# AVIAN POPULATION ANALYSIS OF THE WILLARD SPUR

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OCTOBER 30, 2013

## Introduction

The Willard Spur (hereafter Spur) is located along the northeastern edge of the Great Salt Lake (GSL) near Willard and Perry, Utah. It lies within a region of the GSL known as the Bear River Bay. The Spur is bounded along its northern edge by the Bear River Migratory Bird Refuge, the Willard Bay reservoir dike on the east, the north Harold Crane dike and emergent marsh on the south, and GSL Minerals Company on the west (Figure 1). The Spur represents an important site for avian diversity and abundance within the GSL ecosystem and is an important component of the Bear River Bay Important Bird Area designated in 2004 (Evans and Martinson 2008). The Important Bird Areas Program (IBA) is administered by the National Audubon Society and is a global effort to identify and conserve areas that are vital to birds and other biodiversity. As a component of an IBA, the Spur provides critical habitat for both migrating and breeding birds, primarily aquatic species such as shorebirds, waterfowl and colonial waterbirds.

In 2010, the cities of Willard and Perry completed construction on a joint municipal wastewater project and submitted a Utah Pollutant Discharge Elimination System (UPDES) permit to be allowed the discharge of treated effluent into the nearby Spur. In response, Western Resource Advocates working on behalf of the Utah Waterfowl Association petitioned the Utah Water Quality Board and Division of Water Quality (DWQ) to deny the cities' discharge permits or alternatively change the classification of the Spur to protect this wetland. This petition was denied. However, the Water Quality Board requested impact studies to be conducted on the Spur by the DWQ. These studies resulted in a modified UPDES permit for discharge into the Spur. Subsequently discharge into the Spur began on March 7, 2011. Since then the DWQ, with an agreement with Bear River Migratory Bird Refuge, are pursuing additional studies to protect the Willard Spur ecosystem. This study examines how changing hydrological conditions (lake elevations and water flow) of the Spur may impact avian populations found within the study area.

## Methods

### Avian Population Data

Avian population data from the Great Salt Lake and Spur were obtained from the Utah Division of Wildlife Resources, Great Salt Lake Waterbird Surveys (Paul and Manning 2008). Data used for this analysis were collected from 1999 – 2012 within the Spur. These data were collected as aerial surveys using the same methodologies. Methods are outlined in Paul and Manning (2008) but are summarized here as well. *A total of four, 0.25-mile wide transects were arranged within the Spur. Each transect was spaced one mile apart from adjacent transects. Transects were positioned 0.5 miles from the 1997 shoreline (GSL elevation approximately 4201.10') to avoid overlap with shoreline surveys. The speed of the aircraft varied according to the variety and abundance of waterbirds, but typically ranged from 80-100 mph. Elevation varied, but the pilot and observers worked at maintaining an elevation of approximately 80-200 feet above the water surface. Two observers identified and counted waterbirds out to 0.125 miles on each side of the plane while noting observations on audiocassette recorders* (Paul and Manning 2008).

The range of dates for surveys varied from year to year. Surveys were initially conducted every 2-weeks, late April – late September from 1999 – 2001. Additional data were collected in late July and August 2004; April, May and July 2005; April, July and August 2007; April, July and August 2008, 2009; May, July, August 2010, 2011; April, May, July and August 2012.

To account for seasonal changes in avian abundance and hydrologic cycles, data were grouped into three seasonal categories and analyzed separately in all statistical tests. These categories were defined as spring staging (April), breeding season (May – June) and fall staging (July – September). We assumed data collected within a given month were not independent. Thus, to avoid pseudoreplication (*sensu* Hurlbert 1984), data were first averaged by month and then these means were used in the analyses. Seasonal differences in populations utilizing the Spur were tested with a Kruskal-Wallis non-parametric analysis of variance (Sokal and Rohlf 1981).

**Willard Spur Hydrological Data**

Unfortunately, no hydrological data sets exist for the Spur that cover the entire range of avian survey dates. Monitoring of Spur elevation didn't begin until the spring of 2011. Consequently, only nine Spur elevations were recorded that coincided with avian surveys. These data were insufficient to conduct statistical analyses testing the relationship with aquatic bird counts. This required the use of ancillary data that may provide insight into the use of the Spur by aquatic birds as a function of hydrology. Datasets that span the entire length of aerial survey data are rare but a few sources were available. These included Great Salt Lake elevation measured at Saltair (USGS 2012) and the in-flow of water to the Spur through the Bear River at Corrine (USGS 2012). We utilized these sources of data with the underlying assumption that both GSL elevation and Corrine in-flows are in some way correlated with Spur hydrological cycles. It should be understood that these variables are likely only crude surrogates for Spur hydrological data.

In addition to ancillary data, we obtained satellite imagery from NASA's MODIS instrument provided by the EOSDIS Land and Atmosphere Near-real-time Capability for EOS (LANCE) Rapid Response system (http://lance.nasa.gov/imagery/rapid-response/ accessed September 15, 2013). Images from this dataset were not available for the entire range of survey dates. However, images were located that corresponded with survey dates April 21, 2005 through 2012. These images were qualitatively classified according to the extent of water that could be seen within the Spur. This classification was conducted independently by two different observers. The classification scheme was defined as *low* – little to no water coverage; *mid* – intermediate water coverage; and *high* – extensive water covering the entire Spur (see Figure 2). Following the ranking of images, data were compared between observers. Eighty-three percent of images were classified identically. In the five instances where the classification of images differed, the observers met and agreed on a classification score.

**Relationship between Hydrology and Avian Populations**

The relationship between hydrological variables and Spur avian populations were examined in two different ways. First, Spur imagery classifications were used in an analysis of covariance testing for population differences with Julian day as the covariate. Second, we utilized stepwise regression techniques to build models that predicted avian population use of the Spur with Corrine in-flow and GSL elevation as dependent variables. Transformation of avian population data were made to satisfy assumptions of normality and equal variance.

## RESULTS

**Willard Spur Species Composition**

A total of 56 species were recorded during Spur aerial surveys from 1999-2012. Table 1 provides species names, four-letter codes and summary data for 54 species. Two species, Tundra Swan (*Cygnus columbianus*) and Trumpeter Swan (*Cygnus buccinators*) were not included as they were only recorded during a single survey each. Twenty species detected had peak counts within the Spur that were at least 10% of the GSL peak counts (Table 1). A suite of 11 focal species representing numerically important groups or species that utilize diverse foraging behaviors were chosen to include in statistical tests.

**Focal Species Accounts**
*Cinnamon Teal (CITE)* – The CITE peak count of 8,715 occurred on 8/24/2009 and represents 32.8% of the GSL peak count. Median counts of CITE within the Spur did not differ significantly among seasons (Table 2). There were no significant differences in CITE counts relative to the Spur elevation classification (Table 3). However, fall staging counts of CITE were best described by a regression model that included a negative relationship of GSL elevation (Figure 3, Table 4). No other significant relationships were detected.

*Western/Clark's Grebe* (WCGR) – Differentiating Western from Clark's Grebe is difficult during aerial surveys, so these species were considered together. The peak WCGR count of 1,670 occurred on 8/30/2004. This represents 52.3% of the GSL peak count (Table 1). Median WCGR counts did not differ among seasons (Table 2). The ANCOVA model testing for differences in counts relative to the Spur elevation classification was significant (Table 3). However, the significant model was attributed to significant variation in the covariate Julian day, rather than any effect of Spur classification on variation in WCGR counts. Fall counts of WCGR were best described by a regression model that includes a negative relationship of GSL elevation (Figure 4, Table 4). Spring staging or breeding season counts could not adequately be explained with any combination of GSL elevation or Corrine in-flows (Table 4).

*American White Pelican (AWPE)* – A peak AWPE count of 5,921 was recorded on 9/09/1999. This represents 14.3% of the GSL peak count for AWPE (Paul and Manning 2008). Populations typically begin to increase within the Spur by the beginning of June with high counts recorded in July and August each year. Median fall staging counts were significantly greater than spring counts (Table 2) but not different from counts during the breeding season. Many of the individuals using the Spur likely come from Gunnison Island, a nesting colony located approximately 50 km west in the north arm of the Great Salt Lake. This is one of the largest breeding colonies of AWPE located within the Intermountain West (Cavitt et al. *in press*). The breeding population at this site is quite variable from year-to-year. Utah Division of Wildlife Resources counts conducted from 1999 – 2010 indicate that the Gunnison Island colony has ranged from 8,658 to 17,958 breeding birds (Cavitt et al. *in press*). Despite the proximity to this colony, we found no support for the hypothesis that maximum counts of AWPE found using the Spur are correlated with Gunnison Island colony size ($r = 0.093$; $P = 0.811$). We also found no significant relationship between the Spur elevation classification and counts of AWPE (Table 3). However, counts conducted during the breeding season were positively related to GSL elevation (Figure 5, Table 4).

*White-faced Ibis* (WFIB) – The peak WFIB count of 6,388 occurred on 8/02/2012. This represents 17% of the GSL peak count (Table 1). The median fall count of WFIB within the Spur was significantly greater than the median counts during spring but not significantly different during the breeding and spring seasons, or during fall and breeding seasons (Table 2). The ANCOVA model testing for differences in counts relative to the Spur elevation classification was significant (Table 3). However, the significant model was attributed to the effects of the Julian day covariate rather than any effect of Spur classification (Table 3). Spring counts of WFIB were best described by a regression model that included a negative relationship of Corrine in-flows (Figure 6, Table 4). Fall staging counts were best described by a regression model that included a negative relationship with GSL elevation (Figure 7, Table 4). Spring staging counts could not adequately be explained with any combination of GSL elevation or Corrine in-flows (Table 4).

*American Coot (AMCO)* – The high count for AMCO within the Spur was 8,910 recorded on 8/24/2009. This represents 14.7% of the GSL peak count. Median counts were significantly higher during spring migration relative to either breeding or fall counts (Table 2). Significantly fewer AMCO were counted during periods when the Spur elevation was classified as *low* relative to either classification of *mid* or *high* (Table 3). Fall counts of AMCO within the Spur were positively related to Corrine in-flows (Table 4, Figure 8). AMCO counts were not significantly related to either GSL elevation or Corrine in-flows to the Spur during any other season (Table 4).

*Black-necked Stilt (BNST)* - The high count of BNST within the Spur was 3,148 recorded on 8/3/2010 (Table 1). Median fall counts were significantly greater than counts during either spring migration or the breeding season (Table 2). The ANCOVA model testing for differences in counts between Spur elevation classifications was significant (Table 3). The *low* Spur classification had higher BNST counts than did the *mid* or *high* classifications. Fall migration counts of BNST within the Spur were negatively related to GSL elevation (Table 4, Figure 9). No significant relationships were detected during spring migration or breeding season with either GSL elevation or Corrine in-flows to the Spur (Table 4).

*American Avocet (AMAV)* – The high count of AMAV within the Spur was 9,083 recorded on 7/19/2000 (Table 1). AMAV populations utilizing the Spur typically have two peaks in abundance each year. The largest peak occurs during the fall migration beginning in early July, with a second, smaller peak, occurring during spring migration (mid-April). However, median counts were not significantly different between seasons (Table 2). Spur elevation classifications did not significantly influence AMAV counts (Table 3). Fall migration counts of AMAV within the Spur were positively related to GSL elevation (Table 4, Figure 10). No significant relationships were detected during spring migration or breeding season with either GSL elevation or Corrine in-flows to the Spur (Table 4).

*Marbled Godwit* (MAGO) – Despite the fact that MAGO do not breed in Utah, individuals have been counted in the Spur during May and June (median counts = 103, lower and upper quartiles = 47.5 – 225). We refer to this period as "breeding season" to be consistent with other species accounts. The peak count for MAGO within the Spur was 4,765 recorded on 7/18/2001. This represents 24.3% of the GSL peak count (Table 1). The median fall staging count of MAGO within the Spur was significantly greater than the median counts during the "breeding season" (Table 2). However, counts were not significantly different during the "breeding" and spring seasons or during the fall and spring. There were no significant differences in MAGO counts relative to the Spur elevation classification (Table 3). "Breeding season", fall or spring staging counts could not adequately be explained with any combination of GSL elevation or Corrine in-flows (Table 4).

*Phalarope* (PHAL) – A single grouping of designated as "phalarope" was used to account for difficulty in separating Wilson's and Red-necked Phalarope during aerial surveys. The peak count of 6,055 phalarope occurred on 8/20/2008 (Table 1). The median fall staging count of

PHAL within the Spur was significantly greater than the median counts during the breeding season (Table 2). However, counts were not significantly different during the breeding and spring seasons or during the fall and spring. Spur elevation classifications did not differ significantly in PHAL counts (Table 3). Breeding season, fall or spring staging counts could not adequately be explained with any combination of GSL elevation or Corrine in-flows (Table 4).

*California Gull (CAGU)* – The peak count for CAGU was 2,320 on 8/15/2011. CAGU populations within the Spur undergo a small increase in mid – late April with a larger peak occurring in early to mid-August each year. However, median counts did not differ significantly between seasons (Table 2). There was no significant difference between the Spur elevation classification and counts of CAGU (Table 3). Fall counts of CAGU were negatively related to GSL elevation (Figure 11, Table 4) but no other relationships were detected.

*Forester's Tern* (FOTE) – The peak count for FOTE within the Spur was 690 on 8/20/2008. This represents 42.1% of the GSL peak count of 1,639 (Table 1). Median spring counts of FOTE were significantly smaller than median counts during both the breeding season and fall staging (Table 2). There were no significant differences in FOTE counts relative to the Spur elevation classification (Table 3). No significant relationships were detected with either GSL elevation or Corrine in-flows to the Spur (Table 4).

## DISCUSSION

The Willard Spur represents critical habitat within the GSL ecosystem for tens of thousands of aquatic birds. Peak population counts of 20 different species within the Spur are more than 10% of the peak counts for the entire GSL. In fact, 11 species have peak Spur counts greater than 20% of GSL peak counts and five species greater than 30%.

Unfortunately, direct tests of the relationships between Spur hydrology and avian population use are unavailable at this time. Data analyzed for this report, however may provide some insight into how aquatic bird populations may respond to changing water conditions in and around the Spur. The results from this study can be divided into those species that demonstrate a positive hydrological response, a negative hydrological response and those where no response can be detected.

Three focal species, American White Pelican, American Coot and American Avocet, demonstrated positive hydrological responses. American White Pelican and American Avocet Spur population counts were positively related to mean GSL elevation. Population counts of American Coot at the Spur where higher at greater Bear River in-flows and during periods when satellite imagery of the Spur indicated water coverage as either *mid* or *high*. These results are consistent with the foraging behavior and habitat selection of these species (Robinson et al. 1997, Brisban and Mowbray 2002, Knopf and Evans 2004, Cavitt 2006). In addition, American Avocets become more limited in shoreline habitat as GSL elevation increases. This results in their increased utilization of the Spur during higher GSL elevations (J. Neill *personal communication*).

Spur population counts of six focal species, Cinnamon Teal, Western/Clark's Grebe, White-faced Ibis, Black-necked Stilt, Marbled Godwit and California Gull, were all found to respond negatively to either increases in GSL elevation or Bear River in-flows. In addition, Black-necked Stilts also were found to have higher Spur counts when satellite imagery indicated water coverage as *low*. Cinnamon Teal prefer to forage within shallow, flooded zones along the margins of wetlands with dense stands of bulrush (Gammonley 2012). These conditions are likely maximized within the Spur when GSL mean elevation is low. Similarly, White-faced Ibis, Black-necked Stilt and Marbled Godwit prefer foraging in shallow wetlands and mudflats (Ryder and Manry 1994, Robinson et al. 1999, Gratto-Trevor 2000, Cavitt 2006). California Gulls prefer a wide range of conditions but are also commonly observed congregating in shallow wetlands (Winkler 1996). Somewhat surprisingly was that mean fall counts of Western/Clark's Grebes were negatively related to GSL mean elevation. These species prefer extensive areas of open water bordered by emergent vegetation (Storer and Nuechterlein 1992). One would expect that these conditions most likely occur during periods when the Spur is at higher elevations. There are two possible explanations for this result. Because these species are piscivorous, Western/Clark's Grebes may take advantage of declining water levels within the Spur to forage for fish. Alternatively, the result obtained may be an artifact of detection probability during aerial surveys. It is likely that detections of these species are much higher when water levels within the Spur are low. During these conditions individuals may tend to congregate in the remaining open water habitat.

Both phalarope and Forester's Tern showed no response to hydrological conditions. Counts of both species were relatively low within the Spur. For Forester's Terns in particular it is likely that aerial surveys may not be the best technique to evaluate their abundance within the GSL ecosystem.

The current data-sets available do not provide for direct comparisons of population data and Spur hydrology. However the results of this study demonstrate that several species are likely to respond, either positively or negatively to hydrological changes within the Spur.

## Acknowledgements

Special thanks to John Luft and John Neill from the Great Salt Lake Ecosystem Program, Utah Division of Wildlife Resources for providing data and suggestions on portions of this report. Lessie Swenson provided assistance with processing and formatting.

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Table 1. Species encountered during Willard Spur aerial surveys 1999 – 2012. Bolded species indicate those with Willard Spur peak counts comprising more than 10% of the Great Salt Lake peak counts (Paul and Manning 2008). An * represents focal species utilized within population analyses. Species are listed in taxonomic order.

| Species Code | Common Name | Scientific Name | Peak GSL Count | Total Willard Count | Peak Willard Count | % GSL Peak Count | Mean Willard Count | ± STD Error |
|---|---|---|---|---|---|---|---|---|
| CAGO | Canada Goose | *Branta canadensis* | 15,477 | 2,009 | 448 | 2.9 | 23.9 | 8.3 |
| GADW | Gadwall | *Anas strepera* | 87,892 | 28,143 | 4,060 | 4.6 | 335.0 | 77.2 |
| AMWI | American Wigeon | *Anas americana* | 21,493 | 1,545 | 270 | 1.3 | 18.4 | 5.1 |
| ABDU | American Black Duck | *Anas rubripes* | | 15 | 15 | | 0.2 | 0.2 |
| MALL | Mallard | *Anas platyrhynchos* | 69,066 | 11,684 | 2,605 | 3.8 | 139.1 | 38.9 |
| BWTE | Blue-winged Teal | *Anas discors* | 901 | 53 | 50 | 5.5 | 0.6 | 0.6 |
| *CITE | **Cinamon Teal** | *Anas cyanoptera* | 26,586 | 21,697 | 8,715 | 32.8 | 258.3 | 110.8 |
| NSHO | Northern Shoveler | *Anas clypeata* | 83,894 | 22,149 | 3,747 | 4.5 | 263.7 | 68.2 |
| NOPI | Northern Pintail | *Anas acuta* | 126,940 | 12,353 | 1,580 | 1.2 | 147.1 | 36.5 |
| AGWT | American Green-winged Teal | *Anas crecca* | 159,829 | 76,516 | 15,350 | 9.6 | 910.9 | 271.1 |
| CANV | **Canvasback** | *Aythya valisineria* | 2,040 | 670 | 320 | 15.7 | 8.0 | 4.1 |
| REDH | Redhead | *Aythya americana* | 10,088 | 15,665 | 934 | 9.3 | 186.5 | 27.8 |
| RNDU | Ring-necked Duck | *Aythya collaris* | - | 4 | 4 | - | 0.0 | 0.0 |
| LESC | Lesser Scaup | *Aythya affinis* | 10,864 | 2,254 | 700 | 6.4 | 26.8 | 12.2 |
| LTDU | Long-tailed Duck | *Clangula hyemalis* | - | 1 | 1 | - | 0.0 | 0.0 |
| BUFF | Bufflehead | *Bucephala albeola* | 776 | 237 | 52 | 6.7 | 2.8 | 1.1 |
| COGO | **Common Goldeneye** | *Bucephala clangula* | 1,882 | 647 | 472 | 25.1 | 7.7 | 5.7 |
| COME | Common Merganser | *Mergus merganser* | - | 92 | 37 | - | 1.1 | 0.6 |
| RBME | Red-breasted Merganser | *Mergus serrator* | - | 5 | 5 | - | 0.1 | 0.1 |
| RUDU | **Ruddy Duck** | *Oxyura jamaicensis* | 24,005 | 32,175 | 4,532 | 18.9 | 383.0 | 91.1 |
| EAGR | Eared Grebe | *Podiceps nigricollis* | 156,036 | 11,116 | 2,947 | 1.9 | 132.3 | 43.0 |
| WEGR | Western Grebe | *Aechmophorus occidentalis* | | 11,609 | 1,133 | | 138.2 | 22.5 |
| CLGR | Clark's Grebe | *Aechmophorus clarkia* | | 22 | 10 | | 0.3 | 0.2 |
| *WCGR | **Western/Clark's Grebe** | *Aechmophorus spp.* | 3,193 | 22,335 | 1,670 | 52.3 | 265.9 | 32.6 |
| DCCO | **Double-crested Cormorant** | *Phalacrorax auritus* | 1,179 | 3,125 | 269 | 22.8 | 37.2 | 5.6 |
| *AWPE | **American White Pelican** | *Pelecanus erythrorhynchos* | 41,318 | 77,551 | 5,921 | 14.3 | 923.2 | 149.4 |
| GTBH | **Great Blue Heron** | *Ardea herodias* | 636 | 1,236 | 132 | 20.8 | 14.7 | 2.4 |
| GREG | Great Egret | *Ardea alba* | - | 38 | 7 | - | 0.5 | 0.1 |

| Species Code | Common Name | Scientific Name | Peak GSL Count | Total Willard Count | Peak Willard Count | % GSL Peak Count | Mean Willard Count | ± STD Error |
|---|---|---|---|---|---|---|---|---|
| SNEG | **Snowy Egret** | *Egretta thula* | 1,741 | 5,691 | 656 | 37.7 | 67.8 | 12.2 |
| CAEG | Cattle Egret | *Bubulcus ibis* | - | 9 | 5 | - | 0.1 | 0.1 |
| BCNH | **Black-crowned Night-Heron** | *Nycticorax nycticorax* | 342 | 192 | 52 | 15.2 | 2.3 | 0.7 |
| *WFIB | **White-faced Ibis** | *Plegadis chihi* | 37,568 | 97,596 | 6,388 | 17.0 | 1161.9 | 154.9 |
| *AMCO | **American Coot** | *Fulica americana* | 60,481 | 115,134 | 8,910 | 14.7 | 1370.6 | 195.4 |
| SACR | Sandhill Crane | *Grus canadensis* | 187 | 70 | 9 | 4.8 | 0.8 | 0.2 |
| BBPL | Black-bellied Plover | *Pluvialis squatarola* | | | | | | |
| KILL | Killdeer | *Charadrius vociferus* | 695 | 15 | 7 | 1.0 | 0.2 | 0.1 |
| *BNST | Black-necked Stilt | *Himantopus mexicanus* | 38,353 | 34,422 | 3,148 | 8.2 | 409.8 | 67.0 |
| *AMAV | American Avocet | *Recurvirostra americana* | 122,083 | 91,393 | 9,083 | 7.4 | 1088.0 | 187.6 |
| SPSA | Spotted Sandpiper | *Actitis macularius* | | 5 | 2 | | 0.1 | 0.0 |
| GRYE | Greater Yellowlegs | *Tringa melanoleuca* | | 1 | 1 | | 0.0 | 0.0 |
| WILL | Willet | *Catoptrophorus semipalmatus* | 1,466 | 382 | 100 | 6.8 | 4.5 | 1.7 |
| LBCU | Long-billed Curlew | *Numenius americanus* | 194 | 4 | 3 | 1.5 | 0.0 | 0.0 |
| *MAGO | **Marbled Godwit** | *Limosa fedoa* | 19,599 | 38,252 | 4,765 | 24.3 | 455.4 | 90.4 |
| SAND | Sanderling | *Calidris alba* | 2,491 | 4 | 4 | 0.2 | 0.0 | 0.0 |
| LESA | **Least Sandpiper** | *Calidris minutilla* | 1,826 | 210 | 210 | 11.5 | 2.5 | 2.5 |
| PEEP | Unknown Sandpipers | *Calidris spp.* | - | 4,744 | 1,450 | - | 56.5 | 20.3 |
| LBDO | **Long-billed Dowitcher** | *Limnodromus scolopaceus* | 19,113 | 30,080 | 4,650 | 24.3 | 358.1 | 94.7 |
| *WIPH | Wilson's Phalarope | *Phalaropus tricolor* | 171,876 | 16,586 | 5,470 | 3.2 | 197.5 | 77.0 |
| *REPH | Red-necked Phalarope | *Phalaropus lobatus* | | 40 | 40 | | 0.5 | 0.5 |
| *PHAL | Unidentified Phalarope | *Phalaropus Spp.* | - | 9,207 | 6,000 | - | 109.6 | 75.1 |
| BOGU | Bonaparte's Gull | *Larus philadelphia* | - | 352 | 180 | - | 4.2 | 2.5 |
| FRGU | Franklin's Gull | *Larus pipixcan* | 74,254 | 54,454 | 4,676 | 6.3 | 648.3 | 88.3 |
| RBGU | **Ring-billed Gull** | *Larus delawarensis* | 10,504 | 12,903 | 1,891 | 18.0 | 153.6 | 33.6 |
| *CAGU | California Gull | *Larus californicus* | 142,240 | 44,707 | 2,320 | 1.6 | 532.2 | 59.3 |
| UNGU | Unidentified Gull | *Larus spp.* | - | 13,817 | 1,485 | - | 164.5 | 36.4 |
| CATE | **Caspian Tern** | *Sterna caspia* | 253 | 294 | 52 | 20.6 | 3.5 | 0.9 |
| BLTE | **Black Tern** | *Chlidonias niger* | 1,195 | 1,268 | 500 | 41.8 | 15.1 | 7.1 |
| *FOTE | **Forester's Tern** | *Sterna forsteri* | 1,639 | 10,422 | 690 | 42.1 | 124.1 | 16.4 |

Table 2. Comparison of seasonal median population counts within the Willard Spur. For significant tests, medians with the same letters are not significantly different (P≤0.05).

| | | Median (lower, upper quartiles) | | |
|---|---|---|---|---|
| **Species Code** | ***H, df, P*** | **Spring Counts** | **Breeding Counts** | **Fall Counts** |
| CITE | 2.80, 2, 0.25 | 56.0 (0.6, 122.0) | 12.7 (3.9, 45.8) | 118.3 (0.2, 614.6) |
| WCGR | 2.62, 2, 0.27 | 133.25 (74.38, 221.88) | 211.0 (56.33, 349.75) | 318.92 (46.88, 536.13) |
| AWPE | 7.30, 2, 0.026 | 153.75[a] (64.4, 478.6) | 195[a,b] (114.5, 856.8) | 934[b] (281.4, 1429.0) |
| WFIB | 9.74, 2, 0.008 | 174.5[a] (9.38, 454.88) | 666.83[a,b] (440.25, 1341.58) | 1661.0[b] (498.25, 2405.50) |
| AMCO | 7.19, 2, 0.03 | 2097.0[a] (840.0, 3216.0) | 691.0[b] (115.0, 1045.0) | 512.5[b] (50.0, 2346.25) |
| BNST | 12.51, 2, 0.002 | 116.25[a] (13.75, 253.5) | 60.13[a] (4.67, 148.83) | 536.67[b] (187.17, 1028.5) |
| AMAV | 1.05, 2, 0.591 | 954.75 (355.5, 1446.13) | 623 (132.0, 1016.8) | 429 (169.8, 1309.3) |
| MAGO | 6.84, 2, 0.03 | 459.5[a,b] (38.75, 745.75) | 52.5[a] (3.75, 101.75) | 484.92[b] (50.0, 922.58) |
| PHAL | 7.75, 2, 0.02 | 0.0[a,b] (0.0, 2.63) | 0.0[a] (0.0, 0.0) | 52.5[b] (0.0, 519.80) |
| CAGU | 4.45, 2, 0.110 | 353.25 (147.88, 545.38) | 191.33 (111.75, 657.31) | 648.17 (245.0, 1083.0) |
| FOTE | 22.34, 2, 0.001 | 0.0[a] (0.0, 3.0) | 118.0[b] (73.0, 301.0) | 58.5[b] (6.75, 196.25) |

Table 3. Analysis of Covariance testing for differences in popualtion counts relative to Willard Spur classification with Julian day as covariate.

| | Model | Spur Classification | Julian Day |
|---|---|---|---|
| **Species** | ***F, df*** $_{\textbf{model}}$***,*** $_{\textbf{error}}$***, P*** | ***F, df, P*** | ***F, df, P*** |
| CITE | 2.71, 3,26, 0.07 | 1.35, 2, 0.28 | 5.9, 1, 0.02 |
| **WCGR** | **3.6, 3,26, 0.03** | **0.18, 2, 0.83** | **7.75, 1, 0.01** |
| AWPE | 0.68, 3,26, 0.57 | 1.02, 2, 0.38 | 0.32, 1, 0.58 |
| **WFIB** | **5.21, 3,24, 0.007** | **0.43, 2, 0.66** | **4.79, 1, 0.04** |
| **AMCO** | **3.58, 3,26, 0.03** | **4.56, 2, 0.02** | **5.22, 1, 0.03** |
| **BNST** | **7.54, 3,26, 0.001** | **3.09, 2, 0.06** | **2.96, 1, 0.10** |
| AMAV | 1.53, 3,26, 0.23 | 0.14, 2, 0.87 | 2.04, 1, 0.17 |
| MAGO | 1.67, 3,24, 0.20 | 2.16, 2, 0.14 | 0.07, 1, 0.80 |
| PHAL | 1.26, 3,7, 0.36 | 1.26, 1, 0.34 | 0.64, 1, 0.81 |
| CAGU | 2.23, 3,26, 0.11 | 0.22, 2, 0.81 | 4.5, 1, 0.04 |
| FOTE | 1.67, 3,26, 0.20 | 0.54, 2, 0.59 | 3.54, 1, 0.07 |

Table 4. Regression models testing relationships between Willard Spur population counts and Great Salt Lake elevation or Bear River in-flows at Corrine, Utah.

| | | GSL Elevation Model | Corrine In-flow Model |
|---|---|---|---|
| | | *F, df* regression, residual, *P* | *F, df* regression, residual, *P* |
| **Species** | **Season** | | |
| CITE | Spring | 2.332, 1,6, 0.178 | 0.935, 1,6, 0.371 |
| | Breeding | 1.01, 1,7, 0.349 | 0.01, 1,7, 0.934 |
| | Fall | **5.71, 1,16, 0.03** | 1.776, 1,16, 0.201 |
| WCGR | Spring | 0.210, 1,6, 0.663 | 0.002, 1,6, 0.965 |
| | Breeding | 0.962, 1,8, 0.355 | 2.153, 1,8, 0.181 |
| | Fall | **10.98, 1,22, 0.003** | 1.03, 1,22, 0.320 |
| AWPE | Spring | 1.60, 1,6, 0.253 | 0.164, 1,6, 0.70 |
| | Breeding | **5.09, 1,8, 0.05** | 1.4, 1,8, 0.28 |
| | Fall | 0.68, 1,22, 0.42 | 0.917, 1,22, 0.350 |
| WFIB | Spring | 0.089, 1,6, 0.775 | **6.135, 1,6, 0.048** |
| | Breeding | 0.191, 1,8, 0.673 | 3.677, 1,8, 0.091 |
| | Fall | **7.159, 1,22, 0.014** | 3.760, 1,22, 0.065 |
| AMCO | Spring | 2.98, 1,6, 0.135 | 4.83, 1,6, 0.07 |
| | Breeding | 3.20, 1,8, 0.11 | 0.18, 1,8, 0.68 |
| | Fall | 0.28, 1,22, 0.60 | **4.17, 1,22, 0.05** |
| BNST | Spring | 2.362, 1,6, 0.175 | 1.90, 1,6, 0.218 |
| | Breeding | 3.16, 1,8, 0.113 | 0.562, 1,8, 0.475 |
| | Fall | **12.75, 1,22, 0.002** | 0.177, 1,22, 0.678 |
| AMAV | Spring | 2.95, 1,6, 0.137 | 0.238, 1,6, 0.643 |
| | Breeding | 2.66, 1,8, 0.141 | 0.008, 1,8, 0.930 |
| | Fall | **6.40, 1,22, 0.002** | 0.325, 1,22, 0.575 |
| MAGO | Spring | 4.402, 1,6, 0.081 | 0.041, 1,6, 0.847 |
| | Breeding[1] | 2.17, 1,8, 0.179 | 2.90, 1,8, 0.127 |
| | Fall | 0.036, 1,22, 0.85 | 0.186, 1,22, 0.670 |
| PHAL | Spring | 0.418, 1,6, 0.542 | 0.978, 1,6, 0.361 |
| | Breeding | 0.240, 1,22, 0.630 | 1.104, 1,22, 0.310 |
| | Fall | 1.533, 1,8, 0.251 | 3.416, 1,8, 0.102 |
| CAGU | Spring | 0.352, 1,6, 0.575 | 0.252, 1,6, 0.633 |
| | Breeding | 0.131, 1,8, 0.726 | 3.22, 1,8, 0.111 |
| | Fall | **18.76, 1,22, 0.001** | 0.078, 1,22, 0.783 |
| FOTE | Spring | 0.52, 1,6, 0.50 | 3.47, 1,6, 0.11 |
| | Breeding | 0.97, 1,8, 0.35 | 1.71, 1,8, 0.23 |
| | Fall | 0.49, 1,22, 0.49 | 1.09, 1,22, 0.31 |

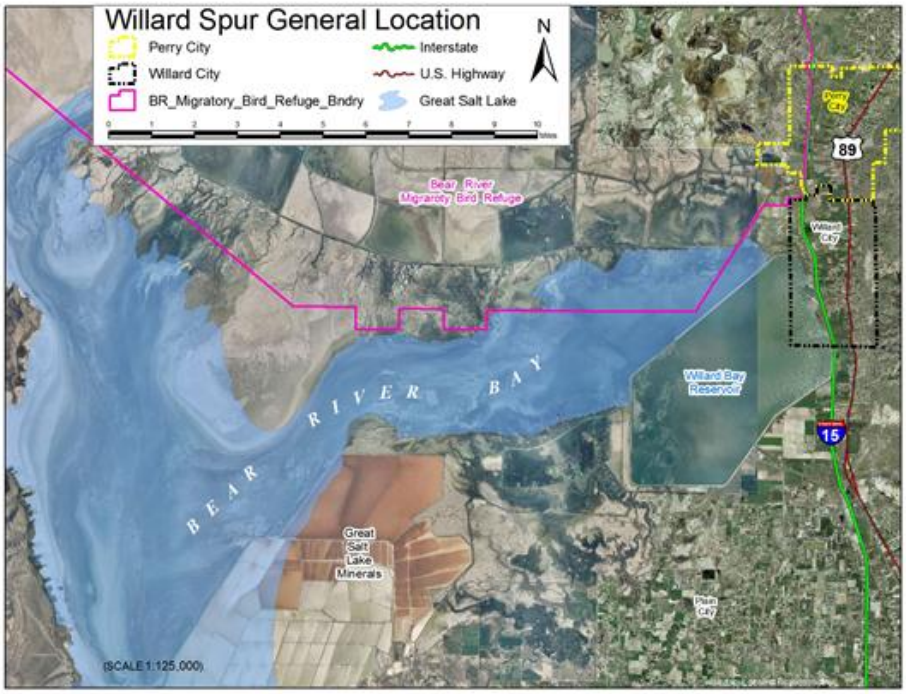


Figure 1. Map of the Willard Spur region of the Great Salt Lake ecosystem.

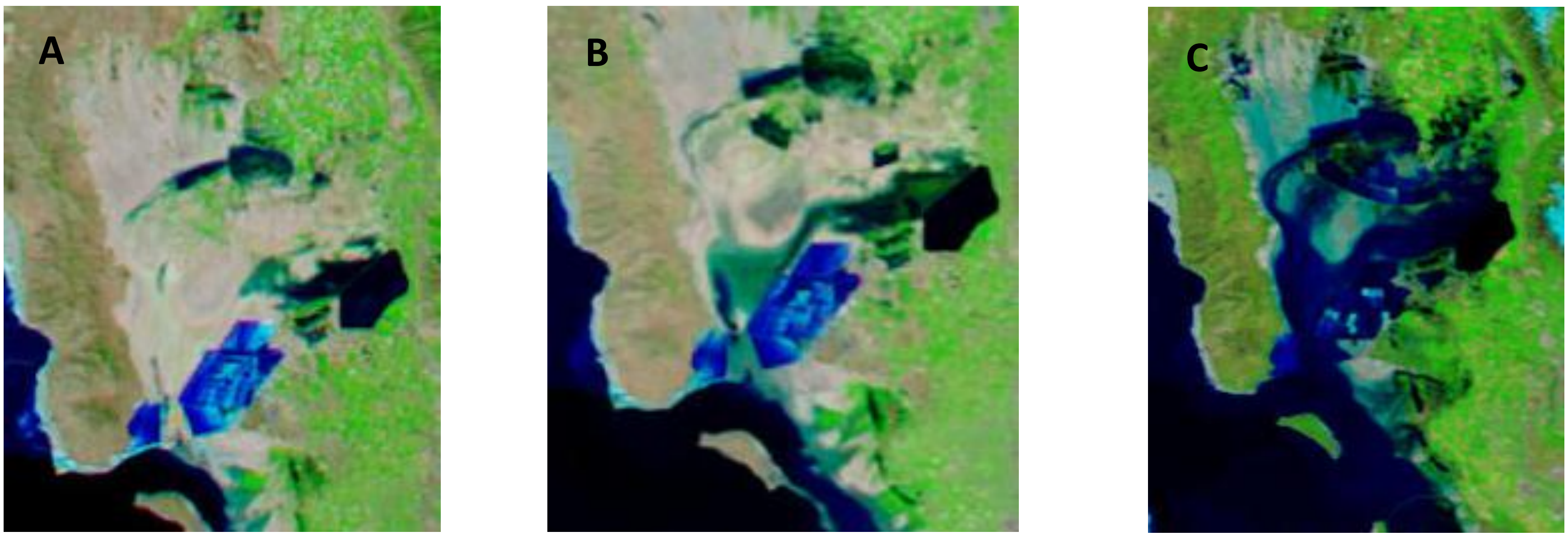


Figure 2. NASA's MODIS imagery illustrating the classification system used for evaluating Willard Spur water coverage. A) conditions of the Spur yielding a classification score of *low*; B) conditions of the Spur yielding a classification score of *mid*; C) conditions of the Spur yielding a classification score of *high* (see text for description of classification scheme).

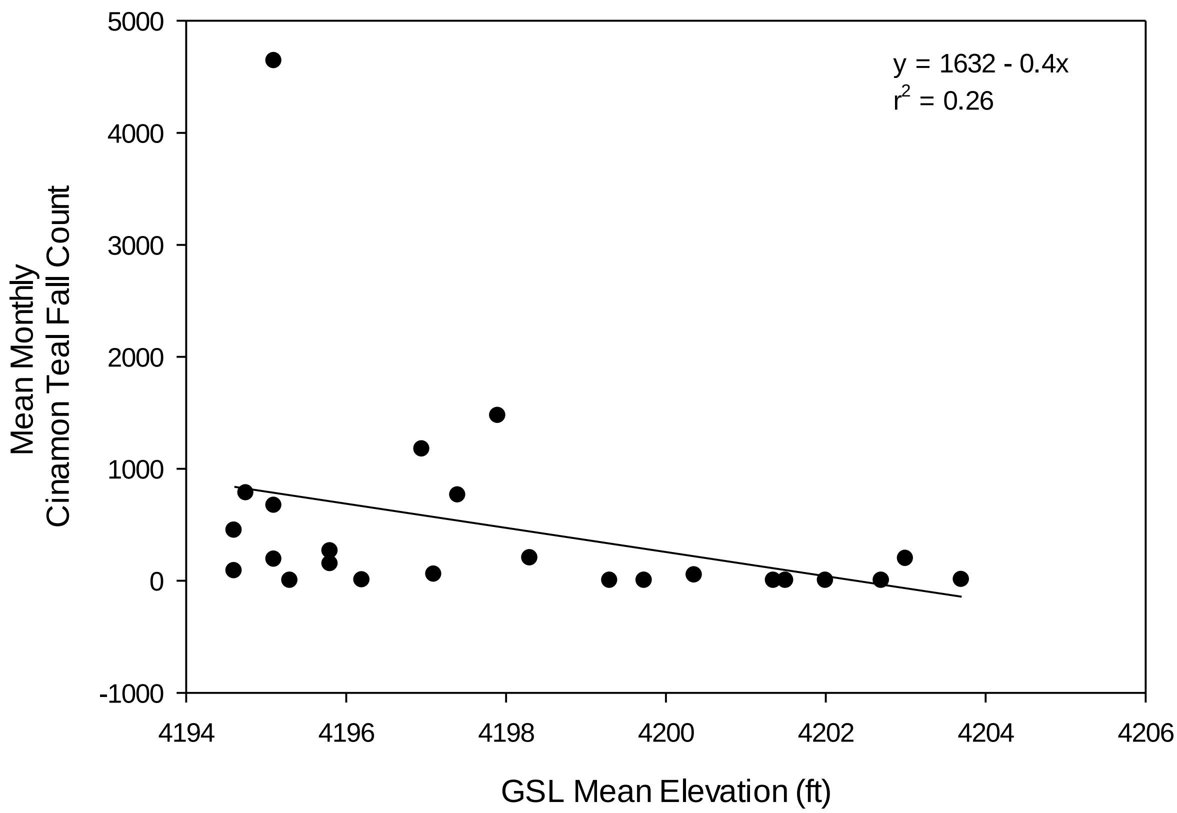


Figure 3. Relationship between mean Cinnamon Teal fall staging counts and GSL mean elevation.

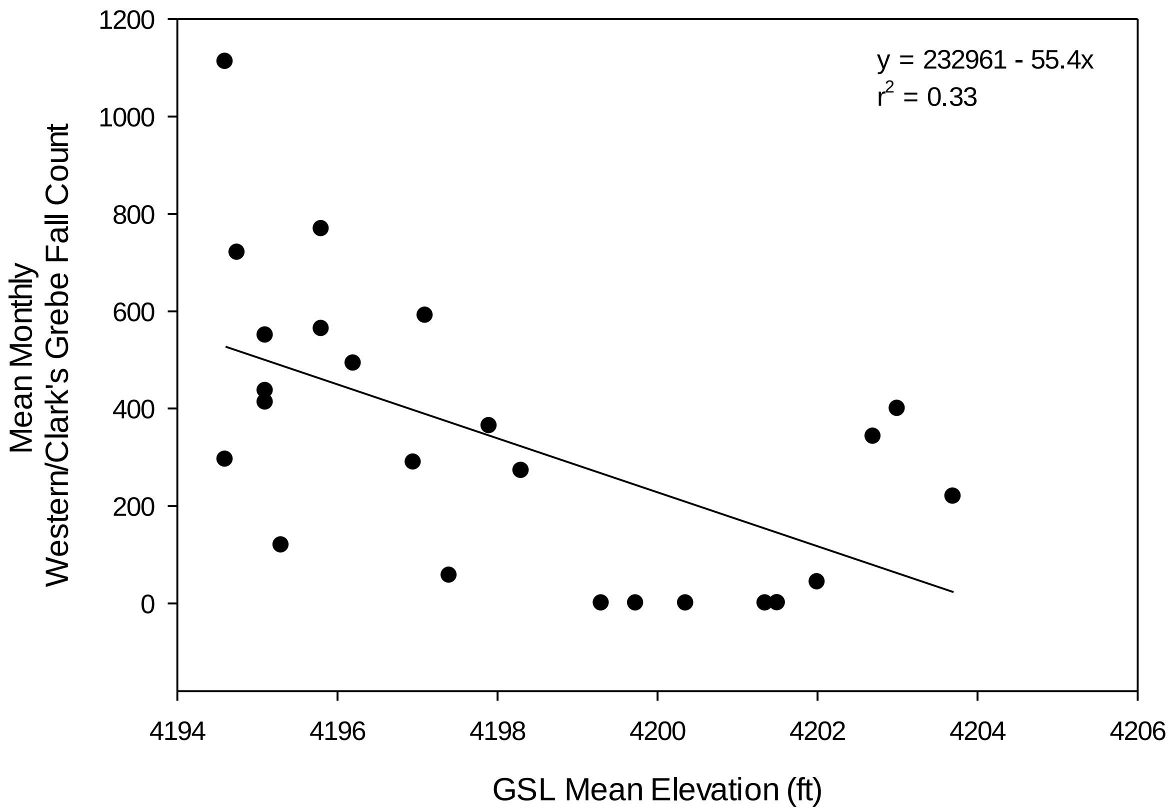


Figure 4. Relationship between Western/Clark’s Grebe mean fall staging counts and GSL mean elevation.

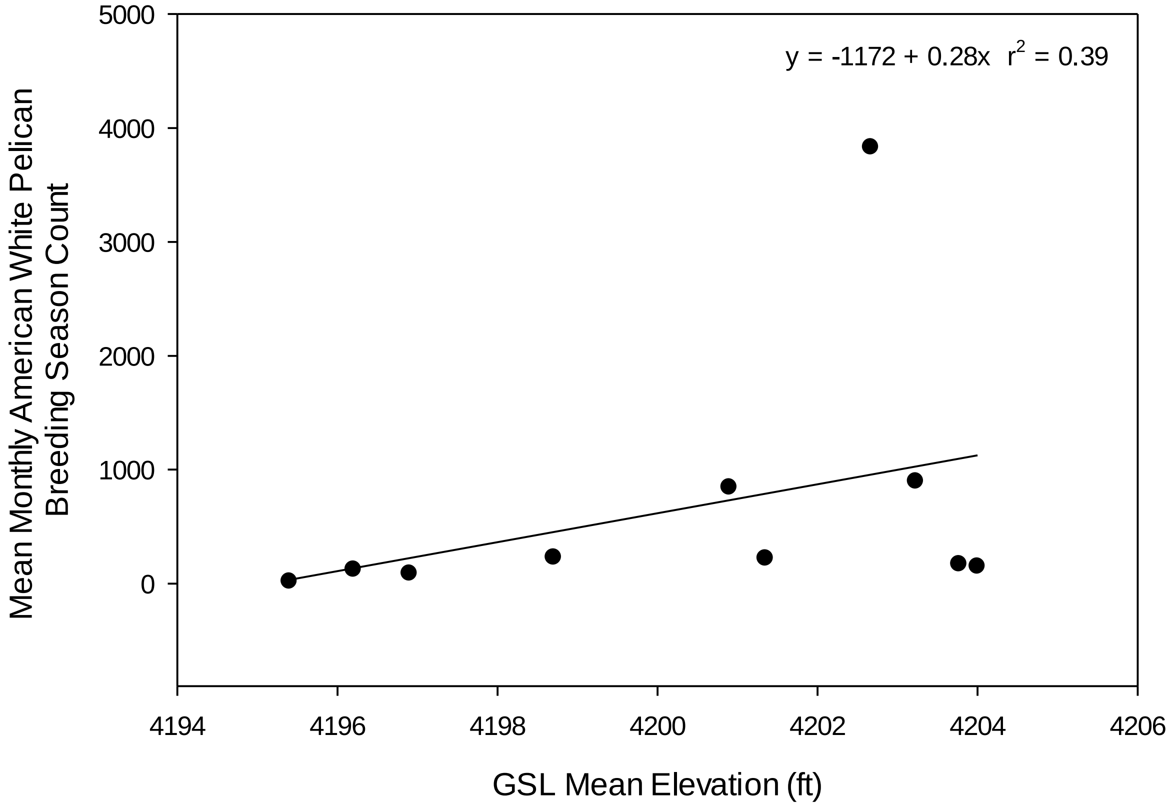


Figure 5. Relationship between mean American White Pelican breeding season counts and GSL mean elevation.

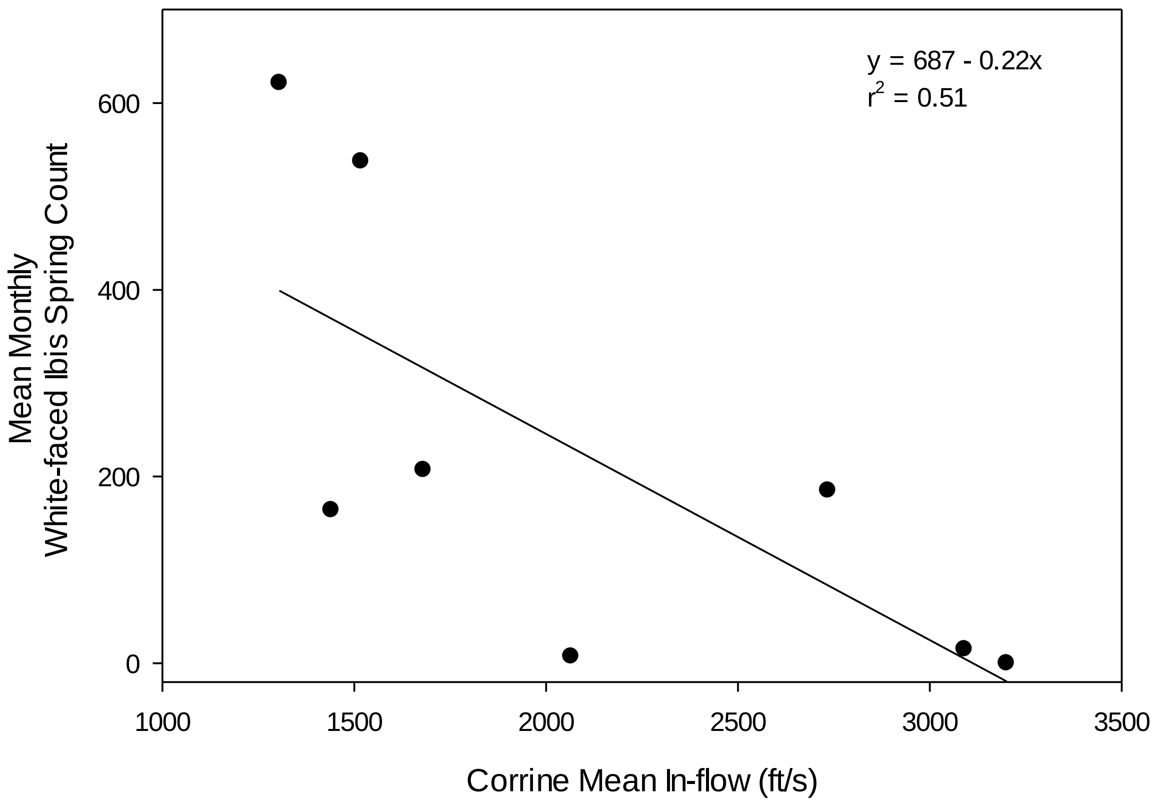


Figure 6. Relationship between mean White-faced Ibis spring counts and Bear River mean in-flow at Corrine, Utah.

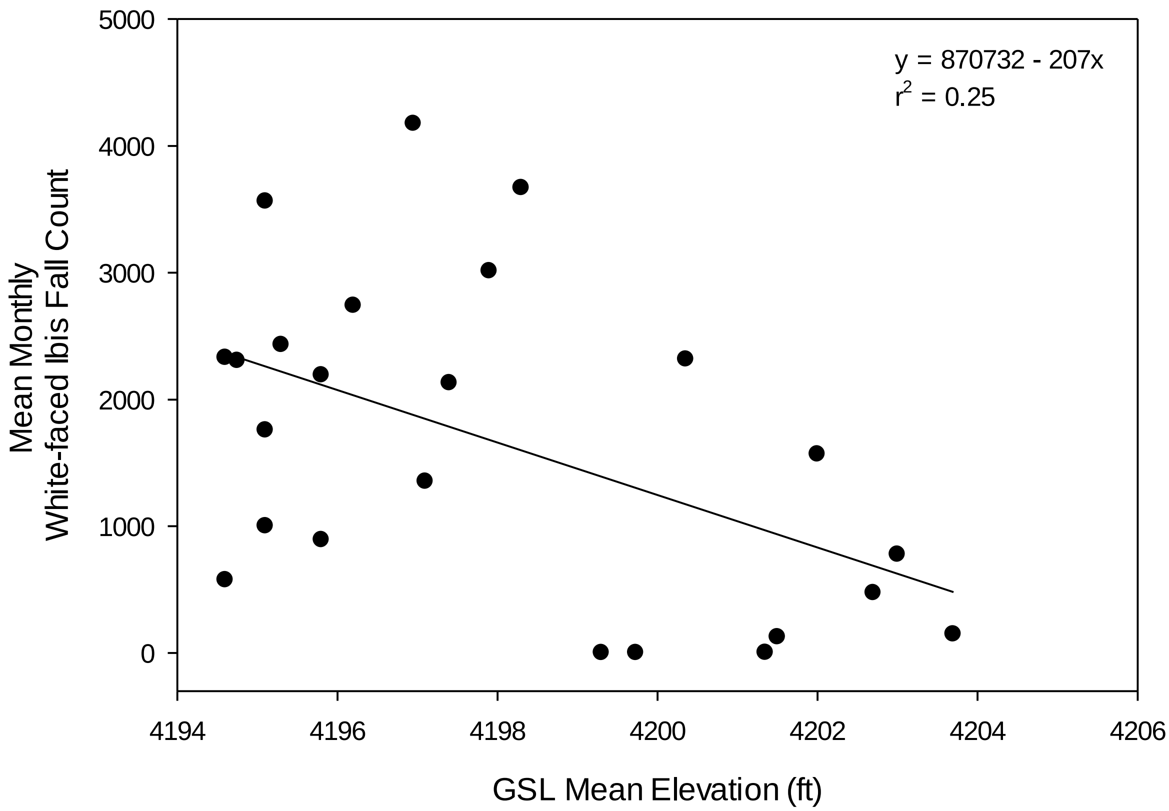


Figure 7. Relationship between mean White-faced Ibis fall staging counts and GSL mean elevation.

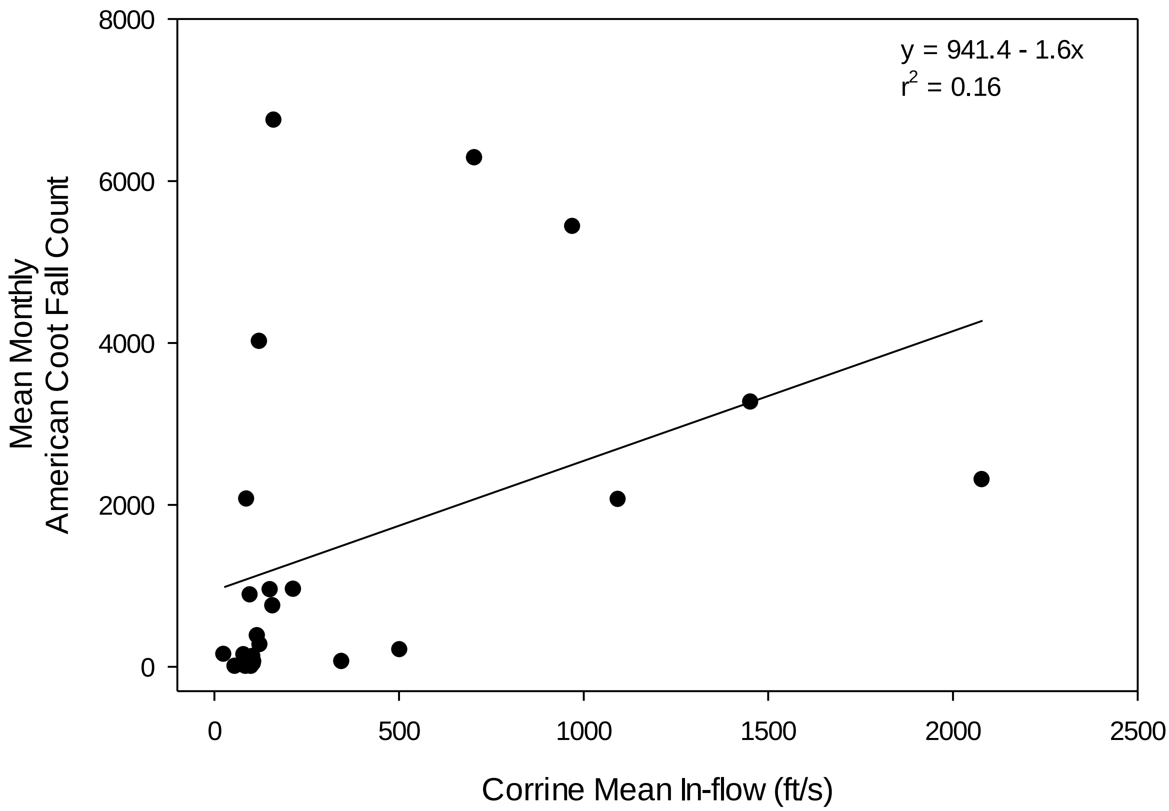


Figure 8. Relationship between mean American Coot fall staging counts and Bear River mean in-flow at Corrine, Utah.

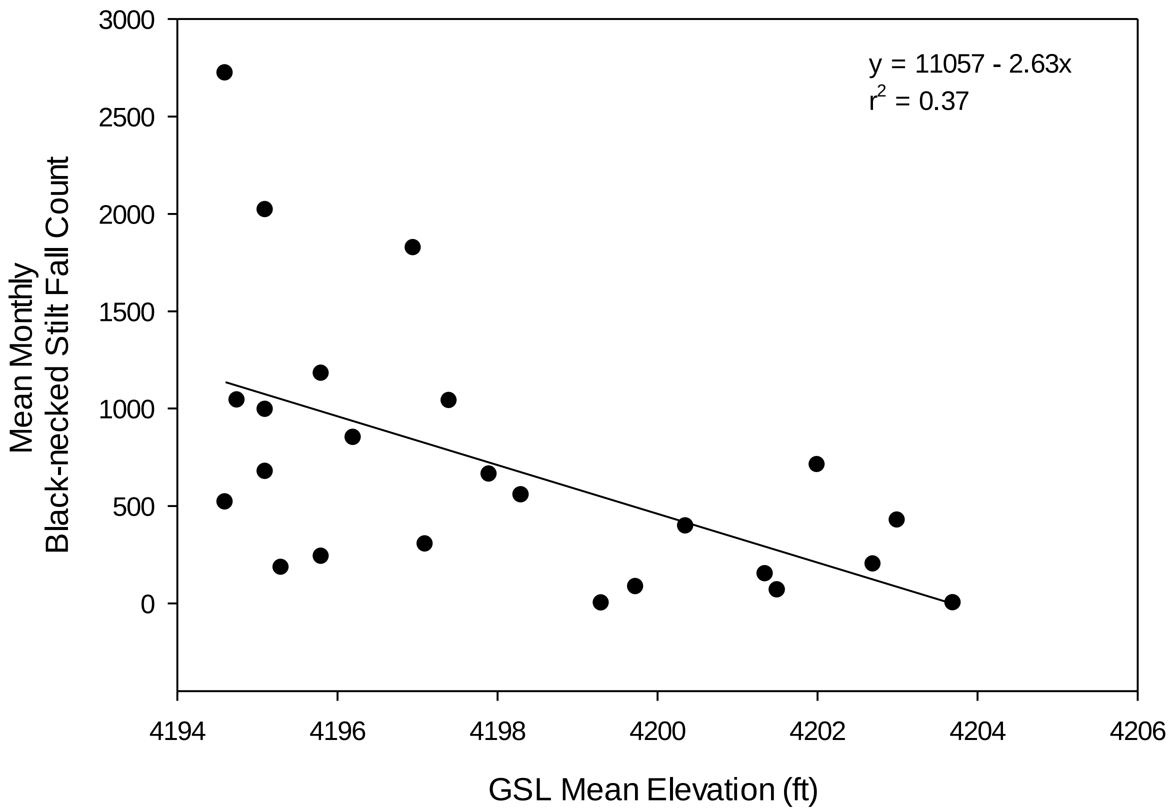


Figure 9. Relationship between mean Black-necked Stilt fall staging counts and GSL mean elevation.

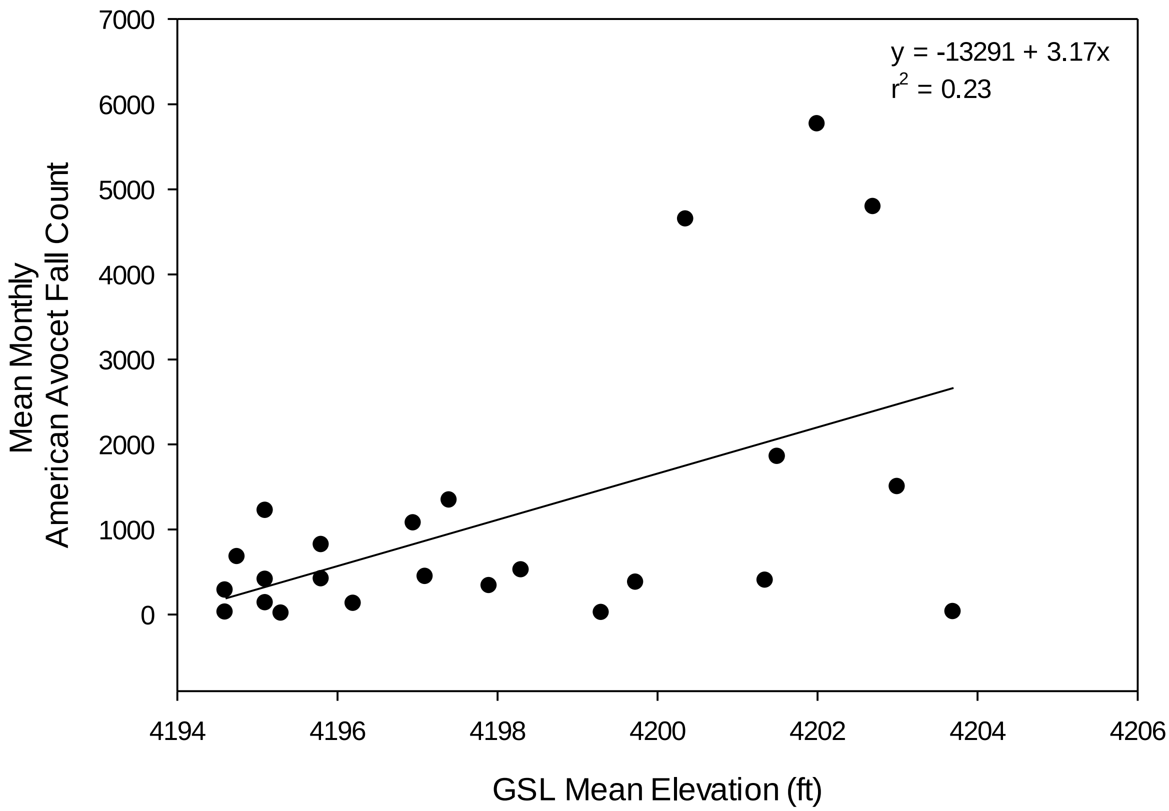


Figure 10. Relationship between mean American Avocet fall staging counts and GSL mean elevation.

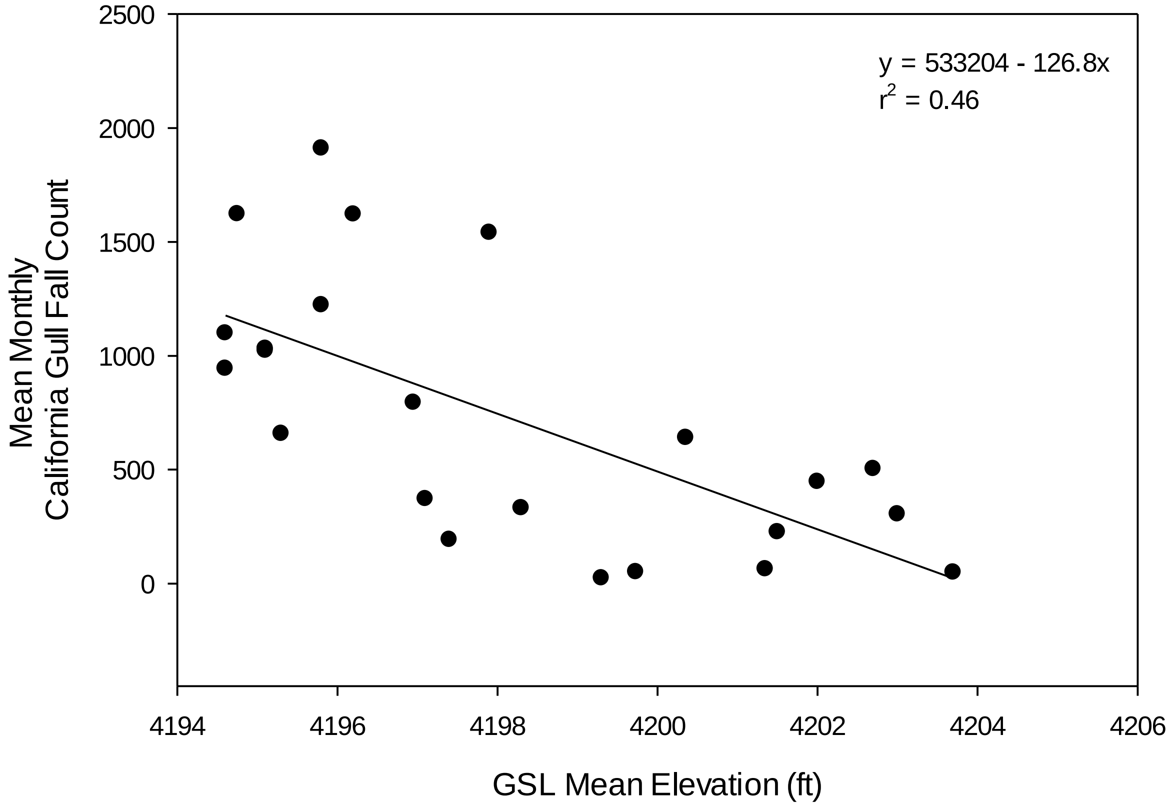


Figure 11. Relationship between mean California Gull fall staging counts and GSL mean elevation.