Reproductive Success and Breeding Population Size of Snowy Plovers in the Monterey Bay Region In 2020

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REPRODUCTIVE SUCCESS AND BREEDING POPULATION SIZE OF WESTERN SNOWY PLOVERS IN THE MONTEREY BAY REGION IN 2020

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Prepared by
Point Blue Conservation Science
Kristina Neuman, Lynne Stenzel, Carleton Eyster, Blake Barbaree, Esther Haile, Dave Dixon, Catherine Hickey

California Dept. of Parks & Recreation
Amy Palkovic

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*Corresponding author: kneuman@pointblue.org

Cover photo: Bill Crowe

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3820 Cypress Drive, #11 Petaluma, CA 94954 T 707.781.2555 | F 707.765.1685
pointblue.org
SUMMARY
The primary results of the 2020 breeding season are the following:
- An estimated 313 snowy plovers (corrected window survey estimate) nested in the Monterey Bay region in 2020.
- We documented 363 nesting attempts (n=339 nests and 24 broods).
- The clutch hatch rate of 39% was below the average of 49% from 2009-2019.
- At least 48% of all nest loss was caused by predators.
- Corvids were responsible for 22% of all nest loss and 47% of nests lost to predators.
- Corvid predation of nests was widespread throughout the study area and common ravens accounted for the majority of corvid-caused losses.
- Mammals were responsible for 10% of all nest loss and 20% of nests lost to predators.
- A minimum of 292 chicks hatched from 363 documented nesting attempts.
- 134 chicks were banded and 19% (n=26) of those survived to fledging. This was below the average fledge rate of 36% from 2009-2019.
- An additional 79 unbanded chicks were confirmed to have fledged for a minimum number of 105 fledglings.
- The minimum estimate of chicks fledged per male was 0.67 which is below the 1.0 target needed for population stability.

INTRODUCTION and BACKGROUND
The Pacific Coast population of the western snowy plover (Charadrius nivosus nivosus) was listed as threatened by the U.S. Fish and Wildlife Service (USFWS) in 1993. Point Blue Conservation Science (Point Blue) in partnership with USFWS, the California Department of Parks and Recreation (California State Parks) and other partners, has monitored nesting western snowy plovers (hereafter snowy plover or plover) in the Monterey Bay region since 1984. Beginning in the mid-1990s, this multi-agency working group has worked collaboratively to plan, implement, and assess the effects of management actions taken to protect nesting plovers and meet the population target of 338 breeding plovers and the annual productivity target of 1.0 chicks fledged per breeding male identified in the federal Recovery Plan (USFWS 2007). Here we report on reproductive success and breeding population size of western snowy plovers in the Monterey Bay region in 2020 to codify information on the known and suspected causes of variation in annual metrics and to assess the effect of management efforts intended to support population recovery.
METHODS

Study Area, Annual Monitoring Objectives, and Permit Activities

The study area includes the beaches of Monterey Bay and the former salt ponds adjacent to Elkhorn Slough, and beaches in northern Santa Cruz County. See Appendices 1-14 for area maps and Appendix 15 for a detailed description of each area.

In 2020, our planned monitoring was reduced due to COVID 19 restrictions. We monitored for 1166 total hours which was approximately 82% of the average annual effort for 2007-2019. Monitoring effort was not evenly distributed among sites; among the 11 major monitoring areas (Appendix 14), three combined accounted for 37% of all effort (Zmudowski, Fort Ord, and Salinas River NWR). The remaining sites individually accounted for between 3% and 9% of total effort, excepting Northern Santa Cruz which was monitored only opportunistically. Because of our reduced monitoring in 2020, our primary objectives were modified from previous targets (see Neuman et al. 2020). In 2020, our specific objectives were to locate and protect all nests, monitor nest fate at each site, and opportunistically band a sample of chicks to determine fledge rate. Due to the high proportion of nests with unidentified (43%) or unbanded (>40%) breeders in 2020, we did not generate a population estimate based on nest monitoring. Instead we generated the monitoring estimate by applying a correction factor of 1.22 to the 2020 window survey estimate. The correction factor of 1.22 is based on the relationship between the window survey estimate and the monitoring estimate for the years 2000-2019 in the Monterey Bay region. For the first time, we estimated the error around the fledge rate for banded chicks based on Henkel et al. 2020. This estimate, the Error Estimate Bound, is based on the approximate proportion of broods that were monitored. The methods we used for nest monitoring, banding and conducting the rangewide window survey followed our standard monitoring protocol described in detail in Appendix 16.

All snowy plover monitoring by Point Blue Conservation Science staff and associates was conducted under **USFWS permit number TE-807078-17**. There were no incidental mortalities of snowy plovers resulting from activities conducted under this permit in 2020. In the course of the 2020 nesting season, pursuant to this permit, the Arcata Fish and Wildlife Office of USFWS granted approval of: 1) removal one clutch of infertile eggs from a nest that was well past normal incubation length, 2) salvage of one egg from one nest to be reared at the Monterey SPCA, 3) capture of an oiled chick and transfer to a captive care facility for cleaning and rehabilitation, and 4) a mini-exclosures design to protect nests. Please see the Results and Discussion sections of this report for pertinent observations on the ecology and status of this species in the Monterey Bay region. Planned monitoring activities in 2021 are expected to be similar to those conducted in 2020 and in previous years.

Management

Management activities to improve snowy plover reproductive success were coordinated and implemented by a multi-agency working group that included Point Blue, California State Parks, USFWS, and other coastal land managers and owners. Activities in 2020 included habitat protection, education and outreach to beach users by plover researchers, predator control by the Wildlife Services Division of the U.S. Department of Agriculture (USDA), water management to provide nesting and foraging habitat in the managed salt ponds of the
CDFW’s Moss Landing Wildlife Area and ongoing restoration of beach and dune habitats by land owners, managers and partner organizations. Habitat was protected using cable or rope fencing and regulatory/informational signs to temporarily (March 1 - Sept. 30) restrict recreational access to nesting areas on upper beaches and dunes and the non-public portions of the salt ponds at Moss Landing Wildlife Area. In 2020, the majority of nests were protected by cable fences (n=322 of 339 nests found at the egg stage), nest exclosures (n=14) or were within closure areas at the aforementioned sites. Wildlife Services biologists conducted selective removal of avian and mammalian predators in 2020 as guided by the multi-agency working group. Water levels at the salt ponds were managed to create dry nesting substrate and wet foraging areas for plovers, though the infrastructure has aged to the point that these activities are limited. The type of recreational uses allowed at each site, the level of recreation, and enforcement of regulations on recreational use vary by site and by land owner or manager.

RESULTS
Breeding Population Size and Return Rates
On the annual rangewide breeding window survey, we recorded a breeding population estimate of 257 adults (150 males, 98 females and 9 unknown sex; Fig. 1). We applied a 1.22 correction factor to the 2020 window survey estimate to generate a corrected breeding population estimate of approximately 313 plovers. In 2020, the total number of banded breeders (n=192) was 9% and 14% lower than in 2019 for males and females, respectively (males; n=103, 89 confirmed breeders, 14 probable breeders; females; n=89, 80 confirmed and 9 probable).

![Figure 1. Estimated number of breeding snowy plovers from monitoring (bars) and window surveys (light blue line) in the Monterey Bay region, 1985-2020. The 2016-2019 monitoring estimate (grey bars) includes confirmed and probable breeders (see App. 15). The 2020 monitoring estimate (orange bar) was generated by applying the correction factor of 1.22 to the 2020 window survey total.](image-url)
Of color-banded adults that were confirmed or probable breeders in the Monterey Bay region in 2019, 74% of males and 71% of females returned and bred or were suspected of breeding in 2020. These return rates were slightly higher than the average rate of 70% for males and 67% for females from 2010-2019. An additional 1 female and 4 males that were confirmed or probable breeders in 2019 were observed on Monterey Bay between April and July but did not have sufficient evidence to be classified as confirmed or probable breeders in 2020.

Of 41 banded fledglings from 2019 (2 additional fledglings from 2019 were confirmed in addition to the 39 reported in Neuman et al. 2020), 32% returned by May 2020 to breed on Monterey Bay. They included 7 females and 5 males confirmed on nests and one additional male detected with sufficient behavioral evidence to be classified as a probable breeder. Two additional males from the 2019 fledgling cohort were observed on Monterey Bay in May or June; one was seen throughout June with no evidence of breeding, and another first discovered fledged in 2020 and seen only twice.

**Nesting Attempts, Clutch Initiation Date, and Nesting Site Use**

In 2020, we documented 363 nesting attempts (339 nests and 24 broods of chicks from undetected nests), and we determined the fate of 88% of the 339 nests found at the egg stage (Table 1, Apps. 1-14). In 2020, nesting occurred at all major sites where nesting was documented in 2019. However, in Northern Santa Cruz in 2020 we did not detect nesting at Seabright beach after 2 years of consecutive nesting but we did detect nesting at Laguna Creek after a 1-year absence. The first nest was initiated on February 25 at Fort Ord and the last nest on July 20 at Moss Landing, with a median clutch initiation date of May 18. Nesting commenced slightly earlier in the South Bay than in the North Bay; of the first 20 nests initiated only 3 were in the North Bay and average clutch initiation date of South Bay nests (May 12) was 8 days earlier than for North Bay nests (May 20).

**Clutch Hatch and Fledge Rates**

Of the 299 known fate nests found at the egg stage, 118 hatched, for a 39% hatching rate (Table 1). The small number of nests (n=14) protected with exclosures had a very high hatch (93%) rate compared with the overall hatch rate. This overall rate of 39% was far below the average of 65% from 2000-2008 and somewhat below the 49% average from 2009-2019 (Fig. 2). The clutch hatch rate should be considered a maximum hatch rate because we suspect that some nests were depredated soon after initiation, before we were able to locate them and that a large proportion of nest where fate was unknown probably did not hatch. Hatched nests were initiated on average 6 days earlier than failed nests (May 13 and May 19, respectively).

We confirmed that a minimum of 292 chicks hatched from 363 nesting attempts (Table 1). An additional 207 chicks may have hatched from the sum of nests where fate was unknown (n=40 nests) and from nesting attempts where part of the clutch was confirmed to have hatched (n=118 hatched nests and 24 nests found at the brood stage; Table 1).

We banded a sample of 134 chicks (46% of the minimum number of chicks that hatched; Table 2) from 63 of the 118 broods that hatched. Of the banded sample, 19% (n=26) survived to fledging (Table 2). Monitoring this proportion of broods (54%) yielded an Error
Estimate Bound of approximately 12% of the fledge rate (i.e., 12% of 19%; Henkel et al. 2020), resulting in an error around the fledge rate of ± 2%, or an overall fledge rate from banding of 17-21%. The bay-wide fledge rate of 19% (± 2%) was significantly lower than either the average of 42% from 2000-2008 or the more recent average of 34% from 2009-2019 (Fig. 2). Because the Error Estimate Bound relies on determining the proportion of broods that hatched, it may have been slightly biased by our failure to detect any chicks hatching at nests that were categorized as unknown fate (n=40 nests), but based on the overall bay-wide hatch rate, it is more likely that most of these unknown fate nests failed.

### Table 1. Reproductive success of snowy plovers in the Monterey Bay region in 2020.

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Nesting Attempts</th>
<th>Found as Broods (n)</th>
<th>Found as Nests (n)</th>
<th>Known Fate Nests (n)</th>
<th>Hatched Nests (n)</th>
<th>Clutch Hatch Rate (%)</th>
<th>Chicks Hatching</th>
<th>Chicks Fledging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Santa Cruz</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>100%</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Sunset-Manresa</td>
<td>27</td>
<td>2</td>
<td>25</td>
<td>8</td>
<td>32%</td>
<td></td>
<td>26</td>
<td>29</td>
</tr>
<tr>
<td>Pajaro</td>
<td>31</td>
<td>1</td>
<td>30</td>
<td>9</td>
<td>36%</td>
<td></td>
<td>21</td>
<td>33</td>
</tr>
<tr>
<td>Zmudowski</td>
<td>66</td>
<td>3</td>
<td>63</td>
<td>28</td>
<td>50%</td>
<td></td>
<td>65</td>
<td>105</td>
</tr>
<tr>
<td>Moss Landing</td>
<td>44</td>
<td>3</td>
<td>41</td>
<td>0</td>
<td>0%</td>
<td></td>
<td>6</td>
<td>23</td>
</tr>
<tr>
<td>Salt Ponds</td>
<td>21</td>
<td>4</td>
<td>17</td>
<td>2</td>
<td>15%</td>
<td></td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td>Molera-Potrero</td>
<td>16</td>
<td>0</td>
<td>16</td>
<td>7</td>
<td>47%</td>
<td></td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>Monterey Dunes</td>
<td>18</td>
<td>0</td>
<td>18</td>
<td>7</td>
<td>35%</td>
<td></td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>North Salinas River</td>
<td>11</td>
<td>1</td>
<td>10</td>
<td>3</td>
<td>33%</td>
<td></td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Salinas River NWR</td>
<td>21</td>
<td>2</td>
<td>19</td>
<td>6</td>
<td>33%</td>
<td></td>
<td>14</td>
<td>26</td>
</tr>
<tr>
<td>Marina Dunes</td>
<td>25</td>
<td>1</td>
<td>24</td>
<td>5</td>
<td>24%</td>
<td></td>
<td>13</td>
<td>24</td>
</tr>
<tr>
<td>Reservation Road</td>
<td>24</td>
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<td>24</td>
<td>12</td>
<td>57%</td>
<td></td>
<td>22</td>
<td>36</td>
</tr>
<tr>
<td>Fort Ord</td>
<td>45</td>
<td>0</td>
<td>45</td>
<td>27</td>
<td>73%</td>
<td></td>
<td>58</td>
<td>103</td>
</tr>
<tr>
<td>Sand City</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td></td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Monterey</td>
<td>8</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>80%</td>
<td></td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>GRAND TOTAL</td>
<td>363</td>
<td>24</td>
<td>339</td>
<td>299</td>
<td>118</td>
<td>39%</td>
<td>292</td>
<td>499</td>
</tr>
</tbody>
</table>

1 Sum of nests found at the egg stage and the brood stage.
2 Nests found as broods are not included.
3 The number of hatched nests divided by the number of known fate nests. Nests found as broods and unknown fate nests not included.
4 Includes all possible hatching eggs from both known and unknown fate nests and from nests found as nests and as broods.
5 Both nests were at Laguna Creek Beach.

At individual sites, fledge rates ranged from 0%-67% (Table 2), though the total number of chicks banded at some sites was very low and rates should be interpreted with this in mind. At the sites with largest proportions and sample sizes of banded chicks (Zmudowski, Fort Ord; Tables 1 and 2), fledge rates were very low (<20%) and the low rates at these sites drove the overall very low bay-wide fledge rate. We confirmed an additional minimum number of 79 unbanded chicks that reached fledge age for a total minimum number of 104 fledglings (Table 1).

The minimum estimate of chicks fledged per male was 0.67. This was calculated as the sum of the number of banded fledglings and the minimum number unbanded fledglings (n=105), divided by the approximate number of males (n=157, or 50% of the corrected window survey total of 313) estimated from the window survey method. The estimate of 0.67 chicks fledged per male is lower than the 1.0 target needed for population stability.
Figure 2. Percentage of clutches hatched and chicks fledged, 2000-2020. Clutches that hatched one or more eggs were considered hatched.

Table 2. Fledging success of banded snowy plover chicks in the Monterey Bay region in 2020.

<table>
<thead>
<tr>
<th>Location</th>
<th>Banded Chick Sample(^1) (n)</th>
<th>Banded Chicks Fledging(^2) (n)</th>
<th>Banded Chicks Fledging (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Santa Cruz</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sunset-Manresa</td>
<td>16</td>
<td>6</td>
<td>38%</td>
</tr>
<tr>
<td>Pajaro</td>
<td>11</td>
<td>2</td>
<td>18%</td>
</tr>
<tr>
<td>Zmudowski</td>
<td>45</td>
<td>8</td>
<td>18%</td>
</tr>
<tr>
<td>Moss Landing</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Salt Ponds</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Molera-Potero</td>
<td>5</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Monterey Dunes</td>
<td>2</td>
<td>1</td>
<td>50%</td>
</tr>
<tr>
<td>North Salinas River</td>
<td>3</td>
<td>2</td>
<td>67%</td>
</tr>
<tr>
<td>Salinas River NWR</td>
<td>6</td>
<td>2</td>
<td>33%</td>
</tr>
<tr>
<td>Marina Dunes</td>
<td>4</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Reservation Road</td>
<td>7</td>
<td>1</td>
<td>14%</td>
</tr>
<tr>
<td>Fort Ord</td>
<td>32</td>
<td>4</td>
<td>13%</td>
</tr>
<tr>
<td>Sand City</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Monterey</td>
<td>3</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td><strong>134</strong></td>
<td><strong>26</strong></td>
<td><strong>19%</strong></td>
</tr>
</tbody>
</table>

\(^1\)Subset of hatched chicks in Table 1. Two captive-reared chicks are not included.

\(^2\)Subset of fledging chicks in Table 1. Two captive-reared fledglings are not included.
Nest Failure

Of the 165 nests that failed in 2020, at least 48% of the losses were caused by predators (Table 3) and corvids were the primary identified predator. Of the losses attributed to predators, 62% were attributed to avian predators (all species combined), 47% to corvid species (raven, crow, unknown corvid, raven event, crow event), 21% to mammalian predators (primarily skunks and raccoons), and 17% to unknown predators. Corvid predation of nests was geographically widespread, affecting 10 of 15 nest sites, whereas mammalian predators primarily affected the North Bay, a pattern that has been observed in recent years. Environmental factors (tide, rain, and wind) and nest desertion were the other major causes of nest loss in 2020 (Table 3). We were unable to determine the cause of loss for 32% of nests that failed, but based on the predominance of predation as a cause of loss, we suspect that most of the unknown loss also was caused by predators rather than environmental factors or humans.

Table 3. Causes of failure for 181 known fate snowy plover nests in the Monterey Bay region in 2020.

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<tbody>
<tr>
<td></td>
<td>CORA</td>
<td>AMCR</td>
<td>Coyote</td>
<td>Canine</td>
<td>Skunk</td>
<td>Mammal</td>
<td></td>
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<td>Northern Santa Cruz</td>
<td>0</td>
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<td></td>
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<td></td>
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<tr>
<td>Sunset-Manresa</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pajaro</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>16</td>
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<tr>
<td>Zmudowski Beach</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>14</td>
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<tr>
<td>Moss Landing</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>14</td>
<td>36</td>
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<tr>
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<td>1</td>
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<td>Molera-Potrero</td>
<td>1</td>
<td>1</td>
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<td>1</td>
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<td>Monterey Dunes</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>11</td>
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<td>1</td>
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<td>1</td>
<td>12</td>
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<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
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<td>1</td>
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<td>1</td>
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<td></td>
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<td></td>
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<td>2</td>
</tr>
<tr>
<td>Total</td>
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<td>3</td>
<td>6</td>
<td>10</td>
<td>3</td>
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<td>1</td>
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</tbody>
</table>

1 common raven (Corvus corax); 2 see App. 16 for definition of an avian predator event; 3 American crow (Corvus brachyrhynchos); 4 unidentified corvid (raven or crow); 5 unknown avian predator; 6 unknown predator species; 7 deserted (includes nests deserted after partial loss of clutch)

Captive Rearing

On May 29, a single oiled plover chick was captured in the wild at south Fort Ord and taken to the Monterey SPCA. It was cleaned and reared in captivity until it was released into the wild at the original natal site on June 12. On May 30, a single egg was salvaged from a partially depredated nest at Sunset State Beach and taken to the Monterey SPCA where it was hatched and reared until release on July 7 at Zmudowski State Beach. On July 29, three eggs from an abandoned nest at Salinas River National Wildlife Refuge were taken to Monterey SPCA for captive rearing but the eggs were not viable. The two captive-reared chicks are not included in the fledging totals in Tables 1 or the banded sample and the fledging totals in Table 2.

Human Activity

The rate of human activity observed in the North Bay and South Bay has increased during the past 11 years (Fig. 3). In 2020 we observed the highest level of beach use that we have ever recorded, though it should be noted that our field effort was concentrated from May onward when many closures had been removed.
DISCUSSION

In 2020, for the first time, we were unable to produce a population estimate from monitoring the identity of nesting plovers and therefore are relying on a corrected window survey to estimate the actual population size. Despite COVID-related reductions in our total monitoring effort, the window survey was conducted in a way that was consistent with past years, and the 1.22 correction factor is based upon more than a decade of data. For these reasons, this estimate probably is a reliable indicator of changes among years. Our corrected window survey estimate of 313 breeding snowy plovers in the Monterey Bay region in 2020 did not meet the USFWS Recovery Plan target of 338 adults for the region for the second consecutive year and for only the second time since 2009. Since 2015, the Monterey Bay breeding population has declined as evidenced by decreases in both types of population estimate (window survey and from monitoring). Corvids, especially ravens, continue to be the primary reason for low hatch rates and this has been reflected in below average productivity for the past several years.

The 105 confirmed fledglings in 2020 was below the benchmark of 169 fledglings needed to maintain the population at the recovery target of 338. The minimum number of chicks fledged per male (0.67) also was well below the recovery target of 1.0 chicks per male for population stability. Even after allowing for the uncertainty around how many additional unbanded chicks may have fledged, it is very unlikely that either the benchmark number of fledglings or the recovery target of 1.0 chicks per male was attained in 2020. This represents the fifth consecutive year of decline in the number of chicks fledged per breeding male.

2020 was marked by low hatch rates and extremely low fledge rates across the bay. This is of particular concern when combined with five years of a decreasing breeding population size. There are two possible explanations for low fledge rates in 2020: avian predation of
chicks and human-caused disturbance resulting from increased human use of beaches. At Zmudowski, we suspect that great-horned owls (Bubo virginianus) were the primary cause of brood loss because of observations of tracks in the habitat. On July 31st a single female great-horned owl was trapped and translocated out of the area. Although this probably was too late to have any significant impact on chick fledging rates, there may have been some survival benefits to recently fledged juveniles and adult plovers in the area. At Fort Ord, raptor predation of chicks was suspected but not observed. The level of nest desertion in 2020 may indicate that raptors were more common than observed in the study area. The spatial occurrence of nest desertion in relation to raptor numbers and other evidence (tracks, pelleting locations) should be a topic of further investigation. Finally, given the widespread impact of ravens on plover nests and the fact that ravens have been observed locating nests by flushing incubating plovers, we suspect that they also could be depredating young chicks that are still being brooded.

Human use of beaches in the Monterey Bay region has increased over the past 11 years (Fig. 3); in 2020 this probably was driven by COVID-related stay at home orders and by one of the warmest summers on record. Both NASA and NOAA concluded that 2020 was the hottest or second hottest year, globally, that has been recorded. Increased summer temperatures is an expected effect of climate change in coastal California (Langridge 2018) and this increase may be driving the observed pattern in increased beach visitation. This is a concern because human disturbance can reduce chick fledging rates (Ruhlen et al. 2003). In addition to increased summer temperatures, climate change also is predicted to have significant negative effects on the physical profile of sandy beach habitats in Monterey Bay that plovers depend upon (e.g., sea-level rise will cause narrower, lower elevation beaches). Climate adaptation efforts should center on prioritizing the conservation of the most resilient habitats, building the adaptive capacity of sites that are predicted to be less resilient, and intensive management of major non-climate stressors (i.e., human use and predators) that negatively impact plovers (Neuman et al. 2019).

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*snowy plover chicks, Esther Haile*
Appendix 1. Overview of Snowy Plover nest locations in the Monterey Bay area in 2020.
Appendix 2. Snowy Plover nest locations north of and at the northern portion of Sunset State Beach in 2020.
Appendix 3. Snowy Plover nest locations at the southern portion of Sunset State Beach and the Pajaro spit at Zmudowski State Beach in 2020.
Appendix 4. Snowy Plover nest locations at the central portion of Zmudowski State Beach in 2020.

Note: This 2018 imagery depicts the Pajaro River mouth in a location different from its location in 2020.
Appendix 5. Snowy Plover nest locations at Jetty Road in the southern portion of Zmudowski State Beach and Moss Landing State Beach in 2020.
Appendix 7. Snowy Plover nest locations at the Molera-Potrero portion of Salinas River State Beach in 2020.
Appendix 11. Snowy Plover nest locations at Reservation Road at Marina State Beach in 2020.
APPENDIX 15. Detailed Area Descriptions
For reporting purposes we divide the study area from north to south, and describe approximate area boundaries, land ownership and management, and refer to corresponding area maps and nest identification codes (in parentheses) as follows:

**Northern Santa Cruz County**
**Laguna Creek Beach:** Located 10km north of the city of Santa Cruz, this cliff-backed pocket beach is approximately 600m long and is part of Wilder Ranch State Park (not depicted on map).

**Seabright Beach:** From the mouth of the San Lorenzo River south to the Santa Cruz Harbor’s north jetty and adjacent to the City of Santa Cruz. Seabright Beach is owned and managed by California State Parks and is part of Twin Lakes State Beach (not depicted on map).

**North Bay Region**
**Sunset-Manresa:** From the northern boundary of Manresa State Beach south to Beach Road, Santa Cruz County. The southern end is backed by residential development. This beach is owned by California State Parks and private owners and managed by State Parks (see App. 2 – NO, NM, NT) and includes all of Manresa State Beach and the northern portion of Sunset State Beach.

**Pajaro:** From Beach Road south to the Pajaro River mouth, Monterey County, and includes the beach north of the river and west of the Pajaro Dunes residential development and the sand spit on the north side of the Pajaro River mouth. This beach is owned and managed by California State Parks and includes portions of Sunset State Beach and Zmudowski State Beach (see App. 3 – PH and PS).

**Zmudowski:** From the Pajaro River mouth south toward Moss Landing. This beach is owned and managed by California State Parks and is part of Zmudowski State Beach (see App. 4 – ZS and ZB).

**Moss Landing:** Approximately the southern third of Zmudowski State Beach and all of the shoreline of Moss Landing State Beach, with the southern boundary located at the mouth of Elkhorn Slough at Moss Landing Harbor. This beach is owned and managed by California State Parks (see App. 5 – JR).

**Salt Pond Region**
This area includes approximately half of the former salt ponds adjacent to the western terminus of Elkhorn Slough that have been converted to managed, diked wetlands and are now encompassed within the California Department of Fish and Wildlife’s (CDFW) Moss Landing Wildlife Area (see App. 6 - SP).

**South Bay Region**
**Molera-Potrero:** From the Sandholdt Road parking lot in Moss Landing south to the northern boundary of the Monterey Dunes Colony. This beach includes the northern portion of Salinas River State Beach and is owned and managed by California State Parks (see App. 7).

**Monterey Dunes:** From the northern to the southern end of the Monterey Dunes Colony, a beachfront residential development. This beach includes the middle portion of Salinas River State Beach and is owned and managed by California State Parks (see App. 8 – MD).

**North Salinas River:** From the southern boundary of the Monterey Dunes Colony south to the Salinas River mouth. This beach includes the southernmost portion of Salinas River State Beach and is owned and managed by California State Parks (see App. 8 – SN).

**Salinas River National Wildlife Refuge:** From the Salinas River mouth south to the northern boundary of Martin Dunes, including the sand spit on the southern side of the Salinas River mouth, and the extensive open dunes of the refuge. This beach is owned and managed by USFWS (see App. 9 – SX).

**Marina Dunes:** From the southern boundary of Salinas River NWR south to Reservation Rd. This beach is owned by the Big Sur Land Trust, private owners, Monterey Peninsula Regional parks District and is managed with assistance from USFWS and California State Parks (see Apps. 9-10 - SG, MN, MA, MX).
Reservation Road: From Reservation Road south to the Lake Court beach access for Marina State Beach. This beach is owned and managed by California State Parks and is part of Marina State Beach (see App. 11 - RR).

Fort Ord: From the southern boundary of Marina State Beach south to the southern boundary of Fort Ord Dunes State Park. This beach is owned and managed by California State Parks and is part of Fort Ord Dunes State Park (see Apps. 12-13 – RO, FO).

Sand City: From the southern boundary of Fort Ord south to West Bay Street in Sand City. This beach is owned by private owners, the City of Sand City, Monterey Peninsula Regional Parks District and California State Parks (see App. 13 – overview map).

Monterey: From West Bay Street in Sand City south to the City of Monterey. This beach (referred to in previous reports as Del Monte) is owned and managed by California State Parks and is part of Monterey State Beach (see App. 14 - HI).
APPENDIX 16. Standard Monitoring Methods

Each year an annual monitoring plan is developed that identifies specific goals, with targets to achieve implementation of these goals. Our overarching goal is to find all nests in each breeding area and determine nest fate and causes of nest loss to inform management. Also to determine annual productivity, we band a subset of chicks with an overall goal of banding 50% of all chicks, with our banding stratified spatially among sites and temporally across the breeding season. The “Monitoring Objectives” section of the main report details the specific annual goals identified in the annual monitoring plan.

Field surveys for nesting snowy plovers are conducted during daylight hours, from March-September at all active breeding areas described in Appendix 15. Most daily monitoring is conducted between 0600 and 1400 hours with most sites surveyed 2-4 times per week. Monitoring effort among sites in a given year is unevenly distributed, with some areas receiving more effort. Factors affecting the distribution of effort include the difficulty of monitoring at a given area (complex or larger areas require more effort), personnel capacity, site logistics (e.g., ease of access), observer experience, and other annual circumstances.

Nest are located by conducted field surveys in areas that have or are suspected to have breeding plover activity. Nests are located by visually searching habitat for nest scrapes and nests and by observing nesting plovers and their behavior. We record the latitude and longitude of each nest with Global Positioning System (GPS) units that are accurate to within 5m. We also used GPS units to create proxy nest locations for all nesting attempts that were found as broods of chicks (i.e. after hatching) by creating a location at the first place a brood was observed. All nest and brood locations are plotted on nest maps for each area. We estimate clutch hatching dates from egg laying dates, when known, or from egg flotation (Hays and Lecroy 1971). Projected hatching dates are refined by examination of eggs for cracked shells, tapping chicks, or peeping chicks in the 4-6 days leading up to the projected hatching date. In order for an egg to be counted as hatched, the chick has to be observed at the nest or with the attending parent during the chick-rearing period. When eggs disappear or are destroyed prior to the projected hatch date, causes of nest loss are determined by examining evidence at nests (e.g. damaged eggshells, predator tracks, evidence of tide wash). When the cause of loss is unknown because evidence at the nest was lacking, we categorize cause of loss as unknown. In certain cases with no visible cause of loss, we assign the nest loss to an avian predator “event” when it meets both of the following criteria: the nest was within or adjacent to an area where nest(s) were lost to an identified avian predator, and the nest was lost during a similar time interval (+/- 3 days). Nests for which the fate of at least one egg was known are considered “known fate” nests.

We use unique color band combinations consisting of four individual bands to mark a sample of chicks to estimate fledge rates and adults to track nest attempts and brood locations. We trap adults at or near the nest using noose mat carpets and capture chicks at or near the nest by hand at the time of hatching. We monitor brood survival throughout the chick-rearing period primarily by observing parental behavior that indicates the presence of chicks (e.g. lure displaying) and also by directly observing chicks with attending males (or females). We consider banded chicks to have reached fledging age if they survive 28 days or more after hatching. Because unbanded chicks within and among similar-age broods are indistinguishable from one another, they are determined to have fledged only when they are directly observed with the attending parent at or within a few days after the fledge date.

To estimate the Monterey Bay breeding population size we use two methods: a monitoring estimate and a window survey estimate. For the first method we derive an estimate from our monitoring across the duration of the breeding season (March-August) that is based on the number of plovers confirmed nesting or attending broods and the probable number of additional breeders based on their observed presence within the study area (see Data Summary for explanation of calculations). We confirm the identity of nesting adults visually in the field by observing them departing from a nest or attending chicks or by using small cameras deployed at nests. For the second method, we conduct a single, coordinated survey of all breeding sites within the study area during the third week of May as part of the rangewide window survey following methods outlined in Elliot-Smith and Haig (2006). This annual window survey is the primary method used by USFWS to estimate the size of the Pacific Coast population of snowy plovers and to monitor population status over time.

We also collect information on survey duration and the number and type of human activities observed within the study area. These data are collected concurrently during regular nest monitoring surveys.
Data Summary
We calculate clutch hatch rates by dividing the number of known fate nests that hatched by the total number of known fate nests for each site and for the study area. Nests found as broods are excluded from clutch hatch rate calculations. To calculate fledge rates we divide the number of banded chicks that are confirmed to have fledged by the total number of chicks that were banded. Site-specific fledging success is based on the broods that originate from the nests that are located at each site, even in cases where broods moved to adjacent areas before fledging. We report minimum and maximum numbers of unbanded chicks that fledge, but we do not report fledge rates for unbanded chicks. Beginning in 2015, we modified our study design, including not attempting to band every chick that hatched, so comparisons with trends in reproductive rates from 2015 onward should be interpreted with this in mind. All rates are expressed as percentages.

We estimate the total breeding population size by summing banded and unbanded plovers confirmed on nests and banded birds that are present during May and June with evidence of likely nesting (probable banded breeders). We also derive the number of probable unbanded breeders, by applying the ratio of confirmed to probable banded breeders to the estimated number of confirmed unbanded breeders. This produces a breeding number for each sex that is the sum of confirmed banded breeders + confirmed unbanded breeders + probable banded breeders + probable unbanded breeders. For each sex, we estimate the minimum number of confirmed unbanded breeding adults by determining the maximum number of simultaneously extant nests with unbanded parents and subtracting the number of unbanded breeding adults that were subsequently banded on nests during the nesting season. We identify probable banded breeders by assessing the evidence for nesting for each candidate; evidence is based on the number of sightings in May and June, the duration of presence in the study area, breeding behaviors exhibited (e.g. paired, broody, copulating, scraping, lure display), past history of confirmed nesting, and natal origin.

We use the population estimate derived from monitoring to calculate a correction factor for the window survey estimate (monitoring estimate/window survey estimate) and we report on the annual correction factor and use long-term averages for reference. These correction factors are derived from Monterey Bay data and should be considered specific to this region.

We calculate annual return rates for banded plovers of each sex as the proportion of confirmed or probable breeders from the previous year that return to breed in the current year (as confirmed or probable breeders). We also report the return rate of juveniles as the number of chicks from the previous year determined to have fledged (by the current breeding season on Monterey Bay) with evidence of breeding (as confirmed or probable breeders) in the current year. Return rates are expressed as percentages.

We calculate an annual encounter rate per survey hour of humans, with all types of human activities summed into one encounter rate. We also pool the summarized data by region and present overall rates for North and South Bay beaches (see area descriptions for beaches in each region).