

Grayling

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Spotting Dottiness:

what is the meaning of the grayling's spottiness?

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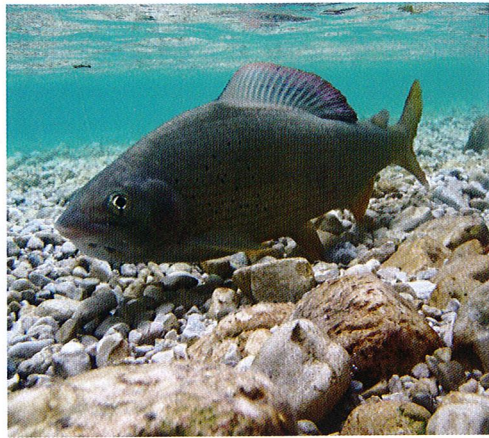
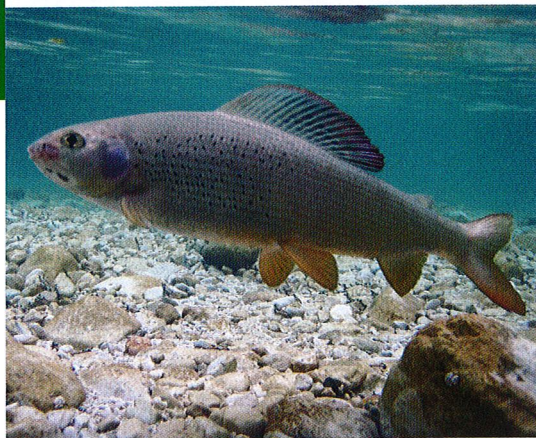
Adult graylings are characterized by conspicuous black spots on their flanks, always located on the dark lines that separate two scale lines. Such spots are generally restricted to the front half of the flanks.

Fish spots, bars and stripes play a role in camouflage and crypsis from predators, foraging strategies, territory defence and individual recognition. Additionally, there is some evidence demonstrating the essential role that spots play as a visual stimulus in the social behaviour of gregarious fishes living in groups. For example, skin colouring and patterning are used as conspicuous visual cues for intraspecific communication, may shape the behavioural interactions among individuals and signals the status of the individual. Indeed, the recognition of individuals within the same group through visual signals may be crucial for survival in gregarious fish: gregarious species tend to have stripes and spots, which are generally used by individuals to establish preferences.

Patterns of spottiness in the European grayling are intriguing. Adult individuals are characterized by conspicuous black spots on their sides (Picture 1), generally restricted to the front half of the flank and always located on the

dark lines that separate two scale lines. These spots have the potential to play an important role in communication within the fish group. Previous studies demonstrated that (i) adult spots are different from those on juveniles, which are spread all along the back of the fish; (ii) the percentage of adult fish without spots is low; (iii) the number and location of spots seems to be stable, that is the amount and disposition of spots do not change over time nor with the size of the fish (larger grayling are neither more nor less spotted than smaller ones); and (iv) the number and disposition of the spots are not symmetrical on the two sides.

Here, I present the results of a study that analysed the relationships between the characteristics of spottiness in graylings and environmental factors and individual features. When thinking on grayling's spottiness, three main, non-exclusive possibilities came to my mind: (1) there is a sexual difference in flank spottiness, which may be the result of sexual



Examples of differently spotted graylings, from a heavily spotted individual...

selection. Indeed, spottiness could be used by males to intimidate or defeat competing males, and/or could have evolved if females prefer to mate with males that exhibit elaborate traits; (2) spottiness differs as a function of the grayling's size, which could support the possibility that spots represent an honest signal of individual quality; and/or (3) spottiness is related to the (genetic) characteristics of the individual and varies as a function of the environmental variables, with the most highly spotted fish representing the most dominant individuals that inhabit the most advantageous but costly sectors of the river.

Samples

During my study, graylings were sampled from five rivers in three different countries: Unec and Soča in Slovenia, Kupa and Kupica in Croatia, and Glomma in Norway. All fish were sampled in June 2013 by means of flyfishing (dry flies only and barbless hooks). Given that one of the aims of the present work was to relate spot patterns to environmental variables, catching on a fly only those graylings rising for insects allowed me to precisely locate the fish along the river bed. Caught fish were measured and photographed immediately after capture, and then released. I measured body length (from the mouth to the fork of the caudal fin) using a ruler. Sex was determined by external morphology, particularly the size and shape of the dorsal fin: the large "sail-like" dorsal fin of the grayling is larger in males than in females, producing

notable sexual dimorphism and generally allowing easy sex identification. From each picture (one per flank), I calculated: (a) the total number of spots; (b) the number of spots per scale line; and (c) the number of spotted lines. The spatial patterns of spots on both sides of an individual were also described by three dispersion indexes, which represent three alternative methods for examining the deviation from a random distribution: (1) the index of dispersion, which under a random distribution of points is expected to equal 1; (2) the index of cluster size, which under a random distribution of points is expected to equal 0; positive values indicate a clumped distribution, whereas negative values denote a regular distribution; and (3) Morisita's Index, which is the scaled probability that two points chosen at random from the whole population occupy the same space. For the latter index, the higher the value, the more clumped the distribution.

For each grayling, I estimated six environmental variables (with an approximation of ~1m around the exact point where the fish was caught): (1) water velocity (slow, medium or fast); (2) type of river bottom (sand, sand with vegetation or rocks); (3) water depth; (4) distance from the river bank; (5) water transparency (low, medium or high); and (6) fish position in the pool/stream (head, middle or end). The head/end were considered as the very beginning/end of a pool/stream, i.e. ca. 1m after the beginning or before the end a pool/stream.



random; and (b) Morisita's index was extremely homogeneous for the whole sample, displaying similar patterns of spot aggregation among graylings.

Furthermore, length and sex of the fish did not show any effects on the characteristics and spatial distribution of spots. In addition, the spatial distribution of spots was never explained by environmental variables, which only explained (i) the number of spots, (ii) the mean number of spots per line and (iii) the number of spotted lines. Intriguingly, quantitative patterns of spots were always positively associated with the same environmental features, i.e. high spottiness was related to fast waters, greater depth and transparency (due to both water colour and type of river bottom), whereas the negative relationship between spottiness and fish position in the river demonstrated that the most highly spotted individuals tended to occupy the head of pools and streams. Thus, spottiness did not show any relationship with sex and body size, but quantitative features such as the number of both spots and spotted lines appeared to be correlated with some physical properties of the river: more highly spotted graylings seemed to generally inhabit fast and deep waters, and were positioned at the head of pools and streams.

I obtained a sample of 55 graylings (26 males, 19 females and 10 individuals of unknown sex), ranging from 100 to 870gr in weight (average = 343gr) and 18 to 43cm in length (average = 32cm). Although graylings generally showed bilateral asymmetry in the patterns of spots, there was no consistency in the direction of this asymmetry, neither for the number of spots nor for the number of spotted lines. The analyses on the spatial patterns of spots revealed that: (a) both the index of dispersion and the index of cluster size showed a distribution of spots close to



...to one with no spots at all.

The recognition that individual differences within a population represent biologically meaningful adaptive traits has raised questions concerning the circumstances that benefit different phenotypes, as well as the costs and benefits of limited plasticity imposed by more or less fixed trait associations. Melanin-based colouration, such as the black spots dappling the skin of the Atlantic salmon *Salmo salar* and rainbow trout, demonstrates that darker individuals are generally more aggressive, sexually active and resistant to stress than lighter individuals. These findings might help explain the recorded observation that more highly spotted (and consequently darker flanked) individuals occupy the most advantageous places (the head of pools and streams where, for a fish mainly preying on drifting insects, the food arrives first and is generally more abundant) and costly portions of the rivers (e.g. faster streams). This might indicate that spottiness signals the status (e.g. quality and/or dominance) of individuals, which obviously plays a role in determining the spatial arrangement of individuals along the river bed and, consequently, within the group, which may be especially important for a gregarious fish like the grayling.

Status symbol

The environment should not affect the spottiness of grayling as there is little evidence that persistent melanin-based pigment patterns arising from melanophore aggregations in fishes are subject to environmental influence.

Moreover, on the basis of previous studies, we know that there is strong heritability in the number of black skin spots and spot patterns and numbers do not change over time. Thus, spottiness may just reflect the status of individuals and, consequently, their position within the natural and social environment. The possibility that spottiness might be a status signal should be considered as an open question. Further experimental and behavioural studies are needed to support or refute this supposition. Actually, it is still unclear how a temporally fixed pattern of colouration might imply that spots function as social signals because social status may be dynamic: a dominant individual in one breeding season may not have the same social status in the next season (although high quality individuals have the potential to have a high social status for longer than low quality individuals).

Graylings continue to surprise us with their peculiarities and the information presented here is only the beginning of the path we need to follow for elucidating the function of flank spottiness and its role in regulating life within a school!

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