Use of saltworks by Red Knots at Guerrero Negro, Mexico

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Mediante 10 censos mensuales, determinamos la abundancia del Playero Rojizo (posiblemente la subespecie *C. c. roselaari*) en un salitral artificial en Guerrero Negro (agosto/2005 a abril/2006); adicionalmente relacionamos las abundancias para cada mes con el nivel de marea. Observamos diferencias significativas entre los meses, con los mayores números en octubre (máximo de 2,907 aves), agosto y noviembre presentaron abundancias medias (hasta 835); en el resto de los meses las abundancias fueron bajas (hasta 297; $F_{1,8} = 40.43$, $p < 0.01$), lo que refleja el patrón de migración diferencial de la especie. Sólo las abundancias de octubre mostraron relación (positiva) con los niveles de marea ($F_{1,8} = 5.46$, $p = 0.04$, $r^2 = 0.41$), lo anterior debido a los mayores requerimientos energéticos de la especie durante la época migratoria. En el resto de los meses, la falta de relación puede deberse a las bajas abundancias o a los bajos niveles de utilización del salitral.

Monthly counts of Red Knots using a low salinity concentration pond at the Guerrero Negro saltworks, Baja California, Mexico during Aug. 2005 to April 2006 showed peaks of 835 in Aug. and 2,907 in Oct. Saltworks are an unusual habitat for knots and we suppose that greater numbers were using the species' more typical intertidal habitats in the adjacent Ojo de Liebre Lagoon. Nevertheless the count of 2,907 is nearly three times any other count of knots in the whole of Mexico. When peak numbers occurred in Oct. 2005, the abundance of knots in the saltworks was significantly and positively correlated with the height of the tide in the adjacent lagoon suggesting that some birds were feeding in the intertidal habitats over low water and moving into the saltworks at high tide. However, up to 1,500 were present in the saltworks at low tide and many fed there.

INTRODUCTION

Of the world's six subspecies of the Red Knot *Calidris canutus*, only *C. c. rufa* and *C. c. roselaari* migrate along the coasts of the Americas (Harrington 2001, Morrison *et al.* 2006). The *rufa* subspecies is the most studied; it migrates primarily along the Atlantic coast from Tierra del Fuego to Canada. It has suffered a major population decline and the US Fish & Wildlife Service has recently concluded that it should be listed as threatened or endangered (USFWS 2006). Currently about 10% of the *rufa* population of the West Atlantic Flyway are marked with individually inscribed colour flags (B. Harrington pers. comm.).

The Red Knots that migrate along the Pacific coast of the Americas are thought to belong to the *roselaari* subspecies which breeds in Alaska and on Wrangel Island. However, their winter distribution is largely unknown. They belong to a population that also appears to have shown a major decline over the past twenty years (from >100,000 to about 20,000) for no readily apparent reason (Morrison *et al.* 2006). There are only miscellaneous observational records of its abundance in different wetlands along the U.S. and Mexican Pacific coast, but there is some evidence of decline, especially in Washington (Buchanan 2006, Page *et al.* 1997, 1999). However, it has been suggested that there might be important stopover and non-breeding sites for *roselaari* in NW Mexico (Buchanan 2006, Harrington 2001, Page *et al.* 1997).

During their migrations, Pacific coast knots, like knots worldwide, feed mainly in intertidal habitats and roost on the foreshore at high tide (Harrington 2001). Such productive habitats often provide the resources for the rapid refuelling that underpins the species' long-distance migrations (Piersma *et al.* 2003). Only occasionally have knots been observed feeding in non-tidal habitats outside the breeding season and only exceptionally have they been recorded to use saltpans (Cramp & Simmons 1983). In NW Australia, for example, counts of knots on Eighty Mile Beach average more than 80,000, but a maximum of only 80 have been recorded at the nearby Port Hedland saltworks (Lane 1987). Similarly, although over 1,000 knots have been recorded in the tidal Ojo de Liebre Lagoon near Guerrero Negro town, Baja California, Mexico (Page *et al.* 1997), a maximum of only ten were recorded in the adjacent saltworks of the Compañia Exportadora de Sal (ESSA, Fig. 1) during monthly counts between Dec. 1995 and Nov. 1996 (Danemann *et al.* 2002).

Both the Ojo de Liebre Lagoon and the ESSA saltworks are key sites for migrant and wintering shorebirds, and the saltworks, which at 33,000 ha and an annual production of

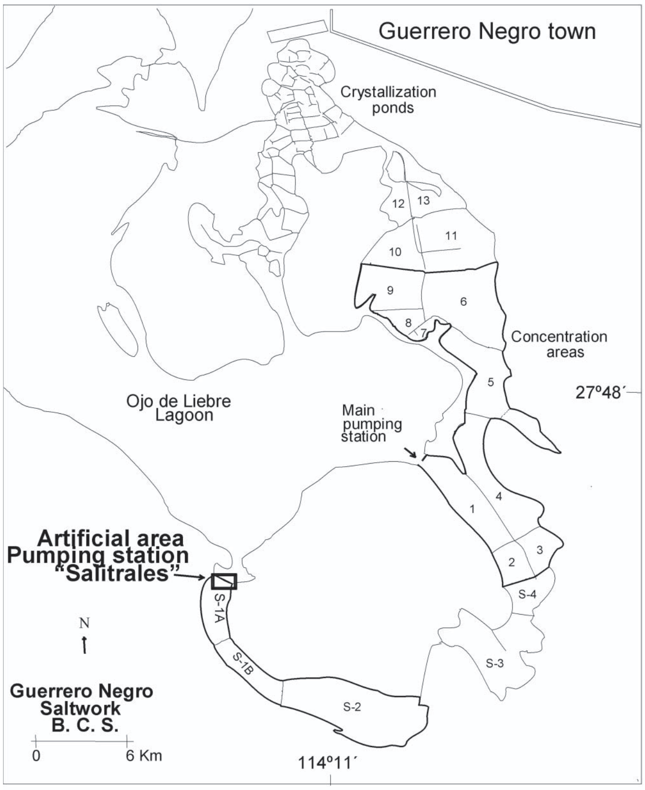

Fig. 1. Map showing the Ojo de Liebre Lagoon and the adjacent saltworks of the Compañia Exportadora de Sal, Guerrero Negro, Baja California, Mexico. Also shown is the pumping station and the main study area comprising the low salinity concentration pond known as Salitrales 1-A where Red Knots were counted between August 2005 and April 2006.

seven million tonnes is the largest saltworks in the world, is recognised as a site of international importance for shorebirds within the Western Hemisphere Shorebird Reserve Network (Carmona & Danemann 1998, Danemann *et al.* 2002, Page *et al.* 1997).

One of the most important areas for shorebirds in the ESSA saltworks is the lower salinity concentration pond known as Salitrales 1A (S-1A) where seawater is pumped into the impoundment system from the lagoon (Fig. 1). There, in Aug. 2005, we recorded 835 Red Knots. In view of this apparently unusual occurrence, we decided to carry out monthly counts in order to establish how regularly and under what conditions knots make use of S-1A.

METHODS

S-1A was originally created by building a dyke across a bay of the Ojo de Liebre Lagoon. There is a pumping station in the dyke that pumps seawater from the lagoon more or less continuously. Therefore S-1A has similar conditions to the lagoon with an only slightly higher salinity, but there is no tidal influence. However, water levels do vary as a result of variable pumping activity. It includes a mudflat of about 1.8 km^2 and there are small patches of vegetation (*Salicornia* sp., *Suaeda* sp. and *Batis maritima*), and some inundated areas have *Zostera marina*.

We counted the Red Knots in S-1A during the spring tide period every month from Aug. 2005 to April 2006. Each month we counted them hourly from a fixed point affording good visibility using binoculars (8× and 10×) and telescopes (15–60×). We counted birds individually in flocks of <300 and estimated numbers by extrapolation in larger flocks. We determined tide levels in the adjacent Ojo de Liebre Lagoon using the software TIDEP 3.0 (CICESE).

To compare abundance across months, we used a one-way analysis of variance. An *a posteriori* test (Tukey; Zar 1999) was used to detect homogenous groups. Simple linear regressions were used to relate the abundance of similar months with the corresponding tide levels (Zar 1999). The analyses were performed using STATISTICA 6.0 (StatSoft 2001). Significance was set at $\alpha = 0.05$.

RESULTS

The number of Red Knots in S-1A varied significantly between months ($F_{1,8} = 40.43$, $p < 0.01$; Table 1, Fig. 2). The first pulse of southward migration occurred in August, followed by a decrease in September. Peak numbers occurred in October followed by a decline but a few hundred continued to use S-1A in winter. The *a posteriori* test identified three groups of months when abundance was statistically

Table 1. Monthly counts of Red Knots in Salitrales 1A of the saltworks of the Compañia Exportadora de Sal, Guerrero Negro, Baja California, Mexico from August 2005 to April 2006. The last column shows which groups were statistically homogenous (see text).

Month	Mean (±SD)	Range	Homogenous groups
August	395.6 (±218.8)	15–835	B
September	19.4 (±20.3)	3–72	A
October	1841.9 (±827.7)	20–2,907	C
November	218.3 (±291.4)	0–669	AB
December	96.9 (±118.5)	0–297	A
January	38.4 (±62.0)	0–150	A
February	5.6 (±5.8)	0–15	A
March	12.5 (±25.6)	0–73	A
April	0.6 (±1.3)	0–4	A

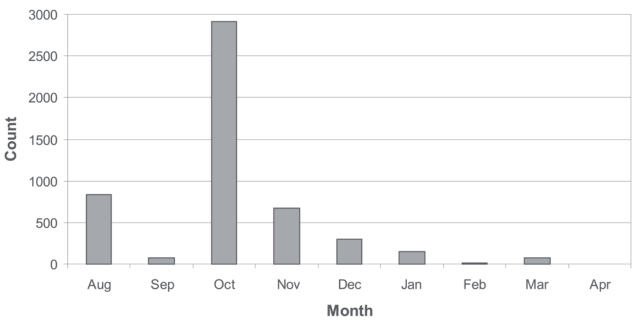

Fig. 2. Monthly maximum count of Red Knots in Salitrales 1A of the saltworks of the Compañia Exportadora de Sal, Guerrero Negro, Baja California, Mexico from August 2005 to April 2006.

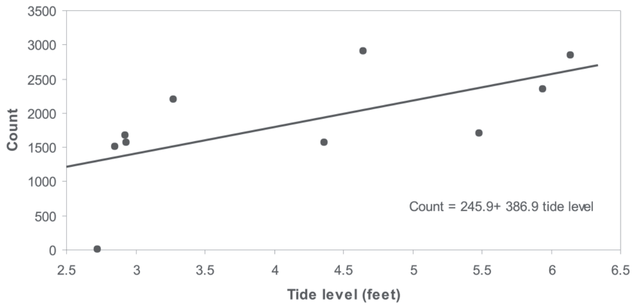

Fig. 3. Counts of Red Knot in Salitrales 1-A in Oct. 2005 plotted against the height of the tide in the adjacent Ojo de Liebre Lagoon (the increasing trend is significant – see text).

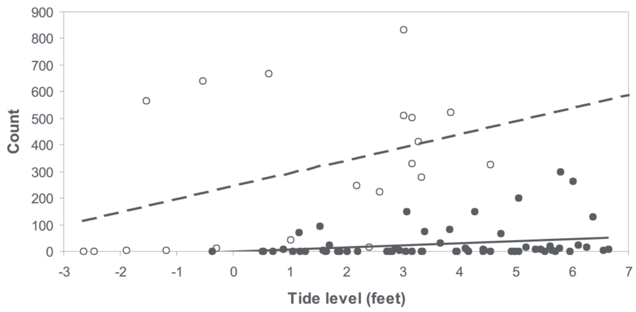

Fig. 4. Counts of Red Knot in Salitrales 1-A during the months with medium abundance (open dots; trend with dashed line) and low abundance (solid dots; trend with solid line) plotted against the height of the tide in the adjacent Ojo de Liebre Lagoon (no significant trends – see text).

homogenous: high (October), medium (August and November) and low (the remaining months; Table 1).

In October, the number of knots counted in S-1A increased significantly with the height of the tide on the Ojo de Liebre Lagoon (Fig. 3; $F_{1,8} = 5.46$, $p = 0.04$, $r^2 = 0.41$). During the October survey, tide levels ranged from 0.0 to 6.2 feet. However, the lowest levels of the tide occurred in darkness. Therefore the counts covered the top 65% of the tidal range. In contrast, there was no relationship between the counts and tide height for the months with low and medium numbers (Fig. 4; $F_{1,62} = 3.82$, $p = 0.06$, $r^2 = 0.05$ and $F_{1,18} = 3.95$, $p = 0.06$, $r^2 = 0.18$, respectively).

DISCUSSION

Apart from our counts in S-1A, we carried out extensive surveys of shorebirds in all parts of the ESSA saltworks throughout the study period but found no other substantial numbers of Red Knots apart from 22 in September. Therefore, it seems that S-1A is particularly favoured by the species probably because it affords feeding opportunities as well as extensive mudflats for safe roosting.

We did not keep a record of the activity of the knots in S-1A but birds were observed both feeding and roosting. Moreover the presence of knots there when the tide was low in the lagoon suggests that at least some were obtaining a substantial part of their daily food requirement there rather than on the nearby intertidal mudflats. No benthic survey has been carried out in S-1A but it has an abundance of mud-snails *Littoridina*, which are an important prey of knots elsewhere (e.g. at Lagoa do Peixe, Brazil (Harrington 1996)).

The increase in numbers in S-1A over high tide in October suggests that birds were moving in from intertidal feeding areas around the lagoon, either to roost or continue feeding over high water (Fig. 3).

It is notable that, despite the reported decline in the *roselaari* population (Morrison *et al* 2006), the number of knots using S-1A appears to have increased substantially. The monthly counts in S-1A in 1996 were not carried out at any specific time in relation to the tide in the lagoon, but the maximum count then was only ten whereas we found up to 1,500 even at low water (Danemann *et al.* 2002; Fig. 3). The migratory strategies of other shorebird species (e.g. Western Sandpiper *C. mauri*; Ydenberg *et al.* 2004) have been affected by increased numbers of avian predators. Possibly the extensive mudflat in S-1A is safer for the knots than the shores of the lagoon. However, we have no data on changes in predator numbers (though Peregrines *Falco peregrinus* and Merlins *F. columbarius* are common) so we do not have enough information to resolve this matter.

Our maximum count of 2,907 knots in October 2005 is the highest recorded for the whole of Mexico. The only comparable record is one for the Ojo de Liebre Lagoon of 1,053 in Jan. 1994 (Page *et al.* 1997). We visited the ESSA saltworks again in October 2006 and found similar numbers to those recorded in this paper. Given that saltworks are not normally a preferred habitat for Red Knots (Cramp & Simmons 1983), it is very likely that the total number using both the saltworks and the adjacent tidal lagoon is much greater than our count for the saltworks alone. Indeed, fieldwork in Oct. 2006 suggests that knots are also common along the shores of the Ojo de Liebre Lagoon, and that possibly 5,000 or more used the saltworks and lagoon in that month (R. Carmona, B. Harrington, *et al.* unpubl. info.). Therefore, despite the fall in the *roselaari* population overall, it seems that knots are no longer “uncommon migrants and winter visitors” in Baja California as reported by Wilbur (1987).

It seems virtually certain that the knots at Guerrero Negro belong to the subspecies *roselaari* which are thought to breed in Alaska and on Wrangel Island (Harrington 2001). This is reinforced by the fact that although about 10% of the *rufa* knots of the West Atlantic Flyway are currently carrying colour flags and bands we found none, despite an intensive search. Similarly none were found among knots staging in April and May 2006 on the coast of Washington (Buchanan 2006).

Although it has been reported that *roselaari* is more common along the Pacific coast in spring than in autumn (Buchanan 2006, Page *et al.* 1999), the majority of our records were for the autumn with relatively few in spring (Fig.2). This might arise because the birds take different routes in spring and autumn. It has been proposed that many shorebirds migrate southwards along Baja California in autumn, but northwards along the coast of mainland Mexico in spring (Carmona *et al.* 2004). Another possibility is that because spring migration is faster than in autumn (Harrington *et al.* 1986), passage migrants are less likely to be detected by monthly surveys.

The decline in the number of knots using S-1A after October (Fig. 2, Table 1) may result from onward migration. Alternatively S-1A may be used in October but not later although knots are still present in the vicinity. The latter possibility is suggested by the observation of 1,053 in the Ojo de Liebre Lagoon in Jan. 1994 (Page *et al.* 1997).

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