Point Blue Report

Population size and reproductive success of California Gulls at Mono Lake, California

Annual Report

December 2019

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Conservation science for a healthy planet

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Cover photo: The west side of Twain Islet May 29, 2019 showing gulls nesting amongst several species of weedy vegetation

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EXECUTIVE SUMMARY

Point Blue conducted the 37th year of monitoring the California Gull (*Larus californicus*) breeding population on Mono Lake in 2019. The population size was estimated by counting nesting gulls from aerial photographs – a technique which was newly implemented in 2017 following a pilot study. Reproductive success was measured by counting the number of chicks in the plots in July and applying the long-term mean post-banding mortality rate to estimate the total number of chicks that successfully fledged per nest.

Each year since 2016 we have recorded the lowest population size of California Gulls nesting at Mono Lake in the history of the project. The 2019 estimate of 22,150 breeding California Gulls was not only the lowest recorded in the 37 year history of this project, but also indicates the current nesting population is less than half of the long-term average that existed before the start of the 2016 decline. The 1983 to 2015 mean average nesting population is 46,395 ± 1324 (n = 33 years). The long term average through 2018 is 44,869 ± 1493 (1983 – 2018, n = 36 years).

The alarming plunge in nest numbers has transpired simultaneously with the growing expansion of *Bassia hyssopifolia*, a non-native weed which began inundating the Negit Islets in 2016. Continued expansion of *Bassia* and other weeds has increasingly reduced nest site availability and invasive weeds are now estimated to cover 70% or more of the Negit Islets. Low average brine shrimp (*Artemia monica*) densities in Mono Lake and the continued abandonment of islets that were raided by Coyote(s) (*Canis latrans*) during the recent drought might also play a role reduced nest numbers.

Average reproductive success in the sample plots was 0.443 ± 0.11 chicks fledged per nest, which is well below the 1983 – 2019 average is 0.87 ± 0.06 chicks fledged per nest. Based on plot data, an estimated 4,909 ± 518 chicks fledged from Mono Lake in 2019, which is the third lowest chick production measured since efforts began in 1983. For comparison, the 10-year average chick production between 1985 and 1995, a particularly productive period for Mono Lake California Gulls, was 29,854 ± 2641 chicks fledged annually. The average chick production over the past 10 years (2009 – 2019) is only 12,084 ± 2630.

Following tremendous success of counting nests via aerial photography rather than disruptive ground counts, we plan to transition to aerial photography for chick counts in future years. Although aerial photography has detected fewer chicks than ground counts (very small chicks, those brooded by adults or obscured by vegetation are missed), the elimination of logistical complexities and disturbance to the gulls, as well as the benefits of removing plot fencing, all provide adequate reason to support aerial chick counts over ground counts. We present 3 years of chick counts comparing ground and air results to use for interpreting future aerial chick counts.

INTRODUCTION

Mono Lake in eastern California is a large hypersaline lake of great ecological importance. Its large seasonal populations of endemic brine shrimp (*Artemia monica*) and alkali flies (*Ephydra hians)* provide important food resources for a large numbers of birds. Mono Lake supports one of the largest breeding colonies of California Gulls in the world (Winkler 1996).

In 1983, Point Blue Conservation Science (founded as Point Reyes Bird Observatory) began standardized monitoring of the population size and reproductive success of California Gulls at Mono Lake. The goal of the project is to use gulls as an indicator to help guide long-term management of the lake ecosystem. Specifically we aim to track the long-term reproductive success and population size of the gulls through changing lake conditions and identify the ecological factors influencing fluctuations in these metrics. This study represents one of the longest term ongoing studies of birds in North America. It is a powerful tool for assessing the conditions at Mono Lake and can be an invaluable tool in understanding how wildlife populations respond to ecological change that manifests over longer periods (e.g. climate change).

In 2019, we conducted Point Blue's 37th consecutive year monitoring the population size and reproductive success of California Gulls (*Larus californicus*) at Mono Lake. We continued to collect information on nest numbers and reproductive success with new methodologies adopted in 2017 which reduce disturbance to the gulls. In this report we provide a detailed summary of the 2019 results with reference to historical conditions. We also discuss the ongoing status of the invasive weed *Bassia hyssopifolia*.

Fig. 1. Locations of islands and islets within Mono Lake.

Study Area

Mono Lake, California, USA, is located at 38.0° N 119.0° W in the Great Basin of eastern California at an altitude of 1945 m. The lake has a surface area of approximately 223 km^2, a mean depth of about 20 m, and a maximum depth of about 46 m. As a terminal lake with no outlet, it is high in dissolved chlorides, carbonates, and sulfates, and has a pH of approximately 10.

Gulls nest primarily on a series of islands located within an approximately 14-km^2 area in the north-central portion of the lake. At various times the gulls have nested on Negit (103 ha) and Paoha (810 ha) islands, and on two groups of smaller islets referred to as the Negit and Paoha islets, which range in size from 0.3–5.3 ha (fig. 1-3, Wrege et al. 2006). The surface elevation of Mono Lake during the 2019 nesting season was similar to that of the 2018 season at about 1945.3 m.

Fig. 2. View of the nesting islets within the Negit Islet complex.

Fig. 3. The Paoha Islet complex.

METHODS

Nest Counts

Aerial Surveys: In 2017, a new standardized method using aerial photography to count gull nests was adopted. This new methodology allows for the population size to be accurately measured without the disturbance involved in ground counts. This switch came following two years of pilot study testing and calibrating aerial photography results with the traditional ground counts. Aerial photo-based nest counts were found to be a good alternative to the ground counts, with results reflecting 90% - 100% of ground count tallies when photographs with sufficient detail were used.

On 24 May 2019 Nelson photographed all islets from the open window of a Cessna TR182 flying above the lake using an 18 – 200mm zoom lens. The typical focal length used was 100mm – 140mm. The goal was to obtain images with sufficient resolution so that incubating and standing gulls are easily differentiated, and the area captured in each photograph is maximized in order to reduce time spent “stitching” images together (using GIS to “stitch” images wasn’t satisfactory in a trial study). For larger islets (Twain, Tahiti) the perimeter and then the interior of the islets are photographed systematically. The plane made multiple passes of each islet so that a large number of photos were available to choose from.

Plot Counts: We continued to count the number of nests within the sample plots with ground based counts as well as by air in 2019. On 29 May we counted the number of nests in each plot on the Negit Islets and recorded clutch size. We walked systematically through the plot and marked each nest with a small dab of water soluble paint to avoid double-counting. Due to consistent outstanding clarity of aerial photographs of nesting gulls and chicks on the Paoha Islets, both nest numbers and chick counts were obtained by aerial photograph on the Paoha Islets exclusively.

Figure 4. Example of images used for counting with drawn boundary lines. The top line on the left image matches the lower boundary line on the right image. Other boundary lines match on adjacent images.

Counting Nests from Aerial Images: Images were selected for counting based on clarity and by area captured. Images chosen for counting contained overlapping zones with adjacent images, covering the entire islet. Nelson used Adobe Photoshop to draw boundary lines on each image with the Brush Tool. In overlapping zones, she drew corresponding boundary lines following matching landmarks between the two images (i.e. rocks, vegetation, etc.). In some cases individual nests were woven around to ensure the boundary lines matched exactly (Fig. 4).

After boundary lines on each image were drawn, the Count Tool on Adobe Photoshop was used to count gulls. Each gull or pair was given a color-coded dot representing one of three count groups: 1. **Incubating**: a gull sitting/incubating within a nesting area. Many but not all of these were obviously nestled in a nest; 2. **Standing**: gulls that are obviously standing (upright posture and shadow angle were useful for assessment). Additionally, gulls that were sitting in an area known not to contain nests were considered standing. The third count group were **Pairs**: An obvious gull pair, in which one bird is sitting/incubating. Combining the totals for Incubating and Pairs were used to count the number of nests for each islet. If it was uncertain if a gull was sitting or standing, it was considered Incubating. Results from the pilot study showed that combining "Uncertain", "Incubating" and "Pairs" consistently provided the closest match to nest numbers obtained by ground counts.

For counting, most images were enlarged to 200% of the original resolution (this varied between 150 – 300%), and each image was systematically scanned side to side or up and down in passes, and gulls were marked with the Count Tool to their corresponding count group. Following this process, the entire image was scanned again for any missed gulls. Gulls are remarkably camouflaged against the Negit Islet topography. Images need to be carefully scrutinized to obtain an accurate count. The bright white heads, clear-cut white neck and gray mantle, and overall shape of nesting gulls were useful search images.

Determining whether a gull is standing or incubating can be a challenge, and develops with experience. Over the past several years I (Nelson) have counted thousands of gulls from images, and have been able to ground truth my aerial photo-based plot-counts with ground-count tallies of nests within the plots. Useful characters I associate with standing birds is that their bodies are angled upwards and the white circles of their breast show prominently. Incubating birds are often nestled down in nests with their gray backs showing prominently (Fig. 5). Some postures appear somewhat intermediate and require extra scrutiny. If the observer remains uncertain, they are considered incubating.

Figure 5. Sample of standing and incubating postures. Birds marked with green stars are considered incubating: they are nestled down with little or no breast showing and their gray backs are prominent. The birds with blue stars are standing: their bodies are angled upwards, and/or their shadows indicate a standing posture. Their white breasts show more prominently in most angles. Birds with orange stars are somewhat ambiguous: their posture appears more upright than those obviously incubating, or they may be seen to be standing over a nest.

Clutch Size and Reproductive Success

Reproductive success (the average number of chicks successfully fledged per nest) has traditionally been measured through site visits to the sample plots to count the number of nests in May, the number of chicks per plot in July, and to measure the post-banding/pre-fledging mortality rate. With the clarity and success of aerial photography, this project has been shifting to aerial photography to measure population size and reproductive success due to the major benefits of aerial surveys. These include eliminating disturbance to the gulls and reduced logistical and safety concerns of ground surveys. In recent years reproductive success data have been measured through both plot visits and aerial surveys to gather information on how the two methodologies compare to enable the switch of calculating reproductive success entirely by air.

Following completion of the nesting season this fall, plot fencing was removed. It is not needed for aerial chick counts and is an unnecessary burden to have remain on the colony. Corner and side posts which formally supported the wire fencing remain, as these are visible in aerial photography for plot boundary determination (weed cover could potentially obscure plot posts). Results of both ground and aerial surveys measuring reproductive success (i.e. chick counts) are presented in Table 1.

Chick Count Surveys: We sampled 7 fenced plots on two Negit Islets to estimate clutch size and sampled 9 plots on three islets to measure reproductive success in 2019. Six fenced plots measuring 10 x 20 m are located on the Negit Islets (four on Twain, two on Little Tahiti) and another plot approximately 20 x 20 m is located on Little Tahiti. Two smaller rounded fenced plots approximately 100 -120 m^2 are located on Coyote Islet of the Paoha Islet complex and were sampled entirely by aerial photography (clutch size was not measured). Average clutch size for the Negit Islet plots was estimated by counting the number of eggs per nest for all nests within the plots in late May.

On July 4 and 10, 2019 chicks within the Negit Islet sample plots were counted by site visits. Due to close proximity to an active Peregrine Falcon nest, chicks in the Cornell plot were not counted on the ground but results were obtained by aerial photography. In some plots older, mobile chicks were temporarily corralled into holding pens within the plot in order to obtain an accurate count. Un-corralled chicks were tallied, and then corralled chicks were counted as they were released. This temporary corralling was used during banding efforts in past years. Chick count trials conducted in 2016 in which volunteers visually counted chicks within the plots using tally meters (i.e. no corralling) consistently underestimated the actual totals when chick concentrations were relatively high. Thus temporary corralling would be necessary to obtain an accurate count in plots with moderate to large numbers of chicks. Plots with very low chick numbers (under about 20), corralling to aid in counting was unnecessary. Two to three observers would independently count chicks (whether in low density plots or the number of un-corralled chicks) several times. If our counts matched, they were considered accurate.

Aerial Chick Survey: On July 8 Nelson photographed all plots from the open window of a Cessna TR182 flying above the lake using a fixed 300mm lens. Using the count tool on Photoshop, chicks, standing adults, and brooding adults were each tallied.

Calculating Average Reproductive Success: The post-banding mortality count (counting the number of dead, banded gull chicks which had been banded in early July to measure the post-banding mortality rate) was dropped in 2017 and instead the mean long-term post-banding mortality rate obtained from 2000 – 2016 data is used. An analysis showed that the post-banding mortality rate is fairly constant and contributes relatively little to the overall annual reproductive success estimate. Thus counting chicks in July and applying the long-term average post-banding mortality rate is an excellent way of estimating overall reproductive success while reducing the disturbance and efforts of banding and mortality counts.

We estimated the fledging rate for each plot, and, applied the average fledging rate to the entire population to estimate the total number of gulls successfully fledged from Mono Lake in 2019. The fledging rate for each plot **(fplot)** is calculated as:

$$fplot = (Cb - Cd) / Np$$

where **Cb** is the number of chicks counted in that plot in July, **Cd** is the number of chicks from that plot that were estimated to have died after being counted in July (obtained using the long-term average post-banding mortality rate of 13.2% applied to the number of chicks counted in July), and **Np** is the number of nests counted in that plot in May. We calculated the total number of gulls successfully fledged **(F)** from Mono Lake as:

$$F = (N/P) \sum_{i=1}^{P} f_i$$

where **N** is the total number of nests on Mono Lake, **P** is the number of plots, and **fi** is the number of young fledged per nest in each of the fenced plots. In years such as 2019 in which the average fledging rate for the Paoha Islets (which represents less than 9% of the total population) is considerably lower than the rate for the Negit Islets, it is prudent to adjust the lakewide average reproductive success estimate to eliminate the bias caused by over-sampling the Paoha Islets, which frequently have much lower reproductive success than the Negit Islets. This correction is done by multiplying the average fledging rate for the Negit and Paoha Islets by their proportion of the population, and combining the totals. In 2019, the ground chick counts were used to calculate the average reproductive success, though aerial results are presented in the Results section below and may be used in the future. Overall chick production is estimated by multiplying the average reproductive success by the total number of nests. Results are presented with plus or minus one standard error.

Calculating Reproductive Success using Aerial Data in the Future: Unlike nest count results, chick count results obtained from aerial photography generally produced results which were considerably lower than ground counts. Very small chicks, those brooded by adults, and those obscured by vegetation are missed in aerial photography. In the three years of available comparative data, the average accuracy of aerial plot counts compared to ground plot counts varied between 41% and 101% (Table 1, Appendix 1). This variation is likely due to vegetative cover, the relative proportion of very small chicks, topography, and perhaps photo quality/angle. In 2019 aerial chick counts were quite accurate, likely due to the large size and advanced age of the chicks. In 2019 there were no very small or downy chicks in the plots, which is unusual. To maximize chick detection, aerial surveys should be conducted immediately prior to the first fledge dates, which happen about the third week of July.

Table 1. Comparison of chick counts obtained from ground surveys and aerial photography. Accuracy is the combined average of aerial totals divided by the ground totals for each plot. Also provided is the average reproductive success value (RS) calculated with ground based and air based count data, including aerial nest counts.

	2016		**2017**		**2019**		
Plot	Ground	Air	Ground	Air	Ground	Air	**Avg. Accuracy**
Corn	55	38	4	0	2	2	**85%**
LT ea	28	17	0	0	1	1	**87%**
LT we	71	26	19	6	26	16	**43%**
Tw We	65	24	26	16	65	59	**63%**
Tw No	17	7	25	9	21	15	**50%**
Tw So	31	18	5	2	26	18	**56%**
Tw Nw	48	13	23	11	57	42	**50%**
CH	13	13	4	2	-	8	**75%**
CC	23	16	8	6	-	5	**72%**
		0.23		**0.12**		**0.41**	
RS value	**0.57**	41%	**0.23**	55%	**0.40**	101%	**66%**

Using aerial counts in the future to calculate reproductive success will produce a rough estimate that likely reflects between 40% – 100% of the actual value. A regression analysis indicated that adding the number of brooding adults present (or half the number of brooding adults) in the plot to the chick counts was not helpful in improving the accuracy of the aerial chick count results (Appendix 1).

RESULTS

Number of Nests and Breeding Adults

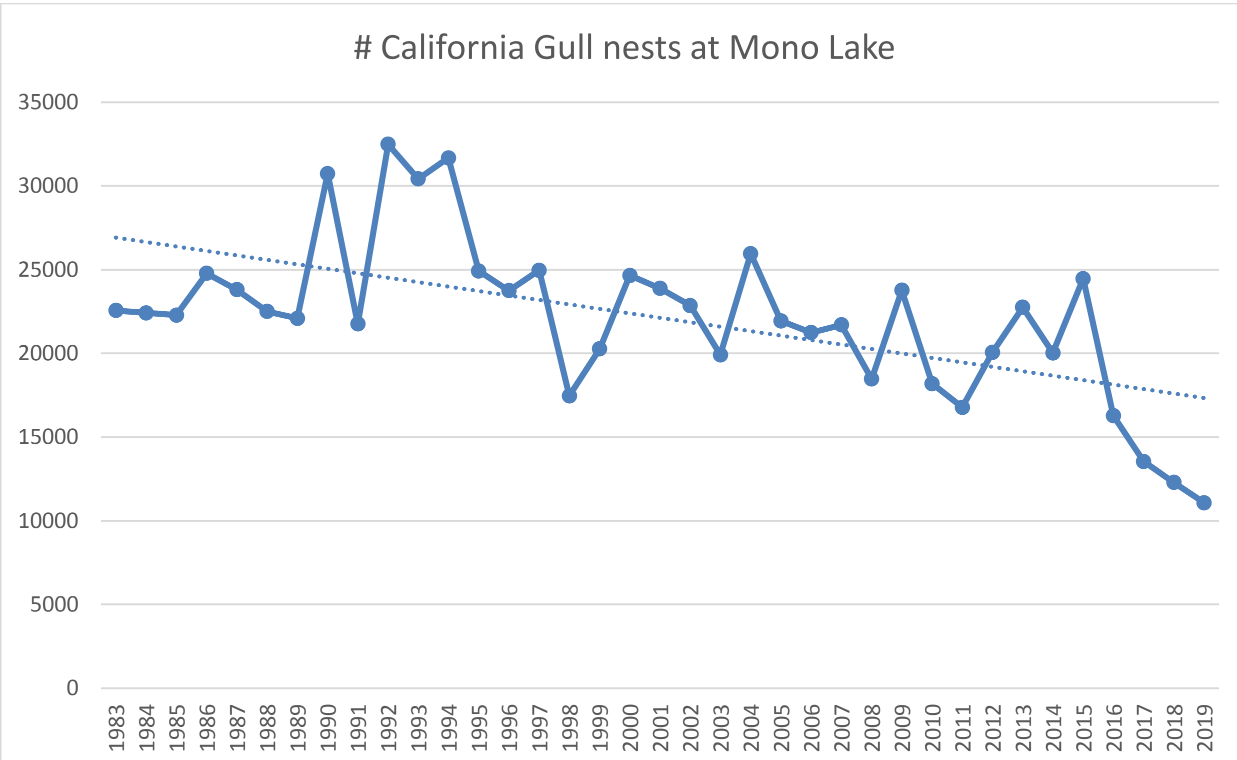
In 2019, a lake-wide total of 11,075 California Gull nests were counted, yielding an estimated population of 22,150 nesting adults. This is the lowest ever recorded over the course of this study (Fig. 6, Appendix 2). If the total estimate was increased by 4% (the amount that 2016 aerial photography underestimated the population compared to ground counts), the result would be similar with an estimated 11,518 nests. The past four consecutive years have each contained the lowest population size recorded, and the population size today is less than half of the long-term average recorded before the start of this recent plunge. The long-term mean population size over the course of this study is 44,869 ± 1493 (1983-2018, n = 36 years), and the long-term mean before the start of the recent population drop in 2016 is 46,395 ± 1324 (1983 – 2015, n = 33 years). The mean population over the past 3 years (2016 – 2018) is only 28,080 ± 2356.

The number of nests counted in 2019 represented a relative decline of about 10% compared to 2018 nest numbers, which was the previous low by a substantial margin. Java Islet, Piglet Islet, and Old Marina and Negit Islands continued to be abandoned in 2019 following Coyote presence in recent years. Steamboat continued to decline sharply in nest occupancy. In 2013 it hosted 1,175 nests and by 2019 only 120 were counted (Appendix 2).

Ninety-one percent of the gulls nested on the Negit Islets and 9% nested on the Paoha Islets (Figures 1 -3, Appendix 2). The number of nests on Twain Islet was about the same this year as it was in 2018, and the number of nests on Tahiti and Pancake islets both declined over 30% compared to 2018 totals. Of the individual islets, Twain was the most populous, supporting 7,601, or 69%, of the lake-wide total number of nests. This is the highest proportion of the population recorded nesting on Twain. Little Tahiti and

Coyote islets were the next most populous islets, containing 1,230 (11%) and 673 (6%) of the nests respectively.

Figure 6. Number of California Gull nests at Mono Lake, 1983 – 2019 with trend line.



Clutch Size

In 2019, the average clutch size recorded for the Negit Islets was slightly above average at 2.03 ± 0.04 eggs/nest (range = 1-3 eggs, *n* = 311 nests). Overall, 17% of the nests contained one egg, 46% had two, and 19% had three. The average clutch size for Mono Lake since 2002 (*n* = 16 years) is 1.90 ± 0.04 eggs/nest.

Reproductive Success

The Negit Islet plots averaged 44 ± 6 nests per plot, with an average nesting density of 0.21 ± 0.03 nests/m². The Negit Islet plots fledged an average of 0.47 ± 0.12 chicks per nest. The Paoha Islet plots averaged 33 ± 8 nests per plot and averaged 0.17 ± 0.10 chicks fledged per nest. Nest density on the Paoha Islets is uncertain due to the irregular sizes of the plots. Combining the 9 plots evenly averages 0.404 ± .10 fledged chicks per nest, however, this result biases the lakewide result downwards because the Paoha Islets, which represent under 9% of the population but 22% of our sample, have very low average reproductive success. The adjusted average reproductive success (see methods, above) is 0.443 ± 0.11 (Table 2).

Table 2. Summary of nest and chick counts from all plots using ground surveys in 2019. Values presented with an asterisk * were collected via aerial survey. The final average reproductive success value marked with double asterisk ** was corrected to avoid over sampling bias of the Paoha Islets (see methods, above).

Plot	# nests in May	Avg. chicks/nest in July	# chicks in July	# estimated to die before fledging (# in July x 0.132)	Total successfully fledged/nest
Cornell	40	0.05	2*	0.26	0.04
L. Tahiti East	18	0.06	1	0.13	0.05
L. Tahiti West	50	0.52	26	3.43	0.45
Twain North	41	0.51	21	2.77	0.45
Twain South	37	0.70	26	3.43	0.61
Twain West	66	0.98	65	8.58	0.85
Twain New	59	0.97	57	7.52	0.84
Negit Islet totals/averages:	**311**	**0.54 ± .14**	**198**	**3.73 ± 1.23**	**0.47 ± .12**
Coyote Cove	25	0.20*	5*	0.66	0.17
Coyote Hilltop	41	0.20*	8*	1.06	0.17
Paoha Islet Totals:	**66**	**0.20 ± 0.20**	**13**	**0.86 ± 0.20**	**0.17 ± .00**
Lakewide totals/averages	**377**	**0.47 ± .12**	**211**	**3.09 ± 1.0**	0.404 ± .10 **0.443 ± .11****

No wing droop was observed this year (see Nelson 2018), and all chicks appeared unusually large and healthy. No small downy chicks were present in the plots this year.

Based on the total of 11,075 California Gull nests counted in late May, and an average of 0.443 ± 0.11 chicks fledged per nest in the sample plots, an estimated 4,909 ± 518 chicks fledged at Mono Lake in 2019. This is the third lowest estimate in the history of this project. The long term average chick production between 1983 and 2018 is 20,480 ± 1838 (*n* = 36 years) and is calculated for the Negit Islets only from 1983 - 2002, and Negit and Paoha Islets combined since 2002.

DISCUSSION

Population Size

The nesting population size of California Gulls at Mono Lake has been in decline since about 2004, and since 2016 the number of nests has plunged at a rate much greater than the trend line (Fig. 6). The primary factor associated with the extremely low California Gull population at Mono Lake in recent years is *Bassia hyssopifolia* encroachment.

Bassia Encroachment

Beginning in 2016 this Eurasian invasive weed, as well as other weedy species, have exploded on the gull colony and are now estimated to cover 70% or more of the Negit Islets (Nelson 2017, Nelson 2018, Fig. 7, 8; aerial photo archives). The unprecedented decline in Mono Lake's gull population recorded in the past four years parallels the significant loss of nest site availability due to weed encroachment. Aerial photo documentation shows large patches of *Bassia* appeared on Twain and other Negit Islets beginning in 2016 (small amounts were present previously). In the late summer of 2017 *Bassia* again exploded on the Negit Islets and Twain Islet in particular, resulting in vast and rapid ecological change on the landscape (Nelson 2017, Nelson 2018, Fig. 7). Areas of Twain Islet which previously contained no vegetation and hosted very high nesting densities were suddenly replaced with weeds including areas of waist-high, nearly impenetrable masses of *Bassia* (e.g. Fig. 8). Although *Bassia* is an annual, the dead carcasses of the plants persist for years, such that nest site availability continues to decline with each seasons' additional growth (Nelson 2018, Fig. 9). Figures in the 2017 and 2018 annual reports (Nelson 2017 & 2018) illustrate several "before and after" images of *Bassia* engulfing areas of the Negit Islets which were previously open and contained very high nest densities.

Figure 7. Twain Islet in 2015, 2016, and 2019 showing development of *Bassia* cover. In 2015, *Bassia* and other weeds were absent on Twain with the exception of a small patch of dead *Bassia* indicated with the yellow circle. *Bassia* growth exploded on Twain in 2016, 2017, and 2019, significantly reducing nest site availability. Oct. 2019 photo courtesy R. DiPaolo

Unlike 2018 when new *Bassia* germination was limited (though thick masses of dead plants from 2017 growth prevented gulls from nesting in many areas, e.g. Fig. 9), in 2019 aerial images and site visits clearly show that *Bassia* and other weeds again germinated in abundance and flourished. Fortunately much of the 2019 growth overlaid older growth (e.g. Fig. 9), so that invasion into new areas was limited, however it did occur. *Bassia* was also common on Piglet Islet this year, which is an islet within the

Paoha Islet complex where *Bassia* had not been previously documented in significant amounts.

Figure 8. The West side of Twain Islet in September 2019. The mass of green *Bassia* weeds represents new 2019 growth.

Figure 9. West shore of Twain Islet in July 2019 and May 2018. Blue and yellow stars indicate matching landmarks. Little new *Bassia* growth germinated in 2018 as indicated by the lack of green vegetation, but dead yellow plants from 2017 growth still provided a barrier for nesting gulls. In 2019 *Bassia* again geminated abundantly though fortunately it largely grew within the existing footprint of previously covered areas.

One trend which suggests *Bassia* may not be the only factor involved in the reduced population is the declining nest occupancy of Coyote Islet. Coyote Islet is part of the Paoha Islet complex, and does not have *Bassia* or other weeds impacting nest site availability. Yet the nesting population on Coyote has generally declined similarly with the overall population (Appendix 2). There was an exception with a small boost in Coyote Islet nest numbers in 2017 following the initial major impact of *Bassia* on the Negit Islets (Appendix 2). However, since then the nesting population on Coyote has declined which would not be expected if weed cover on the Negit Islets was the only factor affecting the population, unless the overall reduced densities of gulls within the colony is a dissuasion to nesting. Average reproductive success on the Paoha Islets is typically much lower than on the Negit Islets, which suggests it is of lower habitat quality. It faces strong prevailing winds relative to the Negit Islets, and its muddy substrate often coats eggs with mud following heavy rains, which likely reduces hatchability.

Other Factors Affecting Population Size in 2019

A previous study using data from 1987 – 2003 (before weeds invaded the islets) found that 4 variables explained over 80% of the variability in the Mono Lake gull population, particularly brine shrimp densities around the time of egg-laying, springtime temperatures, and recruitment (Wrege et al. 2006). Today, the relationship between the population size and some of these variables appears to be shifting in the opposite direction. Brine shrimp have been trending significantly towards an earlier peak in abundance - closer to the gull egg-laying period since 2004 (Jellison and Rose 2012, LADWP 2019), yet the gull population had been in decline relative to the long-term mean since that time. Between 2016 and 2018 (the most recent year shrimp data are available), this pattern showed signs of reversal and the peak shrimp abundance was again somewhat later in the year, similar to pre-2004 peak timing (LADWP 2019).

Springtime temperatures in California and the Mono Lake region have been trending warmer (e.g. LADWP 2019) while the gull population has been declining. What factors are driving these shifts remain unknown and are in need of further investigation.

The breeding population size of California Gulls at Mono Lake may be responding to changes in their primary food source, brine shrimp. Long-term monitoring has shown that in recent years, average brine shrimp abundances in Mono Lake have been low compared to long-term averages (LADWP 2019). The 5 year running mean and median average of adult shrimp abundance from 2014 – 2018 was the lowest on record, and in 2015 and 2016 peak shrimp densities were the lowest recorded since monitoring began in 1979 (LADWP 2019). Promisingly, shrimp numbers have shown considerable resiliency over the study period and shrimp abundances have generally recovered since the all-time low recorded in 2015, although lakewide average abundancies in 2018 dropped relative to those recorded in 2017 (LADWP 2019). One clear trend in shrimp population dynamics is that their populations in Mono Lake peak following the conclusion of periods of meromixis (persistent salinity stratification). These population peaks are larger following longer, more intense periods of meromixis (LADWP 2019). Mono Lake is currently in a period of meromixis, which depresses nutrient cycling within the lake. However, when meromixis ends and nutrients become distributed throughout the water column, primary productivity in the lake usually surges. The brine shrimp would then be expected to experience a relatively large population boost, which may last for subsequent years (LADWP 2019). Shrimp data for 2019 are not yet available.

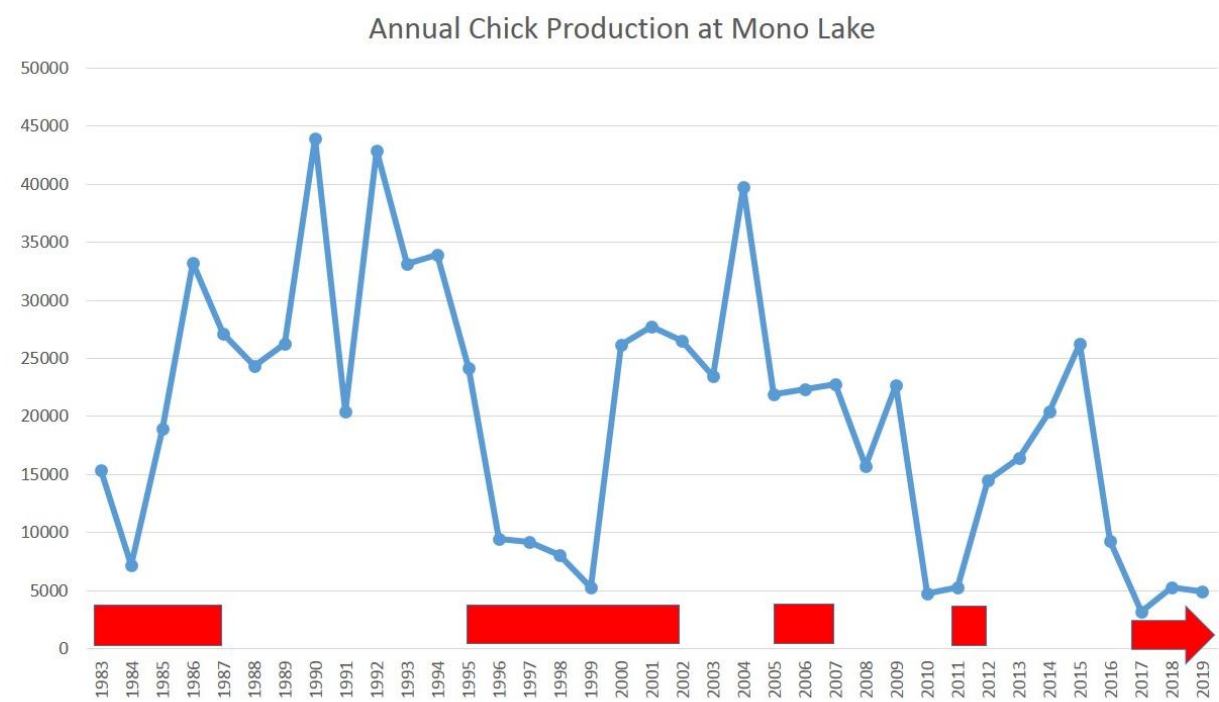
Coyote activity resulting from lowered lake levels during the recent drought has likely contributed to a reduced population size through lingering abandonment of islets raided by Coyotes. Over the course of this study we have found that islets raided by Coyotes are typically abandoned by nesting gulls the following year or longer. In 2019, lingering abandonment caused by Coyote activity during the 2012 - 2016 drought has continued to affect multiple islets from all islet complexes. In 2014 both Piglet Islet and Old Marina Island were raided by Coyotes as lake levels fell and these islets became accessible to them (Paoha Island hosts resident Coyotes which raided Piglet Islet). In 2016, Coyote signs (scat and tracks) were widespread on Negit Island, suggesting multiple Coyotes visited or resided on Negit Islet. Scat was also found on Java Islet in July 2016, confirming that Coyote(s) had swum to Java, probably from Negit Island. The islets surrounding Java including Steamboat had greatly reduced numbers of chicks relative to other islets in July 2016, suggesting that these also may have been raided by Coyote(s) (Nelson 2016). Even though Mono Lake has risen such that Coyote depredation should no longer be a likely threat, these islets have remained abandoned. Nest numbers on Steamboat have sharply declined since 2016 (Appendix 2). This continued abandonment demonstrates the lasting legacy even a single season of Coyote activity, or even a single visit by a Coyote, can result in. It is possible other factors such as weed cover are discouraging gulls from recolonizing these areas.

Low recruitment may also be affecting the Mono Lake gull population. Annual chick production has been relatively low at Mono Lake over the past 10 years, which reduces the number of new breeders joining the colony (see reproductive success, below).

Reproductive Success

The average of 0.443 chicks fledged per nest in 2019 is well below the 1983 – 2018 mean average of 0.87 ± 0.06 chicks fledged per nest. Previous analysis has found that annual average reproductive success of California Gulls at Mono Lake is negatively correlated with meromictic (i.e. highly stratified) conditions (Nelson et al. 2014). Meromixis occurs following high levels of runoff, which creates a stratification of fresh and salty waters. This disrupts nutrient cycling in Mono Lake and depresses lake productivity. Due to high levels of freshwater inputs, Mono Lake entered a period of meromixis in 2017, which is expected to continue through at least 2020 or longer (LADWP 2019). High levels of runoff again in 2019 following a winter snowpack of over 150% of average for the Mono Basin will likely strengthen and/or lengthen this current meromictic condition. Although we expect average reproductive success to remain low during meromictic periods, when meromixis finally ends and proper nutrient cycling resumes, productivity in Mono Lake would be expected to spike above average. Mono Lake brine shrimp flourish with high peak abundances in response to the post-meromictic primary productivity boost (LADWP 2019), and average reproductive success and chick production for Mono Lake gulls has also been relatively high during these post-meromictic periods (Fig. 10).

Figure 10. Estimated chick production (reproductive success x population size) over the study period. Red bars indicate periods of meromixis (persistent salinity stratification). Average reproductive success is negatively correlated with meromictic conditions, although it does tend to increase when meromixis ends.



The estimated 4,909 ± 518 chicks that successfully fledged from Mono Lake in 2019 is the third lowest measured and represents a total that is less than 25% of the long-term average, which is 20,480 ± 1838 (1983 – 2018). For comparison, the 10-year average chick production between 1985 and 1995, a particularly productive period for Mono Lake California Gulls, was 29,854 ± 2641 chicks fledged annually. The average chick production over the past 10 years (2009 – 2019) is only 12,084 ± 2630. In six of the past 10 years annual chick production has been under 10,000 – half the long-term average (Fig. 10). By comparison, over the initial 26-year time period of 1983 – 2008, only 5 years had annul chick production estimates below 10,000.

Annual chick production is driven primarily by the average reproductive success value and to a lesser extent population size. The past decade has experienced two meromictic periods, which are likely the primary drivers behind reduced reproductive success and chick production. The extremely low population sizes associated with *Bassia* encroachment have exacerbated these low reproductive success values and driven chick production lower still. Thus the combination of frequent meromixis and the loss of nesting habitat due to weed encroachment are combining to greatly reduce chick production. This will reduce future recruitment of new breeding adults and contribute to population decline unless action is taken to remove *Bassia* and other weeds.

Conclusion

The breeding population of California Gulls at Mono Lake has been in decline since 2004, and in a steep and alarming decline since 2016. Over the past four years, each year has recorded the lowest population size in the history of this project. Although this period coincides with low average abundances of brine shrimp in Mono Lake, this declining trend is most closely associated with *Bassia hyssopifolia* encroachment. The Negit Islets appear unable to host a robust gull population unless *Bassia* is reduced or removed. The future of a healthy gull population at Mono Lake likely depends on weed removal or burning efforts so that more nesting habitat becomes available. Discussions and site visits with the Inyo National Forest fire personnel have occurred to assess if weeds can be burned off to open up nesting area for the gulls. Newly opened, weed-free areas would likely need to be maintained into the future so that nesting habitat remains available. The Mono Lake Committee and others are committed to continued *Bassia* management within the gull colony. We have found one-time manual pulling of young *Bassia* plants resulted in visibly reduced *Bassia* density lasting 5 or more years.

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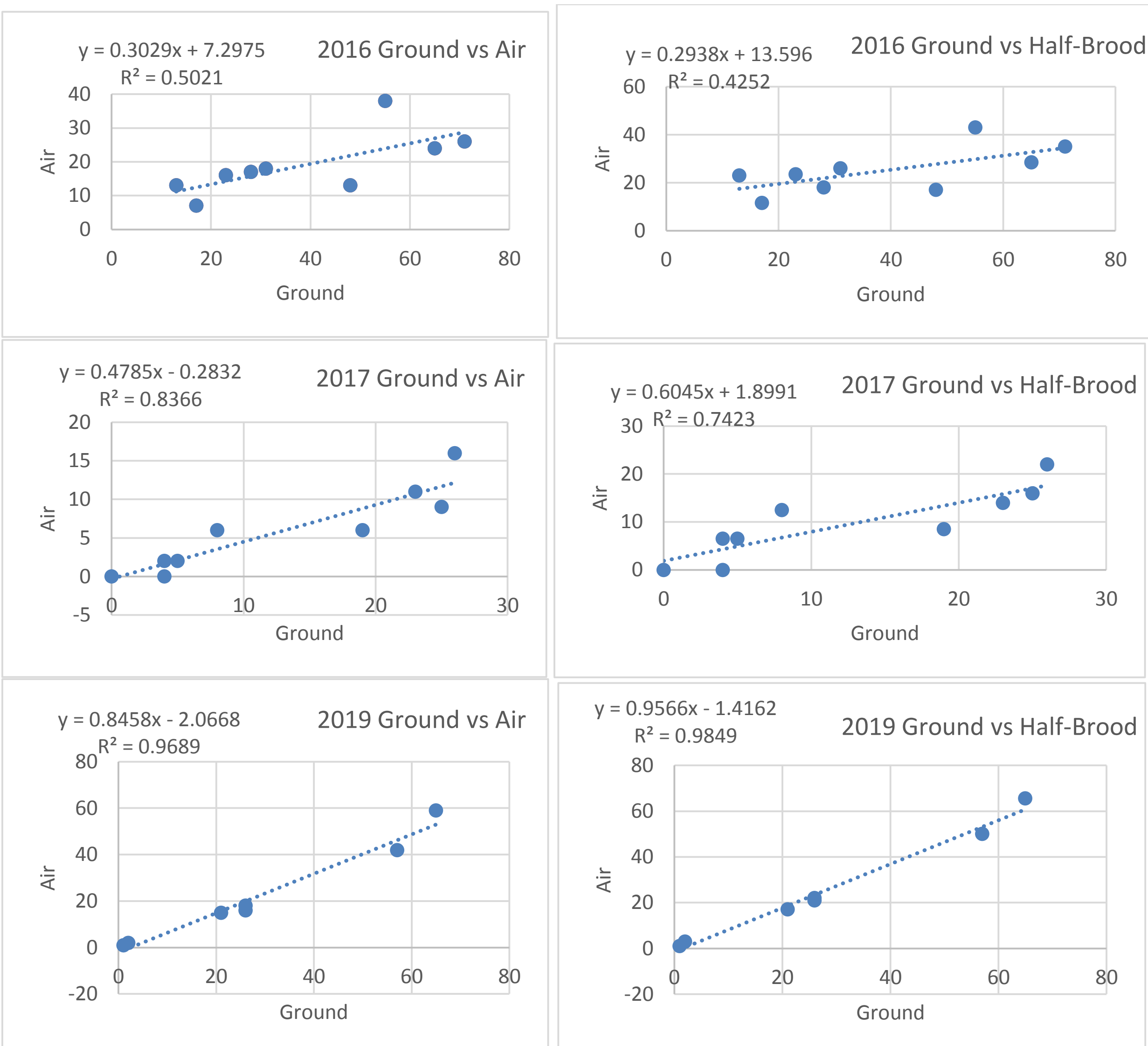
Appendix 1. Regression analysis comparing aerial and ground chick count results for available years. Also tested was whether adding half the number of sitting or brooding adults ("half-brood") counted by aerial photography within the plots improved the result, which it did not. Aerial counts in 2019 were highly accurate relative to 2016 and 2017 results, perhaps because there were fewer small young chicks.



Appendix 2. Nest number by islet, 2010 - 2019

Negit Islets	2010	2011	2012	2013	2014	2015	2016	2017 [a]	2018 [a]	2019 [a]
Twain	8219	8704	9396	9567	9144	12263	7760	7672	7639	7601
L. Tahiti	2429	2049	3366	3995	3899	4258	2923	1795	1860	1230
L Norway	114	171	390	493	384	505	284 [c]	163	220	185
Steamboat	509	579	871	1175	1076	1010	675	217	143	120
Java	367	432	325	234	216	439	60	0	0	0
Spot	122	151	39	95	162	184	144	55	36	59
Tie	55	58	30	56	65	181	170	49	55	36
Krakatoa	2	0	12	9	12	84	38	40	73	50
Hat	0	7	24	30	29	25	21	2	8	2
La Paz	0	0	0	0	4	7	16	19	0	4
Saddle	0	0	0	0	0	0	0	0	0	0
Midget	0	0	0	0	0	0	0	0	0	0
L. Tahiti Minor [c]	151	162	253	282	255	202	116	64	64	63
Pancake	1894	1741	1972	2450	1903	3159	2497	1814	1099	778
Negit Islets Total	**13862**	**14054**	**16678**	**18386**	**17149**	**22317**	**14704**	**11890**	**11215**	**10128**
Paoha Islets										
Coyote	1711	929	1393	2093	2618	2042	1432	1505	1038	892
Browne	116	50	60	75	110	87	146 [c]	152	38	55
Piglet	997	599	344	148	38 [b]	0	0	0	0	0
Paoha Islets Total:	**2824**	**1578**	**1797**	**2316**	**2766**	**2129**	**1578**	**1657**	**1076**	**947**
Negit Island:	0	0	7	8	28	16	0	0	0	0
Old Marina	1496	1133	1541	1665	9 [b]	0	0	0	0	0
O.M. So.	4	9	36	380	70 [b]	0	0	0	0	0
Lakewide Total	**18186**	**16774**	**20059**	**22755**	**20022**	**24462**	**16282**	**13547**	**12291**	**11075**
Nesting Adults	**36372**	**33548**	**40118**	**45510**	**40044**	**48924**	**32564**	**27094**	**24582**	**22150**

a. Nest numbers obtained through aerial surveys and photographs
b. Number of nests known to be depredated by Coyote or abandoned from Coyote activity; likely an underestimate.
c. Nest numbers for Little Tahiti Minor were previously included within the Little Tahiti Total