INTRODUCTION

Black Skimmers *Rynchops niger* are known by the morphological characteristics of the bill and their particular feeding technique, skimming over the water surface to catch fish and other prey. Despite available information on their breeding biology (Erwin 1977a, Burger 1982, White *et al.* 1984) and feeding ecology (e.g. Erwin 1977b, Black & Harris 1983, Burger & Gochfeld 1990), only general descriptions of the diet are given, with no extensive quantitative analysis (see Zusi 1996). Earlier investigators described skimmers feeding in shallow pools and streams with calm water (Erwin 1977b, Black & Harris 1983). They also reported skimmers to be restricted in their habitat use, feeding almost exclusively in marsh channels and tide pools, with open waters occasionally used (Erwin 1977b). Coincidentally, their diet consisted mainly of small inshore fish species, while marine fish species were less important (Erwin 1977a,b, Black & Harris 1983, White *et al.* 1984). All these earlier works were carried out in North America during the breeding season (see Black & Harris 1983). Recent studies (Favero *et al.* 2001) undertaken in southern South America (Buenos Aires Province, Argentina) during the non-breeding season, showed an alternate use of foraging areas by these birds, consuming both estuarine and marine fish prey. Thus, Black Skimmers may be more plastic in their habitat use during the non-breeding season (Favero *et al.* 2001). In this study, we provide additional detailed information on the diet of non-breeding Black Skimmers at Mar Chiquita coastal lagoon, the only coastal lagoon along the Argentine shore.

METHODS

**Study area**

We studied the diet of Black Skimmers by analyzing 1034 regurgitated pellets collected from roosting sites between February and May 2000 at Mar Chiquita, Buenos Aires Province, Argentina. During the austral summer-autumn from 5000 to 10 000 Black Skimmers (by far the most abundant seabird species) roost in Mar Chiquita, which is the most important wintering area in Argentina.

**Field procedures and analyses**

Diet was studied by analyzing regurgitated pellets. Once collected, each sample was dried at ambient temperature, dissected and the hard remains were identified using a stereomicroscope (20–60). Fish otoliths were identified to species using descriptions and illustrations from the literature (Torno 1970, Vilela 1988) and reference material from our own collections. 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. The total length and width of otoliths was used to estimate the fish size (total length) and mass by regression equations used in previous studies (Favero *et al.* 2000a,b, Favero *et al.* 2001). Urostyles found in samples were also used for prey identification. The urostyles were separated into two types by using reference material in our own collection: “atheriniform (Atherinidae) type” and “clupeiform (Engraulidae and Clupeidae) type”. Individuals belonging to each type were assigned to species accordingly to the proportion by number observed by the otoliths. The importance of
prey categories was quantified as: (1) frequency of occurrence (F%), which is the percentage of samples in which a particular food type appeared, (2) numerical abundance (N%) as the percentage of prey items of one type out of all prey items, and (3) importance by mass (W%) as the percentage of biomass provided by one prey item out of the total biomass consumed (Duffy & Jackson 1986, Rosenberg & Cooper 1990).

Data analysis
The composition of the diet was compared throughout the samples by chi-square tests ($\chi^2$). The prey sizes and masses estimations at the different samplings were compared by ANOVAs (F) and by Tukey post-hoc comparisons. In all cases we followed the statistical methods proposed by Underwood (1997) and Zar (1999). The degrees of freedom of the mentioned tests are given as sub-indices. Comparisons through the breeding season were performed by using month as the unit size.

RESULTS

Fish was the main prey in the diet (n = 98%), followed in importance by insects (1.1%, mainly coleoptera), crustaceans (0.5%, decapods, amphipods and isopods), molluscs (0.2%, cephalopods and gastropods) and chelicerates (0.1%, aracnids). The overall comparison of the diet throughout the sampling period showed significant differences both in the occurrence ($\chi^2 = 116.74$, $P <0.0001$) and the importance by number ($\chi^2 = 47.57$, $P <0.0001$). Thirty-eight percent (n = 396) of the pellets analyzed contained otoliths; other samples contained fish bones and scales only. A total of 1680 fish prey was identified to species level from otoliths and bone remains. From 740 otoliths identified to species, 423 of them were measured and used to calculate prey size and mass.

Identified fish prey corresponded to the following species: “Pejerrey” Silverside Odontesthes argentinensis, “Cornalito” Silverside Odontesthes incisa, Marini’s Anchovy Anchoa marini, Argentine Anchovy Engraulis anchoita and Bluefish Pomatomus saltatrix (Table 1). The first is considered an estuarine fish whereas the others are marine species (Rico 2000, Cousseau et al. 2001). Cornalito Silversides and Pejerrey Silversides were the most frequent prey and the most important by number and mass. Marini’s Anchovy and Argentine Anchovy were less frequent and important by number but accounted together for more than 19% by mass (Table 1). Argentine Anchovy, Bluefish and the unidentified items had values of importance by number lower than 2%.

Significant differences were observed in the comparison of the frequency of occurrence ($\chi^2 = 68.81$, $P <0.0001$), numerical abundance ($\chi^2 = 233.86$, $P <0.0001$) and importance by mass ($\chi^2 = 289.15$, $P <0.0001$) of fish prey observed throughout the study. Silversides were present in all the sampled months, whereas Marini’s Anchovy and Argentine Anchovy were only present in samples from February and March (Fig. 1a, b).

Fish prey averaged 73±17 mm in length (range 25.6-127.5 mm, n = 423), and 2.2±1.7 g in mass (range 0.1-11.6 g, n = 423). The average size (total length) of consumed fish varied significantly through the study period ($F_{3,419} = 4.04$, $P <0.01$), with smaller sizes observed in February (70.4 mm) and larger ones in April (78.8 mm). The differences observed in the size of Pejerrey Silversides consumed through the season ($ANOV A_{F_{3,175}} = 4.75$, $P <0.005$) were due to a significant increase of the sizes taken in April (Tukey $P <0.05$) (Fig. 2a). In the case of Cornalito Silverside the differences were the result of the progressive increase of the sizes consumed through the study period ($F_{5,47} = 12.58$, $P <0.0001$) (Fig.

<table>
<thead>
<tr>
<th>Species</th>
<th>F%</th>
<th>N%</th>
<th>W%</th>
<th>Total length (mm) Mean ± sd</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornalito Silverside</td>
<td>46.7</td>
<td>48.6</td>
<td>38.7</td>
<td>67.5 ± 15.3</td>
<td>25.9 - 113.5</td>
</tr>
<tr>
<td>Odontesthes incisa</td>
<td>(185)</td>
<td>(816)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pejerrey Silverside</td>
<td>40.9</td>
<td>38.2</td>
<td>39.3</td>
<td>75.2 ± 14.9</td>
<td>45.4 - 127.5</td>
</tr>
<tr>
<td>Odontesthes argentinensis</td>
<td>(162)</td>
<td>(642)</td>
<td></td>
<td></td>
<td>(179)</td>
</tr>
<tr>
<td>Marini’s anchovy</td>
<td>9.09</td>
<td>9.6</td>
<td>16.8</td>
<td>89.3 ± 22.8</td>
<td>25.6 - 122.5</td>
</tr>
<tr>
<td>Anchoa marini</td>
<td>(36)</td>
<td>(161)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argentine Anchovy</td>
<td>2.02</td>
<td>1.8</td>
<td>2.5</td>
<td>71.8 ± 21.3</td>
<td>48.9 - 102.7</td>
</tr>
<tr>
<td>Engraulis anchoita</td>
<td>(8)</td>
<td>(31)</td>
<td></td>
<td></td>
<td>(7)</td>
</tr>
<tr>
<td>Bluefish</td>
<td>0.5</td>
<td>0.1</td>
<td>2.0</td>
<td>101</td>
<td>-</td>
</tr>
<tr>
<td>Pomatomus saltatrix</td>
<td>(2)</td>
<td>(2)</td>
<td></td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Unidentified fish</td>
<td>7.07</td>
<td>1.6</td>
<td>?</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

a. Only considering samples containing otoliths (n = 396).
b. Including samples containing otoliths and/or bones (n = 1680).
c. Number of samples.
d. Number of fish-prey.

TABLE 1
Frequency of occurrence (F%), numerical abundance (n%) and total length of fish prey in the diet of the Black Skimmer Rynchops niger at Mar Chiquita, Argentina

The same trend was observed while considering the average mass variations of Pejerrey and Cornalito Silversides ($F_{2,17} = 12.57$, $P < 0.0001$, $F_{3,17} = 12.47$, $P < 0.0001$, respectively). Despite the low importance by number of Anchovy, the importance by mass during February and March reached the values observed in both silverside species (Fig. 1b). These large asymmetries between the importance by number and mass were related to the larger mass/length ratio observed in anchovies (0.061 g. cm$^{-1}$) in respect to those observed in silversides (0.037 and 0.039 g. cm$^{-1}$) (R.M.-J. unpubl. data).

In this study, the number of fish prey per sample estimated by using otoliths (0.7±1.1) was significantly smaller than the number based on urostyles (1.4±1.2) (paired $t = 16.6$, df = 1033, $P < 0.0001$), thus accounting for some loss of information. However, some of these differences could be mediated by the large number of samples analyzed and the fact that the number of meals represented in one regurgitated pellet may be higher than those represented in other kind of samples, such as stomach contents or the observation of prey delivered to chicks (Casaux et al. 1997, 1998). Regardless of the possible methodological problems, regurgitated pellets are useful for the identification of individual food items consumed and for studying seabird diets during the non-breeding season (Brown & Ewins 1996). Preliminary results of the estimation of the minimum sample size needed to get accurate information about the diet of Black Skimmers showed that in the case of important prey (silversides in this study), samples larger than 150 pellets are enough to fit into 95% confidence interval of their importance by number. However, results should be carefully considered when considering less important prey such as clupeiform species (minimum sample size >400) (R. Mariano-Jelicich unpubl. data). The contrasting occurrence of clupeiform prey in the diet could be linked with seasonal migration patterns reported for these fish species in the area (Cousseau & Perrota 1998). In spite of the fact that an under-representation of soft-bodied prey is also suspected, this is probably unimportant because this prey type was low in previous studies (Leavitt 1957, Erwin 1977a,b). Since these previous studies are referred to

**DISCUSSION**

These results are similar to North American studies of the diet of the Black Skimmer, in which one of the most important prey was the silverside *Menidia* sp. (Atherinidae), whereas Anchovy and Bluefish were reported as occasional prey (Erwin 1977a,b). The only reference in areas reasonably close to the study area (200 km distance) comes from Punta Rasa, the southern tip of Samborombón Bay, Argentina (Favero et al. 2001) where the diet of skimmers was much more diverse (12 fish prey species, $n = 642$) than that observed in this work (five species, $n = 1034$). Both silversides were the most important fish prey in the diet in Mar Chiquita, whereas in Samborombon the main prey (in order of abundance) were Marini’s Anchovies, White Croakers *Micropogonias furnieri*, Pejerrey Silversides, Argentine Anchovies and Cornalito Silversides (Favero et al. 2001). These differences in prey diversity might be partially related to the large fish diversity reported for Samborombón Bay (35 fish species, Lasta 1995), as compared to Mar Chiquita (28 species, Cousseau et al. 2001).

The average length of the prey consumed by Black Skimmers at Mar Chiquita was very close to the average length found in the diet of skimmers at nearby areas such Samborombon Bay (77±34 mm) (Favero et al. 2001). However, these data differed from the North American studies that reported an average prey length of 55 mm at Florida (Leavitt 1957), and between 10 and 50 mm at colonies from Virginia (Erwin 1977b). Since these previous studies are referred to

**Fig. 1.** Importance by number (a) and by mass (b) of the main prey in the diet of the Black Skimmer at Mar Chiquita, Argentina.

**Fig. 2.** Variation in the total length of Pejerrey (a) and Cornalito Silversides (b) consumed through the season by Black Skimmers. Means (dots) are shown together with ± one SE (boxes) and ± one SD (whiskers). Lines show median prey sizes (estimated on the basis of size ranges) reported by Cousseau et al. (2001)
prey found in stomachs or brought to the chicks, these differences in the sizes could be due to different sampling methods, seasonal variations of the diet, geographic differences, or to a combination of these.

The small proportion of samples with otoliths give rise to some uncertainty about the accuracy of the methodology (i.e. how well the recovered otoliths accurately reflected the fish consumed). Biases due to the loss by digestion and/or loss of the otoliths through the gastrointestinal tract can produce an important underestimate of fish larvae or small juvenile fish consumed (Duffy & Laurensen 1983, Jobling & Breiby 1986, Johnstone et al. 1990). These biases have been experimentally demonstrated in feeding trials on several bird species (Duffy & Laurensen 1983, Johnstone et al. 1990, Causaux et al. 1995).

Our results were consistent with previous studies carried out in Buenos Aires Province (Favero et al. 2001), showing that Black Skimmers in their non-breeding grounds feed both in fresh-water, estuarine and marine habitats, and are not restricted to foraging in estuarine and fresh-water environments as reported for breeding areas in the northern hemisphere. Further studies focused on the foraging behaviour of this species will allow a better understanding about foraging plasticity and constraints linked with their stereotyped foraging behaviour.

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