Point Blue Report

Population size and reproductive success of California Gulls at Mono Lake: 2022

Annual Report

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

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Cover photo: California Gulls foraging on Mono Lake. Photo by Annie Schmidt

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EXECUTIVE SUMMARY

Point Blue conducted the 40th consecutive year of monitoring the California Gull (*Larus californicus*) breeding population on Mono Lake in 2022. We estimated the breeding population size and chick production by counting nesting gulls from high resolution aerial photographs obtained from uncrewed aerial vehicles (UAV's) as in the past two years.

In 2022, we estimated the gull nesting population was 25,860 based on a nest count of 12,930, a decrease of 2,362 breeding birds from the 2021 estimate. Twain islet continued to support the majority of the nesting population with 9094 (70.3%) nests in 2022, an 842 nest decrease from 2021. The islets with the next highest nest counts were: Little Tahiti (1229), Coyote (1015), and Pancake (756). Based on aerial photos Twain islet remains relatively free of invasive Bassia weed that had limited nesting areas prior to its removal in 2019.

In 2022, we documented the lowest breeding productivity in the 40 years of the study. Average reproductive success in the long-term sample plots was 0.09 ± 0.06 chicks fledged per nest. The previous low productivity was 0.24 chicks fledged per nest in 2017. The low per nest productivity coupled with the near historic low nesting population resulted in by far the fewest chicks produced at Mono Lake in the 40-year study. We estimated a mere 1177 chicks fledged from Mono Lake in 2022, less than half the previous low in 2017 and over 11,000 less than fledged in 2021.

We discuss possible causes of this historic low productivity and discuss advances in our monitoring approach going forward.

INTRODUCTION

Mono Lake in eastern California is a large hypersaline lake of great ecological importance (Winkler 1977). Its large seasonal populations of endemic brine shrimp (*Artemia monica*) and alkali flies (*Ephydra hians)* provide important food resources for a large number of birds. Mono Lake supports one of the largest breeding colonies of California Gulls (*Larus californicus*) in the world (Winkler 1996).

In 1983, Point Blue Conservation Science (founded as the 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 has been 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 serves as an important tool for evaluating the conditions at Mono Lake and holds immense value in comprehending how wildlife populations adapt to ecological changes that unfold gradually over extended periods, such as climate change.

In 2022, we conducted the 40th consecutive year monitoring the population size and reproductive success of California Gulls at Mono Lake. This marked the 3rd year of censusing the gull nesting population and chick production by using high-resolution images captured using uncrewed aerial vehicles (UAVs). In this report we provide results of the 2022 breeding season and provided updated long-term trends in the gull nesting population size and productivity.

Fig. 1. Locations of islands and islets within Mono Lake. The Negit Islets and the Paoha Islets had breeding gulls in 2022.

Fig. 2. Negit islets where majority of California Gull at Mono Lake nest in July 2022.

Fig. 3. The Paoha Islets in July 2022 with the western edge of Paoha island.

METHODS

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 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. In recent years they have been confined to two groups of smaller islets referred to as the Negit and Paoha islets, which range in size from 0.3–5.3 ha (Figures 1-3; Wrege et al. 2006). The surface elevation of Mono Lake during the 2022 nesting season was lower than the previous two years at about 1944 m (6379.3 – 6378.8 feet) above sea level during the gull nesting season (LADWP 2022), 13 feet below the State Water Board management level of 6392.

Nest Counts

Aerial Surveys

In 2017, we began piloting a new standardized method using aerial photography to count gull nests and chicks while continuing ground-based counts. This new methodology allowed for the population size to be measured without the disturbance involved in ground counts and with less effort. We used the ground-based counts to evaluate the accuracy of aerial counts and found aerial counts 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 for nesting adults. Thus, in 2020 we switched to remotely sensed data only to minimize disturbance to nesting gulls and reduce effort to complete data collection.

From 2017 to 2019, we captured aerial images from an open window of a fixed wing aircraft (Cessna TR182) flying above the lake with a typical focal length of 100mm – 140mm used (See Nelson & Livingston 2019 for further details). In 2020, we transitioned to using a small UAV platform, deploying two or three DJI Matrice 100 quadcopters each equipped with a Zenmuse X5 camera. The UAVs followed pre-programmed flight paths to capture complete photographic coverage of the target area. The path planning algorithm (Shah et al. 2020) planned routes that were flown autonomously, provided complete coverage of each islet, and were optimized to limit survey time and allow for safe recall of the UAV's at any time during the survey. The UAV's were launched from Java islet for surveys of all of the Negit Islets and from Paoha for all of the Paoha Islets (Figures 4 &5). Pilots maintained visual contact with the UAV at all times during the flights. UAV's maintained a minimum altitude of 30 m above the ground and approached each nesting islet 70 m above the ground, before descending, to minimize disturbance to the gulls.

An observer other than the pilot documented disturbance to gulls, osprey or any other birds from the UAV's for each survey. If disturbance had been noted during a survey, the flight path would have paused until birds had settled or moved away from the UAV. We noted no disturbance of nesting gulls or non-gull birds during our surveys.

Figure 4. Flight planning routes and coverage of the Negit nesting islets from the base on Java islet in 2020.

Images collected during each survey were stitched together using the program Metashape (Agisoft LLC v1.6.3) to make a single, spatially referenced mosaicked image of each island ("orthomosaics"; Figures 6 & 7). Final images in 2022 had < 1 cm resolution per pixel. Imagery was captured for the nest count on June 1 in 2022 and July 12 for the chick survey.

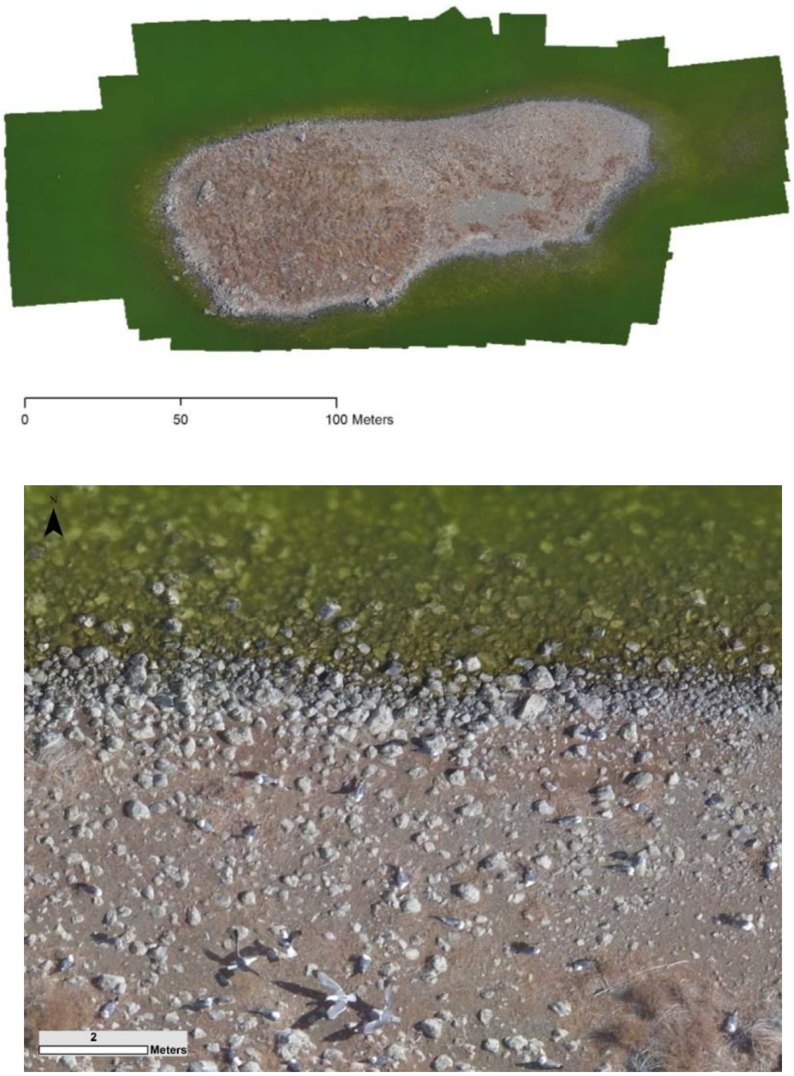

Figure 6. Mosaicked image of Pancake islet from the June, 2020 incubation survey (above) with a zoomed in view (below) showing nesting and non-nesting gulls.

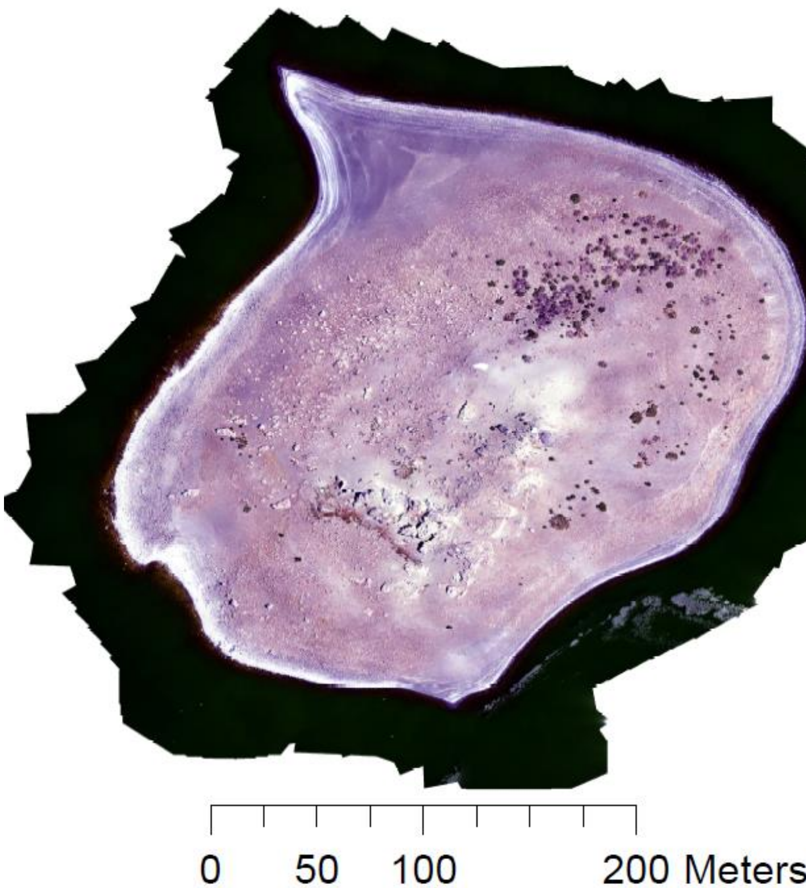

Figure 7. Mosaicked image of Twain Islet from the June 2022 survey.

Counting Nests from Aerial Images

In 2002, we used the Amazon Web Services application "Sage Maker" to label all gull nests as well as standing and sitting, non-nesting gulls so that a machine learning algorithm can be created to assist with future counts. We first tiled the orthomosaics into 256 x 512 pixel (roughly 2.56 x 5.12 m) rectangles that were then manually evaluated by expert observers.

We used clues such as posture, shadows and shadow angle to assist in deciding which category to place the bird in as well as if two birds were sitting in very close proximity to each other, we considered these birds a pair and counted only 1 as nesting (Figure 6). If it was uncertain if a gull was incubating or just sitting, it was considered incubating based on calibration with ground-based counts in previous years that found the vast majority of these birds were incubating. A de-duplication script created in the program R (v 4.3.1) was run on the resulting labels to account for gulls at the edges of rectangles which appeared in more than one image. Only birds labeled as nesting were used in nest counts. We loaded the resulting labels into ArcMap (ESRI; v10.8.1) for display on the full orthomosaics at approximately 1:30 scale so that we could find any nests missed during the labeling process. Conducting this additional review resulted in the discovery of approximately 10% additional nests as in previous years. Chick counts were conducted using the same approach as nest counts in previous years, scanning all long-term nest plots on the orthomosaics in ArcMap at 1:30 resolution for nestlings.

Clutch Size and Reproductive Success

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. We have since used the mean long-term post-banding mortality (13.2%) rate obtained from 2000 – 2016 data, as the annual variation in this metric was small and therefore contributed relatively little to variation in the annual reproductive success estimate.

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 2022. 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, 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 2021 the fledging rate for Paoha and Negit plots was similar, so we used all plots to estimate the number of young fledged from all nests. Overall chick production was estimated by multiplying the average reproductive success by the total number of nests. Results are presented with plus or minus one standard error.

RESULTS

Number of Nests and Breeding Adults

In 2022, the estimated gull nesting population was 25,860 based on doubling the nest count of 12,930 compared to 14,111 nests in 2021 and 14,725 nests in 2020. The 2022 nest number represented the third lowest nest number in the 40-year history of this study, ahead of only 2018 and 2019 where 12,291 and 11,075 nests were counted respectively. The 1181 nest decrease from 2021 to 2022 was almost entirely accounted for by reductions in nests on Twain (842 fewer nests in 2022) and Little Tahiti (301 fewer). Little Norway also experienced a 140 nest decrease between years. The pancake islets had increased nest numbers from 2021 to 2022 (198 more nests) reversing recent trends. The 1983 – 2021 average nesting population was 43,464 ± 1553. The nesting population has been declining on average by 297 nests per year over the 40 years of this project (Figure 8). The breeding population has now been below 30,000 birds every year since 2017.

Twain continued to support the largest nesting concentrations on the lake with 70.3% of all nests in 2022, very similar to the proportion it supported in recent years. Twain was followed by Little Tahiti with 1229 nests, and Coyote with 1015 nests. Pancake numbers rebounded to 756 nests, similar to 2019 and 2020 levels but still well below 2017 where over 1800 nests were counted there. Steamboat, which supported over 1000 nests as recently as 2013, had only 61 nests in 2022, continuing the decline of this islet's nesting numbers.

The proportion of nests occurring in the Negit islets compared to Paoha islets was similar to recent years with 92% of nests occurring in the Negit islets (Appendix B).

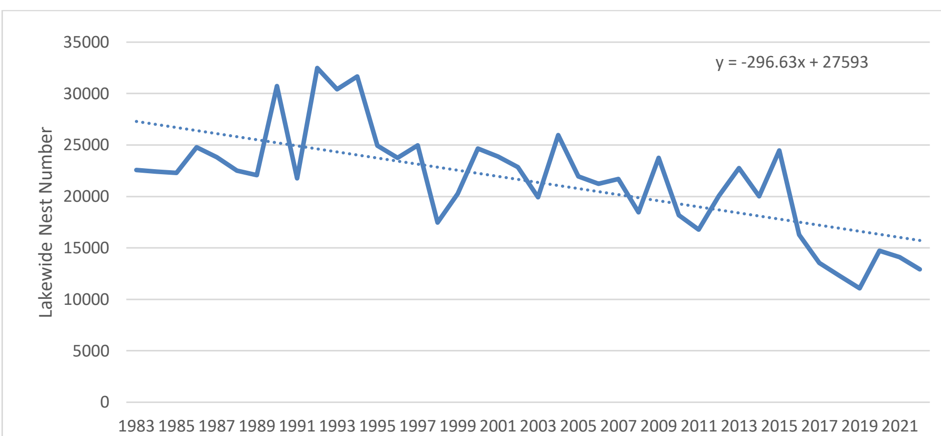

Figure 8. Number of California Gull nests at Mono Lake, 1983 – 2022 with linear trend line and associated regression equation.

Reproductive Success

The Negit Islet plots averaged 72.5 nests per plot in 2022 down from 81 nests per plot in 2021. The Negit Islet plots fledged an average of 0.102 ± 0.06 chicks per nest in 2022 by far the lowest rate in the 40year history of the project. The previous low was in 2017 when average chick fledging rate was 0.24 per nest (Table 2). The Paoha Islet plots (both on Coyote) averaged 33 nests per plot in 2022 and no young fledged from either of these plots. The lake-wide estimate of chick production was 0.09 chicks per nest.

The long-term reproductive success rate has declined at an average of 1.27% per year across the 40 years of this study (Figure 9).

Table 2. Summary of nest and chick counts from all Negit islet plots using aerial surveys in 2022. Chick counts include ½ of the brooding adults observed in imagery during July survey to correct for ground-based counts used in previous years.

Plot	# nests in June	average # chicks/nest in July	# chicks in July	# estimated to die before fledging	Total successfully fledged/nest
Cornell	64	0.11	7	0.79	0.10
L. Tahiti East	8	0.63	5	0.66	0.54
L. Tahiti West	69	0.10	7	0.92	0.09
Twain North	62	0.10	6	0.79	0.09
Twain South	88	0.13	12	1.45	0.11
Twain West	29	0.10	3	0.40	0.09
Twain New	52	0.12	6	0.79	0.10
Spot	208	0.11	22	2.77	0.09
Negit Islet totals/averages:	**580**	**0.18 ± .06**	**68**	**10.64**	**0.102 ± .056**
Coyote Cove	20	0.00	0	N/A	0.00
Coyote Hilltop	46	0.00	0	N/A	0.00
Paoha Islet totals/averages:	**66**	**0.00**	**0**	**N/A**	**0.00**
Lakewide	**646**	**0.11± .06**	**68**	**10.64**	**0.091± .056**

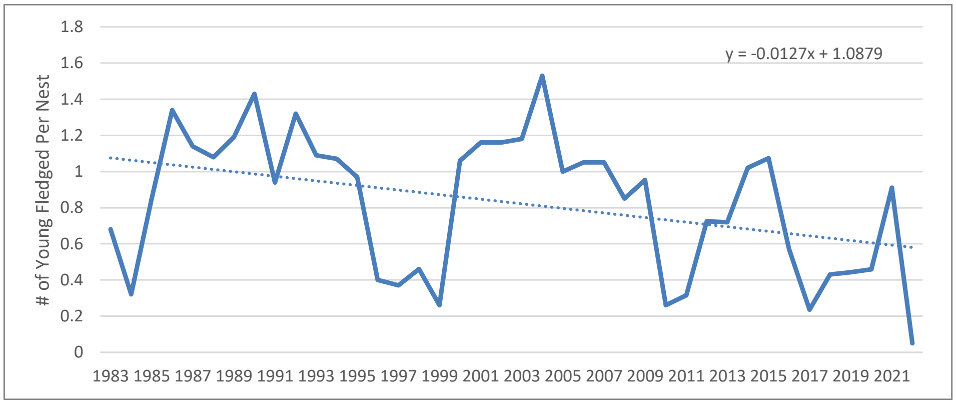

Figure 9. The estimated number of young fledged per nest at Mono Lake from 1983 – 2022 with linear regression line and equation.

Based on the total of 12,930 California Gull nests in early June, and an average of 0.09 ± 0.05 chicks fledged per nest, we estimate 1179 (± 723) young successfully fledged at Mono Lake in 2022. Prior to 2022 the previous low chick production was in 2017 when 3184 young were estimated to have fledged from the lake. Accounting for this historic low chick production in 2022, fledgling production has declined on average by 476 fledgling's pear year across the 40 years of this project (Figure 10).

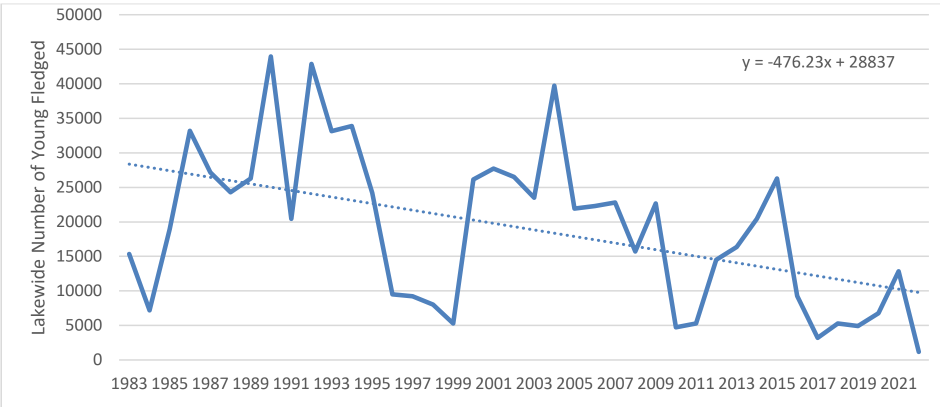

Figure 10. The estimated total number of young fledged from Mono Lake from 1983 – 2021 with linear trend and regression equation.

DISCUSSION

The nesting population size of California Gulls at Mono Lake has declined dramatically over the course of this long-term study. While nests numbers rebounded in 2020 and held fairly steady in 2021, they again declined in 2022 to the second lowest level in the 40-year history of the study. The lower nest numbers in 2022 compared to 2020 and 2021 was counter to our predictions based on previous studies (Wregge et al. 2006, Nelson et al. 2014) that would have predicted higher nest productivity and nesting numbers following the breakup of chemical stratification of the lake in 2020.

In 2022, we documented the poorest chick production in the history of the study with 2,007 less chicks produced than the previous low in 2017 and 11,664 fewer chicks in 2022 than in 2021. Identifying the causes of this near breeding failure in 2022 is beyond the scope of this study but here we provide some theories based on available evidence and long-term study of this species at Mono Lake. We believe the four most likely causes of poor chick production are predation, food availability, disease. We also investigated the less likely scenario that breeding phenology was advanced and chicks had already fledged by the time we captured imagery in mid-July.

Following the discovery of low numbers of chicks in the long-term study plots, we systematically counted chicks across all of Twain Islet (the largest breeding colony by far). We did this to determine if chicks may have fledged early in the relatively dry year and had left nest plots or if chick numbers were markedly different across the entire island compared to the relatively small nest plots. The canvassing of Twain (from aerial imagery) confirmed the results from the nest plots of low chick production. We found 398 chicks across the entire island which equates to 0.044 per nest, even lower than our plot estimate of 0.09 chicks/nest but within 1 standard error of our estimate. This count of the entire island likely missed a small number of chicks but is likely within 10% based on missed nests during the first pass of nest counts using the same method. We also counted chicks across all of Coyote islet and found none – confirming the plot estimates of no chick production on this island in 2022. We searched for recently fledged juveniles along the shorelines and just offshore and found only a few (less than 10) which aligns with patterns observed in previous years. Moreover, the absence of chicks in the nest count imagery from early June, combined with the lack of historical instances of significant shifts in nesting timing, leads us to conclude that nesting phenology was not the underlying reason for the low chick count in the imagery. Based on the lack of large dead young in the images and the presence of a substantial number of nests in early June, the breeding failure likely occurred either late in the incubation period or soon after hatching.

While it is not possible to determine with a high confidence the cause, predation seems unlikely to be able to entirely explain widespread nest/nestling loss across all the islets as they are geographically spread across several miles of the lake. However, the complete breeding failure on Coyote islet, where water levels in the straight between it and Paoha were very shallow in 2022, most closely matches the pattern from previous coyote predation events on the Negit islets and at the Old Marina, so we cannot rule out that predation played a role in 2022. In 2023 we plan to conduct a third visit to the breeding islets to evaluate chick mortality and survey for signs of predators.

Lake elevation at the end of the breeding season in 2022 was 6379 amsl, one of the lowest documented since a California waterboard decision (D-1631) was made in 1994 to manage Mono Lake at 6392 amsl. Low lake levels increase the probability of mammalian predators reaching nesting islands as was documented as recently as 2016 (Nelson et al. 2016) and presumed in 2004 at the Old Marina (Hite et al. 2004). Efforts to ensure predator-free nesting islands are important for reversing declines in the California Gull nesting population at Mono Lake. Higher lake levels will reduce salinity which should increase the lakes' resilience to persistent stratification (meromixis) that is known to reduce gull productivity at Mono Lake (Nelson et al. 2014). The exceptional 2022/2023 winter precipitation has resulted in Mono Lake rising 4 feet above August 2022 levels as of August 2023, reducing the immediate risk of terrestrial predators accessing nesting islands. Raising lake levels several more feet over the next several years would provide a buffer for future extreme drought years leading to predator access to nesting islands.

We believe that adult fitness and inability to procure sufficient food resources to provision young is probably the most likely cause of the poor chick production. The gull nesting population size each year is responsive to lower lake productivity (in the form of brine shrimp abundance). The 2022 spring shrimp hatch was small and considerably delayed compared to 2021 and exceptional post-meromictic year (Figure 11, LADWP 2022).

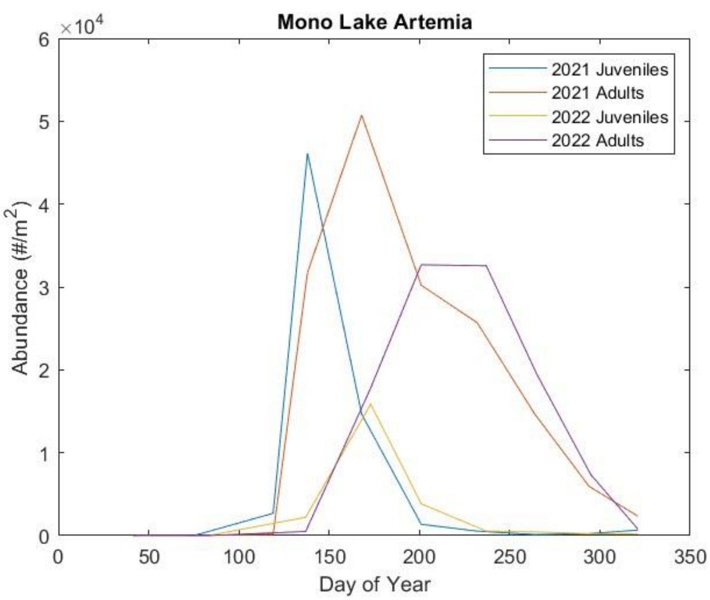

Figure 11. Abundance and phenology of brine shrimp (*Artemia monica*) in Mono Lake in 2021 compared to 2022 (courtesy of LADWP).

Adult shrimp abundance in mid- June was five to six times greater in 2021 than in 2022. In spring and summer 2022 we and others remarked on how green the lake was in early June, lasting even into July. A similar condition existed in 1981, where the persistent green conditions and a small and delayed spring hatch of brine shrimp was noted during the period of lowest lake water levels since exports began in the 1940's (Winkler 1981). Winkler documented a near complete breeding failure with scores of dead chicks found on the islands in late summer after a successful gull hatch was documented in early July. A delay in the proliferation of the gull's primary food sources in most years could result in adults not being able to meet the energetic demands of raising chicks. This could lead to chick mortality from starvation but also from lack of parental vigilance leading to increased mortality from exposure and cannibalism from hungry adult gulls. However, total shrimp abundance and centroid of abundance in 2022 were similar to other recent years such as 2017 – 2019. These years also had poor chick production, but it was still far greater in those years than the nearly complete failure in 2022. The California Gulls at Mono Lake may be rather susceptible to phenological changes in prey availability.

The relationship between brine shrimp abundance and timing and gull chick production is not fully understood. The abundance and timing of peak brine shrimp abundance was not found to be a significant predictor of chick production at Mono Lake using the best available data at the time (Nelson et al. 2014), even though brine shrimp are known to be a significant portion of their diet in most years (Wrege et al. 2001). The gull's ability to turn to other sources of food (cicadas, garbage) may have muted the signal with brine shrimp across the long duration of this study. We have no information on cicada/grasshopper abundance or brine fly abundance at Mono Lake. Now that the landfill does not provide a significant source of food (since mid-1990s), the gulls may be susceptible to breeding failures in years in which low cicada numbers coincide with delayed and low brine shrimp production. Some of the lowest gull chick production years have coincided with late brine shrimp peaks (e.g., 1999, 2017). Further exploration of the relationship between California Gull chick production and food availability, in particular timing of bring shrimp availability, but also other prey (e.g., brine flies and cicadas) is needed to better understand annual variation in gull productivity at Mono Lake.

Commented [RB1]: Wrege, P.H., J.M. Hite, and D.W. Winkler. 2001. The diets of California gull nestlings at Mono Lake: seasonal and diurnal variation. Point Reyes Bird Observatory, Stinson Beach, CA. Contribution No. 939.

Disease and parasites could in part explain the breeding failure. We noticed an unusual number of freshly dead adults in the July 2022 images compared to recent years. These birds were all face down with wings splayed. We did not get a complete count but estimated upwards of 40 freshly dead adults on Twain islet alone in the July imagery. Detecting dead juvenile birds, especially small ones is not possible from the aerial imagery because they are cryptically colored, small, and downy individuals desiccate quickly and blend into their surroundings. California Gulls are susceptible to disease outbreaks such as botulism (Rocke & Friend 1999, Kadlec 2002). Another possible cause is avian influenza (H5N1) which may result in mortality in both adult and young birds and could reduce adult fitness thus increasing nest failure rates. Large tick (*Argus monolakensis*) outbreaks have been identified as a cause of chick mortality at Mono Lake in the past (Hite et al. 2003). However, in the past tick infestations have been variable across plots and islands, never having been documented as widespread. For most chicks, moderate tick infestations have not translated to increased mortality (Hite et al. 2003). We have no direct evidence to suggest disease was the cause of poor chick production in 2022 but it is among the possible explanations. Disease surveillance of gulls at Mono Lake would help better understand factors influencing population changes we have documented.

We continued to improve our use of UAV's to sample the nesting gull population in 2022. We again observed very minimal apparent disturbance to gulls from the UAV's as evidenced by very few gulls taking flight during the survey. We worked this winter on our long-term goal of using artificial intelligence to detect nests and chicks by labeling each gull observed in the nest images. We will continue to work on this aspect of the project to realize significant efficiencies in future years. This will also allow us to use all the nesting birds to assess reproductive success and chick production, which will provide a more robust estimate of productivity. We continue to recommend conducting aerial surveys as late as possible before the oldest birds fledge to maximize detection probability of chicks to minimize bias imparted between the two different methods.

Conclusion

The Mono Lake California Gull population is declining. Continued steep declines in the number of nests and number of young fledged over the 40-year period of the study have resulted in a gull population that is about half the size that it was during the peak population during the course of this study (mid 1990's). Mono Lake, with its permanent protected status as part of the Inyo National Forest and Mono Lake Tufa State Natural Preserve, is of critical importance for the persistence of California Gulls in California. Measures taken to ensure high quality nesting habitat (predator & weed free) and high lake productivity to provide ample food for the gulls, including increasing the resilience of the lake to meromictic conditions, may help reverse declines in this population and ensure California Gulls can thrive at Mono Lake. Additional studies to evaluate factors influencing these declines (food availability, predator activity, disease) would be useful for prioritizing management actions to reverse recent declines.

Literature Cited

ESRI 2021. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Kadlec, John. (2002). Avian botulism in Great Salt Lake marshes: perspectives and possible mechanisms. Wildlife Society Bulletin. 30. 983-989. 10.2307/3784258.

LADWP (Los Angeles Department of Water and Power). 2022. Mono Basin Annual Monitoring Reports. Prepared for State Water Resources Control Board In accordance with the terms and conditions of amended license Nos. 10191 and 10192.

Nelson, K. N., L. J. Roberts, W. D. Shuford, and R. D. Burnett. 2014. Environmental influences on reproductive success of California gulls at Mono Lake, California, U.S.A. Contribution No. 1981, Point Blue Conservation Science, 3820 Cypress Dr. #11, Petaluma, CA 94954.

Nelson, K. N. 2016. Population size and reproductive success of California Gulls at Mono Lake, California. Contribution No. 2108, Pt Blue Conservation Science, 3820 Cypress Dr. #11, Petaluma, CA 94954.

Nelson, K.N. & N. Livingston. 2019. Population size and reproductive success of California Gulls at Mono Lake, California. Contribution No. 2269, Pt Blue Conservation Science, 3820 Cypress Dr. #11, Petaluma, CA 94954.

Rocke, T.E. & M. Friend. 1999. Field manual of wildlife diseases: general field procedures and disease of birds. USGS Technical Report. Reston, VA.

Shah, K., G. Ballard, A. Schmidt, M. Schwager. 2020. Multidrone aerial surveys of penguin colonies in Antarctica. Science Robotics 5: eabc3000.

Winkler, D.W. 1977 (ed.). An ecological study of Mono Lake, California. Institute of Ecology Publication 12. University of California, Davis.

Winkler, D.W. 1981. Report on the 1981 Gull Census and Chick Mortality at Mono Lake. *In* The Mono Lake Newsletter. Vol. 4, No.2. Available at: https://www.monolake.org/wp-content/uploads/2020/09/1981-Autumn-Mono-Lake-Newsletter.pdf

Winkler, D. W. 1996. California Gull (*Larus californicus*). *In* The Birds of North America, No. 259 (A. Poole and F. Gill, eds.) The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Wrege, P.H., J.M. Hite, & D.W. Winkler. 2001. The diets of California gull nestlings at Mono Lake: seasonal and diurnal variation. Point Reyes Bird Observatory. 4990 Shoreline Hwy. Stinson Beach, CA. Contribution No. 939.

Wrege, P. W., W. D. Shuford, D. W. Winkler, and R. Jellison. 2006. Annual variation in numbers of breeding California Gulls at Mono Lake, California: The importance of natal philopatry and local and regional conditions. Condor: 108:82-96.

Appendix B. Nest number by islet, 2010 – 2022.

Negit Islets	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Twain	8219	8704	9396	9567	9144	12263	7760	7672	7639	7601	10737	9936	9094
L. Tahiti	2429	2049	3366	3995	3899	4258	2923	1795	1860	1230	1291	1530	1229
L Norway	114	171	390	493	384	505	284 [c]	163	220	185	467	496	356
Steamboat	509	579	871	1175	1076	1010	675	217	143	120	115	114	61
Java	367	432	325	234	216	439	60	0	0	0	0	0	0
Spot	122	151	39	95	162	184	144	55	36	59	104	163	208
Tie/Hat	55	65	54	86	94	206	191	51	63	38	23	69	47
Krakatoa	2	0	12	9	12	84	38	40	73	50	81	59	27
L. Tahiti Minor [c]	151	162	253	282	255	202	116	64	64	63	62	68	68
Pancake	1894	1741	1972	2450	1903	3159	2497	1814	1099	778	709	558	756
Negit Islets Total	13862	14054	16678	18386	17149	22317	14704	11890	11215	10128	13589	12993	11846
Paoha Islets													
Coyote	1711	929	1393	2093	2618	2042	1432	1505	1038	892	1014	1063	1015
Browne	116	50	60	75	110	87	146 [c]	152	38	55	41	49	69
Piglet	997	599	344	148	38 [b]	0	0	0	0	0	81	6	0
Paoha Islets Total:	2824	1578	1797	2316	2766	2129	1578	1657	1076	947	1136	1118	1084
Negit Island:	0	0	7	8	28	16	0	0	0	0	0	0	0
Old Marina	1496	1133	1541	1665	9 [b]	0	0	0	0	0	0	0	0
O.M. So.	4	9	36	380	70 [b]	0	0	0	0	0	0	0	0
Lakewide Total	18186	16774	20059	22755	20022	24462	16282	13547	12291	11075	14725	14111	12930
Nesting Adults	36372	33548	40118	45510	40044	48924	32564	27094	24582	22150	29450	28222	25860