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# Diet of the Neotropical Cormorant (*Phalacrocorax brasilianus*) in a Patagonian Freshwater Environment Invaded by Exotic Fish

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**Abstract.**—The diet of the Neotropical Cormorant (*Phalacrocorax brasilianus*) was evaluated in the Limay River basin, a freshwater system invaded by exotic salmonids. Analyses of 106 pellets showed that fish were the most important prey (79.9% by numerical frequency and 86.2% by frequency of occurrence), followed by two crustacean species. Among fish, the most common species were exotic salmonids, representing 84% by numerical frequency. Morphometric comparisons enabled differentiation of sagitta otoliths from *Oncorhynchus mykiss* and *Salmo trutta* and permitted determination of similar contributions of these species to the diet. Although a wide prey-size range was found, 85% of fish were smaller than 150 mm in length. The results suggest that the Neotropical Cormorant has adapted to changes in the fish community after the introduction of salmonids. Flexible feeding strategies of the Neotropical Cormorant and/or its capacity to exploit different environments probably make it less vulnerable to environmental changes produced by introduction of exotic fish. *Received 21 March 2011, accepted 17 November 2011.*

**Key words.**—exotic fish, feeding plasticity, Patagonian environments, *Phalacrocorax brasilianus.*

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The Neotropical Cormorant (*Phalacrocorax brasilianus*) is widely distributed in Neotropical regions. This cormorant is one of the more abundant and adaptive *Phalacrocorax* species, occupying marine and continental environments from southern USA to Cape Horn (Telfair and Morrison 1995). Throughout its distribution, many different aspects of the Neotropical Cormorant's biology have been studied (Orta 1992). Particularly, there are several dietary studies which have evidenced a generalist and opportunistic feeding pattern (Oliveros and Beltzer 1983; Telfair and Morrison 1995; Regidor and Terroba 2001; Barquete *et al.* 2008). Although some of these studies were carried out in Argentina, there is little information on the feeding habits of the Neotropical Cormorant in continental Patagonia (Casaux *et al.* 2008; Casaux *et al.* 2009). In this area, most freshwater systems support large exotic salmonid populations that appear to have severely altered native fish populations (Macchi *et al.* 1999; Penaluna *et al.* 2009). Casaux *et al.* (2010) in a study carried out on Imperial Shags (*P. atriceps*) in Nahuel Huapi Lake speculated that an increasing alteration of native fish populations could be forcing shags toward a lower-quality diet dominated by invertebrates. According to the authors, this situation would affect the chick food provisioning during the breeding period and negatively impact bird population trends.

The present work aimed to: (1) evaluate the Neotropical Comorant diet in the upper Limay River for approximately one year and (2) determine its preferred prey sizes. In doing so, we provide the first information on the Neotropical Comorant's diet in the Limay River basin, where typically fish-eating birds have already replaced fish with invertebrates in their diets.

## Methods

A total of 106 pellets (regurgitated casts) of the Neotropical Cormorant were collected between January and November 2008 from a communal roost (40° 57'S, 71° 02'W) located approximately 20 km from the Limay River source in eastern Nahuel Huapi Lake (Fig. 1). During this period, as many as 60 Neotropical Cormorants of different age classes used the roost simultaneously, although it was more common to observe 15-20 adult birds.

Pellet constituents were analyzed under a binocular microscope. There were four main prey categories:


**Figure 1. Location of the roosting site of Neotropical Cormorants Feeding in the Limay River, Patagonia, Argentina.**

fish, crustaceans, molluscs and insects. However, given that the molluscs and insects recovered from pellets were so small (total length < 5 mm), they were not considered part of the cormorants' diet, but derived from secondary or indirect consumption. The latter interpretation was supported by Vigliano *et al.* (2005), who found that molluscs and insects are common prey of the fish caught by Neotropical Cormorants in the study area.

Crustaceans were mainly identified by comparison of their chelae to our own reference collections. Also, in some cases, we recognized individuals of Freshwater Crayfish (*Samastacus spinifrons*) by means of their unique gastroliths (Rudolph 2002). Similarly, most fish species were identified by comparison of their sagitta otoliths, scales and dentaries to reference collections provided by Grupo de Evaluación y Manejo de Recursos Ícticos (GEMaRI) of University of Comahue. To differentiate the salmonid species, discriminate functions of sagitta otolith measurements were applied (Table 1). To obtain such functions, otoliths of 60 Rainbow Trout, *Oncorhynchus mykiss*, (total length range: 53-400 mm) and 54 Brown Trout, *Salmo trutta*, (total length range: 48-400 mm) of GEMaRI collection were photographed with a digital camera. Then, the five otolith variables described by L`Abeé-Lund and Jensen (1993) were measured to the nearest 0.1 mm using an image analysis program (Image Pro Plus; Media Cybernetics, Silver Spring, MD, USA). Log transformation was applied to these five variables and distinct forward discriminate analyses were performed (Sokal and Rohlf 1995) for three prey-total length ranges: small (40-140 mm); medium: (141-270 mm); large: (271-400 mm). We proceeded in this way to avoid intraspecific variations in otolith morphology potentially induced by fish bodily growth (Popper and Coombs 1982; Tombari *et al.* 2005). The effectiveness of these functions was assessed first in terms of percentage of otoliths of known species classified correctly using all samples in the analysis (self-test), and secondly by cross-validation procedure (each case is classified by the function derived from all other cases than that case). The cut-off values for each function were calculated following Svagelj and Quintana (2007). Otoliths with discriminate scores lower than the cutoff value were assigned to Brown Trout and those with greater scores to Rainbow Trout. To determine which of the functions in Table 1 should be used for each otolith, we approximated the total lengths of unidentified salmonids obtained from the pellets by means of equation 1,

$$TL = 78.31*OW1.525, \; (R^2 = 0.92) \quad (1)$$

which simultaneously combined the measurements of otolith width ("OW") with the fish total length ("TL") of the same 60 Rainbow Trout and 54 Brown Trout used for the construction of the discriminate function. Once identified, paired structures of each taxon were separated into right and left and the most abundant was assumed as the number of individuals present in the sample.

Three otolith wear levels (slight, moderate or high) were defined following Bugoni and Vooren (2004): "slight": no sign of digestion or otolith edges slightly worn but *sulcus acusticus* still well defined; "moderate": otolith edges extremely worn, *sulcus acusticus* becoming vague; "high": *sulcus acusticus* worn away. To estimate the fish sizes only slightly eroded otoliths were used (Suter and Morel 1996) and equations 2 and 3 were applied.

$$\text{Rainbow Trout: } TL = 76.20*OW1.50, \; (R^2 = 0.93) \quad (2)$$

$$\text{Brown Trout: } TL = 79.78*OW1.59, \; (R^2 = 0.93) \quad (3)$$

The importance of different items in the diet was reported as absolute number (n), percentage of numerical frequency (%F) and percentage of occurrence (%O).

## RESULTS

Prey remains were identified in 89% (N = 94) of the analyzed pellets, while 11% (n = 12) were either empty (only mucus) or contained stones, sand, and remains of molluscs and insects assumed as derived from secondary consumption. From the total of pellets containing food remains, 558 prey items were identified: 446 fish and 122 crustaceans. The fish belonged to five species and four taxonomic families, while the crustaceans belonged to two taxonomic families (Table 2). The mean number of prey consumed per pellet was 5.9 (SD = 9.4) varying between one and 70.

**Table 1. Unstandardized coefficients (ln A, ln B, ln C) and constant, cut-off values and effectiveness of the three discriminant functions used to identify the salmonid species in the Neotropical Cormorant's diet in the Limay River basin (Patagonia, Argentina).**

| | | | | | | Effectiveness (%) | |
|---|---|---|---|---|---|---|---|
| Function | ln A | ln B | ln C | Constant | Cut-off value | Self-test | Cross-validation |
| $D_1$[a] (40-140 mm) | -15.83 | 15.25 | 0.11 | 6.68 | 0.024 | 84.6 | 82.1 |
| $D_2$ (141-270 mm) | -14.18 | 8.39 | 7.03 | 5.47 | -0.174 | 87.5 | 82.5 |
| $D_3$ (271-400 mm) | -10.12 | 4.47 | 6.92 | 3.44 | -0.122 | 88.9 | 77.8 |

[a]$D_1$, $D_2$ and $D_3$ correspond to discriminant functions for three fish size ranges: small, medium and large, respectively.

**Table 2. Diet composition (n = absolute number, %F = percentage of numerical frequency %O = percentage of occurrence) of the Neotropical Cormorant (Phalacrocorax brasilianus) in the Limay River basin (Patagonia, Argentina) during the period January-November 2008.**

| Food items | n | F% | O% |
|---|---|---|---|
| FISH | | | |
| Salmonidae | | | |
| Salmonidae | | | |
| *Oncorhynchus mykiss* | 206 | 36.9 | 46.8 |
| *Salmo trutta* | 131 | 23.5 | 52.1 |
| Unidentified salmonids | 38 | 6.8 | 17.0 |
| Galaxiidae | | | |
| *Galaxias maculatus* | 20 | 3.6 | 9.6 |
| Percichtyidae | | | |
| *Percichthys trucha* | 6 | 1.1 | 6.4 |
| Atherinopsidae | | | |
| *Odonthestes hatchery* | 1 | 0.2 | 1.1 |
| Unidentified fish | 44 | 7.9 | 33.0 |
| **Fish total** | **446** | **79.9** | **86.2** |
| CRUSTACEANS | | | |
| Aeglidae | | | |
| *Aegla* sp. | 62 | 11.1 | 38.3 |
| Astacidae | | | |
| *Samastacus spinifrons* | 47 | 8.4 | 27.7 |
| Unidentified crustaceans | 3 | 0.5 | 3.2 |
| **Crustaceans total** | **112** | **20.1** | **55.3** |
| MOLLUSCS | | | |
| *Chilina* sp. | — | — | 41.5 |
| *Pisidium* sp. | — | — | 1.1 |
| INSECTS | — | — | 13.8 |
| NEMATODES (*Contracaecum* sp.) | — | — | 6.4 |
| Stones | — | — | 43.6 |
| **Total** | **558** | **100.0** | |

Fish were the most important prey, being found in 86.2% of the samples and representing 79.9 % of numeric frequency (Table 2). Among fish, exotic species were the main fraction (Table 2). Salmonids (Rainbow Trout and Brown Trout) contributed equally to the diet and no statistical difference was found in mean number of individuals per pellet (Mann-Whitney: N = 51; T = 8901.0; p = 0.96). Freshwater Crab (*Aegla* sp.) and Freshwater Crayfish were common and together contributed 20% of numerical frequency. Thus, crustaceans were even more important than the native Patagonian Silverside (*Odonthestes hatchery*), Smallmouth Perch (*Percichthys trucha*) and Inanga (*Galaxias maculatus*) (Table 2).

Size range of the prey eaten by Neotropical Cormorants varied from 18 to 348 mm in total length, with Freshwater Crab and Rainbow Trout being the smallest and largest species, respectively. The total length range of the specimens captured was similar among salmonids. Nearly 85% of salmonids were less than 150 mm in length, with peaks of consumption of the 50-100 mm – size classes, most evident in the case of the Rainbow Trout (Fig. 2).

## Discussion

The analysis of Neotropical Cormorants' diet in the Limay River basin showed fish as main prey and two crustacean species as complementary prey. The fish-invertebrate combination in the diet of this species has been previously reported, so at this resolution level, our findings appear in line with the known diet composition for the species (Oliveros and Beltzer 1983; Telfair and Morrison 1995; Barquete *et al.* 2008). Nevertheless, the Neotropical Cormorants in the study area fed almost exclusively on exotic fish, and it is here that our results differ from previous studies. Although Patagonia supports large salmonid populations and they are the only fish species in some places (Pascual *et al.* 2002), there were no prior reports of intensive predation of exotic fish by Neotropical Cormorants. Recent studies carried out at two Patagonian freshwater environments reported that salmonids are significantly less important in the diet of this cormorant compared to the native

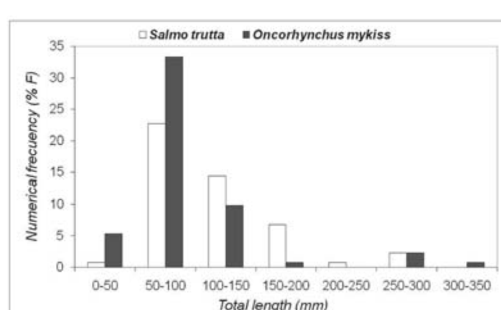


**Figure 2. Total length frequency distribution of the *Oncorhynchus mykiss* and *Salmo Trutta* individuals captured by Neotropical Cormorant (*Phalacrocorax brasilianus*) from January to November 2008 in the Limay river basin (Patagonia, Argentina).**

Patagonian Silverside (*Odonthestes hatchery*) and Smallmouth Perch (*Percichthys trucha*) (Casaux *et al.* 2008; Casaux *et al.* 2009).

Exotic fish have been found in the diet of fish-eating birds, including Phalacrocracidae species, in both Europe and North America (Lekuona 2007; Montesinos *et al.* 2008; Johnson *et al.* 2010). Introductions of exotic fish have been common around the world with alien species often becoming invasive, locally abundant (Leprieur *et al.* 2008), and progressively an integral part of the diet of native piscivorous animals. For instance, owing to its rapid population increase in the Great Lakes region, USA, the exotic Round Goby (*Neogobius melanostomus*) become an main dietary item of the Double-crested Cormorant (*P. auritus*) (Somers *et al.* 2003). Since its introduction, this fish species has clearly become the most important prey item for Double-crested Cormorants in some of the Great Lakes (Johnson *et al.* 2010). Similarly, as a consequence of high local abundance, the exotic Goldfish (*Carassius auratus*) dominated the diet of the overwintering Great Cormorants (*P. carbo*) in Navarra, Spain, for two consecutive years (1999 and 2000) (Lekuona 2007). Phalacrocoracidae species are mainly opportunistic and generalist feeders (Orta 1992), whose diets often reflect relative abundance of fish species in environments. This seems to be the case of the Neotropical Cormorant in the Limay River basin, since as Rechenq (2003), Lippolt (2005) and Vigliano *et al.* (2005) have demonstrated, salmonids are strongly dominant species and sometimes the only fish species in some environments of the Limay River basin.

In contrast to our results, Casaux *et al.* (2010) showed that the Imperial Shag (*P. atriceps*) resident in Nahuel Huapi Lake concentrates its foraging efforts on capturing crustaceans, whereas fish are rarely consumed. Although the causes of this unexpected diet are unclear, Casaux *et al.* (2010) speculated that the important switch in the diet of the Imperial Shag could be generated by low availability of target fish in its environments. Under this scenario, the intensive piscivory of the Neotropical Cormorant in Limay River basin might be favored by an extensive usage of multiple environments in comparison to the Imperial Shag. The latter species is rarely observed at sites other than Nahuel Huapi Lake, while the Neotropical Cormorant is found in many lotic and lentic environments of Nahuel Huapi National Park (personal observation). A wider range of foraging sites, probably differing in prey density and environmental structure, can provide more opportunity for predators to capture elusive prey (Gotceitas and Colgan 1989). On the other hand, the different diets of *P. atriceps* and *P. brasilianus* in Nahuel Huapi National Park might also be associated with different capabilities to forage on mid-water fish such as the Rainbow Trout and Brown Trout (Vigliano *et al.* 2005). Whereas species belonging to the "Blue-eyed Shag Group", such as the Imperial Shag, are predominantly bottom feeders (Casaux and Barrera-Oro 2006), the Neotropical Cormorant is able to obtain its food throughout the water column (Quintana *et al.* 2004).

There are many documented cases of adaptive responses of native organisms to a new invader species, some native species having been favored and some harmed by the new species (Mooney and Cleland 2001). Our results indicate that Neotropical Cormorants inhabiting the Limay River have adapted to changes in the fish community, perhaps as a consequence of their plasticity relative to foraging techniques and/or use of habitat.

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