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Effects of El Niño on Abundance and Breeding of Black-necked Swans on El Yali Wetland in Chile

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Abstract.—The El Niño Southern Oscillation (ENSO) phenomenon has frequently been associated with negative effects on bird populations. Here we analyze the effect of increased rainfall associated with an El Niño event on Black-necked Swans (*Cygnus melancoryphus*) at El Yali National Reserve, an important coastal wetland of the Mediterranean region of Chile. The Black-necked Swan is a regular winter visitor to the El Yali wetland but, during and after El Niño years, it increases markedly in number, stays longer (throughout the summer) and breeds. During and after El Niño years, El Yali has more swans and higher breeding productivity than at other known breeding sites in central Chile. Consequently, after El Niño events, the El Yali wetland may be a source from which swans colonize other wetlands in the Mediterranean and Austral regions of Chile.

Key words.—Black-necked Swan, breeding, Chile, conservation, *Cygnus melancoryphus*, El Niño Southern Oscillation, Mediterranean wetland.

Waterbirds 25 (Special Publication 1):123–127, 2002

The El Niño-Southern Oscillation (ENSO) is a global phenomenon that has an extensive influence around the world (Arntz 1986; Glynn 1988; Grant *et al.* 2000; Holmgren *et al.* 2001). During an El Niño episode, rainfall dramatically increases in certain areas, whereas severe droughts occur in other regions. The next phase, known as La Niña, produces roughly the opposite climatic patterns to those found during an El Niño episode (see Fig. 1 in Holmgren *et al.* 2001).

Multiple ecological effects of El Niño have been noted in marine ecosystems of western South America (see reviews in Jaksic 1998, 2001). Effects include massive die-offs of plankton, macroalgae and marine animals, the occurrence of unusual pelagic and demersal animals, migrations to high sea by fishes of commercial concern, and many others (see Table 1 in Jaksic 2001). Among seabirds, the most obvious effects of El Niño are population declines due to migration of fish to the high seas (Boersma 1978, 1998; Schreiber and Schreiber 1984; Duffy and Merlen 1986; Hays 1986; Araya and Todd 1987; Boulanger 1987; Guerra *et al.* 1988; Duffy 1990; Vilina 1993). In contrast, effects on terrestrial and freshwater ecosystems in western South America have been poorly explored (Holmgren *et al.* 2001; Jaksic 2001). Only in recent years have results of long-term studies become available, revealing evidence that unusual rainfall, associated with El Niño events, strongly affects terrestrial ecosystems (Jaksic *et al.* 1996; Jaksic and Feinsinger 1998). Specifically, El Niño has been shown to affect the abundance and population trends of vertebrates such as small mammals (Meserve *et al.* 1995, 1999; Lima *et al.* 1999a, b), top predators (Jaksic *et al.* 1997) and land birds (Jaksic and Lazo 1999).

Few studies have investigated the effects of ENSO on populations and communities of waterbirds (Vilina and Cofré 2000). Here, we analyze the relationship among an ENSO event, the high rainfall during this disturbance, and changes in abundance, breeding occurrence and local distribution of Black-necked Swans (*Cygnus melancoryphus*). The Black-necked Swan is endemic to the southern cone of South America. Its population is estimated at approximately 100,000 individ-

uals distributed among Chile, Argentina, Uruguay and southeastern Brazil (Schlatter *et al.* 1991).

STUDY AREA

The El Yali wetland is located at the mouth of the El Yali stream (33°47'S, 71°23'W), 20 km south-southeast of San Antonio, Chile. This sub-humid Mediterranean region has warm, dry summers and cold, rainy winters. The rainy period generally lasts from April to September (Di Castri and Hajek 1976). The mean annual rainfall during the last ten years recorded at Fundo Las Dos Puertas Meteorological Station (33°47'S, 70°40'W) was 371 mm (range 852–127 mm) (data of Ministerio de Obras Publicas, Chile). The mean annual temperature was 13.2°C (Di Castri and Hajek 1976). Due to the great diversity of its aquatic avifauna, this wetland has been declared a Ramsar site (under the Convention on Wetlands of International Importance especially as Waterfowl Habitat).

Within the El Yali wetland, five sites were surveyed: El Rey lagoon, Los Molles reservoir, El Yali stream, the Coastal lagoon and the El Convento saltmarsh. These sites were chosen because they are representative of the different habitats in the wetland. El Rey lagoon and Los Molles reservoir are large, seasonal wetlands (106 and 83 ha, respectively), and have large areas of emergent and submergent vegetation. El Yali stream (42 ha) is a permanent wetland with floating and submergent vegetation. The Coastal lagoon (94 ha) is a permanent habitat with a sand beach and floating vegetation only. Each of these four sites is eutrophic and shallow (<3 m). El Convento saltmarsh (60 ha) is flooded by rainfall from autumn to spring, and is artificially flooded during the summer. This saltmarsh is characterized by floating and submerged vegetation, brackish water and a shallow depth of <0.5 m.

METHODS

Data Collection and Statistical Analyses

From January 1993 to August 1999, we conducted 52 seasonal surveys (in at least one month per season) simultaneously in each of the five sites. The abundance of swans at each site was determined through direct counts along fixed transects using the methods and recommendations of Kauppinen *et al.* (1990). Censuses were conducted from 08.30 to 14.00 h. The observer was always the same for a given site, and used a spotting scope and binoculars. The effect of ENSO on swan distribution among the five sites was analyzed for all months (N = 52). These 52 months were divided into breeding months (January 1993 to April 1994, and June 1997 to February 1999; N = 21), and non-breeding months (November 1994 to May 1997, and March to August 1999; N = 31). During the last breeding season (June 1997 to February 1999), we also examined breeding phenology by recording the timing of courtship behavior, nesting, egg laying, and the appearance of chicks, fledglings and juveniles. Due to the sensitivity of Black-necked Swans to human presence, all observations were carried out from a distance (i.e., nest were not approached). Other data collected included the number of chicks (white down), number of pairs with chicks, and the number of chicks and fledglings (gray down) per pair. These data allowed estimation of productivity and numbers of swans at each of the five sites and at the overall El Yali wetland.

Linear regression was used to describe the relationship between annual cumulative rainfall and Black-necked Swan abundance during different seasons in the same, and in the following year, from 1993–1999. Likewise, linear regression was used to describe the relationship between the number of breeding months per year and cumulative rainfall in the previous year. Finally, a chi-square test was used to assess differences between sites in swan abundance during breeding and non-breeding periods (Sokal and Rolf 1995).

RESULTS

Abundance

At the El Yali wetland, Black-necked Swan numbers underwent strong annual and seasonal fluctuations (Fig. 1). In years between ENSO events, there was a clear seasonal pattern: swans were abundant during winter (June to August) and scarce or absent during summer (December to February), when they abandoned several of the lagoons that dried up completely. During El Niño years (1992 and 1997) there was an increase in rainfall during fall and winter. Toward the end of these two years and during the following year, Black-necked Swans stayed at the El Yali wetland throughout the year, and there was an increase in the number of adults both in winter and in summer. No relationship was found between annual rainfall and summer or winter abundance ($R^2_5 = 0.22$, n.s., and $R^2_5 = 0.04$, n.s., respectively). Similarly, annual rainfall was not related to summer abun-

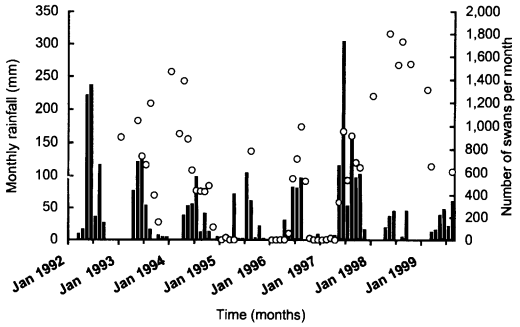

Figure 1. Monthly rainfall (columns) and monthly abundance of Black-necked Swans (open dots) at five sites in El Yali wetland, Chile, 1993–1999. For the monts with no rainfall bars, rainfall was 0 mm.

dance in the following year ($R^2_5 = 0.14$, n.s.). However, there was a positive and significant relationship between annual rainfall and swan abundance during the winter of the following year ($R^2_5 = 0.65$, $P < 0.05$, Fig. 2).

Breeding

Black-necked Swans bred opportunistically at the El Yali wetland. They bred only in those years with abundant rainfall (ENSO and post-ENSO years). There was a significant positive relationship between the number of months of breeding (0–12) and cumulative rainfall (and thus accumulation of water in wetlands) in the previous year ($R^2_5 = 0.74$, $P < 0.05$, Fig. 3). Both years of no breeding (1995 and 1996) were preceded by two years of dry conditions (total rainfall <325 mm per year).

During the 1997–1998 ENSO event, swans bred continuously from June 1997 to February 1999. Among the five sites studied, nesting occurred only at El Rey lagoon. During this period, a maximum of 30% of swans at El Yali bred (Fig. 4). Maximum numbers of breeding pairs (194) were recorded in February 1998, which was also the highest number of breeding pairs ever recorded for a Mediterranean wetland in Chile. We estimated that, during 1997–1999, 300 pairs bred and produced approximately 1,200 fledglings. Brood size ranged from one to nine chicks per breeding pair. Mean productivity varied among sites from 4.5 to 5.4 downy chicks and from 3.6 to 4.1 fledglings per breeding pair.

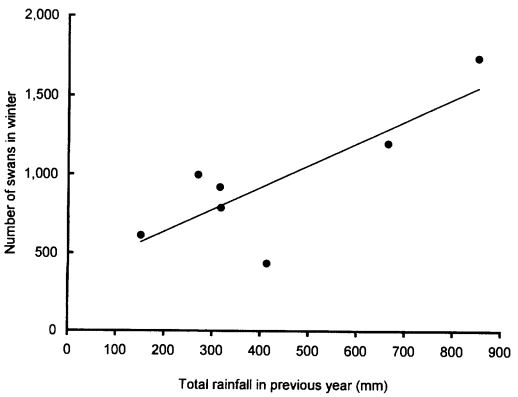

Figure 2. Linear regression ($R^2_5 = 0.65$; $P < 0.05$) between winter abundance of Black-necked Swans and total annual rainfall in the previous year at El Yali wetland, Chile, 1993–1999.

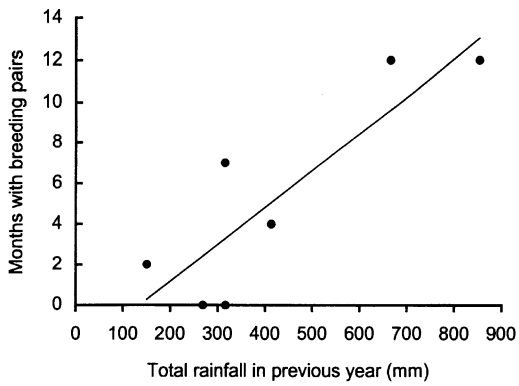

Figure 3. Linear regression ($R^2_5 = 0.691$; $P < 0.05$) between total annual rainfall in the previous year and number of months per year in which Black-necked Swans bred at El Yali wetland, Chile, 1993–1999.

Differences in Abundance Among Habitats

The abundance of swans varied significantly among the five sites surveyed, both during breeding months ($\chi^2_4 = 36{,}552$, $P < 0.0001$), and non-breeding months ($\chi^2_4 = 1{,}953$, $P < 0.0001$). The differences in abundance were more pronounced during the breeding season, because of the substantial influx of swans to El Rey lagoon at this time (Fig. 5).

DISCUSSION

As in other species of vertebrates such as small mammals (Meserve *et al.*, 1995 1999; Lima *et al.* 1999a, b), landbirds (Jaksic and

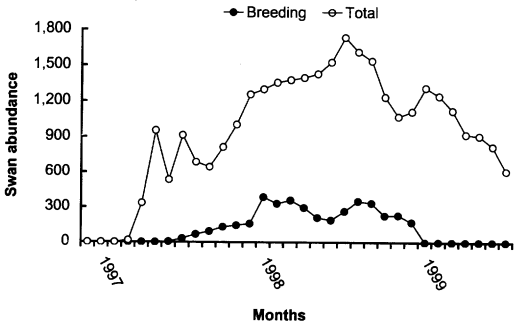

Figure 4. Total abundance and abundance of breeding Black-necked Swans at El Yali wetland during the ENSO event of 1997–1999.

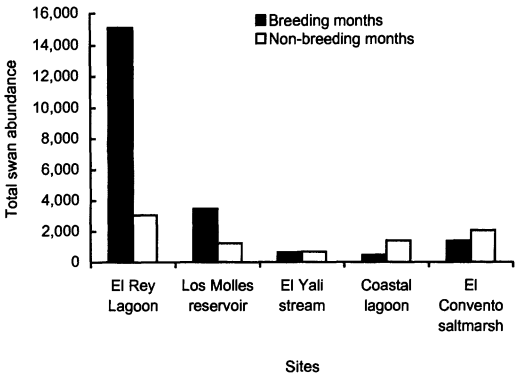

Figure 5. Total abundance of Black-necked Swans at five sites within El Yali wetland during breeding (January 1993 to April 1994, and June 1997 to February 1999, N = 21 months) and non-breeding months (November 1994 to May 1997, and March to August 1999, N = 31 months).

Lazo 1999), raptors (Jaksic *et al.* 1997), foxes (Jaksic *et al.* 1997) and grebes (Vilina and Cofré 2000), the local abundance of Black-necked Swans within the Mediterranean region of Chile is strongly influenced by ENSO events. Like some large rodents in semi-arid ecosystems (Meserve *et al.* 1995, 1999; Jaksic *et al.* 1997), Black-necked Swans take between six months and a year to exhibit increased abundance and productivity (Figs. 3 and 4). This delayed response can be explained because it is due not only to an increase in primary productivity (i.e., food), but also to increased water levels and increased availability of breeding habitats such as extensive beds of the reed *Scirpus californicus.*

During ENSO years (El Niño phase) the El Yali wetland has the largest breeding colony of Black-necked Swans in Chile's Mediterranean region. Birds raised in this wetland (source habitat) may colonize other wetlands where breeding does not occur or is scare (sink habitats). In addition, breeding productivity in the El Yali wetland is higher than that observed in other wetlands of central and southern Chile (Schlatter *et al.* 1991; Schlatter 1998). On the other hand, it is likely that during years between ENSO events, and especially in very dry years (La Niña phase), swans migrate to more stable wetlands that do not dry up and thus can sustain populations during summer months. These may be the wetlands of southern Chile (Schlatter 1998, Schlatter *et al.* 2002), as well as coastal bays and other wetlands in the southernmost part of South America (Blanco *et al.* 1996; Vuilleumier 1997), and even those on the South Shetland islands and Antarctic Peninsula (Olavarría *et al.* 1999).

In conclusion, unlike its effect on seabirds, in which ENSO events are associated with breeding crashes, in Black-necked Swans and other species of aquatic birds such as Silver Grebes (*Podiceps occipitalis*) (Vilina and Cofré 2000), Coscoroba Swans (*Coscoroba coscoroba*) and Black-winged Stilts (*Himantopus melanurus*) (Vilina *et al.* unpublished data), ENSO perturbations increase abundance by facilitating reproduction.

ACKNOWLEDGMENTS

This study is dedicated to the memory of Pablo Canevari, who supported this study from the beginning. We would also like to give special thanks to J. Rottmann, P. Farías, J. Meza, G. Egli, M. Páez and P. Thomson for their field assistance, and to F. Jaksic, R. Schlatter and G. Brewer for their helpful comments on the manuscript. H. L. Cofré is currently supported by a CONICYT (Comisión Nacional de Desarrollo Científico y Tecnológico) Doctoral fellowship.

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