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Freshwater parameters in the state of Rio Grande do Sul, southern Brazil, and their influence on fish distribution and aquaculture

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This study analyzed the relationship between several water quality parameters (pH, hardness, alkalinity, turbidity, iron and manganese) levels measured over a 16 year period with fish distribution and aquaculture in the state of Rio Grande do Sul, Southern Brazil. The mean pH values were within a neutral range (6.5-7.5), but the maximum and minimum values reached inappropriate levels for fish farming in some cities. Alkalinity levels were very low (except in the southwest region of the state), which may have contributed to pH variation. Hardness, turbidity, iron (except the region near Caçapava do Sul City) and manganese were within safe ranges for fish farming; however, turbidity levels occasionally increased to levels outside the safe range. In conclusion, the water quality in the Rio Grande do Sul, in general, can be considered adequate for aquaculture, but the fish farmers must be aware of the methods to reduce turbidity, such as the use of calcium sulfate.

Este estudo analisou a relação entre vários parâmetros de qualidade da água (pH, dureza, alcalinidade, turbidez, ferro e manganês durante 16 anos) com a distribuição de peixes e piscicultura no estado do Rio Grande do Sul, Brasil. O pH ficou em média em uma faixa neutra (6,5-7,5), mas valores máximos e mínimos atingiram níveis não apropriados para a piscicultura em algumas cidades. Os valores de alcalinidade foram baixos (exceto na região sudoeste do estado), o que poderia contribuir para oscilações no pH. Dureza, turbidez, ferro (exceto na região próxima à cidade de Caçapava do Sul) e manganês ficaram dentro de níveis aceitáveis para a piscicultura, mas a turbidez ocasionalmente elevou-se a níveis fora dessa faixa aceitável e os piscicultores devem ter algum mecanismo para reduzi-los. Em conclusão, de forma geral a qualidade da água do Rio Grande do Sul pode ser considerada adequada para a aquicultura, mas os piscicultores devem conhecer métodos para corrigir a turbidez, como a utilização de sulfato de cálcio.

Keywords: Alkalinity, Hardness, Iron, pH, Turbidity.

Introduction

Knowledge of the ideal range of water quality parameters is a crucial factor in aquaculture (Copatti *et al*., 2005). Monitoring water quality is very important because it influences fish metabolism, reproduction, feeding and growth. Some important parameters to be considered in a long-term analysis on the effects on aquaculture are pH, hardness, alkalinity and turbidity (Zweig *et al*., 1999; Kristensen *et al*., 2009; Baldisserotto, 2011).

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The recommended pH range for fish is 6.5 to 9.0 (Baldisserotto, 2011). Water hardness is the concentration of all divalent cations in water, and calcium (Ca^{2+}) and magnesium (Mg^{2+}) are the most common cations in almost all freshwater systems. The recommended water hardness range for raising North American fishes is 20-400 mg $CaCO_3$ L^{-1} (Boyd & Tucker, 1998; Zweig *et al*., 1999), but a recent review indicated that high water hardness is needed only for species that are found in hard water in the environment (Baldisserotto, 2011).

Alkalinity of the water is the ability to accept protons or to neutralize acids, and bicarbonate, carbonate and hydroxide are considered the predominant bases in natural waters. The alkalinity level recommended for growing fish should be above 20 mg L^{-1} (Boyd, 2000). Turbidity is a measure of the light scattering properties of water and is related to transparency. It may be due to colloidal clay particles from the run-off of pond dikes or river shores that contains clay (Yi *et al*., 2003; Rocha *et al*., 2015), or to the presence of phytoplankton (Crossetti *et al*., 2014).

In addition to these more common water parameters, the analysis of some waterborne metals can also be important for fish farming. In southern Brazil the soil is very rich in iron (Fe) and also contains manganese (Mn) (Brasil, 1973), and consequently their water levels are high (Kochhann *et al*., 2013). While iron is a vital micronutrient for teleost fish, as it is an integral component of proteins involved in cellular respiration and oxygen transfer, it is toxic in excess (Bury *et al*., 2003). Manganese is a cofactor of a number of enzymes such as superoxide dismutase and those involved in glucose oxidation, metabolism of fatty acids and amino acids (Satoh *et al*., 2001) and presents a very low toxicity risk for fish (Dolci *et al*., 2013).

Due to economic restraints or lack of knowledge of the best water quality ranges for a given species, fish farmers usually accept general water quality parameters (Colt *et al*., 2006). In southern Brazil, where most fish farmers are small-scale producers, there is almost no analysis, knowledge or control of water quality parameters (Cardoso *et al*., 2009). Therefore, the objective of this study was to analyze water quality parameters (pH, alkalinity, hardness, turbidity, Fe and Mn levels) in continental waters this state, in the last 16 years, relating these data with their use in fish distribution and aquaculture. The knowledge of the variation range of these parameters is important to allow fish farmers to avoid or reduce problems due to water quality parameters in their culture.

Materials and Methods

Mean monthly water quality parameters were provided by the Companhia Riograndense de Saneamento (CORSAN), which measures daily water quality in its water treatment stations (WTS) in the state of Rio Grande do Sul, Brazil. Data were collected from the WTS located in various cities of this state (Alegrete, Alvorada, Bento Gonçalves, Caçapava do Sul, Cachoeirinha, Cachoeira do Sul, Camaquã, Cidreira, Cruz Alta, Carazinho, Frederico Westphalen, Gaurama, Lagoa Vermelha, Palmeira das Missões, Passo Fundo, Quaraí, São Borja, Santa Maria, Santiago, São Marcos, Santa Rosa, Três Passos, Taquara, Torres and Uruguaiana) over 16 years (1996-2011) except water hardness, which was analyzed from 1996 to 2003.

The pH, hardness, alkalinity, Fe and Mn levels were measured by titrimetric methods described by APHA (2005). Turbidity was determined with a turbidimeter (HACH 2100 P). Maps of the water quality parameters analyzed were produced with the software Spring 4.3.3 (Câmara *et al*., 1996), which related the geographic location of the cities to each parameter's overall mean, minimum and maximum values.

Results

Mean water pH in Rio Grande do Sul was 6.5-7.5 (Fig. 1A). Minimum (Fig. 1B) and maximum pH values (Fig. 1C) occurred in the cities of Rio Grande (in the south of the state) (pH 4.3), Alvorada and Cachoeirinha (in the east of the state) (pH 9.5). The mean water hardness range was 18-30 mg $CaCO_3$ L^{-1}. The lowest mean hardness value was measured in the city of Santiago (in the center of the state) (10 mg $CaCO_3$ L^{-1}) (Fig. 2A). The city of Cidreira (in the east of the state) showed the highest mean value (120 mg $CaCO_3$ L^{-1}), but other high values (48-53 mg $CaCO_3$ L^{-1}) and low values (30-36 mg $CaCO_3$ L^{-1}) were observed in the southwest of the state (Figs. 2B-C).

The mean alkalinity values varied between 24-48 mg $CaCO_3$ L^{-1}, and the highest values were found in the southwest of the state (Fig. 3A). The minimum values for this parameter (around 0-10 mg $CaCO_3$ L^{-1}) were observed in the northeast and north-center of the state (Fig. 3B). The maximum alkalinity values were in the southwest of the state, with the cities of Quaraí and Alegrete having the highest values (Fig. 3C).

The mean water turbidity values were lower than 40 NTU in most regions, except the most waters region, which presented the highest values (Fig. 4A). The minimum values demonstrated that most water from Rio Grande do Sul had very low turbidity (0 - 4 NTU) in some months (Fig. 4B). The maximum turbidity values were much higher, with higher values to the north and the highest in the cities of Santa Rosa and Bento Gonçalves (6000 NTU) (Fig. 4C).

The highest mean iron level was 9.8 mg L^{-1} in the city of Caçapava do Sul (in the center of the state), but for most cities examined values were below 2.0 mg L^{-1} (Fig. 5A). The mean Mn level within the state was below 0.1 mg L^{-1} and the highest mean value was found in the city of Alegrete, in the southwest of the state (0.25 mg L_{-1}) (Fig. 5B).

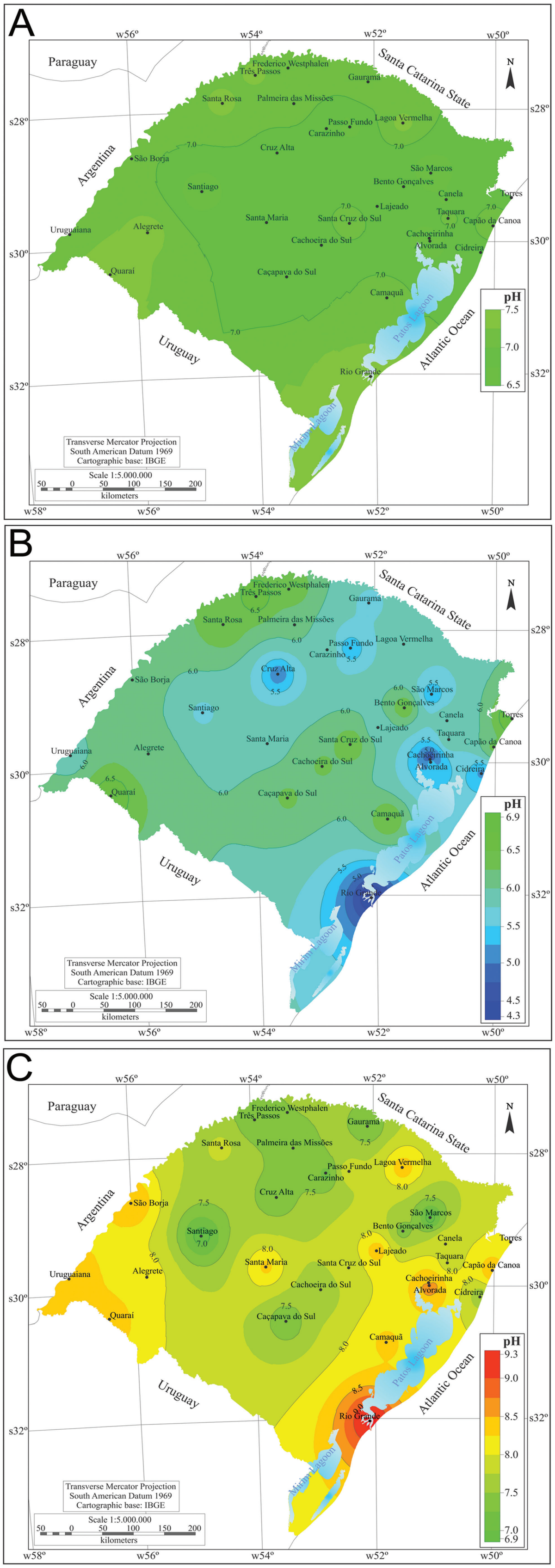


Fig. 1. Water pH in different cities of Rio Grande do Sul in the period of 1996 to 2011 (A) mean, (B) minimum and (C) maximum values (Source CORSAN/RS).

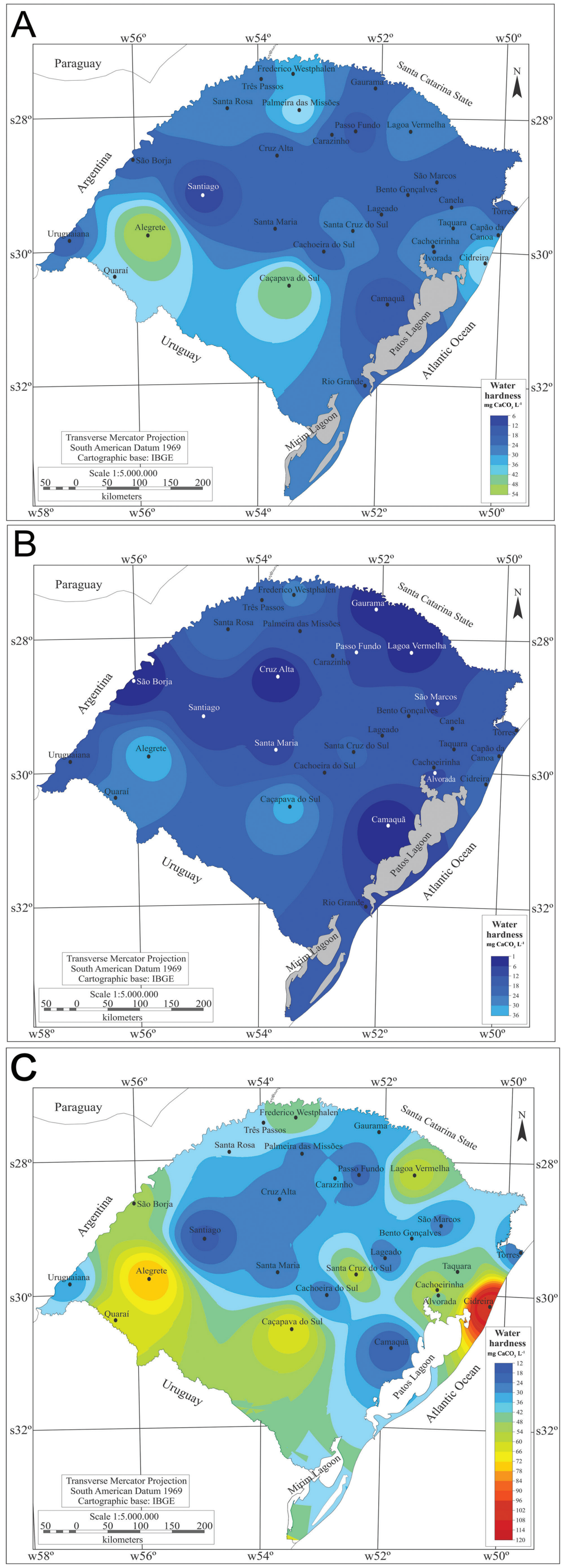
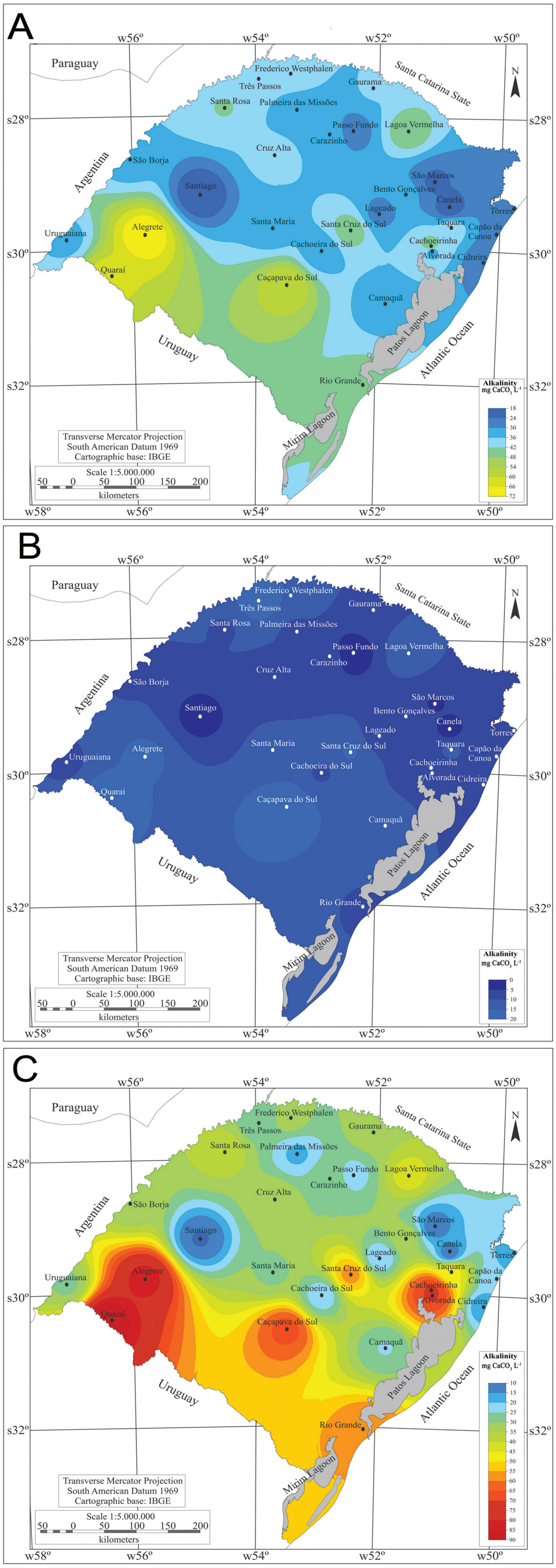


Fig. 2. Water hardness in different cities of Rio Grande do Sul in the period of 1996 to 2011 (A) mean, (B) minimum and (C) maximum values (Source CORSAN/RS).



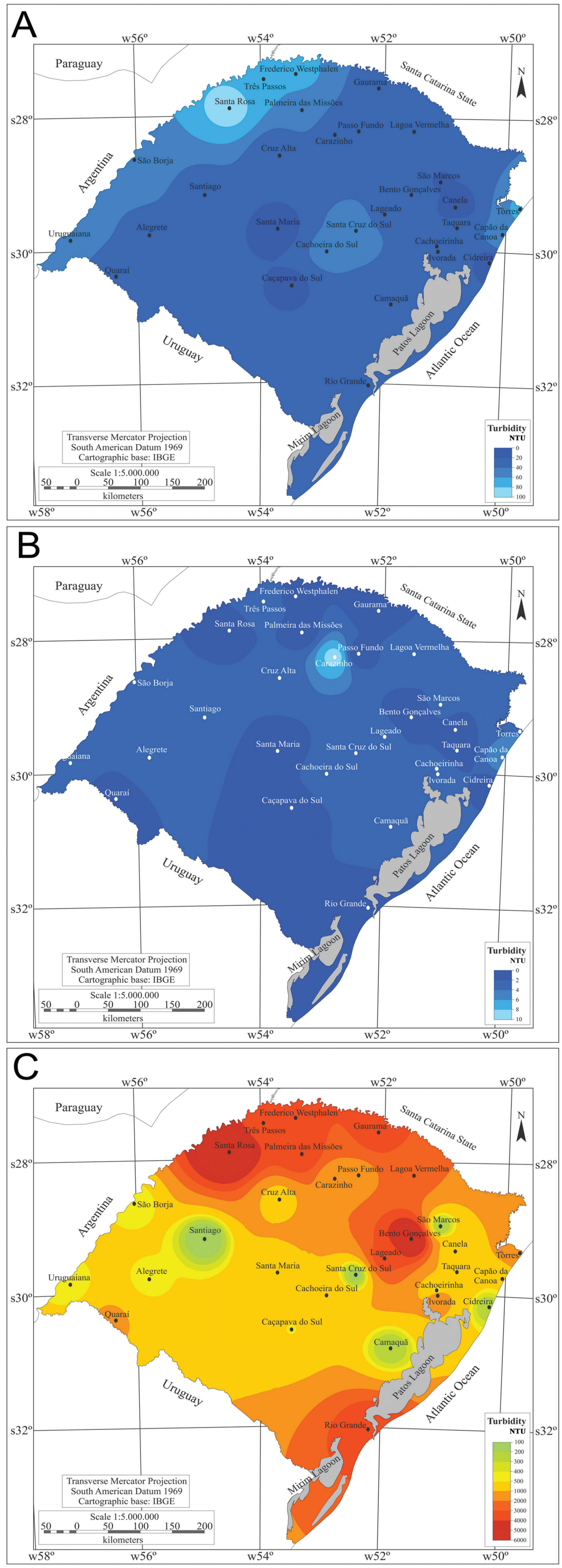


Fig. 3. Water alkalinity in different cities of Rio Grande do Sul in the period of 1996 to 2011 (A) mean, (B) minimum and (C) maximum values (Source CORSAN/RS).

Fig. 4. Water turbidity in different cities of Rio Grande do Sul in the period of 1996 to 2011 (A) mean, (B) minimum and (C) maximum values (Source CORSAN/RS).

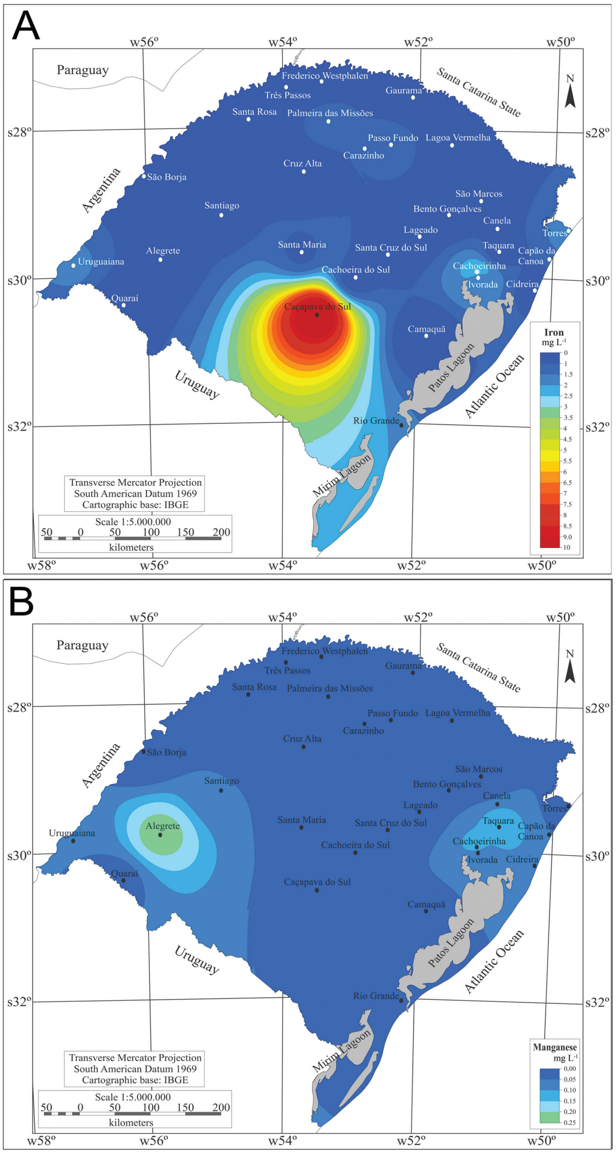


Fig. 5. Mean waterborne (A) iron and (B) manganese in various cities of Rio Grande do Sul in the period of 1996 to 2011 (Source CORSAN/RS).

Table 1. Minimum and maximum pH values in which there is 100% survival in the juveniles of certain species of teleost fish raised in southern Brazil. nd: not determined (adapted from Parra & Baldisserotto, 2007).

Species	Minimum pH	Maximum pH	Time of exposure (days)	Source
Odontesthes bonariensis	4.9	10.4	4	Gómez (1998)
Prochilodus lineatus	4.0	9.5	5	Zaniboni-Filho *et al.* (2002)
Rhamdia quelen	4.0	9.0	4	Zaions & Baldisserotto (2000)
Oncorhychus mykiss	4.4	9.2	15	Alabaster & Lloyd (1982)
Oreochromis mossambicus	4.0	nd	37	Van Ginneken *et al.* (1997)

Discussion

Water quality can be affected by several factors, such as climate, size of the watershed, topography, geology, rain and soil type (Wachholz *et al.*, 2011; Gaida *et al.*, 2012; Mattos *et al.*, 2014). Previous analysis of water from ponds and streams from Rio Grande do Sul presented mean pHs similar to those found in the different regions of this study (Rheinheimer & Souza, 2000; Diel *et al.*, 2007; König *et al.*, 2008; Pimenta *et al.*, 2012; Silva *et al.*, 2012), but in water used for human consumption from artesian wells, from the north central region minimum pH values were down to 4.4 and the maximum up to 10.0 (Rheinheimer & Souza, 2000).

Mean pH values in the Rio Grande do Sul State are within a safe range for juvenile fish farming. However, minimum values indicated that water from a few cities must be alkalinized before using in aquaculture to avoid mortality (Table 1) and/or reduced growth of the native species silver catfish (*Rhamdia quelen*) (Copatti *et al.*, 2005; 2011; Baldisserotto, 2011) and Argentinian silverside (*Odontesthes bonariensis*) (Gómez *et al.*, 2007), or exotic species common carp (*Cyprinus carpio*) (Heydarnejad, 2012) and Nile tilapia (*Oreochromis niloticus*) (El-Sherif & El-Feky, 2009; Cavalcante *et al.*, 2012). Maximum pH values (9.3) were outside the safe range for aquaculture only in the City of Rio Grande (Table 1), but since these are mean monthly values and not absolute maximum values it is likely that alkaline pH values may eventually occur in some cities from the western and eastern regions of this state. Acidic (pH 5.0) and alkaline water (pH 9.0) altered metabolic parameters and osmoregulation of *R. quelen* (Bolner & Baldisserotto, 2007; Bolner *et al.*, 2014).

In the Upper Paraná River basin (Southern Brazil), a greater abundance of larval South American silver croaker (*Plagioscion squamosissimus*) (Baumgartner *et al.*, 2008; Reynalte-Tataje *et al.*, 2011), highwaterman catfish (*Hypophthamus edentatus*) and trahira (*Hoplias malabaricus*) was positively associated with a higher water pH (7.4-8.5), while the presence of larval piava fish (*Leporinus elongatus*) was associated with a pH around 6.8 (Baumgartner *et al.*, 2008). The larvae of streaked prochilod (*Prochilodus lineatus*) had a better chance of survival at an alkaline pH (8.7-9.2) (Zaniboni Filho *et al.*, 2009) with the highest rate of survival of post-larval forms when eggs are incubated at a pH of 7.0-8.5 (Reynalte-Tataje *et al.*, 2015). Greater numbers of juvenile *P. lineatus* and pike cichlid (*Crenicichla lacustris*) were also observed in more alkaline water (pH 8.0-8.2), while greater numbers of catfish (*Pimelodus maculatus*) were observed in water of a lower pH (6.9-7.2) in Paraíba do Sul River, southeastern Brazil (Araújo *et al.*, 2009). The larvae of *R. quelen* also have better growth at a slightly alkaline pH (8.0-8.5) (Lopes *et al.*, 2001), but incubation can be performed at a pH of 6.0-9.0 (Ferreira *et al.*, 2001). Juveniles of this species reduced growth when exposed to pH 5.5 or 9.0 (Copatti *et al.*, 2005; 2011a,b). Consequently, considering the pH, the best regions of Rio Grande do Sul to perform incubation and larviculture of most of these species are the west and southeast regions, in which at least the highest values are close to pH 8.0.

The water hardness values in Rio Grande do Sul indicate that the water is usually soft. The city of Caçapava do Sul and the western region of the state contain reserves of calcite and/or dolomite minerals (Brasil, 1973; Remus *et al*., 2000; Oliveira & Kerber, 2009), which can explain the high water hardness values of the water near these cities. Mean values observed in this study were similar to those previously found in the northern region of this state (Silva *et al*., 2012). Previous studies also detected that the main ions related to water hardness, Ca^{2+} and Mg^{2+}, presented low levels in Rio Grande do Sul (Diel *et al*., 2007; Kochhann *et al*., 2013; Panizzon *et al*., 2013), in accordance with the mean low water hardness noted in this study.

The response to increasing water hardness varies from species to species. Juveniles of *R. quelen* maintained at pHs of 4.0, 7.0 and 9.5 survived for at least 96 h with hardness up to 600 mg/L $CaCO_3$ L^{-1} (higher levels were not tested) even with direct transfer from soft water. Water hardness from 25 to 50 mg $CaCO_3$ L^{-1} (increased with $CaCl_2.2H_2O$) did not affect growth of *R. quelen* juveniles kept at a pH of 6.0 to 8.0 (Copatti *et al*., 2011a,b), neither did the increase of water hardness from 30 to 180 mg $CaCO_3$ L^{-1} in those kept at a pH of 7.0. However, when kept in very soft water (zero water hardness) *R. quelen* juveniles must be raised in a pH of 6.0 to avoid mortality and lower growth (Copatti *et al*., 2011b). On the other hand, those maintained at a pH of 7.6 presented lower growth with an increase in water hardness (Ferreira *et al*., 2013). Therefore, in general, the pH and water hardness of Rio Grande do Sul are appropriate for the aquaculture of *R. quelen* juveniles, since the regions that have a pH around 6.0 also have very low water hardness, and those with a higher or lower pH usually have higher water hardness.

Water hardness higher than 100 mg $CaCO_3$ L^{-1} increased the 96 h survival of *R. quelen* at very acidic (3.75) and alkaline (10.0 and 10.5) pHs (Townsend & Baldisserotto, 2001). The increase of water hardness from 30 to 60 mg L^{-1} $CaCO_3$ also improved the growth of *R. quelen* juveniles exposed to a pH of 5.5, but decreased growth in those kept at a pH of 9.0 (Copatti *et al*., 2011a). Larvae of this species kept at a pH of 8.0 to 8.5 showed the highest survival and growth at both 30 and 70 mg $CaCO_3$ L^{-1} (Townsend *et al*., 2003), but 70 mg $CaCO_3$ L^{-1} is the best level for incubation and larviculture irrespective of the proportions of Ca^{2+} and Mg^{2+} used to increase water hardness (Silva *et al*., 2003, 2005). Consequently, considering the water hardness, the southern region of Rio Grande do Sul is the best area for incubation and larviculture of *R. quelen* because at least the maximum values (except the city of Cidreira) are within the best range for this species.

The recommended water hardness for incubation and larviculture of exotic species raised in Rio Grande do Sul, such as rainbow trout (*Oncorhynchus mykiss*) and silver carp (*Hypophthalmichthys molitrix*) (Baldisserotto, 2009), are 139-230 (Ketola *et al*., 1988) and 300-500 mg $CaCO_3$ L^{-1} (Gonzal *et al*., 1987), respectively. The maximum levels observed in the state are not enough to support normal aquaculture of those species, water hardness levels are even higher than the maximum levels observed in this state, which would not recommend the hatching of these species. In agreement with these observations, there was low survival of eggs and larvae of *O. mykiss* (3.5% in the post-hatching phase) in a river in the northeast of Rio Grande do Sul (Winckler-Sosinski *et al*., 2005). However, juveniles and adults of this species can be raised without a problem because those stages can survive in very low water hardness (2.5 mg $CaCO_3$ L^{-1}) (Perry & Wood, 1985). On the other hand, *H. molitrix* is commonly hatched and raised in southern Brazil (Baldisserotto, 2009), which agrees with the fact that the Yangtze River, the primary natal habitat of *H. molitrix*, has low water hardness (28-84 mg $CaCO_3$ L^{-1}). Hatching rate and egg size in this species were not significantly affected by water hardness ranging from 28.5 to 259.0 mg/L $CaCO_3$ (Chapman & Deters, 2009). The hatching rate and the larval growth of another exotic species raised in Southern Brazil, Mozambique tilapia (*Oreochromis mossambicus*), was not affected by exposure to water with 2-3 or 88-96 mg L^{-1} $CaCO_3$ (using $CaCl_2$ or $CaSO_4$ to increase water hardness) (Hwang *et al*., 1996). However, growth of male sex reversed juvenile *O. niloticus* was higher at 146 mg L^{-1} $CaCO_3$ (increased with $CaCO_3$) than at 82 mg L^{-1} $CaCO_3$ (Cavalcante *et al*., 2009), indicating that water hardness must be increased to raise this species in this state. As observed with *R. quelen*, the increase in water hardness also improved survival and physiologic condition of exotic species, such as *O. mykiss* (McDonald *et al*., 1980), *C. carpio* (Chezhian *et al*., 2011) and *O. niloticus* (Cavalcante *et al*., 2012), exposed to acidic water.

The alkalinity values in Rio Grande do Sul follow water hardness values, *i.e*., regions with higher water hardness also have higher alkalinity values, probably due to the presence of calcium-alkaline rocks in the soil (Fernandes *et al*., 1995). Mean alkalinity values observed in this study were in agreement with the low levels verified in previous studies (Pimenta *et al*., 2012; Silva *et al*., 2012; Kochhann *et al*., 2013). Alkalinity levels of 63 and 92 mg $CaCO_3$ L^{-1} did not affect fertilization and hatching rates, survival or growth of *R. quelen* larvae (Benaduce *et al*., 2008). The increase in alkalinity from 30 to 130 mg $CaCO_3$ L^{-1} without a change in pH or water hardness only decreased growth of *R. quelen* juveniles maintained at high stocking densities (Andrade *et al*., 2007). Larvae of *P. lineatus* and *O. niloticus* had better growth at an alkalinity of 30 mg $CaCO_3$ mg L^{-1} compared to 15-20 and 55-60 mg $CaCO_3$ mg L^{-1} (Rojas *et al*., 2001; Rojas & Rocha, 2004; Paes *et al*., 2011), but these studies used hydrated lime ($CaCO_3.2H_2O$) to increase alkalinity, which also changed water hardness. The increase in alkalinity from 22 to 80 mg $CaCO_3$ mg L^{-1} with the addition of Na_2CO_3 (without changing water hardness) did not affect any growth parameter of male sex reversed juveniles of *O. niloticus* (Cavalcante *et al*., 2010) nor improved growth of those raised in acidic water (Cavalcante *et al*., 2012), demonstrating that for this species water hardness is more important. Therefore, apparently, alkalinity is not a parameter that will affect the aquaculture of native or exotic fishes in Rio Grande do Sul.

The mean turbidity values in Rio Grande do Sul were up to 40 NTU, but in some periods many cities had very high turbidity (up to 6,000 NTU). Low turbidity values (3-97 NTU) were also observed in other studies of rivers in this state (Petry & Schulz, 2006; Salomoni *et al*., 2006; König *et al*., 2008; Blume *et al*., 2010; Pimenta *et al*., 2012; Panizzon *et al*., 2013). High turbidity is associated with a lack of marginal vegetation and deforested areas that favor runoff of sediment during rainy periods (Wachholz *et al*., 2011; Mattos *et al*., 2014). The turbidity values recommended by Conselho Nacional do Meio Ambiente (CONAMA-2005) are up to 100 NTU (around 69-81 mg L^{-1} depending on the type of sediment). Costa *et al.* (2014) suggested that higher values are inappropriate for fish farming. Therefore, in general, water in Rio Grande do Sul is adequate for aquaculture based on turbidity, but fish farmers must avoid direct collection of water from rivers and lakes during periods of high turbidity, since the maximum values observed were up to 60 times the maximum recommended value. They can also reduce turbidity by adding calcium sulfate in the water (Przepiora *et al*., 1997). Periods of higher turbidity in southern Brazil are usually associated with periods of soil preparation for soy (September-November) and wheat (April-May) cultivation (Wachholz *et al*., 2011), in which there is no vegetation covering the soil (Gaida *et al*., 2012). There are no studies analyzing the relationship between turbidity and growth in native fish species, but white sea catfish (*Genidens barbus*) and piava (*Leporinus copelandii*) were associated with turbidity levels of 200-266 NTU, whereas two spot astyanax (*Astyanax bimaculatus*) and lambari (*Astyanax parahybae*) were found at up to 83 NTU in the Guandu River, in southeast Brazil (Mattos *et al*., 2014). Piscivorous fish adapted to visual hunting, as in Cynodontidae, prefer clear water (Melo *et al*., 2009). Water that is turbid (up to 100 NTU) due to clay or silt can also decrease zooplankton consumption and impair growth of some planktivorous fish (Zingel & Paaver, 2009), while not affecting others (Stuart-Smith *et al*., 2007).

The highest Mn and Fe values occurred in the cities of Alegrete and Caçapava do Sul, respectively. The concentration of both metals in the water is related to their concentration in the soil (Minella *et al*., 2007). The highest Fe concentration in the water near the city of Caçapava do Sul is probably due to copper mining, which provokes erosion of hematite (an iron ore) (Remus *et al*., 2000). Water Fe (near the City of Caçapava do Sul) and Mn levels are within the range previously observed by other studies (Reginato *et al*., 2012; Kochhann *et al*., 2013; Weber *et al*., 2013).

The only study that analyzed the effect of Fe on native fish demonstrated that exposure to Fe at 57 mg L^{-1} for 3 h increased sodium (Na^+) loss in tamoatá (*Hoplosternum littorale*) in very soft water and that high Ca^{2+} (866 mg L^{-1}) levels reduced this Na^+ loss (Baldisserotto *et al*., 2012). The growth rate of *O. mykiss* was not affected by 5-10 mg L^{-1} Fe (at pH 6.7-7.4, water hardness 287 mg $CaCO_3$ mg L^{-1}), but the pH must be neutral or slightly alkaline (Steffens *et al*., 1993). Exposure to 23-50 mg L^{-1} Fe reduced growth of catla (*Catla catla*), roho labeo (*Labeo rohita*) and migral carp (*Cirrhina mrigala*) (Hussain *et al*., 2011). Therefore, fish growth could be affected only near Caçapava do Sul, but as this region also has one of the highest mean water hardness values, the effect of Fe may be reduced.

Manganese at 4.2 mg L^{-1} (hardness around 30 mg $CaCO_3$ mg L^{-1}) increased lipoperoxidation in the kidney and reduced mitochondrial activity in the liver of *R. quelen*. Higher concentrations (8.4 and 16.2 mg L^{-1}) impaired oxidative parameters in this species (Dolci *et al*., 2013). There are no growth studies with native or exotic species raised in Rio Grande do Sul, but up to 3.94 mg L^{-1} at 30 mg $CaCO_3$ L^{-1} did not affect mean time to hatch, mortality or weight after 62 days in sea trout (*Salmo trutta*). The increase in water hardness decreased Mn toxicity in this species (Stubblefield *et al*., 1997). Apparently, mean water Mn levels in this state are not a matter of concern for fish farming, since the highest levels were 12-fold lower than the level that changed growth in *S. trutta*. Studies regarding the effects of Fe and Mn levels on growth of native fish are still missing and the effect of the interaction between these metals and water hardness or pH on fish growth are still lacking.

Based on the results of this study, water in Southern Brazil presents adequate levels for fish farming in general, but it is necessary to evaluate pH and water hardness before deciding which species to raise. In addition, fish farmers must have some mechanism to reduce water turbidity, since the turbidity can occasionally increase to a dangerous level. The region near Caçapava do Sul, in spite of having comparatively high water hardness, must be avoided for fish farming due to the high Fe levels.

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