Satellite-tracking the seasonal locations of Trumpeter Swans *Cygnus buccinator* from Red Rock Lakes National Wildlife Refuge, Montana, USA

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Abstract

Six male non-breeding Trumpeter Swans *Cygnus buccinator* were each fitted with an 80 g satellite transmitter, a U.S. Geological Survey leg band and one red patagial wing tag at Red Rock Lakes National Wildlife Refuge (RRLNWR), Montana, USA, in July 2001 to determine where swans from the refuge spent the breeding, post-breeding, winter and pre-breeding seasons. Of 615 locations recorded, only 34% were of sufficient accuracy (location class 0–3) for analysis. There was no significant difference across seasons in the average distances moved by the marked birds. Individual birds did, however, differ significantly in the average distances that they moved within a season. Managers had hoped that following the termination of the winter feeding programme in winter 1992/93 the birds would disperse from RRLNWR during the winter months. Although the birds in this study did not leave the Greater Yellowstone Area, four of the six birds did winter outside of RRLNWR.

Key words: *Cygnus buccinator*, Red Rock Lakes National Wildlife Refuge, satellite telemetry, Trumpeter Swans.

The Trumpeter Swan *Cygnus buccinator* once bred across northern and central regions of North America (Bent 1962), but numbers breeding in the contiguous United States were reduced to just 69 known birds by 1932 (Banko 1960). In 1935, the Bureau of Sport Fisheries and Wildlife (now the U.S. Fish and Wildlife Service) initiated land purchases in the Centennial Valley (CV) of Montana to protect breeding and wintering areas for a range of animal species, but with particular emphasis on the recovery of the

Trumpeter Swan. Intensive management of the Tri-state section of the Rocky Mountain Trumpeter Swan population (RMP) – the last group of Trumpeter Swans still breeding outside of Alaska and Canada – commenced with the establishment of the Red Rock Lakes National Wildlife Refuge (RRLNWR) in 1935. Food was distributed for the swans in winter at RRLNWR from 1935 onwards, to encourage them to remain in CV and RRLNWR, where human disturbance and illegal shooting could be minimised. The provision of food in winter continued, with a few alterations to the regime, for the next 57 years.

Concerns regarding the Trumpeter Swan recovery programme among the agencies and other organisations involved with the programme began to emerge during the late 1980s. Growth in the Canadian flocks of the RMP from < 200 in the early 1970s to > 2,000 by 1994 (Shea 1995) was placing increasing pressure on winter wildfowl habitat in the Tri-state area of Montana, Wyoming, and Idaho (Fig. 1). The Tri-state swans were not joining the rest of the RMP

Figure 1. Location of the Greater Yellowstone Ecosystem study area.

on migration to Canadian breeding grounds, nor moving to other wintering areas. Increasing numbers of swans were relying on limited winter resources, with up to 40% of the birds occurring on just two feeding ponds on the refuge (U.S. Fish and Wildlife Service 1992). Not only were range expansion efforts hampered by the presence of winter feed at the refuge, but concerns were being raised regarding the possibility of disease transmission among the swans concentrated by the feeding programme (U.S. Fish and Wildlife Service 1992). The provision of food for swans at RRLNWR therefore was terminated during the 1992/93 winter.

The RMP Range Expansion Project initiated a management programme which aimed to identify other potential wintering areas and to build a tradition of swan use at each of several selected areas in the Greater Yellowstone Ecosystem (Shea & Drewien 1999). Swan translocations, hazing (*i.e.* harassing swans so they leave overcrowded winter habitat) at Harriman State Park, Idaho (HSP) and RRLNWR, and the suspension of the winter feeding programme at RRLNWR were all part of this effort. Hazing at HSP was initiated in 1990 and continued through to winter 2000/01. Translocations of swans from HSP to selected habitats occurred during winters 1990/91–1993/94, inclusive (n = 771), and from RRLNWR during the 1990/91 winter (n = 116) (Shea & Drewien 1999; Drewien & Bouffard 1994). Mid-winter waterfowl surveys, conducted annually on the refuge, showed that an average of 266 swans wintered on RRLNWR during the 10-year period (1983–1992) prior to the termination of the feeding programme. This declined to an average of 49 swans wintering at the site during 1994–2000 (U.S. Fish and Wildlife Service unpubl. data). Although the range expansion project appeared to succeed in reducing the number of swans wintering on RRLNWR and HSP, the habitats used by the displaced swans were largely unknown.

The Pacific Flyway Management Plan for the RMP identified the swans' restricted winter distribution as being the main issue facing the population and set a target of 2,200 swans to be distributed across four "new" wintering areas without artificial feeding (Subcommittee on Rocky Mountain Trumpeter Swans 1998). The management plan also set an objective of restoring the dispersed Tri-state breeding population of 355 nesting pairs and developing seasonal movements by the swans to "suitable natural wintering habitat" outside of the HSP area. Specifically, the management plan recognised the significance of the CV breeding flock to Tri-state production, and called for the restructuring of the flock so that, like the rest of the RMP population, it would migrate to suitable winter areas. Suitable natural winter habitat was not defined in the management plan, however, and there is a lack of information on the migratory movements and winter habitats of the RMP swans.

The study presented here tracked Trumpeter Swans fitted with satellite transmitters to determine whether a change in management technique (*i.e.* termination of winter feeding) was successful in redistributing the birds, by identifying the migration, winter, and pre-breeding locations

for swans caught at CV during the summer. This information is important for managers in enabling them to make decisions that will enhance winter range expansion and improve swan production in CV and the U.S. portion of the RMP. Additionally, an understanding of habitat use during the winter and pre-breeding periods would enable managers to ascertain the suitability of these habitats, and to protect and improve the sites. The specific aims of the study therefore were: 1) to determine the migration routes and movement patterns of RRLNWR swans from late fall through to the breeding period, and 2) to describe temporal and spatial differences in the individual swans' use of late fall, winter and pre-breeding areas.

Methods

The Tri-state study area included the southwest portion of Montana, the northwest portion of Wyoming (including Yellowstone National Park; YNP), and southeast Idaho (Fig. 1). These areas combined make up the Greater Yellowstone Ecosystem.

Capture and transmitter attachment

Six non-breeding male swans were caught from a boat and kayaks during 11–12 July 2001 at RRLNWR; four males on Upper Red Rock Lake, and one male each on Lower Red Rock Lake and Culver Pond. All swans were sexed, aged, weighed (± 0.1 g) and measured, as described by Drewien & Bouffard (1994). Each swan was fitted with an 80 g ST-19 backpack satellite transmitter (Telonics Inc., Arizona), a U.S. Geological Survey (USGS) leg band, and a red, uniquely numbered patagial tag on the right wing. Transmitters were fitted dorsally between the wings, using two Teflon ribbon loops positioned around the body posterior to the wings and anteriorly along each side of the neck (Malecki *et al.* 2001).

Monitoring Movements

The transmitters were set up to maximise information on wintering areas by programming them to transmit for 6 h on : 186 h off in the breeding season (Season 1: 1 May–30 September), 6 h on : 186 h off in the post-breeding season (Season 2: 1 October–30 November), 6 h on : 66 h off in winter (Season 3: 1 December–29 February) and 6 h on : 186 h off in the pre-breeding season (Season 4: 1 March–30 April). Transmitter signals were received by the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites (POES). Location coordinates and location classes (LC) were downloaded every 3–4 days from Service Argos' Automated Distribution System. Location classes assigned by ARGOS (3, 2, 1, 0, A, B, Z) define the relative accuracy of the location estimated in decreasing order, based on calculation of the orbit of the satellite and the Doppler shift on the PTT transmissions. Accuracy levels described by ARGOS for LC 3, 2, 1, 0 were of < 150 m, 150–350 m, 350–1,000 m, and > 1,000 m, respectively (Service Argos 1996). Each location was examined for plausibility; locations were included in the analyses if the LC was 3, 2, 1 or 0. Locations of quality LC < 0 were not considered suitable for analysis.

Location data were grouped by transmitter identification number, location

class, and season. Locations were mapped in ArcView 3.3 and the programme extension "Animal Movement" (Hooge & Eichenlaub 2000) was used to calculate home ranges and distances between locations. Distances moved within and between seasons were also calculated for all swans in ArcView 3.3, using the "Calculate Successive Distances" command.

Results

A total of 615 locations were recorded from 19 July 2001–15 October 2002, of which 210 (34%) were used in the analyses (*i.e.* LC = 0–3). One PTT stopped transmitting during the first winter of deployment, while the remaining PTTs provided locations through the 2002 pre-breeding season (Table 1). Additionally, one PTT (swan 12855) lasted into the 2002 breeding season, and another PTT (swan 12831) lasted into the 2002/03 winter season. Nearly 55% of the locations used were obtained during the 2001/02 winter season. Only 7.5% of the total locations used were of the highest precision (LC 3), with 13.9% at LC 2, 40.8% at LC 1 and 37.8% at LC 0.

Five of the six marked swans were located in CV during the breeding season (Fig. 2, Table 2). Swan 12843 had no

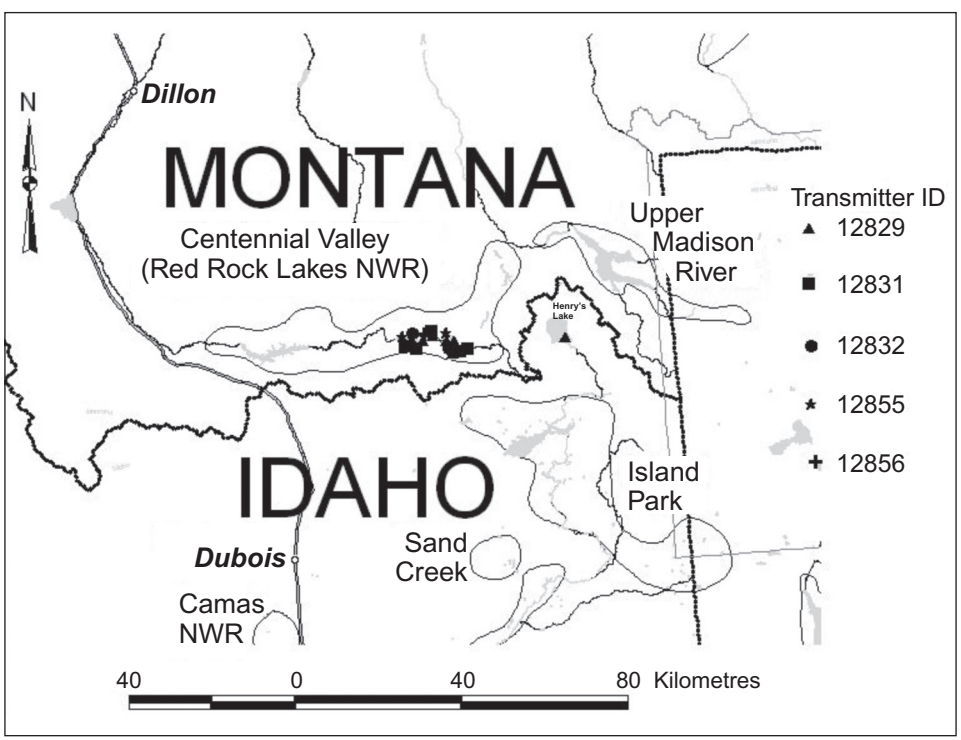

Figure 2. Locations recorded for satellite-tracked Trumpeter Swans during the 2001 breeding season. All swans remained in Centennial Valley, Montana, except for swan 12829 which moved east to Henry's Lake, Idaho.

location classes of 0–3 during this time period, and therefore was not included in breeding season analyses. Swan 12829 flew east to Henry's Lake, Idaho, a distance of 25 km, on 7 September 2001 and returned the same day.

Four of the six marked swans stayed in CV during the post-breeding season and the other two moved south-southeast (Fig. 3, Table 2). Of the two birds that changed site, one (swan 12829) left CV on 20 November 2001 to fly southeast to Jackson, Wyoming, then moved from there to Snake River in Wyoming. The second (swan 12856) flew south from CV on 30 November 2001 to Island Park in Idaho.

All four swans that finished the post-breeding season in CV dispersed into Wyoming and Idaho during the winter season (Fig. 4). Swan 12829, which remained near the Snake River area south of Jackson, Wyoming, was found dead in May 2002. The bird was identified from its red patagial wing tag. There was no evidence of the transmitter or the Teflon ribbon harness. The swans utilised areas east and south-southeast of CV during the winter, making use of the open water on various

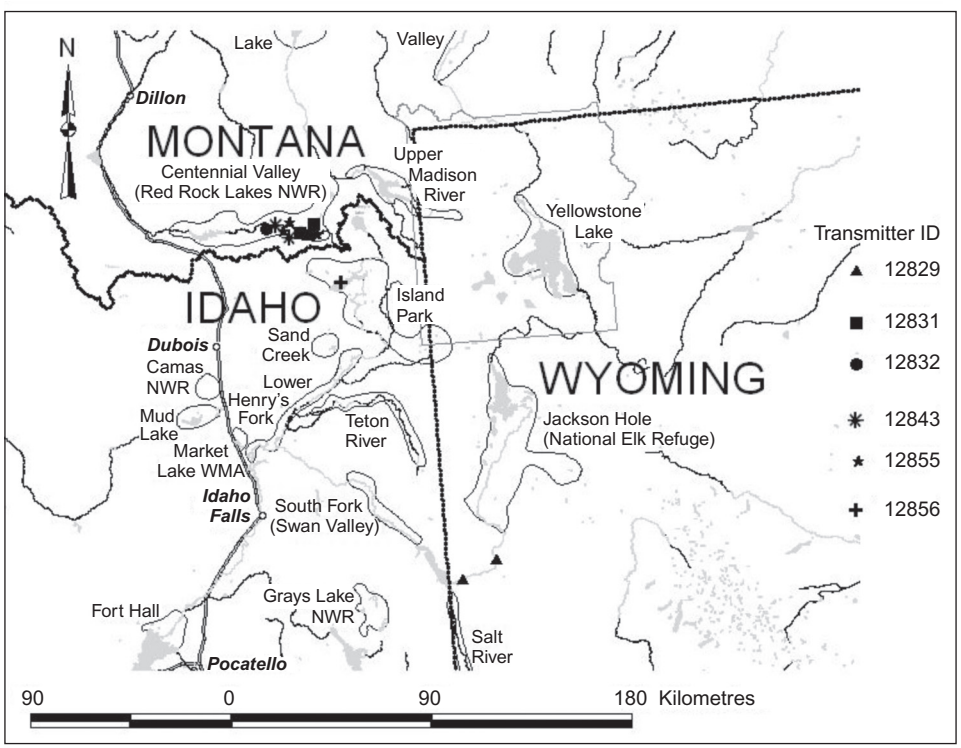

Figure 3. Southward movement out of Centennial Valley, Montana, by two Trumpeter Swans in the 2001 post-breeding season. Swan 12856 moved to Island Park, Idaho and swan 12829 moved south of Jackson, Wyoming.

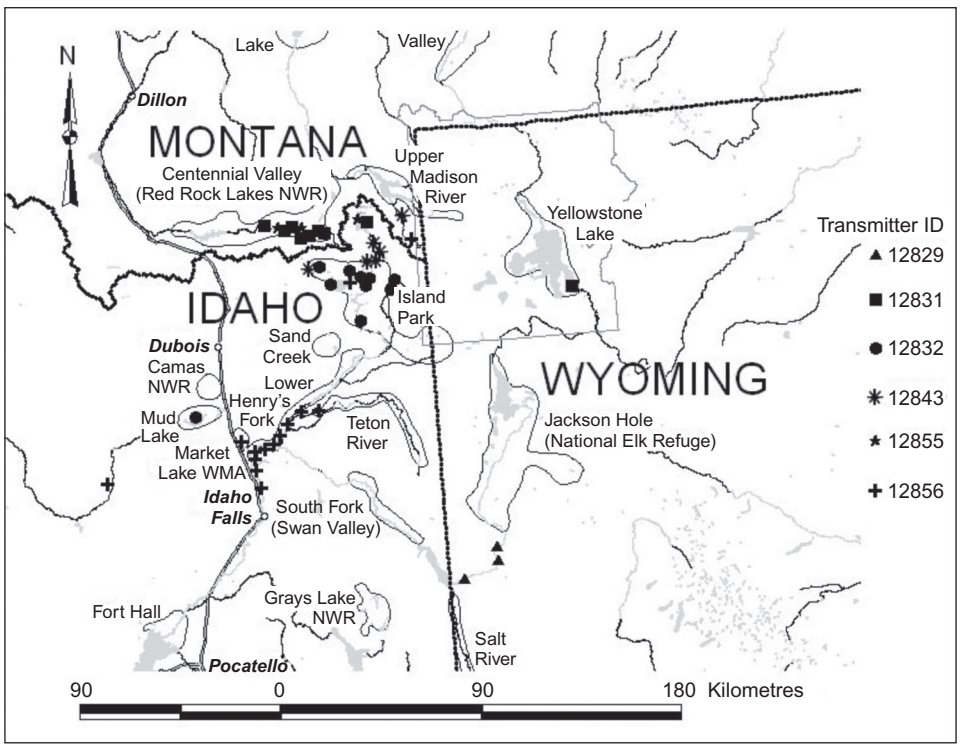

Figure 4. Location of the six satellite-tracked Trumpeter Swans in winter 2001/2002. Four swans wintering to the south and southeast of Centennial Valley, Montana, did not return there during the winter season.

rivers. Swan 12856's transmitter stopped functioning during February 2002.

During the pre-breeding season, swan 12831 returned to CV from YNP, whereas swan 12832 remained in the Island Park area of Idaho throughout the spring, as did swan 12843. Swan 12855 continued to stay in CV until 20 March 2002 when it flew east about 16 km to the eastern part of the Montana–Idaho border. It remained there until 29 March 2002 when it returned to CV.

There was no significant difference between the breeding, post-breeding and winter seasons in the average distance moved by each bird (ANOVA: $F_{5,12} = 0.038$, n.s.; Table 3). However, there were significant differences among birds in the average distance moved within seasons (one-sample *t*-tests: $t_4 = 3.83$, 4.27 and 3.51 for the breeding, post-breeding and winter seasons, respectively, $P < 0.05$ in each case; Table 4). Swans 12829, 12832 and 12856 moved from three to eight times further than swans 12831 and 12855 during the breeding season. However, during the post-breeding season, swans 12831 and 12855 moved twice as far as swans 12829, 12832 and 12856. During the winter season swan

Table 1. Satellite telemetry locations, in percentages by season, for six non-breeding Trumpeter Swans marked at the Red Rock Lakes NWR in 2001. NA = not applicable because the bird had died (*i.e.* swan 12829) or the transmitter had stopped transmitting.

Transmitter no.	Total locations	Dates	Season (% locations)			
			Breeding	Post-breeding	Winter	Pre-breeding
12829	16	19 July 2001 – 2 February 2002	63	13	24	NA
12831	95	19 July 2001 – 25 April 2002	7	4	65	23
	8	2 May 2002 – 15 October 2002	63	37	NA	NA
12832	44	19 July 2001 – 1 April 2002	5	16	43	36
12843	16	19 July 2001 – 6 March 2002	0	19	69	12
12855	16	19 July 2001 – 17 April 2002	25	25	31	19
	2	28 June 2002 – 29 June 2002	100	NA	NA	NA
12856	13	19 July 2001 – 4 February 2002	8	8	84	NA

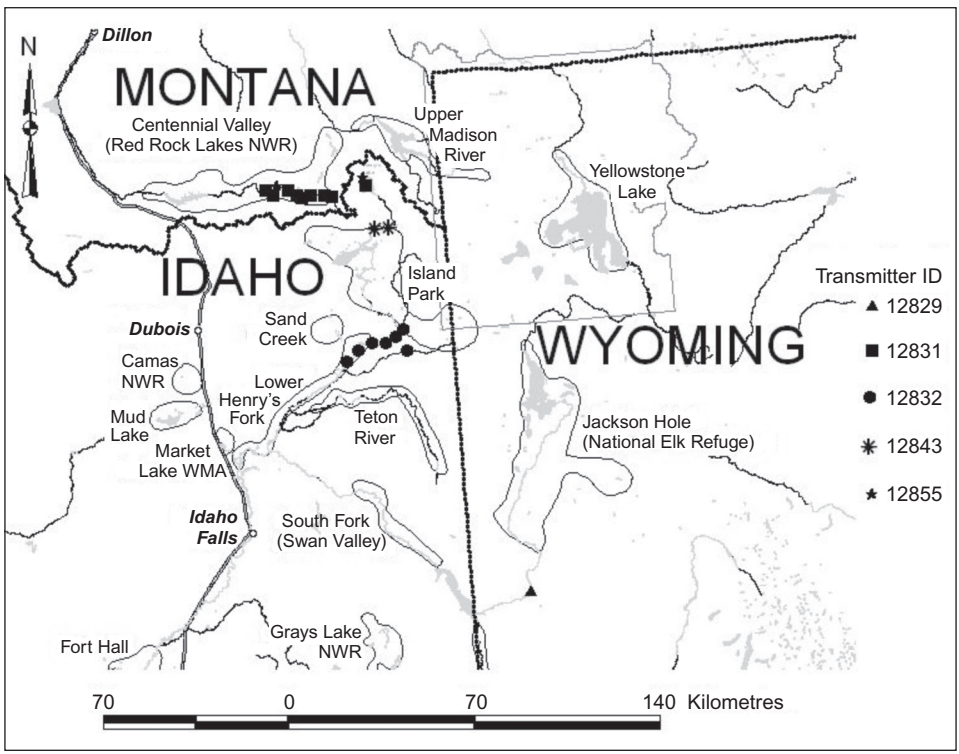

Figure 5. Locations of the satellite-tracked Trumpeter Swans in the 2002 pre-breeding season. Swans 12832 and 12843 are south and east of Centennial Valley, Montana. Swan 12829 was found dead in May near Gros Ventre River, south of Jackson, Wyoming.

12831 moved only 8.4 km, on average, and swan 12843 moved only 15.6 km, whereas swans 12829, 12832 and 12855 moved > 50 km during this period. Swan 12855 moved 36.9 km during the pre-breeding season while swans 12831, 12832 and 12843 moved only 9.1 km on average.

Discussion

Satellite telemetry proved useful in identifying the general movements and locations of Trumpeter Swans within the Greater Yellowstone Ecosystem during 2001–2002. Unfortunately, 66% of the satellite signals were found to be unusable, and the percentage of usable locations (LC 0–3; 32.6%) was below that reported by other researchers for their species: 47% in a study of the Common Loon *Gavia immer* (Kenow *et al.* 2002), 60% for Northern Pintail *Anas acuta* (Miller *et al.* 2005) and 52% for the Lesser White-fronted Goose *Anser erythropus* (Lorentsen *et al.* 1998). The relatively few number of usable satellite telemetry locations limited data analysis; for instance, there were only two data points

Table 2. General location for each of the six satellite-tracked Trumpeter Swans in each season, based on satellite telemetry data collected during 2001–2002. ID = Idaho, MT = Montana, WY = Wyoming, NA = not applicable.

	Season			
Transmitter no.	**Breeding season (1 May–30 Sep.)**	**Post-breeding (1 Oct.–30 Nov.)**	**Winter (1 Dec.–29 Feb.)**	**Pre-breeding (1 Mar.–30 Apr.)**
12829	Centennial Valley, MT	Move to Jackson Hole, WY on 3 Nov.	Found dead in the Jackson, WY area	NA
12831	Centennial Valley, MT	Centennial Valley, MT	Centennial Valley, MT	Centennial Valley, MT
12832	Centennial Valley, MT	Centennial Valley, MT	Moved to Island Park, ID, on 1 Dec. and stayed	Island Park, ID
12843	NA	Centennial Valley, MT	Moved to Island Park, ID, on the Henry's Fork River in December and stayed	Island Park, ID, and Henry's Fork River in ID
12855	Centennial Valley, MT	Centennial Valley, MT	Centennial Valley, MT, most of the time but spent part of December on the Snake River by Idaho Falls, ID	Centennial Valley, MT
12856	Centennial Valley, MT	Moved to Island Park on 1 Nov.	Stayed in Island Park area, ID, until transmitter stopped on 4 Feb. 2002	NA

Table 3. Average daily distances (km) moved per season, by Trumpeter Swans fitted with satellite transmitters at the Red Rock Lakes NWR, from the 2001 breeding season to the 2002 pre-breeding season. Location days indicate the number of days with usable satellite data (location classes 0–3) for each bird.

	Breeding Season (1 May–30 Sep.)		Post breeding (1 Oct.–30 Nov.)		Winter (1 Dec.–29 Feb.)		Pre-breeding (1 Mar.–30 Apr.)	
Transmitter no.	Average distance (km)	Location days	Average distance (km)	Location days	Average distance (km)	Location days	Average distance (km)	Location days
12829	56.0	10	27.0	2	59.3	4	NA	NA
12831	19.5	7	49.1	4	8.4	62	9.5	22
12832	54.0	2	23.2	7	53.0	19	8.9	16
12843	NA	NA	25.0	3	15.6	11	8.8	2
12855	7.6	4	69.0	4	56.9	5	36.9	3
12856	37.6	1	25.8	1	36.7	11	NA	NA

Table 4. Variation in the average daily distances moved by individual Trumpeter Swans during the breeding, post-breeding and winter seasons. One-sample *t*-tests were used to test for differences between individuals in the average daily distance moved, for all birds grouped by season.

Season	Mean distance per individual (km) (± s.d.)	*t* statistic (d.f.)	*P*	95% CI
Breeding	31.22 (± 17.98)	3.83 (4)	0.018	8.89, 53.54
Post-breeding	38.42 (± 20.13)	4.27 (4)	0.013	13.43, 63.41
Winter	34.12 (± 21.72)	3.51 (4)	0.025	7.15, 61.09

available for swan 12829 during the post-breeding season. This may be due to the terrain within the Centennial Valley (elevation 3,000 m), which runs from north to south in close proximity to where the birds stayed on Upper Lake, RRLNWR. As a result of the birds' locations, the satellite could not use the full range of the "Doppler effect" when collecting the signal from the transmitter (Telonics Inc., pers. comm.). Terrain has been identified as a problem in obtaining accurate satellite telemetry locations in previous studies; both Keating *et al.* (1991) and Craighead & Craighead (1987) found that satellite telemetry locations from valleys were less accurate than those from the top of mountains.

The locations of birds during each of the seasons were consistent with earlier reports on the swans of the Greater Yellowstone Ecosystem (Sjostrom 1982; Gale *et al.* 1987). The marked swans did not leave the Centennial Valley until early November when the wetlands began to freeze. Records indicate that even when the swans were fed grain during the winter, non-breeders usually left CV in early November and flew east or south for about 80 km (Gale *et al.* 1987). The areas to which these marked swans dispersed during winter were, and still are, the historic wintering areas of HSP and Island Park, Idaho (Snyder 1991; Shea & Drewien 1999). These areas continue to provide winter habitat for swans. Overall, the movement patterns of the swans in this study were similar to those observed in the past (Banko 1960), which found that the swans remained in CV during summer and part of the fall migration, made occasional trips to the east and south over the mountain ranges during fall migration, dispersed to the east and south during early winter (if no winter grain was available at RRLNWR), then returned to CV prior to the breeding season.

During the 2001/02 winter, movements of swan 12856 may have been influenced by a hazing programme at HSP and Island

Park, Idaho, where it started to winter. This swan moved to the west to the Idaho Falls area, a distance of about 70 km. The timing of its westward movement coincided with the hazing of Trumpeter Swans in the HSP and Island Park area, undertaken to reduce the impacts of birds on the vegetation in the area (U.S. Fish and Wildlife Service 2002). The hazing programme for Trumpeter Swans was considered an essential management tool in the protection of the habitat resources for the areas of HSP and Island Park, Idaho.

Managers had hoped that the Trumpeter Swans would disperse from the RRLNWR area in winter once the feeding programme was terminated, which would reduce the chances of disease transmission within the flock (Subcommittee on Rocky Mountain Trumpeter Swans 1998), but none of the satellite-tracked birds left the Greater Yellowstone Area. It has been suggested other marking programmes such as radio telemetry could have been used to achieve the same result at lower or similar costs. However, had the birds left the Greater Yellowstone Ecosystem, it would have been very difficult to find them without satellite telemetry. Further assessment of satellite telemetry packages is encouraged to determine their suitability in mountainous terrain. Given that eight years have elapsed since the data presented here were recorded, additional research into the movements of the Tri-state Trumpeter Swan sub-population is also required to investigate whether the birds now move between sites more frequently and over greater distances, and particularly whether the number of sites used is increasing.

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