Diet of the Neotropic Cormorant *Phalacrocorax olivaceus* at West Chubut, Patagonia, Argentina

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Abstract.—A total of 124 pellets (regurgitated casts) produced by the Neotropic Cormorant (*Phalacrocorax olivaceus*) were collected monthly between January 2004 and November 2005 from a roosting site at Rosario Lake Chubut, Patagonia, Argentina. Analyses of the samples showed that fish were the most frequent and important prey by number, followed by crustaceans and molluscs. The three fish species inhabiting Rosario Lake were represented in the diet which suggests that this bird is a generalist feeder. However, cormorants positively selected for Patagonian Silverside and Rainbow Trout, which might be related to their foraging strategy and/or to the conspicuousness of potential prey. The estimated annual fish intake by cormorants at Rosario Lake ranged between 2.3 - 3.7 tons of fish or 16,000 - 26,000 individuals. The impact produced by the Neotropic Cormorant on recreational fish resources and local fish farms appears negligible. *Received 29 May 2008, accepted 17 March 2009.*

Key words.—diet composition, fish intake, impact, fish resources, Neotropic Cormorant, Patagonia.

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The Phalacrocoracidae are a controversial Family. Cormorants and shags are opportunistic and generalist ichthyophagous feeders that usually exhibit a strong site fidelity (Orta 1992). An understanding of the alimentary, reproductive and population parameters of these birds can be important for monitoring the status and trend of aquatic ecosystems (see Furness and Greenwood 1993, and references therein) as well as for the management of local fish stocks (Barrett 1991; Montevecchi 1993; Casaux and Barrera-Oro 2006; among others). Conversely, because large colonies locally consume large quantities of fish, there are well established concerns that these birds interact negatively with recreational and commercial fisheries, including aquaculture (for review see Orta 1992).

The Neotropic Cormorant (*Phalacrocorax olivaceus*) is distributed from the south of the USA to Cape Horn, Patagonia (Orta 1992). The species is widespread in Argentina and occupies a spectrum of wetlands in fresh, brackish and salt waters. As with other *Phalacrocorax* species elsewhere (Orta 1992; Bildsoe *et al.* 1998; Cairns *et al.* 1998; Frederiksen *et al.* 2001; Barras 2007), the Neotropic Cormorant is persecuted in West Chubut, Argentina, due to its purported impacts on fishing and aquaculture operations. The usual control practices are shooting and the harassment of colonies. Notwithstanding the abundance of Neotropic Cormorants and their surmised effect on fisheries, few studies have focused on their natural diet, reproduction, and population aspects in Patagonia and all of them were carried out on colonies in marine environments (see Daneri 1960; Quintana *et al.* 2002 and 2004; Forero *et al.* 2004; Frere *et al.* 2005).

Rosario Lake is in the northwest of Chubut, Patagonia, Argentina, in the transition between the Andes and the steppe. The lake area is 14.5 km^2 and the mean and maximum depths are 21.5 and 57.4 m respectively (Quirós and Drago 1985). Recreational fishermen target introduced Rainbow Trout *Oncorhynchus mykiss* and to a lesser extent the native Patagonian Silverside *Odontesthes hatcheri*. Rainbow Trout have been cage farmed since 1993, with a maximum production of 25 t/annum. Although Neotropic Cormorants once nested at Rosario Lake (Ortubay *et al.* 1987) the breeding individu-

als abandoned the area due to persecution and currently only non-breeders are found.

The objective of this study was to analyze the composition of the diet of Neotropic Cormorants at Rosario Lake and provide the first information on their foraging behavior in a Patagonian freshwater environment, as well as to assess the impact of this bird on local fish farm and recreational fishing resources.

METHODS

Pellets (regurgitated casts) of the Neotropic Cormorant were collected monthly (mean 5.4 pellets, range 0-31) between January 2004 and November 2005 at a roosting site located at Rosario Lake (S43°15.24', W71°21.51'), Chubut, Patagonia, Argentina (Fig. 1). The biases associated to the pellet analysis method have been extensively discussed in the literature (see Carss *et al.* 1997, for review). However, after calibration, this is a sound method to quantify the diet of Phalacrocoraciids, which demands little time in the field and does not disturb the birds (Dirksen *et al.* 1995; Casaux 2003).

The pellets were dried at 60°C and their contents sorted into prey classes using a binocular microscope. The otoliths present in the samples were identified to species, when possible, using our own reference collection. The otoliths of each fish species were sorted into right and left and the most abundant was considered as the number of individuals per fish species present in the sample. The otoliths were measured to 0.01 mm in length to estimate the size and mass of the individuals applying the following equations estimated from fish caught in the study area:

Odontesthes hatcheri

$TL = 11.12642*OL^{0.618657}$ ($n = 109$, $r = 0.91$)
$M = 7.428144*OL^{2.041558}$ ($n = 109$, $r = 0.92$)

Galaxias platei

$TL = 7.6719+5.1024*OL$ ($n = 308$, $r = 0.27$)
$M = 4.152005*OL^{3.029642}$ ($n = 308$, $r = 0.73$)

Oncorhynchus mykiss

$TL = 11.03561*OL^{0.809850}$ ($n = 13$, $r = 0.73$)
$M = 50.93738*OL^{1.537905}$ ($n = 13$, $r = 0.57$)

where "TL" is the fish total length in cm, "OL" is the otolith length in mm, and "M" is the fish mass in g.

The fish selectivity by the Neotropic Cormorant was estimated from information on fish abundance in cormorant foraging areas at Rosario Lake during the study period (22 samplings monthly distributed throughout the study period and 1531 individuals caught; see details in Casaux and Di Prinzio 2007) and applying the Ivlev index (Ivlev 1961):

$$I = \frac{Di - Li}{Di + Li}$$

where "Di" is the percentage by number of the species "i" in the diet (for the estimation of these values the individuals that remained unidentified were no considered) and "Li" is the percentage by number of the species "i" in the lake. Positive values indicate that the cormorant select the relevant prey.

To estimate the annual fish intake of Neotropic cormorants at Rosario Lake we considered data on daily food consumption for non-breeding individuals at Chascomús Lagoon, Argentina (229.5g, Padín 1987) and at Lagoa dos Patos Estuary, Brasil (372.3g, Barquete *et al.* 2008), the contribution to the diet by mass of the different fish prey (Table 2), and the maximum number of cormorants observed at dusk at the roosting site in Rosario Lake during the study period (27 individuals, range 9-27, $n = 4$). For the estimation of the number of fish ingested annually we considered the estimated mean mass of the fish represented in pellets: *O. hatcheri* 184.9 g (±67.6, range 38.5-341.4, *n* 88), *G. platei* 45.4 g (±36.9, range 9.6-233.3, *n* 49), and *O. mykiss* 287.4 g (±70.4, range 216.2-377.8, *n* 6).

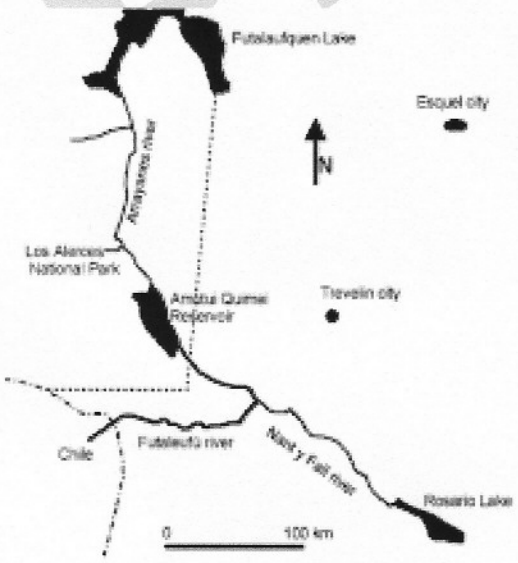

Figure 1: Map showing the location of Rosario Lake, Chubut province, Patagonia, Argentina.

RESULTS

One hundred and twenty two pellets (98.4% of the pellets collected) contained prey remains. Analysis indicated that fish were the most frequent and important prey by number, followed by crustaceans and molluscs (Table 1).

Fish were represented in 97.5% (119) of the pellets containing prey remains. In 78 pellets the fish were identified to species. The mean number of fish and the mean estimated fish mass represented per pellet was 1.9 individuals (sd 1.76, range 1-13) and

260.1 g (sd 187.3, range 21.9-1253.1), respectively. In 72 of the pellets a single fish species was present and two fish species were present in the remaining pellets. Of the three fish species represented in the diet, the Patagonian Silverside was the most frequent and important both by number and mass, Large Puyén *Galaxias platei* and introduced Rainbow Trout followed in importance (Table 2). The size of the fish ingested ranged from 11.8 (Large Puyén) to 35.5 (Patagonian Silverside) cm in total length (Table 2, Fig. 2).

Table 1. Diet of the Neotropic Cormorant as reflected by the analysis of 124 pellets collected at Rosario Lake, Patagonia, Argentina, between January 2004 and November 2005. Percentage frequencies of occurrence (F%) and number (N%, number of prey in parenthesis).

	F%	N% (193)
Fish	97.5	80.3
Molluscs		
Gastropods	2.5	2.1
Bivalves	1.6	1.5
Crustaceans	3.3	2.1
Trychoptera		
Parasericostoma ovale	8.2	10.9
Unidentified	4.9	3.1
Stones	35.3	—

The Ivlev index (Ivlev 1961) indicates that the Neotropic Cormorant positively selects for Patagonian Silverside and Rainbow Trout (Table 3). The cormorant preyed on the whole size range of the Patagonian Silverside (Mann-Whitney U test, $P < 0.001$) represented in the net samples whereas only smaller Large Puyén ($P < 0.00001$) and Rainbow Trout ($P < 0.05$) specimens were consumed (Fig. 2). According to fish intake estimations based on Padín (1987) and Barquete et al. (2008), Neotropic Cormorants at Rosario Lake ingest between 2.3 and 3.7 tons of fish per annum, respectively, which represents between 16,000 and 26,000 individual fish (Table 4).

DISCUSSION

Neotropic Cormorants at Rosario Lake foraged predominantly on fish and less intensively on crustaceans and molluscs, in agreement with its diet known for other localities of South America (Jordán 1967; Oliveros and Beltzer 1983; Kalmbach *et al.* 2001; Regidor and Terroba 2001; Fortuna *et al.* 2003; Barquette *et al.* 2008). However, crustaceans and molluscs were also represented in pellets of Neotropic Cormorants breeding at Carrileufu River, Chubut, but were absent from their regurgitations (Casaux *et al.* unpublished). This might be indicating that those invertebrates are indirect preys (i.e. invertebrates comes from the stomachs of the fish consumed) instead of being directly ingested by cormorants. This hypothesis is also supported by the fact that molluscs and crustaceans are important components in the diet of fish at Rosario Lake (Casaux and Di Prinzio 2007).

The Neotropic Cormorant preyed on the three fish species present in Rosario Lake (Casaux and Di Prinzio 2007), confirming that it is a generalist feeder (Telfair and Morrison 1995; Barquete *et al.* 2008). However, cormorants positively selected the Patagonian Silverside and the Rainbow Trout (species that inhabit the whole water column), whereas the demersal/benthic Large Puyén was avoided. Given that this bird is capable of feeding on benthic and pelagic prey (Quintana *et al.* 2004), the pattern of prey selectivity observed appears to indicate that at Rosario Lake it forages primarily in the water column. Alternatively, as the Large Puyén is a cryptic and sedentary species, the pattern of prey selectivity observed might reflect the conspicuousness of the potential preys.

The Neotropic Cormorant preyed on the whole size range of the Patagonian silverside caught with nets at Rosario Lake (Casaux and Di Prinzio 2007), whereas it consumed only the smaller Large Puyén and Rainbow Trout specimens. At Rosario Lake, cormorants forage mainly in shallow waters close to the coast, but the nets used for fish sampling were deployed on the bottom down to 30 meters water depth (Casaux and Di Prinzio 2007). It is possible that the different sizes of Large Puyén and Rainbow Trout occur in different depths; so that the size ranges represented in pellets might be reflecting the fish

Table 2. Fish in the diet of the Neotropic Cormorant at Rosario Lake, Patagonia, Argentina. Percentage frequencies of occurrence (F%), number (N%) and mass (M%). Total length in cm ± standard deviation, range and the number of specimens measured in parenthesis.

	F%	N%	M%	Total length
Patagonian Silverside	57.4	56.8	80.5	29.2 ± 3.4 (18.3-35.5, n = 88)
Large Puyén	22.1	31.6	11.0	17.0 ± 2.7 (11.8-26.7, n = 49)
Rainbow Trout	3.3	3.9	8.5	27.3 ± 3.5 (23.6-31.7, n = 6)
Unidentified	9.8	7.7	—	—

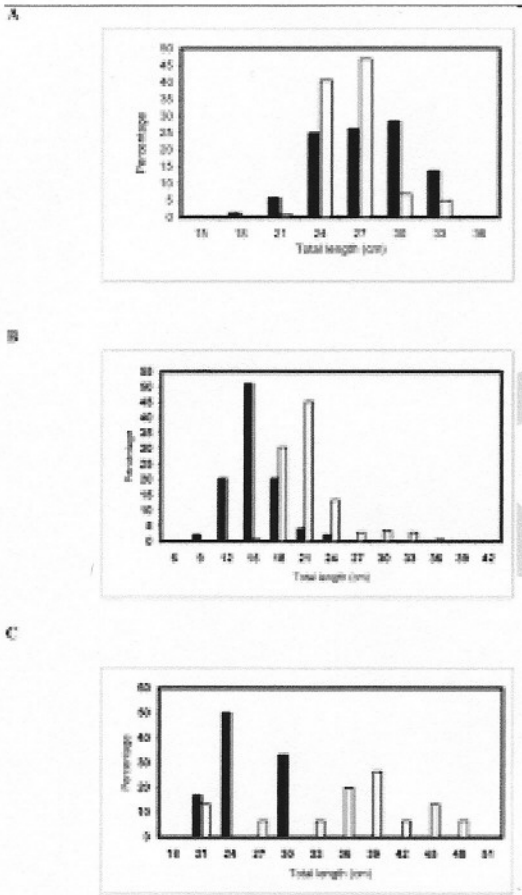

Figure 2: Length frequency distribution of the fish represented in the diet of the Neotropic Cormorant (black) and in net samples at Rosario Lake (white), Patagonia, Argentina. A: Patagonian Silverside, B: Large Puyén, and C: Rainbow Trout.

availability at the foraging depths of the cormorants. Patagonian Silverside specimens are markedly lighter than Large Puyén and Rainbow Trout individuals of comparable size. Thus, the consumption of smaller specimens of these last two species might be alternatively explained by limitations in cormorant's prey handling capacity.

Table 3. Importance by number (%) of the fish represented in the diet of Neotropic Cormorants (the unidentified individuals were not considered) and in net samples at Rosario Lake (RL), and Ivlev index.

	Diet	RL	Ivlev index
Patagonian Silverside	61.5	10.6	0.71
Large Puyén	34.3	88.5	-0.44
Rainbow Trout	4.2	0.9	0.65

Neotropic cormorants are perceived as being harmful to fish resources and also fish farms. In Patagonia, these assumptions are supported simply by the fact that cormorants forage on fish and are frequently seen close to farms. Hence, cormorants are persecuted. On Rosario Lake cormorants ingest between 2.3-3.7 tons of fish and 16,000-26,000 specimens yearly (Table 4). From these amounts, between 9,850 and 16,000 individuals corresponded to Patagonian Silverside and between 660 and 1,080 to Rainbow Trout. The maximum daily allowable catch per fisherman for the lake is ten Patagonian Silverside and two Rainbow Trout. According to the Dirección de Pesca Continental de Chubut (DPCC), at least 339 fishermen visited Rosario Lake during the 180 days of 2007/08 fishing season. By simple calculation, the impact by cormorants on recreational fish resources appears negligible, since the annual fish consumption by these birds represents the specimens that those fishermen could legally obtain in only 2.9-4.7 and 1.0-1.6 days of fishing in the case of Patagonian Silverside and the Rainbow Trout, respectively. Assuming that Neotropic cormorants forage inside cages of the local Rainbow Trout farm, the annual fish consumption would amount to only 0.7-1.1% of the captive fish reported for the period of our study (100,000 individuals, DCPC, Nota N°499-04). We considered also the loss caused by fish escapement from farms

due to the damage produced by cormorants to nets of cages. Only 33.3% of the Rainbow

Table 4. Fish consumption by Neotropic Cormorants at Rosario Lake, Patagonia, Argentina, according to the daily fish requirements estimated by Padín (1987) and Barquete *et al.* (2008): IDFMI, daily fish mass intake per individual in g; IAFMI, annual fish mass intake per individual in Kg; PAFMI, fish mass ingested annually by the population in tons; PAFNI, number of fish individuals ingested annually by the population. Patagonian Silverside (PS), Large Puyén (LP), and Rainbow Trout (RT).

	Padín (1987)			Barquete *et al.* (2008)		
	PS	LP	RT	PS	LP	RT
IDFMI	184.8	25.3	19.3	299.7	41.0	31.6
IAFMI	67.5	9.2	7.1	109.4	15.0	11.6
PAFMI	1.82	0.25	0.19	2.95	0.40	0.31
PAFNI	9850	5492	662	15974	8900	1084

Trout specimens represented in pellets overlapped with the size of the fish kept in captivity at the same time. Hence, present results as a minimum indicate that most of the fish consumed by cormorants had not escaped from broken cages. The presence of cormorants in close proximity of the cages might be explained as opportunistic behavior, since they forage on wild fish gathering there during feeding times in the fish culture.

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