Short communications

A note on flight disorientation over smooth water

This note arises from a fortuitous observation of many dead birds on a peninsula in Lake Magadi in 2000 by IP. When it was mentioned to Alan Root (pers. comm.), he recalled that as far back as the 1960s and since, he had seen many dead birds not normally associated with aquatic habitats on nearby Lake Natron's shores, and suggested that they were casualties of low-level flight over smooth, glassy water. He also recalled another supporting observation for this explanation: in 1962 he camped on the edge of a small soda lake in Ngorongoro Crater frequented by Lesser Flamingos *Phoeniconaias minor*. The night had been still and cloudless, with a full moon. Flamingoes sometimes descend from height by zig-zagging down at high speed. Many did so on this occasion, and periodically there was a loud smack as one of them hit the water with considerable force. In the morning their corpses dotted the surface.

In 1967, one of us (IP) had flown as low as he could over very smooth water on Lake Magadi to test another pilot's assertion of how difficult it was in such circumstances to judge height. Without reference to a shoreline, ripples or floating objects, it was indeed difficult to judge height and the closer to the surface the harder it became. This experience strongly supported Alan Root's contention.

Here we posit the following hypothesis. When absolute calm prevails over a body of water its surface becomes a mirror, radically changing its reflective properties. A rippled surface scatters light from which the eye creates a real composite image that is easy to see and to avoid, even from above. As a mirror, there are no irregularities from which a real image can be formed. All that is visible is the virtual image created by the reflection of the day or night sky above. There being no image of the surface, it becomes invisible to any organism that relies on sight for orientation. Birds and insects flying low over a lagoon cannot see it, hit the water and drown. In lakes Magadi and Natron they are quickly pickled in the saturated carbonate solution. They do not decompose and, due to the brine's density, do not sink but float just under the surface (binocular searches of the major lagoon did not reveal anything protruding above the surface), or become embedded in the trona (a mixture of sodium carbonate and sodium hydrogen carbonate) as it precipitates out of evaporating water.

The outline of Lake Magadi, southern-most of Kenya's Rift Valley lakes, is presented in Figure 1. Numerous hot

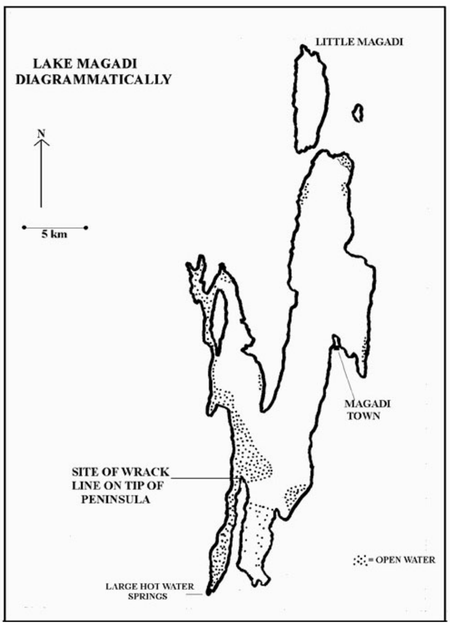

Figure 1. Outline of Lake Magadi.

(40°– 86° C), intensely alkaline springs and seeps continuously charge it from below and around the shoreline with sodium carbonate brine. Evaporation precipitates trona from the brine as a greyish white or pink deposit. Usually, this trona comprises most of the lake's 100 km^2 surface. Rarely, after heavy and prolonged rain, open water may briefly cover the trona to a depth of ± 30 cm so that the entire lake surface appears as open water. More normally, open water is a small fraction of the area, as shown in Figure 1.

Where lake edge spring and seep inflows have temperatures <42° C and a pH of *c.* 9, the shoreline and water support a specialized flora and fauna adapted to these extreme conditions, which host many birds that make Magadi a well-known birding hotspot (Bennun & Njoroge 1999).

Away from the immediate vicinities of such inflows, evaporation concentrates the carbonates, raising the alkalinity beyond the point at which life can exist. In periods of absolute calm these lifeless lagoons form mirrors, the extent of which varies widely over time (Fig. 2). The largest and most persistent of them exists in the southern half of the lake as indicated in Figure 1. Literature on Lake Magadi that may bear on the disorientation hypothesis was summarized from, among others, Bennun & Njoroge (1999), Spawls & Mathews (2012), and Google Earth.

On 20 May 2000 a large deposit of storm wrack between 0.5 and 1 m wide, 0.1 and 0.3 m high and *c.* 200 m long was found on the eastern shore of the tip of a peninsula that projects northward into the largest lagoon (hereafter 'the major lagoon') from the lake's southern end

Figure 2. Eight satellite photographs of the southern end of Lake Magadi from Google Earth, spanning the years 1986–2016. These illustrate variations in the expanse of open water, and changes in the shape of the lagoon, the protrusion of the peninsula into this lagoon and how its tip acts as a windward shore upon wind-blown wrack from the east can be trapped. Note that, as in 1986, the tip was sealed off by trona.

(Fig. 1). This wrack, composed of dry salted insects and birds, had blown ashore in a storm several days earlier. At the time, only cursory observations were made while IP intended to return quickly to make a more detailed record and analysis. Unfortunately, a return was not possible for several months, by which time it had been dispersed.

The volume of the wrack was estimated at 30 m^3 (0.75 m x 0.02 m x 200 m) and consisted overwhelmingly of insects laced throughout with birds. Arbitrarily assuming an average insect volume of 18 cm^3 (6 cm x 3 cm x 1 cm) and an average bird volume of 150 cm^3 (10 cm x 3 cm x 5 cm), and further assuming there were 100 insects to every bird, the wrack line could have held 1.7 million insects and 17 000 birds.

Recognizable invertebrates were primarily flying insects of the orders Orthoptera (particularly a large brown grasshopper or locust), Coleoptera, Lepidoptera and Hymenoptera. The vertebrates were almost all birds, and those identified are listed in Table 1 at least to family level in three subjective categories: abundant; common; and single. As their remains had been bleached and feathers or body parts were lost, identifications erred on the side of caution and were only made with certainty to family. Some genera and a lesser number of species were recognized. Identifications were made more to illustrate the spectrum of types that had drowned than to establish species. They are supported by photographic examples in Figure 3.

Among the 19 bird families listed in Table 1, only three—Phoenicopteridae, Glareolidae, and Scolopacidae—are waterbirds regularly frequenting Magadi. *Falco amurensis* is a Palaearctic visitor that appears seasonally in the vicinity of the lake. All the others are typical of the semi-arid acacia savanna surrounding Lake Magadi. However, the birds listed are only a fraction of the birds expected in that environment (e.g., Zimmerman *et al*. 1996), and are unlikely to have been exhaustive of those in the wrack line. Missing from Table 1 are waders, which are abundant on Lake Magadi, and birds that can swim (e.g., Cape Teal *Anas capensis*). Perhaps they have evolved mechanisms for avoiding disorientation, or it may simply mean that they can swim, and fly off the water. Interestingly, among the insects, the freshwater belastomatids that rely on emergent vegetation or access to a shore to exit water were among the casualties.

Between September 2000 and December 2010 five further visits were made to the lake. Although the large quantity of dead animals seen on the first occasion was not seen again, the shore on the same windward tip of the peninsula always yielded some dried, salted birds and a greater number of insects. Searches along windward shores of other lagoons elsewhere in Lake Magadi and one helicopter trip to the larger soda Lake Natron, also produced scatterings of salted birds and flying insects.

The prevailing easterly winds produce a gradual drift of drowned animals towards the eastern side of the peninsula or past it to the main lake's west shore. The springs and seeps along the western lake edge lower the alkalinity sufficiently for tissue decomposition and consumption by the fish *Alcolapia grahami*. On the peninsula where there are no springs or seeps, pickled specimens washed ashore remain until rain dissolves the salts and they decompose or are scavenged. Occasionally, a strong overhead storm can drop enough water to exhume birds and insects from the trona to rejoin those that were still floating, which may account for the unusually large number washed ashore in May 2000.

A terrestrial shrew, a rodent, scorpions and a guineafowl egg were presumed to have been washed into the lake during heavy rain. The echo-locating bats are likely to have missed the surface because it reflected their sound pulses away when these

Figure 3. Salted birds recovered from the windward shores of lagoons on Lake Magadi, identified to family or genus.

were emitted at oblique angles (pulses directed down at obtuse angles would produce strong echoes back to their source, but as would be the case in a fast flying bat, pulses directed ahead obliquely would produce no echo as a property of mirrors is that incoming radiation whether light, sound or radio is deflected away at the same angle at which it comes in).

Table 1. Birds recognized among Lake Magadi's pickled casualties. Ascription to family, genus and species was only made where certain. Column 1 = abundant, 2 = many, and 3 = singles.

Family	Genus	Species	Common name	1	2	3
Phoenicopteridae	*Phoeniconaias*	*minor*	Lesser Flamingo		x	
Accipitridae	*Elanus*	*caeruleus*	Black-shouldered Kite			x
Falconidae	*Falco*	*amurensis*	Amur Falcon		x	
Phasianidae	*Coturnix*		quail			x
Phasianidae	*Francolinus*	*sephaena*	Crested Francolin			x
Turnicidae	*Turnix*	*sylvatica*	Common Buttonquail		x	
Glareolidae	*Glareola*		pratincole			x
Scolopacidae	*Calidris*		stint, probably Little			x
Columbidae	*Streptopelia*		dove		x	
Tytonidae	*Tyto*		owl, probably Barn			x
Apodidae			swift		x	
Colidae	*Urocolius*	*macrourus*	Blue-naped Mousebird		x	
Phoeniculidae			wood-hoopoe, green?			x
Capitonidae	*Lybius (?)*		barbet			x
Alaudidae	*Eremopterix*	*leucopareia*	Fischer's Sparrow-lark	x		
Motacillidae	*Anthus*		pipit		x	
Hirundinidae	*Hirundo*		swallow		x	
Sylvidae	*Cisticola*		cisticola		x	
Ploceidae	*Ploceus*		weaver		x	
Ploceidae	*Quelea*	*quelea*	Red-billed Quelea	x		
Viduinae	*Vidua*		whydah			x

The frequency of an event such as that recorded in May 2000 is moot. It might have resulted from an unusual combination of an exceptionally violent wind and heavy rain after a long period of accumulating pickles—both those floating and washed out of recently deposited trona—and unusual only in the sheer volume of the wrack line. The presence of smaller numbers of salted birds and insects on the peninsula in subsequent years and on other windward shores elsewhere indicate the process was ongoing. It is tempting to speculate that the large wrack event was the result of accumulating pickles over the period 1992 to May 2000 when the large lagoon had persisted for eight years. However, the rate at which casualties accumulate is also moot and awaits further elucidation.

The difficulty of sensing smooth water surfaces not only influences flying birds, insects and aviators, but high divers. For example, the Australian Diving Association's Hand Book Section FR 5.3.10 states, "Mechanical surface agitation shall be installed under the diving facilities to aid the divers in their visual perception of the surface of the water," confirming our central point.

If our hypothesis is valid, and disorientation is a general feature of flying low over smooth water, it may be a source of hitherto unsuspected mortality for flying animals generally. It only became apparent in situations such as Magadi and Natron because the casualties were preserved, float and do not decompose as would quickly happen in freshwater. As an aside, it might explain the early European belief that Barn

Swallows *Hirundo rustica* hibernated underwater in mud (White 1813). All it needed was a fisherman once finding drowned swallows in his net as the strand of truth that established a myth arising in disorientation over smooth water.

We hope that this record will stimulate other researchers to investigate more methodically what might be a source of hitherto overlooked avian mortality.

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