MOVEMENTS, FORAGING, AND SURVIVAL OF BALD EAGLES REINTRODUCED ON THE NORTHERN CHANNEL ISLANDS, CALIFORNIA

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Abstract–Bald eagle (*Haliaeetus leucocephalus*) populations on the California Channel Islands disappeared by the 1960s likely due to DDT pollution. Since 1980, bald eagles have been reintroduced on the southern Channel Islands but successful reproduction is precluded by DDE, a metabolite of DDT. In 2002, we began a five-year feasibility study to determine if bald eagles could be successfully restored on the northern Channel Islands. Our objectives were to assess eagle movements, survival, and foraging. We were interested in determining if the eagles were foraging on potentially DDE-contaminated items such as marine mammal carcasses and the eagles' potential impact on sensitive seabird species breeding on the islands. A total of twenty-two eagles equipped with patagial tags and backpack-mounted VHF and GPS transmitters were released successfully on Santa Cruz Island from hacking towers between 2002 and 2003. The majority of eagles released remained on the islands, regularly moving among the four northern Channel Islands, and two eagles dispersed to the mainland. First-year survival was 78% in 2002 and 90% in 2003. We observed eagles feeding on carcasses of feral pig (*Sus scrofa*), mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), and marine mammals. Based upon GPS data, the eagles did not appear to concentrate activity around the West Anacapa Island breeding colonies of sensitive seabird species. Continued intensive monitoring and future analyses of known food items will allow us to evaluate potential contaminant loads incurred by the eagles and help guide future management strategies.

Keywords: Argos/GPS PTT, bald eagle, foraging, Haliaeetus leucocephalus, movements, radio-telemetry

INTRODUCTION

Bald eagles (*Haliaeetus leucocephalus*) once nested on all the California Channel Islands off the coast of southern California (Fig. 1). Kiff (1980) estimated that in the early 1900s there were a minimum of 24 pairs nesting on the Channel Islands, including five pairs on Santa Cruz Island, three pairs on Santa Rosa Island, three pairs on San Miguel Island, and three pairs on Anacapa Island. Interviews with long-time island residents suggest there may have been as many as nine eagle pairs nesting on Santa Rosa Island (D. Garcelon pers. comm.). Grinnell and Miller (1944) referred to the Channel Islands as one of two bald eagle "breeding metropolises" in California, the other being the northeastern section of the state.

Bald eagle numbers began declining on the Channel Islands in the late 1800s due to human persecution, including shooting, poisoning and egg-collecting (Kiff 1980). The ultimate cause of bald eagle extirpation from the Channel Islands was likely the introduction of the organochlorine pesticide DDT into the Southern California Bight (SCB; Fig. 1). Around 1970 it was discovered that DDT was entering the Southern California Bight through sewer systems emptying into the ocean at White's Point on the Palos Verdes Peninsula (Fig. 1). The source of the pollution was eventually traced to the Montrose Chemical Corporation's manufacturing plant in Torrance, CA.

In 2002, we began a five-year feasibility study to determine if bald eagles could be successfully restored on the northern Channel Islands. The project objectives are to release 12 bald eagles per year on Santa Cruz Island (hereafter Santa Cruz) by hacking (Garcelon and Roemer 1990) and then carefully monitor the eagles' movements, forage

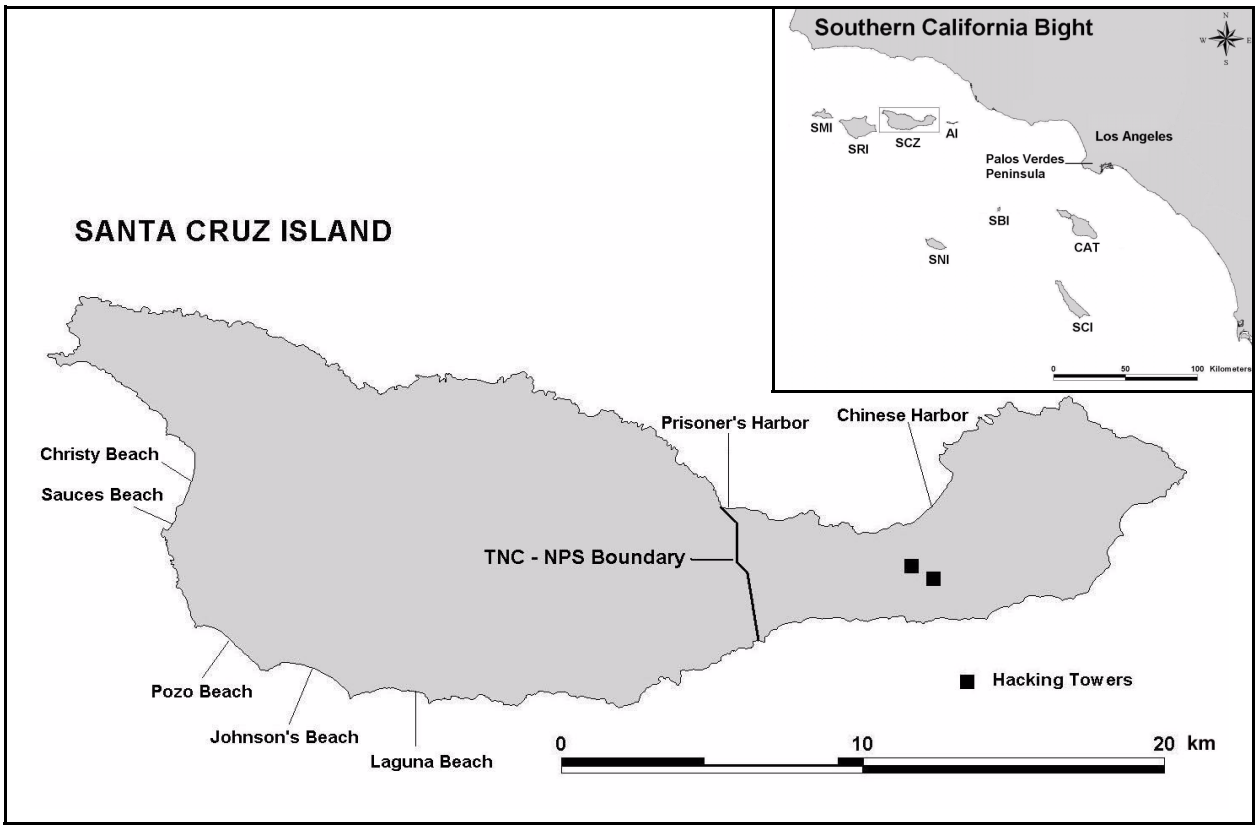

Figure 1. The Southern California Bight showing the locations of the eight California Channel Islands (inset): San Miguel Island (SMI), Santa Rosa Island (SRI), Santa Cruz Island (SCZ), Anacapa Island (AI), Santa Catalina Island (CAT), Santa Barbara Island (SBI), San Nicolas Island (SNI), and San Clemente Island (SCI). Santa Cruz Island showing bald eagle hacking tower locations, the boundary between The Nature Conservancy (TNC) and National Park Service (NPS) managed lands, and locations of beaches where monthly surveys were conducted for beached carcasses from June to December 2003.

use, and survival. Forage use and analyses of prey samples are to be used to evaluate the potential body burdens of organochlorine contaminants that could affect breeding and the feasibility of successful bald eagle restoration.

STUDY AREA

Santa Cruz is located approximately 30 km off the coast of Ventura and Santa Barbara counties (Fig. 1). Santa Cruz is the largest of the eight California Channel Islands, measuring about 38 km in length and 12 km wide at its widest point. The land area is approximately 249 km^2 with 124 km of shoreline and a maximum elevation of 753 m. Santa Cruz is the most rugged and topographically diverse of the Channel Islands and has a Mediterranean climate, with mean monthly temperatures ranging from 11.7 to 20.9ºC and a mean annual rainfall of 50 cm (Junak et al. 1995). The National Park Service (NPS) owns and manages the eastern 24% of the island and The Nature Conservancy (TNC) owns and manages the western 76% of the island (Fig. 1).

MATERIALS AND METHODS

Hacking Towers

In May 2002, we constructed two hacking towers on Santa Cruz (Fig. 2). Our criteria for tower locations included good road access to facilitate tower construction, areas that provided views of the island and ocean for the eaglets while in the towers, and sites that were located so as to reduce the chance of a catastrophic event (e.g., fire or wind storm) destroying both towers. Two flat sites were selected on the NPS portion of Santa Cruz; one on the north side (North Tower) of the

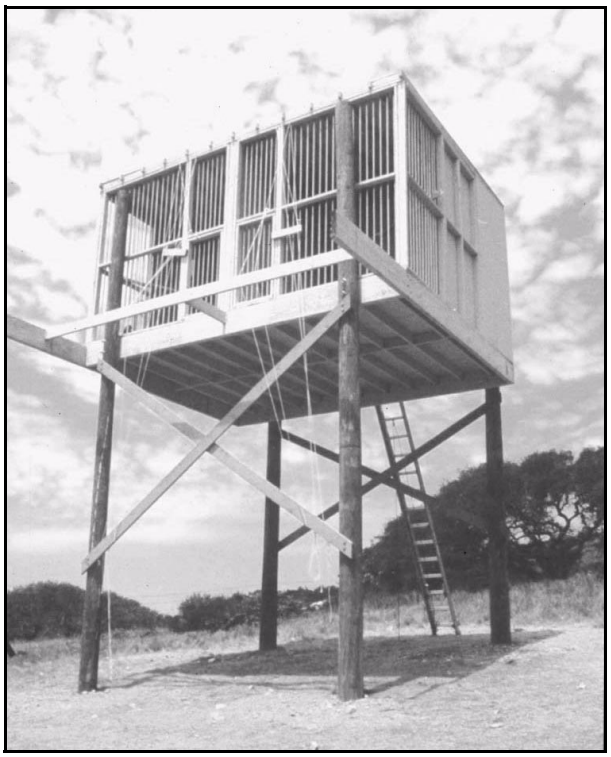

Figure 2. Bald eagle hacking tower on Santa Cruz Island, CA.

main east-west ridge and one on the south side (South Tower; Fig. 1).

Each tower consisted of a platform raised approximately four to five meters above the ground on four utility poles set one to two meters into the ground. Each platform supported a box separated into three sections: two nest boxes and an observation area. The wall separating the observation area and the nest boxes contained feeding doors to add and remove food items and a one-way glass window for watching the eaglets. Each cage also had a solid roof (2.4 m high) and a solid wall separating it from the adjacent cage. The rear half of the outside wall was solid, whereas the front half of the side wall and the entire front of the cage were made of vertical metal bars, allowing the eagles a good view of their surroundings. The front also had a release door that was opened with ropes from outside the tower. Nests and perches were constructed in each cage and a solar-powered video system was installed to allow remote monitoring of each cage.

Eaglet Acquisition

Young bald eagles approximately 8 weeks old were acquired from two different sources: captive-bred birds from the Avian Conservation Center (ACC) at the San Francisco Zoo and from wild nests in Alaska. To find wild nests containing appropriately aged eaglets we flew helicopter surveys near Juneau, AK and then traveled to the collection area by boat. A climber accessed the nests and placed one to two eaglets into a padded nylon bag and carried them to the ground. We examined each eaglet to make sure it was healthy and then transported it back to the boat, where it was placed into an airline dog kennel (56 x 81 x 58 cm; W x D x H) and fed fresh fish two to three times per day. The eaglets were flown from Juneau to Los Angeles, CA, and then transported to Santa Cruz by either NPS boat or charter airplane.

Marking and Release

Upon arriving on Santa Cruz eaglets were placed in the hacking towers and fed fresh fish and feral pig (*Sus scrofa*) until their release. When they were approximately 11 weeks old, we fit each eaglet with a 70-gram Solar Argos/GPS PTT-100 transmitter (Microwave Telemetry, Inc.) combined with a VHF transmitter (Advanced Telemetry Systems), blue patagial wing markers with a unique letter/number combination painted in black on the tag, and a Fish and Wildlife Service (FWS) metal leg band. We also collected ~10 cc of blood from each eaglet to allow for baseline contaminant analyses. The PTT-100 recorded GPS locations of the eagle approximately once per hour and uploaded the locations to a satellite approximately once every three days. The data were then available from Argos, Inc. via computer.

When the eagles were 12 weeks old we opened the release doors on the hacking towers. We provided feral pig carcasses for the released eagles throughout the year. Most carcasses were provided near the hacking towers during the period following the releases (June to September) to provide food for eagles while they developed their flight/scavenging skills. During the remainder of the year carcasses were placed in a variety of locations island-wide at a rate of one to two carcasses per week to encourage eagles to search for their food.

Monitoring

After release, we attempted to locate each eagle two to three times per week to ensure the eagles were eating and mobile. Using radio-

telemetry we generally were able to locate the eagles for observations, but if not, they could usually be located after collecting their most recent GPS location that we retrieved via computer. We relied on the GPS transmitter data for tracking the movements of eagles that left Santa Cruz.

During observations we recorded all instances of foraging by eagles, including the time, location, and species of prey when possible. In addition, solar-powered camera systems were used to monitor eagle activity at some known pig and marine mammal carcasses. The camera system consisted of a video camera inside a weatherproof housing, a tripod, a time-lapse VCR inside a weatherproof case, a flexible solar panel, and a 12-volt marine battery. The systems were placed near carcasses and covered with camouflage netting. We reviewed the tapes and recorded information on any eagle activity observed.

Beach Watch

In order to gain a better understanding of the potential contamination that bald eagles might acquire by feeding on beached animals, we conducted monthly surveys of seven beaches on Santa Cruz Island: Chinese Harbor, Prisoner's Harbor, Laguna Beach, Johnson's Beach, Pozo Beach, Sauces Beach, and Christy Beach (Fig. 1). Beaches were monitored at low tides to maximize likelihood of finding beached organisms.

RESULTS

Eaglets were brought to Santa Cruz in May and July 2002 and 2003 (Table 1). The eaglets from the ACC and Alaska varied widely in date of acquisition and age in both years, so banding and releases were staggered from late June through early September in 2002 and from mid-June through late August in 2003 (Table 1). Once the release doors were opened, it took up to four days for the eagles to fledge.

Two eagles successfully dispersed to the mainland (Fig. 3). Since 2002, Alaska male eagle A-07 has flown as far as southwestern Montana and has returned to within 150 km of the northern Channel Islands. He has flown approximately 8,000 km since his release based upon over 3,500 GPS points. Since 2003, ACC female eagle A-12 has flown approximately 1,500 km based upon over 800 GPS points. Upon reaching the mainland, she flew to northeastern California and remained in the Goose Lake area of California and Oregon through 2003.

Four eagles (three in 2002 and one in 2003) died in apparent unsuccessful attempts to cross the ocean to Anacapa Island (Fig. 1) or the mainland, instead ending up in the ocean. Three of these eagles had been flying less than one month upon attempting their ocean crossings and the other had been fledged just over one month. We recovered two of the eagles' carcasses that washed up on mainland beaches, one directly east of the islands and one southeast of the islands, and divers recovered a leg band and transmitter of a third eagle off Anacapa Island. A fifth eagle (A-06) is assumed dead as we have received no GPS or VHF telemetry data and there have been no sightings of the eagle since one week after it was released. All other released birds are known to be alive. First year survival for the eagles released in 2002 was 78% and, as of December 2003, 90% of the eagles released in 2003 were still alive.

Two eagles were re-released after being treated at raptor rehabilitation centers on the mainland. One of these birds (A-11) landed in the ocean but was picked up by a passing boat. It was taken to the Ojai Raptor Center, CA where it was rehabilitated and then returned to Santa Cruz. This eagle has remained on Santa Cruz since being re-released, except for a 6-day visit to Santa Rosa Island (hereafter Santa Rosa; Fig. 1) in January 2003. The other eagle successfully flew to the mainland, but ended up in the desert near Indio, CA where it was found emaciated and dehydrated at a fish hatchery. It was rehabilitated at the Coachella Valley Wild Bird Center, CA and returned to Santa Cruz. This eagle also has remained on Santa Cruz since its return.

Five eagles have remained on Santa Cruz since being released. These eagles have explored much of the island but most of their activity was concentrated in the Chinese Harbor area (Fig. 1). The remaining eight eagles have moved among the four Northern Channel Islands. West Anacapa Island (hereafter West Anacapa) and Santa Rosa have been visited the most. Six different eagles spent 1 to 25 days on West Anacapa. Three of the eagles released in 2002 spent most of fall 2002 and

Table 1. Identification, release information, and status of bald eagles successfully released on Santa Cruz Island, CA in 2002 and 2003.

FWS leg band	Sex[a]	Patagial marker	Source[b]	Release point	Release date	Status/latest location[c]
629-02795	M	A-00	ACC	North Tower, Box 1	06/25/02	Alive, Santa Rosa Island, CA
629-02796	F	A-01	ACC	North Tower, Box 1	06/25/02	Alive, Santa Rosa Island, CA
629-02798	F	A-02	ACC	North Tower, Box 2	06/25/02	Alive, Santa Cruz Island, CA
629-02797	F	A-03	ACC	North Tower, Box 2	06/25/02	Dead
629-14042	F	A-04	AK	North Tower, Box 2	08/15/02	Alive, Santa Cruz Island, CA
629-14041	F	A-05	AK	North Tower, Box 2	08/15/02	Dead
629-14043	M	A-06	ACC	North Tower, Box 1	08/19/02	Assumed dead
629-14044	M	A-07	AK	North Tower, Box 1	08/17/02	Alive, central Utah
629-14045	M	A-08	AK	South Tower, Box 3	08/26/02	Alive, Hopper Mountain, CA
629-14046	F	A-09	AK	South Tower, Box 3	08/26/02	Dead
629-14047	F	A-10	AK	South Tower, Box 4	09/07/02	Alive, Santa Cruz Island, CA
629-14048	F	A-11	AK	South Tower, Box 4	09/07/02	Alive, Santa Cruz Island, CA
629-47354	F	A-12	ACC	North Tower, Box 2	06/13/03	Alive, Goose Lake, CA/OR
629-47355	F	A-13	ACC	North Tower, Box 2	07/01/03	Alive, Santa Cruz Island, CA
629-47361	F	A-14	AK	South Tower, Box 3	08/21/03	Alive, Santa Cruz Island, CA
629-47357	M	A-15	ACC	North Tower, Box 1	07/25/03	Dead
629-47359	F	A-16	AK	South Tower, Box 3	08/21/03	Alive, Santa Rosa Island, CA
629-47360	F	A-17	AK	South Tower, Box 3	08/21/03	Alive, Santa Rosa Island, CA
629-47362	F	A-18	AK	South Tower, Box 4	08/21/03	Alive, Santa Rosa Island, CA
629-47363	F	A-19	AK	South Tower, Box 4	08/21/03	Alive, Santa Rosa Island, CA
629-47358	F	A-20	AK	North Tower, Box 2	08/31/03	Alive, Santa Cruz Island, CA
629-47356	M	A-21	AK	North Tower, Box 2	08/31/03	Alive, Santa Cruz Island, CA

[a] Determined by karyotyping for eagles from the Avian Conservation Center, San Francisco Zoo, CA and morphometrics for Alaskan eagles.
[b] Bald eagles from the Avian Conservation Center, San Francisco Zoo, CA (ACC), wild nests near Juneau, AK (AK).
[c] As of 12/01/03

winter 2002 to 2003 on Santa Rosa. All three of these eagles' transmitters have failed or fallen off, but two of these eagles were re-sighted on Santa Rosa in November 2003. Four eagles released in 2003 have flown to Santa Rosa. San Miguel, East Anacapa, and Middle Anacapa Islands have been visited only briefly (1 to 7 days).

We confirmed that the eagles regularly utilized the pig carcasses we provided. The eagles also found other sources of food. Thirteen eagles were observed feeding on or perched near 11 different marine mammal carcasses between September 2002 and December 2003. Nine of these carcasses were on the beach at Chinese Harbor (Table 2). Eagle A-01 was seen flying with what appeared to be a snake in her talons and A-21 was seen feeding on a leopard shark (*Triakis semifasciata*) carcass at Chinese Harbor. Biologists working on Santa Rosa have reported multiple instances of bald eagles feeding on

Table 2. Observations of bald eagles feeding on or perched near marine mammal carcasses on Santa Cruz Island, CA from September 2002 through December 2003.

Prey species/location	Date	Eagles present
Harbor Seal (*Phoca vitulina*)		
Chinese Harbor	11/20/2002	A-10
Chinese Harbor	12/05/2002	A-00, A-01, A-04, A-08, A-10, A-11
California Sea Lion (*Zalophus californianus*)		
Chinese Harbor	06/25/2003	A-12
Unidentified Marine Mammal		
Christy Beach	09/05/2002	A-08
Canada del Agua	10/16/2002 and 10/18/2002	A-10
Chinese Harbor	01/30/2003	A-04. A-10. A-11
Chinese Harbor	04/14/2003	A-11
Chinese Harbor	05/25/2003	A-01, A-04
Chinese Harbor	06/08/2003	A-02, A-04, A-11
Chinese Harbor	06/10/2003	A-04, A-11
Chinese Harbor	11/10/2003	A-02, A-10, A-11, A-13, A-14, A-16, A-20, A-21

carcasses or gut piles remaining from mule deer (*Odocoileus hemionus*) and Roosevelt elk (*Cervus canadensis*) hunting activities.

Beach watches to count potential eagle prey began on Santa Cruz in June 2003. Most carcasses were found at Chinese Harbor and Prisoner's Harbor, while Christy, Sauces, Pozo, Johnson's, and Laguna beaches had few carcasses (Fig. 1, Table 3).

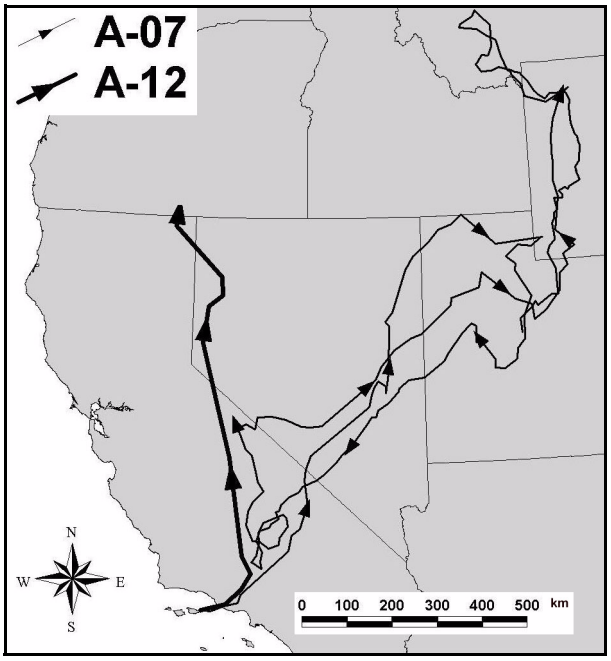

Figure 3. Map showing movements of two bald eagles that successfully dispersed from Santa Cruz Island, CA to the mainland in 2002 (A-07: Aug. 2002 through Nov. 2003) and 2003 (A-12: Jun. 2003 through Nov. 2003).

DISCUSSION

We consider the first two seasons of bald eagle releases on Santa Cruz successful, as fourteen of twenty-two birds successfully released have remained on the Northern Channel Islands. We do not expect these birds to leave the islands because they did not migrate their first fall/winter. The movement of the birds among the four northern Channel Islands suggests that bald eagle releases on Santa Cruz can serve to restore populations on all four islands. In addition, the presence of bald eagles on the northern Channel Islands may attract bald eagles from other areas further increasing the population size and genetic diversity.

First year survival for the Santa Cruz bald eagles was 78 to 90%, which is similar to the estimates of first-year survival of 70 to 75% for eagles released on Catalina (unpubl. data), 63% in Florida (Wood 1992), 71% in Alaska (Bowman et al. 1995), and 77% in northern California (Jenkins et al. 1999). Highest mortality generally occurs during the first year for bald eagles (Hodges et al.

Table 3. Animal carcasses counted at seven beaches surveyed once per month on Santa Cruz Island, CA, June–November 2003.

Species	Chinese	Prisoner's	Laguna	Johnson's	Pozo	Sauces	Christy	Totals
California sea lion (*Zalophus californianus*)	5	2	0	0	2	2	0	11
Common dolphin (*Delphinus* spp.)	1	0	0	0	0	0	0	1
Feral pig (*Sus scrofa*)	2	0	0	0	0	0	0	2
Brown pelican (*Pelecanus occidentalis*)	1	0	0	0	0	0	0	1
Pelagic cormorant (*Phalacrocorax pelagicus*)	1	0	0	0	0	0	0	1
Western gull (*Larus occidentalis*)	0	2	1	0	0	0	0	3
Unknown loon (*Gavia* spp.)	0	0	0	1	0	0	0	1
Unknown gull (*Larus* spp.)	0	1	0	0	1	1	0	3
Unknown bird	5	1	0	0	0	0	0	6
California thornback (*Platyrhinoidis triseriata*)	6	0	0	0	0	0	0	6
Ocean sunfish (*Mola mola*)	1	0	0	0	0	0	0	1
Unknown squid	1	0	0	0	0	0	0	1
Unknown fish	0	1	0	0	0	0	0	1
Unknown	0	0	0	0	0	0	1	1
Totals	23	7	1	1	3	3	1	39

1987, Sharpe and Garcelon unpubl. data) and decreases as the birds mature.

Because five eagles ended up in the ocean (22% of those released) we were initially concerned that the transmitter package we used may have been too heavy. The transmitter package weighs less than or equal to 3% of an average eagle's body weight, which are within the Bird Banding Laboratory guidelines. All four of the 2002 eagles that ended up in the ocean were females and the 2003 eagle was a male. We would expect males to be more impacted by transmitter weight than females because males tend to be smaller than females. Therefore, we do not think that the eagle losses in the ocean were directly related to the transmitters, but instead were more likely a result of a lack of flying experience and/or stamina. All three eagles that died in the ocean in 2002 had been released less than a month prior to their death, and A-11 and A-15 (the 2003 eagle) went into the ocean just over a month after they started flying. On Santa Catalina Island (Catalina; Fig. 1), young eagles that leave the island usually fly to the mainland about two months after fledging (unpubl. data). Several eagles from Catalina have been found dead at sea or on beaches, so it is possible that this historically has been a relatively common source of mortality among Channel Island bald eagles that has been discovered with the use of GPS transmitters.

Bald eagles on Santa Cruz were usually in the area of Chinese Harbor, based upon both sightings and telemetry data. Most of the pig carcasses placed by IWS personnel were along the ridges surrounding Chinese Harbor, and beach watches indicated that the area also had the highest availability of naturally occurring carrion. Chinese and Prisoner's Harbor face north and northwest, the direction of the prevailing winds and currents, which may explain why more carcasses wash up on these beaches as opposed to beaches that face south and west. For these reasons, eagles likely could find food in this area more reliably than other portions of the island.

The eagles that moved to Santa Rosa for much of the fall and winter have been observed feeding on deer and elk carcasses and gut piles left from hunting and culling activities. Annual guided elk and deer hunts begin in late August and continue through mid-November. An annual helicopter survey for deer is conducted in early December to determine if the herd needs to be culled, and if

needed, culling occurs later in December. GPS locations on Santa Rosa indicate that the eagles were using the island during the elk and deer hunting and culling operations and were concentrating their activity along roads and ridgelines, where carcass remains and gut piles were often located. We are concerned about the potential threat of lead bullets used in these activities being ingested by the eagles and causing lead poisoning. The use of non-lead ammunition for hunting and culling activities on Santa Rosa would minimize the risk of lead poisoning while still providing a food source for young eagles. The hunters agreed to use non-lead ammunition for the cull in 2002 and hopefully non-lead will be used in subsequent years.

One concern raised regarding restoring a bald eagle population on the northern Channel Islands was the potential negative impact that the eagles could have on several sensitive seabird species that breed on the northern Channel Islands, particularly West Anacapa. Because West Anacapa is closed to human access for much of the year, we were only able to evaluate potential eagle impacts based upon GPS telemetry data. Of the few eagles that visited West Anacapa, most flew to the island at the end of the summer, which coincides with the end of the seabird breeding season on the island, and none spent more than a month on the island. Also, most of the eagles that spent time on West Anacapa flew there at a young age (2 to 4 weeks post-fledging). At that age eagles are not expected to be actively hunting, but instead to be scavenging (Gerrard and Bortolotti 1988). Only one eagle (A-00) spent time on West Anacapa during the seabird breeding season. This eagle made four separate trips to Anacapa in April 2003, spending 3 to 10 days at a time on the island before flying back to Santa Cruz or the mainland. Because of the times of year of the visits to West Anacapa, the short duration of the eagles' visits (1 to 25 days), and the young age of the eagles using the island, we do not believe the eagles were having a significant negative impact on the seabird species breeding there. Future monitoring of older birds will be needed to determine their impacts on seabirds.

The ultimate factor determining whether bald eagle restoration can be successful on the northern Channel Islands is whether the eagles will reproduce on the islands once they mature, or whether DDE contamination will preclude egg hatching. Eagles on Santa Cruz have been observed feeding upon marine mammals, which have been shown to have high levels of DDE contamination in their tissue on Catalina (Garcelon 1997). In the future, marine mammal carcasses and other potential eagle forage items will be sampled for contaminant analyses to identify the degree to which the eagles may be exposed to contaminants. Further, trapping of eagles as they mature to draw blood for analyses will provide some insight into the current DDE body burden. We plan to continue to release juvenile bald eagles through 2006 and closely monitor resident eagles in the coming years to look for nesting activity. The outcome of future contaminant analyses and reproductive success will help guide bald eagle management strategies on the California Channel Islands.

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