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INVESTIGACIÓN

Environmental, Biological, and Fishing Factors Influencing Fish Mortality and Development of the *Cachirra* event, Navío Quebrao Lagoon

Factores ambientales, biológicos y pesqueros que influyen en la mortalidad de peces y el desarrollo del evento *Cachirra*, Laguna Navío Quebrao

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Abstract

Context: The Navío Quebrao lagoon (NQL) has always played an important role in the economy of the indigenous communities in its surroundings. However, in recent years, the tributaries to the lagoon have been notably impacted by climatic variability and logging activities, therefore clogging the lagoon and causing the loss of depth, which increases the temperature and salinity. In three months, 80 % of the lagoon dries out, causing the mortality of most of the species inhabiting it. This phenomenon is known as the *Cachirra* event. Therefore, this study aims to analyze the incidence of environmental, biological, amd fishing factors in the formation and mortality of the *Cachirra* event.

Methodology: We collected samples from fishing nets used by the fishermen of the *arranchaderos* community. IDEAM provided 2017 climatologic data. Physicochemical variables were measured with a Spectroquant SQ 118 and other direct measurement electronic devices. The R statistical software version 3.2.2 was used to analyze the data and their relationships.

Results: The results showed that 12 species are involved in the formation of the *Cachirra* event, predominantly the Mugilidae family. Salinity was the physicochemical variable that predominantly affected the mortality of the species –October (6,0 ± 0,6 UPS) and March (67,4 ± 1,36 UPS).

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Conclusions: Fish die according to their susceptibility to salinity changes, with *Cathrorops spixii* and *Eugerres plumieri* being the most susceptible species and *Elops saurus and Mugil liza* the most resistant. The species present in the NQL have lengths well below commercial significance and different condition factor and repletion index values before and after the *Cachirra* event.
Funding: Universidad de La Guajira

Keywords: acclimatization, *Cachirra*, mortality, salinity, variables

Resumen

Contexto: La laguna Navío Quebrao (NQL) siempre ha jugado un papel importante en la economía de las comunidades indígenas que se encuentran a su alrededor. Sin embargo, en los últimos años, sus tributarios han sido impactados notablemente por la variabilidad climática y la actividad de tala, trayendo como consecuencia la colmatación de la laguna y causando la pérdida de profundidad, lo cual aumenta la temperatura y la salinidad. En 3 meses se seca el 80 % de la laguna, lo cual causa la mortalidad de la mayoría de las especies que la habitan. Este fenómeno es conocido como evento *Cachirra*. Por lo tanto, este estudio pretende analizar la incidencia de factores ambientales, biológicos y pesqueros en la formación y mortalidad del evento *Cachirra*.
Metodología: Recolectamos muestras de las redes de pesca utilizadas por los pescadores de la comunidad de arranchaderos. El IDEAM proporcionó datos climatológicos de 2017. Las variables fisicoquímicas se midieron con un Spectroquant SQ 118 y otros dispositivos electrónicos de medición directa. Se utilizó el software estadístico R versión 3.2.2 para analizar los datos y sus relaciones.
Resultados: Los resultados muestran que 12 especies están involucradas en la formación del evento *Cachirra*, predominantemente la familia Mugilidae. La salinidad fue la variable fisicoquímica que más afectó la mortalidad de la especie –octubre (6,0 ± 0,6 UPS) y marzo (67,4 ± 1,36 UPS).
Conclusiones: Los peces mueren según su susceptibilidad a los cambios de salinidad, siendo las especies más susceptibles *Cathrorops spixii* y *Eugerres plumieri* y las más resistentes *Elops saurus* y *Mugil liza*. Las especies presentes en la NQL tienen longitudes muy por debajo de la importancia comercial y diferentes valores de factores de condición y del índice de repleción antes y después del evento *Cachirra*.
Financiamiento: Universidad de La Guajira

Palabras clave: aclimatación, *Cachirra*, mortalidad, salinidad, variables

Table of Contents

INTRODUCTION

The Navío Quebrao Lagoon (NQL) is a relevant body of water because it is part of the Flamingos Flora and Fauna Sanctuary (SFFF). The sanctuary was established for the protection of the pink flamingo (*Phoenicopterus ruber*, Linnaeus, 1758). The lagoon also serves as economic support for the fishing communities, mostly indigenous people settled in its surrounding areas. The NQL experiences physiographic and biodynamic changes from October to March, leading to variations in hydrology and water physicochemical variables (Ricerca e Cooperazione - Corpoguajira, 2001). *Cachirra* (a word given by the natives of the area) is an event consisting of the massive mortality of juvenile fish inhabiting the lagoon, which results from changes during a low precipitation season. These changes lead to a progressive increase in salinity and a reduction of food availability, as indicated by de la Lanza-Espino *et al.* (2020). The authors mention that the variations in the coastal physicochemical and biological parameters are the result, among others, of natural factors such as climate.

The *Cachirra* event negatively impacts the economy of the indigenous people living in the area (Rosado *et al.*, 2011) because the species involved in this event, specifically the mugilids, do not reach the commercially required sizes to be well valued in the market. This affects the potential revenues for the local fishermen. The constant opening of the river mouth to allow the influx of water, which is instrumental to the growth of the species, is restricted by the community. This situation creates a dilemma that should be tackled in order to encourage the ancestral culture of the *Cachirra* event, given that it is part of the cultural identity of the people living in the area.

Numerous studies in NQL have focused on the fields of hydrology and hydrodynamics (Negri (2000); hydrodynamic, climatic, biological, and socioeconomic aspects (Ricerca e Cooperazione - Corpoguajira, 2001, Ruiz & Ramírez (2002)); regulation of artisanal use (Pérez & Ceballos, 2002); floristic and ecological aspects (Rosado & Cortés, 2006); physicochemical variables and phytoplankton population (Rosado & Márquez, 2004); mathematical modeling (Annichiarico & Guzmán, 2006, Nardini, 2005); and artisanal fishery (Bedoya, 2004). Several studies assess the impact of salinity and temperature on growth (Shikano *et al.*, 2001). The increased salinity negatively affects the feed conversion rate and efficiency, the protein intake, and the efficiency of protein utilization (Al-Khshali, 2017, Schofield *et al.*, 2011).

In general, Mugilidae species have a high ecological plasticity. Mugilids are able to consume a variety of foods: detritus (which they can also filter out), algae, crustaceans, mollusks, insects, and large amounts of silt from the bottom (Cardona, 2001, Fernández-Delgado *et al.*, 2000). These features make them an ecologically important family due to its decisive contribution to the energy and matter flow from the lower to the upper levels of the ecosystems they inhabit (Almeida, 2003). Several mugilid species can inhabit the same estuary, as they utilize the food distributed from the thin water surface film to the bottom mud, either by direct grazing or using plant-detritus food chains as an energy source (Crosetti & Cataudella, 1995). Due to this, Mugilidae is always one of the dominant fish families in the ecosystems it inhabits (Oliva-Paterna *et al.*, 2006, Simier *et al.*, 2004, Strydom, 2003). The majority of Mugilidae species are highly euryhaline (Cardona, 2001).

This study aims to generate basic information on the behavior of the most relevant aspects regarding the environmental and biological factors that affect the dynamics of the NQL. It also aims to identify the relevant variables causing the massive fish mortality during the *Cachirra* event. The findings of this study could be used by provincial government agencies to design comprehensive policies and strategies that may lead to short-term mitigation of fish mortality and to reduce crustacean and mollusk presence in the lagoon. According to a study by Negri (2000) about the environmental impacts on the hydrological and hydrodynamics of the lagoon, the logging of forests in the main tributary channel and sand extraction activities were found to have a major impact. The research concluded that, within 20 years, the NQL would be completely clogged. Therefore, local authorities need to regulate these activities and must implement strategies to preserve the formation of the *Cachirra* event since it influences the cultural identity of the people living in the area. At the same time, the preservation of the event allows crustaceans to reach a larger size, thus improving their commercial value and the subsequent increase in the income of the indigenous people and afro-descendant communities living in the surroundings of the lagoon.

Methodology

Study area

The area under study is called Navío Quebrao Lagoon or Camarones lagoon, and it is located in the Northwest of the department of La Guajira, in the municipality of Riohacha (11° 27′- 11° 22′ North and 73° 11′-73° 7 ′ West). It is at an altitude of 5 masl and has a maximum flood surface of 9 km^2, approximately 900 ha (Figure 1).

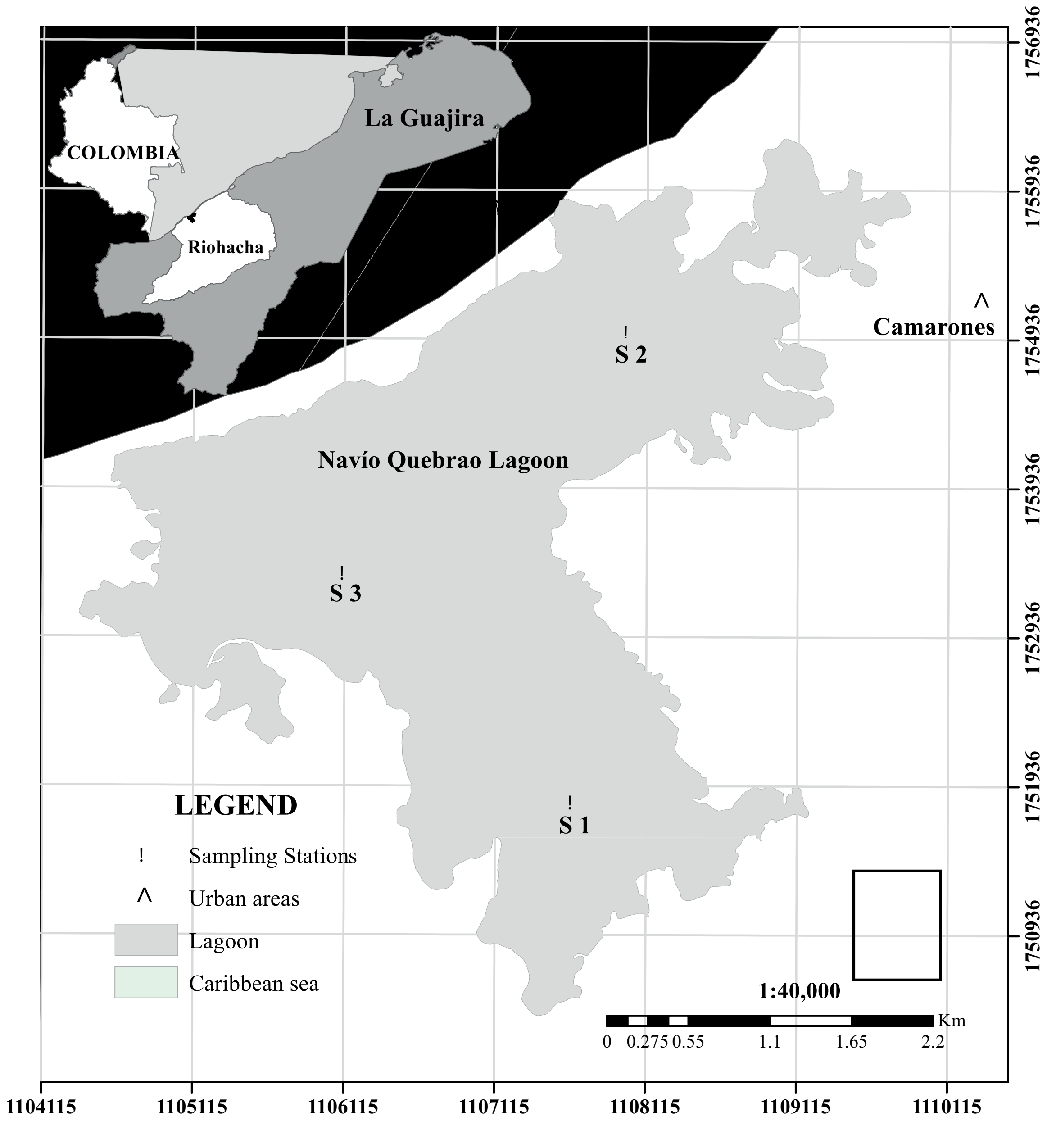

Figure 1. Granulometry results for fine and coarse sand

Source: Authors.

Methods

Research activities were conducted from October 2016 to March 2017. They covered the wet season (October, November, and December) and the dry season (January, February, and March). Climatological, biological, and physicochemical variables, as well as the sequence of fish mortality by species were measured again in 2018. The average values were used for variable analysis. In the wet season, three sampling stations were designated. A sampling station known as S_1 was located 100 m from the mouth of the Camarones river. The S_2 site was located 100 m from Arroyo de Los Indios and S_3 at the center of the lagoon. In the dry season, there is a displacement and a significant reduction of the lagoon area to approximately 5 ha on the western side of the lagoon. The water column also decreases, maintaining a uniform depth during drought time. Thus, only one sampling station was established (S_3) at the center of the lagoon.

The main changes or disturbances occur at the entrance of Arroyo Camarones [Camarones Stream], which correspond to S_1; the others correspond to the mouth of the lagoon (S_2). No additional sampling stations were installed, since the other areas are dead spots where the variables do not show any alteration that is relevant for the study. The location of the S_3 station was selected considering that the evaporation process starting in December causes S_1 and S_2 to disappear, thus reducing the water area to approximately 50 ha in the western sector, where S_3 is located. It is important to mention that there are no major industries or roads in the area. There are only some small houses belonging to indigenous communities who are very isolated from each other, and they have no impact on the dynamics of the lagoon.

Climatological and physicochemical variables

Data corresponding to climatological variables (maximum temperature, minimum temperature, average temperature, relative humidity, sunshine, maximum wind, wind speed, precipitation, evaporation, and cloudiness) were provided by IDEAM (2017). A WTW 3320 Multiparameter was utilized to perform *in situ* monitoring (in triplicate) of physicochemical variables (salinity; potential of Hydrogen, pH; dissolved oxygen, DO; and water temperature). Turbidity was measured with a HACH 2100P turbidimeter. Samples were collected in triplicate in 500 mL polyethylene bottles to determine (*ex-situ*) the concentrations of nitrites and ammonium. They were then transported and kept at 4 ºC to be analyzed at the Environmental Quality Laboratory of Universidad de La Guajira within 8 hours of their collection (APHA, AWWA, & WEF, 2012). Following Camargo & Alonso (2006) recommendations, we selected five variables due to the lethal effects they can have on fish survival: temperature, dissolved oxygen, nitrites, pH, and ammonium.

The standardized methods (APHA, AWWA, & WEF, 2012) used for the analysis of the physicochemical variables are indicated in Table 1.

Inventory of fish species, biometric parameters, and stomach contents

For the identification of the species, previous knowledge and the existing specialized bibliography were used (Cervigón & Fischer, 1979, Chasqui-Velasco *et al.,* 2017, Román, 1979, Rosas-Luis *et al.,* 2016) after weekly manual randomized sampling of moribund floating fish species throug-

Table 1. Variables, methods, and equipment for physicochemical analysis

VARIABLE	ANALYTICAL METHODS	EQUIPMENT
In-situ **physicochemical analysis**		
Water temperature (ºC)	Thermometric (Method 2550 B)	WTW 3320 Multiparameter
pH (Unit)	Electrometric (Method 4500 H+B)	WTW 3320 Multiparameter
Salinity (PSU)	Electrometric (Method 2520 B)	WTW 3320 Multiparameter
Dissolved oxygen (mg/L)	Membrane-Electrode. (Method 4500 - O G)	WTW 3320 Multiparameter
Ex-situ **physicochemical analysis**		
Nitrite (mg/L)	Photometric (Analogous to Method 4500- NO B)	Spectroquant model SQ 118 (Merck brand)
Ammonium (mg/L)	Photometric (Analogous to Method 4500-NH 3 D)	Spectroquant model SQ 118 (Merck brand)

Source: Authors, based on APHA, AWWA, & WEF, 2012.

hout the lagoon. We recorded the sequence of fish mortality for the species involved in the *Cachirra* event. Samples were also taken from *arranchaderos*, places where fish are laid in the open for sun-drying, following their collection with different fishing equipment such as cast nets, trammels, and manuals (Rosado *et al.*, 2011,Ruiz & Ramírez (2002)).

We measured the total length (TL) of the fish with an ichthyometer (a fish measuring board) and the weight (W) with a balance in order to compare the commercial size to the size and weight of the species of the *Cachirra* event. The length-weight relationship of the species was determined using the allometric growth formula $W = a \cdot L^b$ (Froese, 2006, Huxley, 1950) and linearized by means of a logarithmic transformation. The state of gastric repletion (SGR) and food content were determined using a randomized sample of 50 individuals for each species. Their stomachs were extracted, and their content was preserved in 10 % formaldehyde and analyzed with a Nikon E400 stereoscope (Sánchez-Hernández *et al.*, 2010). The Repletion index (RI) was calculated with Equation (1) (dos Santos, 1978,Molina-Ocampo, 1993):

$$RI = \left(\frac{\text{Weight of fish stomach content}}{\text{Fish weight}} \right) \cdot 100 \tag{1}$$

Taxonomic classification of animal samples was conducted only for the upper categories, namely insects, crustaceans, nematodes, and polychaetes. The rest of the samples were classified as detritus, filamentous algae, microalgae, and sand. Following Pauly (1984), the condition factor (CF) was used to determine the relationships between feeding and fish growth during the various stages of development. Equation (2) was used to obtain this factor:

$$CF = \left(\frac{W}{L^3}\right) \cdot 100 \qquad (2)$$

The species involved in the *Cachirra* event were determined through a survey that inquired fishers for the species that they considered to be components of the event. The identified species were those with greater acceptance and demand in the market, as well as those prefferred by the community due to their flavorful taste, which is acquired during the salting and sun-drying process.

Mortality sequence in component species of the Cachirra event

The dry season began in December 2016 and lasted until February 2017. Constant observations were made of the body of water, and, if fish mortality was observed in the area, then the species were collected and measured. The salinity and the salinity range that caused the death of the species were determined using the WTW 3320 Multiparameter.

Statistical analysis

For the analysis and interpretation of the physicochemical and climatic results, the initial data were transformed into a correlation matrix by applying Pearson's product-moment correlation coefficient between pairs of physicochemical and climatic variables using the R statistical package, version 3.2.2. In order to search for associations between the studied variables, a cluster analysis was performed using Ward's algorithm and the similarity matrix based on the Bray Curtis Index. The evaluation of significant differences in the temporal behavior of all the physicochemical variables during the study was carried out by means of the non- parametric Wilcoxon test with a significance level of 0,05.

RESULTS

Climatic variables

Table 2 reports climatic variable data corresponding to the wet months (October, November, and December 2016) and the low water level period (January, February, and March 2017). We observed variations in the records of precipitation, cloudiness, wind speed, and evaporation during the wet and dry seasons, which affected the biodynamics of the lagoon.

Table 2. Record of the main climatic variables in the Navío Quebrao Lagoon

Variables	**Units**	**Rainy season (2016)**			**Drought time (2017)**		
		Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**
Maximum temperature	°C	36,9	34,7	34,6	34,7	36,1	36,4
Minimum temperature	°C	22,4	20,8	21,7	19,8	19,2	18,9
Average temperature	°C	28,4	27,7	27,8	28,0	27,0	27,5
Relative humidity	%	78,0	80,0	75,0	63,0	64,0	66,0
Solar brightness	h/sun	217,8	194,5	228,7	278,7	242,8	231,7
Maximum wind	km/h	42,0	39,0	46,0	65,0	68,0	62,0
Wind speed	m/s	2,8	2,4	2,7	2,8	4,9	4,3
Precipitation	mm	126,4	138,6	14,9	1,9	0,0	0,0
Evaporation	mm/day	6,2	4,6	6,1	7,6	7,9	8,3
Cloudiness	Octas	7/8	6/8	5/8	4/8	3/8	2/8

Source: Authors, based on IDEAM (2017).

Physicochemical variables

Table 3 shows the behavior of the physicochemical variables during the wet and dry seasons, as well as the variations in salinity experienced from October (6,0 ± 0,6 PSU) to March (67,4 ± 1,36 PSU).

Table 3. Average records of physicochemical variables in the months of rain and drought

Variables	**Units**	**N**	**Rainy season (2016)**			**Drought time (2017)**		
			Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**
Salinity	PSU	3	6,0 ± 0,6	23,0 ± 2,64	33,6 ± 1,24	35,0 ± 0,36	41,5 ± 1,41	67,4 ± 1,36
pH	Unit	3	8,0 ± 0,2	7,9 ± 0,3	7,9 ± 0,26	8,5 ± 0,17	8,1 ± 0,2	8,2 ± 0,26
Dissolved oxygen	mg/L	3	5,2 ± 0,4	5,6 ± 0,43	5,4 ± 0,3	5,2 ± 0,1	5,1 ± 0,36	4,4 ± 0,52
Water temperature	°C	3	29,0 ± 0,91	28,0 ± 0,91	28,0 ± 0,62	26,0 ± 0,70	26,0 ± 0,36	28,0 ± 0,52
Nitrite	mg/L	3	0,40 ± 0,04	0,50 ± 0,09	0,40 ± 0,1	0,01 ± 0,01	0,01 ± 0,01	0,01 ± 0,01
Ammonium	mg/L	3	0,20 ± 0,02	0,50 ± 0,04	0,50 ± 0,05	1,00 ± 0,2	1,00 ± 0,1	1,00 ± 0,17

Source: Authors.

Species inventory

Table 4 indicates the presence of 34 species comprised by 20 families, mostly of marine and estuarine origin. We observed four genera belonging to Carangidae and Penaeidae families (11,8 %); three genera belonging to Gerreidae and Mugilidae (8,8 %); and one genus for each of the following families: Belonidae, Clupeidae, Dasyatidae, Gobiidae, Poeciliidae, and Pomacanthidae (2,9 %). Fishermen of the area have linked the *Cachirra* event to twelve species out of the 34 species found. That is 35,3 % of the total number of species living in the lagoon. *Cachirra* species are members of seven families, which is 35,0 % of the total families in the lagoon.

Mortality sequence in species involved in the *Cachirra* event

Table 5 shows the sequential order of deaths for the 12 *Cachirra* species. The species most susceptible to salinity were *C. spixii* and *B. marinus*, with values ranging between 45 and 50 PSU. The most resistant were *M. liza* and *E. saurus*, which died when the salinity exceeded 70,0 PSU.

Parametric variables

M. incilis had the highest number of captures during fishing days (584 fish), followed by *M. liza* (204 fish). **B** values were close to 3,0. *C. spixii* reached the highest value (2,9730). r^2 values were above 0,8, with the highest value (0,9354) corresponding to *C. spixii* (Table 6).

Mugilids were the most abundant species, both before and during the *Cachirra* event. We identified a marked difference in CF and RI values before and after the mortality process. *M. curema* reached its highest CF value (2,10); and *E. saurus* and *M. liza* showed the highest RI values before the *Cachirra* event (1,80 and 1,70). *M. liza* and *M. incilis* had the highest values (0,58 and 0,40) after the event (Table 7).

Table 8 shows the stomach contents of different species that constitute the *Cachirra* event. During the wet season, the food supply is very diverse, predominantly consisting of organic matter, crustacean remnants, detritus, among others. Conversely, the food supply is meager during the dry season.

Discussion

We identified different factors that interact with salinity to significantly reduce the water column during the *Cachirra* event in the NQL. From October to March, variables such as sunshine, evaporation, winds, and cloudiness showed a high correlation with the water temperature of the lagoon, as well as with the increase in salinity (Table 9). During these months, water temperature records showed minor variations. These changes did not affect the fish metabolism. Additionally, the water

Table 4. Reported species and components of the *Cachirra* event

Family	Scientific name
Ariidae	**Bagre Marinus* Mitchill
	**Cathorops spixii* Agassiz
Belonidae	*Strongylura marina* Walbaum
Bothidae	*Citharichthys spilopterus* Günther
Carangidae	*Chloroscombrus chrysurus* L.
	**Caranx hippos* L.
	Oligoplites saurus Bloch & Schneider
	**Trachinotus falcatus* L.
Centropomidae	**Centropomus ensiferus* Poey
	Centropomus undecimalis Bloch
Clupeidae	*Harengula clupeola* Cuvier
Dasyatidae	*Dasyatis guttata* Bloch & Schneider
Elopidae	**Elops saurus* L.
Engraulidae	*Anchovia clupeoides* Swainson
Gerreidae	**Diapterus rhombeus* Cuvier
	Eucinostomus argenteus Baird & Girard
	**Eugerres plumieri Cuvier*
Gobiidae	*Gobioides broussonneti* Lacepède
Lutjanidae	*Lutjanus griseus* L.
Megalopidae	*Tarpon atlanticus* Cuvier & Valenciennes
Mugilidae	**Mugil curema* Valenciennes
	**Mugil incilis* Hancock
	**Mugil liza* Valenciennes
Palaemonidae	*Macrobrachium acanthurus* Wiegmann
	Macrobrachium carcinus L.
Penaeidae	*Penaeus notialis* Perez
	Penaeus schmitti Burkenroad
	Penaeus subtilis Perez
	Xiphopenaeus kroyeri Heller
Poeciliidae	*Poecilia vivipara Bloch* & Schneider
Pomacanthidae	*Pomacanthus paru* Bloch
Portunidae	*Callinectes bocourti* Milne
	Callinectes sapidus Rathbun
Sciaenidae	**Micropogonia furnieri* Desmarest

**Cachirra* component species

Source: Authors.

Table 5. Sequential order of mortality in the component species of the *Cachirra* event

UPS=45-50		50-55		55-60			60-65		>64,7		
C. spixii	→	*D. rhombeus*	→	*C. hippos*	*T. falcatus*	→	*M. curema*	→	*M. liza*	→	*E. saurus*
B. marinus		*E. plumieri*		*C. ensiferus*	*M. furnieri*		*M. incilis*				

Source: Authors.

Table 6. Size-weight relationship for the component species of the *Cachirra* event

Species	Relationship parameters				
	n	Equation	a	b	r^2
C. spixii	74	$W=0{,}01850\ L^{2{,}9730}$	0,01850	2,9730	0,9354
E. saurus	117	$W=0{,}01830\ L^{2{,}8669}$	0,01830	2,8669	0,8080
M. curema	99	$W=0{,}00807\ L^{2{,}4358}$	0,00807	2,4358	0,9565
M. incilis	584	$W=0{,}03280\ L^{2{,}7602}$	0,03280	2,7602	0,9764
M. liza	204	$W=0{,}05460\ L^{2{,}5857}$	0,05460	2,5857	0,8560

Source: Authors.

column did not exceed 30 cm in March, and the action of the northeastern winds, known by the locals as Northeast or trade winds, plays a vital role in the dynamics of the NQL. The wind's strength and origin also determine the climatological (Table 2) and oceanographic features of the area.

Table 9 shows the different correlations that occur between the climatic and physicochemical variables. Salinity is negatively correlated with wind (r = -0,716) and relative humidity (r = -0,707), but positively with evaporation (r = 0,766). The water temperature shows positive correlations with relative humidity (r = 0,802) and cloudiness (r = 0,808), but negative ones with sunshine (r = -0,748), wind (r = -0,807), and pH (r = 0,796). In turn, the pH has a negative correlation with water temperature (r = -0,796) and nitrite (r = -0,753), but a positive one with salinity (r = 0,624).

In Figure 2, two major associations are described: the first, defined by the variables precipitation, relative humidity, cloudiness, water temperature, nitrite, ambient temperature, dissolved oxygen, and ammonia; and the second, which comprises winds, evaporation, salinity, sunshine, and pH. According to the Wilcoxon test, there are no significant differences in the average behavior of the physicochemical variables in the rainy and dry seasons (p>0,05).

Our data (Table 3) showed atypically high values of NO_2^- and NH_4^+ from October to November. During this season, the lagoon receives the most significant water contribution from the Camarones river. Most variables except salinity showed no variations that affected the existing species. In the

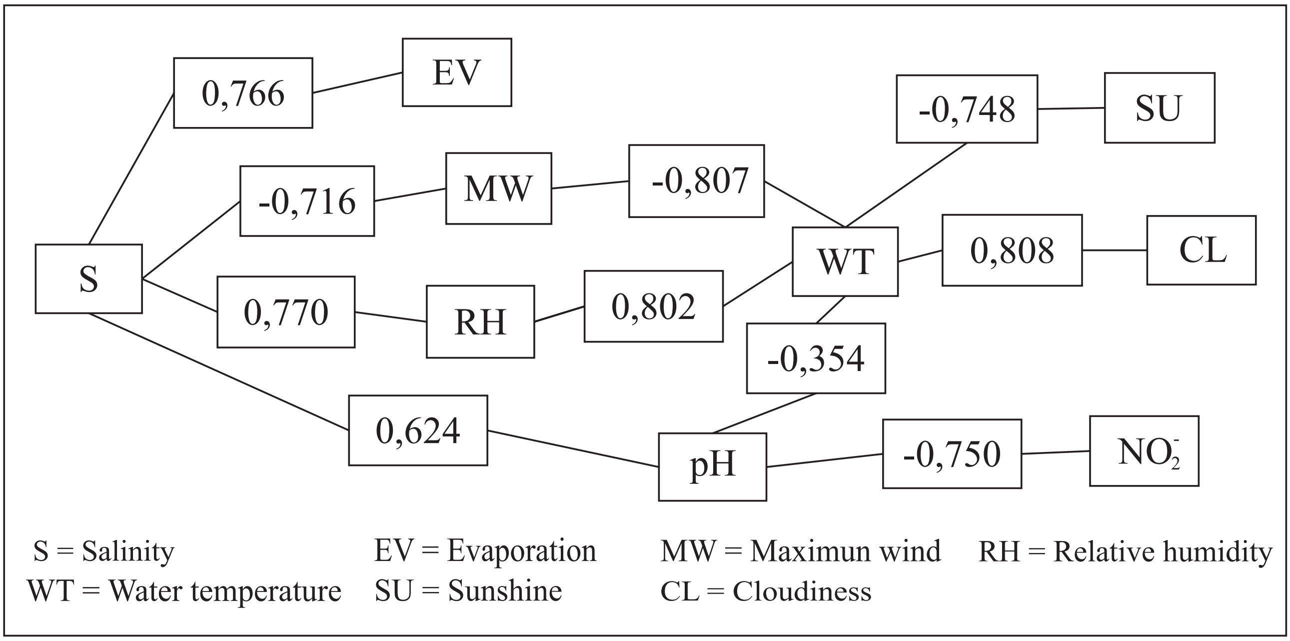

Figure 2. Correlation horizon between climatological and physicochemical variables (October-March)

Source: Authors.

NQL, the increments in salinity are gradual, varying from 35 ± 0,36 to 67,4 ± 1,36 PSU. Therefore, toxicity is also reduced, and, in October and September, NO_2^- and NH_4^+ reach their maximum values while salinity reaches its minimum values. These changes, according to Partridge & Jenkins (2002), may lead to fish stress, exerting its most significant effect at 67,4 ± 1,36 PSU. Water is essential for life, and maintaining its quality is vital (Bueno *et al.*, 2019). Values to protect aquatic animals from nitrogen compound toxicity have been proposed and recommended by different authors (EEA, 2005, Alonso, 2006, CCME, 2010). However, the recommended values are well below the data found during the wet season within the framework of this study. Neither fish nor crustacean mortality have ever been observed in this season. Therefore, we can infer that salinity is the determining factor in the mortality of these species in the NQL, as shown in Table 5.

It is emphasized that the concentration of minerals in shallow water bodies varies significantly from one brackish water body to another, due to differences in climatic, geographical, and topographic conditions, in biological activity, and in the time of analysis. The soil and the erosion or mineralization of rocks constitute edaphic sources of ions for freshwater bodies and eventually for salty bodies (Fuentes & Massol-Deyá, 2002). Bodies of water can be typified according to their total mineral content. Estuarine mineralization is affected by different climatic factors (winds, hours of illumination, precipitation, evapotranspiration, tides, solar brightness) and hydrological factors (current river discharge and tides) in such a way that, in rainy seasons, the salinity shows a tendency towards 0 UPS, as well as during low tides and in times of rising in the rivers that form the estuaries.

Table 7. Number of individuals (n) by species and descriptive statistics of the variables TL, TW, CF, and RI before and after the *Cachirra* event

Species	N	TL (cm)			TW (g)		CF	RI
		Max.	Avg.	σ	Max.	Avg.		
Before the *Cachirra* event								
C. spixii	74	26,3	20,48	3,93	293	162,70	1,89	1,30
E. saurus	117	26,2	19,56	4,09	320	110,03	1,47	1,80
M. curema	99	30,0	14,68	4,50	270	66,40	2,10	1,60
M. incilis	584	39,8	19,28	5,26	736	138,05	1,92	1,50
M. liza	204	37,0	18,68	3,91	430	117,32	1,80	1,70
After the *Cachirra* event								
C. spixii	26	20	11,61	3,143	52	12,84	0,82	0,37
E. saurus	734	35	18,80	5,418	136	41,34	0,62	0,26
M. curema	634	24	12,52	2,950	92	22,77	1,16	0,40
M. incilis	518	38	17,37	5,327	442	53,79	1,02	0,49
M. liza	211	38	19,30	7,465	438	73,47	1,02	0,58

n: number of individuals; **Max:** maximum; **Avg:** average; σ: standard deviation; **CF**: condition factor; **RI**: repletion index

Source: Authors.

On the other hand, in periods of drought or high tide, it tends to increase along with the minerals. Salinity depends on the stratification of the estuary. Thus, in estuaries with a saline wedge, salinity increases (Rosado & Castro-Echavez, 2011).

The inventory of species of the NQL showed that it posseses a great wealth of fish coming from the sea and, in a lesser extent, from its tributaries. Our data (Table 4) indicate that, out of the 20 families and 34 species reported, only 12 species (which represent 35,5 % of the total population) are part of the *Cachirra* event. Our study and the one by SENA & Ministerio de Ambiente y Desarrollo Sostenible, 1998 showed similar results, but notable discrepancies were observed in the number of species living in the NQL. Our study found commercially relevant species usually sold at high prices in regional and national markets, such as different types of prawns (*P. schmitti* and *P. notialis*, *P. monodon*), sea bass (*C. undecimalis* and *C. ensiferus*), and mugilids (*M. liza*, *M. incilis*, and *M. curema*¸). The aforementioned species are the foundation of the economy of the communities located around the NQL.

Table 8. Stomach content of some component species of the *Cachirra* event

Species	Type of food	
	Rainy season	**Drought season**
E. saurus	Detritus, fish remains crustacean remains, and shrimp.	Crustacean remains
M. liza	Organic matter, vegetal detritus, sediments, diatoms, copepods, algae, mud, and organic detritus.	Organic detritus
M. incilis	Organic matter, plant detritus, sediments, diatoms, copepods, crustaceans, algae, mud, and organic detritus.	Organic matter and detritus
M. curema	Organic matter, plant detritus, sediments, diatoms, copepods, mud, organic detritus, and crustacean remains.	Mud and organic detritus
C. spixii	Seaweed and shrimp postlarvae.	Vegetal detritus
M. furnieri	Organic detritus, ostracods, and bivalves.	Organic detritus
C. ensiferus	Fish and shrimp remains, detritus, insects, crabs, and crustacean remains.	Crustacean remains

Source: Authors.

From January to March, an abrupt alteration of conditions begins, and salinity increases from 35 ± 0,36 to 67,4 ± 1,36 PSU (Table 3). This change causes a notable loss in the lagoon's biological biodiversity because salinity (Smyth & Elliott (2016)), temperature (Molina *et al.*, 2020), and turbidity (Romero-Berny *et al.*, 2020) influence the spatial and temporal composition of fish communities. Furthermore, Smyth & Elliott (2016) indicate that there is also an energetic cost required in order to adapt to a changing ambient salinity, which may have consequences for organisms. Therefore, the variation from 34 species in October 2016 to 12 species in March 2017, allows stating that the salinity increase is a prominent factor that affects species mortality. The result is a decrease in the number of susceptible species, which also shows the persistence of those more abundant species, as is the case of mugilids such as *M. curema*, *M. incilis*, and *M. liza*. In some cases, fish can survive due to their osmoregulation capabilities (Stone *et al.*, 2014) and their eating habits when a high concentration of nutrients are available due to evaporation in hypersaline environments, which agrees with what was indicated by Arjonilla & Blasco (2003) regarding the salinity-evaporation parameter, which increases the concentration of both ammonium and silicates.

Organisms from euryhaline environments, namely *M. liza* and *E. saurus*, can adapt to high salinities (Costa *et al.*, 2008) during the dry season, but they do not forfeit their level of acclimatization during the wet season, which contributes to their distribution through salt adaptation (Chung, 2001). This acclimatization extends to other species such as crustaceans and tropical mollusks. Serrano *et al.* (2011) observed successful acclimatization of gray snapper (*L. griseus*) juveniles to hyposaline and hypersaline environments (0-60 PSU) after an adjustment of 96 h, thus demonstrating that ranges of acclimatization to changes in salinity vary from species to species.

In general, the studied species exhibit different values corresponding to negative allometric growth (Table 6), except *C. spixii*, which presented an isometric growth, with a **B** value almost equal to 3,0

Table 9. Correlation matrix of climatological and physicochemical variables

Variables	RT	RH	SU	MW	PR	EV	CL	S	pH	DO	WT	NI	AM
RT	1												
RH	0,495	1											
SU	-0058	**-0,851****	1										
MW	**-0,573***	**-0,992****	**0,797****	1									
PR	**0,516***	**0,867****	**-0,757****	**-0,848****	1								
EV	-0,375	**-0,914****	**0,730****	**0,910****	-0,825**	1							
CL	**0,539***	**0,882****	**-0,796****	**-0,898****	**0,853****	**-0,793****	1						
S	**-0,610***	**-0,707****	0,315	**0,716****	**-0,676**	**0,766****	-0,432	1					
pH	-0,354	**-0,845****	**0,791****	**0,798****	**-0,726**	**0,629***	**-0,598***	**0,624***	1				
DO	-0,102	0,265	-0,075	-0,270	0,163	**-0,609***	0,074	**-0,528***	0,038	1			
WT	**0,554***	**0,802****	**-0,748****	**-0,807****	**0,646***	**-0,503***	**0,808****	-0,323	-0,796**	-0,329	1		
NI	**0,717****	**0,552***	-0,336	**-0,546***	**0,649***	-0,305	0,427	**-0,611***	-0,753**	-0,342	**0,658***	1	
AM	-0,186	**0,516***	**-0,624***	-0,488	**0,549***	**-0,735****	**0,581***	-0,223	-0,151	**0,626***	0,092	-0,273	1

* The correlation is significant at a level of 0,05 (2-tailed).

** The correlation is significant at a level of 0,01 (2-tailed).

RT = Room temperature

RH = Relative humidity

S = Sunshine

MW = Maximum wind

PR = Precipitation

EV = Evaporation

CL = Cloudiness

S = Salinity

pH = Potential of Hydrogen

DO = Dissolved oxygen

WT = Water temperature

NI = Nitrites

AM =Ammonium

Source: Authors.

(2,9730). Negative allometric growth means species have little weight for their length. *Cachirra* event constituents, whose **B** value is less than 3,0, gain length in less time than it takes for their weight to increase, as is the case of *E. saurus* and the mugilids (*M. curema*, *M. incilis*, and *M. liza*). The growth of these species does not increase as a function of size cubic power; these variations depend on time and the sampling system used. Bravo *et al.* (2009) reported comparable results for *H. aurolineatum*, an abundant species in Margarita Island (Venezuela). Studies with various species and environments support the finding that it was possible to ensure that **B** values ranged between 2,5 and 4,0. Under natural conditions, these values are rarely equal to 3,0, a fact that coincides with the results obtained in our study.

Fishermen in the area use selective fishing gear with mesh eyes ranging from ¾ to 1, which is known as 'shrimp *chinchorro*'. This equipment allows older fish to be captured and juveniles to escape. The use of shrimp *chinchorros* explains that the vast majority of fish sizes before and after the *Cachirra* event are well below the average, corresponding to juvenile fish that have not yet achieved their first maturation, a condition reflected in the high values of the CF reached by the species, especially by juvenile mugilids. During December, mugilids abound in the coastal zone and penetrate the lagoon in search of refuge and food. Guerra & Marín (2002) study of *M. liza* in the Unare Lagoon in Venezuela determined that this species reaches an average size of 67,3 cm, and Ruiz & Ramírez (2002) indicate an average length of 23,1 cm for *M. incilis*. Both sizes are above the sizes reported for these species before and after the *Cachirra* event, thus reinforcing the hypothesis that most of the components of this event are in juvenile stages. It is worth adding that fish length-weight relationships may vary according to sex, sexual maturity, and food consumption.

Botero-Arango & Castaño-Rivera (2005) concluded that the fact that they did not find any statistical evidence relating the environmental variables to the CF does not discard their influence on fish welfare. In contrast, Osorio-Dualiby (1985) concluded that CF values are higher in September, October, and November, when environmental conditions such as lagoon depth and salinity are less extreme, which agrees with the values obtained in the present study. Although there was no consistent finding of heavier fish with a higher CF before the *Cachirra* event, it was observed that mugilids showed high CF values, thus reflecting a better condition or nutritional status, increased by the amount of detritus brought by the rivers during the wet season, which constitutes the primary source of food for mugilids (Osorio-Dualiby (2016)).

The difference found in the RI before and after the *Cachirra* event (Table 7) agrees with Franco & Bashirullah (1992) study. These authors found that specimens with empty stomachs (RI<0,5) are larger than those that with an RI>0,5. The abundance and biodiversity of food during the wet months explains that fish before the *Cachirra* event have higher RI than after the event. Alcocer (1997) argues that biodiversity reduction in saline lakes can be very drastic, especially in hypersaline lakes, which may be limited to a primary producer or another biotic group with high osmoregulatory capacities, as is the case of *E. saurus* and *M. liza.*

Castro-Aguirre (1982) and Raz-Guzmán (1995) highlighted the great influence that environmental variations and biological processes exert on the structure and dynamics of estuarine communities. According to the latter, salinity and temperature are the most relevant factors. Guevara *et al.* (2007) found that, during the rainy season in the Términos lagoon (Mexico), penaeid shrimp (Peneidae) and crustaceans predominate in the stomach contents of fish, decreasing during the dry season, which corresponds to December, January, and February in the NQL.

Some studies demonstrate the variation in the stomach contents of the main component species of the *Cachirra* event (Table 8) such as the mugilids *Mugil curema*, *M. incilis*, and *M. liza*, which feed mainly on phytoplankton and secondarily on debris. *Mugil curema* exhibits the highest consumption of phytoplankton among the three species. These results are similar to those reported by Osorio-

Dualiby (2016). Franco & Bashirullah (1992) reported that *M. curema* feeds preferentially on benthic diatoms, organic debris, inorganic fine sediments, and dinoflagellates. Gómez-Canchong *et al.* (2004) indicated that *M. incilis* has a high consumption of detritus, followed by phytoplankton and a very low consumption of zooplankton. Bustos & Pérez (2003) and Cogua *et al.* (2013) indicated that *M. incilis* preferably consumes centric diatoms and pennadas and that *Mugil liza* showed a high consumption of phytoplankton and a low consumption of detritus.

CONCLUSIONS

Climatological, physicochemical, and food availability variables in the dry season exert significant effects on the composition and mortality of fish species in the NQL. These variables determine a sequence of mortality due to the progressive increase in salinity known as the *Cachirra* event. Mugilidae is a family with a higher number of species resistant to salinity increases, which is due to its great osmotic potential and better nutritional status. Most of the components of the *Cachirra* event are in juvenile stages. Their length-weight relationship can vary according to sex, sexual maturity, and food intake.

The mineralization of the Navío Quebrao lagoon is affected by different climatic factors (winds, hours of illumination, precipitation, evapotranspiration, tides, solar brightness) and hydrological factors (discharge from the river, current, and tides), as well as by the winds, high temperatures, salinity increases, and accelerated clogging by transport and dumping of sediments by its tributaries, the latter being the most important and meriting the implementation of public strategies that lead to mitigating the felling of trees and extractive activities of the Camarones riverbed, considering that the *Cachirra* event plays an important role in the cultural identity of the inhabitants of Camarones and serves as sustenance for the economy of the indigenous communities located in their surroundings.

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