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Why does sea-migrating salmon (*Salmo salar* L.) leap?

by

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Abstract

The purpose of this paper is to suggest one possible explanation for the behaviour of Atlantic salmon (*Salmo salar* L.), leaping out of the water, during its sea migration. The eye of salmon is adapted to underwater vision, but it is still possible that salmon may in air see out of focus silhouettes of land above the horizon. The suggested explanation, based on this possibility, is as follows: 1) The salmon postsmolts leap from the water to orient themselves visually away from land. 2) Similarly, but the other way around, the adult homing salmon orient themselves toward land visually, by leaping out of the water. - This way of orientation could lead to errors, however, and weather conditions and photoperiod do not always allow visual guidance. This way of guidance is thus suggested here as just one of several means that the salmon may use to orient themselves.

Introduction

The leaping behaviour of salmon, especially when passing over waterfalls, has interested anglers and other naturalists for centuries. According to Babcock (1930), the very name "salmon" is derived from the latin word "salio" to leap. The purpose of some of these leaps in the river is easily understood as good spawning grounds are often separated from the sea by weirs and waterfalls. But salmon breaks the surface of the seawater too, both during the first days of its sea-migration as postsmolt and also during the last days of the sea-migration, when the maturing adult salmon is homing in on its river of origin. The explanation of the leaping behaviour in the sea however, is not as straight forward as the leaps near waterfalls in the rivers.

Research on leaping behaviour has almost solely been concerned with leaping in rivers, often with the aim of bettering passes or fishways (Stuart 1962). A short survey of the litterature revealed only one paper on leaping behaviour in the sea (Babcock 1930).

The remarkable orienting ability

All scuba divers are familiar with the difficulty to orient themselves underwater. Fish are probably many times better suited and better equipped to orient themselves in water than men are. It still is difficult to see how the postsmolts find their way, when they are over bottom depths of more than 50 meters, when the visibility in coastal seawater is usually limited to only 5-20 meters. How do they find the direction away from land, out of a complicated fjord system? It similarly is hard to understand how the adults manage to home in on small islands like the Faroe Islands, from feeding grounds that may be hundreds or even thousands of kilometers away.

It is true that other fish find their way in the sea and migrate with precision over long distances too. But those migrations are often guided by prevailing currents that transport the eggs, larvae and juveniles passively to the feeding grounds (Harden Jones 1968). The mature adults can then use the same currents, or counter-currents, for guidance back to the spawning grounds. A similar way of current orientation has even been suggested as the main means of migration guidance for the Icelandic salmon (Mathisen and Gudjonsson 1978).

Of the possible orienting aids of fish, many have been suggested, but few proven. Some of these clues may be helpful for the migrating postsmolt, such as currents (Harden Jones 1968), chemical clues such as feromones (Hasler 1966), celestial bodies (Hasler et al. 1958, Hasler 1966), geomagnetism (Metcalfe et al. 1993) or even infrasound (Sand and Karlsen 1986). In the study area, however, frequent winds and the strong tidal currents keep the uppermost 20-30 m well mixed at all times (Thorisson and Sturlaugsson 1995). Currents and chemical clues are probably of limited use in such circumstances. Also, the complicated topography of fjords may necessitate large changes in swimming direction (even U-turns), which makes the use of the sun, geomagnetism and infrasound as orienting aids extremely difficult. One should keep in mind that the postsmolt has no previous experience with the surroundings it is migrating through.

The purpose of the present paper is to suggest a possible explanation for the graceful behaviour of salmon leaping out of the seawater. To support this hypothesis some new data from recent salmon postsmolts research in West-Iceland are presented. Material and methods have already been described (see Thorisson and Sturlaugsson 1995, Sturlaugsson and Thorisson 1995).

Results and discussion

In order to assist their migration at the beginning, the salmon postsmolts from the Silfurlax ranch are always released at high tide. The salmon postsmolts migrate fast out of Kolgrafafjord as can be seen from the decreasing catch of nets with increasing time from release (Table I).

Table I. Average catch of salmon postsmolts at the mouth of Kolgrafafjord in 1993 (% of released postsmolts fished / 1 km of net / hour).

Hours from release	Number of trials	% / km net / hour	Percentage of max. catch
0 - 12 h	17	0.5200	100.0 %
12 - 24 h	16	0.0123	2.4 %
24 - 48 h	6	0.0087	1.7 %
> 48 h	30	0.0003	0.1 %

According to Table I, there are only 2.4 % of the released postsmolts still inside Kolgrafafjord after one tidal cycle, which indicates active swimming out of the fjord. Salmon postsmolts from river Surna, Norway may also be staying in the estuary for only few hours (Hvidsten and Møkkelgjerd 1987). Direct measurements also show that the postsmolts are swimming at an average speed of 1.6 km per hour relative to the water (Sturlaugsson and Thorisson 1995). For a postsmolt of 15-25 cm length, this corresponds to 2-3 body lengths per second, which is close to normal cruising speed for salmon (Beamish 1978, Smith et al. 1981). Therfore the migrating pattern of the postsmolts can not deviate that much from a straigt line, even though the salmon postsmolts are migrating through areas where they have never been before.

The majority of the postsmolts would probably drift with the tide out through the middle of the mouth of Kolgrafafjord if they were not actively orienting themselves. Table II shows where at the opening of Kolgrafafjord the postsmolts were caught during 1993.

Table II. The distribution of catch of salmon postsmolts at the mouth of Kolgrafafjord 1993, as persentage of the total catch (in parethesis: number of fish caught / km net / hour). The catch data is based on the same number of net visits as in Table I.

Hours from release	West coast (floating nets fastened to shore)	Middle of fjord opening (driftnets)	East coast (floating nets fastened to shore)
0 - 24 h	62 % (293)	36 % (171)	2 % (11.4)
> 24 h	8 % (0.4)	17 % (1.0)	75 % (4.1)

More than 60 % of the salmon postsmolts went out close to the West coast, while only few fish were caught close to the East coast. Those East coast fish may not have been determined at all to migrate out to the open sea as more than one third of them were still there days later (Table II). Figure 1 shows how much more prominent the mountain at the East coast of Kolgrafafjord is, compared to the mountains of the West coast. By staying close to the high mountain at the East coast those postsmolts behaved more like adult homing salmon, and observed proportion of maturing males among these postsmolts was indeed abnormally high (Sturlaugsson and Thorisson 1995).

The data above indicate a) a fast and relatively straight migrating and b) a Westward orientation, but available evidence does not exclude other explanations for the leaping behaviour of salmon in the sea. Therefore some additional short notes will be given of supporting evidence collected during the salmon studies in Kolgrafafjord and Breidafjord during the years 1989-94 (Thorisson and Sturlaugsson 1995, Sturlaugsson and Thorisson 1995).

1) During the study, adult homing salmon was often seen leaping (inward) at several places, close to the shores of Kolgrafafjord, but more often close to the East coast. The most remote sightings were about 8-10 km away from the sea-ranching station, just outside the opening of Kolgrafafjord.

2) Postsmolts were also seen leaping (outward), the first 2-3 hours after release, at various distances from the release site. Away from the releasing site, more sightings were close to the West coast of Kolgrafafjord (Fig. 1).

3) By far the largest catch of postsmolts was caught in Breidafjord (430 postsmolts), when the driftnets were set just south of the middle of Breidafjord, about

40 km away from the releasing site. This was on an overcast day, but with exellent view to both shores, and the selected spot was where the mountains of each coast looked about equally high (Fig 1, insert).

The suggested explanation

With its strongly convex lens, the eye of salmon is adapted to underwater vision. It is possible, however, that the salmon may in the air see the horizon and the land as dark shadows above it (Stuart 1962). In this way, the salmon postsmolt would have an effective means of orienting itselves out to the open sea by always swimming away from the highest shadow or silhouette of land above the horizon. The adult homing salmon could, in a similar but reciprocal way, be attracted to the shadows or silhouettes of land above the horizon, wich could guide it to one place or another at the shore. The maturing homing salmon would then have to swim along the seashore until it finds its river of origin.

The following hypothesis is therefore suggested:

The salmon postsmolts leap from seawater to orient themselves visually away from land, probably by swimming away from the highest silhouette of land, above the horizon.

Similarly, but the other way around, the adult salmon home in on land silhouettes, visually, by leaping out of the seawater.

Notes on the hypothesis

Situations, were sight could misdirect, instead of guide the salmon postsmolt are imaginable. A high mountain, close to the opening of a fjord being an example. Also (in addition to darkness) visibility can be limited by weather conditions, although horizontal visibility is often good despite overcast. With the help of other orienting clues air sight could therefore still be useful.

When land is approached from the sea, the tip of peninsulas is first to appear over the horizon. Therfore it is interesting to note that homing adult salmon may approach land first around the tip of the peninsulas of West-Iceland (Isaksson 1994). More than, say 50 km away from the shore, mountains need to be higher than 200 m to be seen from the sea level. Farther away than this, the sun may be the best orienting clue for the salmon (Hasler 1966). Close to the river of origin, chemical clues such as feromones may be increasingly important for the homing adults, but even there, feromones may be more important as a confirmation of a right choice, than a guiding tool (Hasler 1966).

To keep itself buoyant, salmon may have to fill its swimmbladder with air by breaking the surface (Blaxter and Tytler 1978). This would, however, hardly be reason enough to jump entirely out of the water. It has also been suggested that the leaping behaviour of salmon has a delousing effect (Halla Jonsdottir personal communication). This could not be the sole reason for the leaping, however, as the salmon smolts also leap in the river on their way to the sea.

The meagre evidence presented here may all point to the use of air-sight for navigation, but other explanations are still possible. No experiments have been done to verify the above presented ideas and conditions will probably also prevent this in the foreseeable future. This alternative is thus forwarded here as a challenge for other researchers either to support or disprove.

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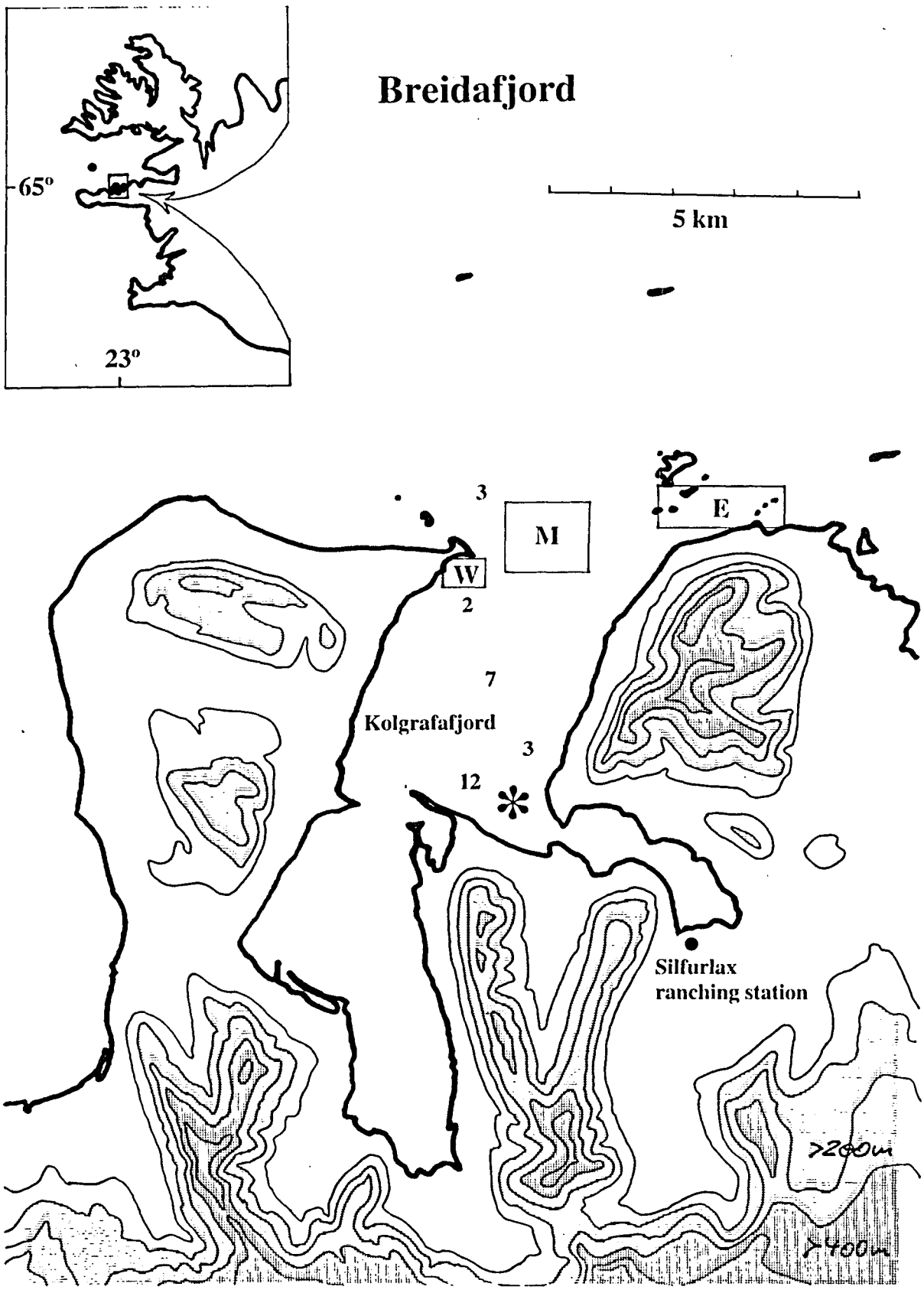

Figure 1. A map of the study area showing the location of the Silfurlax ranching station and the releasing site in Kolgrafafjord *. Each contour line denotes 100 m elevation. On the insert map, the station with the largest catch of postsmolts in Breidafjord is shown •. Boxes: W for West coast, E for East coast and M for middle of fjord opening, indicate fishing areas for salmon postsmolts. Numbers of leaping salmon postsmolts seen are also indicated. (For further information see Thorisson and Sturlaugsson 1995).