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ORIGINAL PAPER

The physical–chemical habitat of the Buenos Aires pejerrey, *Odontesthes bonariensis* (Teleostei, Atherinopsidae), with a proposal of a water quality index

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Abstract The pejerrey, *Odontesthes bonariensis* (Valenciennes 1835) (Atheriniformes, Atherinopsidae) is a highly valued food and sport fish both in Argentina and abroad, and has been introduced in numerous natural and manmade environments in this country, Chile, Japan, and Italy. Considering a wide array of environments, where the pejerrey lives and somewhere it does not, we demonstrate its considerable eurytopy and define its range as water traits and chemical composition concern. Moreover, as pejerrey's natural habitat, the pampasic lagunas (lakes of third-order) in temperate Argentina display a wider range of chemistry traits than many other environments throughout the country, we confirm its adaptability, suggested by previous introduction success. Relative influence of total conductivity and particular ions is evaluated, as well as the relationship of water traits with the fish distribution. A water quality index is provided, which allows the determination of the best conditions for pejerrey cultivation in both artificial and natural conditions. The index summarizes many traits of the realized niche of the fish.

Keywords Water chemistry · Aquaculture · Temperate limnology · Ecological indices

Introduction

The pejerrey *Odontesthes bonariensis* (Valenciennes 1835) is a dominant species in the plain between the Rio de La Plata and the Atlantic to about 63°W from 33°30′ to 38°30′S. It is highly valued as food and as a sport fish and has been cultured since the first years of the 20th century (Valette 1910; López et al. 1991a). It has been used to artificially populate natural and manmade water bodies in Argentina north of 36°S. It was also introduced in Italy (Natili et al. 1986), Japan (Strussmann and Takashima 1989), and Chile (Dyer 2000).

Their typical habitats are 'lagunas', the most common lenitic water bodies of the wet Pampa, an extensive loess plain under an East–West climate gradient of decreasing rain. Lagunas range usually between 30 and 6,078 ha, with depths below 4 m and often rather less. Some of them

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maintain high-salinity levels because of marine origin or the increased East–West aridity gradient. They lack thermal stratification and have a wide range of physical and chemical traits (Ringuelet 1962; Ringuelet et al. 1967). Bottom sediment is mud like, with scarce clay, fine siliceous sand thicker than loess and abundant organic matter. Lower depths and the richness of loess in phosphorous resulted in a common eutrophic state.

In these environments, the pejerrey average production may reach up to about 100 kg ha^{-1} y^{-1} (Comisión de Investigaciones Científicas de la Provincia de Buenos Aires 1982). Rearing techniques for the pejerrey are well established (Ringuelet 1944; Gonzales Regalado and Mastarrigo 1954; Luchini et al. 1984; Bonetto and Castello 1985; Grosman 1995; Reartes 1995).

Although widely distributed, the species is absent from some environments, among them the saline Epecuén lake (37°08′S, 62°52′W) (Ringuelet 1962) and the laguna Los Jagüeles (35°25′S, 60°50′W) (personal observations). The later is a newly formed water body, and the pejerrey absence there was attributed to high-pH values (11.5–12.2). The pejerrey were also absent from the laguna Chasicó (38°37′S, 63°05′W) between 1968 and 1973 because of high salinity (Menni et al. 1988).

Here we establish the limits of chemical variables within which the pejerrey lives, allowing a better understanding of the fish's place in natural communities in southern South America (Menni et al. 1996). For the management of pejerrey, we propose an index [water quality index (WQI)], which allows us to determinate the best conditions for pejerrey culture in both artificial and natural conditions.

Methods

The proposed WQI was developed for the Buenos Aires pejerrey following criteria stated in US Fish and Wildlife Service (1981), Schamberger et al. (1982), Trial et al. (1984), and Weinstein (1986).

The WQI is a continuous unitless variable, taking values between 0, when the water quality is intolerable and 1 when water is the best for the fish. It results from an equation including seven parameters. Each parameter corresponds to one or several transformed environmental variables.

The first parameter is the Water Chemistry Parameter (WP), calculated through a formula (see below). To obtain the other six parameters, Cartesian diagrams are provided, with values of the environmental variable in the *X*-axis (input) and the parameter values in the *Y*-axis (output) (Fig. 1A–E, G). The polygonal continuous line in each graphic (derived from experimental, field, and literature data) shows the relationship between the considered environmental variable and the corresponding parameter. Transformations of the known values of each variable were made according to US Fish and Wildlife Service (1981). For example, if it were experimentally determined that an incubation temperature or pH correspond to maximum or optimum yield the parameter value is 1. In the same form, if nitrogen as ammonia value is lethal, the parameter value is 0. If field data show that a given value of dissolved oxygen (DO) correlate with a capture about 70% of the maximum obtained in the same environment, the parameter value is 0.7. 'Bad quality points' remains in the internal part of the polygonal line, and are not included in it. Entering the graphic with the environment variables in the usual units, the intersection with the polygonal will give a simple unitless number, which the nearer it is to 1, the better is the quality of the variable for the pejerrey. For example, when in Fig. 1A, the value of the variable Maintenance Temperature is 16°C, the Maintenance Temperature Parameter (MTP) is 1 (the maximum). Of course, values near 0 are strongly against cultivation, and those near 1 support it. A performance of the index (WQI) should be calculated to provide its confidence, ranging between 0 and 100%. If all variables were considered, performance is 100%, meaning that the WQI value is accurate, though the WQI may be low (0.4 for instance), and indicates that water quality is not good. On the contrary, if a WQI of 1 (optimum) is obtained, but the performance is 50% (because only half of the variables were considered), the high value should be considered as having a risk of 50%. Empirically, with a WQI about 0.80 or

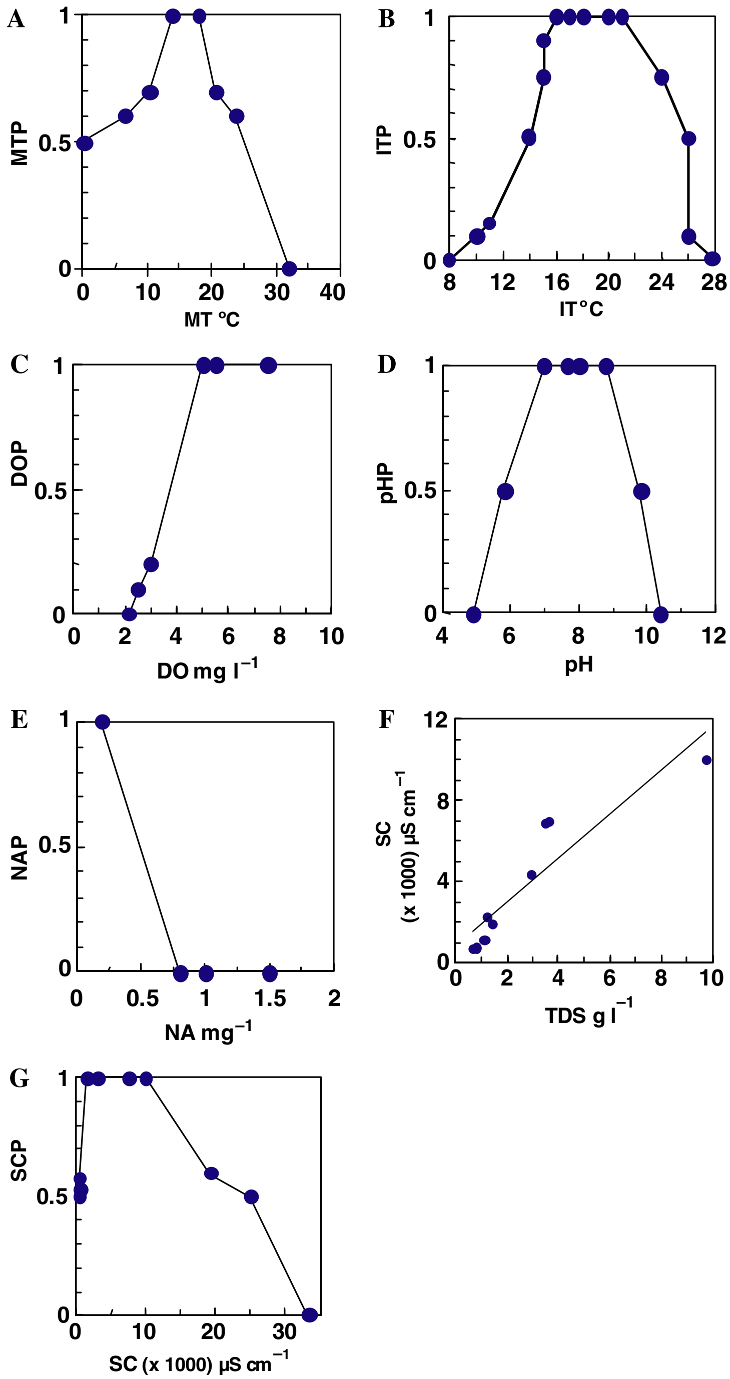

Fig. 1 **A** Graphic for calculation of Maintenance Temperature Parameter (*MTP*) as function of Maintenance Temperature (*MT* in °C). **B** Graphic for calculation of Incubation Temperature Parameter (*ITP*) as function of Incubation Temperature (*IT* in °C). **C** Graphic for calculation of the Dissolved Oxygen Parameter (*DOP*) as function of DO concentration (in mg l^{-1}). **D** Graphic for calculation of the pH Parameter (*pHP*) as function of pH. **E** Graphic for calculation of the Nitrogen as Ammonia Parameter (*NAP*), as function of the Nitrogen as Ammonia concentration (*NA* in mg l^{-1}). **F** Regression line between Total Dissolved Solids (*TDS* in g l^{-1}) and Specific Conductivity (*SC* in µS cm^{-1}). Equation in the text. **G** Graphic for calculation of Specific Conductivity Parameter (*SCP*) as function of SC (in µS cm^{-1})

Table 1 Environmental factors in pampasic lagunas inhabited by the pejerrey

	X	SD	I–95%	CV	N	M	M
SC	3,902.80	3,353.60	1,324.27–6,481.32	85.93	9	483.0	10,029.0
TDS	2.61	2.72	0.66–4.56	104.38	10	0.6	10.4
pH	8.52	0.27	8.33–8.71	3.14	10	6.5	9.8
CO_3^{--}	35.54	22.47	19.46–51.62	63.24	10	0.0	163.2
CO_3H^-	404.09	117.26	320.16–487.97	29.02	10	147.6	801.9
Cl^-	911.95	1,134.65	100.05–1,723.86	124.42	10	62.1	3,869.5
SO_4^{--}	467.47	541.11	80.28–854.66	115.75	10	20.8	1,735.4
Ca^{++}	41.89	34.43	17.26–66.53	82.16	10	11.0	128.3
Mg^{++}	55.79	55.63	15.98–126.80	96.60	10	5.3	166.6
Na^+	845.88	910.30	145.97–1,545.79	107.62	9	102.8	3,064.6
K^+	29.63	24.73	10.61–66.18	48.64	9	9.9	168.5
COD	19.16	7.07	13.25–25.07	36.88	8	7.7	57.0
Mg/Ca	2.00	1.00	1.28–2.72	50.10	10	1.1	4.3
Mg+Ca/Na+K	0.23	0.08	0.17–0.29	33.57	9	–	–
TH	344.53	324.02	112.68–576.38	94.05	10	–	–
TA	387.46	111.96	307.22–467.52	28.89	10	–	–

Mean value (x), standard deviation (*SD*), 95% confidence interval (I–95%), coefficient of variation (*CV*), and number of data (*N*). Minimum (*m*) and maximum (*M*) absolute values of ions (in mg l^{-1}), specific conductivity (SC in µS cm^{-1}), total dissolved solids (TDS in g l^{-1}), and pH. *COD* chemical oxygen demand (in mg O_2 l^{-1}), *TH* total hardness, *TA* total alkalinity (mg l^{-1} of CO_3Ca), Mg/Ca, and Mg+Ca/Na+K as ratios of meq l^{-1}

higher and a performance of 90% or over (meaning than most variables have been considered) water should be good for cultivation.

The sources of variables and support data for the corresponding parameters are discussed below. The name of each variable is indicated complete (e.g., Water chemistry), and the name of the corresponding parameter is given between parentheses; in this case (WP). Total dissolved solids (TDS) and specific conductivity (SC) are,

Table 2 Results of chemical analysis of water utilized in pejerrey culture in A: Instituto de Limnología (March 1994), B: Estación Hidrobiológica de Chascomús (December 1993), C: Estación de Piscicultura de Marcos Paz (October, 1996)

	A	B	C
SC	713.00	2,454.00	725.00
TDS	0.52	1.78	0.53
pH	7.46	8.01	7.70
CO_3^{--}	0.00	0.00	0.00
CO_3H^-	83.70	735.90	558.80
Cl^-	126.80	383.80	10.10
SO_4^{--}	106.60	150.20	21.00
Ca^{++}	28.60	45.70	29.60
Mg^{++}	15.70	35.50	15.30
Na^+	99.60	520.80	152.00
K^+	5.90	15.90	11.20
COD	3.60	7.40	3.40
Mg/Ca	0.90	1.28	0.85
Mg+Ca/Na+K	0.30	0.11	0.40
TH	135.80	258.90	136.70
TA	68.60	603.20	458.00
Nitrite (mg l^{-1})	7.90	1.34	–
Nitrate (mg l^{-1})	2.30	22.40	–
Total phosphorus (mg l^{-1})	0.09	0.26	0.11
Ammonia + Ammonium (mg l^{-1})	<0.25	–	<0.25
N–NH_3 (mg l^{-1})	<0.19	–	<0.19

Units as in Table 1, Lack of data as –

respectively, abbreviations for total dissolved solids and specific conductivity, and were defined and measured according to APHA (1985).

Water chemistry parameter

Physical and chemical water traits from 13 pampasic environments inhabited by the pejerrey were considered, namely: group of lagunas Salada Grande (Dangavs 1988), laguna El Hinojo (López et al. 1991b), laguna Vitel (Olivier 1961), laguna Chascomús (Conzonno and Claverie 1990), lagunas Alsina, Cochicó, del Monte and Del Venado (López et al. 1993), laguna Blanca Grande (Freyre and Sendra 1993), laguna Sauce Grande, the county lake of Colón (Freyre et al. 1993), and laguna Monte and laguna Lobos (Mariñelarena and Conzonno 1997) (Table 1).

Water samples from three pejerrey rearing stations: Estación Hidrobiológica de Chascomús, Instituto de Limnología 'Dr. R.A. Ringuelet' and Estación de Piscultura de Marcos Paz, were analyzed (Table 2). In all, 95 water samples were analyzed. Most chemical analyses were performed at the Chemistry Laboratory of the Instituto de Limnología 'Dr. R.A. Ringuelet' (Dr. V. Conzonno, Director) following APHA (1985) techniques. Molar ratios Mg/Ca and Ca + Mg/Na + K were considered.

Traits of three environments, where the pejerrey does not occur, were also considered including laguna Los Jagüeles (López et al. 1994), Epecuén Lake (López et al. 1993), and laguna Chasicó (Menni et al. 1988; Gómez 1996).

The parameter WP was developed as a 'water trait index'. It is composed of ten variables: TDS, chemical oxygen demand and the concentration of four anions and four cations (in mg l^{-1}, Cl^-, SO_4^{2-}, CO_3^{2-}. HCO_3^-, Ca^{2+}, Mg^{2+}, Na^+, K^+). For a given water sample, the parameter WP is calculated comparing the values of these variables with absolute maximum and minimum values of water from environments inhabited by the pejerrey (Menni and Gómez 1995). If each water variable (V) has a value within the range of Table 1, $V = 1$; if they are out of range, $V = 0$. Values of V's are summed and divided by the number of variables utilized (maximum 10). $WP = (\Sigma V_i)/n$.

Maintenance temperature parameter

Regression and correlation analysis were applied to data from lagunas Vitel (Olivier 1961) and Salada Grande (Dangavs 1988) to obtain the relationship between air temperature and water temperature. As there are not significant differences between air and water monthly mean temperature, air temperature data, which are usually available, may be used instead of water temperature. Climatic data were obtained from the National Meteorological Survey. Experimental data were taken from Bricelj et al. (1977) and field observations from Freyre (1967) and Gallardo (1970).

Incubation temperature parameter

Data on incubation of developing eggs were obtained from Ringuelet (1944), Gonzales Regalado and Mastrarrigo (1954) and Reartes (1995).

Dissolved oxygen parameter

Differences in CPUE for different oxygen values have been reported (Baigún and Delfino 1994).

pH parameter

Lethal incipient maximum and minimum levels experimental results were used together with field data (Gómez 1998).

Nitrogen as ammonia parameter

Bioassays using standardized 50% resistance time techniques (tR_{50}, Gómez 1991, 1993) were used to evaluate the pejerrey response to this factor in water from laguna Los Jagüeles (Gómez in López et al. 1994). The higher critical value for temperate species (Stickney and Kohler 1990) and experimental data for *Odontesthes argentinensis* (Ostrenky and Brugger 1992) have also been considered.

Specific conductivity parameter

There is a consensus on that the pejerrey is euryhaline (Ringuelet 1944), but experimental information on its tolerance to specific conductivity or total dissolved solids is not available. A correlation matrix among species number and physical–chemical traits was calculated and a regression analysis was applied to data from the lagunas Encadenadas del Oeste (36°30′–37°30′S, 61°–63°30′W) (Lopez et al. 1993; Miquelarena and Lopez 1995). Data from the laguna Mar Chiquita (31°S 62°30′W) (Reartes 1995) and pampasic lagunas (Baigún and Anderson 1993; Baigún and Delfino 1994) were compared with salinity lethal levels of other fish from the area (Gómez 1996).

Results

Water chemistry

Table 1 summarizes main statistics of chemical variables from 13 studied lagunas. Cl^- and SO_4^{2-} are the most variable ions. Mean values with their confidence intervals are considered optimum values (Pianka 1982) for the pejerrey development. Information from rearing stations is given in Table 2.

Maintenance temperature parameter

Mean annual temperature of the pampasia ranges from 14 to 18°C Servicio Meteorológico Nacional (1960). Extreme values are recorded from Rosario and Pigüé, where monthly mean temperatures are 23.7 and 20.7°C in summer (January) and 10.3 and 6.6°C in winter (July), respectively (Servicio Meteorológico Nacional 1985). Minimum absolute temperatures about –10°C resulting in ice formation in surface with water temperatures near 0°C have been reported but are quite unusual (Gallardo 1970). In Chascomús 0°C is not a lethal temperature for the pejerrey (Freyre 1967). Experimental higher lethal temperature at 50% is 32.0°C when fish are acclimated to 28°C (Bricelj et al. 1977). The parameter MTP is obtained from Fig. 1A entering with the mean air annual temperature from the close meteorological station.

Incubation temperature parameter

Field data show that the pejerrey produce two annual cohorts, one during September–October, with water temperatures around 14°C, and the other on March–April at around 16°C (Ringuelet 1944). Figure 1B provides the parameter ITP entering with October temperatures of the nearest meteorological station.

Dissolved oxygen parameter

Baigún and Delfino (1994) grouped Argentine lagunas and reservoirs in five categories according to the pejerrey CPUE in kg. Mean values of each category are related with bottom DO in mg l^{-1} according the following exponential equation:

$$\mathrm{CPUE(kg)} = e^{(1.05814\mathrm{DO}-3.04355)},$$

$N = 5$, $r = 0.8528$ ($p < 0.067$).

Although not strictly significant, the equation shows a clear tendency of increasing of CPUE with increasing DO values. With a low-DO value (2.5 mg l^{-1}) the equation predicts an insignificant 0.67 kg CPUE. The higher CPUE, above 150 kg, is obtained with 7.5 mg l^{-1} DO. The parameter DOP for different DO values is obtained from Fig. 1C, entering with the lower monthly mean concentration of DO (mg l^{-1}) at the mean depth, measured in the deeper open water (Weinstein 1986). In the area, the appropriate value is usually that of January because then the lowest DO values are expected.

pH parameter

Minimum and maximum lethal incipient levels of pH (mean ± SD) were 4.91 ± 0.41 and 10.42 ± 0.24, respectively, under a mean exposition temperature of 18.8°C. Tolerance zone has an amplitude of 5.51 units with a center point at 7.66 ± 1.56 (Gómez 1998). Values of pH from ten environments with pejerrey indicate that the larger environmental variation (5.8–9.8) is within the tolerance experimental range. The mean value of the environmental variation (8.02 ± 0.47) is not significantly different ($p < 0.05$) from the experimental physiological optimum. Minimum and maximum values (6.5–9.8) (Table 1) also have been considered. The parameter pHP for different pH values is obtained from Fig. 1D.

Nitrogen as ammonia parameter

Bioassays in water from laguna Los Jagüeles, not inhabited by the pejerrey, resulted in 100% mortality (Gómez in López et al. 1994). Resistance time (tR_{50}) is related with N–NH_3 concentration according with the equation:

$$\log(tR_{50}) = 3.5544 - 2.2647(N - NH_3)$$

A 1.5 mg l^{-1} N–NH_3 concentration produces 50% mortality in about 90 h. A control group composed by ten specimens of the same age maintained in dechlorinated tap water with a $NH_3 + NH_4^+$ concentration < 0.25 mg l^{-1} (= 0.19 mg l^{-1} N–NH_3) did not show mortality within 14 days. The parameter NAP is obtained from Fig. 1E.

Specific conductivity parameter

Specific conductivity data from 23 pampasic lagunas inhabited by the pejerrey range between 520 and 19,200 µS cm^{-1}, with corresponding CPUE of 66.9 and 84.2 kg, respectively (Baigún and Anderson 1993). Maximum CPUE (435 kg) was obtained at specific conductivity of 1,550 µS cm^{-1}. The mean value was 3,221.7 µS cm^{-1} (SD = 4,292.9) and is within the optimum confidence interval we obtained (Table 1). The relationship between TDS and SC (data from nine lagunas) was

$$SC = 905.55 + 1082.58\ TDS$$

with $r = 0.9172$ ($p < 0.05$) (Fig. 1F).

With this equation, the SC adequate for maintaining the two most resistant species, the cyprinodontoid *Jenynsia multidentata* and the pejerrey, is 24,993 µS cm^{-1}, corresponding to 17.76 g l^{-1} TDS. In common pampasic lagunas the pejerrey lives until SC = 10,029 µS cm^{-1} maximum value (Table 1). According this, the critical value for the pejerrey is between 19,200 and 33,300 µS cm^{-1}. Besides, SC is significantly correlated ($p < 0.05$) with TDS, CO_3^-, CO_3H^-, Cl^-, SO_4^{2-}, Na^+, and K^+.

The ratio TDS/SC was very variable, with a mean value of 7.562×10^{-4} (SD = 2.113×10^4) and a 95% confidence interval between 5.938×10^{-4} and 9.187×10^{-4}. The parameter SCP is obtained from Fig. 1G, entering with the value of specific conductivity of the sample at 20°C.

Discussion

The mean values, confidence intervals, and ranges of 16 variables (Table 1) together with temperature ranges obtained from this research established the traits of the pejerrey wide natural habitat. Occasionally, the pejerrey lives within water with values outside Table 1 limits (19,200 µS cm^{-1}) (Baigún and Anderson 1993). Values of pH as low as 5.5 (Gómez 1998) and 5.8 in laguna Lobos (Boltovskoy et al. 1990) were not lethal. *O. bonariensis* occurs nowadays in laguna Cochicó with 28.4 g l^{-1} TDS and in the Mar Chiquita lagoon in Cordoba with 25.0 g l^{-1} TDS.

It has been reported that Mg^{2+} excess is toxic for freshwater fish if not compensated by Ca^{2+} (Ringuelet 1962). Many pampasic fish tolerate a mean 2.0 ratio and a maximum ratio of 4.36 (Table 1) (Ringuelet 1962; Ringuelet et al. 1967). For example, *Oligosarcus jenynsi, Astyanax eigenmanniorum, Cyphocharax voga, Corydoras paleatus, Rhamdia quelen, J. multidentata* and the pejerrey tolerate a mean ratio of 2.85 in the lagunas Encadenadas del Oeste.

Optimum incubation temperature for the pejerrey is 18°C, although rearing is possible between 15 and 21°C with lesser success (Gonzáles Regalado and Mastrarrigo 1954). Ringuelet (1944) reported an optimum range from 16 to 21°C, with low percentages of rearing between 10 and 11 or 24and 25°C. Tests between 18 and 26°C indicated a maximum birth percentage (75%) at 24°C. Incubation takes about 14 days at 17°C, with birth occurring when accumulation reaches 250°C (Ringuelet 1944).

An individual pejerrey weighting 200 g spent 19.54 mg O_2 h^{-1} at 20°C (Freyre et al. 1981). Under the same conditions, the Wimberg (1960) general equation provides a similar value of 20.79 mg O_2 h^{-1}. In spite of being a good swimmer, epipelagic species, the pejerrey does not have a high rate of O_2 consumption. It does not

Table 3 Physical and chemical parameters (labels in Methods) for each of seven studied variables and WQI for culture stations (after Table 2), and for water bodies without pejerrey

	WP	MTP	ITP	DOP	pHP	NAP	SCP	WQI	P
Culture stations									
Est. ILPLA	0.50	1	0.75	1	1.00	1	1	0.81	100.00
Est. Chascomús	0.90	1	1.00	1	1.00	–	1	0.97	93.70
Est. Marcos Paz	0.70	1	1.00	1	1.00	1	1	0.92	100.00
Water bodies without pejerrey									
Lago Epecuén	0.33	1	0.50	1	1.00	–	0	0	87.50
Lag. Los Jagüeles	0.78	1	1.00	1	0.70	0	1	0	93.70
Lag. Chasicó	0.10	1	0.60	1	1.00	–	0	0	93.70

P (%) is the performance in the estimation of the WQI. Lack of data as –

tolerate low-oxygen levels and lives in well-oxygenated open waters with abundant food. The pejerrey's metabolism is similar to other species living in open waters as *O. jenynsi, A. eigenmanniorum* and *Apareiodon affinis* (Freyre and Protogino 1993).

Many temperate fishes tolerate up to 1 mg l^{-1} of ammonium (Stickney and Kohler 1990). For the marine pejerrey *O. argentinensis*, lethal concentration values (LC_{50}) of 1.48 and 0.80 mg l^{-1} N–NH_3 were obtained for 24 and 96 h, respectively (Ostrenky and Brugger 1992). The value tolerated by the Buenos Aires pejerrey is rather low.

Minimum and maximum CPUE of pejerrey were obtained with a mean specific conductivity of 858 and 2,468 μS cm^{-1}, respectively (Baigún and Delfino 1994). Values of the TDS/SC index agree with those reported in literature (Margalef 1983; Boltovskoy et al. 1990). Based on the obtained results, we suggest a WQI for *O. bonariensis*. The index includes the seven studied parameters in the following equation:

$$WQI = [(WP + MTP + ITP + DOP)/4] \times (pHP \times NAP \times SCP)^{1/3}.$$

The Index admits 16 limnological variables. If all are used, the performance (*P*) is 100%. In the common case that some information is not available

$$P = (\text{Number of variables} \times 100)/16.$$

The WQI was tested for rearing stations (Table 2) and for environments without pejerrey (Table 3), using values from six to seven parameters. The resulting WQI ranged between 0 and 0.975. As may be expected, high values of the WQI from 0.812 to 0.975 were obtained at rearing stations. There, the management intends to obtain optimum values (parameters values = 1) of variables, which may reach lethal values easily (pH, nitrogen as ammonia, specific conductivity). On the contrary, basic chemical water composition (WP) is low in some cases because of the simple use of available water or the lack of knowledge of optimum values.

The inadequacy of only one or two variables is sufficient to render the water inappropriate. This is the case of the laguna Los Jagüeles (WQI = 0), where basic water chemistry quality is similar to rearing stations (WP = 0.78) but lethal effects derived from nitrogen as ammonia result in a parameter value NAP = 0 and pHP = 0.7 (Table 3).

On March 26, 1994, pH values ranging from 11.5 to 12.2 at 24°C in laguna Los Jagüeles were lethal for *O. bonariensis*. In spite of strong artificial oxygenation, water was still lethal for the pejerrey within a few hours (Gómez in López et al 1994). Not only does the effect depend on the dilution but also on the relative amount of NH_3 and NH_4^+ in the water. Ammonia (NH_3) is more toxic than the ammonium ion (NH_4^+), the relative quantities are regulated by pH (Jones 1964; United States Environmental Protection Agency 1975). In this laguna the Ca + Mg/Na + K ratio is lower (0.02) than the common value (2.4, Margalef 1977), though pampasic lagunas may have similar ones (e.g. Puan = 0.013, Ringuelet 1962). Besides, the ratio Mg/Ca (1.51) is within the confidence limits (Table 1) of pampasic lagunas.

Another environment without pejerrey is the laguna Epecuén with a WQI = 0. Initially, the lethal factor is the SCP (SCP = 0), the total dissolved solids are 30 g l^{-1}. The basic water chemistry has a low value (WP = 0.33) because five ions and TDS are above the absolute maximum values (Table 1), though Ca^{2+}, Mg^{2+}, K^{+}, and the Mg/Ca ratio are within normal values for pampasic lagunas (Table 1) Years ago, *J. multidentata*, a well-known euryhaline species, did not tolerate 10% Epecuén water more than 5 h (Thormalen de Gil 1949). The species has been captured there at present, according with lower salinity (30 g l^{-1}) related with present climatic conditions.

The ionic compositions of water of pampasic lagunas water exhibit a marked temporal and geographic variability (Ringuelet 1962, 1972; Ringuelet et al. 1967; Mariñelarena and Conzonno 1997). A study of the relative toxicity of the ions is necessary for a better adjustment of the model, because not all the cases can be attributed to the osmotic effect.

During many years, the Chasicó laguna was a hypersaline water body without fish. From 1968 to 1973 the WQI = 0. The most obvious trait (Table 3) was the specific conductivity (SCP = 0, WP = 0.1) with total dissolved solids = 96 g l^{-1}. All ions were also over the absolute values indicated in Table 1.

The three environments without pejerrey share high values of CO_3H^- (from 817 to 1,370 mg l^{-1}) well over the maximum values tolerated by the species.

Different tolerances to chemical factors can be considered a measure of species position along a eurytopic–stenotopic axis (Menni et al. 1996). Considering conductivity, total dissolved solids, temperature, pH, CO_3^{2-}, CO_3H^-, SO_4^{2-}, Na+, K+, Ca^{2+}, and Mg^{2+}, *O. bonariensis* tolerates ten maximum values and three minimum ones, which implies a tolerance of the same order that *Astyanax bimaculatus*, the most eurytopic Argentine species reported till know.

The WQI is a relatively simple index, and does not require special knowledge to be used. Beside its advantages for evaluate objectively and quantitatively the quality of water used for pejerrey culture, it may be applied also to: (a) comparison of WQI from different culture stations, providing information on the efficiency of devices used in the culture, like mechanic filters, biological filters and aeration; (b) values of the WQI in a given environment or in an installation throughout time, allowing the monitoring of water and the establishment of seasonal or other variations, providing the possibility of preventing or predicting consequences of environmental change, or deciding the best moment for repopulating.

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