes matt and wrinkled, and the rain-water accumulates in small pools on the surface. (See Colour Plate I at the end of the issue).

channel, or canal) in the vicinity (within 3 kilometres). The waste oil lake had the only shiny, water-imitating surface with a relatively great area in the district. The waste oil lake in Budapest is not the only man-made oil lake which traps birds in large numbers. Several years after the end of the Gulf War in 1991, crude oil lakes still existed in large numbers in Kuwait (Pearce,

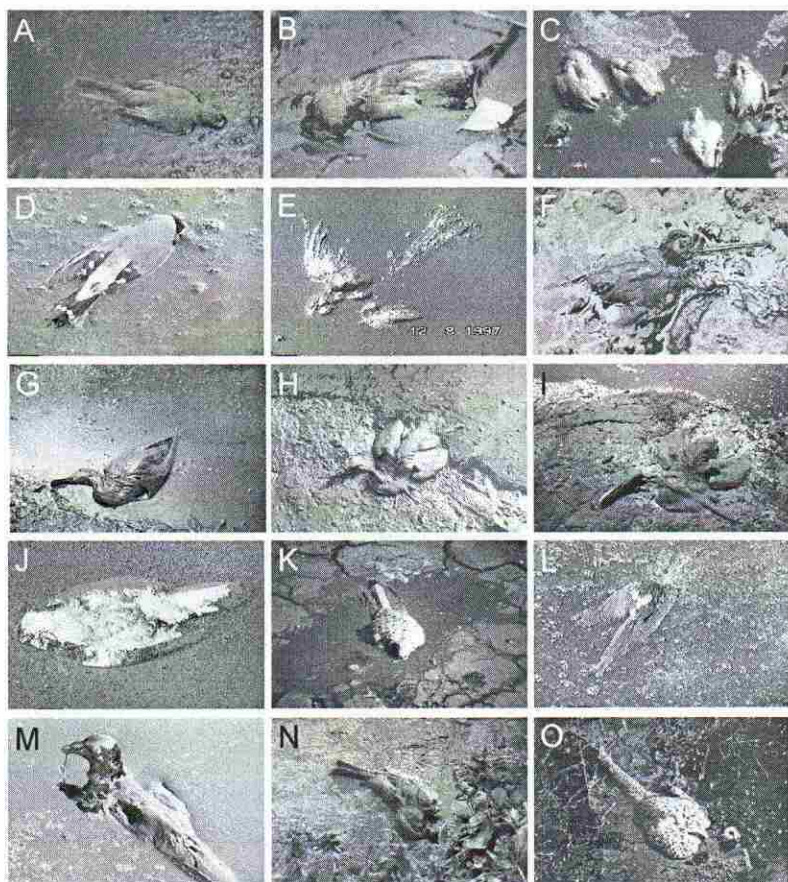


FIGURE 2 The carcasses of some typical representatives of the birds trapped by the waste oil lake in Budapest. (A) A redstart (*Phoenicurus phoenicurus*). (B) A serin (*Serinus serinus*). (C) A flock of greenfinches (*Carduelis chloris*). (D) A goldfinch (*Carduelis carduelis*). (E) A swallow (*Hirundo rustica*). (F) A snipe (*Gallinago gallinago*). (G–I) The carcass of a mallard (*Anas platyrhynchos*) immediately after trapping in September, 1997 (G), in November, 1997 (H) and in March, 1998 (I). (J) A long-eared owl (*Asio otus*). (K) A kestrel (*Falco tinnunculus*). (L) A magpie (*Pica pica*). (M) A feral pigeon (*Columba livia*) living still for some hours after trapping. (N) A house sparrow (*Passer domesticus*; by courtesy of Dr. Béla Borsa). (O) A pheasant (*Phasianus colchicus*). (See Colour Plate II at the end of the issue).

1995). They have been formed when oil wells and pipelines were blasted in the desert and the resulting spills were subsequently accumulated in more than 900 smaller or larger oil lakes. These crude oil lakes trapped thousands of different water-seeking birds (Pilcher and Sexton, 1993; Horváth and Zeil,

1996). Unfortunately, in many countries plenty of smaller or larger temporary inland spills, pools and reservoirs of crude, refused, spent or waste oil exist as a by-product of the oil industry (exploitation, transport, storage and refinery of the oil). We must not underestimate the ecological impact of the man-made oil lakes on the avifauna. We have observed that even a quite small and shallow oil spill with an area of 1 m^2 and a depth of 1–2 centimetres can trap and kill sparrow- or pigeon-sized birds.

Some ancient natural asphalt seeps in the Earth's history have acted as massive animal traps, and their fossil remains play an important role in palaeontology. Cases in point are the famous Pleistocene Rancho La Brea tar pits at Hancock Park in Los Angeles (Miller, 1925; Akersten *et al.*, 1983; Harris and Jefferson, 1985). Carcasses lying in the soft, sticky tar attracted predators and scavengers, which were trapped, too. Seven times more predator species were found than herbivore species. Bird specimens found in the tar seeps were examined by Miller (1925). Bones of 138 bird species were found, 70% (28) of them belonged to diurnal predators and owls (9). Only 5% of the bones belonged to Passerine birds, however every second species found in the tar belonged to this order. Most bird bones found in Rancho La Brea belong to recent species, only a few of them are bones of extinct birds (19 species, 13 of them are birds of prey). Similar fossil deposits associated with natural oil reservoirs are the Pleistocene tar pools at Starunia in Western Ukraine, the Talara tar seeps in Peru, and the tar pits in Binagadin near Baku in Azerbaidjan (Angus, 1973; Kowalski, 1999).

It is a general view in palaeontology that Rancho La Brea and Starunia animals might have stumbled accidentally across these tar pools, which may have been camouflaged by dust or leaves (Miller, 1925; Burchak-Abramovich, 1975; Akersten *et al.*, 1983; Harris and Jefferson, 1985). Alternatively, these asphalt seeps may have been covered by rain-water from time to time, thus attracted animals which then sank into the underlying tar, became entrapped and fossilized (Kowalski, 1999).

Our hypothesis is that water-seeking birds may be attracted to the oil by the bright reflection of light which may imitate the glitter of a water surface. Thus, the birds might mistake the oil, tar or asphalt for water. The optical cues of such smooth, shiny surfaces may be so effective that birds are visually compelled to remain in the immediate vicinity of the oil, tar or asphalt in spite of the fact that other senses signal that this is not water.

To test this hypothesis, we performed dual-choice experiments with birds in the field. We imitated the dark oil (or asphalt, or tar) by means of a huge,

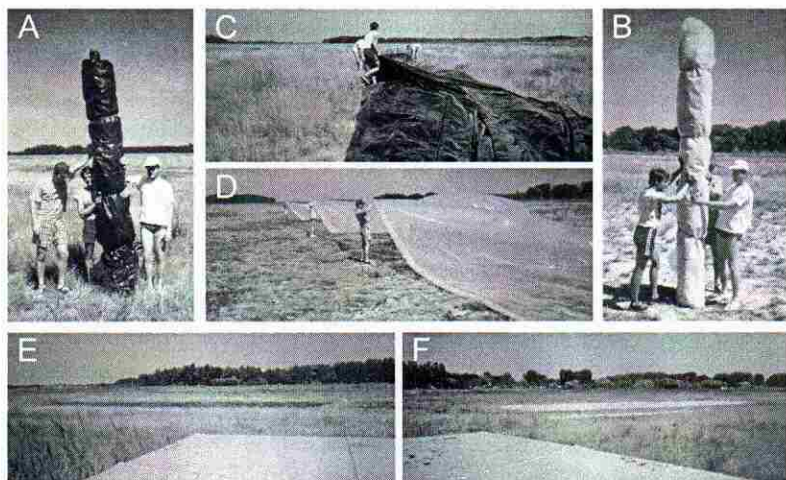


FIGURE 3 (A, B) Rolls (120 kg) of the black and the white plastic sheets used in the dual-choice field experiments. (C, D) Unfolding the black and the white plastic sheets. (E, F) The oil-lake-imitating black plastic sheet and the water-mimicking white plastic sheet laid out in the field and viewed from a hide, the top of which is seen in the bottom part of the pictures. (See Colour Plate III at the end of the issue).

shiny, black plastic sheet laid onto the ground, while the brighter surface of certain natural water bodies was mimicked by means of a huge, shiny, white plastic sheet (Fig. 3). We observed the birds and their reactions to these plastic sheets. Our goal was to learn whether water-seeking birds can be deceived by and lured to such plastic sheets in their natural habitat. If yes, which sheet is preferred by a bird, and how it responds to these dummies. The second aim of this work is to report on the behaviour of certain birds deceived by and attracted to these plastic sheets. In accordance with our expectation, certain important visual aspects of the reasons for the bird's deception by the oil could be revealed on the basis of the results of our dual-choice field experiments. Some behavioural elements of the mechanism of trapping birds by the oil could also be revealed.

MATERIALS AND METHODS

Monitoring the Waste Oil Lake in Budapest

The waste oil lake is positioned (47°27' North, 19°17' East) in the 18th district of Budapest and consists of 7 reservoirs situated within an

approximately 220 m \times 110 m rectangular area as shown in Figures 1A–C. From April, 1998 it is being removed. From 19 August, 1997 to 30 March, 1998 we surveyed every week this oil lake. Using binocular telescopes ($\times 15$), we observed the carcasses of the birds trapped by the oil, and registered their approximate position on the map of the lake (Figs. 1B and 4). The typical examples of the carcasses of birds trapped in the immediate vicinity of the shore of the oil lake were photographed (Fig. 2). The skulls of bird carcasses found on the shore were identified in the laboratory.

Dual-choice Field Experiments with Birds

Every August from 1997 to 1999 we performed dual-choice field experiments at Kunfehértó (46°23' North, 19°24' East), a village in the southern part of the Hungarian Great Plain. Two huge plastic (polyethylene) sheets (Fig. 3) measuring 20 m \times 30 m were laid on the ground in a large alkaline field at about 500 m from a smaller alkaline lake. Such plastic sheets are commonly used in agriculture. One of the sheets was black (Figs. 3A, C, E) and the other milky translucent (Figs. 3B, D, F). The lower surface of the latter dimmed in some minutes following unfolding. Since billions of tiny condensed water drops scattered the incident light diffusely, the plastic sheet became brilliant white (Fig. 3F).

The distance between the two plastic sheets was 30 m. In every experiment in the first half of the period the white plastic sheet was closer to the lake, and in the second half of the period the two sheets were transposed with each other. The vegetation beneath the sheets was mown. The sheets were stretched out horizontally as tightly as possible, and they were pinned down by bricks at the edges. Because of wind-generated wrinkles and thermal dilatation in sunshine the surface of the sheets became sometimes uneven, which was compensated by repeated spanning of the sheets, usually at sunrise, noon and sunset. Carcasses of insects larger than 5 mm were removed from the sheets. This did not disturb the observed birds, because they always rested at these hours in the surrounding vegetation. After rains the water was removed from the plastic sheets.

During the experiments we observed the birds attracted to the plastic sheets from a hide at a distance of 30 m from both sheets (Figs. 3E, F). This distance was large enough not to trouble the observed birds, and small enough to ensure the visual inspection of possible prey animals on the plastic

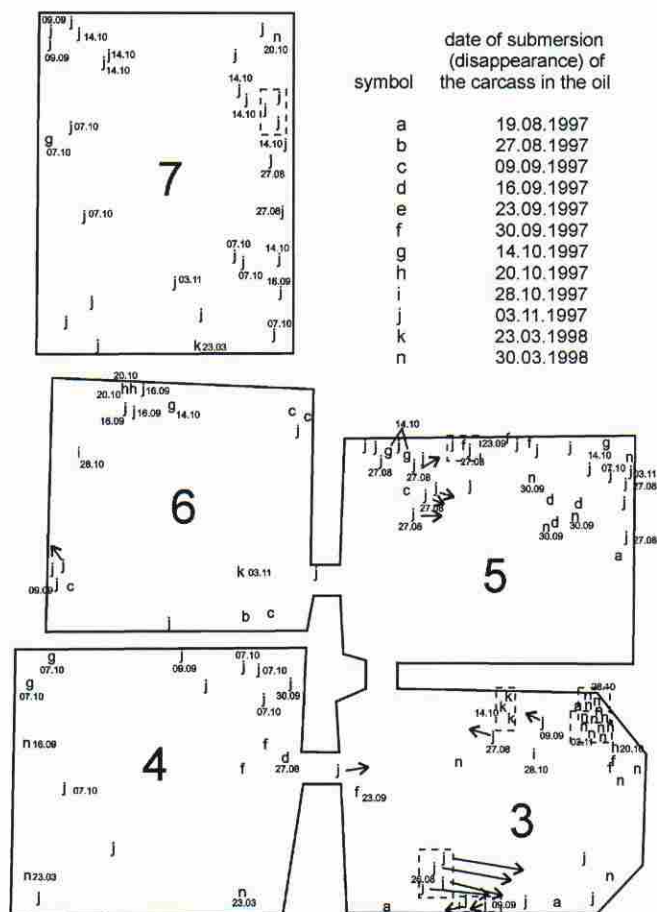


FIGURE 4 The location and time of trapping of birds on the surface of the waste oil lake in Budapest and the time of submersion (disappearance) of their carcasses in the oil from 19 August, 1997 to 30 March, 1998. The position of the letters indicates the approximate site of the trapping on the map of the oil lake estimated visually by binoculars. The date beneath a letter gives the time (day, month) of trapping. Lack of space the year is not indicated on the map. The period from August (8th month) to November (11th month) belongs to 1997, and March (3rd month) belongs to 1998. The time of disappearance of the carcasses in the oil is coded by the different letters as shown in the table of the top-right inset. The arrows represent the direction of the slow drift of certain carcasses due to the convection of the oil in the reservoirs. The carcasses of birds within rectangles drawn by broken line belong to the same flock.

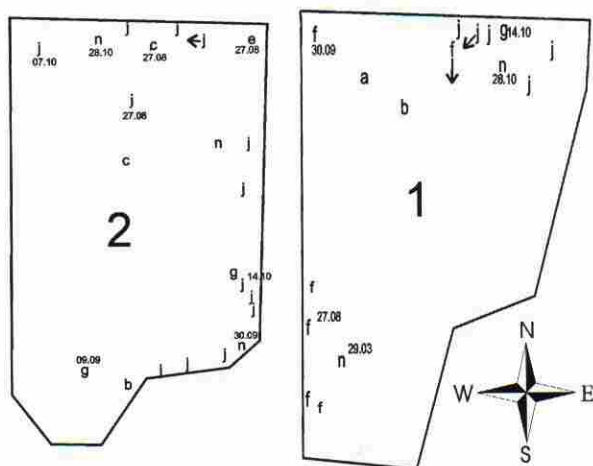


FIGURE 4 (Continued).

sheets. Every August from 1997 to 1999 the observations lasted 2–3 weeks, every day from 05:00 to 20:00 hours by changing the observers over at noon. Using a telescope (Kowa TSN, x60 zoom), we checked both plastic sheets continuously looking for possible preys (*e.g.*, insects, lizards or frogs) for birds. From 40–50 m with our telescope we could observe any object larger than about 1 cm on the plastic sheets. We could observe that there were not any such animals on the plastics during the time the observed birds landed and/or walked on them.

In earlier studies, the optical characteristics (brightness, colour, degree and angle of polarization) of the black and white plastic sheets (Horváth and Pomozi, 1997; Horváth *et al.*, 1998; Kriska *et al.*, 1998) used in the dual-choice experiments were measured and compared with those of oil lakes (Horváth and Zeil, 1996; Horváth *et al.*, 1998) and natural water bodies (Horváth and Varjú, 1997; Horváth *et al.*, 1998; Kriska *et al.*, 1998). On the basis of these measurements we could establish the following: (1) The optical characteristics of the shiny black plastic sheet were practically the same as those of wet, marshy soil; dark, deep water bodies; and black oil surfaces. (2) The optical characteristics of the shiny white plastic sheet were very similar to those of bright-bottomed shallow clear water bodies; and turbid white (*e.g.*, alkaline) water.

Dual-choice Experiment with Captive White Storks

Using plastic sheets, in the Wild Bird Rehabilitation Farm of the Hungarian National Park of Hortobágy (called "Góré's tanya", 47°37' North, 20°46' East) in the eastern part of the Hungarian Great Plain we performed a four-day dual-choice experiment with three captive white storks (*Ciconia ciconia*) in August, 1997. The adult and experienced storks got damaged through electric shocks, street accidents or storms, for example, and were rehabilitated at the farm. We could experiment with them under controlled conditions.

The reactions of the storks to a white and a black, rectangular, shiny plastic sheet of 50 m² were observed. The plastic sheets were placed on the ground in the middle of a walled off space of 50 m × 50 m. The distance between the sheets was 10 m. The storks were always released at a point equally distant (20 m) from both plastic sheets, then their reactions to the sheets were recorded by a video camera. The periods spent by the storks on the plastic sheets and outside them were registered. During the dual-choice experiment there was not any prey animal on the plastic sheets.

RESULTS

Characteristics of the Waste Oil Lake in Budapest and the Carcasses of the Birds Trapped by the Oil

The reflectivity of the surface of the waste oil lake in Budapest (Figs. 1A, C) has a characteristic seasonal cycle: Similarly to the crude oil lakes in Kuwait (Pilcher and Sexton, 1993; Horváth and Zeil, 1996), in summer the surface of the waste oil lake in Budapest is usually flat and shiny as shown in Figure 1D. This is disturbed only rarely by rainfall or cool weather. The viscosity of the oil remains low due to the great thermal inertia of the oil mass. The oil keeps its fluidity also in cooler periods, consequently, the denser rain-water sinks down in the lighter oil. Thus the shiny and flat appearance of the black oil surface remains a characteristic feature throughout the warm months (from April to September). In autumn the oil surface becomes gradually dull (Fig. 1E) as the air temperature decreases and the oil becomes more viscous. In winter the surface of the lake becomes matt and wrinkled, and rain-water accumulates in small pools on it (Fig. 1F). Then the oil surface looks like gluey asphalt if it is not covered by snow.

We have observed that similarly to other asphalt seeps, tar pits or crude oil lakes, the waste oil lake in Budapest deceived, lured and trapped different birds in large numbers. Figure 2 shows the carcasses of some typical representatives of the trapped birds. Figures 2G–I shows the carcass of a mallard (*Anas platyrhynchos*) immediately after trapping in September, 1997 (Fig. 2G), in November, 1997 (Fig. 2H) and in March, 1998 (Fig. 2I). The level of the oil lake gradually decreased from year to year due to evaporation and percolation of the oil into the soil, so that the carcass of the mallard became exposed on the shore (Figs. 2H, I). Then the carcass impregnated with oil has mummified and been preserved.

If a carcass sank to the rain-water layer (of about 1–2 m) underlying the thick (5–6 m) oil layer, it decayed, because its soft parts rotted in the water and only the bones remained. If the submersion of a carcass was not quick enough (see Fig. 5A), its decay already began on the surface because of rotting or due to carrion-eating insects. The latter, too, have been frequently trapped by the oil during such attacks.

The guards at the waste oil lake often witnessed that entire flocks of mallards, swans and other water fowls landed directly in the middle of one of the seven waste oil reservoirs. Then, all of these birds perished quickly. We could observe five times that pigeons landed on the shore of the oil lake, tried to drink from the oil, became trapped by it (Fig. 2M) and perished within some hours.

Figure 4 represents the locations and times of the trapping of birds on the surface of the waste oil lake. It is clear from this figure that birds were trapped by the oil predominantly in the immediate vicinity of the shore. The reason for this, maybe, that water-seeking birds usually landed on the shore and became trapped while tried to drink from the water-imitating (gluey, sticky) oil. This might have happened to every land-bird (e.g., pigeons, sparrows) and shore-bird (e.g., snipes), who tried to drink or forage from the waste oil lake on its shore. The carcasses of typical water birds (e.g., mallards) occurred frequently also in the vicinity of the bank (see the mallard in Figs. 2G–I, for example). These birds had the same fate as the land- and shore-birds mentioned.

We observed a slow drift of the carcasses due to the thermal convection of the oil in the reservoirs and because of the flow of the oil between the neighbouring reservoirs. We could observe drifts always more or less parallel to the shore line. Drifts of the carcasses normal to the shore were never observed. This can be explained by the fact that the thermal convection of

the non-transparent oil in reservoirs always resulted in flows parallel to the shore. Thus, the greater frequency of occurrence of carcasses in the vicinity of the shore cannot be explained by the thermal convection of the oil in the reservoirs. This phenomenon could only have been the result of flows normal to the shore line.

In the middle of the oil reservoirs generally water birds (*e.g.*, mallards, swans), or birds of prey (*e.g.*, owls, kestrels) could have been observed. The water birds probably landed directly in the middle of the oil surface as they frequently do on real water surfaces. Swallows frequently drink from water during flight (Figs. 7B, C), or gather mire in spring (Angera and Rose, 1989). The swallow carcasses observed in the waste oil lake might have been trapped during such drinking manoeuvres or during trying to gather mire. The black oil and the soil impregnated by oil can be easily mistaken for mire. The carcasses of birds of prey were equally frequent both in the middle of the oil lake and in the vicinity of the shore. These birds might have been trapped when they tried to drink on the bank or to catch a carcass of a bird trapped earlier.

In some cases several (3–12) carcasses of birds of the same species were positioned in a relatively small area (of 1–2 m²). These birds probably formed a flock, because they were observed at the same visits. The positions of these carcasses are framed by rectangles drawn by broken line in Figure 4. The largest flock composed of 12 green finches (*Carduelis chloris* marked with *n* in Fig. 4) was found in the north-east corner of reservoir 3 of the waste oil lake. A few carcasses belonging to this flock was observed on 28 October, 1997 and the rest on 3 November, 1997. These birds probably tried to drink from the oil. Insects lured to the oil surface also could be attractive to insectivorous birds, like wagtails (*Motacilla* sp.). In another paper (Bernáth *et al.*, 2001) we report in detail on the insects deceived by and attracted to oil surfaces and shiny black plastic sheets.

Figure 5A shows the number of birds trapped by the waste oil lake in Budapest as a function of the time from trapping to submergence (TTS). The TTS value of a carcass depends predominantly on the viscosity of the oil, which is the lower, the higher the average air temperature. Thus, in summer smaller TTS values occur than in spring or autumn. This phenomenon may influence the attractiveness of the oil lake to birds of prey due to the less number of carcasses in summer floating on the surface. In winter the waste oil is so stiffened that the carcasses do not submerge in it. We have observed that the carcasses of birds, that were trapped in December, 1997, submerged in the oil only in March, 1998. The number of these bird carcasses are

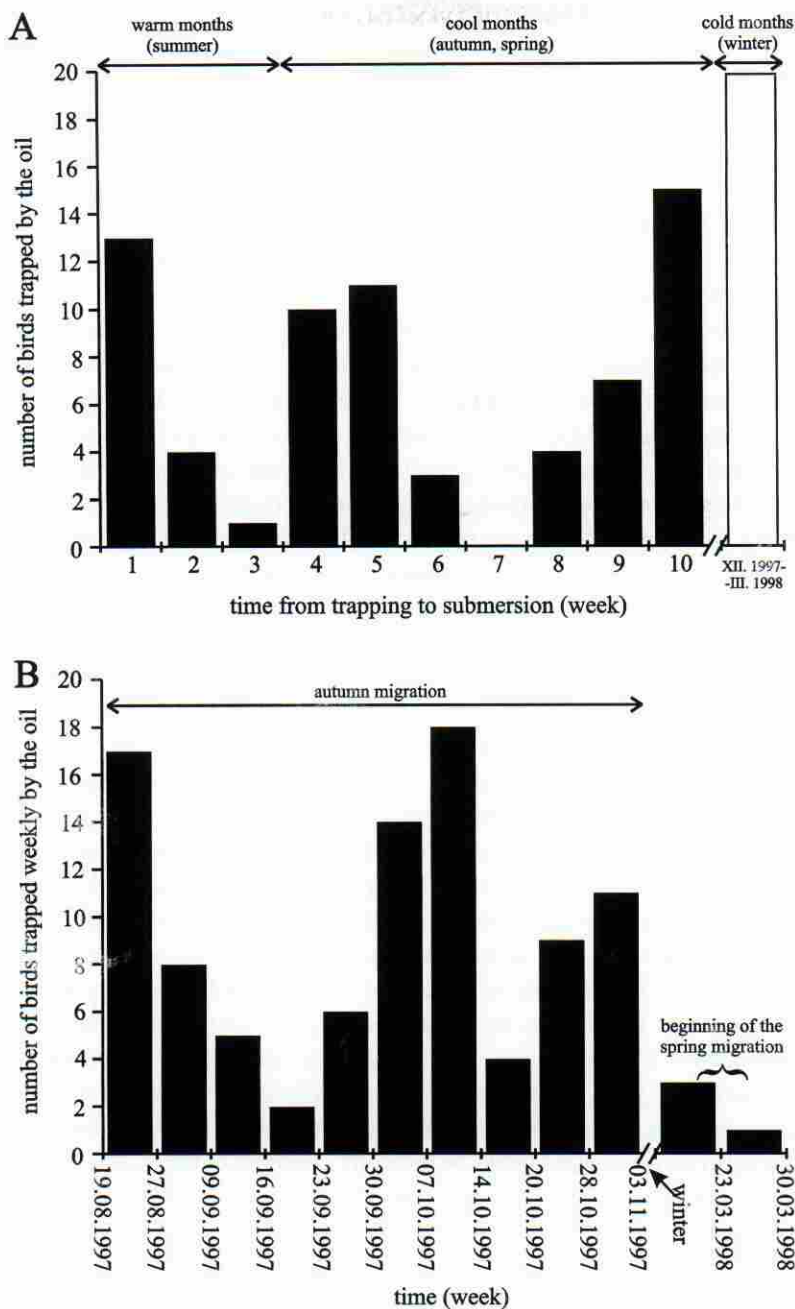


FIGURE 5 (A) Number of birds trapped by the waste oil lake in Budapest as a function of the time from trapping to submersion (disappearance). (B) Number of birds trapped weekly by the oil as a function of the time from 19 August, 1997 to 30 March, 1998.

represented by the white column of the diagram in Figure 5A. We can see in Figure 5A that there are three different characteristic values of the TTS: In the warm months of summer the carcasses submerged in the oil within 1–2 weeks. In the cooler months of spring and autumn certain carcasses sank within 4–5 weeks, while others within 9–10 weeks. The carcasses that have not been submerged in autumn remained on the surface of the stiffened oil in the cold months of winter.

Figure 5B represents the number of birds trapped weekly by the waste oil lake as a function of the time from 19 August, 1997 to 30 March, 1998. We can see that the diagram in Figure 5B has three peaks at 19–27 August, 7–14 October and 28 October–3 November. These peaks are in the autumn migration period of birds in Hungary. The two columns at the right hand side of the diagram in Figure 5B indicate the beginning of the spring migration in March. The expected main migration periods in spring (from April to May in Hungary) could not have been observed in the increase of the number of carcasses trapped weekly by the waste oil lake, because the removal of the lake began in April, 1998.

Let us estimate the number of birds trapped by the waste oil lake in Budapest during the 50 years of its existence. At the beginning of our monitoring, on 19 August, 1997, we counted 83 bird carcasses on the surface of the oil lake. Unfortunately, the time of entrapping of these birds is not known. However, in 1997 from 19 August to 24 November, that is during 104 days, we registered 98 new bird carcasses on the oil surface. Thus the number of entrapped birds during 50 years is $50(\text{years}) \cdot 365(\text{days}) \cdot 98(\text{days})/104(\text{days}) \approx 17200$ supposing that the number of entrapped birds is proportional to the time. If we take into consideration that in winter, from the beginning of December to the end of February birds were practically not trapped by the oil lake, the number of days in a year when birds could be trapped is 275 rather than 365. In this case, the number of entrapped birds during 50 years is $50(\text{years}) \cdot 275(\text{days}) \cdot 98(\text{days})/104(\text{days}) \approx 12950$. These numbers may underestimate the number of entrapped birds, because (i) smaller bird carcasses could be difficultly observed in the middle of the waste oil reservoirs, and (ii) several bird carcasses could submerge in the oil between two consecutive (weekly) inspections.

Although it is clear that the number of weekly or monthly entrapped birds has a seasonal change, the above estimations can be considered as a relatively good approximation. Thus, from 1951 the waste oil lake in Budapest could trap about 13–17 thousands birds. The numbers of the different entrapped

bird species cannot be estimated, because in most cases we were not able to identify the partly submerged carcasses observed by binoculars on the huge surface of the waste oil lake.

Birds Responding to the Plastic Sheets in the Dual-choice Field Experiments

We observed a variety of flying birds, who approached the plastic sheets in 3–10 metres on the wing. Such birds included wood pigeons (*Columba palumbus*), little ringed plovers (*Charadrius dubius*), greenshanks (*Tringa nebularia*), snipes (*Gallinago gallinago*), black-headed gulls (*Larus ridibundus*), lapwings (*Vanellus vanellus*), black kites (*Milvus migrans*) and marsh harriers (*Circus aeruginosus*). They circled or flew along low-altitude loops directly above one or both of the plastic sheets at a height of 1–2 m.

During our dual-choice experiments crested larks (*Galerida cristata*), white storks, wood pigeons, swallows, house martins, sand martins, lapwings, gulls, wagtails (*Motacilla alba*, *Motacilla flava*), starlings (*Sturnus vulgaris*) and a great white egret (*Egretta alba*) landed in the immediate vicinity (0.2–3 m) of the plastic sheets. These birds sometimes looked at the plastic sheets, stood or walked about, sought for prey or foraged in the surrounding grass, rested, plumed, watched, defecated near the plastic sheets, sometimes in their immediate vicinity, within 2–5 decimetres. Considering the white and the black plastic sheet, we could not establish any preference of these birds. Wagtails gathered on the plastic sheets and fed on the insects lured to the sheets every morning and evening, as observed at natural water banks (Davies, 1977). These birds were seen mostly on the black plastic sheet.

During one of the choice experiments (in 1997), flocks composed of several hundreds of starlings landed on the field where the plastic sheets were laid on the ground. They walked about in the grass and foraged the insects. In the meantime, plenty of them approached the plastic sheets within 5–10 centimetres, but did not step onto them, neither tried to drink from the plastics. Sometimes hundreds of starlings surrounded both plastic sheets, but they avoided and simply walked round them during foraging. This observation was important, because among the birds landing in the immediate vicinity of the plastic sheets the starlings were the only species, which avoided the sheets.

The most important events were the landings of certain birds on the plastic sheets. Table I summarizes these birds and their behaviour observed in the choice experiment in August, 1997. These birds were deceived by and attracted to the plastic sheets, and if did not occur any environmental disturbance, they stepped onto them or even landed directly on them, like at a real water surface. Apart from the great white egret, in the other choice experiments performed in 1998 and 1999 practically the same bird species and similar reactions and behaviour of them were observed as those in 1997 (Tab. I). Below we describe in detail the most important reactions and the behaviour of the birds observed on the plastic sheets.

Behaviour of a Great White Egret

We observed a Great White Egret (*Egretta alba*) to return five times to the white plastic sheet and land three times on it whereas it stepped and walked on the black plastic sheet twice. The reactions of the egret to the plastic sheets are summarized in Table I. The egret always flew to the white plastic sheet (Fig. 6A). After landing at or near the edge of the white plastic (Fig. 6B), it stepped onto the sheet, where it stood or walked about (Fig. 6C), frequently picked the plastic or stroke off with its bill, plumed itself, rested, watched, sought for prey, "fished", gazed the white surface with its neck bowed down, looked around, defecated, or even sat down. In spite of any tactile, olfactorial or thermal experience the egret behaved quite similarly on both of the plastics as at real water surfaces (Hancock and Elliott, 1978; Hancock and Kushlan, 1984).

The egret was apparently deceived, because we heard and saw that it pecked at the plastic sheet. Once, "fishing" on the white plastic and reaching its edge (Fig. 6D) the egret passed through the field between the plastic sheets (Fig. 6E) towards the black plastic and stepped onto it. It walked about on the black plastic for some minutes (Fig. 6F) while gazed the dark surface, sometimes stroke off or "fished", however, it crossed the plastic rather quickly. When the bird reached the edge of the black plastic sheet it began to preen on the grass, and finally flew away. After transposing the black and white plastic sheets, the egret landed twice again first on the white plastic sheet. It is remarkable that once the bird stayed for 90 minutes on the white plastic, and showed the same reactions and behaviour elements as earlier. Thereafter the bird visited the black plastic sheet for some minutes, and then flew away (Tab. I).

TABLE I The birds landing on the white and the black plastic sheet during the dual-choice field experiment in August, 1997 apart from the wagtails (*Motacilla alba* and *Motacilla flava*), who were attracted to the plastic sheets many times in every day. The behaviour of the birds, the time (day, hour, minute) of their arrival, and the weather conditions are also enlisted

Bird	Behaviour	Time	Weather
1 crested lark	landed on the white plastic, then flew to the black plastic; flew away in 2 minutes	5th day, 08:10	sunny, breeze, clear sky
1 greenshank (<i>Tringa nebularia</i>)	landed on the black plastic; chased and picked up insects; walked and stood about at the edge of the plastic	6th day, 06:34– 06:47	sunny, calm, clear sky
1 black kite (<i>Milvus migrans</i>)	landed next to the white plastic at a distance of some m; went to the plastic, nodded, tried to drink; stepped onto the plastic, nodded again, tried to drink again; flew away	6th day, 19:13	sunny, calm, clear sky
swallows	a large flock flew about both plastics; chased and caught insects in a low-altitude flying; landed repeatedly on the white plastic for some minutes	7th day 16:30	sunny, breeze, clouded sky
1 great white egret	landed at the edge of the white plastic; stepped onto it; flew away in some seconds	7th day 17:00	sunny, breeze, clouded sky
house martins (<i>Delichon urbica</i>)	a large flock hunted prey about the plastics; several birds landed repeatedly on both plastics; the wagtails drove them away	7th day, 9:24– 19:56	sunny, breeze, clouded sky
1 great white egret	17:36 – landed next to the white plastic and stepped onto it; walked about; stroke off with its bill; looked for prey; 'fished'; gazed the plastic bowed down; looked around with head high up 17:46 – reached the edge of the white plastic; crossed the grass between the plastics; walked to the black plastic 17:48 – stepped onto the black plastic; walked about; neck and head was usually high up; crossed fast the plastic 17:51 – reached the edge of the black plastic; stood about on the grass; plumed; looked around 17:58 – flew away	10th day, 17:36– 17:58	sunny, breeze, clouded sky
1 great white egret	18:03 – landed next to the white plastic and stepped onto it; walked about; picked the plastic with its bill; stood about; watched; plumed; rested 18:33 – sat down; stood up; stood about; defecated 19:25 – flew to the black plastic; walked about; picked the plastic with its bill 19:32 – flew away	12th day, 18:03– 19:32	sunny, calm, clear sky

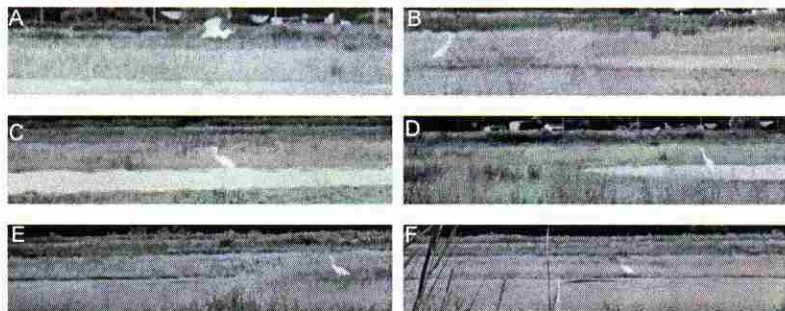


FIGURE 6 A visually deceived great white egret (*Egretta alba*) attracted to the white (A–D) and black (E, F) plastic sheet and photographed from a hide. (A) The bird approached the white plastic sheet on wing. (B) It landed in the immediate vicinity of the white plastic sheet. (C) The egret approached the white plastic sheet and stepped cautiously onto it. The bird walked slowly round about on the white plastic sheet. It frequently pecked the white plastic, stroke off with its bill, sought for prey, “fished”, gazed the surface with its neck bowed down. (D) Reaching the edge of the white plastic sheet, the bird became aware of the black plastic sheet. (E) It passed through the field between the plastic sheets towards the black plastic and stepped onto it. (F) It walked about on the black plastic sheet for some minutes then flew away. (See Colour Plate IV at the end of the issue).

Since we did not see any prey animal on the plastic sheets during the time the egret walked on them, the attractiveness of the plastics can be explained only by visual cues, because the other characteristics (temperature, smell, mechanical properties, *etc.*) were quite different from those of real water. The reactions to the plastic sheets of the egret might be explained in such a way that egrets often forage in shallow water where they can fish and catch prey. Shallow waters are usually brighter than deeper ones. Wading birds rarely fish in deeper, that is, darker waters (Hancock and Elliott, 1978; Hancock and Kushlan, 1984). The five visits of the egret at the plastic sheets, especially its sojourn of 90 minutes in one of the five occasions on the white plastic convinced us of its keen interest aroused and captivated by the plastics. The behaviour of the egret demonstrated that the bird was probably deceived by the water-imitating optical cues of the white plastic sheet, and the bird, undoubtedly, mistook the white plastic sheet for water.

Because only the optical characteristics of the plastic sheets were approximately common with those of real water, the egret was probably attracted to the plastic by the reflection of light. This optical cue was strong enough to strain the egret to react upon the plastic dummies quite similarly as upon natural waters (Hancock and Elliott, 1978; Hancock and Kushlan, 1984). Although this was observed only at a single egret, this observation

is important, because it may explain how oil lakes attract wading birds. We propose that the deceiving capability and attractiveness of these oil lakes to water-seeking birds may be explained by the shiny appearance of their surface. These birds might be deceived by the reflected light, which may imitate them the glitter of a water surface. The egret observed in our dual-choice experiment seemed to prefer the white plastic sheet to the black one. From this we may conclude that the water-specific behaviour might have been elicited in the observed bird by phototaxis.

Behaviour of Swallows

Every day, swallows (*Hirundo rustica*), house martins (*Delichon urbica*) and sand martins (*Riparia riparia*) showed the same behaviour above the plastic sheets (Fig. 7A) as above real water surfaces (Angera and Rose, 1989): Approaching one of the plastic sheets, the swallows stroke off, swept

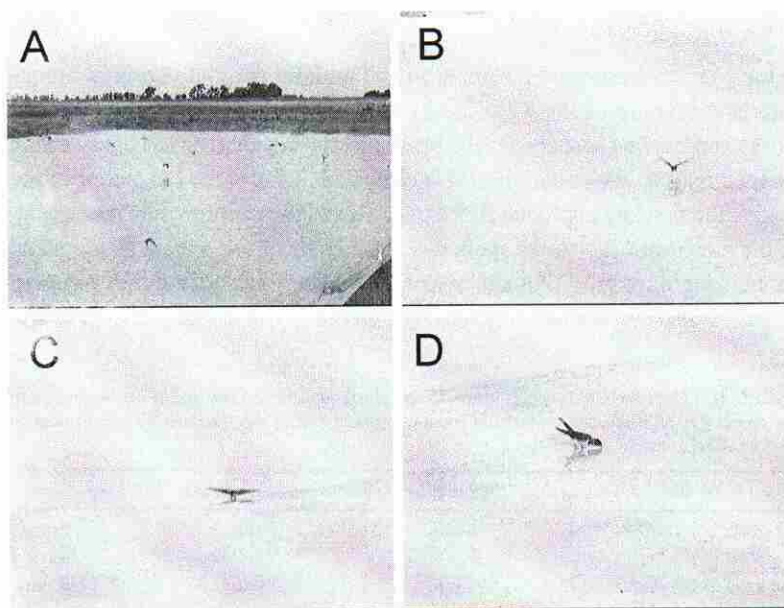


FIGURE 7 (A) A swarm of swallows (*Hirundo rustica*) deceived by and attracted to the shiny white plastic sheet used in the dual-choice experiments. (B, C) A typical drinking-manoevre of a flying swallow: on wing it tried to drink from the water-imitating white plastic sheet. (D) A characteristic drinking-attempt of a swallow: it landed on the white plastic sheet, bowed down and tried to drink from the plastic. (See Colour Plate V at the end of the issue).

parallel to the surface in a low-altitude flying (in such a way that their wings frequently rubbed against the plastic), in zigzagged flight chased insects flying above the plastic sheet, or tried to drink (Figs. 7B–D). Reaching the edge of the plastic sheet they mounted up again, described some loops and turned back continuing their flight above the plastic sheet.

Sometimes only a single swallow appeared above the plastics, but generally a large flock (composed of several tens of individuals) produced the above-mentioned behaviour. Often in air attacks, the swallows were driven away by white and yellow wagtails, who were also attracted to the plastic sheets. The swallows flocking above the plastic sheets sometimes landed and stayed for some minutes on them. On the white plastic sheet they always tried to drink, while on the black plastic they pecked the surface as if tried to gather mire. We could not establish any preference of the swallows: they landed on both plastic sheets approximately with the same frequency.

Behaviour of White Storks

In the choice experiment at “Góres tanya” initially we could observe a characteristic aversion of the white storks to both of the plastic sheets. All three storks approached first always the black plastic, began to observe it and then stepped onto it. We could observe a typical element in the behaviour of the storks: the first shy approach to the plastics and the cautious step onto them. In the meantime, the storks spent their time in the grass, where they walked about, sought for prey, plumed, rested, or watched around, but they returned to one of the plastic sheets repeatedly, especially to the black one (Tab. II).

TABLE II The time (in minutes) spent on the plastic sheets and the number of approach to the sheets by the three white storks (*Ciconia ciconia*) during the dual-choice experiment in August, 1997

Bird	Black plastic sheet	White plastic sheet	Grass	Sum
1st stork	16 min 7	4 min 5	15 min —	35 min 12
2nd stork	3 min 5	1 min 2	54 min —	58 min 7
3rd stork	17 min 16	8 min 8	43 min —	68 min 24
sum	36 min (22.5%) 28 (65.1%)	13 min (8.1%) 15 (34.9%)	111 min (69.4%) —	160 min 43

In the beginning the storks kept looking at the black plastic sheet only walking up and down along its border in the grass. Then, they suddenly stepped onto the plastic. One of the storks performed a characteristic “water-probe” on the black plastic (Figs. 8A–C): the bird flew carefully over the plastic touching sometimes the unknown surface with its legs. After this probe the bird could realize, that it can walk on the plastic without any danger. All three storks also behaved typically at the first encounter with the black plastic sheet: the birds stepped onto the border of the plastic with a cautious, dragged-out movement. At the latter encounters with the black plastic sheet similar cautious step-on of the birds was not observable: then they stepped onto the plastic always without any hesitation.

The storks behaved on the black plastic sheet always typically: They rummaged the plastic surface and performed frequent “scissoring” with their bill in the meantime (Fig. 8D). Such scissoring is a characteristic behaviour of the storks and is performed when they seek for prey with their bill in the

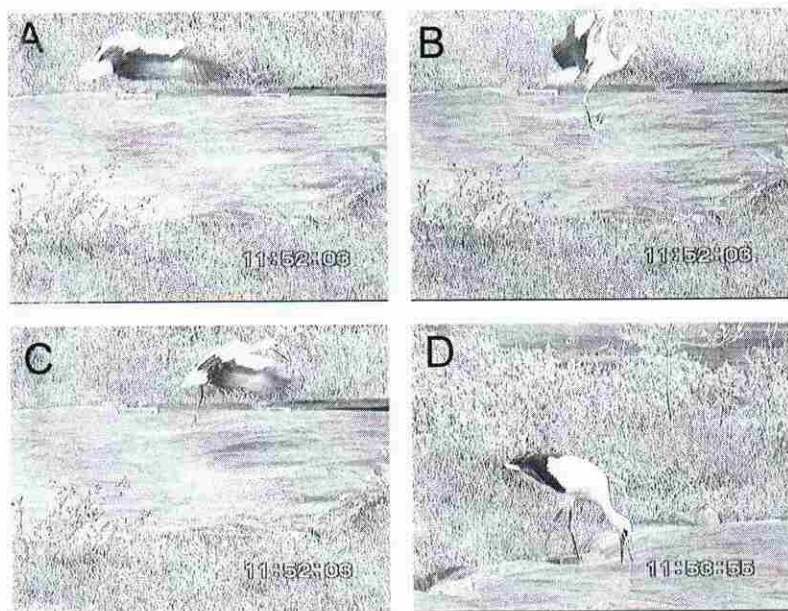


FIGURE 8 Some typical reactions of white storks to the black plastic sheet. (A–C) A characteristic “water-probe”: the bird flew over the plastic sheet touching carefully sometimes the surface with its legs. (D) A typical “scissoring” with the bill on the shiny surface. (See Colour Plate VI at the end of the issue).

mud using tactile cues (Hancock *et al.*, 1992). From time to time they stood or walked about, plumed, rested, scratched, watched, sought for prey, gazed the black surface with their neck bowed down, looked around, or defecated.

The behaviour of the storks at the white plastic sheet was different from that at the black one. After the approach of the white plastic, they did not step onto it. Instead, they walked up and down along the edge of the plastic (Fig. 9A), gazed it, poked and pecked it repeatedly with the bill. After such a hesitation they stepped first always onto a brick at the border of the plastic, and gazed from there the shiny white surface (Fig. 9B). They toddled about on the brick, and started to plume instead of stepping onto the plastic. Toddling and pluming (or comfort activity) are typical displacement activities (Lorenz, 1981), which may arise because of the conflict of the following two, highly activated and antagonistic motivations: (i) the turbid and bright water-imitating shiny white plastic sheet might have been optically attractive

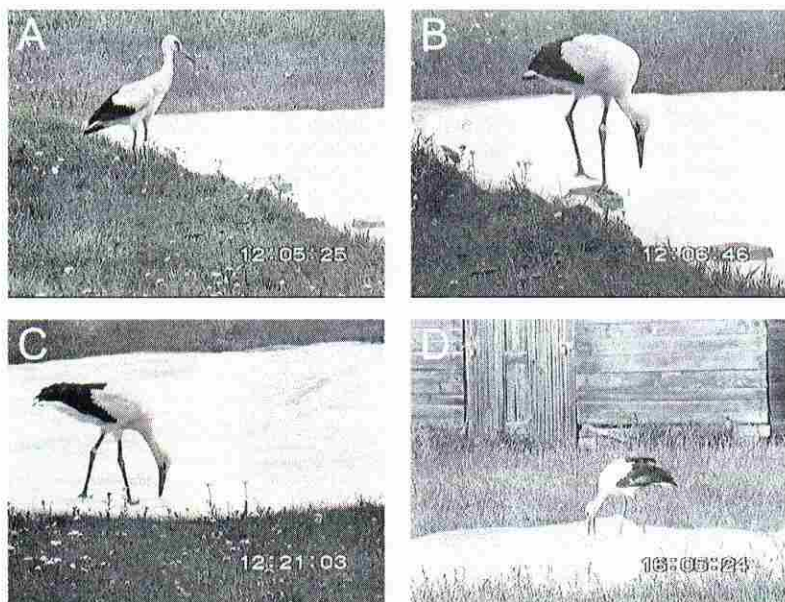


FIGURE 9 Some typical reactions of white storks to the white plastic sheet. (A) Watching the plastic sheet and a typical initial aversion from it. (B) Toddling about on a brick at the border of the plastic sheet and gazing the shiny white surface. The bird hesitated to step onto the plastic sheet. (C) Walking about and rummaging the plastic sheet with the bill. (D) A typical "scissoring" with the bill on the plastic sheet. (See Colour Plate VII at the end of the issue).

to the storks, however, (ii) they did not step onto it, because the depth of the mimicked water body could not be visually estimated.

The hesitation of the storks performed at the white plastic sheet was the same as the initial behaviour at an unknown water body with a turbid water: generally the storks do not wade at once into such a water, because they cannot estimate its depth (Hancock *et al.*, 1992). The white plastic sheet could imitate to the birds a bright but turbid water, the depth of which could not be visually appraised. Standing and toddling about on the brick, the storks touched several times the white plastic sheet with one of their legs, and at the end they stepped onto it. In contrast to the black plastic sheet, at the latter encounters with the white plastic similar careful step-on of the birds was observed: they stepped onto the white plastic henceforward always with hesitation, in spite of the fact that later they should have already been familiar with it. In our opinion, this demonstrates that in spite of their tactile experiences the optical cues of the white plastic (mimicking a bright and turbid water) caused their hesitation.

When the storks stayed on the white plastic sheet, they began to walk about on it (Fig. 9C) and in the meantime performed sometimes the above-mentioned scissoring with their bill (Fig. 9D). This was, however, not so frequent as on the black plastic. They butted and poked rather repeatedly the white plastic. This more frequent poking shows that the storks might regard the white plastic as a deeper water rather than a mud, else the scissoring should have been dominated. Usually, storks scissor with their bill only in the mud of the bottom of shallow waters. If the water is deeper they strike off the aquatic prey with their bill (Hancock *et al.*, 1992). The butting of the white plastic could mean such a strike attempt. Another function of this poking may be an attempt to drink or even a tactile probe of the strange, water-imitating white plastic sheet.

The results of the dual-choice experiment with the white storks are shown in Table II. It is worth mentioning, that the birds spent 69.4%, 22.5% and 8.1% of their time on the grass, the black and the white plastic sheet, respectively. Hence, the black plastic sheet was approximately three times as attractive as the white one.

DISCUSSION

Our dual-choice field experiments show that many different water-seeking birds can be deceived by and attracted to the shiny, water-imitating surface

of the plastic sheets. The behaviour of these birds are surprisingly similar to their behaviour at real waters. The visual cues of our plastic sheets elicited typical water-specific responses in the birds. Our observations during the dual-choice field experiments support the hypothesis that the smooth, shiny open-air oil surfaces mimic water or mud and attract among others water-seeking birds. The optical cues of these shiny surfaces are so strong that birds are visually compelled to remain in the immediate vicinity of the lakes in spite of the fact that other senses signal that these are not water. The consequence is that the deceived birds try to drink from the oil, or land directly on the oil surface, or wade into the oil, or try to catch the insects attracted to the oil surface. All these reactions have the unfortunate consequence that the deceived birds touch the sticky, gluey oil and become trapped by it. The trapped birds perish necessarily within some hours: (i) they simply get drowned in the oil, or (ii) they are poisoned by the oil, because the oil is swallowed or absorbed through the skin; or (iii) they suffer a heat-stroke [using a thermometer, we experienced that the temperature of the topmost (few decimetres) layer of the black oil can be as high as 70–75°C in sunshine]; or (iv) they die of hunger and thirst, because they cannot fly away.

We observed that the birds deceived by the shiny plastic sheets could learn in more or less time and after tactile contacts that the plastic sheets are not water and it is not worth visiting them further on. Of course, these birds neither get trapped by the plastic sheets nor perished (died of hunger or thirst) on them, but all deceived birds contacted both the white and the black plastic sheets at least once. Such a contact with the sticky oil would be enough to be trapped or to become oiled, the necessary consequence of which is death. This makes every open-air oil reservoir extremely dangerous for water-seeking birds.

Beside the water-seeking birds there are two other groups of birds, the members of which are in danger of being trapped by the oil: Birds of prey (*e.g.*, owls, kestrels) belong to the first group that can easily be trapped by the sticky oil if they try to feed on carcasses being trapped. This is the reason why we could observe birds of prey in the waste oil lake in Budapest. In the Pleistocene Rancho La Brea tar pits birds of prey dominated (Miller, 1925; Akersten *et al.*, 1983; Harris and Jefferson, 1985). Also these birds have been trapped by the tar when they tried to feed on the carcasses of other trapped animals. In all likelihood, these birds are attracted to the oil surfaces by the sight of the carcasses rather than by the optical cues of the

light reflected from the oil surface. The composition of the fauna of fossil birds in different localities with fossil tar pits is different. For instance, in the Talara tar seeps in Peru the duck *Anas bahamensis* is the dominant species, but from every deposits approximately hundred or more bird species were described (Kowalski, 1999). Insectivorous birds belong to the second group which learned that the oil reservoirs offer a good source of prey due to the insects attracted to the oil surface. These insects, their behaviour and trapping are described in another paper (Bernáth *et al.*, 2001).

What are the optical cues of the oil surface that deceive and attract the birds observed? Unfortunately almost nothing is known about the water detection mechanism in birds. Birds can theoretically be deceived by the brightness, colour and polarization of light reflected from the oil surface. Certain migrating birds possess polarization sensitivity and during migration they orient on the basis of the celestial polarization pattern if the sun or the stars are not visible (Able, 1993). Similar sensory capability is, however, not studied in many other birds, especially not in water birds. In our dual-choice experiments the observed birds (apart from the storks) preferred the white plastic sheet, which was less polarized than the black one, and its direction of polarization was predominantly vertical. Thus, these birds might find and detect waters by means of the brightness rather than by the polarization of reflected light. Nevertheless, the possibility of water detection by means of polarotaxis is not precluded in certain birds associated with water.

The reported deceiving capability and attractiveness of the shiny, dark oil or tar surfaces in Binagadin, Budapest, Kuwait, Rancho La Brea, Starunia and Talara are in accordance with the common observation that some water birds (*e.g.*, grebes or ducks) are often deceived by dry or wet, shiny, dark grey asphalt roads. These birds are frequently observed by field ornithologists to land on such roads, in our opinion, because they might mistake them for water channels. Young, inexperienced kestrels (*Falco tinnunculus*) were observed to perform typical bathing movements on a white, polished marble sheet (Lorenz, 1981); they apparently mistook visually the shiny marble surface for water surface. In arid fields some birds (*e.g.*, larks) can be lured by a sphere, the surface of which is covered by small pieces of mirrors (Tamás Székely, Centre for Behavioural Biology, School of Biological Sciences, University of Bristol, personal communication). These birds might be deceived by the mirror-reflected light, which may imitate them the glitter of a water surface.

CONCLUSIONS

On the basis of our observations at the waste oil lake in Budapest and during our dual-choice field experiments we may conclude the following:

1. Water-seeking birds can be visually deceived by and attracted to shiny plastic sheets in the field. They apparently mistake the shiny surface of these plastic sheets for water or a wet muddy surface. At the plastic sheets the deceived birds show quite a similar behaviour as at natural water bodies or muddy areas. The black plastic sheet can well mimic the optical characteristics of dark or deep water bodies or of dark and wet muddy areas, while the white plastic sheet imitates rather a shallow, bright and turbid water.
2. A black kite tried to drink from the white plastic sheet. A great white egret preferred the white plastic sheet to the black one. From the reactions of these birds we conclude that they believed the white plastic sheet to be bright and shallow water.
3. Swallows considered the plastic sheets unambiguously as water, or feeding, or mire-gathering place. During flight or after landing, they tried to drink mainly from the white plastic sheet. They hunted the attracted insects more frequently above the black plastic sheet. Sometimes they landed near the plastic sheets or directly on the black plastic sheet and tried to pick up some pieces of mire or on the white sheet and tried to drink.
4. The behaviour of wagtails at and on the plastic sheets was the same as that at real water bodies or wet muddy surfaces (Davies, 1977). Wagtails preferred the black plastic sheet. The black plastic sheet was three times as attractive to white storks as the white plastic, and the storks spent more time on the black plastic than we could interpret it as a random moving. In addition, the storks made such movements with their bills as it is observable at the birds searching in the mud. We think they believed the dark, sparkling plastic surface such kind of feeding place, namely wet, dark and muddy area. From the behaviour of the storks we have to draw the conclusion, that they believed the white plastic sheet light and turbid water, the depth of which could not be estimated.
5. In our dual-choice experiments apart from the wagtails and storks, the deceived birds preferred the white plastic sheet. The behaviour of swallows on the black plastic sheet was different from that on the white plastic, but these activities were always connected with water. Since the black

plastic was a more effective polarizer than the white plastic, which, on the other hand, was much brighter, the water detection in these birds may be based on the brightness of reflected light.

6. Starlings avoided the plastic sheets if they landed directly close to them in the grass. Such land-birds generally avoid the water during their daily activities.
7. Our dual-choice field experiments showed that the optical cues of the shiny surface of open-air oil reservoirs may be so strong that water-seeking birds are visually compelled to remain in the immediate vicinity of the oil in spite of the fact that other senses signal that it is not water. Thus, the deceived birds try to drink from the oil, or land directly on the oil surface, or wade into the oil, or try to catch the insects attracted to the oil surface. The consequence of all these reactions is at least a single contact with the sticky oil, which is enough to be trapped or to become oiled, the necessary aftermath of which is death. That is why all open-air oil reservoirs are so extremely dangerous for water-seeking birds.
8. Birds of prey are also in danger of being trapped by the oil when they try to feed on the carcasses of other trapped birds. Also insectivorous birds are endangered to be trapped, which try to catch the insects attracted to the oil surface.
9. The study of the visual ecological impact of oil surfaces on the avifauna is the prerequisite of the necessary environmental protective measures that should be urgently taken in order to eliminate any man-made oil spills and open-air oil reservoirs. The dangerous impact of these waste, crude, refused and spent oil reservoirs to birds is demonstrated by the estimation that the waste oil lake in Budapest trapped about 13–17 thousands birds during the 50 years of its existence.

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