Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Winter Bird Monitoring Using Constant Effort Mist-Netting at Three Sites along the Lower Colorado River 2005-2006

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

November 2008

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Multi-Species Conservation Program
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Abstract

As part of a year-round avian monitoring program along the Lower Colorado River (LCR), the Bureau of Reclamation (Reclamation) initiated a winter season constant-effort mist netting project in the winter of 2002-03 at two demonstration restoration sites, Cibola Nature Trail Site (CIBO) at the Cibola National Wildlife Refuge in Arizona and the Pratt Restoration Site (PRAT) on Bureau of Land Management (BLM) land near Yuma, Arizona. This project allows Reclamation to gather bird use data at restoration sites to better understand habitat needs of avian species for the LCR Multi-Species Conservation Program (MSCP). In 2005, a third site was added at the Havasu National Wildlife Refuge (HAVA) in Arizona. All three sites were monitored once a month from October to February. Site persistence was analyzed both monthly and annually. Annual returns were found at both the CIBO and PRAT sites. All three sites showed monthly returns during the season. The ruby-crowned kinglet (*Regulus calendula*) showed a high number of captures and returns at all three sites. This was the fourth year of banding at the CIBO and PRAT sites, and comparisons between these sites were made. Statistical analyses for species diversity and community similarity showed much variation between the sites. The CIBO site had the highest species richness during the winter. Winter monitoring will continue at the HAVA and CIBO sites. The continued data collection will allow Reclamation to better understand habitat needs of avian species as habitat creation projects increase with the implementation of the LCR MSCP.

Introduction

The Lower Colorado River (LCR) travels from Lees Ferry, south of Glen Canyon Dam, to the Southerly International Boundary (SIB) with Mexico. Flowing through the Mojave and Sonoran deserts, the LCR provides a large expanse of riparian vegetation in an arid environment. Riparian areas in the Southwest support a disproportionately high bird diversity and abundance, yet form less than 0.5% of the land area (Powell and Stiedl 2000). The decline in size and quality of this habitat has negatively affected the avian species that utilize it (Szaro 1980, Rosenberg et al. 1991, Powell and Stiedl 2000). Much of this habitat has been altered due to climate change, habitat destruction, agricultural land conversion, urban development, mining, overgrazing, and river regulation (Bureau of Reclamation 1996, Powell and Stiedl 2000). A search of the literature finds very little data concerning year-round bird use in xeroriparian areas of the Southwest, especially in restoration sites.

The Bureau of Reclamation (Reclamation) has established native riparian tree restoration demonstration sites along the LCR. These stands were created to evaluate potential restoration techniques to meet objectives set forth in the LCR Multi-Species Conservation Plan (LCR MSCP), for which Reclamation acts as lead implementing agency. The LCR MSCP is a cooperative Federal-State-Tribal-County-Private endeavor to restore over 8,000 acres of covered species habitat along the LCR within 50 years; implementation of the program began in October 2005. To accomplish this goal, Reclamation needs to increase its understanding of restoration science through an adaptive management approach; therefore, monitoring of current restoration sites is crucial.

In the winter of 2002-03, Reclamation initiated a winter season constant-effort mist netting/bird banding operation at two riparian restoration sites along the LCR. In 2005, a third site was initiated in habitat considered to be more typical of the habitat currently found along the LCR, was initiated. Winter season data for the restoration projects will be used, in conjunction with data collected from other times of the year, as a guide to habitat requirements for specific species, particularly those covered under the LCR MSCP. Avian species diversity and richness numbers collected from this project will be used as an indicator of what bird use may be expected in future habitat creation projects conducted along the LCR.

Study Areas

Cibola National Wildlife Refuge is located along the LCR south of Interstate 10, near Blythe, California, in Cibola, Arizona. The refuge was established in 1964 to provide habitat for wildlife. More than 200 species of birds can be seen at the refuge (U.S. Fish and Wildlife Service 2003). The Cibola Nature Trail restoration site (CIBO) contains three distinct areas: 1) 13.6 acres (5.5-ha) of honey mesquite (*Prosopis glandulusa*) and screwbean mesquite (*Prosopis pubescens*), 2) 6.4 acres (2.6 ha) of Goodding's willow (*Salix gooddingii*), and 3) 2.5 acres (1 ha) of Fremont cottonwood (*Populus fremontii*). Most of the willow area, and part of the mesquite area, also have cottonwoods along their edges. The mesquite species range in height from 20 to 26 feet (6 to 8 m), the willow range from 23 to 30 feet (7 to 9 m), and most cottonwoods at the site are greater than 40 feet (12 m) in height. *Baccharis* spp. grows throughout the entire site, exceeding

10 feet (3 m) in height in some areas. Exotic Johnsongrass (*Sorghum halepense*) invaded as an understory in each of the three areas, and serves as a ground cover reaching up to 6 feet (2 m) in height.

The Pratt restoration site (PRAT) is located north of Interstate 8, near Yuma, Arizona, on land administered by the Bureau of Land Management (BLM). The site is north of Laguna Dam, south of Mittry Lake, and is surrounded by farm fields and *Tamarix* spp. In the fall of 2003, *Tamarix* spp. was removed; this area will be restored with native vegetation by the BLM. A leaseholder has farmed the 12-acre (4.9-ha) site since 1949. In 1999, Reclamation established six planting regimes with Fremont cottonwood, Goodding's willow, and coyote willow (*Salix exigua*) using potted plants, seeds, and poles. Reclamation planted potted plants and poles from 3 to 10 feet (1-3 m) apart. Seeded areas contained cottonwood and willow seeds collected locally and broadcast by hand over wet soils. One cottonwood plot contains a thick 13-16 foot (4-5 m) understory of *Baccharis* spp., which was independently established after the initial plantings. *Tamarix* was also established in small numbers in the seeded areas, as well as new individuals of coyote willow in the potted coyote willow area (Bureau of Reclamation 2003). Most of the cottonwood range in height from 26 to 46 feet (8-14 m), Goodding's willow from 20 to 33 feet (6-10 m), and coyote willow from 10 to 20 feet (3-6 m).

In 2005, the Havasu banding site (HAVA) was monitored during the winter season for the first time. This site is located on the Havasu National Wildlife Refuge, at the southern end of Topock Marsh, approximately 1.2 miles (1.5 km) north of the town of Topock, Arizona. The nets were located on either side of the dirt road that follows the new south dike, just off Arizona Route 95. A large portion of the area is covered in *Tamarix* spp. and arrowweed (*Pulchea sercea*) with some large (greater than 45 ft (14 m) in height), mature cottonwoods forming an overstory over roughly 15% of the site. The cottonwoods are the remaining trees from a planting in 1988 where most of the trees planted did not survive. The south side of the dike consists of a monotypic stand of *Tamarix* spp., ranging in height from 20 to 26 ft (6-8 m), while the north side is comprised of *Tamarix* spp., with some areas having an overstory of cottonwoods. The northern edge of the site is bordered by marsh vegetation. This site is typical of the vegetation now found along the LCR.

Methods

Mist-netting/bird-banding

Mist-netting/bird-banding occurred at the Cibola Nature Trail restoration site and the Pratt restoration site for the fourth consecutive season during the winter of 2005-06. The protocol was adapted from the system used by other organizations, including Point Reyes Bird Observatory, which recently instituted winter banding efforts in North America. The protocol calls for six banding sessions of two days each, once a month, from October to March. Inclement weather often causes one or more sessions to be cancelled. In 2005-06, banding started in October and continued through February. Banding did not occur in March due to time constraints and other activities. All nets were 40 ft (12 m) long and 8.5 ft (2.6 m) high, and had a mesh size of 30 mm. At the CIBO site, nine nets were placed in cottonwood-willow habitat and three nets were placed in mesquite habitat. At the PRAT site, 12 nets were placed in cottonwood-willow habitat. At the

HAVA site, seven nets were placed in the areas where cottonwoods formed an overstory above the *Tamarix* spp., and five nets were placed in areas where *Tamarix* spp. dominated.

Nets were set up 30 minutes after sunrise and were open for 6 hours unless conditions such as wind or temperature exceeded protocol limits. Nets were checked every 30-50 minutes. A metal, numbered U.S. Fish and Wildlife Service (USFWS) band was placed on the right leg of most captured birds, except game species and hummingbirds. Each bird was identified to species, aged, sexed, measured for wing chord and body fat, weighed, and released. Time, date, and net location for each captured bird were recorded, as well as total hours of net operations. All data were recorded on a standardized data sheet (Desante *et al.* 2002). Birds were identified using Pyle (1997), National Geographic (1999), and Sibley (2000).

All operations of the banding station were conducted with bird safety as the first priority. If weather conditions, number of captures, or other circumstances were deemed to be unsafe, nets were closed immediately and banding ceased for the day, or until conditions improved. Injured birds were cared for and released as soon as possible. All birds were processed in a quick and timely manner in order to reduce stress caused by handling. Standard protocols for bird extraction and handling as established by Ralph et al. (1993), and De Sante et al. (2002) were followed at all times.

Winter Site Persistence

Winter site persistence is a measure of birds captured in one banding period that are subsequently re-captured in a later banding period of the same season (Latta and Faaborg 2001, 2002). Persistence was determined by the percentage of birds re-captured in a banding period subsequent to the first capture period during the same winter banding season. Winter site persistence is used as an index measure of habitat suitability for birds in the winter. Some species are considered resident birds and stay in the area year-round. If these birds were banded in a previous season, but not a previous year, they were included as birds showing winter site persistence.

Annual Return

Data from birds recaptured between years were used to measure annual return rate. Annual return rate is a measure of birds recaptured in subsequent field seasons after the field season of their initial capture (Latta and Faaborg 2001, 2002). Annual return rate was measured as a percentage of birds recaptured from previous years, from the total of all individually captured birds.

Area Searches

Area searches are conducted at each site during each of the six banding periods to account for species that may not be captured during standard mist-net operations. A standard area search protocol was followed (Ralph et al. 1993). The three sites were split into five sections, which were 2.5 to 7.5 acres (1-3 hectares) in size. An area larger than 7.5 acres could not be thoroughly surveyed in 20 minutes in such dense habitat (Ralph et al. 1993). One 20-minute area search was

conducted in each section. Temperature, cloud cover, and wind speed were recorded before each area search. The start and ending time were also recorded. During the 20 minutes, the observers attempted to survey all areas within each section equally. Each individual bird heard or seen was recorded on the data form along with method of detection (visually or aurally). Birds seen flying over the area but not utilizing the habitat were recorded in a separate category as "flyovers".

Statistical Analysis

Several tests were run on the data to compare the results for species diversity and to create a similarity index comparing quantitative similarity in the data. Species diversity was calculated at each site using the Shannon-Weaver index (Krebs 1989 in Nur et al. 1999), which uses the formula:

$$H' = \sum_{i=1}^{i=s} (p_i)(\ln p),\ I = 1,2\ldots.S \quad ,$$

where S = the number of species in a sample, H' = the species diversity index, and p_i = the proportion of all birds detected belonging to the *i*th species. The index was then transformed using the formula $N_1 = e^H$. N_1 gives a value that expresses diversity in terms of species, giving a value that represents what the species richness (number of species detected) is when the data are statistically transformed to represent even detection numbers for all species (Macarthur 1965 in Nur et al. 1999). This gives a more useful value to use for site comparison in the analysis.

A community similarity index was created using the Renkonen index (Nur et al. 1999). The Renkonen index (P) is calculated using the formula:

$$P = \sum_{i=1}^{i=s} \text{minimum}(p^A_i, p^B_i) \quad ,$$

where p^A_i is the proportion of species *i* to all species for sample A, p^B_i is the proportion of species *i* to all species for sample B, and S is the number of species in the sample. Because the index is on a scale from 0 to 1, each index was converted into a percentage of similarity. A Renkonen index was calculated for the data to compare area search data to mist-netting data, sites between years, and with each other.

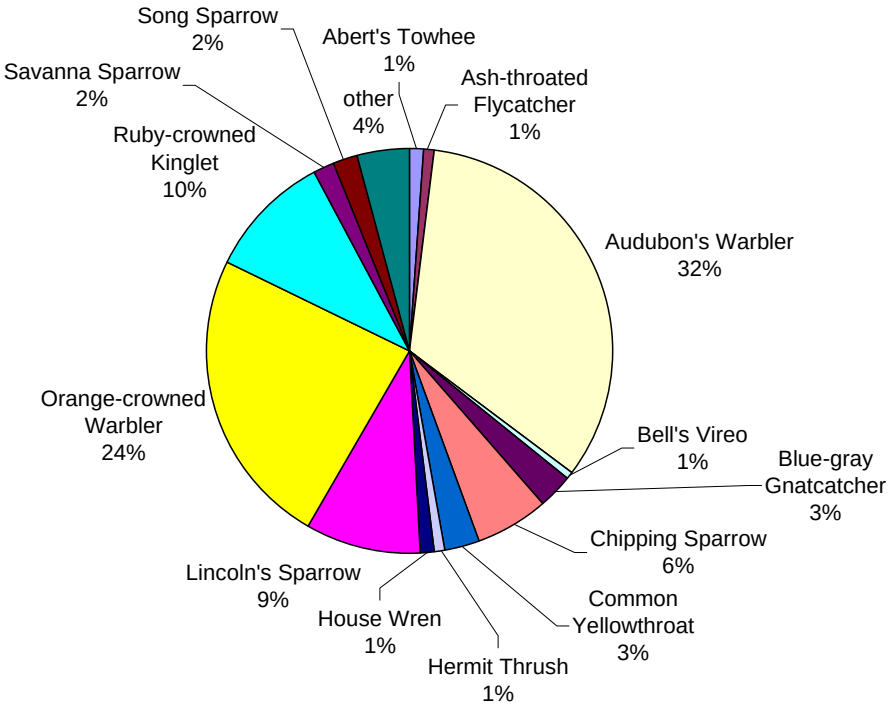
Results

Cibola Nature Trail Site

At the Cibola Nature Trail site, 673.83 net hours were conducted during the winter of 2005-06. A total of 357 birds were captured, including 293 individual birds (0.43 per net hour) and 64 recaptures (0.1 per net hour). Twenty-six species were captured, with four species accounting for 76% of all captures: Audubon's warbler (*Dendroica coronata audoboni*) 33%, orange-crowned warbler (*Vermivora celata*) 24%, ruby-crowned kinglet (*Regulus calendula*) 10%, and Lincoln's

sparrow (*Melospiza lincolnii*) 9% (Figure 1). Individual captures were higher than in 2004-05 and about the same as in previous years (0.430 per net hour in 2005-06, 0.278 per net hour in 2004-05, 0.430 per net hour in 2003-04, 0.434 per net hour in 2002-03). If all captures are considered, including recaptures, the birds per net hour rate increases to 0.519. Species composition varied from the results of previous years (Figure 2). The three most-captured species all had higher captures rates than in the previous three years. Lincoln's sparrow and white-crowned sparrow (*Zonotrichia leucophrys*) both showed a noticeable drop in capture rate in 2005-06. Capture rate varied from year to year for most species. Average and standard error were calculated for all species that had at least 10 captures during any given year (Table 1).

Figure 1. Species composition of birds captured at the CIBO site.



*other category includes 12 species with only one capture, including: Black Phoebe, Eastern Phoebe, Gray Flycatcher, Great-tailed Grackle, House Finch, Loggerhead Shrike, Marsh Wren, Mountain White-crowned Sparrow, Sharp-shinned Hawk, Verdin, Vesper Sparrow, and Warbling Vireo.

Figure 2. Four-year comparison of individual bird captures per net hour at the CIBO site.

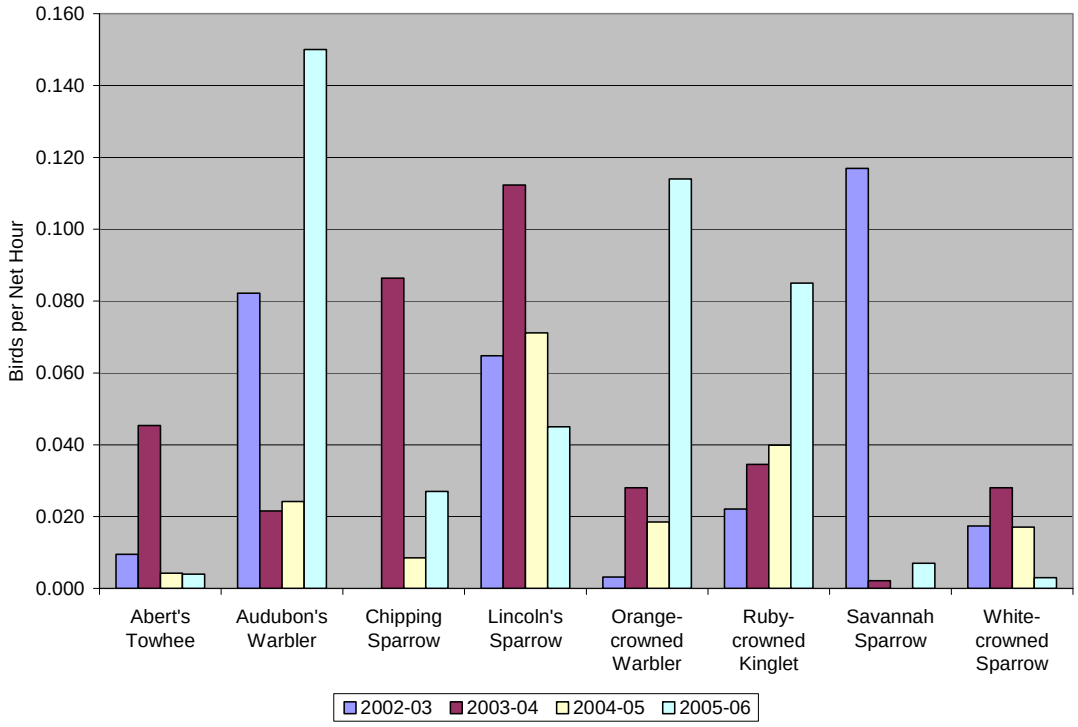


Table 1. Four-year average of birds captured per net hour with standard error at CIBO.

Species	Average (std. error)
Abert's Towhee	0.02 (0.01)
Audubon's Warbler	0.07 (0.03)
Chipping Sparrow	0.03 (0.20)
Lincoln's Sparrow	0.07 (0.01)
Orange-crowned Warbler	0.04 (0.03)
Ruby-crowned Kinglet	0.05 (0.01)
Savannah Sparrow	0.03 (0.03)
White-crowned Sparrow	0.02 (0.01)

Annual Return

Annual return rates were calculated for all species that had at least one individual return. Five species had annual returns at the CIBO site (Table 2). The Bell's vireo (*Vireo bellii*) was originally banded in September 2004. The Lincoln's sparrow was banded in February 2004. The Audubon's warbler was banded in January 2005. One orange-crowned warbler was banded in November 2004; the other two were banded in January 2005. One ruby-crowned kinglet was banded in January 2004, and the other in November 2004.

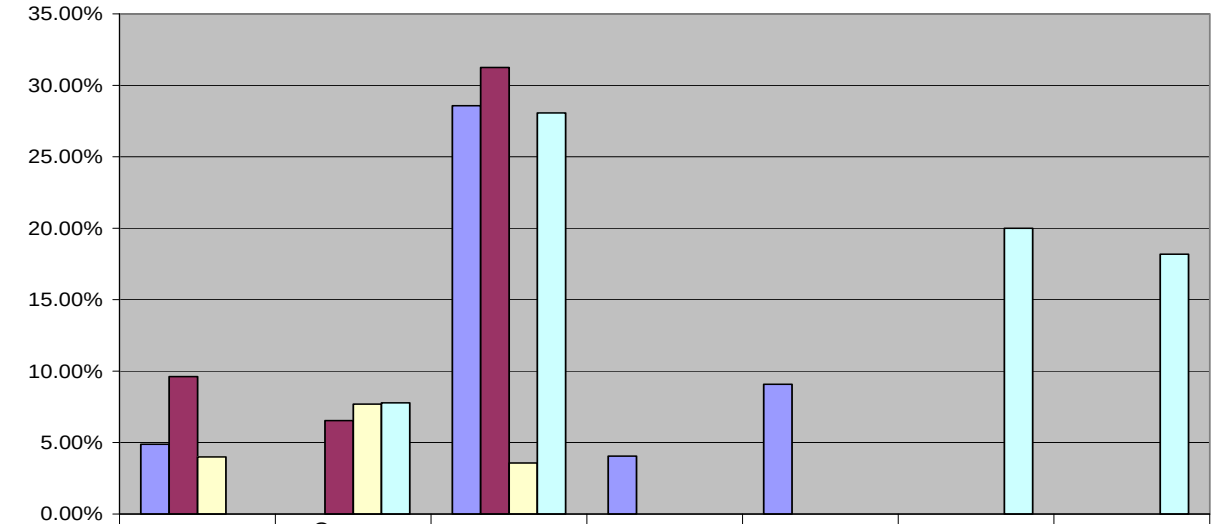
Table 2. Annual return rates at the CIBO site winter 2005-06.

Species	Annual Return	Captures	AR %
Bell's Vireo	1	3	33.33%
Lincoln's Sparrow	1	30	3.33%
Audubon's Warbler	1	101	0.99%
Orange-crowned Warbler	3	77	3.90%
Ruby-crowned Kinglet	2	57	3.51%

Winter Site Persistence

Over-winter site persistence was calculated as a percentage of birds recaptured in at least one other period than that of its original capture from all the individual birds captured during the winter season. A comparison between the last four years was performed for the CIBO site (Figure 3). The ruby-crowned kinglet (n = 16) had the highest rate of site persistence in 2006. This was the first year that winter site persistence was recorded for Audubon's warbler (1 recapture), song sparrow (*Melospiza melodia*) (2 recaptures), and blue-gray gnatcatcher (*Polioptila caerulea*) (2 recaptures). Inter-period returns accounted for 11% of the total individual captures.

Figure 3. Comparison of winter site persistence over the four years of banding at the CIBO site.

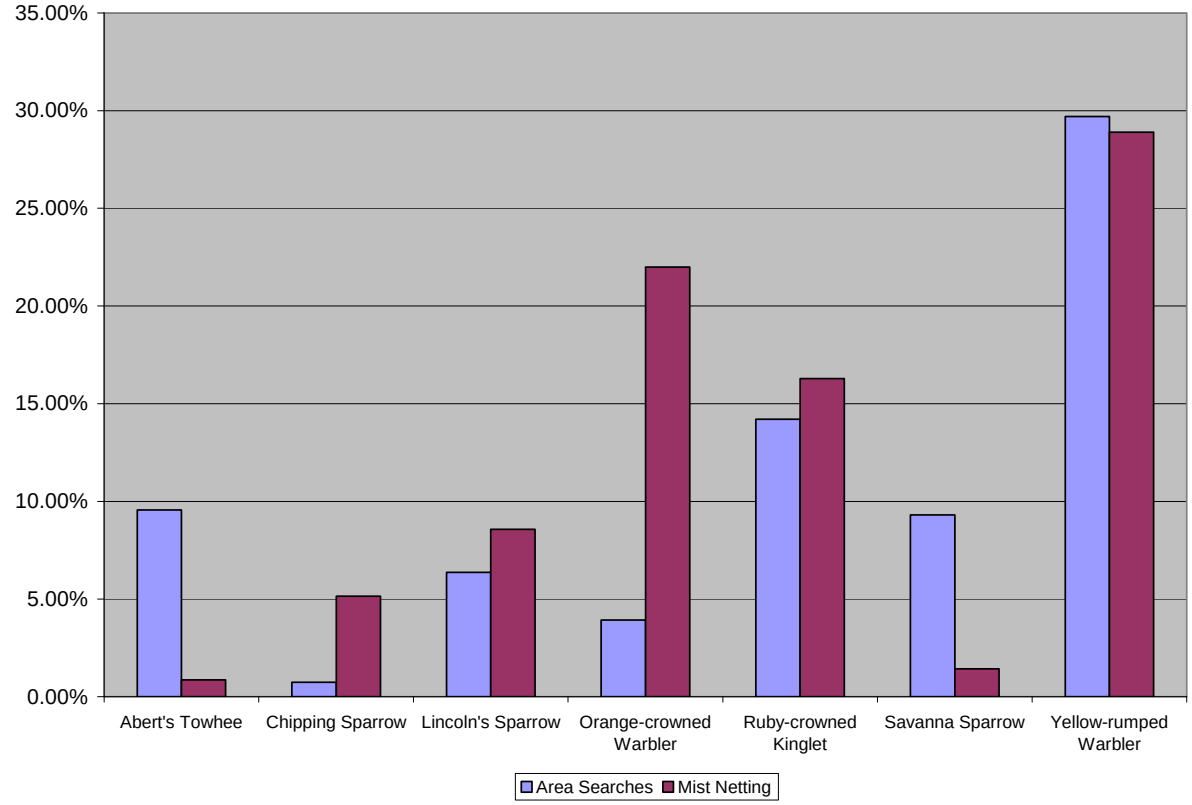


	Lincoln's Sparrow	Orange-crowned Warbler	Ruby-crowned Kinglet	Savannah Sparrow	White-crowned Sparrow	Song Sparrow	Blue-gray Gnatcatcher
2002-03	4.88%	0.00%	28.57%	4.05%	9.09%	0.00%	0.00%
2003-04	9.62%	6.53%	31.25%	0.00%	0.00%	0.00%	0.00%
2004-05	4.00%	7.69%	3.57%	0.00%	0.00%	0.00%	0.00%
2005-06	0.00%	7.79%	28.07%	0.00%	0.00%	20.00%	18.18%

Area Search Analysis

Area searches were performed for all five survey periods. A total 408 birds were detected, an average of 81.6 birds detected per period. Periods 3 and 4 (January and February) accounted for 62% of all birds detected. A comparison was made between area search data and mist-netting data (Figure 4). Yellow-rumped warbler, ruby-crowned kinglet, and Lincoln's sparrow were the only species that showed similar detection rates between the two survey methods.

Figure 4. Species comparison between area search data and mist-netting data at CIBO.



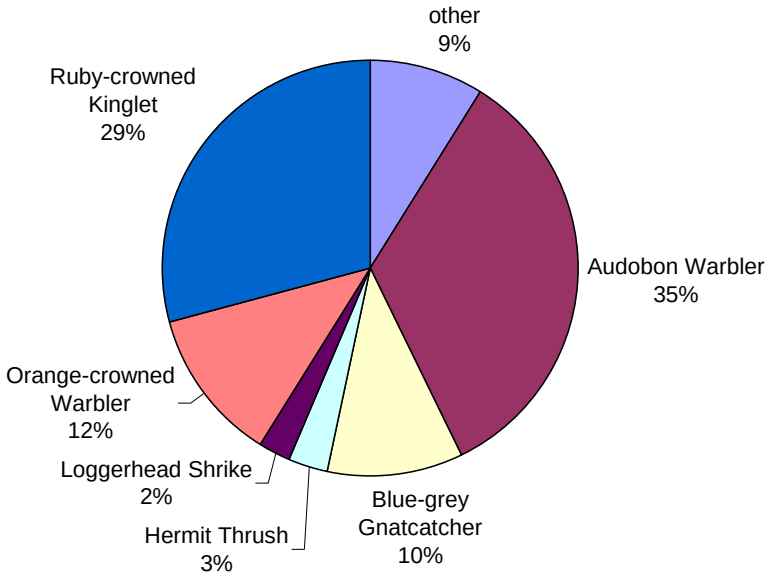
Pratt Restoration Site

At the Pratt restoration site, a total of 480.33 net hours were conducted during the winter of 2005-06. A total of 165 birds were captured, including 124 individual birds captured (0.26 per net hour) and 41 recaptures (0.09 per net hour). Seventeen species were captured, with four species accounting for 76% of all captures: Audubon's warbler 34%, ruby-crowned kinglet 29%, orange-crowned warbler 12%, and blue-gray gnatcatcher 10% (Figure 5). Individual captures were lower than in previous years (0.258 per net hour in 2005-06, 0.297 per net hour in 2004-05, 0.398 per net hour in 2003-04, 0.573 per net hour in 2002-03). If all captures are considered, including recaptures, the birds per net hour rate increases to 0.331. Figure 6 shows the difference in capture rates for the five most-captured species at PRAT. Capture rates per net hour have been variable between years. Average and standard error were calculated for all species that had at least thirteen captures during any given year (Table 3).

Table 3. Four-year average of birds captured per net hour and standard deviation at PRAT.

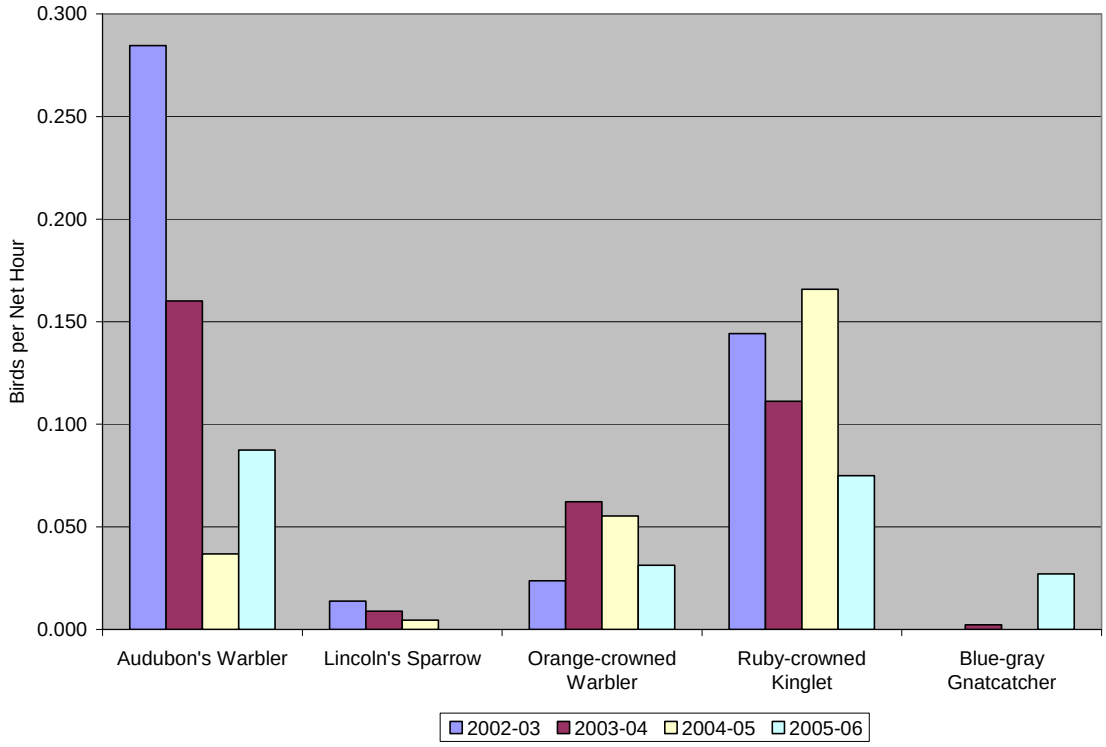
Species	Average (std. error)
Audubon's Warbler	0.14 (0.054)
Lincoln's Sparrow	0.01 (0.003)
Orange-crowned Warbler	0.04 (0.009)
Ruby-crowned Kinglet	0.12 (0.020)
Blue-gray Gnatcatcher	0.01 (0.007)

Figure 5. Species composition of birds captured at the PRAT site.



*other category includes 11 species with only one capture, including: Abert's Towhee, Anna's Hummingbird, Black-and-white Warbler, Bell's Vireo, Black Phoebe, Brewer's Sparrow, Black-tailed Gnatcatcher, Hammond's Flycatcher, Ladder-backed Woodpecker, White-crowned Sparrow, and Yellow-shafted Flicker.

Figure 6. Four-year comparison of individual bird captures per net hour at the PRAT site.



Annual Return

Annual return rates were calculated for all species that had at least one individual return at the PRAT site. Three species had annual returns at the PRAT site (Table 4). The hermit thrush was originally banded in January 2005. The first orange-crowned warbler was banded in February 2004, the second in November 2004, and the third in January 2005. The ruby-crowned kinglet was originally banded in November 2002. The next ruby-crowned kinglet was banded in February 2003. The third ruby-crowned kinglet was banded in January 2004, and the last two were both banded in January 2005.

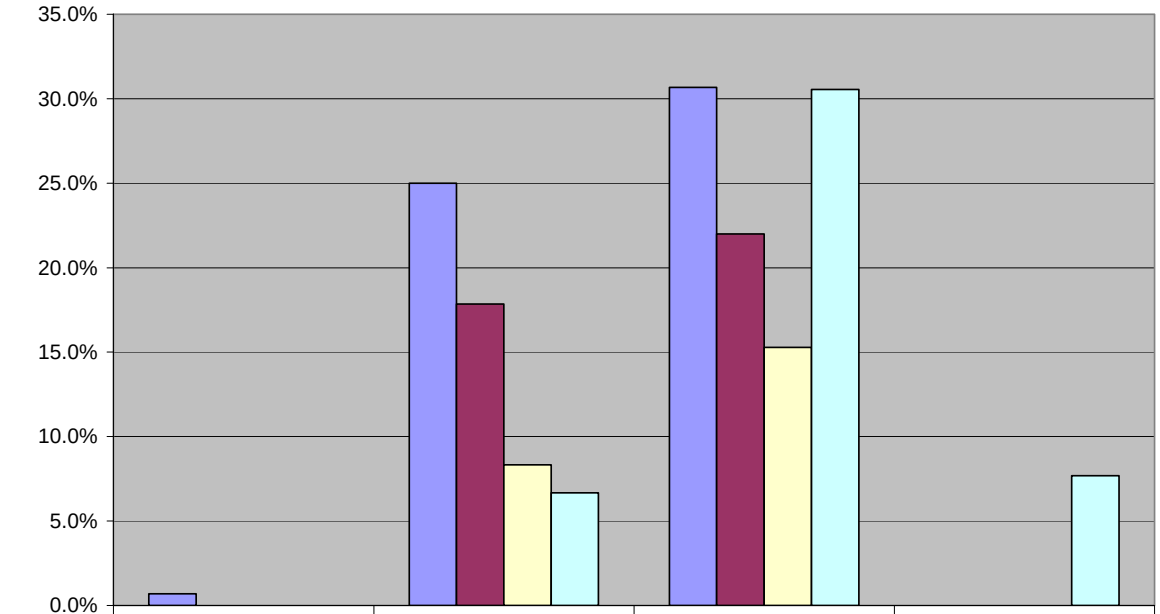
Table 4. Annual return rates at the PRAT site winter 2005-06.

Species	Annual Return	Captures	AR %
Ruby-Crowned Kinglet	5	60	8.33%
Orange-crowned Warbler	3	17	17.65%
Hermit Thrush	1	5	20.00%

Winter Site Persistence

A comparison between the last four years was performed for the PRAT site (Figure 7). This was the first year that winter site persistence was recorded for the blue-gray gnatcatcher. The ruby-crowned kinglet was the only species to show an increase in site persistence. Inter-period returns accounted for 14.5% of the total individual captures, which was slightly higher than at CIBO.

Figure 7. Comparison of winter site persistence over the four years of banding at the PRAT site.

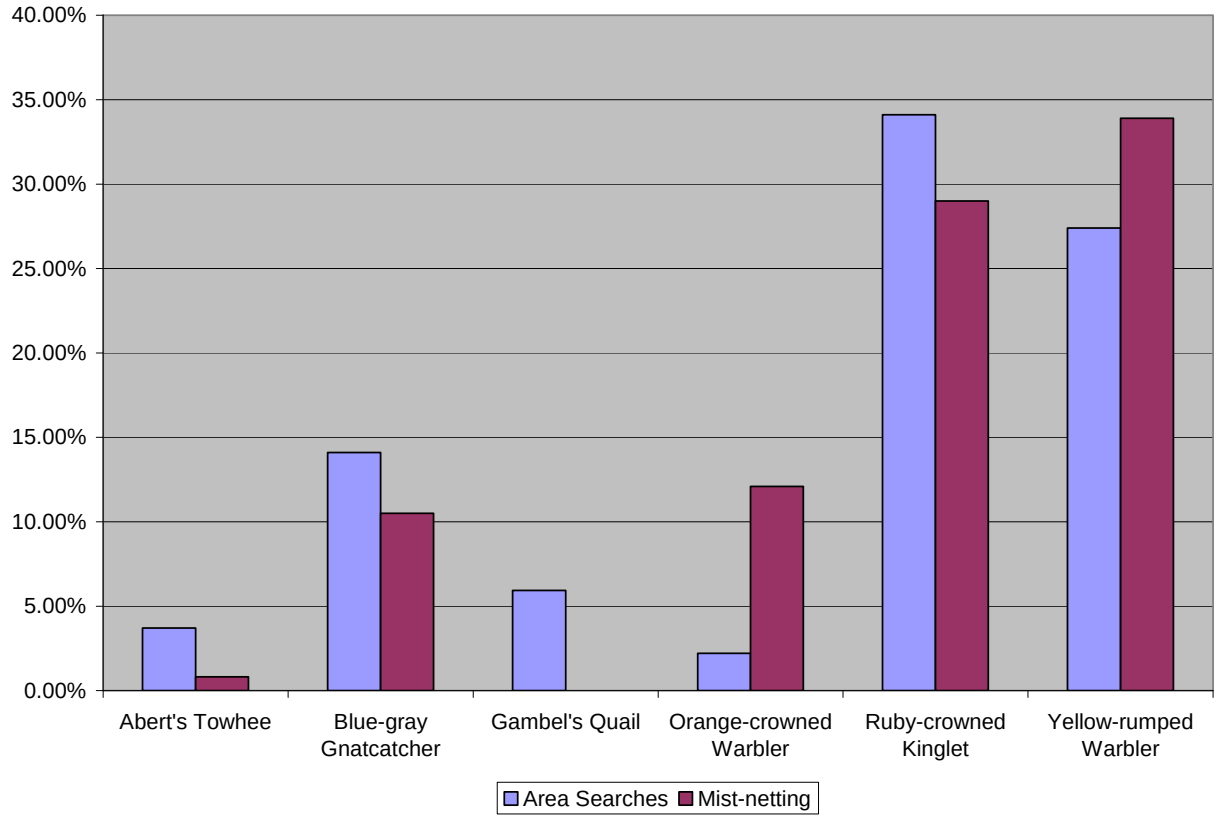


	Audubon's Warbler	Orange-crowned Warbler	Ruby-crowned Kinglet	Blue-gray Gnatcatcher
2002-03	0.7%	25.0%	30.7%	0.00%
2003-04	0.00%	17.86%	22.00%	0.00%
2004-05	0.00%	8.33%	15.28%	0.00%
2005-06	0.00%	6.67%	30.56%	7.69%

Area Search Analysis

Area searches were performed for four of the five survey periods conducted at PRAT. A total of 135 birds were detected, an average of 33.75 birds detected per period. A comparison between area search data and mist-netting data can found in Figure 8. Detection rates were similar for the blue-gray gnatcatcher, ruby-crowned kinglet, and yellow-rumped warbler (*Dendroica coronata*).

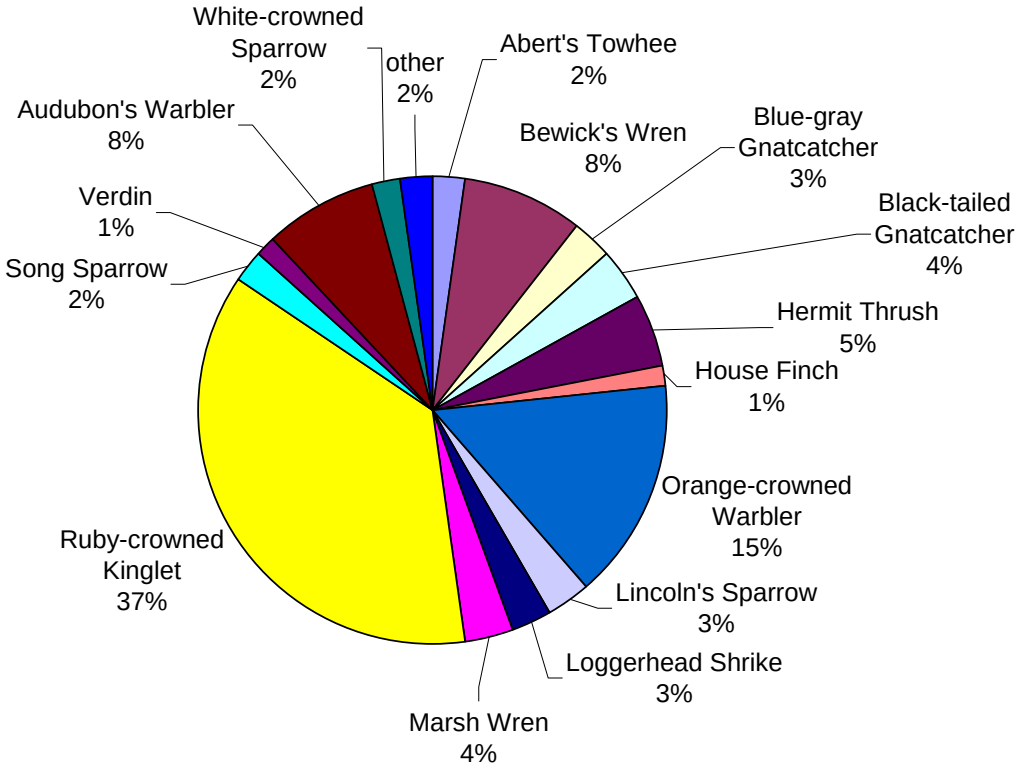
Figure 8. Species comparison between area search data and mist-netting data at PRAT.



Havasu Banding Site

During the winter of 2005-06, 650.83 net hours were conducted at the Havasu site. A total of 184 birds were captured, including 139 individual birds captured (0.21 per net hour) and 45 recaptures (0.069 per net hour). Eighteen species were captured, with four species accounting for 68% of all captures: ruby-crowned kinglet 37%, orange-crowned warbler 15%, Audubon's warbler 8%, and Bewick's wren (*Thryomanes bewickii*) 8% (Figure 9). Because this was the first year of winter banding at HAVA, there are no annual return data from previous years.

Figure 9. Species composition of birds captured at the HAVA site.



*other category included three species with only one capture: Dusky Flycatcher, Golden-crowned Kinglet, and Spotted Towhee.

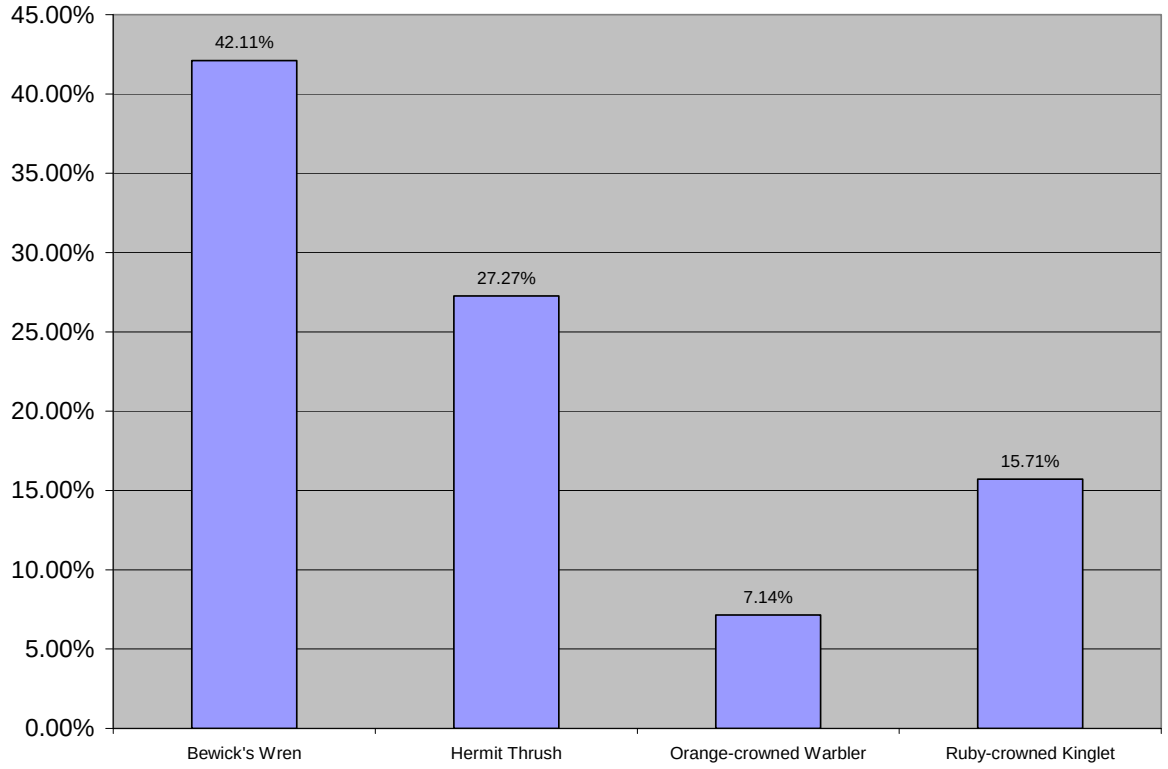
Winter Site Persistence

Site persistence was evaluated for six different species (Table 5). The Bewick's wren showed the highest percentage of site persistence for any species that had more than 10 total captures (Figure 10). Five of the eight Bewick's wren returns had been banded during the summer banding season, confirming that this species is a year-round resident. Inter-period returns accounted for 19.4% of individual captures at HAVA. This was higher than both the CIBO and PRAT sites.

Table 5. All species that had at least one inter-period return at HAVA.

Species	Inter-period return	Total Captures	Inter-period return %
Bewick's Wren	8	19	42.11%
Hermit Thrush	3	11	27.27%
Loggerhead Shrike	1	6	16.67%
Orange-crowned Warbler	2	28	7.14%
Ruby-crowned Kinglet	11	70	15.71%
Song Sparrow	1	3	33.33%
Verdin	1	2	50.00%

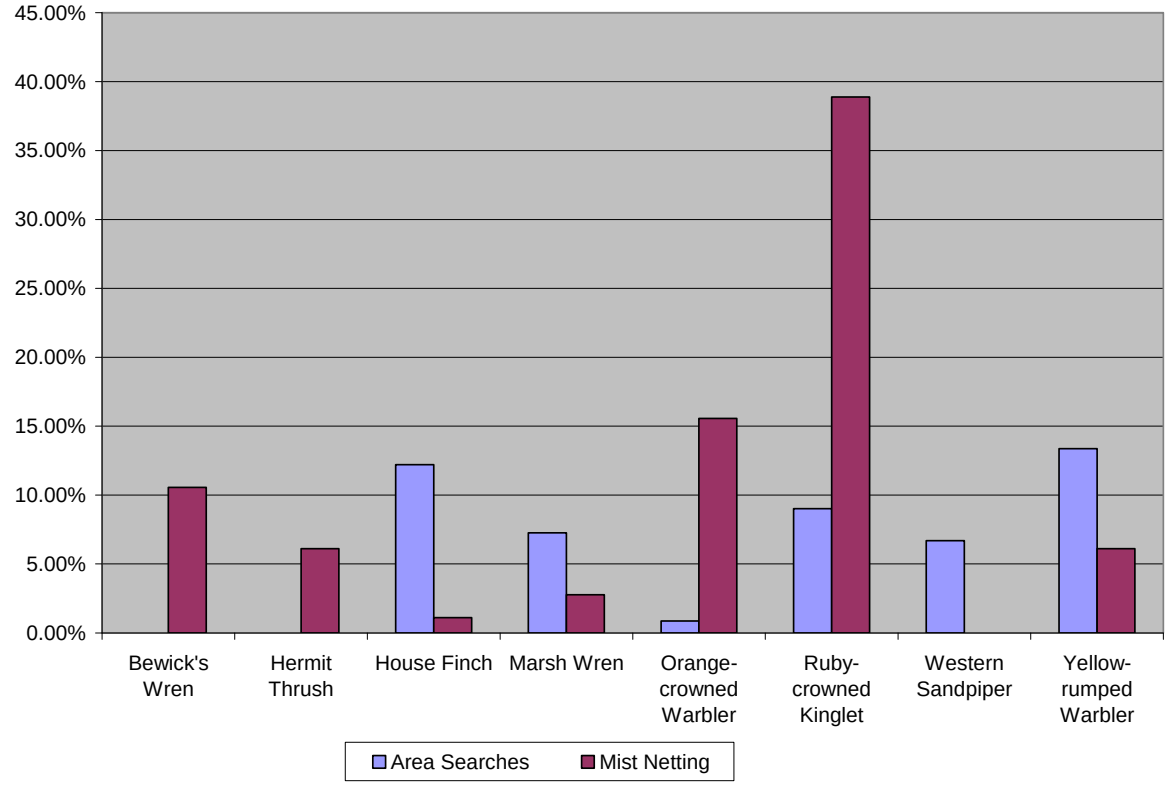
Figure 10. Comparison of inter-period returns for species with >10 total captures at HAVA.



Area Search Analysis

Area searches were performed for all five survey periods. A total 344 birds were detected, an average of 68.8 birds detected per period. The first period only accounted for 7.8% of all detections, while the other four periods accounted for 18-27% of detections each. Area search and mist-netting data were compared (Figure 11). Area search detection rates were higher for the house finch (*Carpodacus mexicanus*), marsh wren (*Cistothorus palustris*), and yellow-rumped warbler. Yellow-rumped warblers cannot be reliably identified to subspecies during an area search, although all birds captured were the Audubon's subspecies. The western sandpiper (*Calidris mauri*) was only detected using area searches.

Figure 11. Species comparison between area search data and mist-netting data at HAVA.



Site Comparison

Species captured per site were compared for all three sites (Figure 12). Species with the most captures at CIBO included Audubon's warbler, chipping sparrow (*Spizella passerine*), Lincoln's sparrow, orange-crowned warbler, and song sparrow. The blue-gray gnatcatcher had the most captures at PRAT. The Bewick's wren, hermit thrush (*Catharus guttatus*), and ruby-crowned kinglet had the most captures at HAVA. Six species were captured at all three sites, while two were only found at one site. Species richness was highest at CIBO in 2005-06 (Table 6). Between 2002 and 2006, species richness was higher at CIBO than at PRAT (see Figure 13). A comparison of birds per net hour each year shows that CIBO had a drop in capture rate during 2004-05 but subsequently rebounded to the same numbers as previous years in 2005-06. PRAT showed a slow decline each year (Figure 14).

Table 6. Species Richness numbers for all three sites for 2005-06.

Site	# of Species
CIBO	26
PRAT	17
HAVA	18

Figure 12. Comparison between all three sites for all species that were captured at least eight times total for all sites.

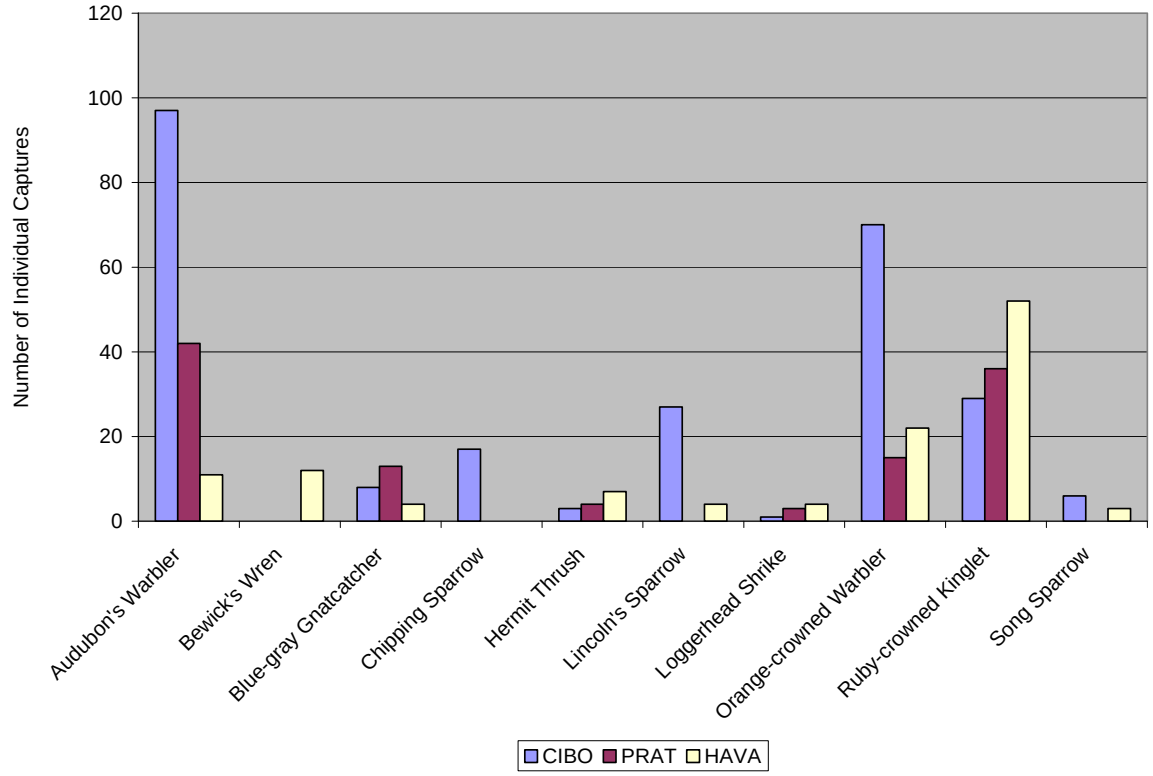
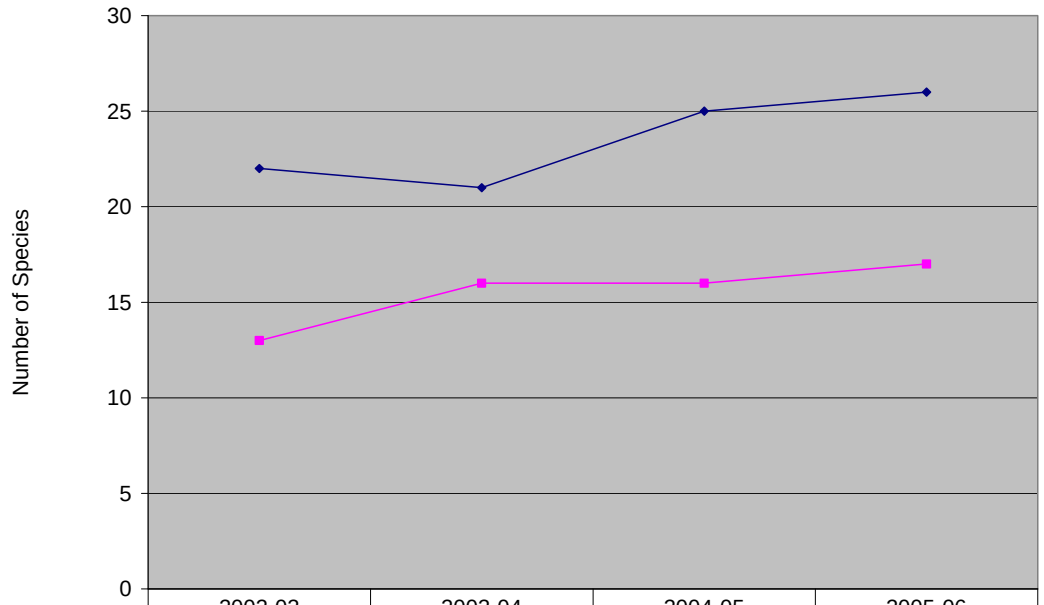
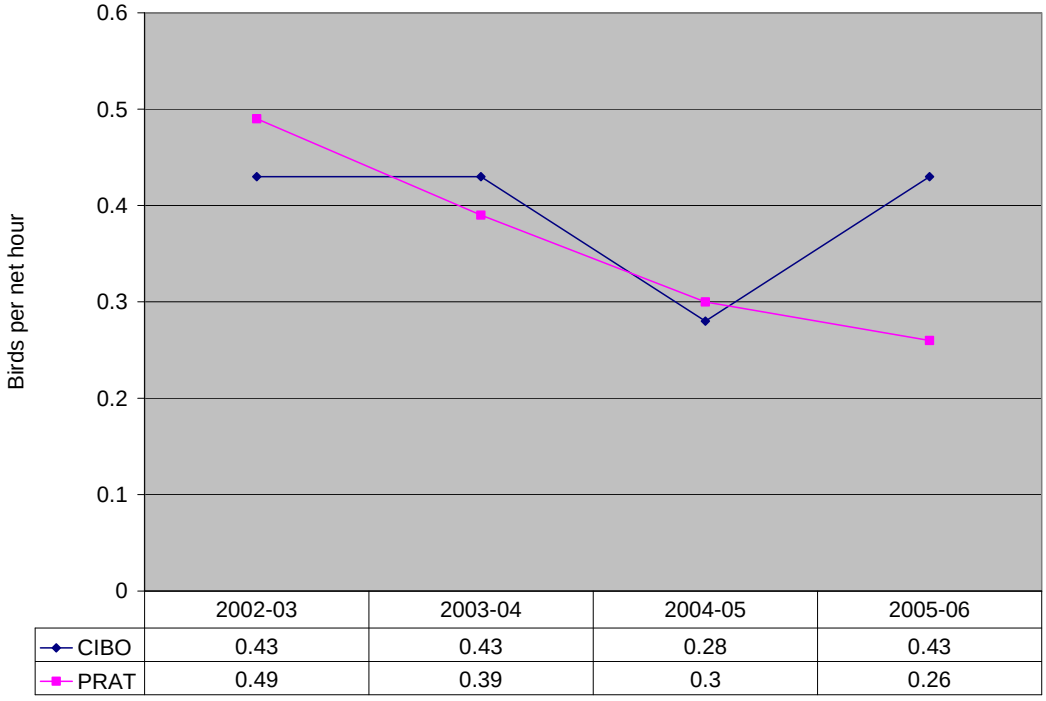


Figure 13. Four-year comparison of species richness between CIBO and PRAT.



	2002-03	2003-04	2004-05	2005-06
CIBO	22	21	25	26
PRAT	13	16	16	17

Figure 14. Four-year comparison of bird captures per net hour at CIBO and PRAT.



	2002-03	2003-04	2004-05	2005-06
CIBO	0.43	0.43	0.28	0.43
PRAT	0.49	0.39	0.3	0.26

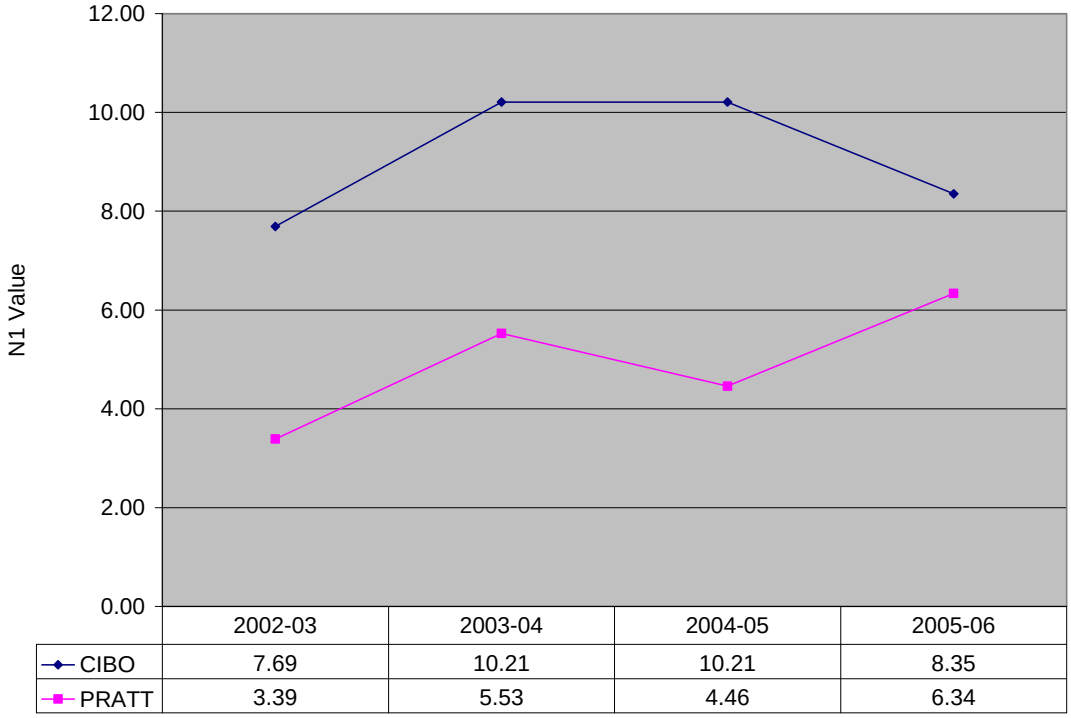
Statistical Analysis

Several tests were run on the data to compare the results for species diversity and to create a similarity index comparing quantitative similarity in the data. The Shannon-Weaver index was calculated for both the banding and area search data to determine species diversity. These indices were then transformed into the N_1 value. N_1 expresses species diversity as species richness (number of species detected) after the data is statistically transformed to represent even detection numbers for all species (Macarthur 1965 in Nur et al. 1999). Once transformed, the higher the N_1 value, the higher the diversity. The HAVA site yields the highest diversity value for both banding data and area searches (Table 7). The CIBO site was found to have a higher diversity value over the four years of banding compared to PRAT (Figure 15).

Table 7. Comparison between sites from the transformed (N_1) Shannon-Weaver diversity index.

Site	Banding Data	Area Search Data
CIBO	8.35	12.09
HAVA	9.20	20.12
PRAT	6.34	6.71

Figure 15. Four-year comparison of species diversity between CIBO and PRAT.



	2002-03	2003-04	2004-05	2005-06
CIBO	7.69	10.21	10.21	8.35
PRATT	3.39	5.53	4.46	6.34

A Renkonen index was calculated for the data in a number of ways. First an index comparing the similarity of area searches and banding data for each site was performed to compare each survey method. This index found that the area search and banding data from PRAT were the most similar (73.9%), with the HAVA site having the least similarity (31.4%) (Table 8). Banding data was compared between sites, as well as for all three sites combined. CIBO and HAVA are the most dissimilar of the three sites. All three sites together are only 20.5% similar (Table 9). A Renkonen index was used to compare year to year changes at both CIBO and PRAT. PRAT had a higher community similarity between all years, except 2003-04/2004-05 when CIBO had a slightly higher percentage of similarity (Table 10).

Table 8. Similarity of area searches to banding data at each site using a percentage of the Renkonen index.

Site	Area Search/Banding
CIBO	**60.1%**
HAVA	**31.4%**
PRAT	**73.9%**

Table 9. Similarity of banding data from each site using a percentage of the Renkonen index.

Sites Compared	Percent Similar
CIBO/PRAT	61.4%
PRAT/HAVA	35.1%
CIBO/HAVA	25.2%
CIBO/HAVA/PRAT	20.5%

Table 10. Similarity between years for CIBO and PRAT using a percentage of the Renkonen index.

Years of comparison	CIBO	PRAT
2002-03/2003-04	40.8%	80.0%
2003-04/2004-05	66.0%	62.5%
2004-05/2005-06	49.5%	56.7%
All years combined	24.5%	46.8%
first year/last year	45.0%	70.1%

Discussion

In 2005-06, the HAVA site was added to better represent existing conditions along the LCR. The HAVA site is dominated by *Tamarisk* spp., with a few large cottonwoods, while CIBO and PRAT are mainly composed of native species. While many of the same avian species were captured at all sites, the number of those species' captured varied between sites. The number of annual and inter-period returns also varied between sites. These variations may be due to the difference in the structure of vegetation at the three sites. Fewer Audubon's warblers were captured at the HAVA site, possibly due to the taller distinct cottonwood overstory. Area search data showed similar patterns. Area searches appear to be a better estimate for the house finch, marsh wren, western sandpiper, and yellow-rumped warbler when compared to the banding data (Figure 11). Mist-netting, on the other hand, may better estimate numbers of the Bewick's wren, hermit thrush, orange-crowned warbler, and ruby-crowned kinglet. Mist-netting appears to better survey an area for species that are quiet and secretive. In the winter, this becomes even more important because very few birds sing. Some secretive species that are important to monitor, such as the Bell's vireo, usually will not be detected during an area search. With the evidence of site persistence both annually and seasonally for the Bell's vireo, it is important to continue monitoring through constant effort mist-netting to better understand its migration and winter behavior.

The HAVA site also had a much higher diversity during area searches as compared to banding. This site is bordered by a marsh so area searches detect shorebirds, waterfowl, and marsh birds that are not captured in mist nets. When these data are excluded, the N_1 value drops from 20.12 to 12.75.

The HAVA site will continue to be monitored during future winter seasons. Additional data will enable the HAVA and CIBO sites to be evaluated for seasonal and annual persistence. HAVA had a somewhat higher species diversity compared to CIBO; however, CIBO had a capture rate that was almost double that of HAVA.

After acquiring four seasons of data at the CIBO and PRAT sites, some species are exhibiting strong site persistence. The ruby-crowned kinglet has shown high site fidelity at all three sites and a high number of annual returns at CIBO and PRAT. These numbers cannot reliably be compared to other species because of the possibility that the ruby-crowned kinglet may be more prone to be captured in mist-nets than other species. Ruby-crowned kinglets are very active birds that forage anywhere in the habitat where small branches are available for perching (Laurenzi et al. 1982). At the CIBO and PRAT sites, they appear to forage throughout the canopy, including areas close to the ground, while other species may spend more time in specific height strata within the canopy, which may limit capture success. At the CIBO site, two Bell's vireos were captured: one was an inter-period return and the other an annual return. The Arizona Bell's vireo (*Vireo bellii arizonae*) is an MSCP covered species. It is not possible to identify subspecies in the field, although it is thought that the Arizona subspecies migrates farther south in the winter. The birds were captured in January and February. A better understanding of migration timing of the Bell's vireo may be necessary to understand why these birds were found at this site during this time of year. Another interesting capture at the CIBO site was an eastern phoebe (*Sayornis phoebe*) that was captured in December and recaptured in January. It is unknown why this bird spent at least one month at this site.

Area searches at CIBO appear to better estimate the number of Abert's towhee (*Pipilo aberti*) and savannah sparrow (*Passerculus sandwichensis*) when compared to the banding data. The savannah sparrow was most frequently observed in the mesquite area where dense Johnsongrass occurred. Only one mist-net was located in this area, which probably decreased capture success. Mist-netting may be a better estimate for the orange-crowned warbler and chipping sparrow (*Spizella passerine*) at CIBO. Both of these species are small and secretive, making it difficult to see or hear during an area search.

The PRAT site was monitored from 2002-03 though 2005-06. During 2005-06, a Bell's vireo was captured at the PRAT site in January and recaptured in February, showing another inter-period return during the winter for this species along the LCR. Another interesting capture at PRAT was of a black-and-white warbler (*Mniotilta varia*) in October. This species is known to breed from the Midwest to the east coast, as well as throughout Canada, and winter along the southern coast of the United States and both the Pacific and Atlantic coasts of Mexico. Other noticeable observations in 2005-06 were a complete absence of the Lincoln's sparrow and a large increase in blue-gray gnatcatchers detected. It is unknown why Lincoln's sparrows were not captured in 2005-06. The increase in blue-gray gnatcatcher detections may have occurred because *Baccharis* spp. may have reached the age that the structure of the vegetation became more appealing to this species.

Area searches at PRAT appear to better estimate Abert's towhee and Gambel's quail (*Callipepla gambelii*), when compared to mist-netting data. Quail, like Abert's towhees, are large in comparison to other passerines, which may decrease capture success. Mist-netting may better

estimate numbers for the orange-crowned warbler because of the difficulty in seeing or hearing this species during an area search.

Comparisons were made with the four years of data from CIBO and PRAT. Species diversity was higher at the CIBO site, although diversity at PRAT may be increasing. Species richness was also higher at CIBO (n = 26), which contributed to the increased diversity at that site. Capture rate at both of these sites also varied. The large decline in captures at CIBO in 2004-05 may be a normal wintering population fluctuation. More data are needed to better understand potential population fluctuations. The gradual decrease in capture rate at PRAT may be more site related; one possible cause is that the site has been watered less every year since banding began in 2002-03.

When looking at community similarity, PRAT and CIBO also showed different patterns. The PRAT site never had a year to year change in similarity lower than 56%, while CIBO only had one year to year change in similarity that was above 50%. Also, when comparing the first year of data to the last year of data at both sites, PRAT was 70% similar while CIBO was only 45% similar. Habitat differences between these sites may be one reason for these differences in community similarity. The CIBO site has a large mesquite component that includes a large area of tall Johnsongrass as an understory. This greater habitat mosaic can bring a wider variety of species to the site, such as sparrows, which utilize the abundance of seeds produced by the Johnsongrass. These species may also be much more transient from year to year when a habitat mosaic is present. The PRAT site is more homogeneous and does not have a mesquite component.

Avian community similarity was compared between all three sites during the 2005-06 winter season. Capture rates for some species varied between CIBO and HAVA. Habitat patch size and shape may be one reason for this difference in community similarity. HAVA is a linear site, comprising both monotypic stands of *Tamarix* spp. and areas with a high canopy of cottonwood trees. CIBO is a non-linear habitat mosaic that includes areas of cottonwoods, willows, and mesquites.

Site location and landscape habitat mosaic may also influence avian community similarity. The HAVA site is near a *Tamarix* spp. dominated habitat located next to a large marsh complex. The PRAT site is bordered by *Tamarix* spp. and agricultural land. The CIBO site is bordered by agricultural fields, experimental restoration fields, and a seasonal wetland field that is usually flooded during the winter for waterfowl. The proximity of other habitat may affect bird use.

Continuing winter banding efforts at CIBO and HAVA will allow Reclamation to better understand how habitat creation sites can be managed to increase species richness and diversity, especially of those species that are covered under the LCR MSCP.

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Appendix A. Standard AOU (American Ornithological Union) Codes used for North American Bird Species banded along the LCR.

Code	Common Name	Scientific Name
GAQU	Gambel's quail	*Callipepela gambelii*
SSHA	sharp-shinned hawk	*Accipiter striatus*
AMKE	American kestrel	*Falco parverius*
WWDO	white-winged dove	*Zenaida asiatica*
MODO	mourning dove	*Zenaida macroura*
COGD	common ground-dove	*Columbina passerine*
GRRO	greater roadrunner	*Geococcyx californianus*
LENI	lesser nighthawk	*Chordeiles acutipennis*
BCHU	black-chinned hummingbird	*Archilocus alexandri*
ANHU	Anna's hummingbird	*Calypta anna*
COHU	Costa's hummingbird	*Calypte costae*
LBBO	ladder-backed woodpecker	*Picoides scolaris*
NOFL	northern flicker	*Colaptes auratus*
WWPE	western wood pee-wee	*Contopus sordidulus*
WIFL	willow flycatcher	*Empidonax trailii*
LEFL	least flycatcher	*Empidonax minimus*
HAFL	Hammond's flycatcher	*Empidonax hammondii*
GRFL	grey flycatcher	*Empidonax wrightii*
DUFL	dusky flycatcher	*Empidonax oberholseri*
WEFL	western flycatcher	*Empidonax difficilis/occidentalis*
PSFL	Pacific-slope flycatcher	*Empidonax difficilis*
EAPH	eastern phoebe	*Sayornis phoebe*
BLPH	black phoebe	*Sayornis nigricans*
SAPH	Say's phoebe	*Sayornis saya*
VEFL	vermillion flycatcher	*Pyrocephalus rubinus*
ATFL	ash-throated flycatcher	*Myiarchus cinerascens*
BCFL	brown-crested flycatcher	*Myiarchus tyrannulus*
CAKI	Cassin's kingbird	*Tyrannus vociferans*
WEKI	western kingbird	*Tyrannus verticalis*
LOSH	loggerhead shrike	*Lanius ludovicianus*
BEVI	Bell's vireo	*Vireo belli*
PLVI	plumbeous vireo	*Vireo plumbeus*
WAVI	warbling vireo	*Vireo gilvus*
VERD	verdin	*Auriparus flaviceps*
RBNH	red-breasted nuthatch	*Sitta canadensis*
BEWR	Bewick's wren	*Thryomanes bewickii*
HOWR	house wren	*Troglodytes aedon*
MAWR	marsh wren	*Cistothorus palustris*
GCKI	golden-crowned kinglet	*Regulus satrapa*
RCKI	ruby-crowned kinglet	*Regulus calendula*
BGGN	blue-grey gnatcatcher	*Polioptila caerulea*
BTGN	black-tailed gnatcatcher	*Polioptila melanura*
SWTH	Swainson's thrush	*Catharus ustulatus*
HETH	hermit thrush	*Catharus guttatus*
AMRO	American robin	*Turdus migratorius*
NOMO	northern mockingbird	*Mimus polyglottos*
CRTH	crissal thrasher	*Toxostoma crissale*
PHAI	phainopepla	*Phainopepla nitens*
OCWA	orange-crowned warbler	*Vermivora celata*
NAWA	Nashville warbler	*Vermivora ruficapilla*

Code	Common Name	Scientific Name
LUWA	Lucy's warbler	*Vermivora luciae*
YWAR	yellow warbler	*Dendroica petechia*
AUWA	yellow-rumped (Audubon's) warbler	*Dendroica coronata audoboni*
MYWA	yellow-rumped (Myrtle's) warbler	*Dendroica coronata coronata*
BAWW	black-and-white warbler	*Mniotilta varia*
BTYW	black-throated gray warbler	*Dendroica nigrescens*
TOWA	Towsend's warbler	*Dendroica townsendi*
HEWA	hermit warbler	*Dendroica occidentalis*
AMRE	American redstart	*Setophaga ruticilla*
NOWA	northern waterthrush	*Seiurus noveboracensis*
KEWA	Kentucky warbler	*Oporornis formosus*
MGWA	Macgillivray's warbler	*Oporornis tolmiei*
COYE	common yellowthroat	*Geothypis trichas*
WIWA	Wilson's warbler	*Wilsonia pusilla*
YBCH	yellow-breasted chat	*Icteria virens*
SUTA	summer tanager	*Piranga rubra*
WETA	western tanager	*Piranga ludoviciana*
GTTO	green-tailed towhee	*Pipilo chlorurus*
SPTO	spotted towhee	*Pipilo maculatus*
ABTO	Abert's towhee	*Pipilo aberti*
CHSP	chipping sparrow	*Spizella passerine*
BRSP	Brewer's sparrow	*Spizella breweri*
VESP	vesper sparrow	*Pooecetes gramineus*
BTSP	black-throated sparrow	*Amphispiza bilenata*
SAVS	savannah sparrow	*Passerculus sandwichensis*
FOSP	fox sparrow	*Passerela iliaca*
SOSP	song sparrow	*Melospiza melodia*
LISP	Lincoln's sparrow	*Melospiza lincolnii*
WTSP	white-throated sparrow	*Zonotrichia albicollis*
WCSP	white-crowned sparrow	*Zonotrichia leucophrys*
GWCS	Gambel's white-crowned sparrow	*Zonotrichia l. gambelii*
MWCS	mountain white-crowned sparrow	*Zonotrichia l. oriantha*
DEJU	dark-eyed junco	*Junco hyemalis*
BHGR	black-headed grosbeak	*Pheucticus melanocephalus*
BLGR	blue grosbeak	*Passerina caerulea*
LAZB	lazuli bunting	*Passerina amoena*
INBU	indigo bunting	*Passerina cyanea*
RWBL	red-winged blackbird	*Agelaius phoeniceus*
WEME	western meadowlark	*Sturnella neglecta*
YHBL	yellow-headed blackbird	*Xanthocephalus xanthocephalus*
GTGR	great-tailed grackle	*Quiscalus mexicanus*
BHCO	brown-headed cowbird	*Molothrus ater*
HOOR	hooded oriole	*Icterus cucullatus*
BAOR	Baltimore oriole	*Icterus galbula*
BUOR	Bullock's oriole	*Icterus bullocki*
SCOR	Scott's oriole	*Icterus parisorum*
HOFI	house finch	*Carpodacus mexicanus*
LEGO	lesser goldfinch	*Carduelis psaltria*
HOSP	house sparrow	*Passer domesticus*