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Liva Lucentini [a]; Antonella Carosi [a]; Rocco Erra [a]; Giancarlo Giovinazzo [a]; Massimo Lorenzoni [a];Mario Mearelli [a]
[a] Istituto di Idrobiologia e Pescicoltura, Università di Perugia, Perugia, Italy

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Fluctuating asymmetry in Perch, *Perca fluviatilis* (Percidae) from three lakes of the Region Umbria (Italy) as a tool to demonstrate the impact of man-made lakes on developmental stability

LIVIA LUCENTINI
ANTONELLA CAROSI
ROCCO ERRA
GIANCARLO GIOVINAZZO
MASSIMO LORENZONI
MARIO MEARELLI

Istituto di Idrobiologia e Pescicoltura, Università di Perugia, via Elce di Sotto, I-06100 Perugia (Italy)

ABSTRACT

Fluctuating asymmetry (FA), the random deviation from perfect bilateral symmetry, is the basis of an acknowledged method to analyse developmental stability in animals and plants. This study investigates the fluctuating asymmetry in perch (*Perca fluviatilis* L.) from one natural lake (Trasimeno) and two regulated lakes (Corbara, Piediluco) of central Italy. Seven morphometric (pectoral and ventral fins length, pre-pectoral fin distance, pre-ventral fin distance, pectoral-ventral fins distance, postorbital distance, head length) and six meristic (lateral line scales, pectoral and ventral fins rays, mandibular pores, upper and lower gill rakers) bilateral characters were selected to detect fluctuating asymmetry. Total and standard length, weight, sex and age were employed to investigate growth of perch. On the basis of FA levels a comparison of the three lakes was then made. Statistical analysis shows a relationship between fluctuating asymmetry levels and growth, and the possibility to order the lakes according to FA levels. Therefore, FA can be considered a tool to detect stress occurring during development.

KEY WORDS: Fluctuating asymmetry - Developmental stability - Perch - Growth.

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INTRODUCTION

Bilaterality is the most widespread model of symmetry in the animal kingdom (D'Ancona, 1966) and gives the possibility to identify a single plane dividing the body in two mirror-like parts.

There are various exceptions to bilateral symmetry: directional asymmetry, antisymmetry and fluctuating asymmetry, and a frequency distribution of right-left (R_i-L_i) is used to analyse them (Van Valen, 1962, 1992).

a) Directional asymmetry - occurs when an organ or apparatus is located on one side of the body according to a genetically determined morphological organisation. It is the case of the gonads size in man, usually more developed in the right side (Leary & Allendorf, 1989). Directionally asymmetric characters exhibit a normal distribution of R_i-L_i, but the mean is significantly different from zero (Palmer & Strobeck, 1986).

b) Antisymmetry - occurs when some individuals develop a right or a left bias for a given character. A typical example is the signalling claw of fiddler crabs (*Uca uca*) whose male has one claw larger than the other, although the frequency of right- and left-handed individuals is roughly equal (Davis, 1978). Antisymmetrical traits exhibit a platykurtic (broad peaked) or bimodal distribution of R-L (Palmer & Strobeck, 1986).

c) Fluctuating asymmetry (FA) - "is the random deviation from perfect bilateral symmetry caused by developmental perturbation" (Øxnevad *et al.*, 1995) and is one of the most common manifestations of developmental mutability. FA is widely used as a measure of developmental stability (Palmer & Strobeck, 1986; Zakharov, 1992).

The evaluation of developmental stability is important mostly for the possibility to point out changes in the population's condition before their extent is such as to influence the survival of individuals (Clarke, 1992; Pankakoski *et al.*, 1992), i.e. when the conditions are still sub-lethal or sub-pathological.

Developmental stability analysis by means of FA allows to simplify the various research stages and to obtain in a short time a picture of environmental conditions influencing the population under exam. Moreover, as Clarke also reminds (1992), it is a relatively simple analysis, not too costly and applicable to a wide range of organisms and types of stress.

The basic principle of studies on FA is that the development of the two sides of a bilaterally symmetrical individual is influenced by identical genetic and environmental strains and that any casual difference of a character between the two sides of the organism (FA) could be due to disturbances occurred during development (Clarke, 1992).

MATERIALS AND METHODS

About 308 individuals of *Perca fluviatilis* were analysed to determine differences in FA levels among populations from three Umbrian Lakes.

These lakes differ greatly (Table I) and were selected for their

environmental characteristics. Trasimeno (43°09'11" N, 12°15'00" E) is a natural laminar lake characterised by a long turnover (24.4 years) and by shallow waters that do not allow the summer thermal stratification (Lorenzoni *et al.*, 1993). Corbara (42°42'00" N, 12°13'43" E) is a reservoir created between 1958 and 1963 by means of a dam built on the River Tiber for hydroelectric exploitation (Menghini, 1975). Piediluco (42°30'54"- 42°32'28" N, 0°17'21"- 0°19'17"E) is a regulated natural lake employed since 1920s for hydroelectric exploitation. It presents a nictemeral dynamics in which the water level decreases during the day and rises at night, producing a mean daily level range of 52.75 cm, with a turnover of about 0.024 years.

On the whole 117 samples from Corbara, 99 from Piediluco, and 92 from Trasimeno were analysed, of which 216 were females and 69 males.

In order to determine the growth of perch, total and standard length, weight, sex and scale for age detection (Baglinière, 1985; Baglinière & Le Louarn, 1987) were measured on every sample. Growth was analysed using length-weight multiplicative regression on data disaggregated according to sex and lake. Differences between regressions for sexes were estimated through the t-test on regression coefficient b; since significant differences were not detected, subsequent analyses were carried out on the total sample. ANCOVA and ANOVA (Camussi *et al.*, 1995) were used to compare the three length-weight regressions transformed using logarithm.

In order to define FA, seven morphometric (pectoral and ventral fins length, pre-pectoral, pre-ventral and pectoral-ventral fins distance, postorbital distance and head length) and six meristic (lateral line scales, pectoral and ventral fins rays, mandibular pores, upper and lower gill rakers) characters on the left and right side of each fish were counted. For morphometric traits, the linear regression between single trait and total length was estimated in order to exclude that larger fish exhibit greater asymmetry as a consequence of their size (Øxnevad *et al.*, 1995). Data were transformed into asymmetry values using the formula right-left ($d = R_i - L_i$) (Palmer & Strobeck, 1986, 1992; Øxnevad *et al.*, 1995). Differences in asymmetry levels between sexes were analysed with Wilcoxon's test. In order to analyse FA it was necessary to exclude alternative hypotheses, directional asymmetry and antisymmetry, since an unknown fraction of their R-L variation has a genetic basis, i.e. individuals "are genetically or developmentally direct to become asymmetrical" (Palmer & Strobeck, 1992). Directional asymmetry was excluded through the sign test, antisymmetry through the kurtosis analysis (Øxnevad *et al.*, 1995). Normality of absolute values distributions was tested using the Shapiro-Wilk's test. Since they were not normal, the non-parametric Kruskall-Wallis' test was used to compare lakes for each character and for total meristic and morphometric indexes (Palmer & Stobeck, 1986, Øxnevad *et al.*, 1995). These two indexes were made up adding the single absolute values of all the morphometric characters and of all the meristic characters. They were treated separately because they have different statistical properties and development in the various stages of development (Øxnevad *et al.*, 1995). Lakes were ranked by asymmetry level using Bonferroni's multiple comparison method (Camussi *et al.*, 1995; Øxnevad *et al.*, 1995, 1997).

TABLE I - *Principal characteristics of the three Umbrian lakes investigated (from: Di Giovanni e Prosperini, 1966; ENEL, 1989; Carollo, 1969; Italconsult, 1977).*

	Corbara	Piediluco	Trasimeno
Quota (m s.l.)	138	369	257
Surface (km^2)	15	1.7	126
Volume (m^3)	207×10^6	19.534×10^6	586×10^6
Deep-max (m)	42	22.2	6.3
Deep-media (m)	30	11.4	4.7
Perimeter (km)	55,3	15.1	53.1

CNF, curve of the cumulative number of individual first captures.

RESULTS

There was no difference in growth between sexes; male and female growths can be described by a single model, as already shown by other authors (Alessio *et al.*, 1991; Lorenzoni *et al.*, 1996). Length-weight multiplicative regressions (Table II) were analysed through ANCOVA ($F_{3;768} = 19.755$) and ANOVA (parallelism test $F_{2;768} = 15.392$) which show significant differences among lakes and the impossibility to describe them through a single model. Morphometric characters were not correlated to body size and no standardisation was necessary. Wilcoxon's test highlights differences between sexes only in the case of pectoral-ventral fins distance. This character was eliminated because of the limited number of males. Ventral fin length and postorbital distance showed directional asymmetry and were eliminated. No character was platicurtic, i.e. none showed antisymmetry with the graphical method of normal probability plot (Sokal & Rohlf, 1981). Therefore, the subsequent analyses were carried out only on ten of the original thirteen characters. The Kruskall-Wallis test shows ($P > 0.05$) no significant differences between lakes for the ten characters and for the meristic and morphometric indexes. Subsequently lakes were ranked by asymmetry level of the total meristic and morphometric indexes, showing that perches from Lake Corbara were more symmetric than the others (Figs 1, 2).

DISCUSSION

Values of the functional regression coefficient b for the length-weight regression are greater than 3 and consequently they show an allometric growth (Ricker, 1975). As Ricker (1975) points out, "the term allometry applies to changes in the ratios of linear measurements of the fish" and it is possible to use the value of coefficient b in order to detect marked differences between different populations. Overall results for the three perch populations show a non-homogeneous or not comparable growth: Corbara's population, length being equal,

TABLE II - *L-W regressions for Perch in three lakes of central Italy.*

Corbara	$P = 0.005 \times L^{3.271}$	$r = 0.976$, $R^2 = 0.953$
Piediluco	$P = 0.009 \times L^{3.112}$	$r = 0.969$, $R^2 = 0.939$
Trasimeno	$P = 0.008 \times L^{3.122}$	$r = 0.973$, $R^2 = 0.947$

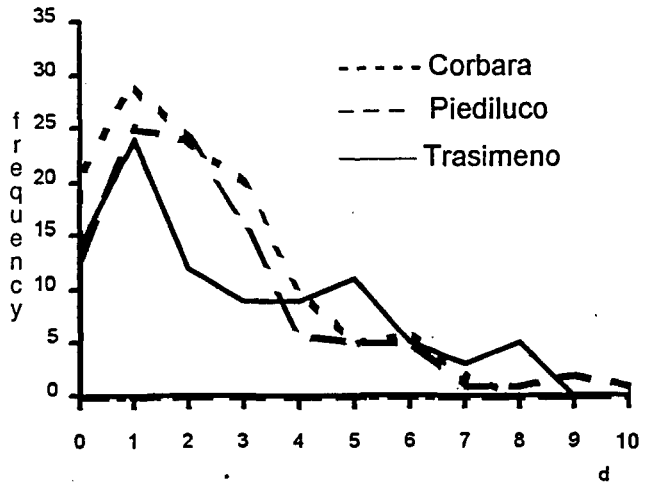

Fig. 1 - Distribution of d = Di-Li (fluctuating asymmetry levels) for the total meristic index.

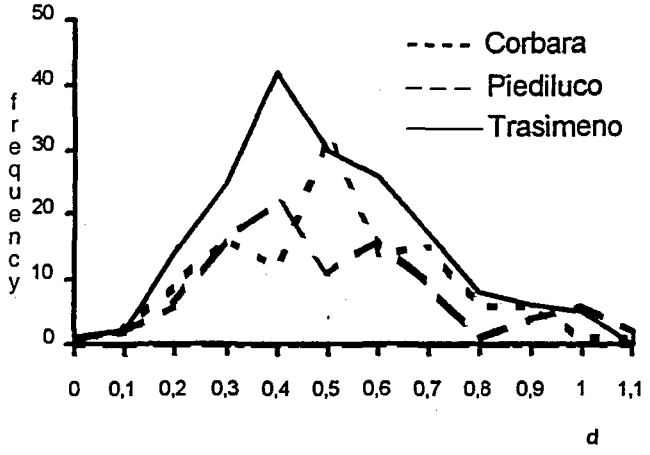

Fig. 2 Distribution of d = Di-Li (fluctuating asymmetry levels) for the total morphometric index.

grows best in weight, Piediluco's worst (Table II). The critical environmental conditions of Piediluco's perch were already documented (Giovinazzo, 1988; Lorenzoni *et al.*, 1991). Referring to the Tesch standards (Tesch, 1955), growth of Piediluco's population was been evaluated 'modest' and the one of Trasimeno 'very good' (Lorenzoni *et al.*, 1993, 1996). That is, the perch from Piediluco grows under critical environmental and nutritional conditions that may be caused by the daily dynamics of water levels, that modifies all chemical and physical characteristics.

Ranking according to Bonferroni's multiple comparison method applied on the meristic and morphometric total indexes showed that the population from Piediluco is in any case the most asymmetrical. Since FA is considered as an index of stress occurring during development, these results highlight that the critical environmental situation of Lake Piediluco is checked through the analysis of asymmetry levels. This relationship between growth and FA level, both influenced by genetic and environmental factors and indexes of the fish condition, may be the ultimate validation of the reliability of the FA method.

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