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A standard weight equation to assess the body condition of pejerrey *Odontesthes bonariensis*

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ABSTRACT: We developed a standard weight equation Ws to aid in the analysis of pejerrey *Odonthestes bonariensis* body condition over time and across populations using the relative weight index Wr. Weight - length data were compiled from 73 populations of pejerrey (N=16.022) from the Argentine pampas region. We used the regression-line-percentile technique, which provides a 75th-percentile standard by length intervals of 10 mm, to develop the Ws equation. The proposed equation is $\log_{10} Ws=-5,267+3,163 \log_{10} Lst$; Ws is weight in grams and Lst is standard length in millimeters. This equation is proposed for use with pejerrey between 120 and 520 mm of Lst. Values for Wr calculated with the Ws equation did not consistently increase or decrease as function of fish length, indicating absence of length bias. We analyze the values and distribution of Wr for pejerrey and suggest how to interpret its results. The equation of Ws that intends to calculate the index of Wr, represents a useful tool of analysis, because not only it allows to statistically compare the physical condition of the pejerrey, independently of its size, capture moment or the individual origin, but also it facilitates to relate it with other variables.

Why develop a standard weight equation for pejerrey?

In inland waters of Buenos Aires Province, the pejerrey *Odontesthes bonariensis* is the main species for commercial and sport fisheries (Thorton *et al.*, 1982). This fish is zooplanktivorous, and typically develop high-density populations in shallow lakes located in the pampean plain.

In Pampean lakes, fisheries biologists and managers have used Fulton type condition factors (K) to assess the relative plumpness of fish in a population as a current tool. However, direct comparisons of different fish populations or fish length using such indices present conceptual problems (Wege and Anderson, 1978). To overcome such limitations, Wege and Anderson (1978) proposed the use of relative weight (Wr) as an index to evaluate and compare fish condition (Wr=the ratio of a fish weight, W, to the weight standard of fish of the same length, Ws; Wr=W/Ws 100). The index utilizes

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range-wide species weight-length relationship data, and it is therefore applicable for individuals to all populations of given species. Relative weight index values allow users to perform comparative condition assessments of fish from different total length groups, facilitate comparison between populations, and avoid the inherent length and species biases of Fulton type condition factors (K). (Neumann and Murphy, 1991; Willis *et al.*, 1991). Since its creation the Wr index has been widely accepted, and it is customarily used for condition analysis of many species (Anderson and Neumann, 1996; Bister *et al.*, 2000; Blackwell *et al.*, 2000). But the applicability is limited by the availability of an appropriate database for developing the standard weight equation for the species.

The objectives of this study were to develop a standard weight (Ws) equation for Pejerrey that could be used to assess and compare the body condition of any fish, independently of the size, moment of capture, population, in order to make reliable comparisons with physiological and environmental variables.

Improvement of standard weight equation for pejerrey

Weight length data of pejerrey *O. bonariensis* obtained from 89 fish surveys in Pampean lakes were used as basic information. Fish standard lengths were measured to the millimeter whereas fish weights were taken with a digital scale with a 2g precision. Population data represented by less than 50 individuals or with a correlation coefficient, for log10 transformed weight-length regressions less than 0.90 were removed from the analyses. When data for more than one sample year were available for a particular population, we used data from the year that contained the most observations. All weight-length data were examined as scatter plots, and outliers (more than 3 standard deviations) were eliminated from subsequent analyses (Brown and Murphy, 1996; Kruse and Hubert, 1997; Neumann and Flammang, 1997; Fisher and Fielder, 1998).

The minimum length for weight precision was determined by plotting the variance-to-mean ratio for individual log10 weight by 10 mm length intervals, as suggested by Murphy *et al.* (1991). Only 120 mm or longer pejerrey were included in the further calculations because 120 mm was the inflection point at which the ratio stabilizes as a function of length (Neumann and Murphy, 1991). The maximum standard length used to develop the Ws equation was 520 mm.

The regression line percentile technique (RLP) was used to develop the Ws equation for pejerrey (Murphy *et al.*, 1990).

Log10 weight-log10 length regression equation was calculated for 120 and longer fish from 77 pejerrey populations Table 1 that met the above requirements for inclusion in the development of the Ws equation. As suggested by Neumann and Flammang (1997), we plotted individual pairs of weight-length regression slopes and intercepts detecting and removing four populations with extremes values from the Ws equation calculation.

Mean weights were predicted for the midpoints of 1 cm length intervals from 120 mm to 520 mm standard length for each population, and the 75th percentile weights (a value slightly superior to the average that represent the "optimal condition") were regressed on length to develop the proposed Ws equation.

The following Ws equation for pejerrey was calculated with the 75th-percentile RLP technique:

$$\log_{10} Ws = -5.267 + 3.163 \log_{10} Lst.$$

were Ws is the standard weight in grams and Lst the standard length in millimetres. This equation is proposed for use with pejerrey from 120 mm to 520 mm.

We calculated and regressed the Wr values for individual pejerrey as a function of fish length for each population to determine whether there was a consistent tendency for Wr values to increase or decrease as fish size increased. The total number of significant ($p \leq 0.05$) positive and negative slopes were compared using Chi-square analysis to detect consistent length-related bias.

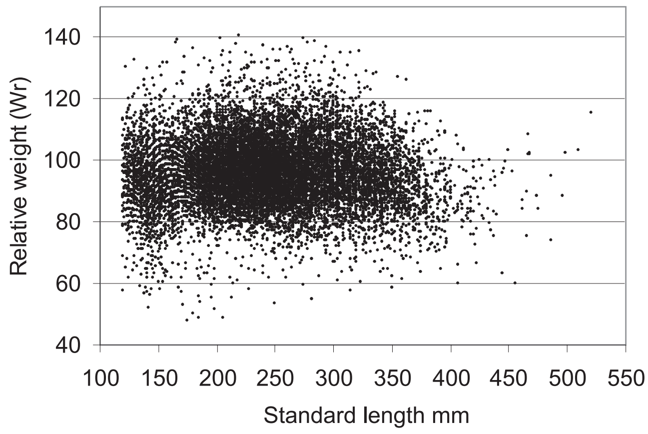

FIGURE 1. Individual relative weights of pejerrey sampled in 73 pampean lakes (N=16.022) in function of its lengths.

TABLE 1.

Sample populations by location (county, latitude lat, longitude long) and regression parameters for weight-length regression equations developed for 73 populations of pejerrey. a:intercept, b:slope, R^2: coefficient of determination, N:sample size, Max and Min: maximum and minimum standard length in population sample. All regressions were developed using common ($\log_{10}$) logarithms. Lengths were measured as standard length in millimeters and weights were measured in grams. Asterix indicates the parameters not used in Ws equation calculation.

Water body	County	Long.	Lat.	year	a	b	R^2	N	Max	Min
Alsina	Guaminí	-62.10	-36.85	1996	-5.479	3.252	0.98	285	348	121
Arrillaga	Pehuajó	-62.55	-35.68	2003	-4.996	3.049	0.97	208	373	204
Bragado	Bragado	-60.50	-35.08	1999	-5.739	3.374	0.99	109	280	121
Chascomús	Chascomús	-58.03	-35.60	2000	-5.508	3.261	0.99	387	291	120
Chasicó	Villarino-Puán	-63.08	-38.62	1997	-5.602	3.299	0.99	587	418	121
Chasicó	Villarino-Puán	-63.08	-38.62	1998	-5.478	3.251	0.99	610	398	123
Chasicó	Villarino-Puán	-63.08	-38.62	1999	-5.412	3.221	0.98	508	410	124
Cochicó	Guaminí	-62.30	-36.92	1996	-5.558	3.290	0.99	103	300	120
Cuero Zorro	Rivadavia	-62.95	-35.75	1999	-5.921	3.439	0.99	254	446	141
Curaú	Pehuajó	-62.17	-35.78	1999	-5.301	3.172	0.99	295	352	122
El Venado	Guaminí	-62.63	-37.05	1996	-5.163	3.088	0.99	145	374	122
Catuzzi	C.tejedor	-62.30	-35.40	2003	-5.130	3.107	0.98	258	373	128
Gómez	Junín	-61.12	-34.62	2001	-4.861	2.989	0.98	532	418	121
Gómez	Junín	-61.12	-34.62	2000	-5.505	3.269	0.97	183	334	131
Hinojo	TrenqueLauquen	-62.52	-35.95	1999	-5.038	3.064	0.98	408	400	132
Juancho	Daireaux-Bolivar	-61.53	-36.70	1997	-5.421	3.208	0.99	450	345	122
Cochicó	Guaminí	-62.30	-36.92	2003	-4.933	3.007	0.97	163	281	128
Lobos	Lobos	-59.12	-35.28	2001	-5.401	3.218	0.95	229	315	135
Lobos	Lobos	-59.12	-35.28	1997	-5.082	3.074	0.98	429	369	123
S.Grande	Gral.Madariaga	-56.97	-36.92	1996	-5.074	3.075	0.99	58	351	120
Cochicó	Guaminí	-62.30	-36.92	2002	-4.858	2.960	0.97	104	370	120
S.Grande	Gral.Madariaga	-56.97	-36.92	2000	-4.927	3.016	0.98	155	384	153
Curaú	Pehuajó	-62.17	-35.78	2003	-5.235	3.131	0.98	77	344	136
Monte	Monte	-58.78	-35.45	1997	-5.824	3.377	0.99	82	437	121
Monte	Monte	-58.78	-35.45	1998	-5.510	3.250	0.99	173	437	122
Salada	Pehuajó	-61.90	-35.78	1997	-5.646	3.332	0.96	149	291	122
San Luis	Bolivar	-61.05	-36.42	1997	-5.402	3.217	1.00	94	520	120
Las Tunas	TrenqueLauquen	-62.42	-35.95	1999	-4.855	2.971	0.99	403	346	120
Las Tunas	TrenqueLauquen	-62.42	-35.95	1998	-5.213	3.125	0.99	760	358	120
Lobos	Lobos	-59.12	-35.28	1986	-5.170	3.114	0.98	893	410	120
Monte	Monte	-58.78	-35.45	1991	-5.258	3.159	0.98	258	432	181
Monte	Monte	-58.78	-35.45	1997	-5.310	3.159	0.99	176	474	125
Monte	Monte	-58.78	-35.45	1998	-4.873	2.970	0.97	79	374	136
Monte	Monte	-58.78	-35.45	1991	-5.134	3.096	0.99	383	496	120
Chasicó	Villarino-Puán	-63.08	-38.62	2003	-5.280	3.178	0.98	246	462	133
Del Monte	Guaminí	-62.47	-36.98	2000	-5.051	3.073	0.99	236	400	128
Cochicó	Guaminí	-62.30	-36.92	2000	-5.129	3.107	1.00	186	325	120
Vitel	Chascomús	-58.12	-35.53	2000	-5.584	3.288	0.99	120	272	120
Del Monte	Guaminí	-62.47	-36.98	2003	-5.645	3.289	0.95	65	318	120
El Venado	Guaminí	-62.63	-37.05	2003	-4.899	2.956	0.95	223	313	120
La manga	Cnel. Dorrego	-60.7	-38.8	2000	-5.596	3.285	0.96	106	343	129
Colón	Colón	-60.9	-33.8	1996	-4.667	2.890	0.98	101	362	137
Brava	Balcarce	-57.97	-37.88	2001	-4.895	2.974	0.98	90	433	122
El palenquito	Gral. Guido	-57.88	-36.67	2004	-4.979	3.033	0.96	392	324	120
Hinojal	Chascomús	-57.80	-35.77	2002	-4.865	2.985	0.97	69	391	213
S.Grande	Gral.Madariaga	-56.97	-36.92	1995	-4.976	3.037	0.98	189	440	140
La isla	Bragado	-60.8	-35.2	2003	-5.842	3.401	0.99	59	352	162
La Tigra	9 de julio	-61.27	-35.47	2003	-4.665	2.906	0.97	113	372	196
Puán	Puán	-62.8	-37.6	1997	-5.078	3.078	0.99	152	396	123
La Tigra	C.tejedor	-62.45	-35.68	2003	-4.862	2.970	0.98	113	314	144
Norris	Cnel. Dorrego	-60.85	-38.87	2000	-5.268	3.164	0.99	211	390	123
Tamariscos	Cnel. Dorrego	-60.72	-38.80	2000	-5.744	3.340	0.99	75	424	167
El recado	Pehuajó	-61.9	-35.7	2000	-5.063	3.043	1.00	84	400	123
S.Darragueira	Puán y Alsina	-63.08	-37.55	2001	-5.446	3.216	1.00	103	468	138
Limpia	Chascomús	-57.80	-35.62	2001	-4.664	2.875	1.00	64	362	140
Brava	Balcarce	-57.97	-37.88	1999	-4.797	2.938	0.99	122	343	142
Hinojal	Chascomús	-57.80	-35.77	2002	-5.625	3.307	1.00	170	422	122
Cochicó	Guaminí	-62.30	-36.92	2001	-4.913	3.004	1.00	166	378	142
Chasicó	Villarino-Puán	-63.08	-38.62	2001	-5.433	3.221	0.99	305	395	128
Del Monte	Guaminí	-62.47	-36.98	2001	-5.247	3.125	0.99	131	331	120
El Venado	Guaminí	-62.63	-37.05	2001	-5.147	3.094	0.99	227	340	130
Paraiso	Laprida	-60.8	-37.6	2004	-4.761	2.939	0.99	62	295	153
Salada	Pehuajó	-61.90	-35.78	2003	-4.597	2.873	0.97	166	321	162
Sau.Grande	Monte Hermoso	-61.38	-38.93	2003	-5.111	3.087	0.99	170	346	127
S.Grande	Gral.Madariaga	-56.97	-36.92	2004	-4.512	2.830	0.98	370	486	134
S.Granada	Gral. Pintos	-62.20	-34.75	2003	-5.277	3.155	0.99	245	413	123
Salada	San Cayetano	-59.5	-38.2	2004	-5.663	3.320	0.93	56	257	180
Las Tunas	TrenqueLauquen	-62.42	-35.95	2004	-4.832	2.945	0.99	116	328	139
Lobos	Lobos	-59.12	-35.28	2004	-5.926	3.434	1.00	67	342	132
Salada*	Monasterio	-57.9	-35.8	1997	-6.090	3.500	0.99	92	379	146
Kakel Huincul*	Maipú	-57.8	-36.8	1998	-6.000	3.470	0.99	102	352	176
Las Tunas*	TrenqueLauquen	-62.42	-35.95	2000	-5.260	3.050	0.98	148	379	120
S.Grande*	Gral.Madariaga	-56.97	-36.92	1998	-4.390	2.760	0.96	323	440	126

Although Wr may vary with length in a given population, there should be no consistent pattern of increasing or decreasing Wr values for a series of populations. When Wr was regressed on fish length for 73 populations, slopes were all significant ($p \leq 0.05$), being 30 of them positive and 43 negative: Chi-square test ($p=0.128$) indicates no length bias associated with the Ws equation (Fig. 1).

The relative weigth index and its interpretation in pejerrey

In order to use the relative weight as a diagnostic tool it is essential to count with a formula to estimate the standard weights of the species. The tests we carried out indicate that the proposed index has correctly compensated the change of body form due to growth and normal distribution (Figs. 1 and 2), which makes possible to carry out meaningful comparisons among individuals with different sizes. Furthermore, the wide geographic area covered by the data qualifies the use of this equation as reference for Pampean lakes, allowing to compare individual condition among populations. In consequence, variation in Wr may be primarily due to ecological factors and their influence on pejerrey populations (Murphy *et al.*, 1990). Several studies also documented that Wr is related to growth rate, reproductive potential, recruitment, production-biomass ratio, prey abundance, population density, structural indices, and environmental variables such as surface, depth, salinity, average temperature and primary production (Guy and Willis, 1991; Liao *et al.*, 1995; Marwitz and Hubert, 1997; Blackwell *et al.*, 2000).

To take advantage of the index, we suggest to make individual analyses instead of calculating population averages that could hide or mask the condition of different population strata. However, since Wr is not related to length, a mean Wr can be estimated by size strata (Marwitz and Hubert, 1997; Quist *et al.*, 1998). Baigún and Anderson (1993) proposed several interval size for the pejerrey. On the other hand, the interpretation of results must consider management objectives and the environmental limitations (Blackwell *et al.*, 2000), thus defining optimal or "desirable" Wr values. Current optimal conditions have been set to 95-105 (Murphy *et al.*, 1990; Blackwell *et al.*, 2000), but 85-95 Wr values were noted in high productive populations (Gabelhouse, 1987; Fisher and Fielder, 1998). Adjusting of optimal Wr values for pejerrey will require to analyze their variablity and relationship with environmental conditions, biological and fisheries parameters. Colautti *et al.* (2003) found that Wr was inversely related to pejerrey capturability by the recreational fishery.

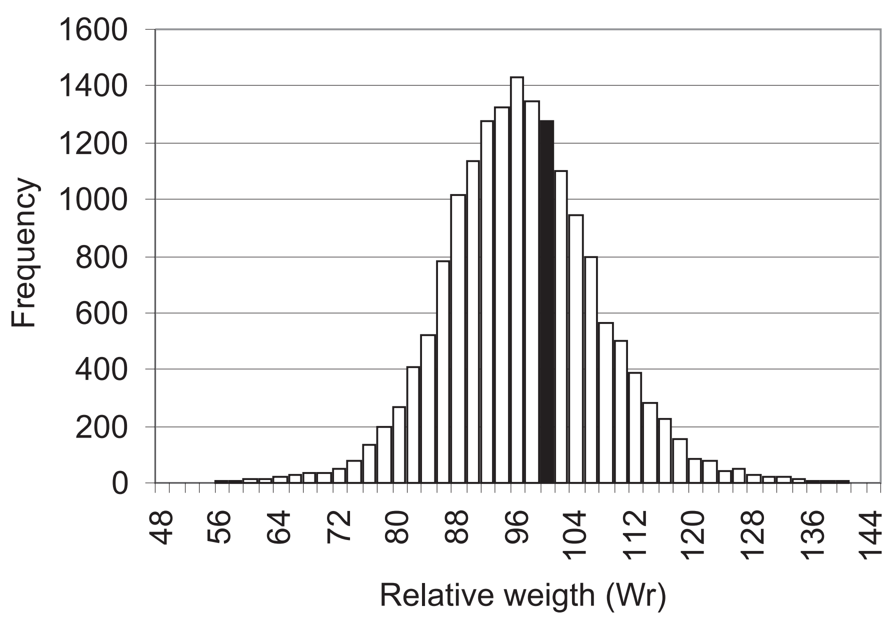

FIGURE 2. Frequency distribution of relative weight values for individual pejerrey (N=16022) sampled from 73 pampean lakes. Full bar indicates the 75th percentile (Wr=100).

Use of Wr represents also a valuable tool for management objectives and can be very effective if it is combined with structural indices such as PSD, RSD and abundance or density data. We encourage colleagues/ readers to incorporate such indices in regular fisheries assessments and to test their effectivity for population management.

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