North Basin Waterbird Study
Eastshore State Park
Berkeley, California
2004-2007

Prepared by

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Contents

Figures

Tables

Photographs

I. Introduction

In early December 2003 the California Department of Parks and Recreation (DPR) issued a Request for Proposals (RFP) for a waterbird study for Eastshore State Park stating the following Project Objectives:

- Conduct a survey of waterbird and wader use of the North Basin;
- Study the impacts that non-motorized boating activities may or may not have on waterbirds and waders in the North Basin;
- Provide recommendations and management guidelines for boating activities so that waterbirds and waders are not adversely affected.

Avocet Research Associates (ARA) prepared a proposal in response to that RFP and submitted it to DPR on December 12, 2003. On January 8, 2004, DPR completed its evaluation of the proposals and informed ARA that it had been selected as the consultant for the Eastshore State Park waterbird study.

ARA submitted a "North Basin Rafting Waterbird Study Plan," as required by the RFP on February 23, 2004. Both the RFP and the study plan were circulated to interested parties and comments were submitted to DPR. These parties provided extensive comments on and criticisms of the original study plan. ARA agreed with DPR to revise the study plan in an attempt to address the various comments of the reviewers and to clarify the methods and scope of the study. This revised study plan was sent to a team of scientists with expertise in San Francisco Bay waterfowl and disturbance studies for peer review in April 2004. The Plan was finalized on June 2, 2004.

ARA began conducting observational surveys of waterbirds in the North Basin in January 2004, prior to completion of the Plan. This initiative was taken in order to capture waterbird data during the 2004 winter season and thereby complete the study in a timely manner. These initial observational surveys were modified *post hoc* (where possible). Surveys conducted in the 2004-07 period were designed to conform to the methods described in the final Revised Study Plan. The experimental portion of the study—to determine waterbird response to disturbance—commenced in November 2004.

In this report we present the results of avian population surveys over four winter periods (October through April) and three summer periods (May through September) and the results of disturbance trials conducted during three winter periods. We evaluate waterbird abundance and distribution with respect to season, locations within the basin (subareas), and depth classes within the basin. “Waterbirds” include species belonging to the following avian taxonomic groups: *Anatidae* (Ducks, geese, and swans); *Gaviidae* (loons); *Podicipedidae* (grebes); *Pelecanidae* (pelicans); *Phalacrocoracidae* (cormorants) and *Rallidae* (coots). “Waders” refers to the *Ardeidae* (herons and egrets) and shorebirds of the Order *Charadriformes* (plovers, oystercatchers, sandpipers). The *Laridae* (gulls and terns) are treated separately. For the purposes of this study, these groups were divided into categories based on feeding behaviors that do not conform to taxonomic boundaries: divers, dabblers, waders, and larids (Appendix A).

The disturbance trials were conducted independently from the avian population surveys and are treated in a separate section of the report. However, results of the disturbance trials were used in concert with the results of the population surveys to inform management recommendations.

II. Purposes of the Study.

Two basic questions were addressed in this study:

1) What species of waterbirds currently use the North Basin, in what abundances, and in what seasons?
2) How might the increased use of non-motorized watercraft affect distribution and abundance of waterbirds within the basin?

To measure waterbird use of the Basin, ARA conducted 75 observational surveys over a three-year period, capturing four winter seasons and three summer seasons. Surveys were conducted at approximately two-week intervals from August through April to frame and capture the period of greatest waterbird bird use. Two additional surveys each winter were added opportunistically to capture anomalous weather events. During the period of minimum use (May through August), surveys were conducted once a month at minimum. Survey dates, and tidal conditions are summarized in Table 1.

Table 1. Schedule of avian abundance surveys with weather and tidal conditions.

Shaded surveys (n=51) were included in analysis of the "winter period" (season of maximum abundance). Non-shaded surveys (n=24) were classified as "summer period" and were conducted to capture wader use, migratory pulses, and breeding season use by locally nesting species. Tidal categories (high, mid, low) were classified according to tidal levels (relative to the NOAA chart datum, mean lower low water) that dominated throughout the census: high = >3.0 feet; mid = 2.0 to 4.0 feet; low = <3.0 ft. Tidal trend describes the predominate tidal dynamic during the census period: rising (rise), static (slack), or falling (fall). Wind categories are based on the Beaufort scale and cardinal direction given in degrees (°).

#	Date	Time	Tide	Trend	Wind speed	Wind dir °
1	1/22/04	9:45	high	slack	2	120
2	1/29/04	10:00	low	fall	1	170
3	2/12/04	9:50	low	fall	2	310
4	2/26/04	7:30	low	slack	6	210
5	3/11/04	9:30	low	slack	1	200
6	3/26/04	9:30	low	slack	3	300
7	4/8/04	9:18	low	slack	4	270
8	4/22/04	9:15	low	slack	5	280
9	5/9/04	9:15	low	rise	5	280
10	5/20/04	10:00	low	rise	4	270
11	6/3/04	10:10	mid	rise	4	260
12	6/15/04	11:15	high	rise	3	260
13	6/28/04	11:15	high	rise	4	280
14	7/13/04	10:10	high	rise	2	270
15	7/23/04	9:30	high	rise	4	290
16	8/5/04	9:35	low	slack	3	270
17	8/17/04	9:30	low	rise	4	270
18	9/2/04	9:15	low	slack	3	340
19	9/14/04	9:55	mid	rise	3	270
20	9/29/04	9:00	low	rise	4	280
21	10/11/04	9:30	high	rise	1	90
22	10/26/04	9:30	high	rise	4	260
23	11/9/04	9:45	high	slack	2	250
24	11/30/04	9:35	low	rise	0	0
25	12/16/04	9:35	low	slack	2	320
26	1/1/05	9:00	high	slack	3	190
27	1/19/05	9:30	high	fall	3	90
28	2/2/05	9:30	high	fall	0	0
29	2/18/05	9:40	high	fall	2	160
30	3/1/05	9:50	low	slack	3	290
31	3/15/05	9:35	low	slack	3	20
32	4/1/05	9:30	low	fall	3	300
33	4/13/05	9:45	low	slack	4	260
34	5/3/05	9:40	high	slack	4	280
35	5/16/05	9:30	high	slack	4	270
36	6/14/05	9:30	mid	fall	4	280
37	7/13/05	9:45	low	slack	4	290
38	8/18/05	9:30	mid	rise	4	310
39	9/14/05	9:35	high	rise	4	280

#	Date	Time	Tide	Trend	Wind speed	Wind dir °
40	10/4/05	9:30	mid	rise	3	320
41	10/18/05	9:30	mid	rise	2	300
42	11/3/05	9:30	high	rise	4	270
43	11/16/05	9:00	high	fall	3	80
44	12/2/05	9:30	high	fall	5	200
45	12/15/05	9:30	high	rise	0	0
46	1/3/06	9:30	high	slack	2	260
47	1/16/06	9:30	high	fall	2	300
48	2/4/06	9:45	high	slack	2	250
49	2/17/06	9:30	high	fall	3	290
50	3/3/06	9:30	low	rise	4	230
51	3/17/06	9:30	high	fall	4	170
52	3/29/06	9:30	high	fall	4	230
53	4/18/06	9:30	high	slack	4	290
54	5/5/06	9:30	high	rise	4	280
55	6/16/06	9:30	high	fall	4	270
56	7/11/06	9:30	mid	fall	3	270
57	8/10/06	9:30	mid	fall	3	320
58	10/13/06	9:30	high	rise	4	260
59	11/3/06	9:30	low	slack	2	190
60	11/14/06	9:30	low	rise	4	140
61	11/29/06	9:30	low	rise	3	310
62	12/13/06	9:30	low	rise	2	180
63	12/27/06	9:30	mid	rise	6	150
64	1/12/07	9:30	mid	fall	7	290
65	1/20/07	9:30	high	rise	0	0
66	1/30/07	9:30	high	slack	3	330
67	2/13/07	9:30	mid	fall	0	0
68	2/20/07	9:30	low	rise	1	260
69	2/27/07	9:30	high	fall	3	240
70	3/6/07	9:30	high	rise	3	280
71	3/13/07	9:30	high	fall	2	300
72	3/27/07	9:30	high	fall	4	260
73	4/10/07	9:30	mid	fall	4	280
74	4/20/07	9:30	low	rise	1	180
75	4/24/07	9:30	mid	fall	5	290

In order to quantify responses of wintering waterbirds to disturbance by non-motorized watercraft, experimental disturbance trials were conducted on six days each year during the period of peak waterbird abundance (November through February). A total of 24 trials per year (±4 per survey date) were conducted, for a total of 74 disturbance trials along 5 separate transect lines (Table 2, Figure 5). Each trial generated multiple independent events (see Methods), leading to 689 measurements of waterbird species disturbances.

From the results of these surveys we developed recommendations designed to "minimize disturbance to rafts of wintering ducks and other waterbirds in the North Basin" and prevent "significant adverse impacts" (Eastshore State Park General Plan, pg III-76, Section c. North Basin).

Table 2. Schedule of disturbance trials conducted at North Basin, 2004-07.

Trial#	**Date**	**start**	**end**	T1	T2	T3	T4	T5	**# events**	**Tide**	**Trend**	**Beaufort**	**Wind dir**	**weekend?**
1	11/12/04	10:15	12:30	√		√	√	√	38	L	F	1	320	N
2	12/09/04	9:50	11:10		√	√	√	√	27	L	S	3	160	N
3	12/30/04	10:00	11:30	√	√	√			30	H	S	3	150	N
4	01/15/05	15:00	15:30					√	17	H	F	2	110	Y
5	02/12/05	10:55	13:00		√	√	√		48	H	S	0	0	Y
6	03/04/05	8:30	10:45	√	√	√		√	37	H	R	1	340	N
7	03/27/05	12:00	14:35	√	√	√	√	√	53	H	S	1	300	Y
8	10/30/05	7:10	10:13	√	√	√	√	√	46	H	R	2	290	Y
9	11/19/05	12:30	15:10	√	√	√	√	√	54	H	F	1	70	Y
10	12/09/05	9:00	11:30	√	√	√	√	√	48	H	F	2	80	N
11	01/11/06	14:12	16:20	√	√	√	√	√	44	L	S	1	140	N
12	01/25/06	11:00	13:30	√	√	√	√	√	36	M	F	0	0	N
13	02/18/06	8:15	11:30	√	√	√	√	√	34	L	R	1	30	Y
14	03/04/06	8:50	11:20	√	√	√	√	√	33	L	R	2	220	N
15	11/17/06	7:30	10:00	√	√	√	√	√	48	H	R	1	350	N
16	12/15/06	12:00	2:30	√	√	√	√	√	61	L	F	0	0	N
17	02/20/07	8:00	10:30	√	√	√	√	√	35	L	R	1	250	N
				14	15	16	14	15	689					

III. Study site

The study site included the shoreline and open water of the North Basin, a roughly rectangular embayment, on the eastern shore of central San Francisco Bay (SFB), located on the waterfront adjacent to the City of Berkeley (Figure 1). The Basin is fully tidal but somewhat buffered from prevailing winds and waves by a man-made peninsula, Caesar Chavez Park (45.8 ha), along its western boundary. The Basin itself is 54 ha in aerial extent bound by a shoreline 2228 meters in length (east shore 831-m; south shore 554-m; west shore 843-m). The north boundary, the mouth of the basin (734 m), is open to SFB waters. The shoreline is highly disturbed substrate. Much of the eastern shore during this study was a parking lot, and a footpath follows the remainder of the shoreline. There is now a sports field complex along the north portion of the eastern shore, where the parking lot once was. The western shore accommodates a rather intensive amount of recreational foot traffic, especially during fair weather and on weekends.

We expanded the study site beyond the strict boundaries to include adjacent waters that were used by the waterbirds that occurred within the basin (often drifting, swimming, or flying in-and-out the mouth) and waters that might be accessed by small watercraft entering or leaving the basin. These waters included an additional 46 hectares outside the basin (Figure 3). Therefore, the size of the entire study site was 100 ha.

Intertidal habitat is limited (<5% of area) to the southern edge of the site, concentrated mostly in the southeast corner. Subtidal habitat predominates, but the Basin is relatively shallow, with depth contours ranging from 0.0 to 1.5 meters below mean lower low water. Depths greater than 1.5 meters extend into the north boundary and predominate in the adjacent waters (Figure 1).

Figure 1. North Basin study site with depth contours overlain at 0.5 meter intervals [NGVD 29 @ 0.0']. The red line (separating water depth zones 2 and 3) delineates the 1-m depth contour.

IV. Methods

<u>Waterbird Counts: Protocols and Methods.</u>

Bird censuses (absolute counts) were conducted from six fixed points evenly distributed around the perimeter of the basin (Figure 2).

Figure 2. North Basin study site with distribution of observation points used during avian population surveys. UTM coordinates [NAD83 Zone 10S] for each point are:

#1. 0560488/4192832
#2. 0560709/4192342
#3. 0560891/4191668
#4. 0560288/4191690
#5. 0560038/4192093
#6. 0559531/4192156

We partitioned the study area into five subareas, to facilitate coverage and to identify areas of relative use by waterbirds (Figure 3).

Figure 3. Survey plots within the North Basin Study Area. The study area encompassed 100 hecatares. The size of each plot is as follows: A (46.0 ha); B (17.4 ha); C (11.7 ha); D (10.7 ha); E (14.2 ha).

Each avian population survey was conducted in the morning and spanned approximately three hours. In the study plan we had anticipated initiating surveys on high (flood) tide and continuing through the falling tide to capture low tide conditions. We modified the protocol for two reasons: (1) after several trial surveys (1/20/04 and 1/22/04) it became apparent that the entire site was subtidal and numbers of open-water birds seemed not to vary noticeably between high- and low-tide phases; and, (2) constraints imposed by such tidal conditions would have limited the number of potential survey days and prevented thorough coverage of variation in waterbird abundances. Therefore, we modified protocols to capture both high- and low-tide conditions within a seasonal period (Table 1).

Tide heights were determined from the nearest NOAA correction location at Alameda and a designated minimum time period of 0.5 hrs between counts. Each count was assumed to be independent in the analysis.

Overall, high tides dominated on nearly half the surveys (47.4%) and low tides dominated on approximately one-third (35.5%); mid-range tides were less frequent (17.1%). These proportions were roughly equivalent during winter and summer census periods. Regarding tidal trend, rising tides predominated (40.8%), whereas falling tides (30.2%) and slack tides (28.9%) were roughly equivalent. Considering the winter period only, the tidal trends were fairly evenly divided between falling (38.5%), slack (32,7%) and rising (28.9%).

On each survey, birds present were identified to species. The total number of individuals using the site during each census period was tallied and assigned to a subarea (Figure 3). Beginning in December of 2005, each individual or flock was assigned to a band-width based on its distance from shore (0-100 m, 200-300 m, 300-400 m, and >400 m). *Post hoc*, each individual or flock was assigned to one of four mean tide depth contour intervals of the study area (Figure 2). These were then pooled into two depth classes (<1-m or >1-m) during data analysis: (1) shallow (<1-m), and (2) deep (>1-m). The subarea boundaries were considered fixed boundaries regardless of tide height (Figure 3).

The sample unit of measurement consisted of total number of birds (abundance) by species in each depth section of the Basin per survey. One or two ARA biologists counted the number of birds present on each census ("absolute counts") using 20x (or higher) power telescopes. Observer(s) used field judgment to avoid multiple counting within or among subareas, i.e., movement of flocks or individuals was noted and accounted for in the final tally for that time period. The manageable bird numbers at the site combined with the site's small size and well-defined boundaries allowed constant observation, even when moving between observation points. Birds were assigned to the section in which they were first observed on a given census. Parenthetical notes indicated when a flock was detected in an additional section and these numbers were not included in the census totals. A recorder accompanied the observer to transcribe the data to a data sheet. Data was electronically archived and is stored with ARA and California State Parks.

To avoid over- or under-counting, the field observer(s) made a rough estimate of the total numbers of birds on the lagoon at the beginning and end of each census. Discrepancies between overall estimates and recorded numbers were adjusted in the field based on recounts of common species and on the observer's best judgment.

Movements of individuals or flocks in-and-out of the basin were noted and reconciled with overall numbers by the observer in the field. The cause of the movement, if known, was recorded. Each census measured the peak number of individuals of each species and relied on peak counts during the census period.

Analysis of Waterbird Count Data

We analyzed differences in species abundances using a mixed-model analysis of variance, with Year as a random effect and Subarea and Water Depth zones (Figures 1 & 3) as fixed effects. Prior to analysis, we natural-log-transformed the abundance data to improve the normality of residuals and stabilize group variances. The results for uncommon species that did not meet the assumptions of parametric (ANOVA) tests are reported with summary statistics. To facilitate comparisons among count areas and water depth zones that differed in areal extent, and to compare the results with values from other Bay Area locations, we converted bird abundances to densities (birds per 100 ha) prior to analysis of each species (or pooled species group) and weighted the density for each water depth within each count area by its areal extent. Significant main effects of count area or water depth on species densities were followed by pairwise multiple comparisons based on an experimentwise error rate of $P < 0.05$.

Disturbance Trials: Protocols and Methods.

The waterfowl disturbance experiments described by Rodgers and Smith (1997) and Rodgers and Schwikert (2003) provided a template for the design of this portion of the study. The methodology was modified, however, to accommodate non-motorized watercraft and the smaller size of the study area. Kayaks were used exclusively during the disturbance trials and are considered surrogates for other watercraft types (canoes, sailboards, etc.).

Human disturbance to waterbirds has been documented and quantified in a number of studies (Burger 1981, Dahlgren and Korschgen 1992, Davidson and Rothwell 1993, Kahl 1991, Klein 1993, Masden 1994, Rodgers and Schwikert 2003). In this study, ARA biologists used an experimental approach to answer the question: To what extent do non-motorized watercraft affect distribution, abundance, and behavior (decision to flush) of waterbirds within the Basin?

On six occasions each year within the November-March time period of peak waterbird use we initiated disturbance events with kayaks. (Birds are more sedentary and site tenacious in mid-winter than during migratory periods.) On each occasion we initiated four independent disturbance trials building a sample size of 74 trials over three winter periods. Each set of experimental trials was spaced at 2-week minimum intervals to avoid the problem of habituation in responses of birds to the disturbance stimulus. We judged that the site was large enough and experimental treatments mild enough to allow a planned disturbance event in one quadrant of the site without disturbing birds in other quadrants. To ensure independence, each trial on a given date targeted different individuals or flocks. Trials conducted on a given date were separated by at least 30-minutes and by 400-m and were conducted in a different subarea of the site (Table 2). We attempted to sample species responses evenly across transects, 1 *versus* 2 kayaks, weekday *versus.* weekend. Each trial included multiple disturbance events. We assumed each of these events to be an independent response to disturbance because each trial was separated from another in distance (>100 meters) and time (0.5 hrs), different individuals and flocks were targeted, and flushed flocks usually moved out of the subarea in which the disturbance had occurred.

Birds were approached by kayak when foraging or loafing. We intended to record the initial alert response (e.g. head alert) to a watercraft approach when possible, but this proved impossible given the background level of disturbance (traffic noise, runners and walkers along the shoreline, etc.). Therefore, flush distance was used as the primary measure of disturbance. Flush distance was defined as the distance from the kayak(s) at the moment a bird begins swimming, diving, or flying away from the approaching watercraft. The distance was measured to the first (closest) bird in the group that flushed. Kayaks ceased paddling immediately when the first bird(s) began to flush and waited for several minutes before continuing to progress along the transect path.

A laser digital range finder (Bushnell Yardage Pro with calibrated accuracy of ±1-m from 10 to 500-m) was used to measure distance at which the first flush response was observed. When conditions precluded use of a rangefinder (e.g rain), the observer simply estimated the distance to the nearest meter.

The observer approached the target bird or flock from a distance of at least 200-meters, in a direct (<30°) path, using a steady stroke and moderate speed typical of a touring kayak. At the moment the bird(s) began to move from the foraging or loafing location a straight-line distance was measured or estimated. For each trial we recorded:

- First flush distance and flush species;
- Group size (all species);

- Proportion of individuals in each group, by species;
- Proportion of individuals of each species that flushed.

An effort to measure differential disturbance responses of waterbirds to sailing craft that had been contemplated in the study plan was not completed as part of this study.

<u>Analysis of Disturbance Trials</u>

We conducted 74 disturbance trials, with a combined total of 689 disturbance events, following transect routes through the North Basin (see Figure 5) with varying species composition among trials. We analyzed the responses of each species for which we obtained at least 10 disturbance-distance observations.

We examined the scatter plots of flock size vs. response distances for evidence of outliers or nonlinear patterns that might confound estimates of recommended distances for particular flock sizes.

We used analysis of variance (ANOVA) to examine possible differences in species disturbance responses between number of kayaks (1 vs. 2 or 3; three kayaks were used on only one of 16 trial days), tide level (high, medium, low), year (winters of 2003-2004, 2004-2005, 2005-2006, 2006-2007), weekday vs. weekend, and transect area (shoreline: Transects 1 and 2; mid-basin: Transects 3 and 4; outer-basin: Transect 5; Figure 5). Disturbance trials were scheduled to sample as evenly as possible among these categories. Although the number of samples for each species varied among categories, linear analyses can easily handle the unbalanced data among groups if the assumptions of ANOVA are satisfied (Quinn and Keough 2003). We used the Shapiro-Wilk test statistic to determine if disturbance responses were normally distributed for each species. Natural-log transformations [$y = \ln(x)$] successfully normalized the data for all species analyzed. We examined plots of residuals against predicted values and used Levene's Test to test for equality among group variances. Results suggested that the ln-transformed data satisfied the assumption of homogeneity of variances. No significant differences were found in species responses related to the main effects of year, tide level, transect area, weekday vs. weekend, or number of kayaks ($P > 0.05$). We did not examine the possibility of influences related to interactions among these effects. Therefore, we pooled the data for each species across these categories.

Intraseasonal declines in disturbance response would suggest habituation to human activity, whereas intraseasonal increase would suggest increasing sensitivity through the winter. Therefore, we included Intraseasonal timing (number of days since 30

October within each winter season) and species flock size (number of conspecific individuals in each flock) as covariates in determining patterns of variation of disturbance responses and in estimating recommended distances to avoid disturbance to waterbirds. However, we found no evidence among the species analyzed for habituation based on the intraseasonal timing of disturbance trials (linear regressions, $P > 0.05$).

Other investigators have determined that disturbance distances of waterbirds are likely to be influenced by the presence of individuals of other species (Thompson and Thompson 1985; see citation in Rodgers and Smith 1997). Although response distances of multiple species were recorded during each trial, we considered each trial-x-species response to be independent,. The disturbance sensitivity (response distances) of five species increased significantly with the size of species groups (Table 11; significant linear regressions, $P < 0.05$). Although the overall size of mixed species flocks is likely to increase waterbird sensitivity (response distance) to disturbance, species flock size and mixed-species abundance were significantly correlated ($r = 0.36$ over all species combined, $n = 432$, $P < 0.001$) and, after accounting for flock size, the residual effects of mixed-species abundance were no longer significant ($P > 0.05$) in all species except Bufflehead and Clark's Grebe. Therefore, we adjusted the predicted response distances for species flock size but not for mixed species abundance. In addition, the influence of overall waterbird abundance seemed less likely to influence species responses because single-species groups were often encountered sequentially as the kayak(s) traveled along the transect, rather than simultaneously during each trial. Whenever flock size significantly affected response distances, we reported the recommended distance to avoid disturbance of single individuals and also the maximum flock size observed during the disturbance trials (Table 11).

The recommended distances use the upper 0.95 quantile of the standard normal deviate of disturbance distances to provide a conservative and reasonable margin in predicting distances that are sufficiently unlikely to result in disturbance to resting or feeding waterbirds (Rodgers and Smith 1997).

$$\text{Recommended distance} = \exp(\hat{\mu} + z_{0.95} * \hat{\sigma}) + 40 \text{ m},$$

where $\hat{\mu}$ and $\hat{\sigma}$ are the sample mean and standard deviation of ln-transformed response distances [$y_i = \ln(x_i)$] and $z_{0.95}$ is the upper 0.95 quantile of the standard normal variable ($z_{0.95} = 1.6495$). The addition of 40 m to the recommended distance provides a buffer that allows for:

(1) unmeasured increases in the sensitivity (response distances) of birds responses associating in mixed-species flocks (Thompson and Thompson 1985);

(2) undetected physiological responses, alert behaviors, or foraging interruptions in bird response prior to flushing (swimming, diving, or flying);

(3) potentially reduced stimulus related to the low-profile of kayaks; and,

(4) responses to larger groups of kayaks or other non-motorized watercraft.

V. Avian Surveys: Results and Discussion

On 75 avian surveys we recorded 70,778 individual waterbirds (96.1 percent during the winter period, 3.8 percent in the summer period). The total number of waterbirds in the winter period averaged 1081.5 birds per count [SE = 164.1; min-max = 124-5488] and 113 birds per count [SE = 24.4; min-max = 16-607] in the summer period. Overall, we observed 83 species of waterbirds during our avian surveys of North Basin (Appendix A); 81 species occurred during the winter period and 63 occurred during the summer period.

Seasonal Use

In a two-year baywide study, Accurso (1992) reported peak numbers of wintering waterfowl in early December and mid-January with diving ducks accounting for >92% of the Central Bay's waterfowl throughout winter. Bollman *et al*. (1970), surveying selected sites, reported peak waterfowl numbers in early and mid-December. Annual mid-winter surveys by USFWS are normally conducted in early January, and may not sample the peak. The seasonal occurrence of diving ducks in the North Basin (Figure 4) was typical of seasonal abundance patterns in San Francisco Bay. Graphs depicting seasonal abundance of each the four most abundant rafting waterbird species counted in North Basin are given in Appendix B.

As in the greater San Francisco Bay (see Takekawa *et al*. 2000), the winter period at North Basin supported the highest abundance of waterbirds and species that raft on open water. Winter percentages by species group were 35% diving birds; 31.3% shorebirds;15% "dabblers" (surface feeding waterfowl); 13% larids (gulls and terns); and 5% ardeids (herons and egrets). Diving ducks tend to arrive *en masse* in mid-October to early November, with some variation among years, a mid-winter peak in numbers, and fairly rapid decline during spring. By mid-April abundances are relatively low. This seasonal use pattern is well represented by four of the most abundant waterfowl species at North Basin, all diving ducks (see Figure 4 and Appendix B).

Summer numbers, though substantially lower than winter numbers, captured more waders as a percentage of the avian community: waders (36.5%); divers (31.8%); dabblers (13%); larids (14.3%), and ardeids (5%). This was expected since wader occurrence peaked during fall and spring migratory pulses, as it does at other SFB sites (Takekawa *et al*. 2000, Stenzel *et al*. 2002).

Scaup serve as an emblematic species, not only because they are one of the most abundant waterbird species at North Basin (this study) and throughout SFB (Accurso 1992), but because they were among the first to arrive in the fall and the last to depart in the spring, a pattern noted in other studies (Denson and Bently 1962, Accurso 1992). Scaup were also the most sensitive species to kayak disturbance with the largest mean flush distance (Table 11) and therefore they should be used to implement buffer zones for mixed-species sites (Rodgers and Schwikert 2003).

Interannual variation in arrival and departure dates of waterfowl varies as the result of either local conditions or those distant from the Bay Area. Accurso (1992) surveyed the entire bay from October through April and reported peak numbers for some species as early as October 3-4 and as late as March 20-21.

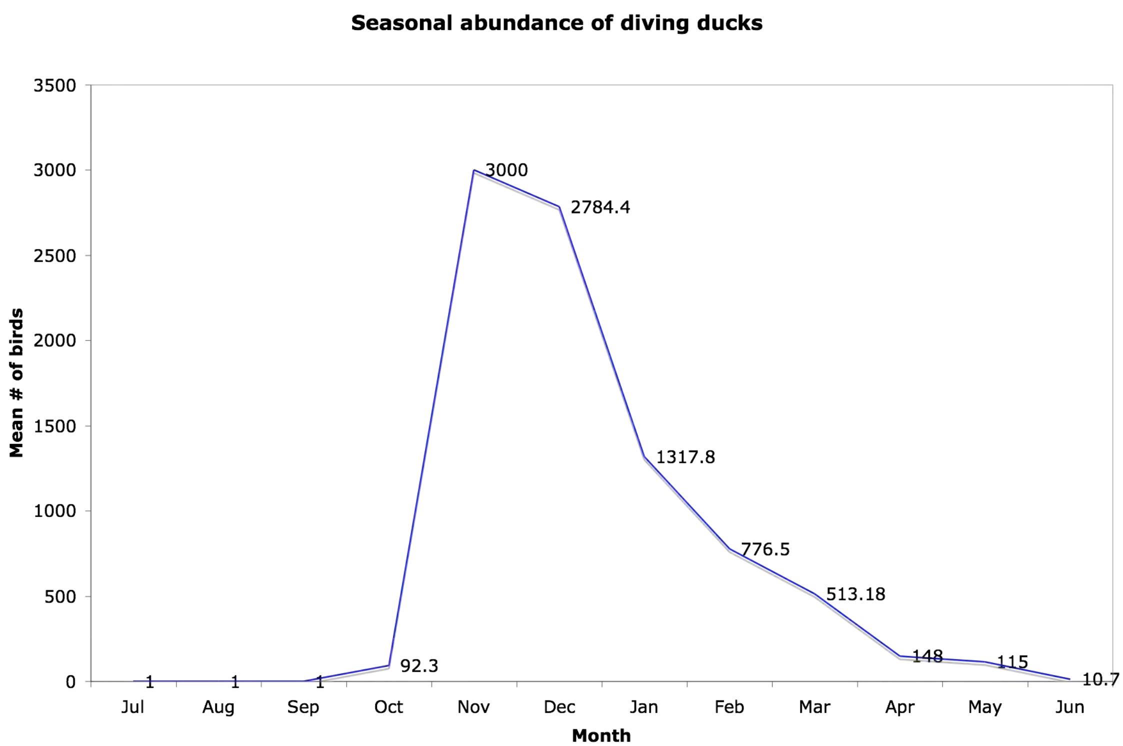

Figure. 4. Seasonal mean abundance of the four most common species that comprised 90 percent of all waterbirds counted in all winter period surveys, 2004-07 [Ruddy Duck 47.3%; two scaup species 36.3%; Bufflehead 6.4%].

<u>Summer Bird Use</u>

For the 15 most abundant species overall (which accounted for >98 % of birds counted), summer use was approximately 10 percent of the winter use for both waterbirds and shorebirds. Non-migratory (locally breeding) species Double-crested Cormorant and Canada Goose showed the highest summer values relative to winter numbers. Shorebird densities were derived only from counts on which birds were present, i.e., zero counts were omitted, due to the paucity of available intertidal habitat and the consequent sporadic occurrence of low numbers of shorebirds. As a result of omitting zero counts, the mean numbers of shorebirds in Table 3, below, appear inflated. Summer bird abundance for all waterbirds detected in the North Basin over three seasons (2004-2006) ranked by mean abundance values, is given in Appendix C.

Table 3. Comparison of winter and summer mean abundance values of the most common waterbirds at North Basin. (Unidentified scaup were apportioned to species based on percentages of identified birds.)

Species	winter mean	summer mean	summer/winter ratio
Waterbirds (total)	948.9	92.2	0.10
Ruddy Duck	445.5	34.5	0.08
Greater Scaup	292.6	22.6	0.08
Bufflehead	60.7	7.2	0.11
Lesser Scaup	55.2	2.1	0.04
Surf Scoter	27.5	3.5	0.13
Clark's Grebe	15.1	2.3	0.15
Horned Grebe	11.9	2.0	0.17
Western Grebe	11.2	1.5	0.13
American Coot	10.8	1.8	0.07
Common Goldeneye	9.78	4.4	0.35
Double-crest. Cormorant	7.6	7.5	0.99
Canada Goose	1.0	2.8	0.45
Shorebirds (total)*	135.0	14.8	0.11
Western Sandpiper*	62.3	3.5	0.06
Least Sandpiper*	48.3	4.2	0.09
Willet*	24.4	7.1	0.29

* *shorebird values omit zero counts therefore represent peak counts.*

Species richness was also related to season. Overall, summer surveys detected 63 species on site; winter surveys detected 81 species. Species occurring during the winter period but not during summer are given in Table 4, below.

Table 4. Waterbird species detected during winter period, but not during summer period.

American Avocet	Gr. White-fronted Goose	Red-breasted Merganser
Black-necked Stilt	Herring Gull	Redhead
Blue-winged Teal	Lesser Yellowlegs*	Ring-necked Duck
Canvasback	Mew Gull	Red-throated Loon
Common Merganser	Northern Pintail	Ruddy Turnstone
Great Blue Heron	Northern Shoveler	Surf Scoter

*late migrant; not a winter species

Only two species were detected in summer, but not in winter: Heermann's Gull and Baird's Sandpiper.

Winter Bird Use

Mean winter abundances of all waterbirds on all winter surveys, by year, ranked by relative abundance are given in Table 5. Mean densities of each species by subarea are given in Table 6. Species codes are provided in Appendix A. Because the size of the census area was 100 hectares (1-km^2), overall mean abundance values are equivalent to overall mean densities (birds/ km^2).

Accurso (1992) reported scaup as the most abundant species in SFB accounting for 43-47 percent of the bay's waterfowl. In North Basin, the Ruddy Duck were more abundant than scaup (Table 5), possibly reflecting the relative shallowness of the site and the protection from open bay waters it affords.

The occasional absence of common species or species groups may have been the result of disturbance events in which birds were flushed from the site (e.g. low-flying plane) prior to an individual survey. Excluding zero counts of important species (e.g. scaup), mean waterbird density during winter was 1920.9 birds/km^2 [SE = 161.5; min-max = 142-5424] and during summer 184.6 bird/km^2 [SE = 57.7; min-max = 121.0-299.8]. Including all surveys, mean winter density of all subareas combined was 1081.5 birds/ km^2 [SE = 164.1; min-max = 756 to 1697].

Table 5. Winter waterbirds at North Basin, 2004-07, ranked by abundance.

Code	Species	Mean	SE	Median	Min	Max
RUDU[1,2]	Ruddy Duck	445.45	79.25	267.00	0	2326.0
Scaup[1,2]	Scaup species	342.00	46.40	219.00	0	1641.0
GRSC[1,2]	Greater Scaup	292.58	42.79	198.64	0	1577.0
BUFF[1,2]	Bufflehead	60.65	8.61	43.00	0	294.0
LESC[1,2]	Lesser Scaup	33.08	10.25	13.00	0	471.0
SUSC[1,2]	Surf Scoter	27.45	6.70	14.00	0	327.0
CLGR[2]	Clarks Grebe	15.44	1.97	13.00	2	82.0
HOGR[2]	Horned Grebe	11.90	1.11	11.00	0	40.0
WEGR[2]	Western Grebe	11.22	1.90	8.00	0	84.0
AMCO[2]	American Coot	10.78	1.60	10.00	0	47.0
COGO[1,2]	Common Goldeneye	9.78	3.14	5.00	0	158.0
DCCO[2]	Double-crested Cormorant	7.63	3.51	3.00	0	177.0
AMWI[3,4]	American Wigeon	1.29	0.58	0.00	0	26.0
EAGR[2]	Eared Grebe	1.14	0.31	0.00	0	12.0
ACGO[3]	"Aleutian" Cackling Goose	1.04	1.04	0.00	0	53.0
CAGO[3]	Canada Goose	1.04	1.04	0.00	0	53.0
CANV[1,2]	Canvasback	0.76	0.67	0.00	0	34.0
PECO[2]	Pelagic Cormorant	0.47	0.10	0.00	0	2.0
COLO[2]	Common Loon	0.45	0.11	0.00	0	3.0
PBGR[2]	Pied-billed Grebe	0.45	0.13	0.00	0	5.0
GWTE[3,4]	Green-winged Teal	0.43	0.30	0.00	0	12.0
RNDU[3,4]	Ring-neck Duck	0.41	0.39	0.00	0	20.0
GADW[3,4]	Gadwall	0.39	0.16	0.00	0	6.0
NOSH[3,4]	Northern Shoveler	0.35	0.35	0.00	0	18.0
BAGO[1,2]	Barrow's Goldeneye	0.27	0.09	0.00	0	2.0
CITE[3,4]	Cinnamon Teal	0.27	0.15	0.00	0	5.0
AWPE[3]	American White Pelican	0.22	0.22	0.00	0	11.0
NOPI[3]	Northern Pintail	0.14	0.14	0.00	0	7.0
RBME[1,2]	Red-breasted Merganser	0.12	0.05	0.00	0	1.0
RTLO[2]	Red-throated Loon	0.06	0.03	0.00	0	1.0
BWTE[3,4]	Blue-winged Teal	0.04	0.04	0.00	0	2.0
COME[2]	Common Merganser	0.02	0.02	0.00	0	1.0
COMU[2]	Common Murre	0.02	0.02	0.00	0	1.0
LTDU[1,2]	Long-tailed Duck	0.02	0.02	0.00	0	1.0
REDH[1,2]	Redhead	0.02	0.02	0.00	0	1.0
ROGO[3]	Ross's Goose	0.02	0.02	0.00	0	1.0
WWSC[1,2å]	White-winged Scoter	0.02	0.02	0.00	0	1.0
	All waterbird species	954.083	124.452	735.00	100	3545.0
	Diving ducks[1]	886.58	124.35	679.00	56	3488.0
	Diving birds[2]	949.04	123.90	733.83	99	3526.0
	Surface-feeding species [3]	4.20	2.17	0.00	0	105.0
	Dabbling ducks[4]	2.92	1.25	0.00	0	51.0

[1] Diving ducks: CANV, REDH, LESC, GRSC, BUFF, LTDU, BAGO, COGO, SUSC, WWSC, COME, RBME, RUDU

[2] Diving birds: Diving ducks + AMCO, CLGR, WEGR, COLO, RTLO, HOGR, EAGR, PBGR, DCCO, PECO, COMU

[3] Surface feeders: Dabbling ducks + AWPE, ACGO, CAGO, ROGO

[4] Dabbling ducks: GADW, GWTE, AMWI, NOPI, NOSH, BWTE, CITE.

Table 6. Mean densities (standard errors) of winter waterbirds in the North Basin, 2003-4 through 2006-7. See Figure 3 for subarea locations and Table 5 for species codes.

	Bird density (birds / 100 ha.)									
Species	Area A	SE	Area B	SE	Area C	SE	Area D	SE	Area E	SE
AMCO	3.794	(1.360)	33.807	(7.740)	20.278	(5.495)	2.199	(1.216)	3.866	(1.767)
AMPE	0.469	(0.469)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
AMWI	0.554	(0.512)	1.578	(0.967)	6.536	(4.417)	0.000	(0.000)	0.000	(0.000)
BAGO	0.128	(0.095)	0.451	(0.316)	0.335	(0.335)	0.733	(0.441)	0.138	(0.138)
BUFF	62.916	(14.458)	43.611	(8.704)	57.818	(9.663)	95.290	(18.209)	50.400	(14.342)
BWTE	0.000	(0.000)	0.000	(0.000)	0.335	(0.335)	0.000	(0.000)	0.000	(0.000)
CAGO	1.961	(1.961)	0.000	(0.000)	1.173	(1.173)	0.000	(0.000)	0.000	(0.000)
ACGO	3.794	(1.360)	33.807	(7.740)	20.278	(5.495)	2.199	(1.216)	3.866	(1.767)
CANV	1.066	(1.023)	0.225	(0.225)	1.341	(1.341)	0.733	(0.576)	0.000	(0.000)
CITE	0.085	(0.085)	0.000	(0.000)	1.676	(1.173)	0.367	(0.367)	0.000	(0.000)
CLGR	19.922	(3.993)	7.971	(1.880)	5.195	(1.458)	15.576	(3.276)	18.442	(3.195)
COGO	10.614	(1.566)	2.705	(1.072)	4.022	(1.382)	4.765	(1.489)	24.303	(20.041)
COLO	0.725	(0.199)	0.113	(0.113)	0.000	(0.000)	0.367	(0.257)	0.414	(0.234)
COME	0.000	(0.000)	0.000	(0.000)	0.168	(0.168)	0.000	(0.000)	0.000	(0.000)
COMU	0.043	(0.043)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
DCCO	4.092	(0.958)	2.705	(1.035)	30.334	(27.617)	11.545	(4.837)	3.452	(1.253)
EAGR	0.853	(0.286)	1.352	(0.635)	1.508	(0.572)	1.649	(0.815)	1.105	(0.536)
GADW	0.128	(0.095)	0.000	(0.000)	2.514	(1.317)	0.367	(0.367)	0.000	(0.000)
GRSC	264.659	(49.746)	212.869	(54.679)	321.930	(123.98)	383.544	(153.993)	387.965	(103.045)
GWTE	0.938	(0.659)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
HOGR	9.548	(1.157)	8.677	(1.397)	14.245	(2.529)	25.289	(5.144)	11.461	(1.719)
LESC	45.473	(18.639)	29.750	(9.858)	40.864	(9.446)	17.592	(6.312)	2.255	(1.295)
LTDU	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.138	(0.138)
NOPI	0.298	(0.298)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
NOSH	0.682	(0.682)	0.225	(0.225)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
PBGB	0.341	(0.127)	0.225	(0.158)	0.838	(0.359)	0.367	(0.257)	0.829	(0.701)
PECO	0.895	(0.221)	0.000	(0.000)	0.000	(0.000)	0.550	(0.311)	0.000	(0.000)
RBME	0.128	(0.072)	0.000	(0.000)	0.000	(0.000)	0.183	(0.183)	0.276	(0.193)
REDH	0.000	(0.000)	0.000	(0.000)	0.168	(0.168)	0.000	(0.000)	0.000	(0.000)
RTLO	0.128	(0.072)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)

Bird density (birds / 100 ha.)

Species	Area A	SE	Area B	SE	Area C	SE	Area D	SE	Area E	SE
RNDU	0.810	(0.768)	0.225	(0.225)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
ROGO	0.043	(0.043)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
RUDU	264.194	(93.965)	604.237	(211.224)	514.832	(121.231)	1082.646	(235.265)	300.746	(168.253)
SUSC	30.520	(4.759)	44.512	(34.925)	11.061	(3.258)	19.058	(5.656)	16.432	(5.011)
WEGR	12.126	(2.569)	3.634	(1.253)	4.357	(1.132)	14.477	(3.885)	20.768	(10.118)
WWSC	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.138	(0.138)
SCAUP	322.195	(56.649)	249.268	(61.303)	404.524	(127.598)	421.294	(155.051)	405.686	(107.030)
Dabbling ducks	2.685	(2.139)	1.803	(0.985)	11.061	(6.160)	0.733	(0.513)	0.000	(0.000)
Divering ducks	692.570	(155.629)	945.233	(247.068)	994.267	(173.981)	1624.702	(317.838)	798.257	(260.129)
Surface-feeers.	5.158	(4.128)	1.803	(0.985)	12.234	(6.229)	0.733	(0.513)	0.000	(0.000)
Diving birds	749.384	(155.644)	1005.633	(247.860)	1071.023	(175.592)	1696.170	(318.338)	863.012	(262.100)
All waterbird species	756.246	(154.844)	1007.436	(247.878)	1083.253	(175.257)	1697.453	(318.258)	863.012	(262.100)

Mean winter density of Ruddy Duck [445.5 birds/100 ha] at North Basin was near the high end of the range reported at other studies. Accurso reported 148 birds/100 ha on open water; Swarth *et al*. (1982) found 550 birds/100 ha on low salinity salt ponds in the South Bay. The disparity in the reported densities among habitats suggests that Ruddy Ducks concentrate in relatively confined and shallow bodies of water like North Basin.

Mean winter scaup density [341.6 bird/100 ha] for the site was lower than reported by Accurso [597-603 birds/100 ha], but within the range found elsewhere in the Central Bay (Avocet 2002; Table 9). Scaup tend to use larger bodies of deep water, but to concentrate in protected embayments to loaf when conditions are not ideal for foraging. Accurso's study identifies the Central Bay as supporting 20% of the waterfowl in the SFB system and as an especially important subregion for scoter, scaup, and bufflehead. During mid-winter surveys in 1989, SFB scaup accounted for 56-92 percent of the population on the Pacific flyway (Accurso 1992).

Bufflehead occurred in higher overall densities (mean = 60.6 birds/100 ha) than reported in Accorso's study (37.8 birds/100 ha), but within the range reported by Shuford et al. (1989) for Point Reyes (25.7-102.4 birds/100 ha) and in lower densities than reported by Kelly and Tappen (1998; 97-405 birds/100 ha) on the outer coast.

Table 7. Comparison of overall waterbird densities at different SFB sites.

Area name	Area size (ha)	D (birds/km^2)	Months/Years	Source
South Bay-East[1]	132.5	1302.5	Nov 2000-Feb 2001	Ford *et al.* 2001
Tomales Bay	28.5	516-1091	Winter 1989-96	Kelly & Tappen 1998
North Basin	**100.00**	**954**	**Oct-Apr (4 yrs)**	**This study**
W. Central SFB (SFO)	14.6	450.7	Winter 2000/01	Avocet 2000
SFB total	1016.9	421.6	Winter 1998/89	Accurso 1992
North SFB baylands	858.3	320	Winter	Takekawa *et al*. 2001*
South SFB open water	194.7	260-290	Winter 1998/89	Accurso 1992
Central SFB open water[2]	214.5	179-246	Winter 1998/89	Accurso 1992
SFB total	1016.9	210.9	Jan. 9. 2002	USFWS 2002*
South SFB open water	194,7	203.3	Jan. 9. 2002	USFWS 2002*
Central SFB open water[2]	214.5	118.5	Jan. 9. 2002	USFWS 2002*

[1] South Bay-East included the eastern half of SFB between the San Mateo Bridge and the Oakland Bay Bridge.
[2] Areal values for SFB and subareas were calculated from Goals Report (1999), Appendix B—"Past and Present Acreage" using values for "bays."
* Sources followed by asterisks are based on aerial surveys which include a low bias, especially for smaller species such as Bufflehead and Ruddy Duck (Kelly & Tappen 1998).

Overall densities of waterbirds at North Basin compared with densities available from other sites, albeit over a wide disparity of years, show North Basin supporting relatively high concentrations of waterbirds in winter (Table 7). This is explained by high concentrations of Ruddy Duck, two scaup species, and Bufflehead.

The North Basin provides waterbird habitat relatively protected from wind and storm surges and adjacent to the open waters of the Central Bay. Numbers of waterbirds peak in winter and may reach very high densities sporadically, during extreme weather or migratory staging. Highest concentrations of each species are provided below (Table 8).

Table 8. Most common open-water birds at the North Basin study site (100 ha) with peak count densities (birds/ km^2), dates, and coefficient of variation (CV of densities). These 12 species comprised 98.7% of all wintering waterbirds.

Species	peak density	peak date	CV
Ruddy Duck	2326	11/30/04	0.25
Greater Scaup	1577	11/29/06	0.57
Lesser Scaup	471	12/13/06	0.71
Surf Scoter	327	12/15/04	0.30
Bufflehead	294	11/30/04	0.19
Double-crested Cormorant	177	2/18/05	0.35
Common goldeneye	158	2/4/06	0.30
Western Grebe	84	3/26/04	0.50
Clark's Grebe	82	4/22/04	0.39
Canada Goose*	53	1/3/06	0.28
American Coot	47	3/3/06	0.22
Horned Grebe	40	1/3/06	0.19

*Includes Cackling Goose

Table 9. Mean densities of the five most common waterbird taxa at North Basin compared with other sites in the Greater San Francisco Bay Area and Humboldt Bay. Values in bold are calculated from means of multiple year surveys. Values from other studies are based on single surveys or peak numbers reported in a single year. Fractional values are rounded off except for values <10 birds/km^2.

Species	Area	D (birds/km^2)	Years of study	Source
Scaup spp.	North Basin	**342**	2004-07	This study
	North SFB	597-603	1988-89	Accurso 1998
	W. Central Bay (SFO)	**302**	2000-01	Avocet 2002
	S. Humboldt Bay	257	1987-88	Nelson 1989
	Point Reyes	**26-102**	1967-82	Shuford et al. 1989
	Tomales Bay	**109**	1989-96	Kelly & Tappen 1998
Ruddy Duck	North Basin	**446**	2004-07	This study
	S. SFB salt ponds	550	1982	Swarth et al. 1982.
	S. SFB salt ponds	148	1989	Accurso 1992
	Point Reyes	**103-410**	1967-82	Shuford et al. 1989
	W. Central Bay (SFO)	**36**	200-01	Avocet 2002
	S. Humboldt Bay	16	1987-88	Nelson 1989
	SFB open water	13	1988/9	Accurso 1998
	Tomales Bay	**46**	1986-96	Kelly & Tappen 1998
Bufflehead	North Basin	**60**	2004-07	This study
	W. Central Bay (SFO)	63	2000-01	Avocet 2002
	SFB open water	6.6	1988-89	Accurso 1998
	N. SFB salt ponds	38	1988-89	Accurso 1998
	S. Humboldt Bay	287	1987-88	Nelson 1989
	Point Reyes	**26-102**	1967-82	Shuford et al. 1989
	Tomales Bay	**194**	1986-96	Kelly & Tappen 1998
Surf Scoter	North Basin	**33**	2004-07	This study
	SFB	137	1988-89	Accurso 1992
	S. Humboldt Bay	67	1987-88	Nelson 1989
	Point Reyes	**26-102**	1967-1982	Shuford et al. 1989
	Tomales Bay	**239**	1986-96	Kelly & Tappen 1998
	W. Central Bay (SFO)	**5.2**	2000-01	Avocet 2002

These comparisons, for all their limitations, illustrate that North Basin provides relatively high-value habitat for Ruddy Duck. Scaup (both species pooled) and Bufflehead occur in similar densities to other proximate San Francisco Bay waters, and Surf Scoter occurs in somewhat lower densities than SFB as a whole.

<u>General Comments on Locally Abundant Species.</u>

Ruddy Duck and two scaup species account for 83.5% of all rafting waterbirds in winter. When Bufflehead and Surf Scoter are included in the totals, these five species together account for 92.9% of all wintering waterbirds.

Ruddy Duck, one of the smallest of the North Amrican diving ducks, uses a variety of open wetlands and is often associated with Bufflehead. More than one-half the Ruddy Ducks in North America winter along the Pacific Coast and the majority of these in California, primarily in SFB and at the Salton Sea (Miles 2000, Brua 2001). Densities observed at North Basin were among the highest reported for Central San Francisco Bay (see Accurso 1992, Miles 2000). Unlike many waterfowl species, Ruddy Duck populations are apparently stable or increasing throughout North America (Brua 2001). The fact that they are not a favored hunting target may account for their population health. Ruddys tend to dive rather than fly to escape danger (disturbance).

Scaup are a favored target species for hunters and are therefore “generally wary of the human form and alert to nearby human activity; increase distances when activities perceived threatening. . . [and] sensitive to disturbance from recreational boating (kayaks, canoes, sailing dinghies, etc.)” (Kessel *et al*. 2002). The population data for U.S. midwinter scaup populations (1955–1999) indicates a significant declining trend ($r^2 = 0.632$; $P< 0.001$). This decline represents a continent-wide loss of 21,400 scaup/yr since 1975 (Kessel *et al*. 2002).

Bufflehead, like Ruddy Duck, is a small diving duck, whose predominant winter habitat is saltwater where it uses “shallow waters in secluded coves, harbors, estuaries . . . [but] avoids open coastlines” (Gaulthier 1993). Buffleheads feed in open, shallow water (ca. < 3 m deep). All prey is captured when diving; it feeds on mollusks and crustaceans. Bufflehead is one of the few species of ducks whose numbers have increased over the last 50 years (Gaulthier 1993). Our observations indicate that Buffleheads forage actively in North Basin. Ruddy Ducks often occur in mixed flocks with Bufflehead in North Basin.

Surf Scoter is rather heavy-bodied and tends to occur in deeper and rougher, more open waters than the other diving ducks. It occurs in the highest densities (140 birds/100 ha) in Subarea A of North Basin. Apparently the population is experiencing a downward trend in the West. (Savard *et al.* 1998).

Distribution of waterbirds within the North Basin

Differences in waterbird densities among subareas of the North Basin (Figure 3) and between water depth zones (Figure 1) indicate use of all subareas by waterbirds and predominant use of areas greater than 1 m in depth (Table 10)

Image 2. Ring-necked Duck (*Aythya collaris*), male, a typical diving duck, similar to the scaup, but uncommon at North Basin. Photograph by Len Blumin.

Table 10. Effects of Area (A), Water Depth (D), and Year (Y) on waterbird densities in the North Basin. Significant main effects of D are followed by "<" or ">" indicating greater density in water depths less than or greater than 1 m, respectively. Significant main effects of A are followed by multiple pairwise comparisons, with Subareas arranged left-to-right, from largest to smallest mean density (Table 6), and horizontal lines above groups of comparisons that did not significantly differ (Tukey procedure, experimentwise *P* < 0.05).

Species	ANOVA[a]	Water depth with highest density	Subarea densities (ranked from left to right)
American Coot	A D AD	<1 m	B C E A D
Clarks Grebe	Y** A** D** AD**	>1 m	A E D B C
Common Goldneye	A*		A E[b] D C B
Double-crested Cormorant	Y** D* AD	>1 m	
Eared Grebe	Y**		
Greater Scaup	Y* D** AD**	>1 m	
Horned Grebe	Y AD** YD		
Lesser Scaup	A AD* YD*		A C B D E
Pied-billed Grebe	Y**		
American Wigeon[c]	(no significant effects)		
Ruddy Duck	Y** D** AD**	>1 m	
Surf Scoter	Y A** D AD**	>1 m	A B[d] D E C
Western Grebe	A D** AD**	>1 m	A E D C B
Bufflehead	D** AD**	>1 m	
Common Loon[e]	A** D**	>1 m[f]	A E D C[g] B
Scaup species	Y** D** AD**	>1 m	
Diving ducks	Y** D AD** YD YAD**	>1 m	
Diving birds	Y** A AD		D C B A E
Dabblers	A		C A B D E
Surface-feeding birds	A		C A B D E
All waterbird species	Y** A AD		D C B A[h] E

[a]Mixed-model ANOVA with Year as random effect; letter indicates *F*-ratio significant at *P* < 0.05, **P* < 0.01, ***P* < 0.001.
[b]Mean density E>A but not significantly different from other areas because of large variance (Table 6).
[c]Analysis limited to reduced area of occurrence (Areas A-C).
[d]Mean density B>A but not significantly different from other areas because of large variance (Table 6).
[e]Analysis limited to main effects because Common Loons did not occur at water depths < 1 m.
[f]No Common Loons at depths < 1 m (one-sample t_{254} = 32.7, P < 0.001)
[g]Mean density C<B but not significantly different from other areas because of large variance (Table 6).
[h]Mean density A<E but not significantly different from other areas because of large variance (Table 6).
[h]Mean density A<E but not significantly different from other areas because of large variance (Table 6).

The results (Table 10) led to the following inferences regarding waterbird use within the North Basin.

1) Overall, waterbirds (as a combined group) did not show preferential use of water depths.

2) Based on species-by-species analysis, neither American Coot, Common Goldeneye, Pied-billed Grebe, Eared Grebe, Horned Grebe, Lesser Scaup, nor American Wigeon showed significant preferential use of waterdepth.

3) Eight of 15 species analyzed occurred in significantly greater densities in subareas where water depths were > 1m; none of the species analyzed showed a preference for shallow subareas < 1m.

4) Many species showed variation in use of water depth that was at least partly dependent on choice of subarea. (Feeding activity vs. resting behavior was not distinguished in the data. This suggests that areas may be used for different purposes or that birds may be responding to other influences such as wind exposure or human disturbances.)

5) Twelve of 15 species analyzed, as well all combined species groups, had depth preferences that differed among the subareas where they occurred (i.e., significant "AD" interaction.

6) Common Loon, Common Goldeneye, and Surf Scoter significantly preferred the outer waters of Subarea A over all other subareas.

7) Although Surf Scoter preferred Subarea A, Diving Ducks as a group showed no significant subarea preference.

8) Diving birds in general as a group significantly avoided Subarea E.

9) Most species and species groups significantly avoided Subarea E.

10) American Coot significantly preferred the west side of the Basin.

11) Western Grebe significantly preferred the outer waters (Subarea A) and west side of the Basin (Subareas D and E).

12) Lesser Scaup, Common Loon, Surf Scoter, and Common Goldeneye significantly avoided the west side of the North Basin.

13) Clark's Grebe significantly avoided Subarea C (independently of water depth, even though they prefer deeper water).

14) Subarea C supports significantly more Surface Feeders and Dabblers than Subarea E, and "tended" (this tendency did not cross the threshold of experimentwise significance among multiple comparisons) to support more surface feeders and dabblers than

Subareas A, B, or D. (This is an important point because the “experimentwise error rate of P<0.05” means that there is < 5% random chance that <u>any</u> between-subarea comparisons for a given species would be as great as those observed.)

15) Subarea D supports significantly more Diving Birds than Subarea E, and "tended" (see comment 12 above) to support more diving birds than Subarea A, B, or C.

16) Subarea preferences were not evident for Double-crested Cormorant, Eared Grebe, Horned Grebe, Pied-billed Grebe, Greater Scaup, American Wigeon or Diving Duck species combined.

17) The relative use of count areas and water depths by most species varied significantly among years ("YA, "YD," and "YAD" interactions)

VI. Disturbance Trials: Results

During disturbance trials performed over three winter periods, we covered 72.8 km of open water and initiated 689 disturbance events (one event every 105.7 meters traveled). Of those, we examined a total of 568 events for the 16 species or species groups for which there was a large enough sample size per species (≥10 events) to determine reliable flush distances (Table 11). Fifty-two percent of the earliest (most distant) flush responses of species were by swimming, 31% by diving, and 16 % by flight.

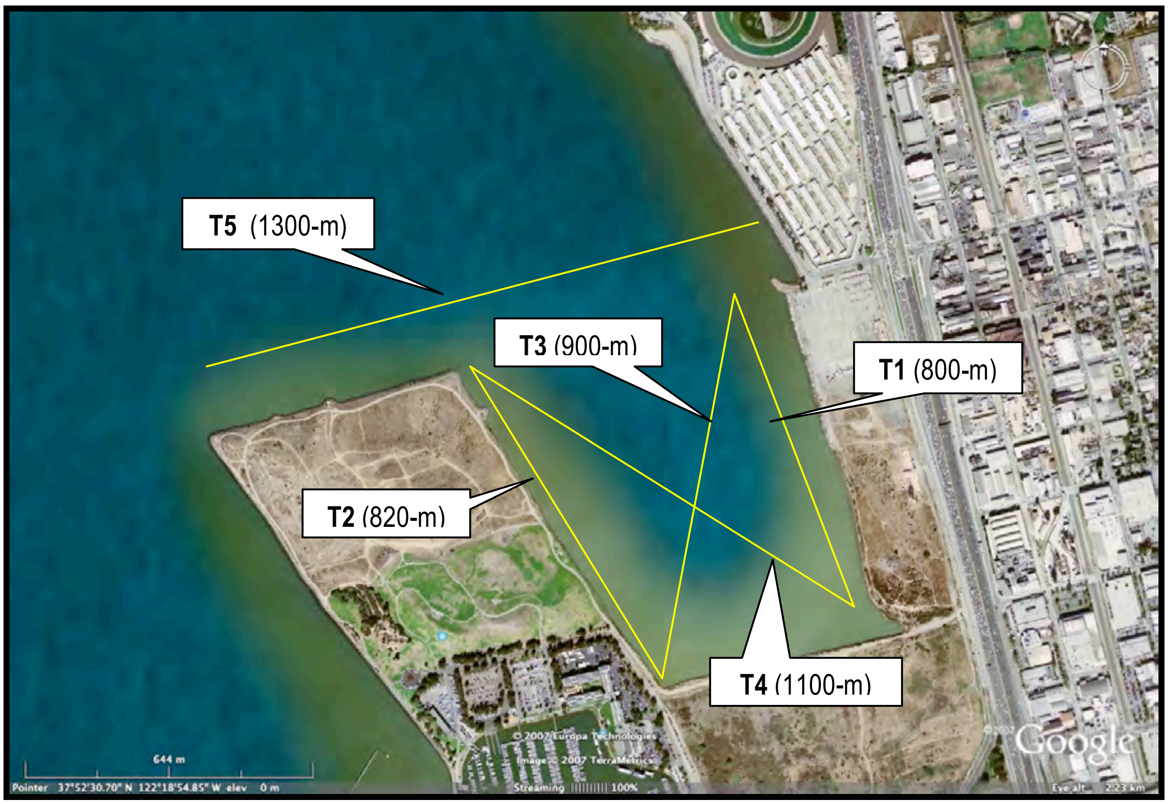

Figure 5. Distribution of the five transects (T1-5) within the North Basin that were traversed by kayak in the disturbance trials. The length (m) of each transect is given in parentheses.

Table 11. Mean and standard deviation (SD) of ln-transformed disturbance response distances, back-transformed mean response distance, and recommended distances (m) to avoid disturbance of waterbird, based on species behavioral responses to 1 or 2 approaching kayaks.

Species	n	Mean[a]	SD[a]	Mean response distance (m)[b]	Flock size[c]	Recommended distance (m)[d]
American Coot	28	3.18	0.621	24		107
Bufflehead	51	4.06	0.556	58	1	92
					50	174
Canada Goose	19	3.99	0.602	54		186
Clark's Grebe	23	3.72	0.668	41	1	78
					12	202
Cm. Goldeneye	24	3.62	0.724	37		163
Common Loon	16	3.93	0.756	51		218
Double-crested Cormorant	23	4.11	0.628	61		213
Greater Scaup	31	4.59	0.433	99	1	127
					120	246
Horned Grebe	37	3.17	0.779	24		126
Lesser Scaup	16	3.94	0.699	51	1	86
					8	252
Mallard	19	2.87	0.534	18		83
Red-br. Merganser	13	3.32	1.136	28		219
Ruddy Duck	56	4.10	0.623	60		209
Scaup species	30	4.54	0.549	94	1	141
					100	218
Surf Scoter	37	4.11	0.762	61	1	97
					25[e]	153
Western Grebe	30	3.68	0.649	40		156

[a] Mean and standard deviation of log-transformed data: $y_i = \ln(x_i)$

[b]Back-transformed mean: $\hat{\mu} = \exp(\bar{y})$

[c]If the linear effect of species flock size on disturbance response was significant ($P < 0.05$), the regression equation was used to calculate recommended distance for solitary individuals (Flock size = 1) and maximum observed flock size (Flock size > 1):

Bufflehead: y = 3.81 + 0.017*(Flock size) - 0.0012*(Intraseasonal day)

Clark's Grebe: y = 3.08 + 0.110*(Flock size) + 0.002*(Intraseasonal day)

Greater Scaup: y = 4.16 + 0.007*(Flock size) + 0.002*(Intraseasonal day)

Lesser Scaup: y = 3.17 + 0.194*(Flock size) + 0.001*(Intraseasonal day)

Scaup species: y = 4.16 + 0.004*(Flock size) + 0.003*(Intraseasonal day)

Surf Scoter: y = 3.64 + 0.024*(Flock size) + 0.003*(Intraseasonal day)

[d] Recommended distance = $\exp(\hat{\mu} + 1.6495 * \hat{\sigma}) + 40$ m.

[e] Outlier observations for Surf Scoters flocks of 70 and 35 occurred but the remainder of the Surf Scoter flocks observed during trials were less than 25 individuals.

We developed species specific buffer zones based on observed flush distances (Table 11). The recommended distances in Table 11 are likely to underestimate the sensitivity of waterbirds to more than one or two kayaks or to some other types of stimuli. Flock size effects appeared to be linear on a natural-log scale for all species analyzed, but the limited sample sizes suggest that these effects are only roughly estimated and may result in biases that over or underestimate the sensitivity of waterbird species.

VII. Discussion of avian disturbance.

To reduce or minimize human disturbance of wildlife in a public place, some research provides direction. People are more likely to support restrictions if they understand how wildlife will benefit (Shay 1980, Purdy *et al*. 1987, Klein 1993). This brief synopsis of the available evidence on human disturbance to wildlife, and waterbirds in particular, provides a rationale for management decisions.

"Disturbance" describes any interruption in the normal behavior of waterbirds. Normal behaviors primarily involve foraging or roosting, although social interaction and community dynamics may be affected as well. "Flushing" is the most observable response to disturbance and involves moving away or fleeing from the source. In waterbirds, a flushing response includes swimming, diving, or flying and is usually preceded by an alert response (e.g. "head alert"). Subtle behavioral or physiological responses to disturbance are likely to precede flushing and go undetected by observers.

Many studies have demonstrated that birds concentrate where there is the best opportunity to maximize energy gain (Cayford 1993, Davidson & Rothwell 1993). Flushing may reduce the time waterbirds spend feeding or resting and cause them to move to suboptimal feeding or resting areas. Studies have documented displacement of wintering waterfowl to less productive foraging areas (Tuite *et al*. 1983, Knapton et al. 2000) or complete abandonment of foraging habitat under increased levels of disturbance (Tuite *et al*. 1983). Repeated flushing increases energy costs to waterbirds, and may have cumulative effects on migratory energy budget and, ultimately, reproductive success (Ward and Andrews 1993, Galicia and Baldassarre 1997,Cywinski 2004).

Several studies have documented loss of feeding time due to disturbance by motorized watercraft (Kaiser and Fritzell 1984, Kahl 1991, Galicia and Baldasserre 1997). The literature contains fewer studies of disturbance response of waterbirds to non-motorized watercraft. However, Kaiser and Fritzell (1984) found that a high density of canoeists correlated with reduced use of the river edge by green herons in the Missouri

Ozarks. In general, "*Approaches from the water seem to generally disturb birds more than from the land: e.g. in one study Curlews flew from a sail board at 400 m away compared with about 100 m from a walker (Smit & Visser 1993)"* (Rothwell & Davidson 1993). However, that observation was in reference to migrant and/or wintering birds; nesting herons are more sensitive to sources of disturbance from land than from boats-Vos *et al*. 1985.

Human disturbance of various types may reduce species diversity and abundance at both the landscape and regional level (Boyle and Samson 1985, Rodgers and Smith 1997). Increasing human use of natural areas increases incidence of disturbance and tends to disrupt foraging and social behavior of wildlife (Burger 1981, 1986, Klein 1993, Werschkul *et al*. 1976). Mori *et al*. (2001) found that flight distances (between the position of a flush response and the disturbance source) correlated positively with flock size and species diversity, and flight distances tended to be longer for waterfowl species that used open water for foraging than those that used it primarily for resting. Our observations suggest that North Basin is used both for foraging and loafing.

A variety of activities on the open water habitat increase the likelihood of disturbance. Less disturbance is likely to result from one type of recreational activity than from many (see Davidson & Rothwell 1993). Low variation in the type and intensity of watercraft activity, it may allow wintering birds to habituate and thereby reduce the incidence of disturbance.

Various studies have tried to evaluate the biological impacts of habituation. Tolerance of human activity, resulting in habituation, is well-known among birds (Nisbet 2000). In a study of waterbird response to human use of a sanctuary in Florida, Klein *et al*. (1995), found that resident birds were less affected than migrants by humans, and migrants were more affected upon arrival than they were after a subsequent period of exposure. For these reasons we eliminated Mallard, the predominant resident waterfowl at North Basin and an essentially domesticated species, from consideration in our disturbance analysis.

It is difficult to determine or predict when and what level of disturbance will threaten the energy balance in waterbirds, However, even before birds begin to operate on an energy deficit, disturbance behaviors may compromise bird's foraging efficiency or their avoidance of predation risk. During certain conditions and times of year, waterbirds are close to their energy balance thresholds and are, therefore, more vulnerable to increased energy demands imposed by disturbance.

- During periods of prolonged storm events, foraging is more difficult and the energy demand for thermoregulation tends to be higher.
- Periods of feather molting have high-energy demands, however, most of the most common waterbirds that occur in North Basin molt on their breeding grounds, not in SFB.
- Migration exacts high energy costs and waterbirds must build up their stores of fat in preparation for their long-distance migration from San Francisco Bay to their nesting grounds in the spring. (Indeed, there is evidence that prior to the spring migration birds are feeding at or near their maximum intake (Ens *et al*. 1990)).

Recreational activity tends to be markedly seasonal, as does the occurrence of waterbirds. Fortuitously, these periods phase each other, at least in part. Boating activity is highest when weather is most temperate (April through September). Bird abundance is greatest during the “winter” period (mid-October thru mid-April). October and April, months of heightened migratory activity, are the periods when use of the Basin by recreational watercraft and rafting waterbirds are most likely to conflict.

Rodgers and Schweikert (2003) recommended that buffer zones for mixed species flocks should be based on the largest flush distance or the species most sensitive to human disturbance. However, these authors also point out a danger of unnecessarily alienating boating enthusiasts by proposing buffer zone distances that are too large and biologically unsound.

From a resource management perspective and as a practical matter, it is probably best to use a “one size fits all” approach when designing set-backs (buffer zones) between areas of human activity and areas of high-use by waterbirds. Scaups showed the greatest sensitivity to disturbance and were one of the most abundant waterbird species in the population surveys. If Rodgers and Schweikert’s model was applied to North Basin, a buffer zone of 250 meters from areas of high-use by rafting waterbirds would be a conservative guideline for minimizing the impacts of non-motorized watercraft on rafting waterbirds. However, given the relatively small size of the Basin, and the fact that it is enclosed on three sides, such a conservative approach may not be tenable.

VIII. Conclusions and Recommendations

The San Francisco Bay estuary is arguably the most valuable migratory and wintering habitat for waterbirds on the west coast of North America. San Francisco Bay is included as one of 34 waterfowl habitats of major concern in the North American Waterfowl Management Plan (USFWS 1989) and is the winter home for more than 50 percent of the diving ducks in the Pacific Flyway (Accurso 1992, Takekawa *et al*. 2000). SFB is also included within the Western Hemisphere Wader Reserve Network as a site of international importance because it supports more than a million waders (shorebirds) in migration (Kjelmyr *et al*. 1991, Harrington and Perry 1995).

How does North Basin fit into and contribute to the value of SFB as waterbird habitat? The Basin's primary value is as a loafing and foraging area for several species of diving birds in winter (October through March). The vast majority (95.8%) of these belong to eight species of diving birds: Ruddy Duck, scaup (two species), Bufflehead, Surf Scoter, and three species of grebes (Table 5). We found relatively low use of the site by waders and dabbling ducks.

Based on our abundance surveys and disturbance trials, the following characteristic of the site should provide a basis for management decisions relevant to human access.

1) Subarea E, the northwest quadrant of the North Basin proper, tends to support the lowest numbers of waterbirds (with the exception of Western Grebe).
2) Subarea D, the southwest quadrant of the Basin, is a section with relatively high waterbird use.
3) Most waterbird species occurred in significantly greater densities in areas where water depths were > 1m; only American Coot showed a preference for shallow (<1 m) areas.
4) Use of count areas and water depths by most species varied significantly among years.
5) Diving birds tended to occur in higher numbers in subarea A. All species combined, however, showed the highest numbers, on average, in Subarea D (significantly higher than in Subarea E, but not significantly higher than in Subareas A-C).

The inferences drawn from the analysis of waterbird distributions within the North Basin, coupled with the results of the disturbance trials, lead us to the following guidelines for designing and permitting access to the North Basin by non-motorized watercraft. These parameters will have to be balanced against other considerations when designing access points to the North Basin.

1) A buffer zone of 250 meters from areas of high-use by rafting waterbirds is recommended for avoiding the impacts of non-motorized watercraft on rafting waterbirds.
2) If a boat launch area is designated in North Basin, the northwest corner of the site (Subarea E) with watercraft traffic directed around the Caesar Chavez Park to the west, within 50 meters of the shoreline, would be the best site to minimize disturbance to rafting waterbirds. However, because this shoreline is not under State Park ownership (Cyndy Shafer and Brad Olson, pers comm.), the next most appropriate site would be the northeast corner of Subarea B (Figure 3). To minimize disturbance, watercraft should be directed to paddle due west, cross the Basin, then hug the shoreline of Caesar Chavez Park en route to the open water of SFB. Education could enhance this option; see recommendation #4, below. This location would also serve to route users away from Subarea D, a sector of the site that supported some of the highest numbers of waterbirds in this study.
3) Allowing kayaks or other watercraft to traverse the deeper, open water of North Basin in seasons of high waterbird use (mid-October through mid-April) will increase disturbance incidents and may cause a decrease in the use and value of the site to rafting waterbirds. Disturbance events will be much reduced in the season of low use by rafting waterbirds (mid-April to mid-October). Serendipitously, we expect watercraft use to be much greater in the summer months than in late fall and winter, therefore providing a de facto reduction in level and frequency of disturbance. Furthermore, rafting waterbirds tend to congregate in greater numbers within North Basin during wind and storm events, a weather variable that discourages use of the site by recreational watercraft users. These complementary circumstances will help to minimize disturbance of waterbirds.
4) Seasonal (winter) closures could further reduce impacts. The most effective period for closure would be the season of greatest use, typically mid-October through January. (Numbers start to decline rather dramatically beginning in January—Figure 4). Because intermittent disturbance is likely much more tolerable than constant disturbance, winter weekday closures would be another tool for reducing the frequency of disturbance.
5) Education has been shown to be an effective tool in conservation. People are more likely to support restrictions if they understand how wildlife will benefit (Shay 1980,

Purdy *et al*. 1987, Klein 1993). Educational outreach—either through signage, pamphlets, presentations to boating groups, or a combination of these approaches—could augment seasonal restrictions and provide an opportunity to further reduce the incidence of disturbance.

IX. Postscript: Limitations of the Study and Caveats

Concurrent surveys of control sites for evaluating waterbird abundances in the North Basin, where the shoreline is dominated by public recreational use, were not within the scope of this study and it is not clear that any adequate control sites exist. Two sites have been suggested, however: (1) Clipper Cove between Yerba Buena and Treasure Islands; and, (2) the basin on Richmond shoreline between the Point San Pablo and the West Contra Costa County Landfill site (J. LaClair, BCDC, pers. comm.). We did conduct concurrent surveys at Seabreeze Cove, immediately south of North Basin, and those data are archived with ARA and State Parks. Analysis of those data was beyond the scope of this study, but it is apparent that Seabreeze Cove supports even higher densities of waterbirds, especially waders, than North Basin (R. Stallcup, pers, comm.).

Because larger birds are less tolerant of human disturbance than smaller birds (Rodgers and Schwikert 2003, Fernandez-Juricic *et al*. 2002), large species like pelicans, cormorants, and herons may already be avoiding the site as a result of current human use levels. Also, individuals of some sensitive species may be avoiding the site because of current levels of human use. If so, underlying habitat values and potential waterbird use might be higher than those observed. We have taken a conservative approach to disturbance statistics in an attempt to compensate for this likelihood.

We have discussed with the respective researchers the methods and results of two other recent (or ongoing) disturbance studies—the San Francisco Bay Trail and the Albany Flats. Both of those studies measured a wide array of potential shore-based disturbances and environmental factors using stepwise multiple regression to examine the effects of human approach on wader behavior (Trulio and Sokale 2006, Stenzel *et al*. 2003). Neither study found strong correlations between wader disturbance and trail use, possibly because the responses of waterbirds to disturbance may be primarily behavioral, rather than numerical, or because differences in bird use associated with human disturbance may be obscured by substantial underlying variation in waterbird abundance. To avoid confounding factors that may have been encountered in those studies, and to contribute to the economy and efficiency of this study, we elected to employ an experimental approach rather than an observational approach to evaluate disturbance effects based on overall abundance variation. Experimental responses are easily distinguished and measured, and they often lead to stronger inferences than can be generated by observational results.

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Appendix A.

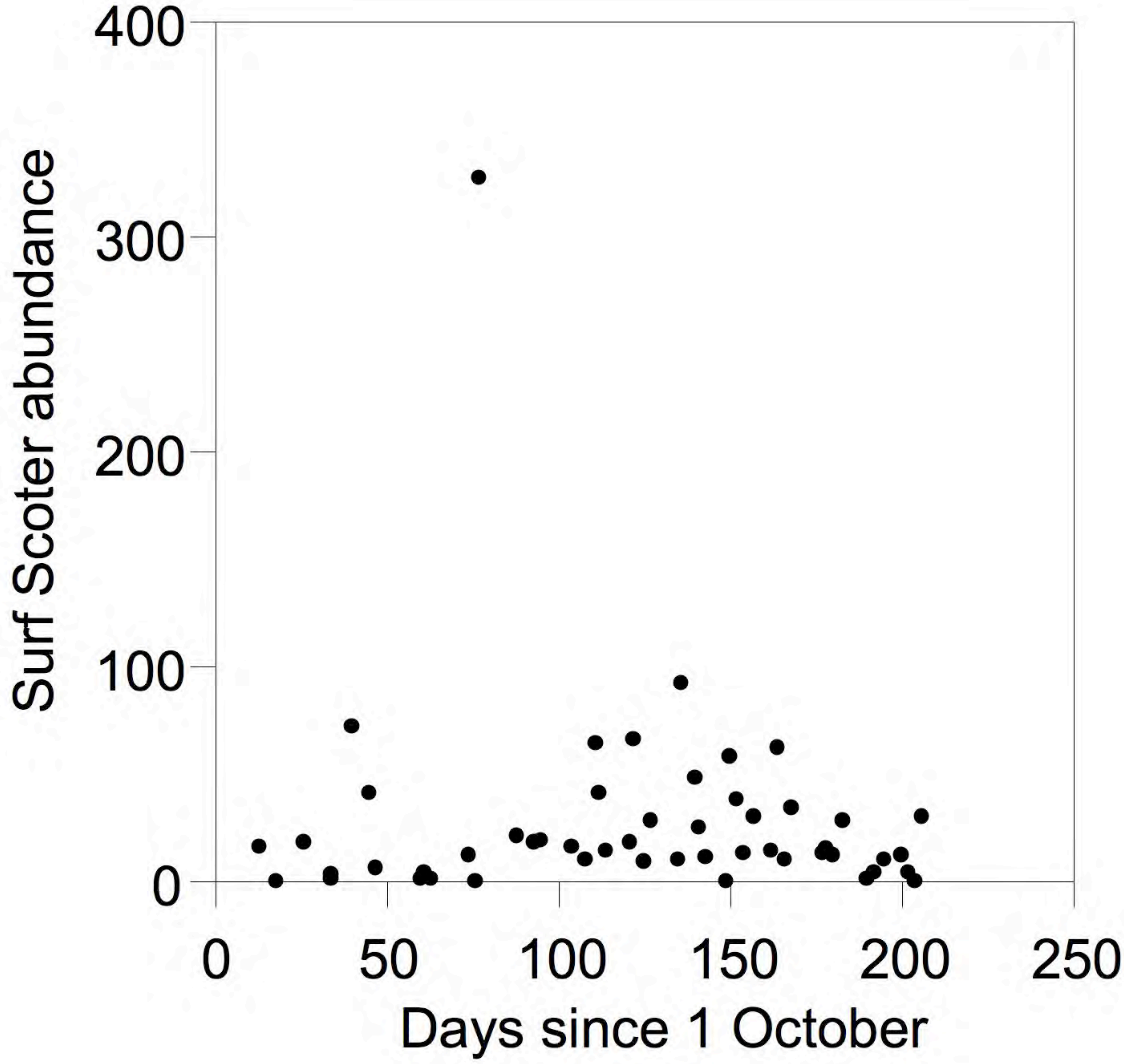
Avian species observed at North Basin 2004-07, with codes and assigned categories.

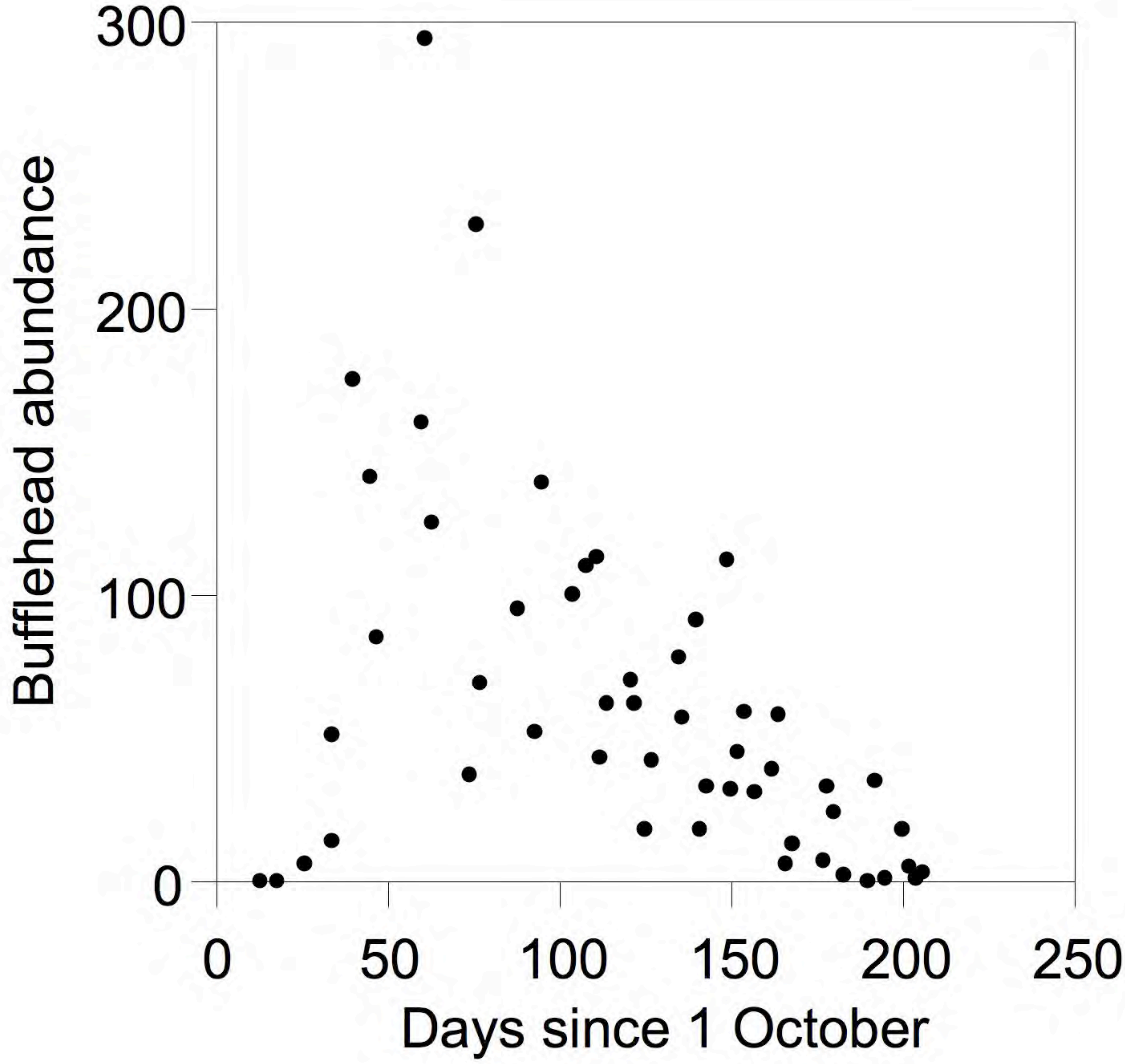
Code	Species name	Category	Sub-category
	"Aleutian" Cackling Goose *Branta hutchinsii*	Waterbird	Surface feeder
AMAV	American Avocet *Recurvirostra americana*	Wader	Shorebird
AMCO	American Coot *Fulica americana*	Waterbird	Diving bird
AMWI	American Wigeon *Anas americana*	Waterbird	Surface feeder
BAGO	Barrow's Goldeneye *Bucephala islandica*	Waterbird	Diving duck
BBPL	Black-bellied Plover *Pluvialis squatarola*	Wader	Shorebird
BCNH	Bl-cr. Night-Heron *Nyctacorax nyctacorax*	Wader	Surface feeder
BLOY	Black Oystercatcher *Haematopus bachmani*	Wader	Shorebird
BLTU	Black Turnstone *Arenaria melanocephala*	Wader	Shorebird
BOGU	Bonaparte's Gull *Larus philadelphia*	Larid	Surface feeder
BRCO	Brandt's Cormorant *Phalacrocorax penicillatus*	Waterbird	Diving bird
BRPE	Brown Pelican *Pelecanus occidentalis*	Waterbird	Diving bird
BUFF	Bufflehead *Bucephala albeola*	Waterbird	Diving duck
BWTE	Blue-winged Teal *Anas discors*	Waterbird	Dabbling duck
CAGO	Canada Goose *Branta canadensis*	Waterbird	Surface feeder
CAGU	California Gull *Larus californicus*	Larid	Surface feeder
CANV	Canvasback *Aythya valisineria*	Waterbird	Diving duck
CATE	Caspian Tern *Sterna caspia*	Larid	Surface feeder
CITE	Cinnamon Teal *Anas cyanoptera*	Waterbird	Dabbling duck
CLGR	Clark's Grebe *Aechmophorus clarkii*	Waterbird	Diving bird
COGO	Common Goldeneye *Bucephala clangula*	Waterbird	Diving duck
COLO	Common Loon *Gavia immer*	Waterbird	Diving bird
COMU	Common Murre Uria aalge	Waterbird	Diving bird
DCCO	Double-crested Cormorant *Phalacrocorax auritus*	Waterbird	Diving bird
DOWI	Dowitcher species *L. griseus or scolopaceus*	Wader	Shorebird
DUNL	Dunlin *Calidris alpina*	Wader	Shorebird
EAGR	Eared Grebe *Podiceps nigricollis*	Waterbird	Diving bird
ELTE	Elegant Tern *Sterna elegans*	Larid	Surface feeder
FOTE	Forster's Tern *Sterna forsteri*	Larid	Surface feeder
GADW	Gadwall *Anas strepera*	Waterbird	Surface feeder
GBHE	Great Blue Heron *Ardea herodias*	Wader	Surface feeder
GREG	Great Egret *Ardea alba*	Wader	Surface feeder
GRSC	Greater Scaup *Aythya marila*	Waterbird	Diving duck
GRYE	Greater Yellowlegs *Tringa melanoleuca*	Wader	Shorebird
GWGU	Glaucous-winged Gull *Larus glaucescens*	Larid	Surface feeder
GWTE	Green-winged Teal *Anas crecca*	Waterbird	Dabbling duck
HEGU	Heermann's Gull *Larus heermanni*	Larid	Surface feeder
HOGR	Horned Grebe *Podiceps auritus*	Waterbird	Diving bird
KILL	Killdeer *Charadrius vociferus*	Wader	Shorebird
LBCU	Long-billed Curlew *Numenius americanus*	Wader	Shorebird
LBDO	Long-billed Dowitcher *Limnodromus scolopaceus*	Wader	Shorebird
LESA	Least Sandpiper *Calidris minutilla*	Wader	Shorebird
LESC	Lesser Scaup *Aythya affinis*	Waterbird	Diving duck
LETE	Least Tern *Sternula antillarum*	Larid	Surface feeder
LEYE	Lesser Yellowlegs *Tringa flavipes*	Wader	Shorebird
LTDU	Long-tailed Duck *Clangula hyemalis*	Waterbird	Diving duck

MAGO	Marbled Godwit *Limosa fedoa*	Wader	Shorebird
MALL	Mallard *Anas platyrhynchos*	Waterbird	Dabbling duck
MEGU	Mew Gull *Larus canus*	Larid	Surface feeder
NOPI	Northern Pintail *Anas acuta*	Waterbird	Dabbling duck
NOSH	Northern Shoveler *Anas clypeata*	Waterbird	Dabbling duck
PBGB	Pied-billed Grebe *Podilymbus podiceps*	Waterbird	Diving bird
PECO	Pelagic Cormorant *Phalacrocorax pelagicus*	Waterbird	Diving bird
PESA	Pectoral Sandpiper *Calidris melanotos*	Wader	Shorebird
RBGU	Ring-billed Gull *Larus delawarensis*	Larid	Surface feeder
RBME	Red-breasted Merganser *Mergus serrator*	Waterbird	Diving duck
REDH	Redhead *Aythya americana*	Waterbird	Diving duck
REKN	Red Knot *Calidris canutus*	Wader	Shorebird
RNDU	Ring-necked Duck *Aythya collaris*	Waterbird	Diving duck
RNPH	Red-necked Phalarope *Phalaropus lobatus*	Wader	Shorebird
ROGO	Ross's Goose *Chen rossii*	Waterbird	Shorebird
RTLO	Red-throated Loon *Gavia stellata*	Waterbird	Diving bird
RUDU	Ruddy Duck *Oxyura jamaicensis*	Waterbird	Diving duck
RUTU	Ruddy Turnstone *Arenaria interpres*	Wader	Shorebird
SAND	Sanderling *Calidris alba*	Wader	Shorebird
SBDO	Short-billed Dowitcher *Limnodromus griseus*	Wader	Shorebird
SCAU	Scaup species *Aythya spp.*	Waterbird	Diving duck
SEPL	Semipalmated Plover *Charadrius semipalmatus*	Wader	Shorebird
SNEG	Snowy Egret *Egretta thula*	Wader	Surface feeder
SNPL	Snowy Plover *Charadrius alexandrinus*	Wader	Shorebird
SPSA	Spotted Sandpiper *Actitis macularia*	Wader	Shorebird
SURF	Surfbird *Aphriza virgata*	Wader	Shorebird
SUSC	Surf Scoter *Melanitta perspicillata*	Waterbird	Diving duck
WATA	Wandering Tattler *Tringa incana*	Wader	Shorebird
WEGR	Western Grebe *Aechmophorus occidentalis*	Waterbird	Diving duck
WEGU	Western Gull *Larus occidentalis*	Larid	Surface feeder
WESA	Western Sandpiper *Calidris mauri*	Wader	Shorebird
WFGO	Greater White-fronted Goose *Anser albifrons*	Waterbird	Dabbling duck
WHIM	Whimbrel *Numenius phaeopus*	Wader	Shorebird
WHPE	Am. White Pelican *Pelecanus erythrorhynchos*	Waterbird	Diving bird
WILL	Willet *Catoptrophorus semipalmatus*	Wader	Shorebird
WISN	Wilson's Snipe *Gallinago delicata*	Wader	Shorebird
WWSC	White-winged Scoter *Melanitta fusca*	Waterbird	Diving duck

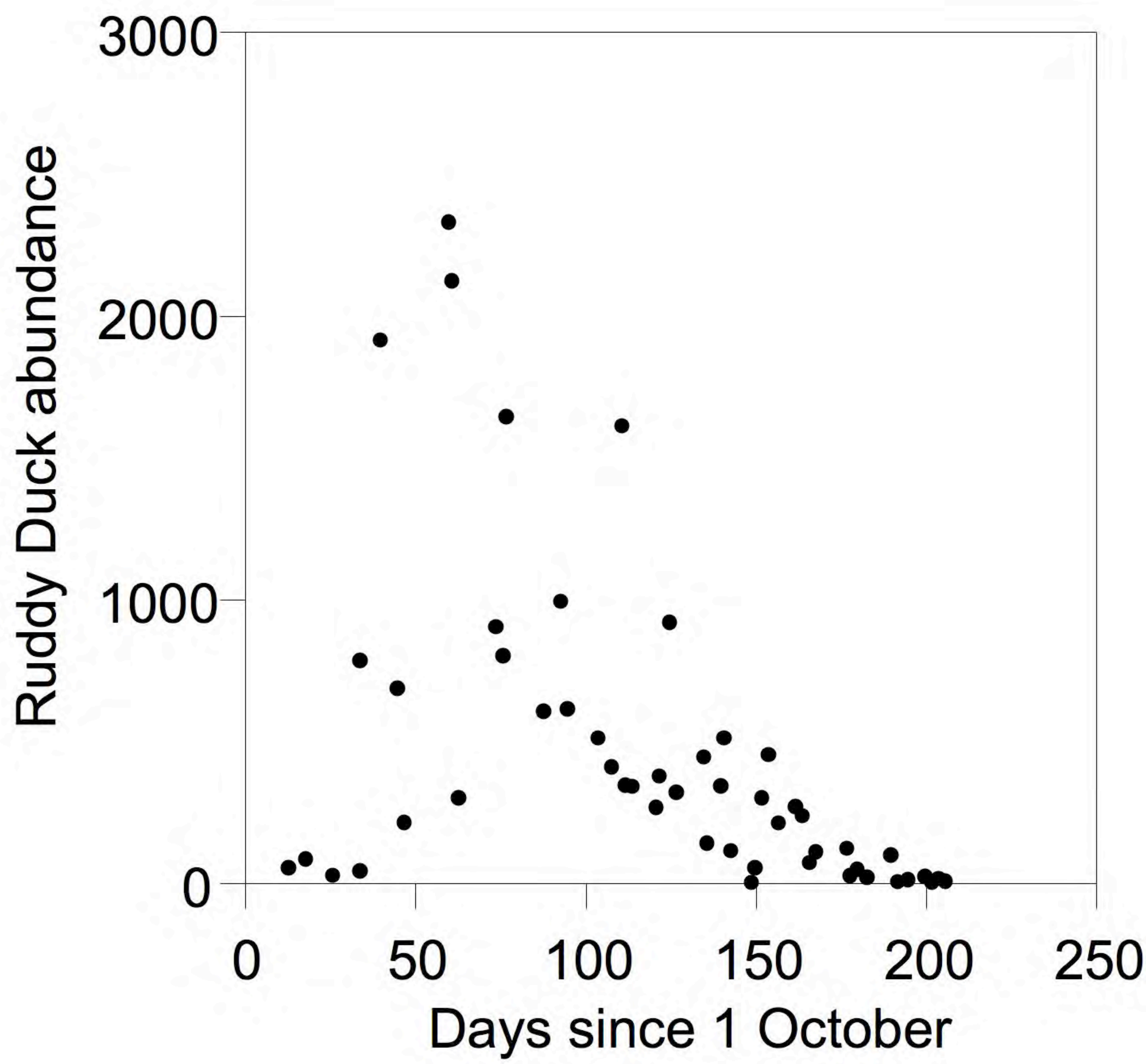
APPENDIX B.

Common Diving Ducks: Interseasonal Abundance

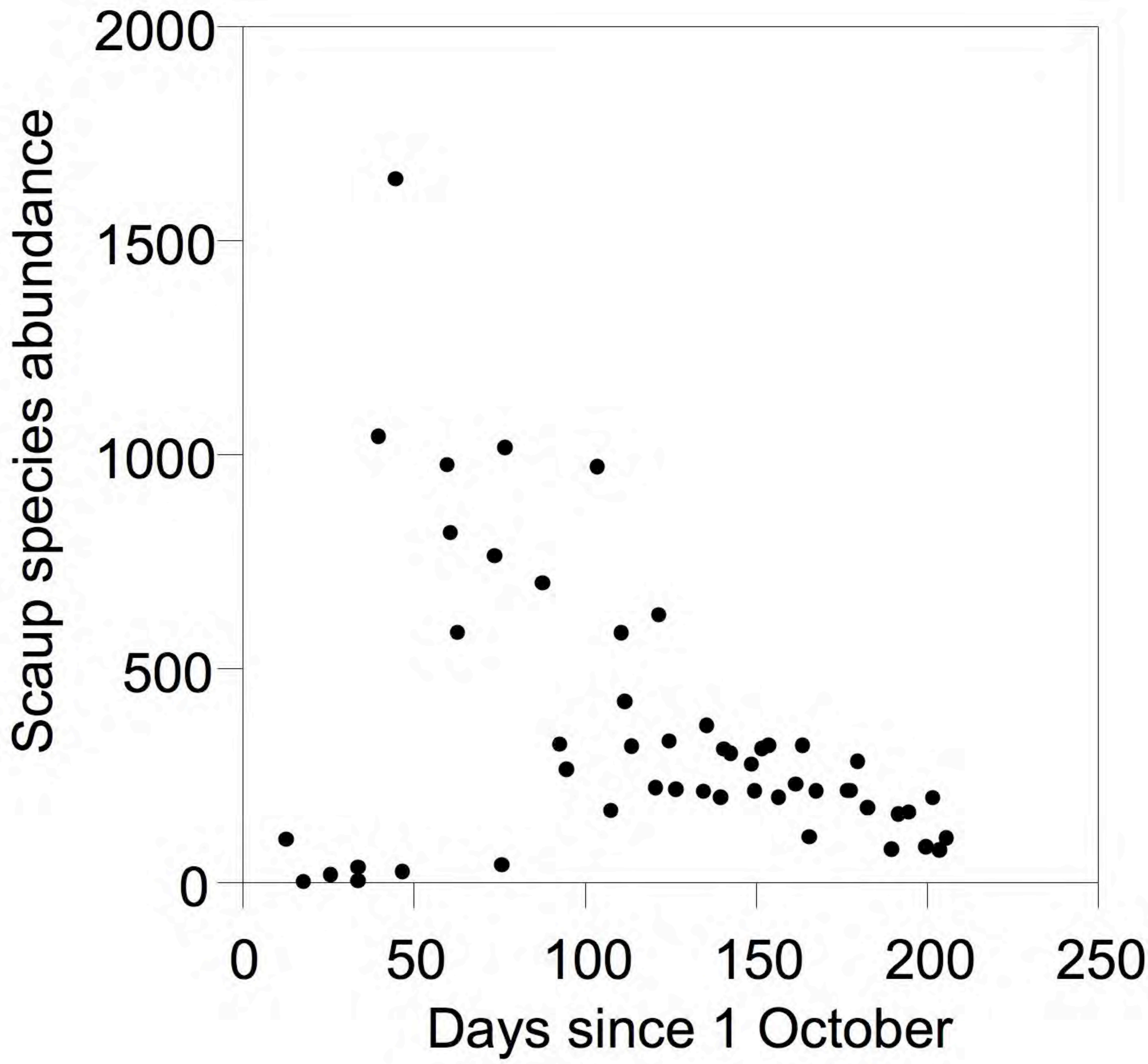

400
300
200
100
0
Surf Scoter abundance
0
50
100
150
200
250
Days since 1 October



Bufflehead abundance
300
200
100
0
0
50
100
150
200
250
Days since 1 October



3000
2000
1000
0
Ruddy Duck abundance
0
50
100
150
200
250
Days since 1 October



2000
1500
1000
500
0
Scaup species abundance
0
50
100
150
200
250
Days since 1 October

APPENDIX C.

NORTH BASIN:

Waterbird Abundance: Summer Period, 2004-2006.

Summer summary
2004-2007

	2004		2005		2006		3-yr		Mean	
SPECIES	mean	SE	mean	SE	mean	SE	mean	SE	D	D/100 ha
RUDU	0.00	0.00	0.71	0.47	102.63	223.68	34.45	34.09	0.55	55.12
GRSC	3.00	2.08	7.43	4.20	57.42	124.42	22.62	17.45	0.36	36.19
WEGU	6.69	5.06	7.71	2.94	20.05	16.35	11.48	4.29	0.18	18.38
DCCO	4.77	3.27	6.14	1.16	11.68	11.71	7.53	2.11	0.12	12.05
BUFF	0.00	0.00	0.14	0.14	21.53	46.67	7.22	7.15	0.12	11.56
WILL	5.08	4.92	6.57	2.20	9.58	15.11	7.08	1.32	0.11	11.32
COGO	0.00	0.00	2.71	2.55	10.58	23.06	4.43	3.17	0.07	7.09
LESA	1.85	3.60	5.57	5.04	5.26	8.98	4.23	1.19	0.07	6.76
WESA	10.54	27.47	0.00	0.00	0.05	0.11	3.53	3.50	0.06	5.65
SUSC	0.08	0.28	4.57	1.32	5.89	12.85	3.51	1.76	0.06	5.62
CAGO	0.92	2.78	2.71	2.55	4.79	5.89	2.81	1.12	0.04	4.49
FOTE	3.15	3.74	3.00	0.87	1.11	1.18	2.42	0.66	0.04	3.87
CLGR	0.69	1.11	3.29	1.71	3.00	5.13	2.33	0.82	0.04	3.72
RNPH	0.00	0.00	0.00	0.00	6.79	14.80	2.26	2.26	0.04	3.62
LESC	0.00	0.00	0.14	0.14	6.26	13.65	2.13	2.06	0.03	3.42
HOGR	1.15	4.16	1.00	0.84	3.84	8.37	2.00	0.92	0.03	3.20
BLTU	0.54	1.94	1.43	1.43	3.58	7.80	1.85	0.90	0.03	2.96
AMCO	0.00	0.00	0.00	0.00	5.26	11.47	1.75	1.75	0.03	2.81
CATE	1.23	1.48	2.57	1.46	0.89	0.78	1.57	0.51	0.03	2.50
WEGR	1.85	3.24	1.14	0.67	1.53	2.64	1.50	0.20	0.02	2.41
MALL	3.15	3.51	0.00	0.00	0.95	1.01	1.37	0.93	0.02	2.19
BLOY	1.62	1.39	0.43	0.20	1.84	1.62	1.30	0.44	0.02	2.07
SAND	0.00	0.00	3.71	2.73	0.00	0.00	1.24	1.24	0.02	1.98
KILL	2.46	4.24	0.29	0.18	0.63	0.95	1.13	0.67	0.02	1.80
BBPL	1.77	3.70	0.43	0.30	1.16	2.06	1.12	0.39	0.02	1.79
LETE	1.23	1.74	1.57	0.53	0.47	0.42	1.09	0.32	0.02	1.75
MAGO	1.77	1.96	0.29	0.18	1.21	1.36	1.09	0.43	0.02	1.74
RBGU	0.85	0.99	0.71	0.36	1.58	1.92	1.05	0.27	0.02	1.67
ROGO	0.00	0.00	2.71	2.55	0.00	0.00	0.90	0.90	0.01	1.45
SCAUP Sp	0.15	0.55	0.00	0.00	2.42	5.28	0.86	0.78	0.01	1.37
DUNL	0.00	0.00	2.57	2.57	0.00	0.00	0.86	0.86	0.01	1.37
PECO	0.54	0.66	1.14	0.67	0.47	0.45	0.72	0.21	0.01	1.15
LBCU	0.69	0.85	0.43	0.30	0.58	0.51	0.57	0.08	0.01	0.91
AMWI	0.00	0.00	1.29	1.29	0.32	0.69	0.54	0.39	0.01	0.86
SNEG	0.77	0.93	0.71	0.29	0.11	0.16	0.53	0.21	0.01	0.85
BRPE	0.54	1.39	0.43	0.30	0.42	0.38	0.46	0.04	0.01	0.74
SPSA	0.85	0.99	0.14	0.14	0.32	0.37	0.43	0.21	0.01	0.69
BCNH	1.00	1.15	0.29	0.18	0.00	0.00	0.43	0.30	0.01	0.69
REKN	0.00	0.00	0.00	0.00	1.16	2.52	0.39	0.39	0.01	0.62
GWGU	0.15	0.55	0.00	0.00	0.89	1.95	0.35	0.28	0.01	0.56
SBDO	0.92	3.33	0.00	0.00	0.11	0.23	0.34	0.29	0.01	0.55
CAGU	0.23	0.60	0.00	0.00	0.74	0.94	0.32	0.22	0.01	0.52
GREG	0.38	0.65	0.14	0.29	0.37	0.45	0.30	0.08	0.00	0.48
WATA	0.46	1.13	0.29	0.18	0.11	0.23	0.29	0.10	0.00	0.46
SEPL	0.85	3.05	0.00	0.00	0.00	0.00	0.28	0.28	0.00	0.45
GADW	0.31	0.75	0.29	0.29	0.11	0.23	0.23	0.06	0.00	0.37

Summer summary
2004-2007

Aechmopho	0.00	0.00	0.00	0.00	0.68	1.49	0.23	0.23	0.00	0.36
LBDO	0.62	2.22	0.00	0.00	0.00	0.00	0.21	0.21	0.00	0.33
EAGR	0.08	0.28	0.00	0.00	0.47	1.03	0.18	0.15	0.00	0.29
WHIM	0.08	0.28	0.00	0.00	0.37	0.38	0.15	0.11	0.00	0.24
WEGU x GV	0.15	0.55	0.29	0.29	0.00	0.00	0.15	0.08	0.00	0.24
GRYE	0.38	0.65	0.00	0.00	0.05	0.11	0.15	0.12	0.00	0.23
ELTE	0.15	0.55	0.14	0.14	0.00	0.00	0.10	0.05	0.00	0.16
PBGR	0.08	0.28	0.00	0.00	0.21	0.46	0.10	0.06	0.00	0.15
COMU	0.00	0.00	0.14	0.14	0.11	0.16	0.08	0.04	0.00	0.13
COLO	0.00	0.00	0.14	0.14	0.05	0.11	0.06	0.04	0.00	0.10
BUOW	0.08	0.28	0.00	0.00	0.11	0.23	0.06	0.03	0.00	0.10
BRCO	0.15	0.55	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.08
GWTE	0.15	0.55	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.08
WWSC	0.00	0.00	0.14	0.14	0.00	0.00	0.05	0.05	0.00	0.07
HRGU	0.00	0.00	0.14	0.14	0.00	0.00	0.05	0.05	0.00	0.07
AMAV	0.08	0.28	0.00	0.00	0.05	0.11	0.04	0.02	0.00	0.07
RNGR	0.08	0.28	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.04
BAGO	0.00	0.00	0.00	0.00	0.05	0.11	0.02	0.02	0.00	0.03
CITE	0.00	0.00	0.00	0.00	0.05	0.11	0.02	0.02	0.00	0.03
BOGU	0.00	0.00	0.00	0.00	0.05	0.11	0.02	0.02	0.00	0.03
GBHE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX D

Special Status Species

Many of the waterbird species on the list of “Special Animals” (CDFG 2006) are included on that list in order protect nesting or roosting sites. Species that have occurred at North Basin and fall into this category include: American White Pelican (also BSSC, 1st priority[1]); California Brown Pelican (State and Federally Endangered); Great Egret, Great Blue Heron (Sensitive), Snowy Egret, Black-crowned Night Heron, Black Oystercatcher, Long-billed Curlew, California Gull, Caspian Tern, Elegant Tern, Forester’s Tern. Each of these species occurred in limited numbers and none nests at or near the study site. Only listed species that occurred with some regularly or in significant numbers are considered here.

California Least Tern *(Sterna antillarum browni).* Status: Federally Endangered (1970); State Endangered (1971). Occurrence at North Basin: Least Tern occurred regularly during the breeding season; 1-5 individuals were detected (foraging actively) on 18 surveys between April 22 and August 18. Almost all observations were of birds foraging over open water.

Cackling Goose (formerly “Aleutian” Canada Goose) *(Branta hutchinsii)*. Status: Federally Endangered (10/13/70), Federally threatened (12/12/90); Natural Heritage status “2”, imperiled. Delisted 3/20/01. In 2004 the polytypic Canada Goose was split into two separate species, creating the Cackling Goose (Banks *et al*. 2004). Occurrence at North Basin: A flock of 53 Cackling Geese present on January 19, 2005. (Migratory flocks of this species occur regularly in mid-winter in the Bay Area.)

Double-crested Cormorant *(Phalacrocorax auritus).* Status: Department of Fish and Game, California Special Concern Species (rookery sites). Occurrence at North Basin: Fairly regular year-round, but more common in winter. Forages in flocks on open water. Most censuses detected less than ten individuals, but occasionally larger flocks were present. The winter high count was 177 on 2/18/04; the summer high count was 76 birds 6/16/05.

Western Snowy Plover *(Charadrius alexandrinus nivosus)*. Status: Federally Threatened (1993). Occurrence at North Basin: one record of 2 birds on January 12, 2007.

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[1] U.S. Fish and Wildlife Service “Bird Species of Special Concern.”