FISH COMPOSITION AND PREY UTILIZATION OF THE BLACK SKIMMER (RYNCHOPS NIGER) IN MAR CHIQUITA COASTAL LAGOON, ARGENTINA

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http://dx.doi.org/10.1590/S1679-87592014034806201

ABSTRACT

Lagoons along the western coast of the South Atlantic Ocean shelter high densities of juvenile fish and are key areas for several seabirds that rely on the resources offered by this kind of ecosystem. The objective of this study was to analyze fish composition and abundance in shallow-water areas of the estuarine region of Mar Chiquita Coastal Lagoon (Argentina) and the diet composition of the Black skimmer (*Rynchops niger*) during its non-breeding season as well as evaluating its inter-annual variations. Fish were sampled with a beach-seine net and the skimmers' diet was analyzed from their pellets. The estuarine-dependent marine fishes were the best represented bio-ecological category followed by freshwater fishes. Significant differences were observed in fish abundance and composition between and within years. Species richness was higher during the summer season and during the first year sampled. The occurrence of freshwater fishes as an important and diverse group of the Mar Chiquita estuarine area contrasted with previous reports. The diet of the Black skimmer included freshwater, estuarine and marine fish species. Skimmers forage in the shallow waters of the estuarine area of the Mar Chiquita Coastal lagoon though little similarity was observed between its diet and local fish abundance. These results emphasize the importance of performing these evaluations in order to improve the quality of studies and the interpretations of top predators foraging ecology.

RESUMO

As lagoas costeiras do Oceano Atlântico Sul abrigam altas densidades de peixes juvenis e são áreas-chave para diversas aves marinhas que dependem dos recursos oferecidos por esses ecossistemas. O objetivo do presente trabalho foi analisar a abundância e a composição de peixes na região estuarina da Lagoa Costeira Mar Chiquita (Argentina), a dieta do talha-mar (*Rynchops niger*) e as variações interanuais. Os peixes foram coletados com uma rede de praia tipo picaré e a dieta do talha-mar analisada a partir de suas fezes. O peixe-marinhos dependentes do estuário foram a categoria bio-ecológica melhor representada, seguido por peixes de água doce. Foram observadas diferenças intranuais e interanuais significativas na abundância e composição da ictiofauna. A riqueza de espécies foi maior durante o verão e no primeiro ano da amostragem. A ocorrência de peixes de água doce como um grupo importante e diversificado na área estuarina do Mar Chiquita contrasta com resultados de estudos anteriores realizados na área. A dieta do talha-mar incluiu peixes de água doce, estuarinos e marinhos. Apesar dessa ave se alimentar em águas rasas da área estuarina do Mar Chiquita, uma baixa similaridade entre sua dieta e abundância local de peixes foi observada. Esses resultados reforçam a importância da realização de avaliações a fim de proporcionar avanço nos estudos e melhorar as interpretações sobre a ecologia alimentar de predadores de topo.

Descriptors: Argentina, biodiversity, coastal lagoon, fish abundance, diet of seabirds, predator-prey relationship.
Descritores: Argentina, Biodiversidade, Lagoa costeira, Abundância de peixe, dieta de aves marinhas, relação predador-presa.

INTRODUCTION

Coastal lagoons are shallow estuarine environments, connected to the sea by one or more restricted inlets (ISLA, 1995). The functional role of these areas for fish has been widely studied; the great environmental diversity and productivity observed in these areas makes this type of environment an important source of habitat and food resources for fish, also functioning as important nursery and refuge areas (VEIGA et al., 2006; GONZÁLEZ-CASTRO et al., 2009).

It is well known that these ecosystems lying along the western coast of the South Atlantic Ocean

(SAO) shelter high densities of juvenile fish, some of them of commercial importance for artisanal and small-scale fisheries (LASTA et al., 2000; COUSSEAU; PERROTTA, 2004; ISACCH et al., 2010; VALIÑAS et al., 2010). One of the main lagoons along the coast of the SAO is Mar Chiquita Coastal Lagoon in Argentina. This shallow estuarine system is separated from the sea by a sandbar, and connected to the ocean through an inlet of about 6 km long and 200 m wide. The lagoon's drainage basin covers 10,000 km^2. Seawater enters the system at high tide, and the magnitude depends on the direction and intensity of the prevailing winds. Several streams and artificial channels contribute abundant freshwater during rainy periods (RETA et al., 2001; MARCOVECCHIO et al., 2006). The fish composition in this estuarine environment has been studied over the last 15 years and several fish species have been reported to make extensive use of the lagoon in permanent, temporal or occasional ways (COUSSEAU et al., 2001; GONZÁLEZ-CASTRO et al., 2009). The available literature on the fish communities of this lagoon suggests that the area is likely an important nursery ground for some marine species, providing high food availability and refuge for juvenile fishes (MARTINETTO et al., 2007; VALIÑAS et al., 2010). Mar Chiquita Coastal Lagoon is a unique ecosystem with a high conservation value for the biodiversity it holds, and it has been declared a Biosphere Reserve under the UNESCO Man and the Biosphere Programme (CANEVARI et al., 1998; IRIBARNE, 2001). As many other wetlands, Mar Chiquita is used as a breeding, foraging, roosting and/or refueling area by several bird species both during breeding and non-breeding seasons (FAVERO et al., 2001; MARTÍNEZ, 2001; SILVA RODRÍGUEZ et al., 2005). This wetland has been reported as one of the most important wintering sites in southern South America for species such as the Common Tern *Sterna hirundo* and the Black Skimmer *Rynchops niger* (FAVERO et al., 2001; SILVA RODRÍGUEZ et al., 2005, and quotations therein). Particularly for this latter species, Mar Chiquita is its main non-breeding site in southern South America, congregating *ca.*10,000 individuals during the austral summer-autumn season (SILVA RODRIGUEZ et al., 2005). The large fish biomass occurring in the shallow waters of western SAO estuaries (LASTA et al., 2000; COUSSEAU et al., 2001; LOEBMANN et al., 2008), likely constitutes an important resource for piscivorous birds whose populations are largely sustained and nourished by the feeding resources offered by this kind of system (SILVA RODRÍGUEZ et al., 2005). Most of the studies on seabirds' diet at this particular site report a high consumption of juveniles and/or small-sized fish species, and behavioral observations confirm the wide use of shallow estuarine areas as foraging sites (MARIANO-JELICICH et al., 2003, GARCÍA; MARIANO-JELICICH, 2005, SILVA RODRIGUEZ et al., 2005). Despite this background only a few studies have analyzed the fish composition in these waters, mostly comparing them spatially with variations - depending on the size group of the fish species considered (COUSSEAU et al., 2001; GONZÁLEZ-CASTRO et al., 2009). Moreover, there has been no evaluation of the relationship between fish abundance and seabirds' diet. In this study we analyzed the fish composition and abundance in shallow-water areas of the estuarine region of Mar Chiquita Coastal Lagoon and the fish contribution to the diet of the Black skimmer during its non-breeding season. We have integrated these results over two consecutive and contrasting years. This characterization will contribute to an increased understanding of this particular ecosystem, allowing a better interpretation of predator-prey relationship studies.

Material and Methods

Study Area

Mar Chiquita Coastal Lagoon (37°32'S, 57°19'W, Argentina; a UNESCO Man and the Biosphere Reserve, UNESCO 1996) is a saltmarsh located on the south-west Atlantic coast (Fig. 1). This is a 46 km^2 body of brackish water of 25 km length, affected by a microtidal regime (≤1 m range) with low amplitude and 0.79 m of mean variation (FASANO et al., 1982; RETA et al., 2001).

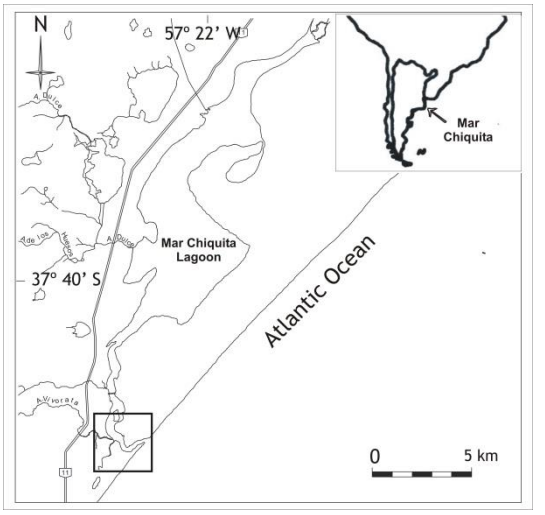

Fig. 1. Study site in Mar Chiquita Coastal Lagoon. The square inset on main picture shows the sampling area in the vicinity of the mouth of the estuary.

In this study, the fish species were sorted into four bio-ecological categories in accordance with the descriptions adapted to Mar Chiquita Coastal Lagoon made by Cousseau et al. (2001): (1) *Freshwater fish* (FW): typically inhabiting freshwater environments and rarely occurring in estuaries; (2) *Estuarine-dependent marine fish* (EdM): marine species which are predominantly found in estuaries at some stage of their life cycle; (3) *Estuarine non-dependent marine fish* (EndM): species found in both estuarine and coastal inshore areas with no dependence upon estuarine environments to complete their life cycles; (4) *Occasional visitors* (OC): species rarely occurring or occurring in very low frequency in the study area.

Fish Sampling

Samplings were conducted within the frame of a long-term study of seabirds' foraging ecology and predator-prey relationships. A beach seine net designed for juveniles and/or small-sized fish (10.0 x 1.8 m; 12-mm mesh size) was used. The net was fitted with hauling ropes and set perpendicular to the shore at approximately 1.5 m depth. Seine hauls were performed by two persons, covering a distance of approximately 50 m; the hauls lasting an average of 10 min. The distance seined and the time required for each haul was standardized, thus allowing comparisons between collections. The total area sampled was taken to be the distance the net was laid offshore multiplied by the mean width of the haul, resulting in an effective fishing area of approximately 500 m^2. Sampling was undertaken monthly between December and April of both 2002-2003 and 2003-2004. Between eight and ten transects, at least 50 m but no more than 100 m apart, were made on each side of the inlet. Fish were fixed in 5% formalin (in the field), and identified to species level, counted, measured with a digital caliper (accuracy 0.01 mm) and weighed on digital scales (accuracy 0.01 g) in the laboratory. Species were identified with the help of identification guides, dichotomous keys, and reference material from our own collection.

Analysis of Seabirds' Diet

Data on seabirds' diet were obtained at the same time as the net catches were made (seasons 2002-03 and 2003-04). The Black skimmer (*Rynchops niger*) was used as a model species, the diet of this bird was monitored from 2000 to 2006 (MARIANO-JELICICH unpub. data). Moreover, it has been recorded foraging in shallow waters in the estuarine region of Mar Chiquita Coastal Lagoon, and both estuarine and marine fish species have been reported in the skimmers' diet in this area (MARIANO-JELICICH et al., 2003; MARIANO-JELICICH; FAVERO, 2006). A total of 1648 regurgitated pellets of the Black skimmer (*Rynchops niger*) wintering at Mar Chiquita Coastal Lagoon were analyzed. In order to avoid samples from other species, pellets were only taken in areas where no other bird species were present with skimmers. Only fresh pellets were collected, assuming that they contained remains of prey consumed during the previous day (FAVERO et al., 2001; MARIANO-JELICICH et al., 2003). Once collected, each sample was dried at ambient temperature and dissected and the hard remains were identified using a stereomicroscope. Fish otoliths were identified to species level using descriptions and illustrations from the literature (VOLPEDO; ECHEVERRÍA, 2000; WAESSLE et al., 2003) and reference material from our own collections. Quantifications always followed the minimum number rule (*i.e.* otoliths were separated into right and left, and the most abundant was considered as representing the number of fish prey of each species in the sample, see BROWN; EWINS, 1996). The importance of prey categories was quantified as numerical abundance (N%): the percentage of prey items of one type out of all prey items (BARRETT et al., 2007). The total length of otoliths was used to estimate the fish size (total length) by the regression equations used in previous studies (MARIANO-JELICICH et al., 2003; MARIANO-JELICICH; FAVERO, 2006).

Data Analysis

Monthly counts were grouped in their corresponding season for the analysis (i.e. summer 2003-2004, autumn 2003-2004). For each family and species registered a value of frequency of relative occurrence (number of samples in which the family or species was observed over the total number or samples) was calculated (BIBBY et al., 1992). To estimate the importance of each species an Index of Relative Importance (IRI) modified in accordance with Gatto *et al.* (2005) was developed:

$$IRI = 100\ (N_i / N_t)\ (S_i + T_i) / (S_t + T_t),$$

where N_i is the sum of species *i* abundance, N_t is the sum of overall abundance, M_i is the number of seasons in which the species *i* was present, E_i is the number of seasonal transects in which the species *i* was observed, and M_t and E_t are the total number of seasons and transects of the sampling, respectively (GATTO et al., 2005; GARCÍA; GÓMEZ LAICH, 2007).

Seasonal specific richness was calculated as the total number of species registered in each transect, grouped by season. These values were standardized by the rarefaction method by adjusting the measure of species richness to sample size and allowing the comparison between assemblages with different densities. In this case the rarefaction for each season

was calculated taking the smallest sample (n = 459) as the reference abundance value (GOTELLI; ENTSMINGER, 2006). Diversity was calculated using the Shannon-Wiener Index (H').

Multivariate analysis of fish assemblage data between and within years was performed using the PRIMER software package version 5.2 (CLARKE; GORLEY, 2001). First a similarity matrix of the samples was built using the Bray-Curtis similarity coefficient after square root transformation of the data (CLARKE, 1993). Then, a non-parametric permutation-based procedure was used, the ANOSIM, yielding a test statistic R that takes a value of 1 when all samples within a group are more similar to each other than any sample from other groups, and is approximately zero when there are no differences between groups. A randomization process was used to find the probability of gaining particular values of R by chance (CLARKE; WARWICK, 2001). Similarity percentage (SIMPER) was employed to determine the species that contributed most to the dissimilarity between groups (CLARKE, 1993). Fish species most responsible for the multivariate pattern were identified using similarity percentage analysis (SIMPER). Species contributing at least 10% dissimilarity were considered important differentiators between years (BULLERI et al., 2005).

Logarithmic transformation (Log10(x+1)) of fish abundance data (number and biomass) were performed to meet assumptions of normality and homocedasticity in order to apply parametric statistics, and also to reduce the bias of abundant species. Analyses of variance (Two-way ANOVA) were performed to test for differences in number within each year of main fish species. An *a posteriori* comparison of means was made using the Tukey test (ZAR, 1999).

An evaluation of similarity between the composition of beach-seine net catches and prey items in seabirds diet was quantified using Renkonen's percentage similarity coefficient (*S*, KREBS, 1999; DÄNHARDT et al., 2010), ranging from 0 (no similarity) to 100 (complete similarity).

RESULTS

Species Composition and Abundance

Over 26,000 fish belonging to 12 families and 15 species were collected in 139 samples obtained over the study period. Clupeidae (IRI = 35.1%), Atherinopsidae (IRI = 14.8%) and Anablepidae (IRI = 8.4%) were the most important families in terms of relative importance. Of these families *Brevoortia aurea* (N = 61.4%), *Odontesthes argentinensis* (N = 16.0%) and J*enynsia multidentata* (N = 14.5%) were the most abundant species, together accounting for 92% of the total catch. Remaining species had low representation. In terms of biomass the more representative species were *Brevoortia aurea* (W = 39.7%), *Odontesthes argentinensis* (W = 27.0%), *Jenynsia multidentata* (W = 15.8%) and *Micropogonias furnieri* (W = 11.6%), accounting for 94 % of the total biomass of the total capture. Total length of captured specimens ranged between 15 and 194 mm. The larger specimens caught represented *Oligosarcus jenynsii*, *Odontesthes argentinensis* and *Micropogonias furnieri* (see Table 1).

Representation of Bio-Ecological Categories

The estuarine-dependent marine fish (EdM) was the best represented group with seven species from the orders Atheriniformes, Clupeiformes, Mugiliformes, Perciformes and Pleuronectiformes. This group accounted for 82.7% in importance by number. Within EdM, *Odontesthes argentinensis* and *Brevoortia aurea* were species found throughout the seasons sampled although the abundances varied between years. *Mugil platanus* and *Micropogonias furnieri* showed different patterns of abundance among years, being absent in summer 2004 and autumn 2004, respectively. Freshwater fish (FW) was the following best represented bio-ecological category accounting for 17.0% in importance by number. Summer 2003 was characterized by higher freshwater fish diversity, with *Jenynsia multidentata* and *Plathanichthys platana* as the most important species. Occasional visitors (OC) and the estuarine non-dependent marine fish (EndM) occurred in very low frequencies and occasionally during the sampling period (see Table 2).

Between and Within Year Comparison of Fish Assemblages

Significant differences were observed in fish composition between years (ANOSIM, global R = 0.08, P = 0.012). According to SIMPER analyses, the species that contributed most to the differences observed were *Brevoortia aurea*, *Odontesthes argentinensis*, *Jenynsia multidentata* and *Mugil platanus*. These four species accounted for more than 83% of the average dissimilarity (69%) in fish species composition between years.

Within each year significant differences were observed in fish species composition through the seasons sampled (ANOSIM, R_{2003}=0.3, P = 0.001; R_{2004}=0.5, P=0.001). In 2003, *Brevoortia aurea* (41.3%), *Jenynsia multidentata* (17.3%) and *Odontesthes argentinensis* (14.8%), explained most of the average dissimilarity (71.6%) within the group. In 2004 the species contributing most to the average dissimilarity (67.0%) were *Odontesthes argentinensis* (43.8%), *Mugil platanus* (21.3%) and *B. aurea* (13.7%) (Table 2).

Table 1. Frequency of occurrence (F%), index of relative importance (IRI%), number (N), biomass (W) and size range of fish species. Between brackets is the total number of samples.

Taxa	F% (139)	IRI%	N	W (g)	Size range (mm)
Atheriniformes					
Atherinopsidae	**92.8**	**14.85**			
Odontesthes argentinensis	92.8	14.85	4185	3563.0	21 - 142
Clupeiformes					
Clupeidae	**54.0**	**35.10**			
Brevoortia aurea	51.1	32.20	16082	5247.0	21 - 102
Platanichthys platana	17.3	0.42	560	226.2	19 - 61
Ramnogaster arcuata	1.4	<0.01	6	2.6	21 - 50
Engraulidae	**16.5**	**0.19**			
Anchoa marinii	5.8	0.01	45	28.0	16 - 98
Lycengraulis olidus	10.8	0.10	224	47.9	15 - 118
Cyprinodontiformes					
Anablepidae	**56.8**	**8.44**			
Jenynsia multidentata	56.8	8.44	3809	2091.0	16 -74
Characiformes					
Characidae	**4.3**	**0.01**			
Cheirodon interruptus	2.2	0.01	60	25.9	26 - 41
Oligosarcus jenynsii	4.3	0.01	33	227.1	47 - 147
Mugiliformes					
Mugilidae	**39.6**	**0.99**			
Mugil platanus	39.6	0.99	639	201.4	20 - 65
Perciformes					
Sciaenidae	**23.0**	**0.50**			
Micropogonias furnieri	23.0	0.50	539	1533.0	19 - 194
Pleuronectiformes					
Cynoglossidae	**0.7**	**<0.01**			
Symphurus jenynsi	0.7	<0.01	2	1.0	37 - 48
Paralichthyidae	**2.2**	**<0.01**			
Paralichthys orbignianus	2.2	<0.01	5	4.4	48 - 78
Siluriformes					
Callichthydae	**1.4**	**<0.01**			
Corydoras palleatus	1.4	<0.01	3	7.7	39 - 57
Pimelodidae	**3.6**	**<0.01**			
Pimelodella laticeps	3.6	<0.01	10	6.5	32 - 52

Table 2. Seasonal abundance for each fish species, observed / expected richness and diversity (H') during the sampled years. Bio-ecological categories are freshwater fish (FW), estuarine dependent marine fish (EdM), estuarine non-dependent marine fish (EndM), and occasional visitors (OC). Between brackets is the number of samples.

Bio-ecological categories	2003 (100)		2004 (39)	
	Summer	Autumn	Summer	Autumn
FW				
Jenynsia multidentata	3264	482	16	47
Platanichthys platana	50	409	100	1
Cheirodon interruptus	60	0	0	0
Oligosarcus jenynsii	33	0	0	0
Pimelodella laticeps	10	0	0	0
Corydoras palleatus	3	0	0	0
EdM				
Brevoortia aurea	3548	12320	162	52
Odontesthes argentinensis	2018	451	1567	149
Micropogonias furnieri	7	461	31	0
Mugil platanus	109	320	0	210
Lycengraulis olidus	203	0	21	0
Paralichthys orbignianus	0	5	0	0
Ramnogaster arcuata	0	0	6	0
EndM				
Symphurus jenynsi	0	2	0	0
OC				
Anchoa marinii	0	38	7	0
Total Abundance	9305	14528	1910	459
Observed Richness	11	9	8	5
Expected Richness[1]	8	6	8	6
Shannon-Wiener Index (H')	1.30	0.68	0.72	1.22

[1] Value obtained through rarefaction. Value of reference: 459 individuals.

Odontesthes argentinensis, *Brevoortia aurea* and *Jenynsia multidentata* were found throughout the study period. For *O. argentinensis* the interaction years x seasons was significant ($F_{1, 135}$=8.0, P<0.001). Highest abundance was observed during summer 2004 (Tukey HSD for unequal N, P<0.001). The interaction year x season was significant as well for *B. aurea* ($F_{1,135}$=21.8, P<0.001), with higher abundance during autumn 2003 (Tukey HSD for unequal N, P<0.001). *Jenynsia multidentata* varied between years ($F_{1, 135}$=21.6, P<0.001) being more abundant during 2003, but not between seasons ($F_{1, 135}$=0.4, P=0.54)

The diversity index (H') ranged between 0.68 and 1.30. The diversity of fish sampled showed an inverse pattern between years, with higher values in summer 2003 and autumn 2004 than in autumn 2003 and summer 2004, respectively. Seasonal species richness ranged between 5 and 11; higher values were observed during summer (11 and 8, for 2003 and 2004 respectively), and 2003 showed higher richness values in both seasons with respect to 2004 (see Table 2).

Diet of the Black Skimmer

A total of 582 fish remains were identified to species level from regurgitated pellets. Fish were the main prey in the diet of Black skimmers in numerical importance (N% > 96%). Identified fish prey corresponded to FW, M and EdM fish species (Table 3). Mean size of identified fish prey was 78.3 ± 17 mm. Beach seine catches did not match the diet composition of Black skimmers very closely, which was the case in both years ($S_{2002-03}$ = 12%, $S_{2003-04}$ = 36%) and integrated over the years sampled (S = 20%). However, when only estuarine fish prey were considered, different proportions were observed with lower similarity during the first year (S = 13%) as compared to the second year analyzed (S = 75%) (Fig. 2).

Discussion

In general terms, the composition of the ichtyofauna of the Mar Chiquita estuary described in this study was in line with those of previous ones and is in agreement with the icthyofauna structure of other temperate lagoons and estuaries, characterized by a lower diversity than is found in tropical and subtropical areas (BLABER, 2002; GONZÁLEZ-CASTRO et al., 2009). As has been stated in previous studies, the low number of fish species in Mar Chiquita Coastal Lagoon might not just be explained by the latitudinal hypothesis (*i.e.* tropical areas presenting greater diversity than temperate ones) but also by the fact that the width of the mouth and the surface areas of estuaries and lagoons are important factors predicting the number of species and diversity in these habitats (ARAÚJO; COSTA DE AZEVEDO, 2001; GONZÁLEZ-CASTRO et al., 2009). This may explain the important differences in icthyofauna diversity between Mar Chiquita Coastal Lagoon and other much larger estuarine areas of the South Atlantic Ocean such as Los Patos Lagoon (GARCÍA et al., 2001, 2003; LOEBMANN et al., 2008).

Table 3. Importance by number (N%) of Black skimmers' prey items. Fish species grouped in bio-ecological categories: freshwater fish, estuarine dependent marine fish, marine fish, and occasional visitors. Total number of identified fish otoliths between brakets.

Prey categories	N%	
	2003 (365)	2004 (217)
Fish	**96.7**	**97.0**
Freshwater species		
Pimelodella laticeps	4.7	0
Corydora palleatus	2.7	0
Rhamdia quelen	0.3	0
Estuarine dependent marine species		
Brevoortia aurea	0.8	0.9
Odontesthes argentinensis	27.4	35.0
Micropogonias furnieri	0.3	0
Marine species		
Cynoscion guatucupa	6.6	0
Odontesthes incisa	44.9	58.5
Engraulis anchoita	3.6	2.8
Pomatomus saltatrix	4.7	1.4
Occasional visitor species		
Anchoa marinii	4.1	1.4
Cephalopods	**0.9**	**2.5**
Insects	**1.2**	**0.1**
Other	**1.2**	**0.7**

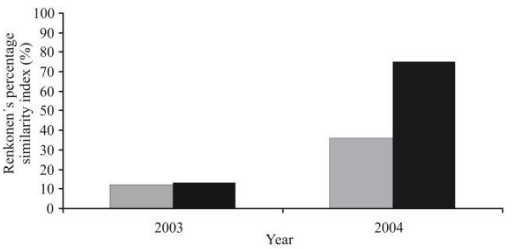

Fig. 2. Percentage similarity index between beach seine net caught fish species and fish prey species present in regurgitated pellets of skimmers in Mar Chiquita Coastal Lagoon. Grey bars indicate similarity considering all fish species found in skimmers' diet, black bars indicate similarity when marine fish species were excluded from the analysis. Values range from 0 (no similarity) to 100 (complete similarity).

The ichthyofauna of Mar Chiquita Costal Lagoon has been described as consisting of 28 fish species, 20 of which occurred in the outer area of the lagoon (COUSSEAU et al., 2001). In this study we reported 15 fish species, which is close to the number given in previous reports. The differences observed in species richness could be a result of using a single sampling technique (*i.e.* the beach seine net in our study vs. the combination of beach seine net and monofilament gill-nets in previous studies), our focus on the estuarine area of the lagoon and/or the water depth sampled (*i.e.* shallow waters).

Clupeidae, Atherinopsidae and Anablepidae were the best represented families in the present study. This was partly in line with previous studies although the occurrence and importance of *Jenynsia multidentata* contrasted with those in previous studies where this species was reported as scarce in or absent from the study area (COUSSEAU et al., 2001; GONZÁLEZ-CASTRO et al., 2009; VALIÑAS et al., 2010). The occurrence of these families together with Mugilidae and Scienidae was largely in line with reports from other temperate south-western Atlantic shallow estuarine areas (RAMOS; VIEIRA, 2001; GONZÁLEZ-CASTRO et al., 2009).

As occurs with many estuarine fish assemblages worldwide, the ichtyofauna of the estuarine area of Mar Chiquita Coastal Lagoon was dominated by relatively few species (GARCÍA et al., 2003). *Brevoortia aurea*, *Odontesthes argentinensis* and *Jenynsia multidentata* constituted the bulk of the capture. *Brevoortia aurea* and *O. argentinensis*, marine species that migrate into the lagoon to shelter and forage, have been reported as the most abundant fish species in Mar Chiquita Lagoon (COUSSEAU et al., 2001). *Jenynsia multidentata* is a freshwater fish species with a distribution limited to the head of the lagoon where lower salinities are found. The occasional occurrence of this species has been explained by the contribution of the freshwater streams which drain, as tributaries, into the lagoon (COUSSEAU et al., 2001). However, several differences in the number and occurrence of fish species (*i.e. Ramnogaster arcuata, Lycengraulis olidus, Anchoa marinii, Mugil platanus*) were found in comparison with earlier studies (see COUSSEAU et al., 2001; GONZÁLEZ-CASTRO et al., 2009; VALIÑAS et al., 2010). Some of these differences could be an artifact of areas sampled in different studies (*e.g.* outer and inner areas of Mar Chiquita Coastal Lagoon in COUSSEAU et al., 2001; GONZÁLEZ-CASTRO et al., 2009). Also, at least in part, these differences could be the result of the seasonal occurrence of certain species not observed in our study conducted in summer and autumn seasons (*e.g. R. arcuata* particularly abundant in spring, see VALIÑAS et al., 2010). Moreover, previous studies reported other species and/or greater length, but as those studies were conducted using different sampling methods (*i.e.* monofilament gill nets, COUSSEAU et al., 2001), they cannot be compared with our study.

As has been long considered the case for estuarine ecosystems, González-Castro et al. (2009) reported the estuarine-dependent marine fish and the estuarine non-dependent marine fish as the most representative categories for this same area. On the other hand, freshwater fishes are considered to be a minor group in estuarine systems, occurring with variable intensity - depending on the hydrological conditions or relative location within the estuary (VEIGA et al., 2006). In the present study, while the EdM was one of the most abundant bio-ecological groups, the FW constitued, at least during the first year of samplings, an important and diverse group as well, and this contrasted with most previous reports from the study site in the same region (COUSSEAU et al., 2001; LOEBMANN et al., 2008; GONZÁLEZ-CASTRO et al., 2009).

Previous studies from the same area have stated that the abiotic factors ruling fish assemblage composition and abundances are temperature and salinity (MARTINETTO et al., 2007; VALIÑAS et al., 2010). In general, the salinity in the Mar Chiquita Coastal lagoon varies spatially, delimiting three main areas: the mouth of the lagoon, the middle part, and an upper part next to major river inflows (IRIBARNE, 2001). Great variation in salinity from freshwater to sea water has also been reported for this environment as the combined effect of wind strength and rainfall (RETA et al., 2001). These variations in salinity could certainly affect ichtyofauna, as has been described in other estuaries (GARCÍA et al., 2003). In this context, higher fish abundances and particularly freshwater fish abundance, as well as the overall fish diversity reported in this study during the summer of the first year could be, at least in part, related to prevailing hydroclimatic conditions, since October 2002 (late spring) and January 2003 (early summer) were characterized by heavier rainfall than historical values would have led us to expect (Fig. 3). Such anomalies in monthly rainfall at Mar Chiquita Coastal Lagoon had been recorded previously - for the year 1998. Those authors reported remarkable modifications in salinity in the estuarine region after rainfall events, returning to normal levels after 45-60 days (MARCOVECCHIO et al., 2006).

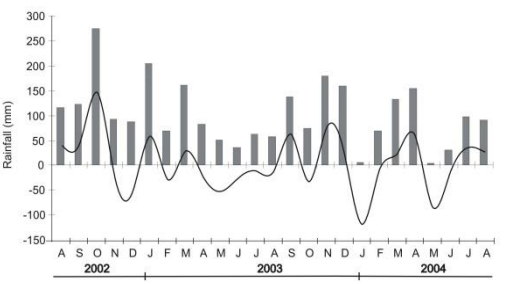

Fig. 3. Monthly rainfall (grey bars) registered in Mar Chiquita Coastal Lagoon basin from August 2002 to August 2004 (data obtained from the Global Historical Climatological Network, http://lwf.ncdc.noaa.gov/oa/climate/climatedata.html), along with a smooth series of residual rainfall (solid line) estimated as the difference between monthly rainfall and mean monthly rainfall from 1980 to 2004 (data obtained from the National Meteorological Service).

An increase in freshwater species has been reported in other estuarine areas of the South Atlantic Ocean after a period of heavy rainfall, while a gradual recovery of the estuarine fish assemblage occurred almost immediately after the return to normal conditions. These studies also highlighted the drop in the abundance of estuarine-dependent marine species during these periods, likely associated with a limited intrusion of saltwater during high freshwater discharge (GARCÍA et al., 2001, 2003). However, our study does not reflect such a pattern, since there was a significant peak in estuarine-dependent marine fish species during the following season due to high rainfall (Table 2). This might be a result of an intrusion of larval and postlarval individuals from adjacent waters and also of higher productivity due to nutrient additions from freshwater discharge (GARCÍA et al., 2003; VALIÑAS et al., 2010). Recent studies accounting for seasonal hydrographic variables of the Mar Chiquita Coastal Lagoon showed higher productivity (in terms of chlorophyll *a* concentration) in the estuarine region during summer, with a particular bloom after a rainfall event (MARCOVECCHIO et al., 2006). Further monitoring of both fish fauna and environmental conditions on a larger temporal scale could shed some light on this hypothesis.

The importance of Mar Chiquita Coastal Lagoon for the conservation of biodiversity has been recognized as a MAB-UNESCO Biosphere Reserve (UNESCO, 1996) and a Nature Reserve for Buenos Aires Province (CANEVARI et al., 1998). Among other ecosystem services, it provides refuge for juvenile fish, including important species for outdoor and artisanal fisheries; and is also known for the abundance and diversity of birds it holds, being a particularly important site for wintering and replenishment of several Patagonian, neartic and neotropical migrant bird species (SILVA RODRIGUEZ et al., 2005). There is a vast literature in the field of seabird feeding ecology showing how many of these species rely on juvenile and small-sized fish occurring in these shallow waters (ISACCH et al., 2010). The high concentration of small-sized fish and the higher spatio-temporal predictability that estuarine resources might provide, buffering the lower predictability of marine resources, are probably among the causes which explain the congregation of marine and coastal birds in these areas (BECKER et al., 1997). Our results on the diet of the Black skimmer at Mar Chiquita were in line with previous studies (MARIANO-JELICICH et al., 2003). However, this was the first attempt to relate seabirds' diet in this environment to fish abundance and composition. Given that Black skimmers forage in shallow waters of the estuarine area of Mar Chiquita Coastal lagoon, a higher similarity of diet to fish composition was foreseen (MARIANO-JELICICH et al., 2003). Little similarity was, however, observed between skimmers' diet and beach seine catches, though when the comparison was restricted to estuarine and freshwater fish species a higher similarity was observed (Fig. 2). Moreover, higher similarity occurred when lower richness in fish species captured was recorded (year 2004). The *O. argentinensis*, one of the most abundant fish species in Mar Chiquita Coastal Lagoon, seems to be an important item for the Black skimmer (*Rynchops niger*), the Common tern (*Sterna hirundo*) and the Snow-crowned tern (*S. trudeaui*) (MARIANO-JELICICH et al., 2003; MAUCO; FAVERO, 2004; GARCÍA; MARIANO-JELICICH, 2005). This overall low similarity could also be a result of biases in diet-study methodologies. Several drawbacks have been reported in the use of regurgitated pellets for seabirds' diet studies. Biases due to the erosion and/or loss of the otoliths through the gastrointestinal tract can produce an important underestimation of fish larvae, juvenile or small fish consumed (BARRETT et al., 2007). This has been particularly observed with the remains of Menhaden *B. aurea* in previous studies on Black skimmers' diet (MARIANO-JELICICH; FAVERO, 2006). The occurrence of freshwater species (*i.e*. *Pimelodella laticeps, Corydoras palleatus*) in the diet of the Black skimmer (also reported in the Common tern's diet, MAUCO; FAVERO, 2005) matched the occurrence of freshwater fish species in the outer area of the Lagoon shown in this study. These results highlight the need for an improvement in existing efforts to elucidate trophic interactions at this particular site; possibly the inclusion of other methodologies for seabird trophic studies such as direct observation and/or stable isotope analysis should be considered (BARRETT et al., 2007). Nevertheless this issue deserves further study; we emphasize the importance of undertaking assessments of fish assemblage composition and its seasonal variability in order to enhance interpretations on top predators' foraging ecology. Moreover, in this study, the monitoring of two consecutive summer-autumn seasons allowed the detection of variations in the occurrence of fish species in the estuarine area of Mar Chiquita Coastal Lagoon, and the importance of freshwater species not previously reported in the literature.

ACKNOWLEDGEMENTS

We thank L Josens for her field assistance. All the samplings were undertaken with the permission of the Reserve authorities and comply with current Argentinian conservation legislation. Financial support was provided by Universidad Nacional de Mar del Plata (grant UNMDP 15/E238). RMJ was

supported by a fellowship from the National Research Council (CONICET, Argentina).

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(Manuscript received 28 September 2011; revised 09 February 2014; accepted 10 March 2014)