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Waterfowl Migration on Klamath Basin National Wildlife Refuges 1953-2001

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Cover: Background photo, tundra swans on water and Canada geese in flight with snowcovered hills in background at Lower Klamath National Wildlife Refuge, T. A. Blake; inset, white-fronted geese in flight with Mt. Shasta in the background at Tule Lake National Wildlife Refuge, D. Menke, USFWS.

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Contents

Abstract 1
Introduction 2
Areas Surveyed 2
  Refuge Complex 2
  Lower Klamath National Wildlife Refuge 2
  Tule Lake National Wildlife Refuge 3
  Clear Lake National Wildlife Refuge 4
  Upper Klamath National Wildlife Refuge 5
  Klamath Marsh National Wildlife Refuge 5
Methods 6
  Aerial Surveys 6
  Identifying and Counting Waterfowl 6
  Data Files and Handling 6
  Characteristics of Survey Data 6
  Terminology 7
    Seasons 7
    Waterfowl Abundance 7
    Multi-Year Averaging 7
    Seasonal Chronology 8
  Other Data Files 8
Results and Discussion 8
  Reliability of Waterfowl Surveys 8
  Waterfowl Abundance on Klamath Basin National Wildlife Refuge Complex 8
    All Waterfowl 8
      Overview 8
      Long-Term Period Versus Most Recent Period 8
      Early Period Versus Recent Period 9
    Composition of Waterfowl Groups and Species 10
      Overview 10
      Long-Term Period Versus Most Recent Period 11
      Early Period Versus Recent Period 11
      Monthly Changes in Composition 12
    Potential Influence of Central Valley Habitats 12
    Relation to Other Surveys 12
      Northern Breeding Grounds 12
      California Midwinter 13
  Waterfowl Abundance on Individual Refuges 13
    Lower Klamath National Wildlife Refuge 13
    Tule Lake National Wildlife Refuge 14
    Upper Klamath, Klamath Marsh, and Clear Lake National Wildlife Refuges 15
  Changing Status of Prominent Species 16
    Northern Pintail 16

Changing Status of Prominent Species—Continued
Mallard 17
White-Fronted Geese 18
Cackling Canada Geese 19
White Geese 19
Other Waterfowl 20
Migration Chronology 20
Autumn 20
Long-Term Period Versus Most Recent Period 20
Early Period Versus Recent Period 21
Spring 21
Long-Term Period Versus Most Recent Period 21
Early Period Versus Recent Period 21
Conclusions 21
Acknowledgments 23
References 23
Appendix 1 27
Appendix 2 29
Appendix 3 43
Appendix 4 59
Appendix 5 63

Figures

1. The Klamath Basin National Wildlife Refuge (NWR) complex includes Lower Klamath, Tule Lake, Clear Lake, Upper Klamath, Klamath Marsh, and Bear Valley NWRs. Bear Valley NWR, a forested refuge for bald eagles, was not included in aerial surveys 3
2. An example of a smooth curve fitted to survey counts of northern pintails on Lower Klamath NWR during autumn through spring 1990-91 using a cubic spline function 7
3. Three-year running average of total waterfowl abundance (birds per day) during autumn and spring for the Klamath Basin NWR complex, 1953-2001 9
4. Three-year running average of total waterfowl abundance (birds per day) during autumn and spring for Lower Klamath NWR, Tule Lake NWR, Upper Klamath NWR, Klamath Marsh NWR, and Clear Lake NWR, 1953-2001 9
5. Abundance (birds per day) of waterfowl groups on the Klamath Basin NWR complex for the early period (1953-76) compared to the recent period (1977-2001), for autumn and spring. The most abundant species within each group are shown 11
6. Changing composition of waterfowl groups and the most abundant species on Klamath Basin NWR complex each month, September through April, for the early period (1953-76) and the recent period (1977-2001) 12
7. Abundance (birds per day) of waterfowl groups on Lower Klamath, Tule Lake, and other (Upper Klamath, Klamath Marsh, and Clear Lake) refuges for the early period (1953-76) compared to the recent period (1977-2001), for autumn and spring. The most abundant species within each group are shown 14

8. Annual total waterfowl use-days on Klamath Basin NWR complex, annual total waterfowl use-days by refuge, and annual total waterfowl use-days by waterfowl groups, for the early period (1953-76) and the recent period (1977-2001) 22

Tables

1. Comparison of average waterfowl abundance (birds per day and peak spline counts) on the Klamath Basin NWR complex for the long-term (1953-2001) period and the most recent 3 years (1998-2001) 10
2. Comparison of average waterfowl abundance (birds per day and peak spline counts) on the Klamath Basin NWR complex for the early period (1953-76) and the recent period (1977-2001) in autumn and spring 10
3. Klamath Basin NWR complex autumn waterfowl counts regressed on the previous May breeding ground counts for the early period (1953-76) and the recent period (1977-2001) 13
4. The average California midwinter (January) survey counts for prominent species during 1953-76, 1977-2001, and 1998-2001 17

Waterfowl Migration on Klamath Basin National Wildlife Refuges 1953-2001

By David S. Gilmer[1], Julie L. Yee[2], David M. Mauser[3], and James L. Hainline[3]

Abstract

The Klamath Basin National Wildlife Refuge (NWR) complex, located in northeastern California and southern Oregon, is situated on a major Pacific Flyway migration corridor connecting waterfowl breeding grounds in the north with major wintering grounds in California and Mexico. The complex comprises five waterfowl refuges including Lower Klamath NWR, Tule Lake NWR, Upper Klamath NWR, Klamath Marsh NWR, and Clear Lake NWR, and one bald eagle refuge, Bear Valley NWR. Lower Klamath and Tule Lake NWRs are the largest refuges in the complex; historically, they supported some of the greatest autumn and spring concentrations of migrating waterfowl in North America. Starting in 1953, standardized waterfowl surveys from small aircraft have been conducted in autumn through spring. This report summarizes waterfowl migration activity (i.e., abundance, species composition, distribution on refuges, and chronology) over four time periods—the long-term (1953-2001), early (1953-76), recent (1977-2001), and the most recent (1998-2001)—to describe changing patterns of migration on Klamath Basin refuges from autumn 1953 to spring 2001.

Over the long term, waterfowl abundance (birds per day) on the refuge complex averaged about 1.0 million in autumn and about 360,000 in spring. A record peak count of 5.8 million waterfowl was recorded September 24-25, 1958. Average abundance of autumn staging waterfowl for the refuge complex, after reaching record levels in the 1950s and early 1960s, began a decline that lasted until the 1980s. A gradual recovery occurred during the 1990s, but autumn abundance has not recovered to pre-1970 levels. In contrast to autumn, average spring abundance was generally lower in the early decades but has gradually increased through the 1990s, particularly on Lower Klamath NWR.

Dabbling ducks represented an average of 68% of all waterfowl in autumn and 55% in spring for the long term. Northern pintail (*Anas acuta*) was dominant, representing 62% of all dabblers in autumn and 51% in spring. A significant decline in pintail abundance starting in the late 1950s altered waterfowl composition on Klamath Basin refuges. As pintail declined, other species such as mallard (*Anas platyrhynchos*) and green-winged teal (*Anas crecca*) increased in abundance. Although Arctic nesting geese, including white-fronted (*Anser albifrons*), cackling Canada (*Branta canadensis minima*), white geese (lesser snow [*Chen caerulescens caerulescens*], and Ross's [*Chen rossii*]) have become less prominent in recent decades, they reached an historically high abundance during autumn in the 1960s and 1970s, particularly on Tule Lake NWR.

Tule Lake NWR supported the highest average autumn waterfowl populations until surpassed by Lower Klamath NWR around 1980. During the recent period (1977-2001), Lower Klamath NWR accounted for 60% of all waterfowl using the refuge complex in autumn and 61% in spring. Habitat diversity and wetland productivity contributed to its greater waterfowl abundance. Tule Lake NWR supported the most geese over the long term, 79% in autumn and 66% in spring; however, total waterfowl abundance on this refuge in autumn has been in decline, likely because of reduced diversity and productivity of sumps in the refuge. Upper Klamath, Klamath Marsh, and Clear Lake NWRs accounted for less than 8% of total waterfowl use in autumn and spring but provided diverse habitats for migrants.

Waterfowl use-days on Klamath Basin refuges typically peaked in mid-autumn, decreased as migrants passed through the basin, and then reached a lesser peak during spring passage. Waterfowl abundance reached a pronounced peak in autumn during the early period (1953-76), but spring peak buildup was much less pronounced. For the recent period the autumn peak was more subdued.

Waterfowl abundance, species composition, and distribution on Klamath Basin refuges have fluctuated over the decades and have been influenced by events such as productivity on breeding grounds and habitat conditions on wintering grounds that cause shifts in migration patterns. A major challenge for the future appears to be the availability of adequate water for wetland management on Klamath Basin refuges.

Key words: California, chronology, Klamath Basin refuges, migration, Oregon, survey, trends, waterfowl

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Introduction

The Klamath Basin[4] of California and Oregon has long been recognized as an important migration staging area for waterfowl[5]. Pioneers passing through the basin in the 1850s reported huge numbers of waterfowl along the shores of Tule Lake (R.M. Abney, USFWS, unpub. rpt., 1964). Early ornithological explorations described large concentrations of waterbirds throughout the extensive marshes of the region (Chapman, 1908; Bryant, 1914). Early settlement and agriculture in the basin resulted in reclamation projects (Byrne-Shirley, 1996a, 1996b) and railroad developments that greatly reduced the marshes that had attracted legendary numbers of staging and breeding waterfowl. The earliest and most significant of these projects was the Klamath Reclamation Project, which started in 1905 and initiated an era of loss and degradation of the wetlands in the basin (see Rienecker and Anderson, 1960; Blake and others, 2000). Concerns of conservationists resulted in the establishment of the nation's first waterfowl refuges in 1908, the Lower Klamath National Wildlife Refuge (NWR) and the Malheur NWR in eastern Oregon (Gabrielson, 1943). However, threats to basin habitats continued, including a railroad bed which blocked water flows into the Lower Klamath NWR until the 1940s (USFWS, KBNWR, unpub. rpt.; Weddell, 2000; H. McCollum, USFWS, written commun., 2000; E. O'Neill, USFWS, written commun., 2000). Following the establishment of Lower Klamath NWR, a succession of other units was added, including Clear Lake NWR (a water storage reservoir) in 1911, Tule Lake and Upper Klamath NWRs in 1928, and Klamath Marsh NWR (originally Klamath Forest Refuge) in 1958. Bear Valley NWR, a sixth refuge, was acquired in 1978 to protect a major night roost for wintering bald eagles. Today, the national wildlife refuges of the Klamath Basin comprise these six units and are a complex of marshes and uplands of critical importance to waterfowl and other migratory birds in the Pacific Flyway under the management of the U.S. Fish and Wildlife Service (USFWS). Congress passed the Kuchel Act (Public Law 567-88) in 1964, legislation intended to ensure that certain refuge habitats are preserved for migratory waterfowl but that allow for continued agricultural practices consistent with waterfowl conservation.

The Klamath Basin is situated in a high desert transition zone between the southern Cascade and the northern Sierra Nevada Mountains. The basin forms a natural corridor for migrants traveling between major wintering areas in California's Central Valley (Gilmer and others, 1982) and Mexico (Bellrose, 1980) and breeding grounds in Alaska, northern and boreal forests, Canadian parklands and prairies, the U.S. prairies, and the intermountain areas in Oregon and Washington (Bellrose, 1980). Few areas in North America support such an impressive mix of waterfowl populations from different source areas. The strategic location of the Klamath Basin in the Pacific Flyway creates a situation unique in North America. Tule Lake NWR and Lower Klamath NWR provided resting and feeding habitat for 80% of the ducks of the Pacific Flyway (Laycock, 1973) and have been described as North America's greatest goose concentration area (Gabrielson, 1943; Butcher, 1963; Bellrose, 1980). They also are listed as key conservation sites for birds in North America (CEC, 1999). Over 30 species of waterfowl and numerous species of shorebirds, waders, and other wetland-dependent birds migrate through Klamath Basin.

We analyzed estimates of waterfowl abundance on Klamath Basin refuges from aerial surveys conducted from autumn 1953 through spring 2001. Our objectives were to (1) describe waterfowl abundance and species composition on Klamath Basin refuges during autumn and spring, (2) describe migration chronology, and (3) describe and evaluate changes in abundance, species composition, and migration chronology for this complete time period.

Areas Surveyed

Refuge Complex

Klamath Basin NWR complex is within the Upper Klamath Basin, a 17,626 km^2 region comprised of watersheds for the Lost, Sprague, and Williamson Rivers and Upper Klamath Lake drainage (fig. 1) (USFWS, unpub. data, 2002). The complex comprises five waterfowl refuges and one bald eagle refuge encompassing a wide range of habitat and topography. Regional climate is dry with 25-41 cm of annual precipitation, and with hot summers and cold winters. The average elevation is about 1,200 m above sea level. Tule Lake NWR and Lower Klamath NWR are the largest and best known refuges. Both units are situated mostly in northern California, immediately south of the Oregon state line. A portion of land on each refuge is farmed in accordance with the Kuchel Act under a 1977 cooperative agreement between the U.S. Bureau of Reclamation (USBR) and the USFWS.

Lower Klamath National Wildlife Refuge

Lower Klamath NWR is located in Klamath County, Oregon, and Siskiyou County, California, about 8 km southwest of Merrill, Oregon, and west of Tule Lake NWR. These two refuges are separated by Sheepy Ridge, a 3.2 km-wide ridge several hundred feet high. The 21,692 ha refuge is the largest in the complex and supports a diverse mix of shallow seasonal marshes, open water, grasslands, and croplands managed to provide forage, resting, nesting, molting, and

[4]The Klamath Basin as referenced in this report is the Upper Klamath Basin watershed defined by the U.S. Fish and Wildlife Service (USFWS unpub. data; C. Mullis, USFWS, written commun., 2002).

[5]Nomenclature for the species mentioned in this report is in Appendix 1.

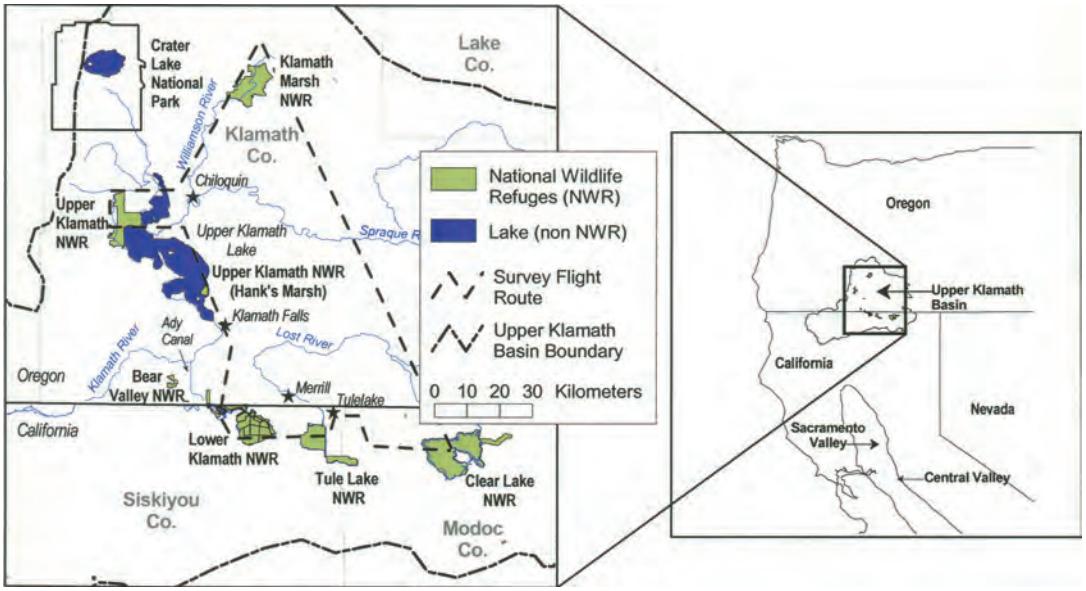

Figure 1. The Klamath Basin National Wildlife Refuge (NWR) complex includes Lower Klamath, Tule Lake, Clear Lake, Upper Klamath, Klamath Marsh, and Bear Valley NWRs. The general route followed for the aerial waterfowl surveys are indicated by the dashed line. Bear Valley NWR, a forested refuge acquired to protect bald eagles, was not included in the aerial surveys. The Upper Klamath Basin watershed is indicated by a broken line.

brood-rearing habitat for waterfowl and other birds (see Miller and Collins, 1953; Mauser and others, 1994b). Large numbers of waterfowl and colonial nesting birds breed on the refuge. Water for this refuge is pumped from the Tule Lake NWR and is also available from the Klamath River via the Ady Canal.

Tule Lake National Wildlife Refuge

This 15,824-ha refuge, located in California in Siskiyou and Modoc Counties, about 10 km west of Tulelake, consists of two open water sumps (reservoirs) totaling 5,261 ha (about

Lower Klamath National Wildlife Refuge (NWR) in Siskiyou County, California, established in 1908, was one of the first waterfowl refuges in the nation. It is the largest unit of the Klamath Basin NWR complex. Habitat diversity and wetland productivity on this refuge have contributed to high waterfowl abundance. Competition for limited water supplies in the Klamath Basin has the potential to affect this refuge more than any other in the complex.

3,200 ha-m) surrounded by croplands. A portion (currently, about 6,880 ha) of the surrounding area is farmed by USBR lessees. Refuge permittees farm another 770 ha of cereal grain. This crop, together with the waste grain and potatoes from the lease program, is a major food source for migrating and wintering geese and other field-feeding waterfowl. Irrigation water is managed by the Tule Lake Irrigation District under a contract with USBR. During the 1950s and 1960s, the open water and agricultural lands of this refuge supported North America's greatest concentration of autumn migrant waterfowl (Butcher, 1963), and in the 1970s, it was considered the most important waterfowl refuge in the nation (Laycock, 1973).

Clear Lake National Wildlife Refuge

The 8,094-ha Clear Lake reservoir surrounded by high desert is the dominant feature of this 13,517-ha refuge, located about 16 km east of Tulelake, California, in Modoc County. The reservoir, with water levels regulated by the USBR, is the primary source of agricultural water for the eastern half of the Upper Klamath Basin. Small islands provide nesting sites for the American white pelican, double-crested cormorant, and other colonial nesting birds. Upland vegetation consisting of various perennial grasses, common sagebrush and Sierra juniper surround the reservoir.

Tule Lake National Wildlife Refuge in Siskiyou and Modoc Counties, California, is well known for the large concentrations of geese that traditionally use this refuge. The refuge comprises two large open water sumps surrounded by croplands of mostly cereal grains and alfalfa, which provide foraging areas for migrating geese. Agricultural acreage and crops grown are determined by the Kuchel Act of 1964. The southern boundary of the refuge is adjacent to the Lava Beds National Monument. This is an aerial view of the upper sump, a portion of which is a large emergent marsh.

Clear Lake National Wildlife Refuge in Modoc County, California, is a large open water reservoir surrounded by high desert, consisting mostly of sagebrush and juniper. The reservoir serves as a storage for irrigation water and supports relatively sparse aquatic habitat. Islands in the reservoir are important to colonial nesting waterbirds such as American white pelicans.

Upper Klamath National Wildlife Refuge

Situated in Klamath County, Oregon, on Upper Klamath Lake, this 5,828-ha refuge comprises primarily freshwater marsh and open water providing excellent resting, foraging, nesting, and brood-rearing areas for waterfowl and colonial nesting birds. Hank's Marsh, a 607-ha unit situated on the southeastern edge of Upper Klamath Lake, was acquired in 1965.

Klamath Marsh National Wildlife Refuge

Located about 32 km north of Chiloquin, Oregon, in Klamath County, this refuge was acquired in 1958 and contained approximately 6,637 ha of wetlands. In 1990, additional acquisitions increased the total refuge area to 15,217 ha. Originally designated as Klamath Forest NWR, the refuge was recently renamed because virtually all of the historic Klamath Marsh now lies within the refuge boundaries. This largely unmanaged marsh provides important nesting, feeding, and resting habitat for waterfowl, while the surrounding meadowlands are attractive nesting and feeding areas for waterfowl, sandhill crane, yellow rail, and various shorebirds and raptors.

Upper Klamath National Wildlife Refuge in Klamath County, Oregon, is situated near the northern end of Upper Klamath Lake. A smaller unit (Hank's Marsh) is located on the southeast shore of the lake. The open water and emergent marsh provides excellent habitat for migrating waterbirds. This view looks across the lake over the northern unit of the refuge. Because this marsh is open to Upper Klamath Lake, marsh water depths are dependent on lake levels mandated for endangered fish and irrigation deliveries.

Klamath Marsh National Wildlife Refuge in Klamath County, Oregon, is surrounded by mountains, and at an elevation of about 1,400 m, is the highest refuge in the Klamath Basin NWR complex. This largely unmanaged marsh provides important migration and breeding habitat for waterfowl and other waterbirds including sandhill cranes. Klamath Marsh supports the largest population of breeding Yellow rails in the Klamath Basin.

Methods

Aerial Surveys

The first recorded aerial survey of migratory birds on a Klamath Basin refuge took place April 4, 1944, on Tule Lake NWR and was followed later by surveys on Clear Lake NWR in 1949 and Lower Klamath in 1952 (KBNWR, unpub. rpts., 1944-52 [refuge surveys]). Migratory bird populations were censused primarily from the ground until 1953 when refuge biologists began conducting two or more aerial surveys per season on Lower Klamath, Tule Lake, Clear Lake, and Upper Klamath NWRs. From 1953 to 1977, both ground and aerial surveys were conducted, but starting in 1978 ground surveys were mostly discontinued.

Waterfowl surveys were usually initiated in late August or early September when the first white-fronted geese and northern pintails typically arrived. Surveys continued approximately biweekly through late April or early May to include late spring flights of cinnamon teal and gadwall. Surveys of the five waterfowl refuges (fig. 1) were usually conducted in two consecutive days but were sometimes delayed because of fog, snow, or wind (>28 km/h). Surveys of Lower Klamath and Tule Lake NWRs were usually conducted on the same day to reduce double counting of waterfowl moving between the two refuges. Surveys were flown in a single-engine, high-wing aircraft, 30-50 m above terrain, with a speed of 140-150 km/h and were conducted along standardized, parallel transects spaced 0.4 km apart at each refuge except at Clear Lake NWR where the shoreline of the reservoir was followed. The observer sat in the right front seat and counted birds within a 0.4-km swath that was parallel to the aircraft track. Large waterfowl concentrations were circled to obtain a complete count before resuming the track. The pilot-observer team developed their own maneuvering procedures to survey individual wetland units within each refuge efficiently and safely. Double counting was considered to be minimal because most waterfowl were seldom flushed by the survey aircraft (E. O'Neill, USFWS, written commun., 2000; J. Hainline). Counts were dictated on a voice recorder. The amount of time it took to survey each refuge ranged from 1.5 hr at Lower Klamath NWR during peak populations and full-flood in the autumn to less than 10 min at smaller refuges during a freeze or drought.

Identifying and Counting Waterfowl

Aerial techniques developed by Glahn (1967) were used to identify and count waterfowl. To improve species identification, air-ground transects were used in the 1970s (E. O'Neill, USFWS, written commun., 2000). Observers routinely tallied the following species: northern pintail, mallard, American wigeon, northern shoveler, gadwall, green-winged teal, cinnamon teal, wood duck, ruddy duck, canvasback, redhead, ring-necked duck, bufflehead, cackling Canada goose, tundra swan, and American coot[6].

Some closely related species were difficult to reliably identify from aircraft and instead were tallied as groups. These "groups" included white geese (combined lesser snow geese and Ross's geese; see McLandress, 1979); white-fronted geese (combined Pacific greater white-fronted geese and greater tule white-fronted geese; see Timm and others, 1982); large Canada geese (combined western [Great Basin] Canada geese and lesser Canada geese; see Mowbray and others, 2002); scaup (combined lesser scaup and greater scaup); goldeneye (combined common goldeneye and Barrow's goldeneye); cinnamon teal (included blue-winged teal, present in relatively low numbers; see Wheeler, 1965); and mergansers (combined common, red-breasted, and hooded mergansers). Ducks were classified as either dabbling ducks (*Anas* spp., and *Aix sponsa*) or diving ducks (*Aythya* spp., *Bucephala* spp., *Mergus* spp., and *Lophodytes cucullatus*). In rare situations, such as low visibility or flock mixing, ducks were grouped as unidentified dabbling ducks or unidentified diving ducks.

Data Files and Handling

Aerial survey data were transcribed from voice recorders to data forms upon return to the office. Computer data files were started in 1993, and all survey data acquired before then were transcribed into a single database. In 1996, a systematic database evaluation was created to eliminate errors and inconsistencies and to ensure the computer database agreed with refuge narrative reports and records. A standard data record included fields describing the following: refuge, date (month, day, year), observer's initials, survey method (aerial, ground), type of survey (periodic, midwinter, breeding duck, and special surveys), count reliability (complete, incomplete), individual species count (26 species), and group counts (total dabblers, total divers, total geese and swans, total waterfowl). Data files were managed by using FoxPro and Excel software in preparation for data analysis. All statistical analyses were conducted by using SAS software (SAS Institute Inc., 1999).

Characteristics of Survey Data

Our analysis included survey data from autumn 1953 through spring 2001. We used only data from aerial surveys that were conducted for waterfowl inventories. Ground surveys and the occasional incomplete and special surveys (survey focused on only selected species) were not considered in our analysis. During this period, 2,831 aerial surveys were

[6]American coot (Family Rallidae) was included with waterfowl (Family Anatidae) in this survey because they were closely associated with ducks, geese, and swans and were among the most abundant waterbird on Klamath Basin refuges during migration.

conducted on the five waterfowl refuges during the autumn and spring seasons. Percentages of total surveys conducted at each refuge were: Lower Klamath NWR - 24%, Tule Lake NWR - 23%, Clear Lake NWR - 19%, Upper Klamath NWR - 19%, and Klamath Marsh NWR - 15%. The average number of aerial surveys conducted per year on each refuge was 6.7 during the autumn period (August through December) and 5.5 during the spring period (January through May). Surveys were usually conducted on a biweekly schedule. At least two surveys were conducted on refuges each season in all years except no spring surveys were conducted on Clear Lake NWR in 1955 and Klamath Marsh NWR in 1982, and no autumn surveys were conducted on Upper Klamath NWR in 1959 and Klamath Marsh NWR in 1994. Survey schedules were sometimes altered because of drought (Klamath Marsh NWR), weather, and budget constraints.

Terminology

Seasons

The annual migration cycle was partitioned into two seasons: autumn and spring. Autumn surveys included those conducted in August (only prior to 1982), September, October, November, and December. Spring season surveys included those conducted in January (January 1 was arbitrarily defined as the start of spring), February, March, April, and May (only prior to 1984). December and January were mostly transition months, and waterfowl present in the Klamath Basin NWRs during those months were considered to be overwintering.

Waterfowl Abundance

Waterfowl abundance was described in various ways to give several dimensions to population assessment and to assist in characterizing migration patterns and measuring change. Abundance between surveys was interpolated between survey dates by a cubic spline method, a piecewise cubic polynomial function that fits a smooth curve for all observed abundance (fig. 2). This method allowed us to describe seasonal trends and also estimate a spline peak value that may be greater than the observed peak count (highest survey count for that season and year). In calculating seasonal average abundance, we standardized the range of dates for the autumn and spring seasons to reduce relative biases in years having an extended schedule of surveys. The autumn season was constrained to fall between September 1 and December 31, inclusive, and the spring season between January 1 and April 30, inclusive. In certain years, when the surveys did not span the entire range of autumn or spring, September 1 and April 30 abundances were not interpolated, and their values were estimated to be equal to that of the nearest survey date.

For each year, refuge, species, and waterfowl group, seasonal abundances were summarized into a total or an average abundance. Total abundances across the autumn and spring seasons were equal to the number of waterfowl use-days. Use-days were calculated on a monthly basis to give a profile of the rate at which birds passed through the refuges during migration. The autumn total was divided by 92 (number of days in autumn), and the spring total by 89 (90 when including leap day) to determine an average abundance, or the average birds per day (bpd) (fig. 2). The average abundance of birds per day gave us a description of sustained refuge use, and peak count abundance provided an assessment of surges in migrating populations, whereas the number of waterfowl use-days gave us a description of cumulative days of refuge use. Average birds per day were plotted versus per year to discern annual patterns.

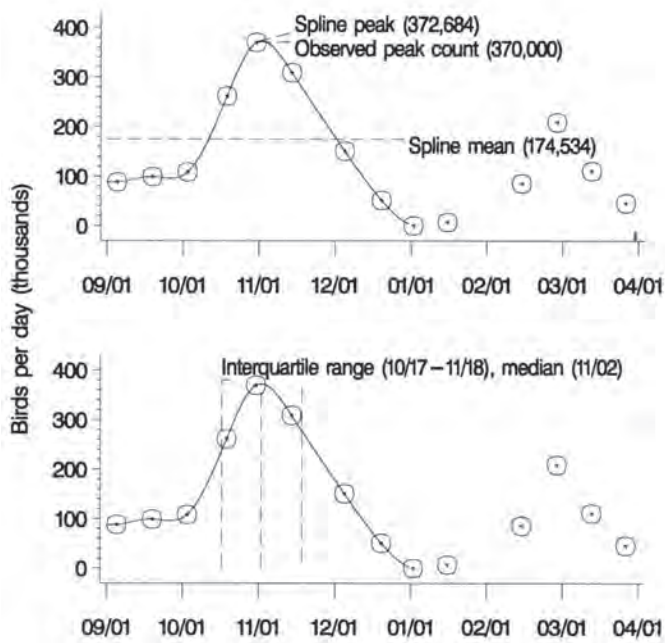

Figure 2. An example of a smooth curve fitted to survey counts of northern pintails on Lower Klamath NWR during autumn through spring 1990-91 using a cube spline function. The top graph illustrates the derivation of total bird use-days and average birds per day. The bottom graph illustrates the derivation of median use-date and interquartile range.

Multi-Year Averaging

Three-year running averages were calculated to dampen yearly fluctuations inherent in variability among surveys without masking significant annual changes. For describing changes over longer periods the running average time period was increased to 24 years, which smoothed all short-term fluctuations and allowed us to compare simply the “early period” (24-year average 1953-76 including autumn 1953 through spring 1977) to the mutually exclusive and “recent

period" (24-year average of 1977-2001, including autumn 1977 through spring 2001). The "long-term" average included all survey years (1953-2001). Comparisons involved contrasting periods and long-term averages with the present status. To describe present status, but to avoid biases inherent in considering only 1 year, we averaged the most recent 3 years (1998-2001, from autumn 1998 to spring 2001).

Seasonal Chronology

Daily abundance estimated by spline interpolation was used to depict the seasonal pattern of abundance and approximate migration chronology (fig. 2). The distribution of use-days helped to identify central periods of abundance during the season and in the process delineated early migrating species from late migrating species. For ease of comparison, the distributions were summarized by their lower, middle, and upper quartiles that represented the dates at which, respectively, 25%, 50%, and 75% of the use-days have occurred. Box plots were used to graphically depict the estimated range of dates during which the middle 50% of seasonal use-days was allocated, defined by the lower and upper quartiles, also known as the interquartile range. The middle quartile, also known as the median, was the date that separated the early 50% of use-days from the later 50% of use-days. Seasonal patterns also were described in terms of total use-days distributed per month.

Other Data Files

Breeding ground waterfowl counts (1955-2001) for ducks from the traditional North American survey areas (strata 1-18, 20-50, and 75-77, see Smith, 1995; USFWS, 2000) and California midwinter survey counts (1955-2001) (USFWS, unpub. data) were compared to Klamath Basin survey data. Breeding ground surveys were begun in May, typically after Klamath Basin spring surveys were completed. Midwinter surveys occurred in early January during the transition between Klamath Basin autumn and spring surveys. Analyses included (1) Klamath Basin autumn survey counts regressed on the previous spring breeding ground survey counts, (2) midwinter survey counts regressed on previous Klamath Basin autumn counts, and (3) Klamath Basin spring survey counts regressed on previous midwinter survey counts.

Results and Discussion

Reliability of Waterfowl Surveys

Observer bias in aerial surveys has been discussed in numerous papers (see Diem and Lu, 1960; Martinson and Kaczynski, 1967; Smith, 1995; Hodges and others, 1996). We could not assess the accuracy of the aerial survey data presented in this report. However, consistency and continuity were inherent in the conduct of Klamath Basin surveys. About 90% of all aerial surveys from 1953 to 2001 were conducted by four biologists; two biologists conducted nearly all aerial surveys from 1962 to 2001. Observers were very familiar with habitat conditions on each refuge, and aerial surveys were conducted 8-10 months each year, providing frequent opportunities for experience. We believe that the low turnover rate of and the considerable survey skills acquired by a few experienced refuge biologists undoubtedly improved the quality of the data. Experienced observers reported that survey skills improved over time, particularly in counting difficult species such as green-winged teal (J. Hainline; also see Moisan and others, 1967; Sauer and others, 1994). Observer bias undoubtedly was a factor in Klamath Basin aerial counts, but biases that existed were consistent because of the low number and overlap of observers. For instance, McLandress (1979) tended to overestimate flocks of white geese of greater than 1,500 birds, whereas, if flocks were greater than 2,000, Boyd (2000) considered his observations to be biased low. The difficulty of multispecies waterfowl identification further complicated the analysis. Regardless, these data serve as the best available indices to autumn and spring waterfowl populations in the Klamath Basin NWRs. Indeed, aerial surveys are the basis for most estimates of waterfowl populations.

Waterfowl Abundance on Klamath Basin National Wildlife Refuge Complex

All Waterfowl

Overview

The highest ever observed peak count of about 5.8 million waterfowl occurred in autumn on September 24-25, 1958. The highest observed peak count in spring was about 1.2 million on March 1, 1960. After reaching record populations in the 1950s, total waterfowl populations in autumn in the Klamath Basin complex began to decline in the mid-1960s (fig. 3), mostly because of the steep population declines at both Tule Lake and Lower Klamath NWRs (fig. 4). Average autumn abundance for the complex reached the lowest levels in the 1980s. However, the lowest spring counts occurred in the early 1950s. Populations began a slow recovery through the 1990s mostly because of increasing autumn and spring use of Lower Klamath NWR. Waterfowl estimates greater than 1.0 million for the complex were not observed again until March 16, 1994, when a spring peak count exceeded 1.1 million.

Long-Term Period Versus Most Recent Period

Long-term (1953-2001) waterfowl abundance on the Klamath Basin NWR complex averaged about 1.0 million birds per day (bpd) in autumn and about 360,000 in spring.

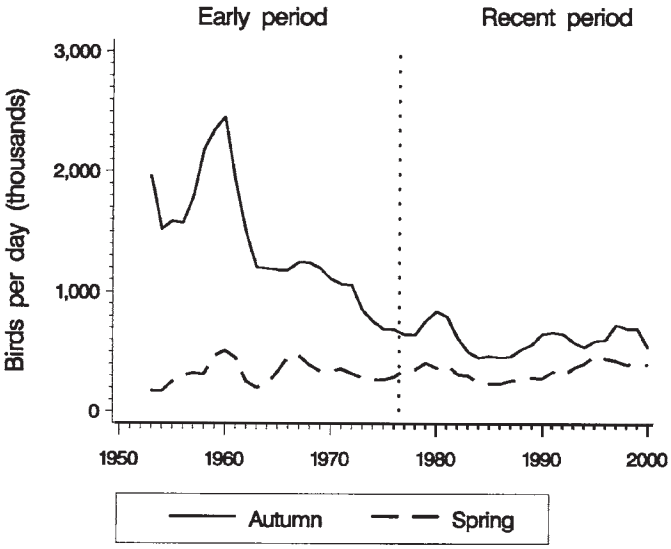

Figure 3. Three-year running average of total waterfowl abundance (birds per day) during autumn and spring for the Klamath Basin NWR complex, 1953-2001.

In contrast, autumn abundance for the complex during the most recent 3-year period (1998-2001) was about 46% less, or about 450,000 bpd less. However, spring waterfowl abundance was greater by 11%, averaging about 40,000 more bpd (table 1; Appendixes 2a, 2b, and 3a). Population peaks tracked similar changes in waterfowl abundance. Over the long-term period, peaks averaged about 2.1 million in autumn, and about 660,000 in spring. Compared to the long-term period, the average peak count in the most recent 3 years decreased by 47% to about 1.1 million in autumn, but the spring peak increased 2% to about 680,000 (table 1).

Early Period Versus Recent Period

Waterfowl abundance on Klamath Basin refuges declined greatly between the early (1953-76) and recent (1977-2001) periods. Autumn abundance for the early period averaged about 1.4 million bpd, and the average peak count was about

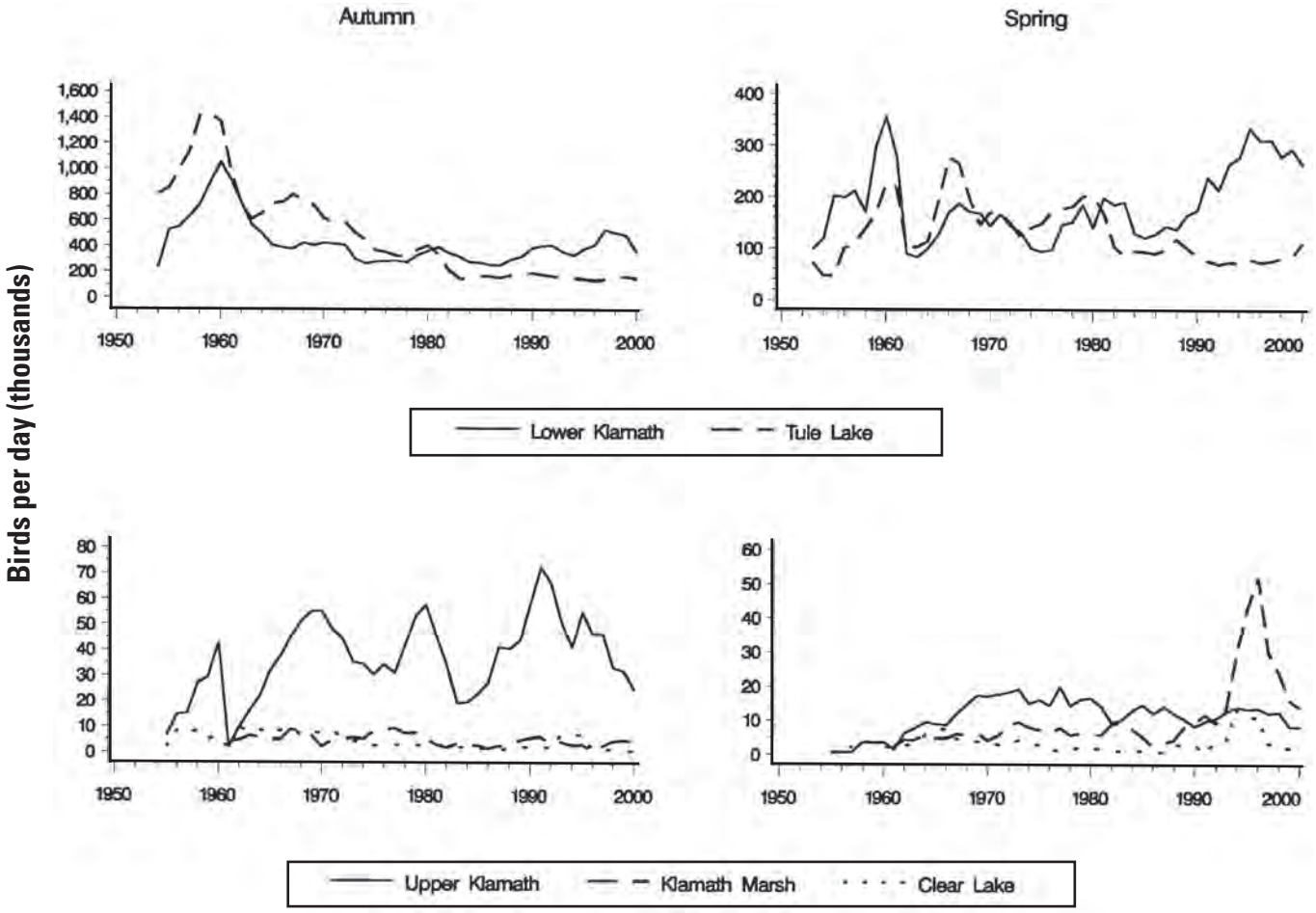

Figure 4. Three-year running average of total waterfowl abundance (birds per day) during autumn and spring for Lower Klamath and Tule Lake NWRs (upper plots) and Upper Klamath, Klamath Marsh, and Clear Lake NWRs (lower plots), 1953-2001.

Table 1. Comparison of average waterfowl abundance (birds per day and peak spline counts) on the Klamath Basin NWR complex for the long-term (1953-2001) period and the most recent 3 years (1998-2001).

	Autumn			Spring		
	Long-term period (1953-2001)	Most recent period (1998-2001)	Percent change	Long-term period (1953-2001)	Most recent period (1998-2001)	Percent change
Birds per day	1,001,045	545,486	- 45.5	359,191	400,229	+ 11.4
Peak counts	2,073,504	1,108,128	- 46.6	663,194	677,542	+ 2.2

3.0 million (table 2; Appendixes 2a and 3a). Autumn abundance decreased 56% to an average of 620,000 bpd, and the average peak count decreased 64% to 1.1 million from the early to the recent period. The decrease in abundance between the early and recent periods was not as great in spring as it was in autumn. For instance, average abundance and peak counts in spring for the early period were about 370,000 and 710,000, respectively (table 2; Appendix 2b). Spring abundance decreased, but only by 3%, and average peak count decreased 12% from the early to the recent period. The difference between autumn and spring abundance on the complex also diminished over time (fig. 3). Spring waterfowl abundance averaged about 26% of autumn abundance during the early period, versus 57% in the recent period.

Availability of habitat was more widespread in spring than in autumn because spring runoff created numerous seasonal wetlands on nonrefuge lands. This may partly explain why fewer migrants were counted on refuges in spring than autumn. (Refuge lands supported an average 62% of all waterfowl in the Klamath Basin in autumn and 59% in spring from 1991-2001. Surveys of nonrefuge waterfowl areas began in 1991 and were done in conjunction with routine survey flights [KBNWR, unpub. rpt., 1992-2002].) But slower population turnover rates in autumn compared to spring could also account for some disparity between seasons. Additionally, as autumn populations have decreased over time, spring abundance increased or remained fairly constant, thereby narrowing the difference between autumn compared to spring. Seasonal wetland conditions, particularly on Lower Klamath and Klamath Marsh NWRs during the 1990s, appeared to have attracted increased numbers of spring migrants. A combination of these factors interacted to cause changes in autumn versus spring waterfowl abundance; however, the trends between the early period and the recent period, coupled with the population increase in the most recent period (1998-2001), strongly suggest that spring use of some Klamath Basin refuges did increase.

Composition of Waterfowl Groups and Species

Overview

Waterfowl species were divided into the following four groups: dabbling ducks, diving ducks, geese and swans, and American coot. Dabbling ducks, influenced greatly by changing northern pintail populations, attained peak numbers in the late 1950s and then declined in the 1960s (Appendix 3a). In contrast, diving duck numbers were relatively stable over the years and less influenced by changes in individual species. Geese and swans, dominated by Arctic nesting geese (white-fronted, cackling Canada, and snow/Ross's), reached historically high peaks during autumn in the 1960s and 1970s on Tule Lake NWR but became less significant on Klamath Basin NWRs in more recent decades. Tundra swans increased in spring during the 1980s and 1990s, which can be attributed mostly to an increase on the Lower Klamath NWR. American coots decreased in autumn during the 1960s, but their numbers have increased in spring on the Lower Klamath NWR in recent

Table 2. Comparison of average waterfowl abundance (birds per day and peak spline counts) on the Klamath Basin NWR complex for the early period (1953-76) and the recent period (1977-2001) in autumn and spring.

	Autumn			Spring		
	Early period (1953-76)	Recent period (1977-2001)	Percent change	Early period (1953-76)	Recent period (1977-2001)	Percent change
Birds per day	1,387,027	615,053	-55.7	365,124	353,263	-3.2
Peak counts	3,039,553	1,107,454	-63.6	705,389	621,000	-12.0

decades. Typically, geese, swans, and diving ducks made up a greater proportion of the total waterfowl during spring compared to autumn.

Long-Term Period Versus Most Recent Period

Dabbling ducks were the dominant waterfowl group on the Klamath Basin NWR complex over the long-term period, representing on average 67% (674,506 bpd) of all waterfowl use-days in autumn and 55% (197,483 bpd) in spring. (Northern pintails accounted for 63% of dabbling ducks in autumn and 51% in spring.) Geese and swans were the second ranked group, accounting for about 17% of all waterfowl abundance in autumn and 28% in spring (Appendixes 2a and 2b). For comparison, counts on the refuge complex during the most recent 3 years (1998-2001), included an average of 73% (395,959 bpd) dabbling ducks in autumn and 52% (209,698 bpd) in spring. Geese and swans represented about 7% of total waterfowl in autumn and 28% in spring. Diving ducks and American coots made up the balance of waterfowl on the refuge complex in autumn (12% and 8%, respectively) and spring (13% and 7%, respectively).

Early Period Versus Recent Period

Dabbling ducks maintained clear dominance during both the early and recent periods in autumn and spring. This dominance was in spite of a major autumn decline in total waterfowl abundance from the early period compared to the recent period. Dabblers represented 67% (929,951 bpd) of all waterfowl in autumn during the early period (fig. 5; Appendix 2a). The group's percentage increased slightly to 68% (419,052 bpd) in the recent period even as abundance declined. Diving ducks, as a proportion of total waterfowl in autumn, increased from 4% to 8% between periods, but the proportion of geese and swans declined from 17% in the early period to about 15% in the recent period. In spring, dabbling and diving ducks increased as a percentage of total waterfowl from the early to the recent period, but geese and swans decreased between periods (fig. 5; Appendix 2b).

A substantial decline in northern pintail abundance starting in the late 1950s altered waterfowl composition on Klamath Basin NWRs (also see Banks and Springer, 1994). As northern pintails declined, other species increased in prominence. Noteworthy in autumn were mallards, which increased from 5% in the early period to nearly 16% of total waterfowl in the recent period, and green-winged teal, which increased from less than 1% to nearly 9% (Appendix 2a). In spring, American wigeon, northern shoveler, and green-winged teal each increased in relative prominence by 4% or more of total waterfowl from the early to the recent period (Appendix 2b). These increases were due not only to declines in northern pintail dominance but also to substantial increases in abundance

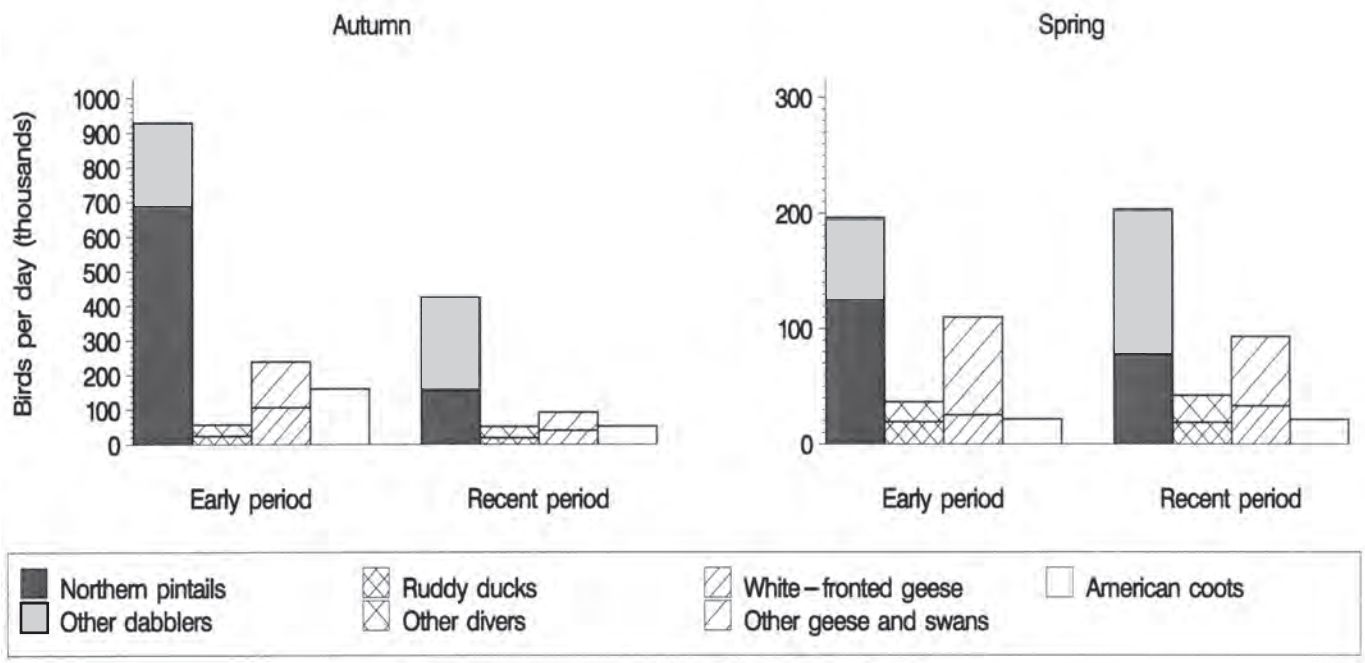

Figure 5. Abundance (birds per day) of waterfowl groups on the Klamath Basin NWR complex for the early period (1953-76) compared to the recent period (1977-2001), for autumn and spring. The most abundant species within each group are shown. [Note: Some closely related species were tallied as groups. See Identifying and Counting Waterfowl, p. 6. Other dabblers = all dabblers except Northern pintails. Other divers = all divers except ruddy ducks. Other geese and swans = all geese and swans except white-fronted geese.]

(>13,000 bpd) of these species despite major declines in total waterfowl abundance between early and recent autumn periods. The increased importance of several duck species in Klamath Basin in the recent period relative to the early period was probably a reflection of a strong recovery in breeding ground populations (except for northern pintails) in the 1990s after drought conditions on traditional breeding grounds in the late 1980s (USFWS, 2001a).

Monthly Changes in Composition

From the beginning of autumn migration to the end of spring migration, the proportion of species and waterfowl groups on the Klamath Basin refuge complex was constantly changing (fig. 6). For instance, dabbling ducks represented a greater proportion of total ducks in autumn compared to spring. During December and January mallards reached their highest proportion of total waterfowl. Diving ducks, geese, and swans, particularly white geese (see Identifying and Counting Waterfowl, p. 6), were most abundant in spring months compared to autumn.

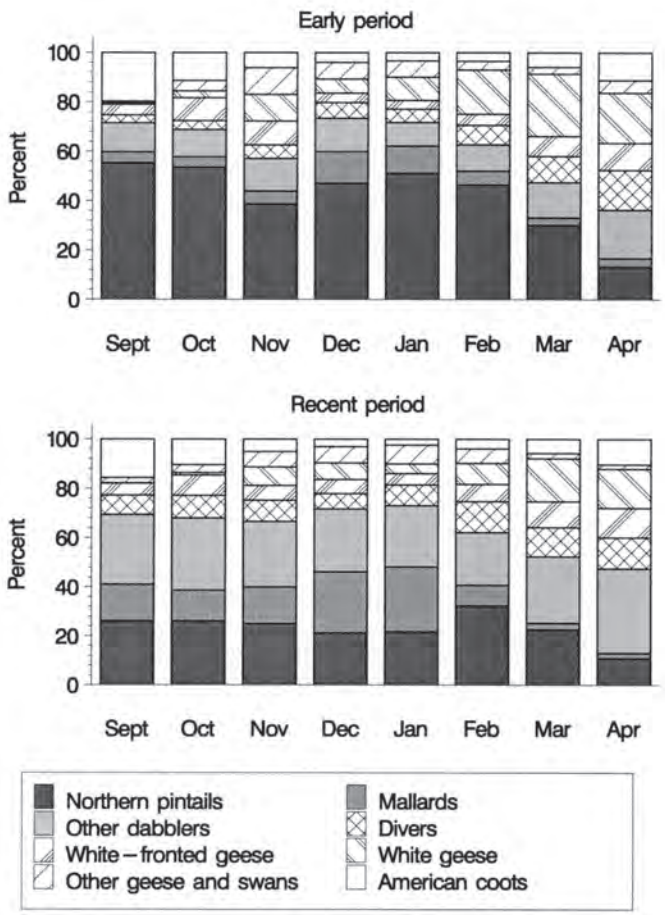

Figure 6. Changing composition of waterfowl groups and the most abundant species on Klamath Basin NWR complex each month, September through April, for the early period (1953-76) and the recent period (1977-2001). [Note: Some closely related species were tallied as groups. See Identifying and Counting Waterfowl, p. 6. Other dabblers = all dabblers except Northern pintails and mallards. Other geese and swans = all geese and swans except white-fronted and white geese.]

Potential Influence of Central Valley Habitats

The Sacramento Valley, which forms the northern region of the Central Valley, is the wintering ground for a majority of waterfowl passing through the Klamath Basin, and along with the Sacramento–San Joaquin River delta and the San Joaquin Valley, accounts for about 60% of wintering waterfowl in the Pacific Flyway (Gilmer and others, 1982). The northern terminus of the Sacramento Valley is about 160 km south of the Klamath Basin, a relatively short flight for migrating waterfowl. Weather patterns can trigger migration movements (Richardson, 1978); however, other factors were important in this region. Agricultural practices and water management in the Central Valley, particularly the Sacramento Valley, probably influenced the timing and rate of migration through the basin, as well as the duration of time spent on the wintering area. For instance, in an effort to decompose rice straw without exceeding burning limitations (imposed for air quality standards), autumn flooding of rice fields in the Sacramento Valley increased from about 25,000 ha in 1985 to about 61,000 ha by 1995 (CVHJV, 1996) and averaged about 130,000 ha from 1997 to 2001 (J. Garr, Ducks Unlimited, Inc., oral commun., 2002). Also, new varieties of rice are currently harvested 10-30 days earlier and fields are flooded earlier than they were in the late 1970s (J. Williams, University of California Cooperative Extension, oral commun., 2002). The overall effect has been that in recent decades, more habitats have been available for waterfowl earlier in autumn than they were prior to the late 1970s. These and other changes from 1985 to 1995 throughout the Central Valley, including expanded area of duck clubs and publicly managed habitats (32% increase) and increased sanctuary (40% increase) (CVHJV, 1990; CVHJV, 1996), may encourage a tradition for waterfowl to pass more rapidly through Klamath Basin enroute to the Central Valley. On the other hand, drainage of flooded rice fields starting in late January, spring burning of rice fields, and drought, such as in the winter of 1980-81 (Miller, 1986), reduce available habitats and may hasten spring departures from the Central Valley. Also, cropping patterns in response to world agricultural markets can change rapidly, potentially greatly altering the distribution and abundance of Central Valley waterfowl habitats.

Relation to Other Surveys

Northern Breeding Grounds

The relation between waterfowl average abundance on the Klamath Basin NWR complex and waterfowl population

indices for northern breeding grounds varied. Correlations at the 0.05 significance level were apparent for only two of nine species for the early period, but six of nine species were significant during the recent period (table 3). Mallard and northern shoveler appeared to have no correlation within either period, and scaup showed negative correlation within both periods.

California Midwinter

Ultimate destinations for most waterfowl migrating through the Klamath Basin were traditional wintering grounds in California, mostly in the Central Valley, so one might expect abundance of waterfowl staging on the Klamath Basin NWR complex would predict midwinter counts for California's wintering grounds. This expectation was tested for 20 species by using a statistical regression of California midwinter survey counts on the previous Klamath Basin autumn average abundance. Similarly, the relationship was tested again by regressing the spring average abundance on Klamath Basin refuges from the previous midwinter counts for the same species. Comparisons were made separately for the early and recent periods. During autumn, correlations significant at the 0.05 level were apparent for three species during the early period and 10 species for the recent period (Appendix 4a). Indeed, during autumn for the recent period, the correlation was significant for total waterfowl. The regression of midwinter counts from Klamath Basin abundance in spring produced only one significant correlation in the early period; however, eight species had significant correlations for the recent period (Appendix 4b). And similar to autumn, Klamath Basin total waterfowl spring abundance during the recent period was significantly correlated with midwinter counts. The poor association during the early period may be related to variability in surveys conducted in the early years. For instance, variability (e.g., differences in observers, timing, and weather) in midwinter counts could explain poor tracking. Also, this variability could be due in part to the single survey for the midwinter counts, whereas Klamath Basin estimates were the result of a smoothing and averaging process over several surveys per season.

Waterfowl Abundance on Individual Refuges

Lower Klamath National Wildlife Refuge

Lower Klamath refuge had its highest waterfowl abundance in autumn during the late 1950s and early 1960s when populations averaged nearly 1.0 million birds per day (bpd), with a peak of 2.1 million on October 12, 1960. A count of about 640,000 waterfowl on February 24, 1968, was the highest spring waterfowl count to date on a single refuge. (A new record spring count of nearly 810,000 occurred March 13, 2002.)

Waterfowl habitats on Lower Klamath refuge traditionally largely consisted of seasonal wetlands and agricultural lands periodically flooded to control weeds (KBNWR, unpub. rpt., 1960-2002 [various dates]). These wetlands provided a rich diversity of foods to meet nutritional demands of migration and reproduction for many species of ducks (Pederson and Pederson, 1981,1983).

Over the long-term period (1953-2001) the refuge supported an average of about 45% (about 450,000 bpd) of Klamath Basin NWR complex waterfowl during autumn (Appendix 2c) and about 54% (nearly 200,000 bpd) in spring (Appendix 2d). Waterfowl populations in autumn declined steeply in the early 1960s, stabilized somewhat through the 1970s and 1980s, and recovered partially in the 1990s (fig. 4; Appendix 3b). Spring abundance declined after peaking in the 1950s, fluctuated through the 1970s and early 1980s, then sharply increased through the late 1980s and early 1990s. In the early period (1953-76), Lower Klamath NWR supported 38% of total waterfowl in autumn and 47% in spring. During the recent period (1977-2001), this refuge accounted for 60%

Table 3. Klamath Basin NWR complex autumn waterfowl counts regressed on the previous May breeding ground counts for the early period (1953-76) and the recent period (1977-2001). Bold = significant correlation.

Species	Early period (1953-76)				Recent period (1977-2001)			
	Slope	SE	*P*-value	r^2	Slope	SE	*P*-value	r^2
Northern pintail	0.78	0.43	0.08	0.14	**0.93**	**0.25**	**0.00**	**0.40**
Mallard	0.58	0.42	0.18	0.09	-0.26	0.32	0.42	0.03
American wigeon	0.19	0.47	0.68	0.01	**0.72**	**0.30**	**0.02**	**0.22**
Northern shoveler	0.30	0.29	0.32	0.05	0.41	0.34	0.24	0.06
Gadwall	0.10	0.25	0.70	0.01	**0.59**	**0.27**	**0.04**	**0.18**
Green-winged teal	-0.24	0.44	0.59	0.01	**2.70**	**1.21**	**0.04**	**0.19**
Canvasback	1.14	0.97	0.26	0.06	**1.24**	**0.41**	**0.01**	**0.30**
Redhead	**-1.09**	**0.44**	**0.02**	**0.24**	0.52	0.61	0.40	0.03
Scaup	**-1.50**	**0.65**	**0.03**	**0.21**	**-1.55**	**0.50**	**0.01**	**0.32**

of all waterfowl using the complex in autumn and 61% in spring. For comparison, the refuge supported an average of 66% (361,771 bpd) of all waterfowl in autumn during the most recent 3-year (1998-2001) period. Starting about 1980, Lower Klamath NWR displaced Tule Lake NWR as the most heavily used refuge in autumn (fig. 4). It was the dominant refuge in spring most years. The refuge has seen a steady increase in spring abundance in all waterfowl groups from about 170,000 bpd in the early period, to about 220,000 in the recent period (fig. 7), and most recently (1998-2001) the average is over 260,000 bpd (Appendix 2d).

But these patterns in total waterfowl abundance did not carry over to separate waterfowl groups. For example, over the long-term period, there was a higher proportion of dabbling ducks using this refuge, but for geese, the proportion was lower compared to Tule Lake NWR (Appendixes 2e and 2f).

Adequate water for optimal wetland management, habitat diversity, increased wetland productivity, and perhaps the relative decline in the sumps at Tule Lake NWR have made Lower Klamath NWR the keystone of the Klamath Basin NWR complex in recent decades.

Tule Lake National Wildlife Refuge

Tule Lake NWR recorded its highest waterfowl abundance in autumn during the 1950s when populations averaged more than 1.1 million bpd, with a peak count of about 4.2 million on October 13, 1957 (the highest count ever recorded on a Klamath Basin refuge).

Over the long-term period (1953-2001), the refuge supported an average of about 50% (about 500,000 bpd) of Klamath Basin refuge complex waterfowl during autumn

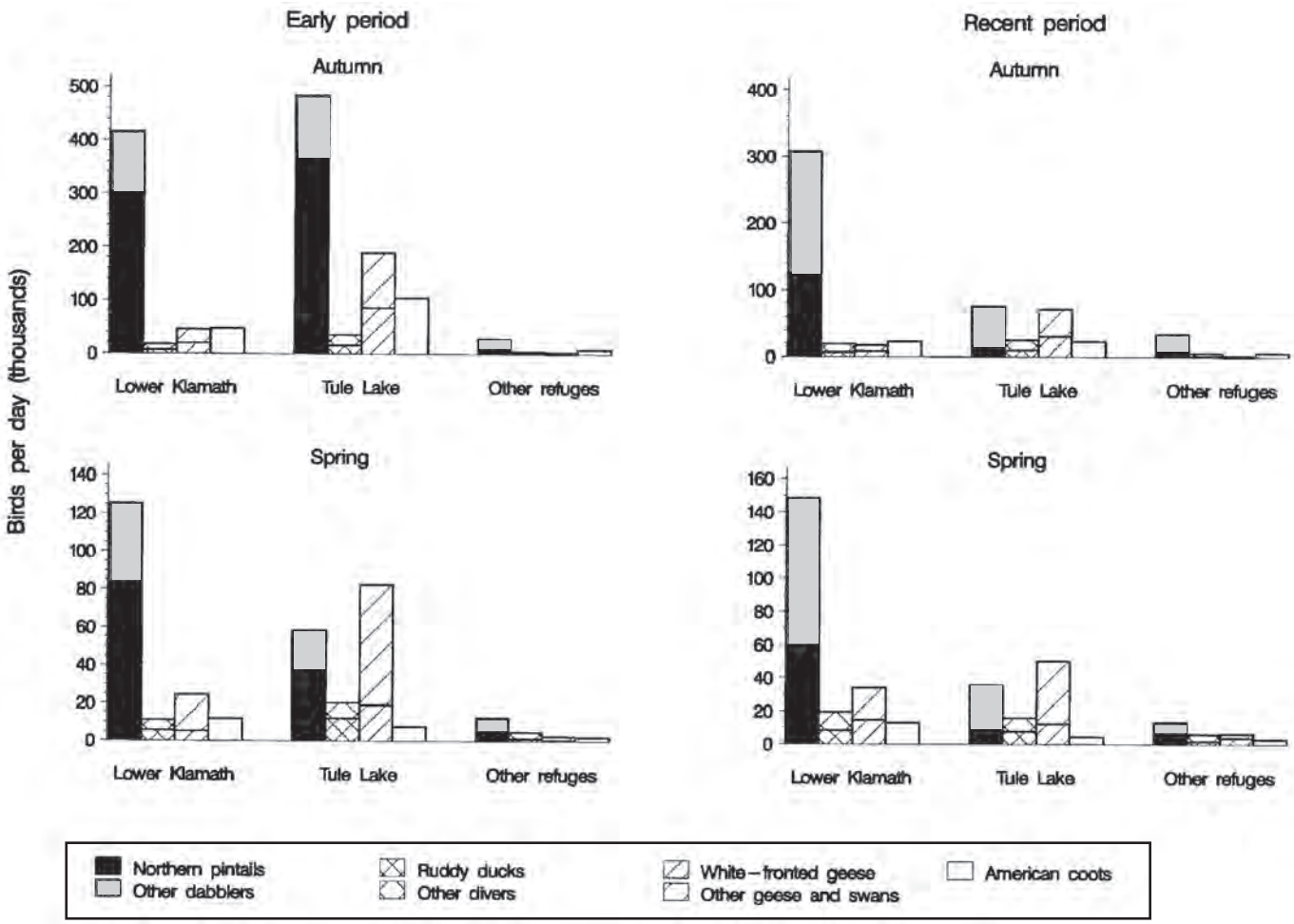

Figure 7. Abundance (birds per day) of waterfowl groups on Lower Klamath, Tule Lake, and other (Upper Klamath, Klamath Marsh, and Clear Lake) refuges for the early period (1953-76) compared to the recent period (1977-2001), for autumn and spring. The most abundant species within each group are shown. [Note: Some closely related species were tallied as groups. See Identifying and Counting Waterfowl, p. 6. Other dabblers = all dabblers except Northern pintails. Other divers = all divers except ruddy ducks. Other geese and swans = all geese and swans except white-fronted geese.]

(Appendix 2e) and about 38% (nearly 140,000 bpd) in spring (Appendix 2f). During the mid to late 1950s, waterfowl populations on Tule Lake refuge in autumn increased to record levels (fig. 4; Appendix 3b). These spectacular waterfowl concentrations were composed mostly of northern pintails, which averaged more than 80% of total waterfowl using the refuge in autumn at that time. Autumn abundance sharply declined, from about 1959 through the early 1960s. The downward trend continued until the early 1980s when populations appeared to stabilize. Waterfowl on Tule Lake refuge during the early period (1953-76) averaged 59% of total waterfowl using the entire complex in autumn and 46% in spring. During the recent period (1977-2001) average abundance on the refuge had decreased to about 32% of total waterfowl in autumn and about 30% in spring. In comparison, abundance averaged 28% (152,729 bpd) of total waterfowl in autumn and 27% (110,232 bpd) in spring for the most recent period (1998-2001).

Although dabbling ducks represented the majority of waterfowl on Tule Lake refuge, geese accounted for about 26% of waterfowl in autumn and 48% in spring. Indeed, Tule Lake NWR supported a long-term average of 79% of the total goose population using the complex in autumn and 66% of all geese in spring. Dabbling ducks (mostly northern pintails), geese and swans, and American coots showed the largest proportional declines on the Tule Lake NWR in the recent period compared to the early period (fig. 7; also see Appendixes 2e and 2f). The decline in autumn populations on Tule Lake NWR, even as North American duck populations increased in the late 1960s and 1970s (USFWS, 2001a) and Lower Klamath NWR counts trended mostly upward in autumn and spring (1980s and 1990s; fig. 4), suggested that local habitat conditions were a factor.

Contributing to this was the Kuchel Act, which was created in 1964 to protect the refuge by preventing further homesteading on reclaimed land and stopping any further reduction in the size of the Tule Lake NWR sumps. Ironically, the Act inadvertently restricted the ability of refuge managers to manipulate water levels in future years. Fixed water levels and siltation eventually contributed to reduced productivity and diversity of the sumps (D.M. Mauser, 1995, USFWS, unpub. rpt.; Mauser and others, 1995; USFWS, KBNWR, 2000). During the 1950s, small grains accounted for more than 80% of crops grown on the refuge. Waste grain provided an abundant food source for field-feeding ducks and geese in autumn (O'Neill, 1999). Acreage of row crops increased and small grain acreage decreased through the 1960s, but grain crops still averaged about 70% of the refuge's leased croplands in recent decades (USFWS, KBNWR, and U.S. Bureau of Reclamation, unpub. rpt., 1970-2000 [various dates]). Continued availability of waste grain, supplemented in recent decades by potatoes, suggested that food availability in fields on Tule Lake NWR was not a factor limiting usage by waterfowl (also see Frederick and others, 1992). A likely cause of decline in waterfowl use on Tule Lake NWR, relative to Lower Klamath NWR, was the deterioration of its sumps (Line, 1997) and the concomitant habitat improvements on Lower Klamath NWR. Refuge managers have initiated programs to reverse trends in wetland habitat decline by effective use of water to mimic the hydrological diversity of historic Tule Lake (USFWS, KBNWR, 2000).

Snow geese feeding in barley fields on Tule Lake National Wildlife Refuge with Mt. Shasta in the background. Cereal grains planted for waterfowl food and waste grains in harvested fields provide abundant high energy forage for field-feeding geese, mallards, and Northern pintails.

Upper Klamath, Klamath Marsh, and Clear Lake National Wildlife Refuges

From 1953-2001, waterfowl abundance on these three refuges combined averaged about 47,000 bpd in autumn and 27,000 in spring (Appendixes 2g-2l). Waterfowl distribution among the refuges as a percentage of the total Klamath Basin NWR complex was: Upper Klamath, 4% (autumn), 3% (spring); Klamath Marsh, less than 1% (autumn) and 3% (spring); and Clear Lake, less than 1% (autumn) and 1% (spring). Peak waterfowl populations for these refuges were about 286,000 (autumn 1990) and 64,000 (spring 1972) for Upper Klamath; 98,000 (autumn 1960) and 145,000 (spring

1995) for Klamath Marsh; and 74,000 (autumn 1993) and 59,000 (spring 1995) for Clear Lake. Since surveys began, average waterfowl abundance changed relatively little on Klamath Marsh and Clear Lake NWRs until the 1990s when both refuges saw large fluctuations in spring (fig. 4; Appendix 3c). In contrast, Upper Klamath has seen large fluctuations in autumn abundance throughout its history. Among these three refuges in autumn, Upper Klamath NWR typically held the most dabblers and divers and Clear Lake NWR held the most geese. In spring, most dabblers and geese were found on Klamath Marsh NWR and most divers on Upper Klamath NWR. Events such as drought, grazing, and fire may explain some of the major fluctuations in waterfowl abundance. For instance, in 1990 a new acquisition to Klamath Marsh NWR more than doubled its size. The new addition had been intensively grazed and the refuge was burned in the early 1990s following drought. For 3 years following flooding in the mid-1990s, waterfowl use in spring on this refuge reached unusually high levels (fig. 4; Appendix 3c). Average waterfowl abundance in autumn increased on Upper Klamath NWR but decreased on the other refuges from the early period to the recent period. New marsh developments on private ranches around Upper Klamath Lake in the last decade may have altered waterfowl usage patterns on Upper Klamath NWR (H. Carlson, University of California, written commun., 2002). In spring, between the early and recent period, waterfowl abundance for Klamath Marsh NWR nearly doubled, for Upper Klamath NWR it increased slightly, and for Clear Lake NWR it decreased except for a temporary rise in the mid-1990s. However, little overall change was noted in total waterfowl using these three refuges as a proportion of the whole refuge complex (fig. 7). Clear Lake NWR supported limited forage, and most waterfowl use on this refuge was attributed to overflow from nearby Tule Lake NWR, particularly when waterfowl populations peaked during the 1950s to around 1976 (H. McCollum, USFWS, oral commun., 1999). From 1998-2001, average waterfowl abundance, when compared to the long-term period, declined on these refuges, with only Klamath Marsh NWR showing an increase in spring.

Changing Status of Prominent Species

Northern Pintail

The northern pintail was the most abundant waterfowl species on the Klamath Basin NWR complex, averaging 42% (420,000 birds per day) of total waterfowl in autumn and 28% (100,000 bpd) in spring over the long-term period (1953-2001) (Appendixes 2a and 2b). No other species on Klamath Basin NWRs has come close to the pintail in abundance. In the early period (1953-76), pintails averaged 50% of total waterfowl in autumn and 35% in spring. During the 1950s and 1960s, pintails often represented more than 60% of total waterfowl during autumn. A count of 3.3 million pintails on Tule Lake NWR on October 13, 1957, was the highest count to date for a single waterfowl species on any refuge in the Klamath Basin complex. After several decades of decline, starting in the late 1950s, autumn pintail abundance in the Klamath Basin NWRs stabilized in the 1980s (Appendix 3a). Currently, North America's pintail breeding population is 23% below the 1955-2000 long-term average (USFWS, 2001a), and unlike most other ducks, it has not responded to favorable wetland conditions on breeding grounds (Miller and Duncan, 1999). In the Klamath Basin complex during autumn 1998-2001, pintails

Northern pintails resting at Lower Klamath National Wildlife Refuge during autumn migration. Pintails are the most abundant waterfowl using the Klamath Basin NWRs and were concentrated by the millions in autumn in the 1950s and 1960s. In recent decades pintail populations have declined, and numbers have not responded to improved conditions on northern breeding grounds as other species have.

were 73% below their long-term average. During the recent period (1977-2001) pintails averaged 25% of total waterfowl in autumn and 22% in spring. Most recently (1998-2001), pintail populations have changed little, averaging about 22% of both autumn and spring total waterfowl. Pintail abundance in the Klamath Basin complex in autumn for the recent period reflected trends similar to breeding ground counts (table 3), suggesting linkage between autumn flights from traditional breeding grounds and Klamath Basin populations. Also, there appeared to be association between both autumn and spring abundance in the Klamath Basin NWRs and populations wintering in California's Central Valley during the 1977-2001 period (Appendixes 4a and 4b). Recent satellite telemetry studies (Miller and others, 2000) have highlighted the importance of refuges and private lands in southern Oregon and northeastern California as spring stop-over sites for pintails returning to breeding grounds. The autumn index for Klamath Basin pintails was higher for the early period compared to the recent period and most recent years (1998-2001) (table 4), reflecting the large population buildups (mostly on Tule Lake NWR) that occurred during autumn migrations from the 1950s through the 1970s. The spring index was relatively unchanged for all periods.

Mallard

The mallard, North America's most abundant waterfowl (USFWS, 2001a), was the second most abundant waterfowl (excluding coot) on the Klamath Basin NWR complex, averaging 8% (85,000 bpd) of total waterfowl in autumn (Appendix 2a) and 6% (23,000 bpd) in spring (Appendix 2b) from 1953-2001. During the early period, mallards averaged 5% of total waterfowl in autumn and 5% in spring. Mallard numbers in autumn declined on the complex (primarily on Tule Lake NWR) from the late 1950s through the late 1970s. But starting in the early 1980s and continuing through the 1990s, mallard abundance increased (primarily on Lower Klamath refuge) (Appendixes 3a and 3b). During the recent period, mallards averaged 16% (97,000 bpd) of total waterfowl in autumn and 7% (26,000 bpd) in spring. Abundance has changed slightly during the most recent years, and mallards represented 17% (93,000 bpd) of total waterfowl in autumn and 5% (20,000 bpd) in spring from 1998-2001; abundance was about 10% above the long-term average in autumn and about 13% below in spring.

There appeared to be no association between mallards in Klamath Basin NWRs in autumn and traditional breeding ground counts (table 3). Some investigators noted only weak linkages between surveys of mallards in most Pacific Flyway states and the breeding ground survey (USFWS, 2001b). Further, recoveries from mallards in California showed little connection to traditional breeding grounds (Munro and Kimball, 1982; Rienecker, 1990; also see Trost, 1986). A portion of the mallards in Klamath Basin NWRs in autumn may originate from breeding areas outside the traditional survey range (i.e., British Columbia, Washington, Oregon). Moreover, Bellrose (1980) identified Klamath Basin NWRs as a major waterfowl production area of the intermountain

Table 4. The average California midwinter (January) survey counts for prominent species during 1953-76, 1977-2001, and 1998-2001.

[The average Klamath Basin NWR complex spline peak counts for the autumn and spring expressed as a proportion of the midwinter count shown as the autumn index and the spring index, respectively. The index is considered a minimum estimate of waterfowl staging on the Klamath Basin NWRs because turn-over rate is unknown]

Species	Early period (1953-76)			Recent period (1977-2001)			Most recent period (1998-2001)		
	California midwinter	Autumn index[1]	Spring index[2]	California midwinter	Autumn index[1]	Spring index[2]	California midwinter	Autumn index[1]	Spring index[2]
Northern pintail	2,204,660	0.77	0.15	1,458,530	0.22	0.13	1,113,563	0.22	0.18
Mallard	497,510	0.34	0.11	409,241	0.43	0.18	437,083	0.38	0.12
White-fronted goose[3]	129,616	2.40	0.47	108,813	0.77	0.57	188,105	0.26	0.59
Cackling Canada goose	118,720	2.05	0.24	25,057	2.22	0.43	2,265	7.48	0.25
White goose[4]	424,288	0.55	0.41	411,599	0.22	0.28	442,173	0.09	0.26
Total waterfowl	5,500,000	0.55	0.13	4,296,323	0.26	0.14	4,716,963	0.23	0.14

[1] Klamath Basin NWR complex average spline peak count in autumn divided by California midwinter count.
[2] Klamath Basin NWR complex average spline peak count in spring divided by California midwinter count.
[3] White-fronted goose includes Pacific greater white-fronted goose and greater tule white-fronted goose.
[4] White goose includes lesser snow goose and Ross's goose.

West. Others have observed that Klamath Basin NWRs may be a wintering area for mallards produced in northeast California (see Rienecker, 1990; Mauser and others, 1994a, 1994b; McLandress and others, 1996). Also, the Klamath Basin appears to be a molting area (see Rienecker, 1990) for post-breeding mallards from northern California (Yarris and others, 1994), further complicating the relation between Klamath Basin NWRs and wintering areas to the south. No relationship was apparent between mallard abundance in autumn in Klamath Basin NWRs and the California midwinter survey (Appendixes 4a and 4b). Also, there was no association between mallards overwintering in the Columbia Basin, Washington (see Rienecker, 1990), and autumn abundance in the Klamath Basin NWRs during the early (r^2= 0.07, P=0.22) or the recent periods (r^2=0.11, P=0.12). The autumn index for mallards has increased for the recent and current periods compared to the early period. The spring index also increased after the early period (table 4), suggesting mallard use of the basin had increased in recent decades. According to Rienecker (1990), banding data from California suggested that two subpopulations of mallards were evident, one associated with the Central Valley and the other with the northeastern part of the state.

White-Fronted Geese

The Klamath Basin NWR complex, and particularly Tule Lake NWR, exceeded any other staging site for white-fronted geese in the Pacific Flyway. Always the most abundant goose, "white-fronts" averaged 7% (73,000 bpd) of total waterfowl in autumn (Appendix 2a) and 8% (28,000 bpd) in spring (Appendix 2b) over the long-term period. Peak numbers occurred in autumn during the 1950s and 1960s, but a decline starting about 1969 (see O'Neill, 1979) reached the lowest levels in the 1990s (Appendix 3a). The Pacific Flyway population of white-fronted geese, measured by peak populations in the Klamath Basin NWRs, decreased by almost 90% between 1967 and 1986 (USFWS, unpub. data, 1967-86 [survey data]; Pacific Flyway Council, 1987), an event attributed to subsistance harvest on Alaska's Yukon-Kuskokwim Delta (Klein, 1966) and recreational hunting in the Pacific Flyway (Bartonek and others, 1971; Raveling, 1984; Pamplin, 1986). Nearly coincidental with the sharp downturn in white-fronted goose abundance in Klamath Basin NWRs was the largest outbreak of avian cholera (*Pasteurella multocida*) ever recorded, which affected mostly white-fronted geese and snow geese (Rosen, 1971) and occurred in California in the winter of 1965-66 and again in 1970-71 (Rosen, 1971; Botzler, 1991). The Pacific Flyway white-front population began a recovery starting about 1985 (USFWS, 2000), but autumn populations on Klamath Basin NWRs indicated no concurrent increase; instead the population showed an apparent decline. For instance, white-front abundance in autumn decreased from an average 40,000 bpd to 21,000 bpd between the recent and the most recent (1998-2001) periods, respectively. A slight increase occurred between the mid-1980s to the mid-1990s. In comparison, the midwinter number for white-fronts in California (mostly the

White-fronted geese were the most abundant geese migrating through Klamath Basin. Populations reached high levels during the 1960s and 1970s but declined sharply from excessive subsistance and sport harvest. Pacific populations have recovered, but Klamath Basin autumn numbers have not returned to former levels. White-fronts breed primarily in Alaska's Yukon-Kuskokwim Delta.

Sacramento Valley) surged from an average count of about 109,000 for the recent period to current counts averaging nearly 190,000 (table 4). These numbers suggest that although the flyway population has increased in recent decades, no proportional increase in white-fronts that stopover in Klamath Basin in autumn has occurred. Changing migration patterns (Takekawa and Ely, 1997) and expanding wetland habitats in the Central Valley (CVHJV, 1990, 1996) starting in the 1990s may explain the apparent autumn white-front decline on Klamath Basin NWRs (see Frederick and others, 1992). However, as the importance of the white-front on Klamath Basin NWRs waned in autumn, it became more prominent in spring. From the early period to the recent period, white-fronts increased from 7% (25,000 bpd) of total spring waterfowl to 9% (32,000 bpd), and currently to 12% (50,000 bpd) in 1998-2001. This trend was reflected in the autumn index, which has declined from the early to recent periods, but spring indices have increased (table 4). There was no significant relation between the abundance of white-fronted geese in the Klamath Basin NWRs in autumn and the California midwinter survey (Appendix 4a). Correlation in spring was significant, however, (Appendix 4b) suggesting that some white-fronts overfly Klamath Basin refuges in autumn but stop on return spring migration.

Cackling Canada Geese

Populations of cackling Canada geese in Klamath Basin NWRs followed a pattern similar to white-fronted geese. Originating from breeding grounds on the Yukon-Kuskokwim Delta (Nelson and Hansen, 1959; Michelson, 1975), "cacklers" have traditionally passed through Klamath Basin en route to wintering grounds in California's Central Valley. As early as the 1930s these geese were an important component in the bag of Klamath Basin hunters (Gilmer and others, 1986; Fleskes and others, 1994). Cacklers staging at Klamath Basin NWRs, mostly Tule Lake NWR, averaged 4% (42,000 bpd) of total waterfowl in autumn (Appendix 2a) and 2% (6,200 bpd) in spring (Appendix 2b) over the long-term period (1953-2001). During the early period (1953-76) they represented 5% (64,000 bpd) of total waterfowl in autumn and 3% (9,200 bpd) in spring. Cacklers were never a prominent species in spring on basin refuges. Autumn abundance reached a peak in the 1960s, then steadily decreased until the mid-1980s (see O'Neill, 1979) (Appendix 3a). Similar to white-fronted geese, the cackler population declined Pacific Flyway-wide and was attributed to excessive harvest (Raveling, 1984; Pamplin, 1986). From about 1984 to 2000 the Pacific Flyway population increased steadily (USFWS, 2000). However, the population in Klamath Basin NWRs showed a corresponding increase only from about 1985 through the mid-1990s, and counts have since declined to nearly insignificant levels (table 4; Appendix 3a). The concurrent decline of cacklers in traditional wintering areas in the Central Valley was confirmed by the correlation between population counts in the Klamath Basin NWRs and the California midwinter counts (Appendixes 4a and 4b). During the recent period, cacklers averaged 3% (20,000 bpd) of total waterfowl in autumn and less than 1% (3,300 bpd) in spring. And from 1998 to 2001, cacklers represented less than 1% (4,300 bpd) of total waterfowl in autumn and less than 1% (200 bpd) in spring. The decrease in cacklers in Klamath Basin NWRs was related to their increasing tendency to overwinter in the Lower Columbia River of Washington and Oregon, and in the Willamette Valley of Oregon, a tradition which began about 1984 (Raveling and Zezulak, 1992; Cornely and others, 1998; Jarvis and Bromley, 1998) and continued to increase through the mid-1990s (USFWS unpub. rpts., 1990-98 [survey data]). The autumn index was higher for cacklers compared to most other species and increased from the early to the recent period as the number of birds in Klamath Basin NWRs exceeded numbers wintering to the south (table 4). The spring index increased between the early and recent periods but decreased in recent years as cackler numbers dwindled in California.

White Geese

White geese migrating through Klamath Basin NWRs include snow geese from the western Arctic and Wrangel Island, Russia, and Ross's geese from the central and western Arctic (USFWS, 2000). Following a pattern similar to other Arctic geese staging on Klamath Basin NWRs in autumn, populations of white geese decreased after reaching peak levels in the late 1960s and early 1970s (see O'Neill, 1979) (Appendix 3a). The decline of both the western Arctic and Wrangel Island populations passing through the Klamath Basin and wintering in California seems to have been due more to changes in movement patterns than to population or regional differences in survival and productivity (Hines and others, 1999; Armstrong and others, 1999). However, like white-fronts, the initial white geese decline occurred nearly coincidental to a major avian cholera outbreak that struck wintering waterfowl (mostly white-fronts and white geese) in California (Rosen, 1971; Botzler, 1991). For the long-term period (1953-2001) staging white geese averaged 4% (43,000 bpd) of total waterfowl in autumn (Appendix 2a) and 16% (58,000 bpd) in spring (Appendix 2b). For the early period (1953-76) white geese represented 4% (61,000 bpd) of total waterfowl in autumn and 19% (70,000 bpd) in spring, but they decreased to 4% (24,000 bpd) in autumn and 13% (47,000 bpd) in spring in the recent period. White geese populations varied in most recent years (1998-2001), averaging 2% (9,500 bpd) of total waterfowl in autumn and 12% (49,000 bpd) in spring (Appendixes 2a and 2b). The declining importance suggested white geese may have begun bypassing Klamath Basin NWRs during autumn migration starting about the late 1980s, which has been reflected in declining autumn indices (table 4). The spring index changed only slightly between the recent and current periods. Habitat improvements in the Central Valley starting in the 1990s (CVHJV, 1990, 1996)

may encourage an accelerated passage of white geese, as with white-fronted geese, through Klamath Basin en route to Central Valley wintering grounds. Relationships were not significant between abundance of white geese in the Klamath Basin and the California midwinter surveys in autumn (Appendix 4a) and spring (Appendix 4b).

Other Waterfowl

Significant ($P < 0.05$) abundance changes in other waterfowl species varied greatly among time periods, season, and refuge (Appendixes 2 and 3). Most population declines on the Klamath Basin NWR complex occurred in autumn, but most increases were noted in spring. For instance, for autumn migration during the early period (1953-76), significant decreases occurred for six species (bufflehead, canvasback, redhead, ring-necked duck, ruddy duck, and American coot), and no species showed an increase (Appendix 2a). For the recent period (1977-2001), autumn changes were nearly equally divided with five decreases (American wigeon, cinnamon teal, wood duck, mergansers, and redhead) and six increases (green-winged teal, gadwall, canvasback, ring-necked duck, ruddy duck, and scaup). For the long-term period (1953-2001) significant decreases occurred for seven species in autumn (American wigeon, cinnamon teal, wood duck, redhead, ruddy duck, merganser, and American coot) and three species increased (green-winged teal, ring-necked duck, and scaup). Population changes in spring migration contrasted to autumn. For the early period, an increase in refuge complex use occurred for two species (cinnamon teal and mergansers) and no species declined (Appendix 2b). However, in the recent period, increases occurred for nine species (green-winged teal, gadwall, northern shoveler, bufflehead, canvasback, ring-necked duck, scaup, tundra swan, and American coot), but only cinnamon teal declined. For the long-term period, spring increases occurred in nine species (American wigeon, green-winged teal, gadwall, northern shoveler, bufflehead, canvasback, ring-necked duck, scaup, and tundra swan), and no species decreased.

Several of the above species were noteworthy for large (>50%) changes in abundance between time periods. For instance, green-winged teal in autumn increased from less than 1% (10,192 bpd) of total waterfowl in the early period to 9% (52,324 bpd) in the recent period, representing a 413% increase in abundance (Appendix 2a). For spring the increase was 285% (Appendix 2b). Over the long-term period the teal population increased about 8% per year in autumn and 6% in spring. For the period of 1998-2001, green-winged teal averaged 17% (95,000 bpd) of all waterfowl in autumn, ranking below only northern pintail, even as their population had begun a decline from a record high. Next to green-winged teal, the ring-necked duck had the largest proportional change in abundance, increasing 172% in autumn and 442% in spring for the recent period compared to the early period. Scaup increased 63% in autumn and 59% in spring for the recent period compared to the early period. Northern shoveler and tundra swan abundance increased in spring 51% and 77%, respectively, while redhead abundance decreased 57% in autumn.

The American coot was among the most abundant waterfowl on Klamath Basin NWRs in autumn, representing 11% (106,445 bpd) of all waterfowl over the long-term period. However, autumn average abundance declined about 68% from the early to the recent period. For the long-term period the American coot declined about 5% per year (Appendix 2a). Abundance during the most recent period (1998-2001) changed little compared to the previous period.

Increases in green-winged teal, gadwall, and northern shoveler abundance on Klamath Basin NWRs during the recent period reflected trends on traditional breeding grounds (USFWS, 2000), but only the increases for gadwall and green-winged teal were significant (table 3). Some of the increase in green-winged teal may be attributed to improving ability over time in sorting out teal from other species during surveys (J. Hainline). Significant increases in scaup in Klamath Basin NWRs have run counter to decreases in the North American breeding population (Austin and others, 2000; USFWS, 2001a). The redhead was a prominent breeder on Tule Lake and Lower Klamath NWRs in the 1950s and 1960s (Rienecker, 1968), but the local breeding population has declined (USFWS, KBNWR unpub. rpt., 1953-70 [various surveys]), and the species has been relatively unimportant, averaging less than 1.0% of total waterfowl in autumn and spring from 1998-2001. In contrast, the continental redhead population has exceeded the long-term average since the early 1990s (USFWS, 2001a).

Migration Chronology

Autumn

Long-Term Period Versus Most Recent Period

The passage of waterfowl through the Klamath Basin NWR complex, measured by average use-days, typically peaked in October then decreased until spring migration began in January and February. Exceptions to this pattern were diving ducks and geese, which reached autumn peak use-days in November during the 1950s and 1960s. The average median use-date, a marker to judge the timing of migration, was October 25 for dabbling ducks, October 27 for diving ducks, and November 4 for geese. From 1998 to 2001 the median use-dates for both dabblers and divers, when compared to the long-term period, occurred 4 days later and for geese 3 days later. The time span between median use-dates of the earliest arriving migrant (typically cinnamon teal in mid-September) and the last arrival (tundra swan in early December) averaged 76 days (Appendix 5a). The average time span of the interquartile range was 39 days. Arrival, buildup, and departure dates among Klamath Basin NWRs were nearly synchronous.

Early Period Versus Recent Period

During the early period (1953-76), waterfowl rapidly reached peak use-days in October. This pattern was influenced by the behavior of the large population of northern pintails staging on Tule Lake NWR in the 1950s through the 1970s. Compared to the early period, use-days in the recent period (1977-2001) increased more slowly, reaching a maximum in November, and a prominent peak was not apparent (fig. 8). During the 1950s and early 1960s, the first migrant northern pintails moved into Klamath Basin NWRs in August but did not arrive until 1 month later by the late 1960s (Rienecker, 1987). Successful nesting conditions on prairie breeding grounds during early decades may have allowed a large proportion of northern pintails to migrate earlier, thereby reaching the Klamath Basin NWRs earlier in the autumn season. Conditions on traditional northern pintail nesting grounds have likely been less favorable in more recent decades (see Miller and Duncan, 1999). Median use-dates were later (0 = 7 days) for all waterfowl groups in the recent period than during the early period, indicating a shift in the timing of migration over the long-term period (see Appendix 5a). Field observations over a 10-year period suggested a tendency for waterfowl to arrive later in autumn and leave earlier in spring in the 1980s than in the 1970s (H. McCollum, USFWS, written commun., 2000). Shifting migration chronology may be a response to climatic change (see LaRoe, 1991; LeBlanc and others, 1991; Melillo, 1999; Magnuson and others, 2000). For total waterfowl, the time span of the interquartile range averaged 35 days during the early period compared to 43 days in the recent period.

Spring

Long-Term Period Versus Most Recent Period

Waterfowl use-days on the Klamath Basin NWR complex from 1953-2001 increased through January and February, reached a relatively shallow peak in March, and then decreased in April. Monthly changes were much less pronounced in spring than in autumn. The average median use-dates were March 2 for dabbling ducks, March 15 for diving ducks, and March 15 for geese. In comparison, median use-dates from 1998-2001 were later by 13 days for dabblers, 4 days for divers, and 8 days for geese. However, the short (3-year) time period probably inflated the influence of annual weather patterns that may determine regional migration timing (see Richardson, 1978). The time span between median use-dates of the earliest arrival (tundra swan) and the last arrival (cinnamon teal) was 58 days (Appendix 5b). The average time span of the interquartile range was 42 days.

Early Period Versus Recent Period

Use-day chronology in spring for the early (1953-76) and recent (1977-2001) periods had similar patterns but were less pronounced when compared to autumn. Use-day peaks for all waterfowl groups, particularly dabbling ducks, were higher and more prominent in the recent period compared to the early period (fig. 8). During the recent period, spring use-days increased rapidly, reaching a peak in March, whereas during the early period, use-days rose gradually from January through March, and a prominent peak did not occur. Median use-dates were later for dabblers and geese but earlier for divers in the recent period compared to the early period. The average time span of the interquartile range in spring was similar for both periods, averaging 43 days (Appendix 5b). Migration chronologies for most species were comparable to autumn and spring patterns for Klamath Basin NWRs described by Bellrose (1980).

Conclusions

Standardized aerial surveys conducted on the Klamath Basin NWR complex since 1953 provided an opportunity to assess waterfowl populations and migration behavior over nearly half a century. Because of its strategic location as a gateway between major breeding and wintering grounds, migration staging patterns in the Klamath Basin provide some insight to the status of Pacific Flyway waterfowl. Cycles of population declines and increases have been common. Northern pintails, which once had a major presence on Klamath Basin NWRs, declined to less than 30% of their pre-1970s autumn populations. In the 1950s and 1960s this species accounted for more than 60% of all waterfowl staging in autumn on Klamath Basin NWRs. Presently, they have yet to recover to anything approaching their former numbers. Other significant events include flyway-wide declines in Arctic nesting geese in the 1960s through the 1980s. The international reputation of Tule Lake NWR was established because of vast autumn goose flights that took place in the 1950s and 1960s. In recent decades, flyway populations of Arctic geese have rebounded, but their migration through the Klamath Basin suggests declining use in autumn. These changes appear to be related to shifts in wintering grounds (cackling Canada geese) or migration patterns (white-fronted geese, white geese). Several duck species have increased, partially filling the void created by the decline of the northern pintail. For instance, mallard, green-winged teal, and gadwall use has increased significantly, particularly on the Lower Klamath NWR. However, a long-term decline in waterfowl use of Tule Lake NWR has raised questions about the quality of its wetland habitat. Management programs to enhance productivity of refuge wetlands have been developed to address these concerns.

Increasing spring waterfowl use on Klamath Basin NWRs in recent decades has run counter to declines in autumn use. The Central Valley, because of its proximity to Klamath Basin, may strongly influence Klamath Basin migration patterns. The decline in autumn but increase in spring waterfowl activity in the

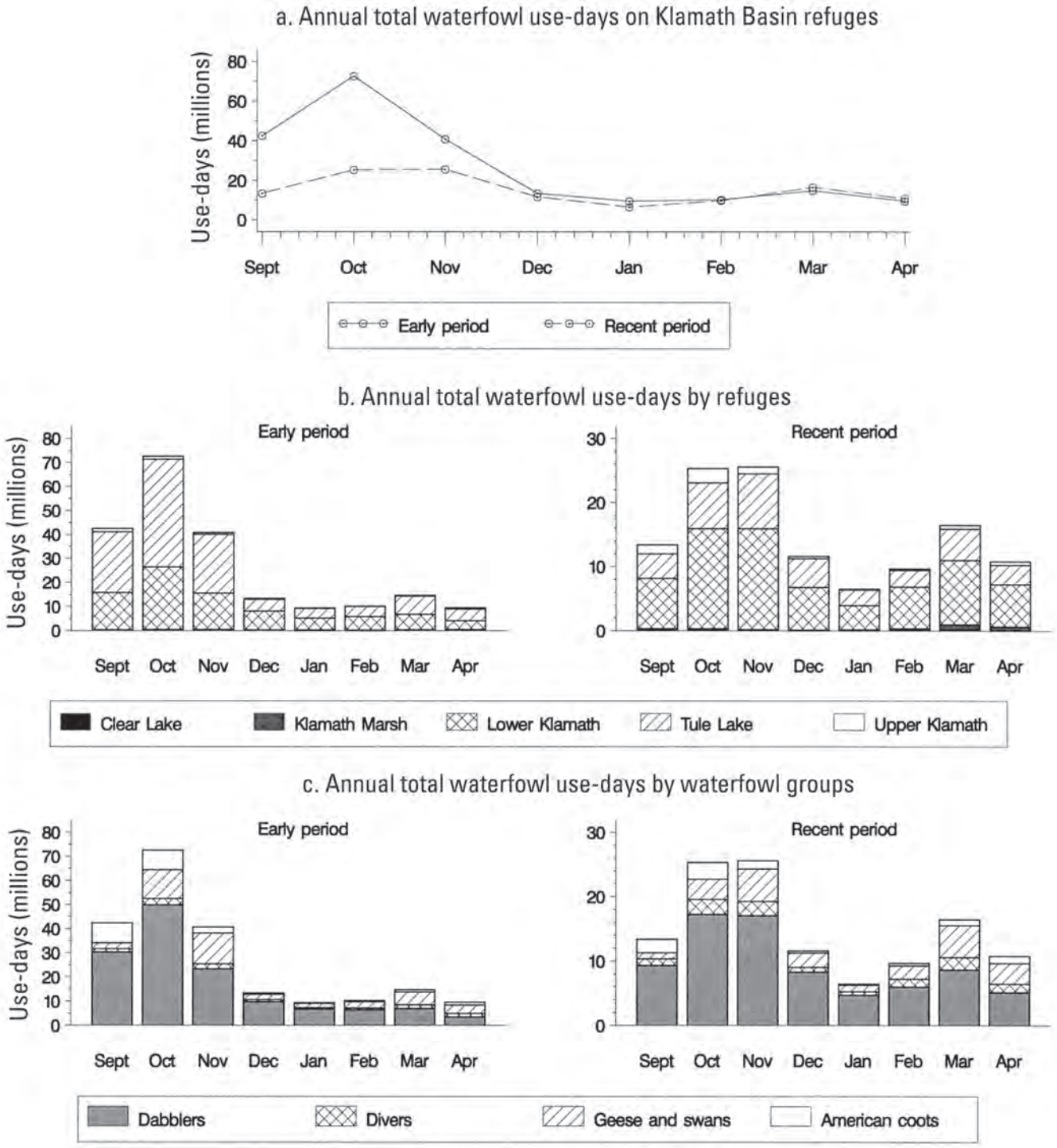

Figure 8. (a) Annual total waterfowl use-days on Klamath Basin NWR complex, (b) annual total waterfowl use-days by refuge, and (c) annual total waterfowl use-days by waterfowl groups, for the early period (1953-76) and the recent period (1977-2001). [Note: Some closely related species were tallied as groups. See Identifying and Counting Waterfowl, p. 6.]

Klamath Basin NWRs in the recent decade may be related to major habitat transformations (mostly related to rice production) in the Central Valley. However, Central Valley habitat conditions are influenced greatly by agricultural market forces and water allocations. These factors have the potential to create significant and rapid change in Central Valley environments, perhaps creating future changes in waterfowl behavior in Klamath Basin NWRs.

A major concern of refuge managers in the future will be securing adequate water supplies for Lower Klamath and Tule Lake NWRs, as available water resources in the Klamath River drainage are seriously over-allocated. Water issues in the Klamath Basin have been a concern of national importance in recent years, and W. Kettredge (Blake and others, 2000, p. 31) colorfully articulated this problem:

> Blame El Niño, global warming, gases emitted by industries. Ultimately the allocation and uses of water, its pollution, and the shortfalls are the ranking problems in the Klamath Basin. They will not, in any foreseeable future, go away. But perhaps if the citizens of the basin are persistent and resilient, those problems will over time drive them to a reinvented sense of communality.

Only time will tell if northern pintails and Arctic geese return in numbers characteristic of earlier decades. It is certain, however, that the Klamath Basin refuge complex serves as a critical junction in the Pacific Flyway. Periodic fluctuations in breeding ground populations, wintering ground habitat, and local conditions will continue to produce the ebb and flow patterns observed in waterfowl abundance on the Klamath Basin complex. Throughout these variations it is important that Klamath Basin NWR management continue to meet the needs of waterfowl and the uncounted thousands of other migratory birds that depend on these ancestral habitats for critical staging, wintering, and breeding requirements.

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References

Austin, J.E., Afton, A.D., Anderson, M.G., Clark, R.G., Custer, C.M., Lawrence, J.S., Pollard, J.B., and Ringelman, J.K., 2000, Declining scaup populations: issues, hypotheses, and research needs: Wildlife Society Bulletin, v. 28, p. 254-263.

Armstrong, W.T., Meeres, K.M., Kerbes, R.H., Boyd, W.S., Silveira, J.G., Taylor, J.P., and Turner, B., 1999, Routes and timing of migration of lesser snow geese from the Western Canadian Arctic and Wrangel Island, Russia, 1987-1992, *in* Kerbes, R.H., Meeres, K.M., and Hines, J.E., eds., Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia: Canadian Wildlife Service Paper 98, p. 75-88.

Banks, R.C., and Springer, P.F., 1994, A century of population trends of waterfowl in western North America, *in* Jehl, J.R., and Johnson, N.K., eds., A century of avifaunal change in western North America: Studies in Avian Biology No. 15, Cooper Ornithological Society, p. 134-146.

Bartonek, J.C., King, J.G., and Nelson, H.K., 1971, Problems confronting migratory birds in Alaska: Transactions of the North American Wildlife and Natural Resources Conference, v. 36, p. 345-361.

Bellrose, F.C., 1980, Ducks, geese and swans of North America: Harrisburg, Pa., Stackpole Books, 540 p.

Blake, T.A., Blake, M.G., and Kittredge, W., 2000, Balancing water: restoring the Klamath Basin: Berkeley, University of California Press, 175 p.

Botzler, R.G., 1991, Epizootiology of avian cholera in wildfowl: Journal of Wildlife Diseases, v. 27, p. 367-395.

Boyd, W.S., 2000, A comparison of photo counts versus visual estimates for determining the size of snow goose flocks: Journal of Field Ornithology, v. 71, p. 686-690.

Bryant, H.C., 1914, A survey of the breeding grounds of ducks in California in 1914: Condor, v. 16, p. 217-239.

Butcher, D., 1963, Exploring our national wildlife refuges: Boston, Houghton Mifflin Co., 340 p.

Byrne-Shirley, B.L., 1996a, The reclamation of Tule Lake, *in* Gooch, S., ed., The Tule Lake Area, Twentieth Century

Development: The Journal of the Modoc County Historical Society, No. 18, p. 49-68.

Byrne-Shirley, B.L., 1996b, The Tule Lake-Lower Klamath region, a historical overview, *in* Gooch, S., ed., The Tule Lake Area, Twentieth Century Development: The Journal of the Modoc County Historical Society, No. 18, p. 3-17.

CEC (Commission for Environmental Cooperation), 1999, North American important bird areas, a directory of 150 key conservation sites: Montreal, Ontario, Canada, Commission for Environmental Cooperation, 253 p.

Chapman, F.M., 1908, Camps and cruises of an ornithologist: New York, D. Appelton and Co., 432 p.

Cornely, J.E., Naughton, M.B., Hills, M.R., and Raftery, K.M., 1998, Distribution of wintering dusky and cackling Canada geese in western Oregon and western Washington, 1985-89, *in* Rusch, D.H., Samuel, M.D., Humburg, D.D., and Sullivan, B.D., eds., Biology and management of Canada geese: Proceedings of the International Canada Goose Symposium, Milwaukee, Wis., p. 221-229.

CVHJV (Central Valley Habitat Joint Venture Implementation Board), 1990, Central Valley Habitat Joint Venture Implementation Plan, a component of the North American Waterfowl Management Plan: U.S. Fish and Wildlife Service, 102 p.

CVHJV (Central Valley Habitat Joint Venture Technical Committee), 1996, Hunting success in the Central Valley, California during 1995-96 compared with previous years: U.S. Fish and Wildlife Service, Central Valley Habitat Joint Venture Special Technical Report 1, 17 p.

Diem, K.L., and Lu, K.H., 1960, Factors influencing waterfowl censuses in the parklands, Alberta, Canada: Journal of Wildlife Management, v. 24, p. 113-133.

Fleskes, J.P., Hicks, J.M., Gilmer, D.S., and Yparraguirre, D.R., 1994, Changing patterns of goose harvest on California public hunting areas: California Fish and Game, v. 80, p. 133-149.

Frederick, R.B., Clark, W.R., and Takekawa, J.Y., 1992, Application of a computer simulation model to migrating white-fronted geese in the Klamath Basin, *in* McCollough, D.R., and Barrett, R.H., eds., Wildlife 2001: Populations: New York, Elsevier, p. 696-706.

Gabrielson, I.N., 1943, Wildlife refuges: New York, The Macmillan Co., 257 p.

Gilmer, D.S., Miller, M.R., Bauer, R.D., and LeDonne, J.R., 1982, California's Central Valley wintering waterfowl: concerns and challenges: Transactions of the North American Wildlife and Natural Resources Conference, v. 47, p. 441-452.

Gilmer, D.S., Hicks, J.M., Bartonek, J.C., and McCollum, E.H., 1986, Waterfowl harvest at Tule Lake National Wildlife Refuge, 1936-1941: California Fish and Game, v. 72, p. 132-143.

Glahn, R.M., 1967, Waterfowl from the air: an inventory guide: Portland, Oreg., U.S. Department of the Interior, U.S. Fish and Wildlife Service, Bureau of Sports Fisheries and Wildlife, 26 p.

Hines, J.E., Baranyuk, V.V., Turner, B., Boyd, W.S., Silveira, J.G., Taylor, J.P., Berry, S.J., Meeres, K.M., Kerbes, R.H., and Armstrong, W.T., 1999, Autumn and winter distribution of Lesser Snow Geese from the Western Canadian Arctic and Wrangel Island, Russia, 1953-1992, *in* Kerbes, R.H., Meeres, K.M., and Hines, J.E., eds., Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia: Canadian Wildlife Service Occasional Paper 98, p. 39-73.

Hodges, J.I., King, J.G., Conant, B., and Hanson, H.A., 1996, Aerial surveys of waterbirds in Alaska 1957-94: population trends and observer variability: National Biological Service Information and Technology Report 4, 24 p.

Jarvis, R.L., and Bromley, R.G., 1998, Managing racially mixed flocks of Canada geese, *in* Rusch, D.H., Samuel, M.D., Humburg, D.D., and Sullivan, B.D., eds., Biology and management of Canada geese: Proceedings of the International Canada Goose Symposium, Milwaukee, Wis., p. 413-423.

Klein, D.R., 1966, Waterfowl in the economy of the Eskimos on the Yukon-Kuskokwim Delta, Alaska: Arctic, v. 19, p. 319-336.

LaRoe, E.T., 1991, The effect of global climate change on fish and wildlife resources: Transactions of the North American Wildlife and Natural Resources Conference, v. 56, p. 171-176.

Laycock, G., 1973, The sign of the flying goose: the story of the national wildlife refuges: Garden City, N.Y., Anchor Press/Doubleday, 265 p.

LeBlanc, A., Dudek, D.J., and Allegretti, L.F., 1991, Disappearing ducks: the effect of climate change on North Dakota's waterfowl: New York, N.Y., Environmental Defense Fund.

Line, L., 1997, Foul play in the Klamath Basin: Inside Audubon, May-June 1997, p. 119-120.

Magnuson, J.J., Robertson, D.M., Benson, B.J., Wynne, R.H., Livingstone, D.M., Arai, T., Assel, R.A., Barry, R.G., Card, V., Kuusisto, E., Granin, N.G., Prowse, T.D., Stewart, K.M., and Vuglinski, V.S., 2000, Historical trends in lake and river ice cover in the northern hemisphere: Science, v. 289, p. 1743-1746.

Martinson, R.K., and Kaczynski, C.F., 1967, Factors influencing waterfowl counts on aerial surveys, 1961-66: U.S. Department of the Interior, U.S. Fish and Wildlife Service, Special Science Report Wildlife No. 105, 78 p.

Mauser, D.M., Gilmer, D.S., Shennan, C., and Carlson, H.L., 1995, An alternative management approach for the Tule Lake National Wildlife Refuge [abs.], Klamath Basin Ecosystem Research and Restoration Coordination meeting, March 14-16, 1995, Klamath Falls, Oreg.

Mauser, D.M., Jarvis, R.L., and Gilmer, D.S., 1994a, Movements and habitat use of mallard broods in northeastern California: Journal of Wildlife Management, v. 58, p. 88-94.

Mauser, D.M., Jarvis, R.L., and Gilmer, D.S., 1994b, Survival of radio-marked mallard ducklings in northeastern California: Journal of Wildlife Management, v. 58, p. 82-87.

McLandress, M.R., 1979, Status of Ross' geese in California, *in* Jarvis, R.L., and Bartonek, J.C., eds., Management and Biology of Pacific Flyway Geese, a Symposium: Corvallis, Oregon State University, p. 255-265.

McLandress, M.R., Yarris, G.S., Perkins, A.E.H., Connelly, D.P., and Raveling, D.G., 1996, Nesting biology of mallards in California: Journal of Wildlife Management, v. 60, p. 94-107.

Melillo, J.M., 1999, Warm, warm on the range: Science, v. 283, p. 183-184.

Michelson, P.G., 1975, Breeding biology of cackling geese and associated species on the Yukon-Kuskokwim Delta, Alaska: Wildlife Monograph, v. 45, p. 1-35.

Miller, A.W., and Collins, B.D., 1953, A nesting study of Canada geese on Tule Lake and Lower Klamath National Wildlife Refuges, Siskiyou County, California: California Fish and Game, v. 39, p. 385-396.

Miller, M.R., 1986, Northern pintail body condition during wet and dry winters in the Sacramento Valley, California: Journal of Wildlife Management, v. 50, p. 189-198.

Miller, M.R., and Duncan, D.C., 1999, The northern pintail in North America: status and conservation needs of a struggling population: Wildlife Society Bulletin, v. 27, p. 788-800.

Miller, M.R., Takekawa, J.Y., Orthmeyer, D.L., Fleskes, J.P., Casazza, M.L., and Perry, W.M., 2000, Progress report 2000: tracking spring migration of northern pintails with satellite telemetry, "Discovery for recovery: An international pintail research initiative." 1 October 2000, U.S. Geological Survey, unpub. rpt., Sacramento, Calif.

Moisan, G., Smith, R.I., and Martinson, R.K., 1967, The green-winged teal: its distribution, migration and population dynamics: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 248 p.

Mowbray, T.B., Ely, C.R., Sedinger, J.S., and Trost, R.E., 2002, Canada goose (*Branta canadensis*), *in* Poole, A., and Gill, F., eds., The birds of North America, no. 682: Philadelphia, Pa., The Birds of North America, Inc.

Munro, R.E., and Kimball, C.F., 1982, Population ecology of the mallard: VII, distribution and derivation of the harvest: U.S. Fish and Wildlife Service, Resource Publication No. 147, 127 p.

Nelson, U.C., and Hansen, H.A., 1959, The cackling goose its migration and management: Transactions of the North American Wildlife Conference, v. 24, p. 174-186.

O'Neill, E.J., 1979, Fourteen years of goose populations and trends at Klamath Basin refuges, *in* Jarvis, R.L., and Bartonek, J.C., eds., Management and Biology of Pacific Flyway Geese, a Symposium: Corvallis, Oreg., Oregon State University, p. 316-321.

O'Neill, E.J., 1999, From behind the blue goose sign ... : Klamath Falls, Oreg., Graphic Press, 412 p.

Pacific Flyway Council, 1987, Pacific flyway management plan for the Pacific Flyway population of white-fronted geese: Portland, Oreg., U.S. Fish and Wildlife Service and Canadian Wildlife Service, 28 p.

Pamplin, W.L., Jr., 1986, Cooperative efforts to halt population declines of geese nesting on Alaska's Yukon-Kuskowim Delta: Transactions of the North American Wildlife and Natural Resources Conference, v. 51, p. 487-506.

Pederson, G.B., and Pederson, R.L., 1981, A brief vegetation study of selected areas in Lower Klamath National Wildlife Refuge, Contract 14-16-0001-79106: Arcata, Calif., Humboldt State University, 78 p.

Pederson, G.B., and Pederson, R.L., 1983, Feeding ecology of pintails and mallards on Lower Klamath Marshes, Final rpt., Contract 14-16-0001-79106: Arcata, Calif., Humboldt State University, 89 p.

Raveling, D.G., 1984, Geese and hunters of Alaska's Yukon Delta: management problems and political dilemmas: Transactions of the North American Wildlife and Natural Resources Conference, v. 49, p. 555-575.

Raveling, D.G., and Zezulak, D.S., 1992, Changes in distribution of cackling Canada geese in autumn: California Fish and Game, v. 78, p. 65-77.

Richardson, W.J., 1978, Timing and amount of bird migration in relation to weather: a review: Oikos, v. 30, p. 224-272.

Rienecker, W.C., 1968, A summary of band recoveries from redheads (*Aythya americana*) banded in northeastern California: California Fish and Game, v. 54, p. 17-26.

Rienecker, W.C., 1987, Migration and distribution of northern pintails banded in California: California Fish and Game, v. 73, p. 139-155.

Rienecker, W.C., 1990, Harvest distribution and survival of mallards banded in California, 1948-82: California Fish and Game, v. 76, p. 14-30.

Rienecker, W.C., and Anderson, W., 1960, A waterfowl nesting study on Tule Lake and Lower Klamath National Wildlife Refuges, 1957: California Fish and Game, v. 46, p. 481-506.

Rosen, M.N., 1971, Avian cholera, *in* Davis, J.W., Anderson, R.C., Karstad, L., and Trainer, D.O., eds., Infectious and parasitic diseases of wild birds: Ames, Iowa State University Press, p. 59-74.

SAS Institute Inc., 1999, SAS OnlineDoc7, Version 8: Cary, N.C., SAS Institute Inc.

Sauer, J.R., Peterjohn, B.G., and Link, W.A., 1994, Observer differences in the North American breeding bird survey: Auk, v. 111, p. 50-62.

Smith, G.W., 1995, A critical review of the aerial and ground surveys of breeding waterfowl in North America: U.S. Department of the Interior, National Biological Service Biological Science Report 5, 252 p.

Takekawa, J.Y., and Ely, C.R., 1997, Tracking white-fronted geese from Bristol Bay, Alaska, to Mexico: California Waterfowl, October/November, p. 36-37.

Timm, D.E., Wege, M.L., and Gilmer, D.S., 1982, Current status and management challenges for tule white-fronted geese: Transactions of the North American Wildlife and Natural Resources Conference, v. 47, p. 453-463.

Trost, R.E., 1986, A preliminary assessment of the recent distribution and derivation of the mallard harvest in the United States based on recoveries from breeding ground bandings, 1975-1984: U.S. Fish and Wildlife Service, Office of Migratory Bird Management, unpub. rpt., Laurel, Md., 17 p. + appendix.

USFWS (U.S. Fish and Wildlife Service), 2000, Waterfowl population status, 2000: Washington, D.C., U.S. Department of the Interior, 33 p. + appendixes.

USFWS (U.S. Fish and Wildlife Service), 2001a, Waterfowl population status, 2001: Washington, D.C., U.S. Department of the Interior, 50 p.

USFWS (U.S. Fish and Wildlife Service), 2001b, Adaptive harvest management: 2001, Hunting season: Washington, D.C., U.S. Department of the Interior, 47 p.

USFWS, KBNWR (U.S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuges), 2000, Integrated land management on Tule Lake National Wildlife Refuge: Tulelake, Calif., U.S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuges.

Weddell, B.J., 2000, Relationship between flows in the Klamath River and Lower Klamath Lake prior to 1910. Unpub. rpt. prepared for the U.S. Department of the Interior, U.S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuge, Tulelake, Calif., 10 p. + figures.

Wheeler, R.J., 1965, Pioneering of the blue-winged teal in California, Oregon, Washington and British Columbia: Murrelet, v. 46, p. 40-42.

Yarris, G.S., McLandress, M.R., and Perkins, A.E.H., 1994, Molt migration of postbreeding female mallards from Suisun Marsh, California: Condor, v. 96, p. 36-45.

Appendix 1

The following appendix lists scientific names for birds and plants mentioned in the text.

Table 1. Common and scientific names.

Common Name	Scientific Name
Birds[1]	
American white pelican	*Pelecanus erythrorhynchos*
Double-crested cormorant	*Phalacrocorax auritus*
Pacific greater white-fronted goose	*Anser albifrons frontalis*
Greater tule white-fronted goose	*Anser albifrons gambelli*
Lesser snow goose	*Chen caerulescens caerulescens*
Ross's goose	*Chen rossii*
Cackling Canada goose	*Branta canadensis minima*
Western (Great Basin) Canada goose	*Branta canadensis moffitti*
Lesser Canada goose	*Branta canadensis parvipes*
Tundra swan	*Cygnus columbianus*
Wood duck	*Aix sponsa*
Gadwall	*Anas strepera*
American wigeon	*Anas americana*
Mallard	*Anas platyrhynchos*
Blue-winged teal	*Anas discors*
Cinnamon teal	*Anas cyanoptera*
Northern shoveler	*Anas clypeata*
Northern pintail	*Anas acuta*
Green-winged teal	*Anas crecca*
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Ring-necked duck	*Aythya collaris*
Greater scaup	*Aythya marila*
Lesser scaup	*Aythya affinis*
Bufflehead	*Bucephala albeola*
Common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*Bucephala islandica*
Hooded merganser	*Lophodytes cucullatus*
Common merganser	*Mergus merganser*
Red-breasted merganser	*Mergus serrator*
Ruddy duck	*Oxyura jamaicensis*
Bald eagle	*Haliaeetus leucocephalus*
Yellow rail	*Coturnicops noveboracensis*
American coot	*Fulica americana*
Sandhill crane	*Grus canadensis*
Plants[2]	
Sierra juniper	*Juniperus occidentalis* spp.
Common sagebrush	*Artemisia tridentata* spp.

[1]Scientific names of birds are consistent with the AOU (1983) and supplements, Bellrose (1980), or the following: see McLandress (1979) for white geese (lesser snow goose and Ross's goose); see Timm and others (1982) for white-fronted geese (greater tule white-fronted goose and Pacific greater white-fronted goose); and see Mowbray and others (2002) for large Canada geese (western [Great Basin] Canada goose and lesser Canada goose).

[2]Scientific names according to Jepson (1975).

References

AOU (American Ornithologists' Union), 1983, Check-list of North American birds, 6th edition: Lawrence, Kans., Allen Press, Inc. [The 7th edition of the check-list including 42nd and 43rd supplements is available at http://www.aou.org/aou/birdlist.html]

Bellrose, F.C., 1980, Ducks, geese and swans of North America: Harrisburg, Pa., Stackpole Books, 540 p.

Jepson, W.L., 1975, A manual of the flowering plants of California: Berkeley, University of California Press, 1,238 p.

McLandress, M.R., 1979, Status of Ross' geese in California, *in* Jarvis, R.L., and Bartonek, J.C., eds., Management and Biology of Pacific Flyway Geese, a Symposium: Corvallis, Oregon State University, p. 255-265.

Mobray, T.B., Ely, C.R., Sedinger, J.S., and Trost, R.E., 2002, Canada goose (*Branta canadensis*) *in* Poole, A., and Gill, F., eds., The birds of North America, no. 682: Philadelphia, Pa., The Birds of North America, Inc.

Timm, D.E., Wege, M.L., and Gilmer, D.S., 1982, Current status and management challenges for tule white-fronted geese: Transactions of the North American Wildlife and Natural Resources Conference, v. 47, p. 453-463.

Appendix 2

The following appendix tables provide waterfowl migration activity data for the Klamath Basin National Wildlife Refuge complex and for its five waterfowl refuges: Lower Klamath, Tule Lake, Upper Klamath, Klamath Marsh, and Clear Lake.

Table 2a. Klamath Basin NWR complex waterfowl migration activity in autumn.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
Group / Species	**Abundance**	**Percent[1]**	**Percent change**	**Abundance**	**Percent**	**Percent change**	**Abundance**	**Percent**	**Percent change**	**Abundance**	**Percent**	**Percent change**
Dabbling ducks	**674,506**	**67.4**	**-3.4****	**929,951**	**67.0**	**-5.5****	**419,052**	**68.1**	**0.4**	**395,959**	**72.6**	**-10.6***
Northern pintail	422,739	42.2	-6.2**	693,141	50.0	-7.0**	152,338	24.8	-3.2**	114,355	21.0	-10.3**
Mallard	84,458	8.4	0.8*	72,102	5.2	-4.1**	96,815	15.7	2.2**	92,891	17.0	2.0
American wigeon	67,246	6.7	-1.9**	84,353	6.1	-1.0	50,139	8.2	-2.0*	36,627	6.7	-5.0
Northern shoveler	47,530	4.7	-0.2	49,491	3.6	0.9	45,567	7.4	-0.1	36,630	6.7	-5.0
Green-winged teal	31,259	3.1	7.7**	10,192	0.7	0.2	52,324	8.5	11.2**	94,579	17.3	-26.9**
Gadwall	18,737	1.9	0.8	17,426	1.3	0.2	20,046	3.3	2.9**	20,791	3.8	-4.2
Other dabblers[2]	2,537	0.3	-2.6*	3,246	0.2	1.5	1,823	0.3	-12.3**	86	0.0	-28.2
Diving ducks	**54,556**	**5.4**	**-0.4**	**57,478**	**4.1**	**-3.4****	**51,637**	**8.4**	**3.2****	**63,050**	**11.6**	**-22.4**
Ruddy duck	22,074	2.2	-1.0*	24,607	1.8	-4.0**	19,541	3.2	2.8*	24,543	4.5	-27.7**
Canvasback	12,190	1.2	0.3	11,142	0.8	-9.8**	13,238	2.2	6.3**	23,062	4.2	-17.6
Scaup	7,339	0.7	1.9**	5,580	0.4	-2.2	9,101	1.5	3.8*	6,505	1.2	-26.2*
Bufflehead	3,430	0.3	1.2	2,579	0.2	-6.0**	4,282	0.7	1.4	4,362	0.8	-25.0
Redhead	2,951	0.3	-3.4**	4,117	0.3	-3.0*	1,785	0.3	-4.4*	743	0.1	-31.4
Ring-necked duck	1,255	0.1	4.1**	675	0.0	-12.2**	1,835	0.3	10.4**	3,085	0.6	-9.4
Other divers[2]	5,317	0.5	-3.4*	8,778	0.6	6.2	1,855	0.3	-11.3**	750	0.1	37.0
Geese / Swans	**165,538**	**16.5**	**-3.2****	**238,817**	**17.2**	**0.0**	**92,255**	**15.0**	**-4.9****	**40,595**	**7.4**	**-20.1**
White-fronted geese	73,280	7.3	-3.1**	106,657	7.7	-0.3	39,905	6.5	-2.4*	20,949	3.8	-24.8
White geese	42,837	4.3	-3.3**	61,362	4.4	0.6	24,312	4.0	-9.2**	9,506	1.7	-25.5**
Cackling Canada goose	42,306	4.2	-3.7**	64,220	4.6	0.1	20,391	3.3	-6.5**	4,310	0.8	-9.6
Canada goose	5,810	0.6	0.3	5,371	0.4	-0.9	6,247	1.0	-0.2	5,456	1.0	-4.8
Tundra swan	1,305	0.1	-0.2	1,207	0.1	-2.7	1,400	0.2	-2.5	374	0.1	154.9**
American coot	**106,445**	**10.6**	**-4.7****	**160,781**	**11.6**	**-6.3****	**52,109**	**8.5**	**-1.8***	**45,882**	**8.4**	**-20.1**
Total	**1,001,045**	**100.0**	**-3.3****	**1,387,027**	**100.0**	**-4.5****	**615,053**	**100.0**	**-0.4**	**545,486**	**100.0**	**-13.6***

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers (significance shown for group). Other divers = goldeneye, merganser, and unknown divers (significance shown for group).
*Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2b. Klamath Basin NWR complex waterfowl migration activity in spring.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
Group / Species	**Abundance**	**Percent[1]**	**Percent change**	**Abundance**	**Percent**	**Percent change**	**Abundance**	**Percent**	**Percent change**	**Abundance**	**Percent**	**Percent change**
Dabbling ducks	**197,483**	**55.0**	**-0.2**	**196,559**	**53.8**	**-2.4**	**198,410**	**56.2**	**1.0**	**209,698**	**52.4**	**6.9**
Northern pintail	101,522	28.3	-2.2**	127,009	34.8	-3.9	76,033	21.5	-0.3	88,810	22.2	-1.0
Mallard	23,145	6.4	0.1	19,852	5.4	-4.4**	26,441	7.5	-1.8	20,143	5.0	26.8
American wigeon	21,975	6.1	2.4**	13,466	3.7	3.4	30,484	8.6	-2.2	21,197	5.3	-22.0**
Northern shoveler	32,327	9.0	2.2**	25,727	7.0	2.2	38,928	11.0	4.5**	49,355	12.3	30.1**
Green-winged teal	12,939	3.6	5.8**	5,340	1.5	-1.2	20,540	5.8	7.9**	23,066	5.8	11.5
Gadwall	4,536	1.3	1.5*	3,967	1.1	1.3	5,102	1.4	4.3**	7,060	1.8	-1.0
Other dabblers[2]	1,039	0.3	-1.1	1,198	0.3	5.5	882	0.2	-8.8**	67	0.0	-39.9
Diving ducks	**39,309**	**10.9**	**0.7**	**36,557**	**10.0**	**0.5**	**42,064**	**11.9**	**1.7**	**54,195**	**13.5**	**26.1**
Ruddy duck	19,028	5.3	-0.2	19,264	5.3	-1.0	18,790	5.3	0.4	23,710	5.9	40.3
Canvasback	3,310	0.9	1.9**	2,453	0.7	-2.4	4,167	1.2	3.3*	5,430	1.4	2.7
Scaup	7,505	2.1	2.1**	5,797	1.6	1.1	9,214	2.6	3.3**	11,842	3.0	20.9
Bufflehead	3,341	0.9	3.0**	2,101	0.6	-0.5	4,579	1.3	3.7**	6,134	1.5	47.5**
Redhead	1,221	0.3	-1.1	1,365	0.4	-0.5	1,079	0.3	-2.3	675	0.2	-7.6
Ring-necked duck	861	0.2	8.2**	268	0.1	-0.4	1,453	0.4	12.5**	3,179	0.8	-20.5
Other divers[2]	4,043	1.1	-1.1	5,309	1.5	8.4*	2,782	0.8	-4.3	3,225	0.8	22.6
Geese / Swans	**100,842**	**28.1**	**-0.1**	**110,193**	**30.2**	**2.1***	**91,490**	**25.9**	**1.5**	**110,052**	**27.5**	**16.0****
White-fronted geese	28,374	7.9	1.6**	25,122	6.9	0.0	31,624	9.0	6.9**	49,986	12.5	14.7
White geese	58,184	16.2	-0.8	69,515	19.0	3.9**	46,855	13.3	-1.3	48,924	12.2	24.3
Cackling Canada goose	6,232	1.7	-4.7**	9,158	2.5	-4.4	3,306	0.9	-10.5**	169	0.0	-69.4*
Canada goose	3,136	0.9	0.7	2,843	0.8	0.7	3,427	1.0	0.4	3,226	0.8	-5.7
Tundra swan	4,916	1.4	2.4**	3,555	1.0	0.4	6,278	1.8	3.9**	7,747	1.9	-8.7
American coot	**21,557**	**6.0**	**-0.1**	**21,815**	**6.0**	**-2.5**	**21,299**	**6.0**	**2.0***	**26,284**	**6.6**	**4.5**
Total	**359,191**	**100.0**	**-0.1**	**365,124**	**100.0**	**-0.8**	**353,263**	**100.0**	**1.2**	**400,229**	**100.0**	**11.6****

[1]Percent derived by dividing species abundance by total abundance.

[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.

* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2c. Lower Klamath NWR waterfowl migration activity in autumn.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

Group / Species	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
	Abundance	Percent[1]	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change
Dabbling ducks	**362,564**	**80.9**	**-1.4****	**417,253**	**79.0**	**-4.2****	**307,873**	**83.7**	**1.6***	**316,771**	**87.7**	**-12.4****
Northern pintail	213,947	47.7	-3.8**	302,645	57.3	-5.2**	125,249	34.0	-2.1	101,202	28.0	-11.5*
Mallard	48,965	10.9	2.7**	31,906	6.0	-3.6**	66,025	17.9	4.4**	73,377	20.3	12.4**
American wigeon	36,757	8.2	-1.0*	40,934	7.7	-1.8	32,579	8.9	-0.3	26,060	7.2	-5.2
Northern shoveler	28,564	6.4	0.0	28,536	5.4	-0.2	28,592	7.8	0.2	22,200	6.1	-16.1
Green-winged teal	23,262	5.2	10.4**	4,360	0.8	-1.2	42,163	11.5	12.9**	83,243	23.0	-31.3**
Gadwall	9,818	2.2	2.0**	7,430	1.4	-1.5	12,207	3.3	3.7**	10,635	2.9	-18.0
Other dabblers[2]	1,251	0.3	-1.6	1,442	0.3	3.1	1,058	0.3	-10.7**	54	0.0	-37.0
Diving ducks	**18,478**	**4.1**	**0.7**	**17,370**	**3.3**	**-1.6**	**19,585**	**5.3**	**4.0****	**18,147**	**5.0**	**-35.6****
Ruddy duck	7,336	1.6	0.1	7,187	1.4	-3.4*	7,485	2.0	3.3*	7,595	2.1	-33.2**
Canvasback	3,326	0.7	2.5**	2,355	0.4	-4.9	4,296	1.2	7.0**	4,511	1.2	-36.4
Scaup	2,145	0.5	3.3**	1,350	0.3	-2.4	2,941	0.8	6.1**	1,768	0.5	-62.2
Bufflehead	1,599	0.4	3.6**	839	0.2	-2.8	2,359	0.6	3.3*	2,210	0.6	-29.9**
Redhead	1,321	0.3	-3.0**	1,761	0.3	-3.6*	881	0.2	-2.8	350	0.1	-53.7**
Ring-necked duck	582	0.1	7.7**	173	0.0	-8.7	991	0.3	11.9**	1,648	0.5	-14.0
Other divers[2]	2,169	0.5	-3.8*	3,705	0.7	5.9	632	0.2	-13.5**	65	0.0	-13.8
Geese / Swans	**31,988**	**7.1**	**-4.0****	**46,149**	**8.7**	**-6.3****	**17,824**	**4.8**	**1.0**	**10,323**	**2.9**	**-8.2****
White-fronted geese	14,245	3.2	-3.3**	19,585	3.7	-6.2**	8,905	2.4	2.8	5,418	1.5	-16.1
White geese	2,455	0.5	-1.9	3,395	0.6	0.8	1,515	0.4	4.4	2,028	0.6	-9.6
Cackling Canada goose	11,191	2.5	-7.4**	19,304	3.7	-8.2**	3,077	0.8	-3.1	165	0.0	560.4**
Canada goose	3,336	0.7	-0.2	3,227	0.6	-2.9**	3,444	0.9	-0.4	2,472	0.7	-6.5
Tundra swan	761	0.2	0.1	638	0.1	-5.8*	883	0.2	-2.3	240	0.1	232.7**
American coot	**35,110**	**7.8**	**-3.4****	**47,452**	**9.0**	**-5.6****	**22,767**	**6.2**	**-1.6**	**16,102**	**4.5**	**-17.2***
Total	**448,140**	**100.0**	**-1.6****	**528,224**	**100.0**	**-4.4****	**368,049**	**100.0**	**1.5***	**361,343**	**100.0**	**-13.8****

[1]Percent derived by dividing species abundance by total abundance.

[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.

* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2d. Lower Klamath NWR waterfowl migration activity in spring.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

Group / Species	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
	Abundance	Percent[1]	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change
Dabbling ducks	**137,099**	**70.5**	**0.5**	**125,395**	**72.4**	**-3.2**	**148,802**	**68.9**	**2.4***	**162,014**	**60.9**	**4.4**
Northern pintail	71,707	36.9	-1.7*	83,771	48.4	-4.7*	59,642	27.6	0.4	68,181	25.6	-3.4
Mallard	12,944	6.7	1.2*	9,858	5.7	-5.9**	16,030	7.4	1.9	16,779	6.3	39.7
American wigeon	14,117	7.3	3.1**	7,908	4.6	3.1	20,325	9.4	0.1	16,251	6.1	-10.4
Northern shoveler	24,901	12.8	2.6**	18,531	10.7	1.9	31,271	14.5	5.0**	37,188	14.0	9.9
Green-winged teal	10,184	5.2	6.9**	3,237	1.9	-3.1	17,131	7.9	8.5**	17,934	6.7	17.3
Gadwall	2,715	1.4	4.1**	1,605	0.9	2.4	3,824	1.8	6.7**	5,628	2.1	-12.4
Other dabblers[2]	531	0.3	0.2	485	0.3	4.6	579	0.3	-6.7	53	0.0	-41.2
Diving ducks	**15,381**	**7.9**	**2.7****	**11,119**	**6.4**	**-0.6**	**19,641**	**9.1**	**6.1****	**30,649**	**11.5**	**3.5**
Ruddy duck	7,163	3.7	1.5*	5,729	3.3	-2.9	8,596	4.0	3.7*	10,950	4.1	-7.5
Canvasback	1,132	0.6	6.5**	544	0.3	0.3	1,719	0.8	14.9**	4,261	1.6	17.6
Scaup	2,887	1.5	5.0**	1,456	0.8	-1.7	4,317	2.0	8.8**	7,527	2.8	-0.7
Bufflehead	1,819	0.9	6.1**	728	0.4	-0.2	2,909	1.3	8.5**	4,762	1.8	59.8**
Redhead	609	0.3	-0.1	609	0.4	-3.7	610	0.3	2.6	547	0.2	-16.6
Ring-necked duck	382	0.2	15.3**	40	0.0	0.5	725	0.3	19.0**	2,045	0.8	-33.3**
Other divers[2]	1,389	0.7	-2.1	2,013	1.2	8.2*	765	0.4	-9.9*	557	0.2	4.5
Geese / Swans	**29,490**	**15.2**	**1.6****	**24,704**	**14.3**	**-2.3**	**34,277**	**15.9**	**6.2****	**54,507**	**20.5**	**2.9**
White-fronted geese	10,031	5.2	4.7**	5,166	3.0	-2.8	14,895	6.9	8.2**	25,487	9.6	20.0
White geese	11,470	5.9	1.3	10,729	6.2	0.4	12,212	5.7	6.7**	20,899	7.9	-10.7
Cackling Canada goose	3,273	1.7	-7.0**	5,375	3.1	-9.4**	1,172	0.5	-5.3	66	0.0	-72.1**
Canada goose	1,609	0.8	0.8	1,437	0.8	-1.2	1,781	0.8	1.7	1,698	0.6	-13.9
Tundra swan	3,107	1.6	3.2**	1,997	1.2	1.2	4,217	2.0	4.1**	6,357	2.4	-5.9
American coot	**12,542**	**6.4**	**0.5**	**11,902**	**6.9**	**-3.3**	**13,182**	**6.1**	**4.1****	**18,647**	**7.0**	**-3.9**
Total	**194,512**	**100.0**	**0.8**	**173,120**	**100.0**	**-2.9**	**215,902**	**100.0**	**3.4****	**265,817**	**100.0**	**3.4**

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.
*Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2e. Tule Lake NWR waterfowl migration activity in autumn.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

Group / Species	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
	Abundance	Percent[1]	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change
Dabbling ducks	**280,440**	**55.4**	**-7.2****	**484,627**	**59.5**	**-7.2****	**76,251**	**38.6**	**-4.8****	**60,616**	**39.7**	**3.7**
Northern pintail	199,388	39.4	-10.3**	381,458	46.8	-8.7**	17,319	8.8	-12.9**	9,688	6.3	15.0
Mallard	31,249	6.2	-2.4**	37,394	4.6	-5.2**	25,104	12.7	-3.5**	15,427	10.1	-25.9**
American wigeon	27,213	5.4	-3.8**	40,700	5.0	-0.6	13,726	7.0	-7.4**	8,204	5.4	7.0
Northern shoveler	12,860	2.5	-1.1*	15,095	1.9	0.2	10,625	5.4	-0.6	12,571	8.2	17.0
Green-winged teal	3,385	0.7	1.9**	2,798	0.3	-0.6	3,971	2.0	6.0**	6,944	4.5	33.0
Gadwall	5,372	1.1	-0.0	5,674	0.7	-0.8	5,070	2.6	3.9**	7,763	5.1	12.9
Other dabblers[2]	973	0.2	-4.6**	1,508	0.2	-1.0	436	0.2	-14.8**	19	0.0	-9.5
Diving ducks	**30,680**	**6.1**	**-1.5****	**35,650**	**4.4**	**-5.4****	**25,712**	**13.0**	**3.3****	**37,641**	**24.6**	**-17.7**
Ruddy duck	12,698	2.5	-1.8**	15,380	1.9	-5.0**	10,016	5.1	3.0*	14,170	9.3	-24.3
Canvasback	8,638	1.7	-0.6	8,590	1.1	-12.0**	8,687	4.4	6.1**	17,719	11.6	-16.3
Scaup	3,514	0.7	0.1	3,415	0.4	-4.1**	3,613	1.8	3.6	2,572	1.7	-8.6
Bufflehead	1,356	0.3	-2.1*	1,457	0.2	-11.1**	1,255	0.6	-1.6	1,243	0.8	-14.9
Redhead	1,374	0.3	-4.7**	2,104	0.3	-3.6**	644	0.3	-6.6**	266	0.2	5.2
Ring-necked duck	498	0.1	-0.0	478	0.1	-15.3**	518	0.3	12.2**	1,086	0.7	-4.2
Other divers[2]	2,602	0.5	-3.2*	4,226	0.5	6.3	979	0.5	-10.1**	585	0.4	46.0**
Geese / Swans	**130,862**	**25.9**	**-3.0****	**189,411**	**23.2**	**1.6**	**72,313**	**36.6**	**-6.5****	**29,220**	**19.1**	**-24.2**
White-fronted geese	58,770	11.6	-3.1**	86,787	10.7	1.1	30,753	15.6	-4.0**	15,446	10.1	-27.2
White geese	40,251	8.0	-3.4**	57,713	7.1	0.6	22,789	11.5	-10.3**	7,478	4.9	-29.5
Cackling Canada goose	30,327	6.0	-2.5**	43,372	5.3	4.2*	17,283	8.8	-7.2**	4,145	2.7	-14.3
Canada goose	1,069	0.2	0.7	1,055	0.1	0.9	1,083	0.5	4.0**	2,042	1.3	-2.0
Tundra swan	445	0.1	-0.7	484	0.1	0.7	405	0.2	-2.5	109	0.1	140.7
American coot	**64,129**	**12.7**	**-6.2****	**105,164**	**12.9**	**-7.4****	**23,094**	**11.7**	**-2.0**	**25,252**	**16.5**	**-22.8**
Total	**506,111**	**100.0**	**-5.4****	**814,852**	**100.0**	**-5.0****	**197,370**	**100.0**	**-4.0****	**152,729**	**100.0**	**-12.0**

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.
* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2f. Tule Lake NWR waterfowl migration activity in spring.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

Group / Species	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
	Abundance	Percent[1]	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change
Dabbling ducks	**47,247**	**34.2**	**-2.4****	**58,660**	**34.6**	**-2.1**	**35,833**	**33.5**	**-6.0****	**37,768**	**34.3**	**21.3**
Northern pintail	23,774	17.2	-5.2**	37,937	22.4	-3.4	9,610	9.0	-9.2**	14,007	12.7	6.6
Mallard	8,534	6.2	-1.1	7,930	4.7	-4.5*	9,139	8.5	-8.0**	2,883	2.6	-15.7
American wigeon	6,031	4.4	0.9	4,047	2.4	5.0	8,016	7.5	-9.7**	4,024	3.7	-56.0
Northern shoveler	6,098	4.4	0.8	5,874	3.5	2.0	6,322	5.9	2.4	11,161	10.1	149.0
Green-winged teal	1,538	1.1	1.5	1,365	0.8	1.6	1,711	1.6	4.2	4,456	4.0	0.8
Gadwall	937	0.7	0.1	1,004	0.6	6.1*	870	0.8	-1.9	1,229	1.1	101.0*
Other dabblers[2]	335	0.2	-3.3*	503	0.3	4.0	165	0.2	-13.3**	8	0.0	-57.1
Diving ducks	**18,220**	**13.2**	**-1.1**	**20,392**	**12.0**	**-0.9**	**16,048**	**15.0**	**-2.3**	**17,034**	**15.5**	**104.7***
Ruddy duck	10,087	7.3	-1.6*	12,075	7.1	-1.0	8,099	7.6	-2.1	9,843	8.9	183.0**
Canvasback	1,832	1.3	-0.3	1,571	0.9	-6.5*	2,092	2.0	-3.4	981	0.9	-35.9*
Scaup	2,949	2.1	-0.8	3,201	1.9	-0.5	2,698	2.5	-1.4	2,670	2.4	140.0*
Bufflehead	842	0.6	-1.5	868	0.5	-5.4	816	0.8	-4.7**	459	0.4	25.4
Redhead	443	0.3	-3.1*	600	0.4	0.7	286	0.3	-12.8**	92	0.1	226.5
Ring-necked duck	181	0.1	2.2	123	0.1	-11.9*	238	0.2	7.0**	347	0.3	5.4
Other divers[2]	1,886	1.4	0.3	1,954	1.2	5.9	1,819	1.7	-1.7	2,642	2.4	28.4
Geese / Swans	**66,510**	**48.1**	**-1.2***	**82,626**	**48.8**	**3.7****	**50,392**	**47.1**	**-2.2**	**50,712**	**46.0**	**34.4**
White-fronted geese	15,907	11.5	-0.8	19,298	11.4	0.8	12,516	11.7	4.7**	21,324	19.3	9.2
White geese	46,514	33.7	-1.2*	58,391	34.5	4.8**	34,637	32.4	-3.9**	28,021	25.4	61.3
Cackling Canada goose	2,455	1.8	-1.7	2,901	1.7	4.8	2,009	1.9	-13.6**	103	0.1	-67.7
Canada goose	591	0.4	-1.1*	720	0.4	1.5	461	0.4	0.2	649	0.6	0.7
Tundra swan	1,043	0.8	-2.6*	1,316	0.8	-2.7	769	0.7	-4.8	615	0.6	12.2
American coot	**6,157**	**4.5**	**-2.1****	**7,630**	**4.5**	**-3.4**	**4,683**	**4.4**	**-0.4**	**4,718**	**4.3**	**27.5****
Total	**138,134**	**100.0**	**-1.6****	**169,308**	**100.0**	**0.7**	**106,956**	**100.0**	**-3.4****	**110,232**	**100.0**	**37.3**

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.
* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2g. Upper Klamath NWR waterfowl migration activity in autumn.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

Group / Species	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
	Abundance	Percent[1]	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change[3]
Dabbling ducks	**24,881**	**68.4**	**2.1****	**19,658**	**64.1**	**6.3****	**30,103**	**71.6**	**0.7**	**14,874**	**56.9**	**-20.1**
Northern pintail	7,343	20.2	0.7	6,179	20.1	2.0	8,507	20.2	-1.8	2,731	10.4	-31.6
Mallard	3,101	8.5	4.8**	1,435	4.7	8.5**	4,768	11.3	3.7	3,254	12.4	-42.7**
American wigeon	2,287	6.3	3.6**	1,397	4.6	10.1**	3,178	7.6	2.9	1,903	7.3	-37.3
Northern shoveler	5,746	15.8	0.7	5,454	17.8	7.6**	6,037	14.4	-1.1	1,555	5.9	13.7
Green-winged teal	3,471	9.5	4.3**	1,800	5.9	3.4	5,141	12.2	4.9	3,468	13.3	-9.0
Gadwall	2,723	7.5	-0.8	3,192	10.4	5.7	2,253	5.4	-2.2	1,962	7.5	23.6
Other dabblers[2]	210	0.6	-1.1	201	0.7	5.7	219	0.5	-15.5**	1	0.0	0.0
Diving ducks	**4,625**	**12.7**	**1.8***	**3,858**	**12.6**	**4.3**	**5,392**	**12.8**	**1.8**	**6,749**	**25.8**	**-12.2**
Ruddy duck	1,801	5.0	-0.4	1,858	6.1	-0.0	1,744	4.1	1.0	2,532	9.7	-35.2**
Canvasback	205	0.6	2.8	166	0.5	18.1**	244	0.6	2.5	831	3.2	147.8
Scaup	1,509	4.1	4.2**	742	2.4	5.1	2,276	5.4	3.0	2,112	8.1	-9.3
Bufflehead	384	1.1	3.7**	228	0.7	8.6**	540	1.3	2.9	808	3.1	-27.5
Redhead	202	0.6	0.1	206	0.7	7.4*	198	0.5	-3.4	102	0.4	-19.4
Ring-necked duck	138	0.4	9.9**	5	0.0	22.3**	270	0.6	5.3	300	1.1	-5.7
Other divers[2]	386	1.1	-4.1*	653	2.1	5.4	120	0.3	-14.3**	64	0.2	40.3
Geese / Swans	**618**	**1.7**	**3.7****	**313**	**1.0**	**3.3**	**922**	**2.2**	**0.8**	**513**	**2.0**	**-22.6****
White-fronted geese	85	0.2	6.4**	20	0.1	-6.8	151	0.4	4.6	19	0.1	-97.0**
White geese	1	0.0	-2.5	1	0.0	3.4	1	0.0	-3.1	0	0.0	
Cackling Canada goose	18	0.0	-2.6	26	0.1	-0.8	10	0.0	7.8	0	0.0	
Canada goose	454	1.2	4.0**	199	0.6	4.4*	708	1.7	0.9	473	1.8	-17.9**
Tundra swan	60	0.2	-2.4	67	0.2	0.2	52	0.1	-12.8**	21	0.1	-38.4
American coot	**6,245**	**17.2**	**-0.7**	**6,849**	**22.3**	**2.3**	**5,641**	**13.4**	**-1.0**	**4,005**	**15.3**	**-14.9**
Total	**36,369**	**100.0**	**1.6***	**30,678**	**100.0**	**5.3***	**42,058**	**100.0**	**0.6**	**26,141**	**100.0**	**-17.4**

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.
[3]Blank values indicate there were insufficient data to calculate percent change.
* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2h. Upper Klamath NWR waterfowl migration activity in spring.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
Group / Species	**Abundance**	**Percent[1]**	**Percent change**	**Abundance**	**Percent**	**Percent change**	**Abundance**	**Percent**	**Percent change**	**Abundance**	**Percent**	**Percent change[3]**
Dabbling ducks	**3,911**	**32.7**	**-0.7**	**4,884**	**43.2**	**11.3****	**2,941**	**23.3**	**-6.7****	**820**	**9.9**	**-43.9**
Northern pintail	1,388	11.6	-1.7	2,092	18.5	16.3**	685	5.4	-9.4**	133	1.6	-20.4
Mallard	628	5.3	-1.3	722	6.4	6.9	535	4.2	-10.5**	183	2.2	-34.8
American wigeon	473	4.0	0.6	404	3.6	7.4*	542	4.3	-5.4	48	0.6	-85.3**
Northern shoveler	771	6.4	-1.3	969	8.6	6.4	573	4.5	-3.6	115	1.4	-83.2**
Green-winged teal	259	2.2	2.3*	170	1.5	8.8**	349	2.8	-1.8	225	2.7	-8.8
Gadwall	285	2.4	-2.7	394	3.5	2.9	175	1.4	-6.4**	116	1.4	-74.6**
Other dabblers[2]	107	0.9	-1.5	133	1.2	12.5**	82	0.6	-16.7**	0	0.0	0.0
Diving ducks	**4,367**	**36.5**	**1.7***	**3,795**	**33.6**	**9.8****	**4,942**	**39.2**	**-0.7**	**5,389**	**64.9**	**-1.7**
Ruddy duck	1,546	12.9	0.9	1,322	11.7	5.5	1,771	14.0	-2.0	2,816	33.9	0.1
Canvasback	320	2.7	1.3	311	2.8	13.2**	330	2.6	0.4	169	2.0	-52.7*
Scaup	1,283	10.7	2.6**	869	7.7	10.2**	1,697	13.4	-0.0	1,241	14.9	5.8
Bufflehead	478	4.0	1.7	357	3.2	6.3*	599	4.7	-1.5	638	7.7	21.9
Redhead	96	0.8	1.3	84	0.7	8.7*	108	0.9	-1.2	36	0.4	-83.0**
Ring-necked duck	200	1.7	7.2**	67	0.6	14.8**	332	2.6	7.2**	480	5.8	-22.8
Other divers[2]	444	3.7	-3.2	785	6.9	11.7*	105	0.8	-12.2**	9	0.1	-79.5**
Geese / Swans	**1,538**	**12.9**	**3.2****	**925**	**8.2**	**2.6**	**2,150**	**17.0**	**2.2**	**628**	**7.6**	**-6.4**
White-fronted geese	836	7.0	6.9**	211	1.9	7.9	1,460	11.6	4.6	206	2.5	-19.5
White geese	13	0.1	-6.1*	26	0.2	3.4	0	0.0	-3.1	0	0.0	
Cackling Canada goose	234	2.0	-8.1*	426	3.8	-5.1	42	0.3	-24.2*	0	0.0	
Canada goose	272	2.3	3.4**	132	1.2	6.2**	412	3.3	-0.9	282	3.4	2.2
Tundra swan	183	1.5	2.1	130	1.2	13.1**	236	1.9	-2.9	140	1.7	-2.2
American coot	**2,139**	**17.9**	**0.9**	**1,694**	**15.0**	**2.0**	**2,585**	**20.5**	**-2.4**	**1,467**	**17.7**	**-29.5****
Total	**11,955**	**100.0**	**1.0**	**11,298**	**100.0**	**8.6****	**12,618**	**100.0**	**-1.9**	**8,304**	**100.0**	**-12.3**

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.
[3]Blank values indicate there were insufficient data to calculate percent change.
* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2i. Klamath Marsh NWR waterfowl migration activity in autumn.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

Group / Species	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
	Abundance	Percent[1]	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change[3]
Dabbling ducks	**4,479**	**76.4**	**-1.7**	**5,663**	**83.7**	**1.3**	**3,289**	**66.3**	**-2.1**	**3,410**	**74.6**	**-32.3****
Northern pintail	1,254	21.4	-7.1**	1,735	25.6	-13.7*	773	15.6	-7.4	635	13.9	-40.6**
Mallard	766	13.1	-3.9**	891	13.2	-11.9*	640	12.9	-1.6	757	16.6	-41.7
American wigeon	668	11.4	-6.5**	932	13.8	-11.4	404	8.1	-5.1	445	9.7	-31.2
Northern shoveler	245	4.2	0.4	242	3.6	18.7**	247	5.0	1.5	289	6.3	-41.8**
Green-winged teal	881	15.0	-2.4	946	14.0	-13.5**	816	16.5	4.3	876	19.2	-17.6**
Gadwall	589	10.0	-8.0**	843	12.5	-20.1*	334	6.7	-4.2	396	8.7	-24.2
Other dabblers[2]	76	1.3	-2.6	74	1.1	1.9	75	1.5	-9.1	12	0.3	-15.7
Diving ducks	**505**	**8.6**	**2.7**	**237**	**3.5**	**13.4****	**774**	**15.6**	**-7.3**	**442**	**9.7**	**22.1**
Ruddy duck	161	2.7	2.4	66	1.0	5.1	255	5.1	-3.2	246	5.4	74.9
Canvasback	8	0.1	-1.8	6	0.1	14.9	10	0.2	-17.3*	1	0.0	-95.3**
Scaup	133	2.3	1.9	24	0.4	9.9	243	4.9	-10.4	22	0.5	-62.7
Bufflehead	68	1.2	1.2	26	0.4	11.3*	110	2.2	-9.0	100	2.2	-11.6*
Redhead	44	0.8	-0.8	27	0.4	-2.9	62	1.3	-10.0	25	0.5	-57.6
Ring-necked duck	29	0.5	5.7**	4	0.1	8.9	55	1.1	-0.4	46	1.0	19.7
Other divers[2]	62	1.1	-4.4	84	1.2	12.3	39	0.8	-19.0**	2	0.0	69.3
Geese / Swans	**295**	**5.0**	**1.7**	**213**	**3.1**	**3.9**	**380**	**7.7**	**-2.6**	**216**	**4.7**	**-54.4****
White-fronted geese	57	1.0	2.2	22	0.3	-8.2	93	1.9	-3.2	66	1.4	-84.1**
White geese	1	0.0	-7.1**	2	0.0	-8.5	1	0.0	-37.3**	0	0.0	
Cackling Canada goose	5	0.1	-9.3**	7	0.1	-22.6*	3	0.1	-18.8*	0	0.0	
Canada goose	213	3.6	-1.1	178	2.6	-6.5*	249	5.0	-3.0	149	3.3	-39.4*
Tundra swan	19	0.3	6.9**	4	0.1	8.5	34	0.7	4.2	1	0.0	-57.2*
American coot	**585**	**10.0**	**-2.5**	**654**	**9.7**	**7.3**	**516**	**10.4**	**-6.7***	**503**	**11.0**	**-17.2**
Total	**5,864**	**100.0**	**-1.0**	**6,767**	**100.0**	**2.6**	**4,959**	**100.0**	**-3.4**	**4,571**	**100.0**	**-27.7****

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.
[3]Blank values indicate there were insufficient data to calculate percent change.
* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2j. Klamath Marsh NWR waterfowl migration activity in spring.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
Group / Species	**Abundance**	**Percent[1]**	**Percent change**	**Abundance**	**Percent**	**Percent change**	**Abundance**	**Percent**	**Percent change**	**Abundance**	**Percent**	**Percent change[3]**
Dabbling ducks	**6,939**	**62.3**	**2.0**	**5,663**	**73.2**	**-1.1**	**8,216**	**56.5**	**6.3***	**8,184**	**55.4**	**-3.7**
Northern pintail	3,376	30.3	2.3	2,225	28.7	-13.7*	4,527	31.1	8.4**	6,187	41.9	12.9
Mallard	808	7.3	-6.3**	1,047	13.5	-17.9**	569	3.9	-4.7	279	1.9	-50.9**
American wigeon	1,004	9.0	-0.8	831	10.7	-24.0*	1,177	8.1	3.2	735	5.0	-41.2**
Northern shoveler	432	3.9	5.5**	212	2.7	4.9	653	4.5	10.2*	442	3.0	-30.2
Green-winged teal	744	6.7	3.8*	373	4.8	-17.6**	1,115	7.7	8.1*	450	3.0	-59.0
Gadwall	522	4.7	-18.5**	910	11.8	-46.8**	133	0.9	-4.0	85	0.6	6.7
Other dabblers[2]	53	0.5	-3.3*	65	0.8	5.6	42	0.3	-7.1	6	0.0	0.0
Diving ducks	**1,100**	**9.9**	**1.6**	**945**	**12.2**	**13.0****	**1,257**	**8.6**	**-3.0**	**1,080**	**7.3**	**23.4**
Ruddy duck	207	1.9	1.8	96	1.2	12.1*	317	2.2	-5.1	101	0.7	-0.8
Canvasback	16	0.1	-1.1	14	0.2	14.6*	18	0.1	-9.1	19	0.1	-20.7
Scaup	299	2.7	0.8	200	2.6	3.7	398	2.7	-2.4	391	2.6	39.6
Bufflehead	188	1.7	0.4	126	1.6	2.9	250	1.7	-4.1	274	1.9	-19.8
Redhead	66	0.6	-2.0	60	0.8	0.2	73	0.5	-8.1	0	0.0	-61.3
Ring-necked duck	85	0.8	10.1**	15	0.2	18.7*	155	1.1	10.3**	292	2.0	82.1**
Other divers[2]	239	2.1	-7.0**	434	5.6	10.1	46	0.3	-26.5**	3	0.0	-58.3
Geese / Swans	**2,429**	**21.8**	**9.1****	**618**	**8.0**	**9.3****	**4,238**	**29.1**	**10.4****	**4,067**	**27.5**	**1.6**
White-fronted geese	1,502	13.5	10.7**	254	3.3	-1.0	2,749	18.9	12.4**	2,967	20.1	13.8
White geese	4	0.0	-4.4	3	0.0	-3.1	5	0.0	-57.0**	1	0.0	
Cackling Canada goose	66	0.6	-1.4	54	0.7	35.4*	77	0.5	-18.0*	0	0.0	
Canada goose	371	3.3	0.9	256	3.3	-1.1	485	3.3	-0.3	489	3.3	12.1
Tundra swan	486	4.4	14.1**	51	0.7	13.3	922	6.3	15.4**	610	4.1	-48.0
American coot	**671**	**6.0**	**0.6**	**514**	**6.6**	**5.4**	**829**	**5.7**	**-1.0**	**1,452**	**9.8**	**174.7**
Total	**11,139**	**100.0**	**3.1****	**7,740**	**100.0**	**1.8**	**14,540**	**100.0**	**6.0***	**14,783**	**100.0**	**8.7**

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.
[3]Blank values indicate there were insufficient data to calculate percent change.
* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2k. Clear Lake NWR waterfowl migration activity in autumn.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

Group / Species	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
	Abundance	Percent[1]	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change[3]
Dabbling ducks	**2,142**	**47.0**	**-1.2**	**2,750**	**42.3**	**2.4**	**1,536**	**58.7**	**2.4**	**288**	**41.0**	**-68.3***
Northern pintail	807	17.7	-2.3	1,124	17.3	0.8	490	18.7	3.3	99	14.1	-60.8
Mallard	377	8.3	-1.6	476	7.3	3.0	278	10.6	-2.1	76	10.8	-45.1
American wigeon	321	7.0	-0.8	390	6.0	1.7	252	9.6	4.5	15	2.1	-42.1
Northern shoveler	115	2.5	-2.6	164	2.5	2.4	66	2.5	-2.1	15	2.1	-85.4
Green-winged teal	260	5.7	0.3	288	4.4	1.3	233	8.9	8.7	48	6.8	-97.1
Gadwall	235	5.2	-1.2	287	4.4	0.1	182	7.0	3.0	35	5.0	
Other dabblers[2]	27	0.6	-0.5	21	0.3	9.7*	35	1.3	-23.0**	0	0.0	
Diving ducks	**268**	**5.9**	**-1.9**	**363**	**5.6**	**6.4**	**174**	**6.6**	**-8.4****	**71**	**10.1**	**2.5**
Ruddy duck	78	1.7	-2.7	116	1.8	9.0	41	1.6	-15.4**	0	0.0	
Canvasback	13	0.3	-4.9	25	0.4	7.4	1	0.0	-17.5*	0	0.0	
Scaup	38	0.8	-1.8	49	0.8	5.7	28	1.1	-7.4	31	4.4	-0.6
Bufflehead	23	0.5	-3.7*	29	0.4	-2.3	18	0.7	-18.7**	1	0.1	0.7
Redhead	10	0.2	-9.3**	19	0.3	-4.6	0	0.0	-53.2**	0	0.0	
Ring-necked duck	8	0.2	-3.9	15	0.2	6.7	1	0.0	22.2*	5	0.7	-24.9
Other divers[2]	98	2.1	-0.7	110	1.7	6.2	85	3.2	-4.7	34	4.8	10.1
Geese / Swans	**1,775**	**38.9**	**-5.3****	**2,731**	**42.0**	**-6.5***	**816**	**31.2**	**-5.6****	**323**	**46.0**	**35.7****
White-fronted geese	123	2.7	-14.1**	243	3.7	-12.7**	3	0.1	-44.8**	0	0.0	
White geese	129	2.8	-26.0**	251	3.9	-31.6**	6	0.2	-11.0	0	0.0	
Cackling Canada goose	765	16.8	-12.8**	1,511	23.2	-10.7*	18	0.7	-16.4**	0	0.0	
Canada goose	738	16.2	-0.5	712	10.9	1.5	763	29.2	-5.5**	320	45.6	37.0**
Tundra swan	20	0.4	1.8	14	0.2	-1.6	26	1.0	0.5	3	0.4	-43.6
American coot	**376**	**8.2**	**-5.5****	**662**	**10.2**	**1.3**	**91**	**3.5**	**-15.2****	**20**	**2.8**	**0.0**
Total	**4,561**	**100.0**	**-3.0****	**6,506**	**100.0**	**-1.1**	**2,617**	**100.0**	**-1.3**	**702**	**100.0**	**-22.3**

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.
[3]Blank values indicate there were insufficient data to calculate percent change.
* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Table 2I. Clear Lake NWR waterfowl migration activity in spring.

[Waterfowl abundance (average birds per day), species composition (percent), and rate of population change (percent per year) for the long-term period (1953-2001), early period (1953-76), recent period (1977-2001), and most recent period (1998-2001). Closely related species were tallied as "groups," such as white-fronted geese; see Identifying and Counting Waterfowl, p. 6]

Group / Species	Long-term (1953-2001)			Early (1953-76)			Recent (1977-2001)			Most recent (1998-2001)		
	Abundance	Percent[1]	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change	Abundance	Percent	Percent change[3]
Dabbling ducks	**2,287**	**66.3**	**2.4**	**1,957**	**53.5**	**5.0**	**2,618**	**80.6**	**7.2**	**912**	**83.4**	**81.1***
Northern pintail	1,277	37.0	2.8	984	26.9	4.5	1,569	48.3	6.7	302	27.6	-26.5
Mallard	231	6.7	-1.5	295	8.1	3.9	168	5.2	-1.5	19	1.7	-54.4
American wigeon	350	10.1	3.3	276	7.5	2.9	424	13.1	12.8	139	12.7	-21.3
Northern shoveler	125	3.6	1.8	141	3.9	13.0*	109	3.4	13.2*	449	41.1	3898.9
Green-winged teal	214	6.2	1.6	195	5.3	-1.1	234	7.2	10.0	1	0.1	
Gadwall	77	2.2	3.4	54	1.5	7.9*	100	3.1	5.4	2	0.2	
Other dabblers[2]	13	0.4	-1.7	12	0.3	3.6	14	0.4	-24.9**	0	0.0	
Diving ducks	**241**	**7.0**	**-0.2**	**306**	**8.4**	**6.5***	**176**	**5.4**	**6.4**	**43**	**3.9**	**56.1**
Ruddy duck	25	0.7	-2.8	42	1.1	11.4*	7	0.2	-2.8	0	0.0	
Canvasback	10	0.3	-0.1	13	0.4	5.7	8	0.2	12.9	0	0.0	
Scaup	87	2.5	2.6	71	1.9	3.3	104	3.2	7.8	13	1.2	78.9
Bufflehead	14	0.4	-2.1	22	0.6	14.6**	5	0.2	-6.5	1	0.1	6986.2
Redhead	7	0.2	-7.8**	12	0.3	-8.9	2	0.1	-9.7	0	0.0	
Ring-necked duck	13	0.4	-3.1	23	0.6	7.0	3	0.1	28.4**	15	1.4	
Other divers[2]	85	2.5	-1.6	123	3.4	5.8	47	1.4	5.6	14	1.3	-64.5
Geese / Swans	**875**	**25.4**	**-6.1****	**1,320**	**36.1**	**-12.6****	**433**	**13.3**	**-3.1**	**138**	**12.6**	**-8.5**
White-fronted geese	98	2.8	-27.1**	193	5.3	-33.0**	4	0.1	-0.5	2	0.2	
White geese	183	5.3		366	10.0	-72.2**	1	0.0	-12.3	3	0.3	
Cackling Canada goose	204	5.9	-16.0**	402	11.0	-15.5**	6	0.2	-54.8**	0	0.0	
Canada goose	293	8.5	-1.0	298	8.1	-1.2	288	8.9	-4.6**	108	9.9	-3.8
Tundra swan	97	2.8	3.2	61	1.7	8.9	134	4.1	0.9	25	2.3	-49.5
American coot	**48**	**1.4**	**-2.9**	**75**	**2.1**	**12.0****	**20**	**0.6**	**-24.7****	**0**	**0.0**	**0.0**
Total	**3,451**	**100.0**	**0.1**	**3,658**	**100.0**	**-0.9**	**3,247**	**100.0**	**5.5**	**1,093**	**100.0**	**63.7****

[1]Percent derived by dividing species abundance by total abundance.
[2]Other dabblers = wood duck, cinnamon teal, blue-winged teal, and unknown dabblers. Other divers = goldeneyes, mergansers, and unknown divers.
[3]Blank values indicate there were insufficient data to calculate percent change.
* Significant at 0.05 significance level; ** significant at 0.01 significance level.

Appendix 3

The following appendix figures show population changes for waterfowl species in the Klamath Basin NWR complex for 1953-2001 (long-term period).

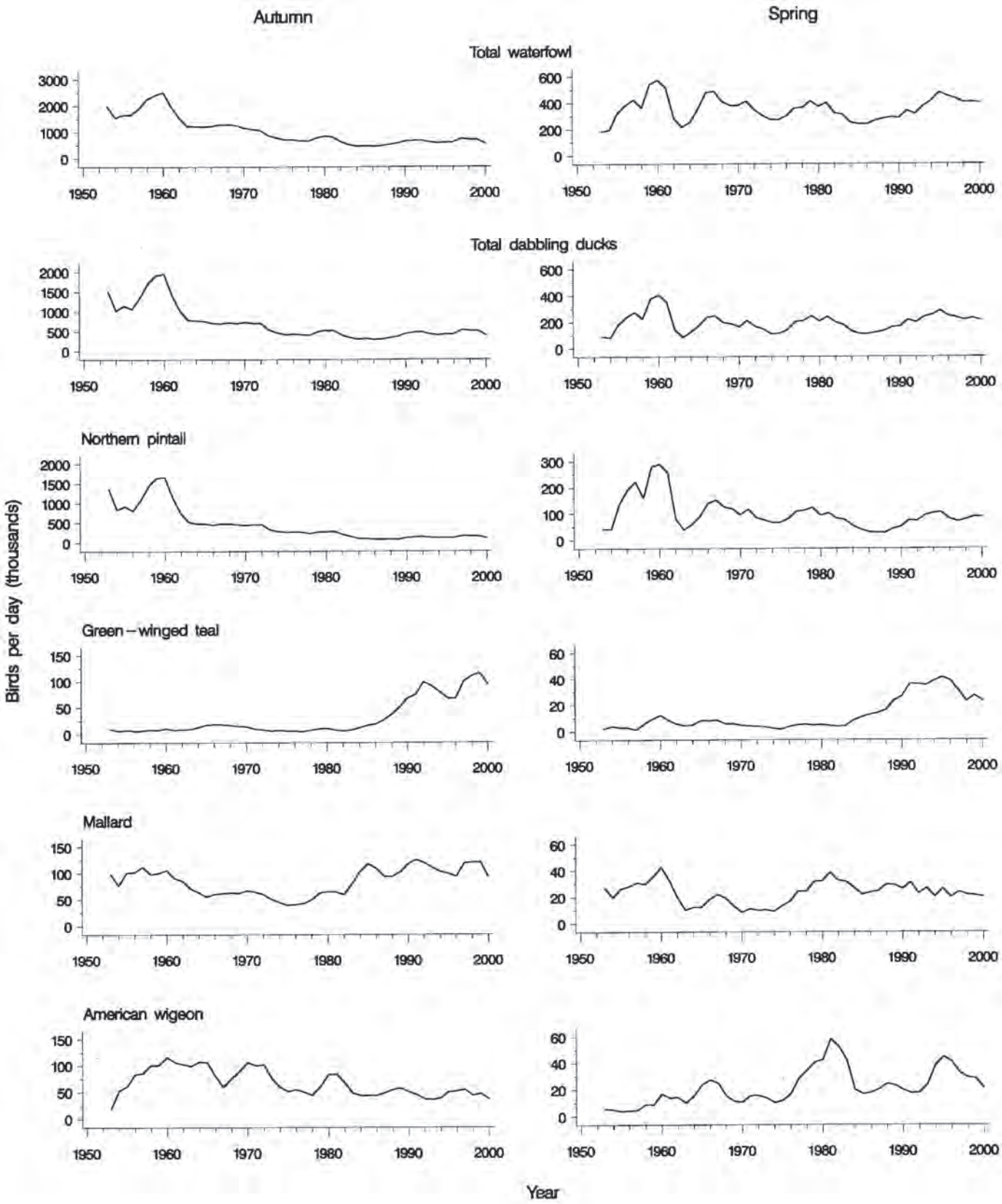
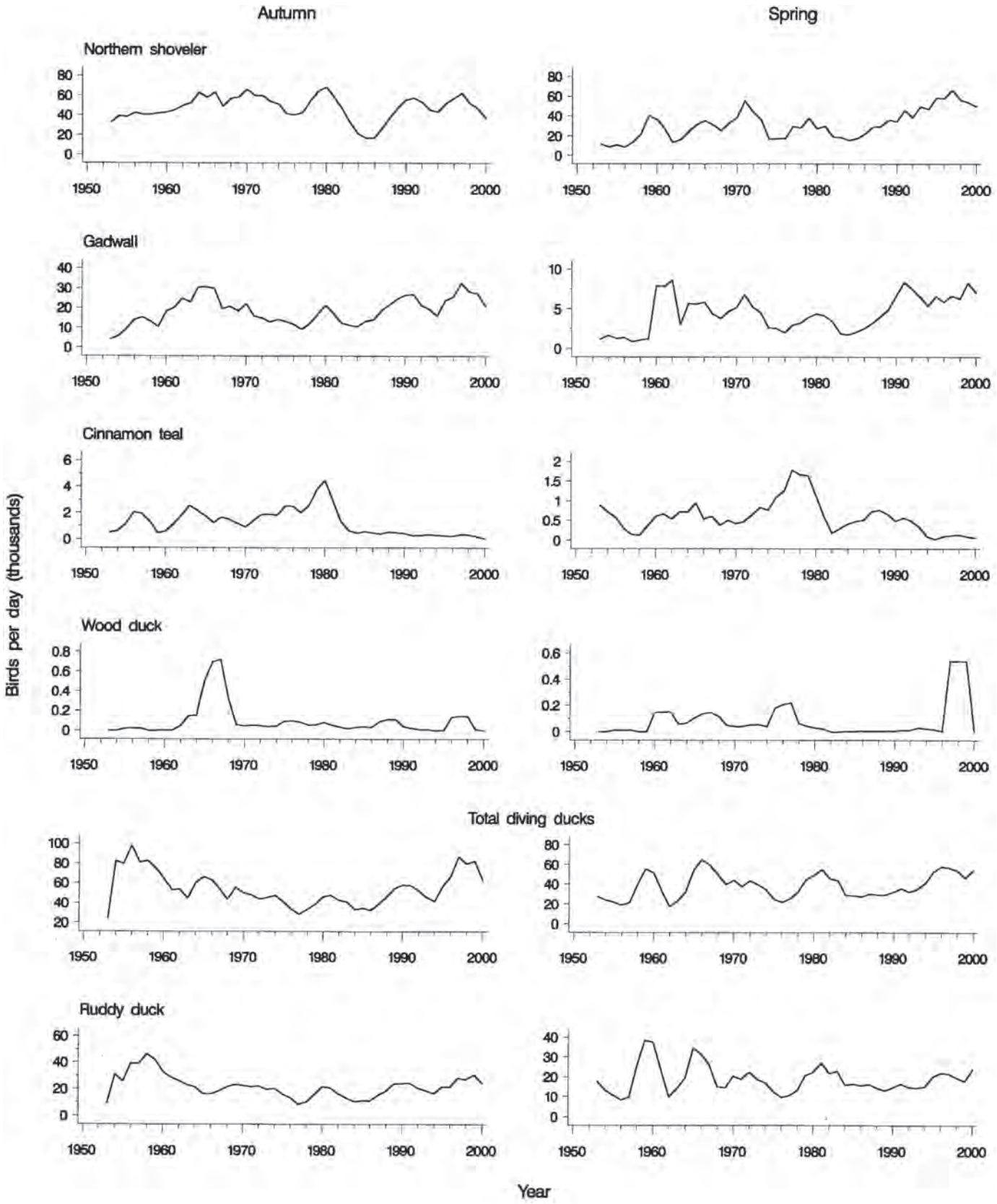


Figure 3a. Three-year running average of waterfowl counts (birds per day, thousands) for waterfowl groups and species on the Klamath Basin NWR complex during autumn and spring 1953-2001. Closely related species were tallied as "groups." For an explanation, see Identifying and Counting Waterfowl, p. 6.



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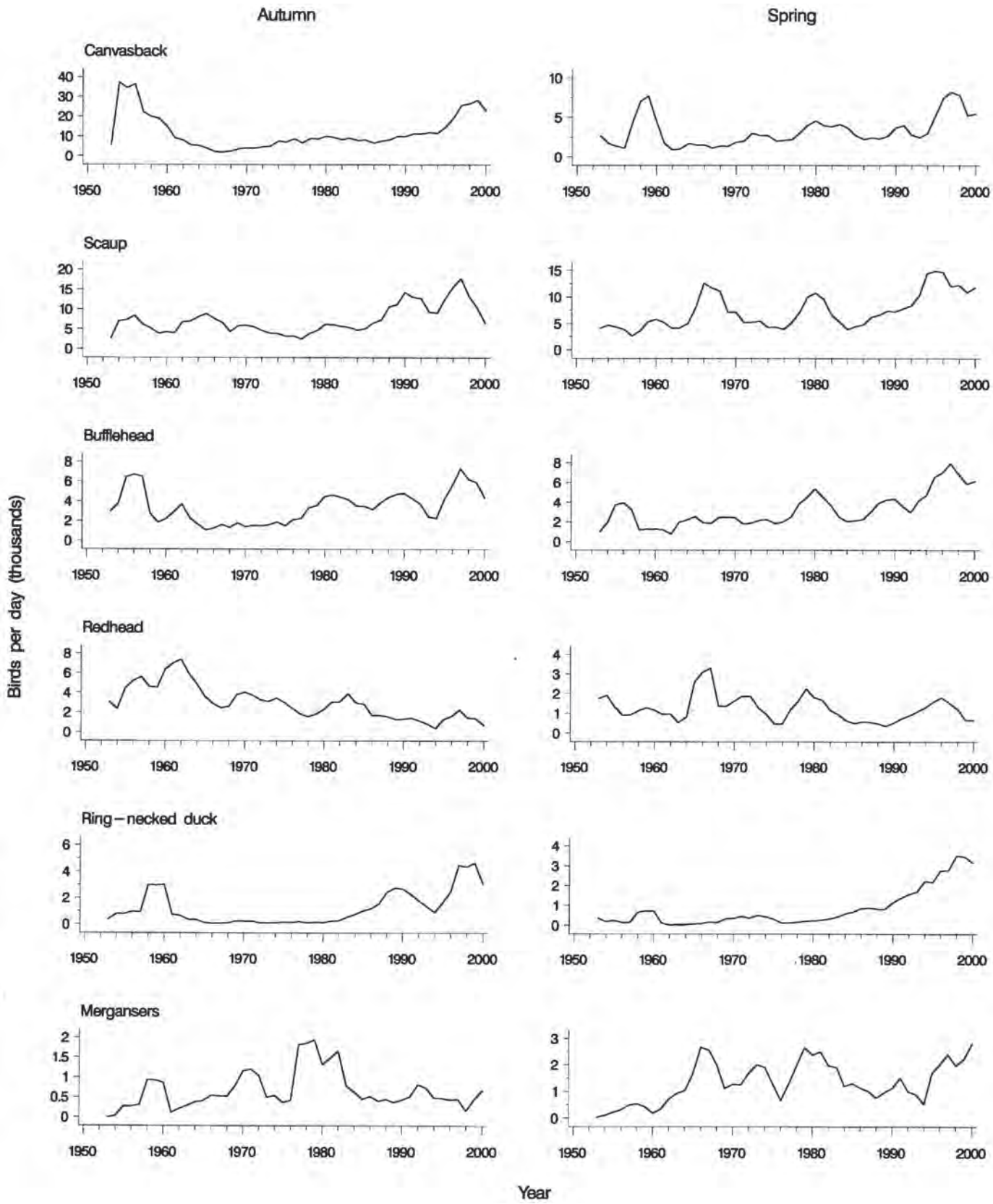

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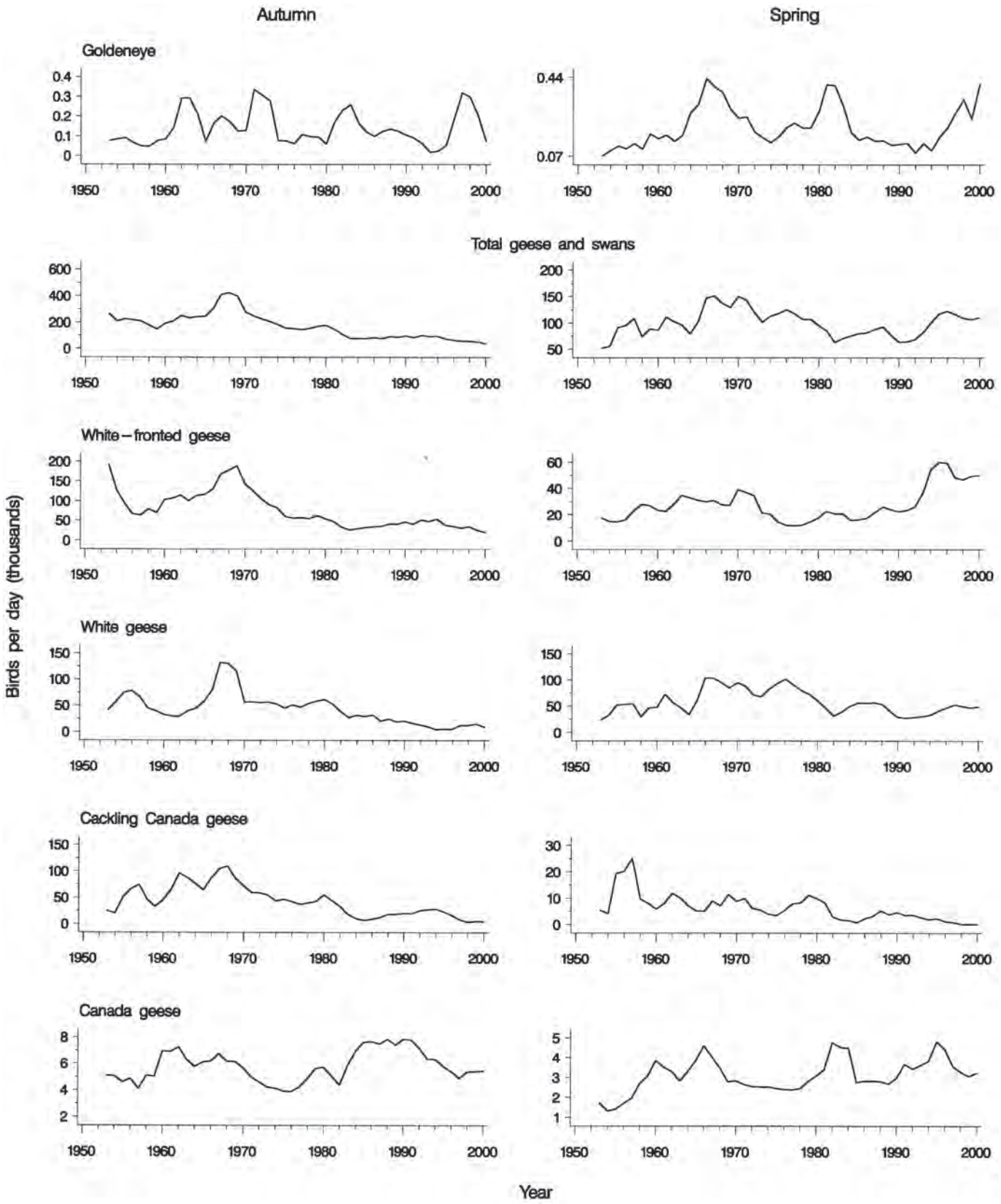

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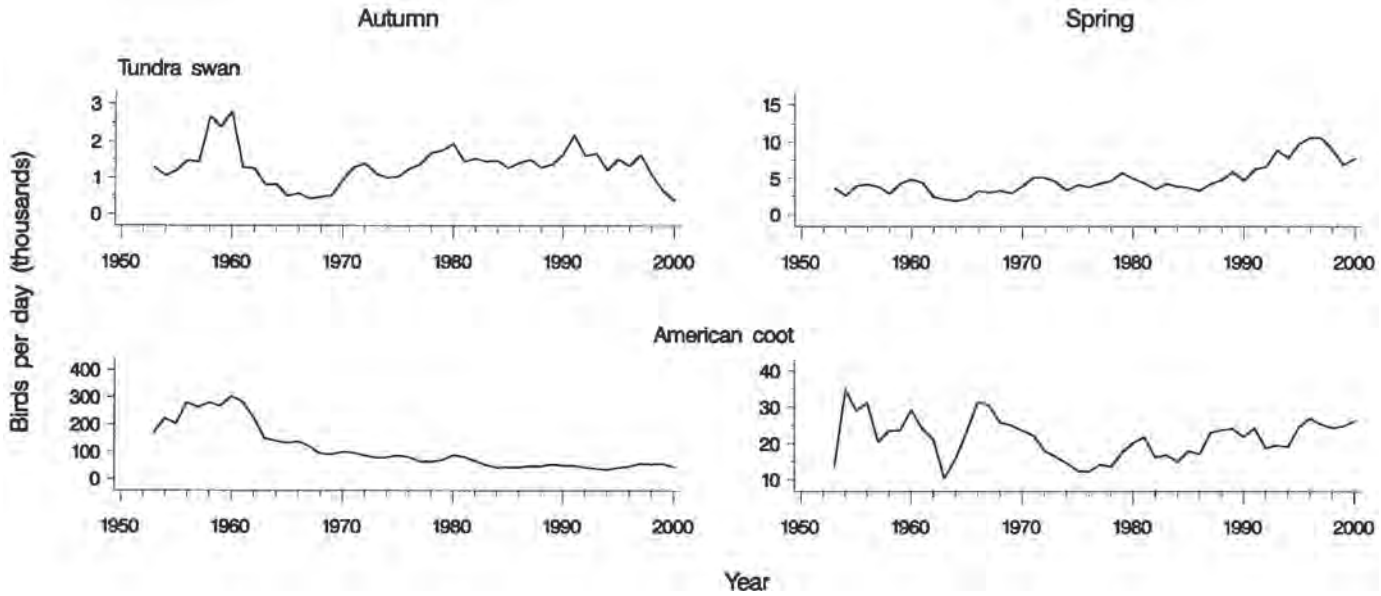

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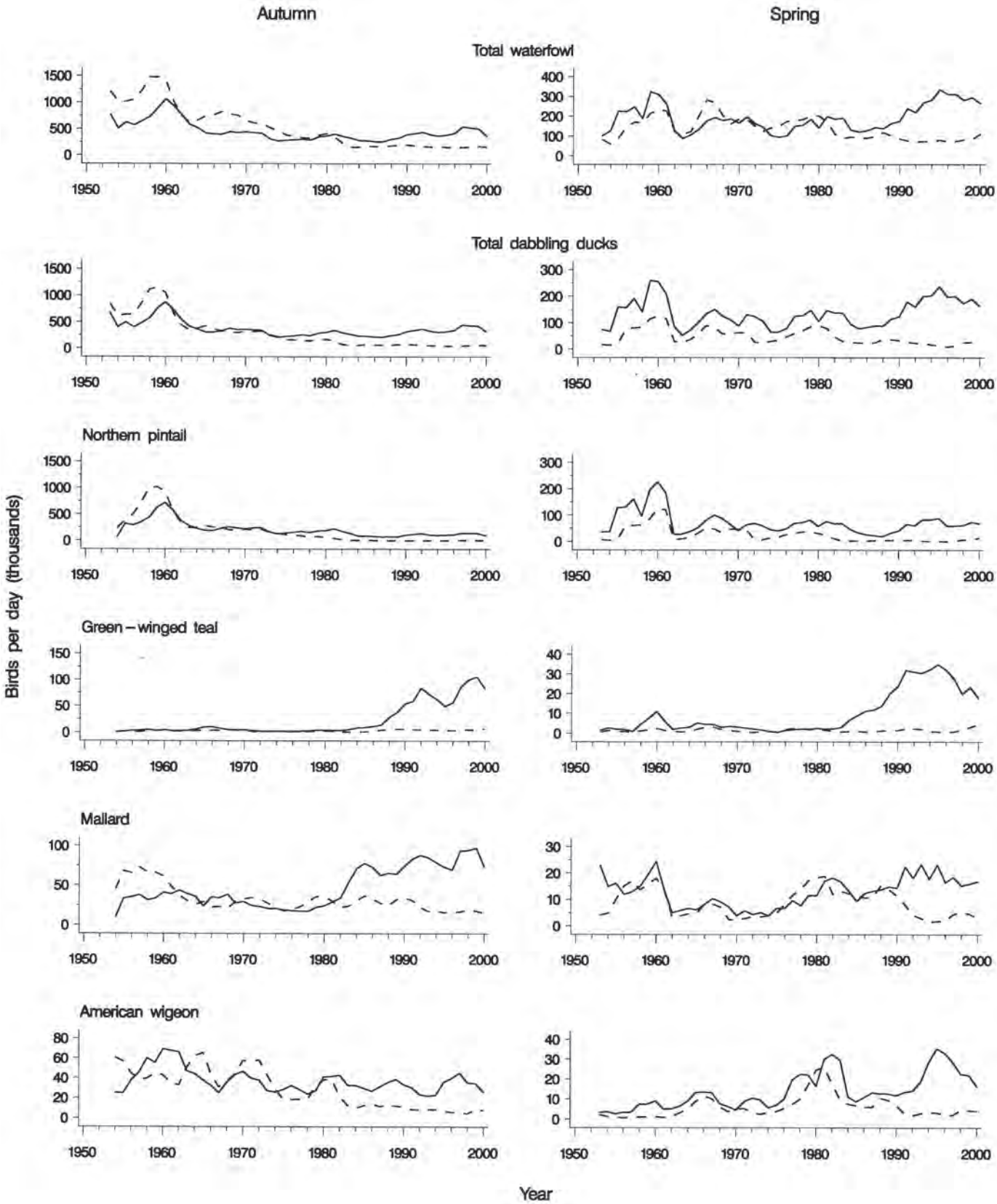
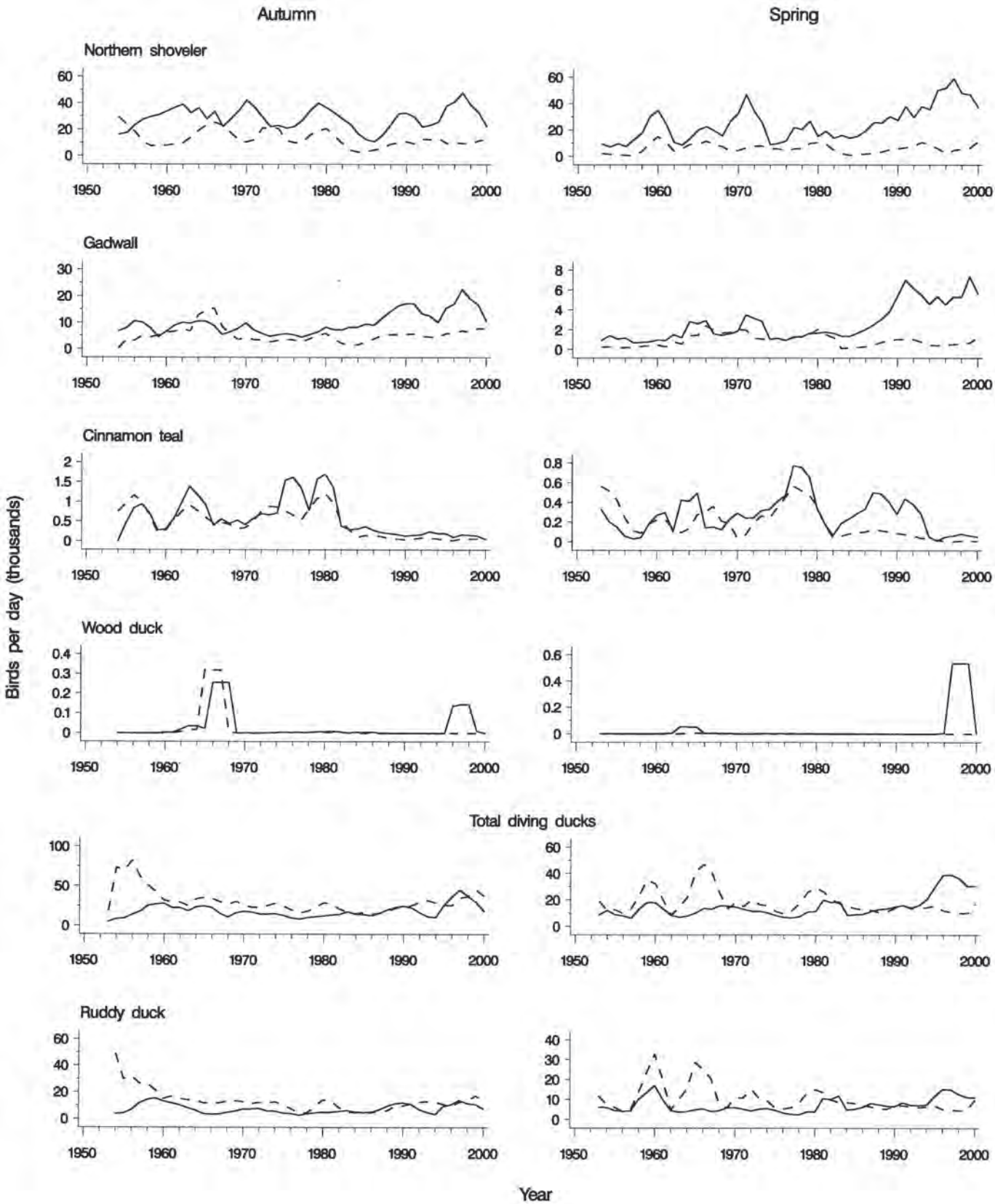


Figure 3b. Three-year running average of waterfowl counts (birds per day, thousands) for waterfowl groups and species on the Lower Klamath (solid line) and Tule Lake (dashed line) NWRs during autumn and spring 1953-2001. Closely related species were tallied as "groups." For an explanation, see Identifying and Counting Waterfowl, p. 6.



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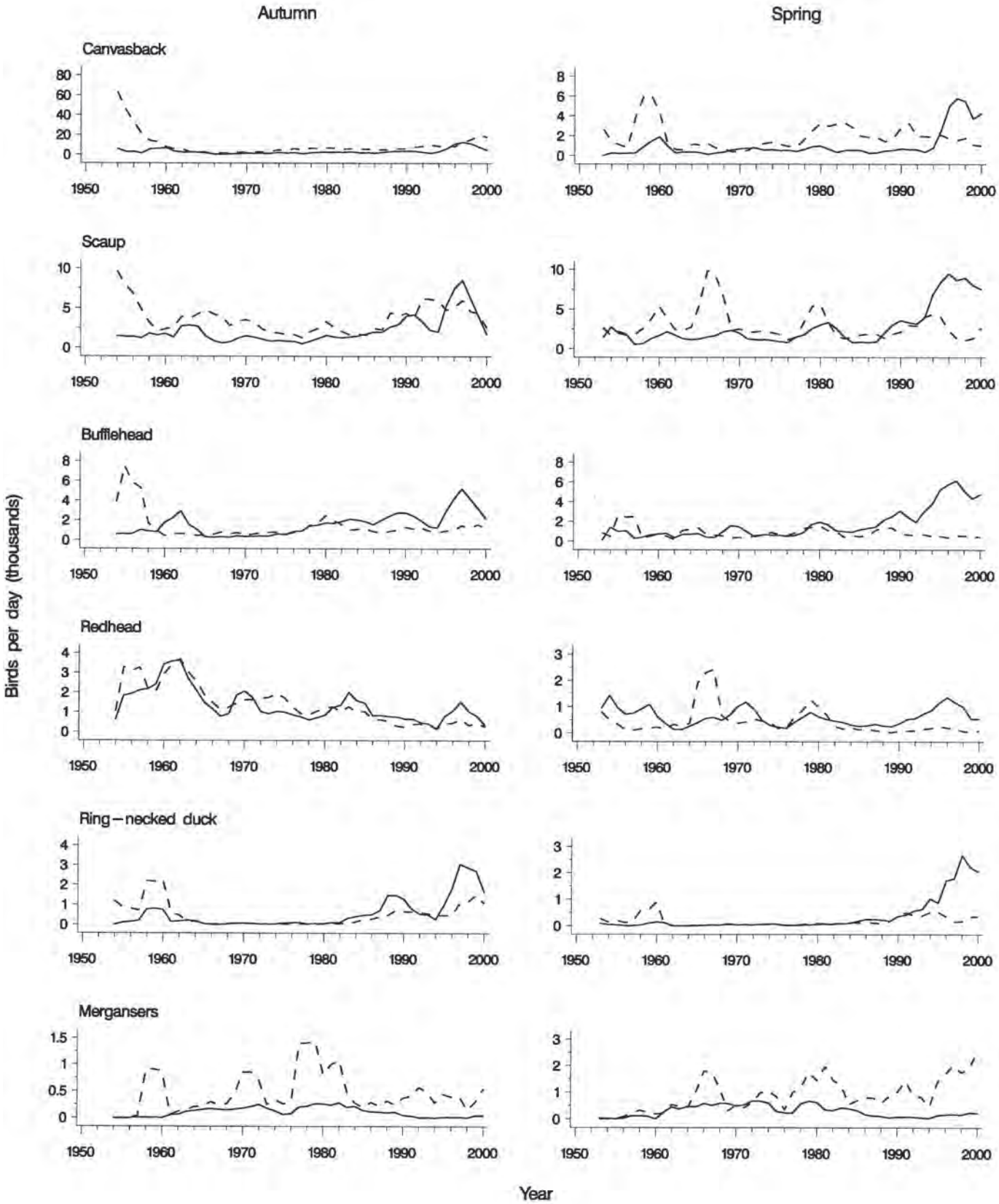

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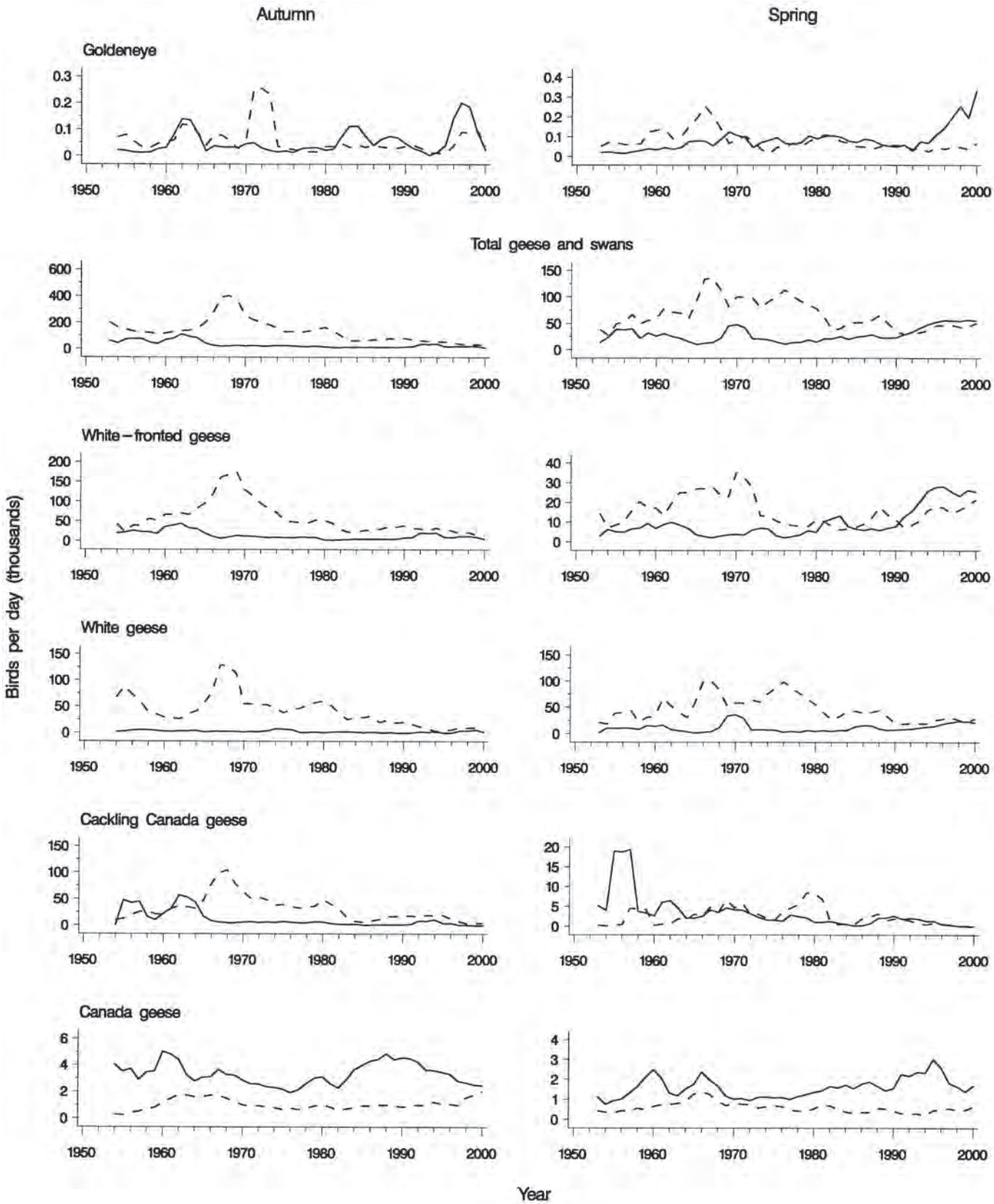

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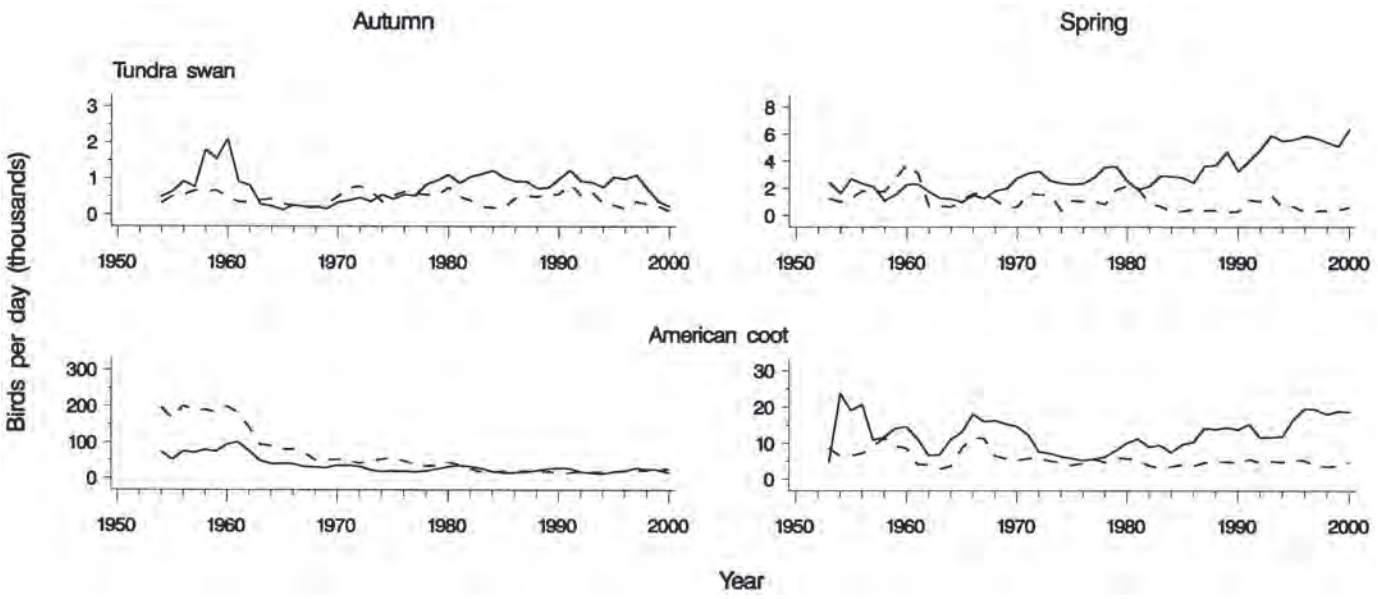


Figure 3b. Three-year running average of waterfowl counts (birds per day, thousands) for waterfowl groups and species on the Lower Klamath (solid line) and Tule Lake (dashed line) NWRs during autumn and spring 1953-2001. Closely related species were tallied as "groups." For an explanation, see Identifying and Counting Waterfowl, p. 6.—Continued

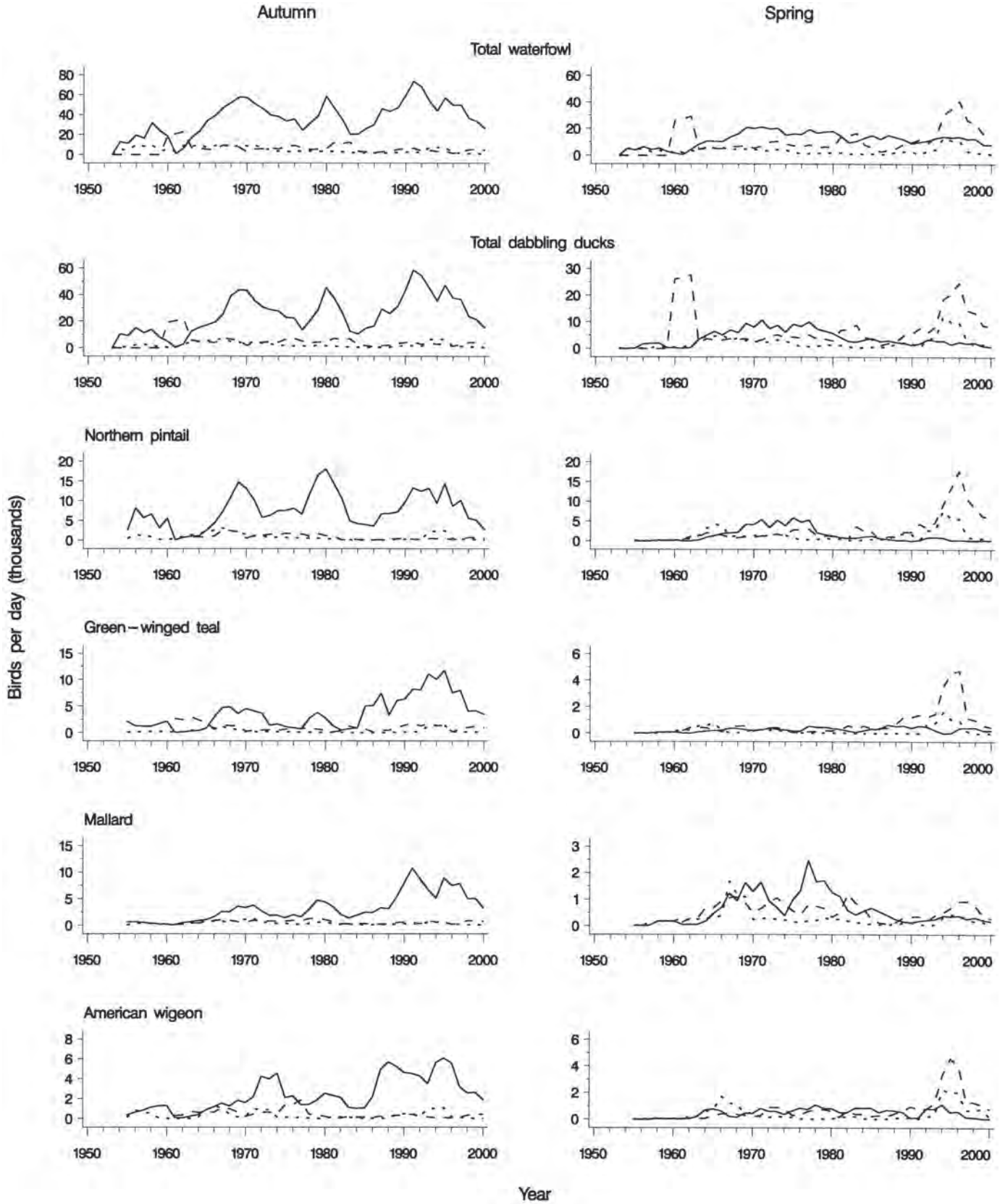
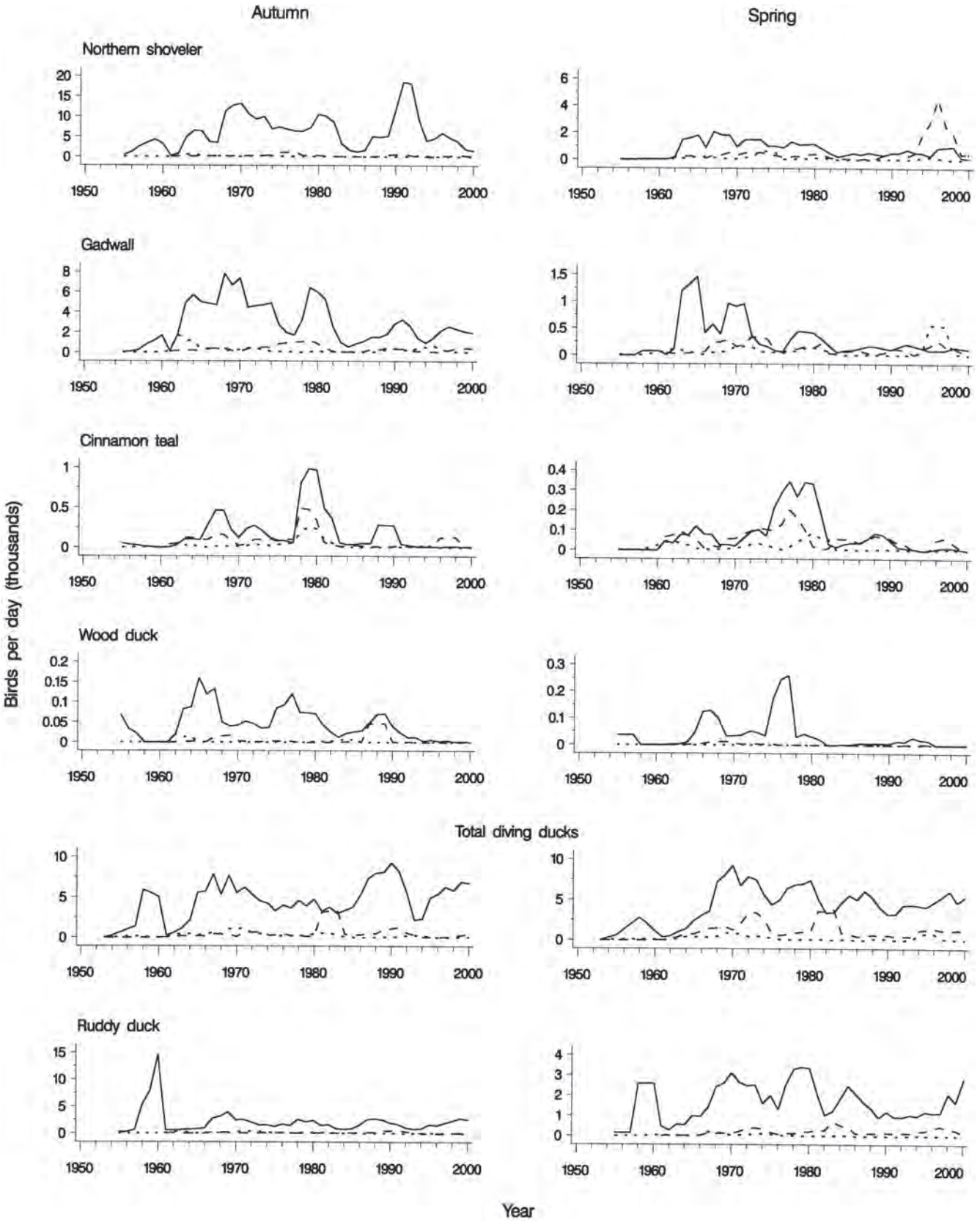


Figure 3c. Three-year running average of waterfowl counts (birds per day, thousands) for waterfowl groups and species on the Upper Klamath (solid line), Klamath Marsh (dashed line), and Clear Lake (dotted line) NWRs during autumn and spring 1953-2001. Closely related species were tallied as "groups." For an explanation, see Identifying and Counting Waterfowl, p. 6.



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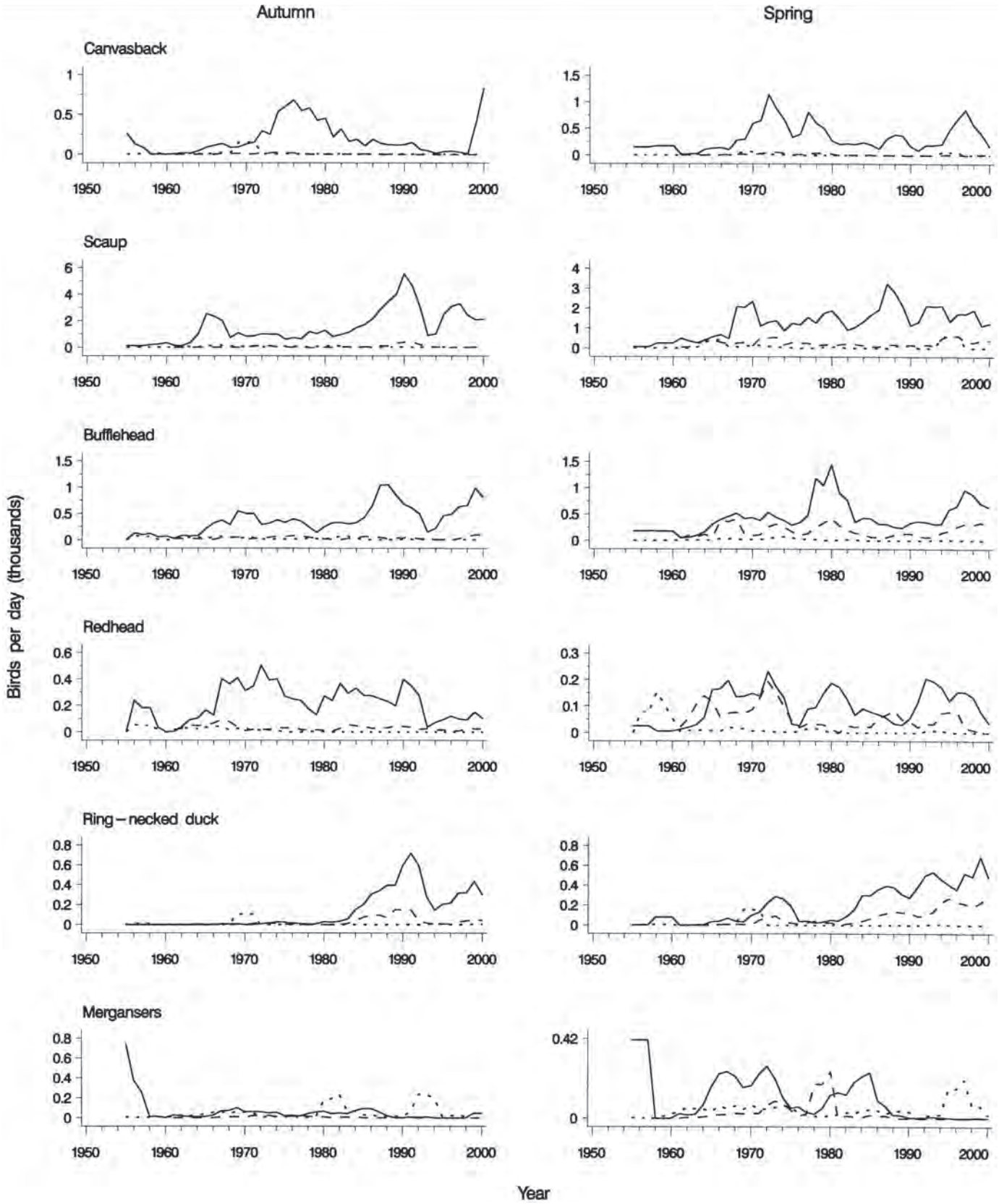

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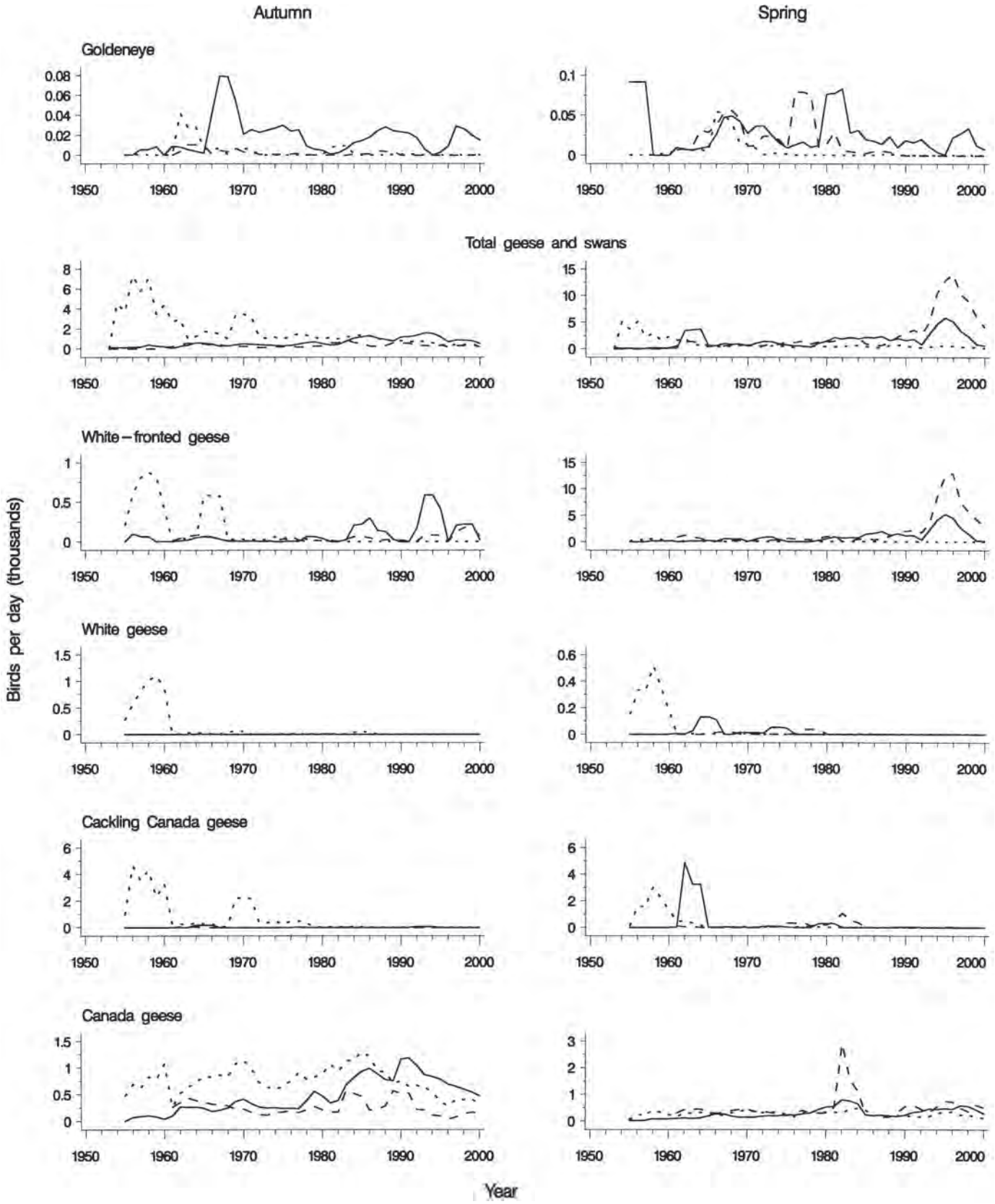

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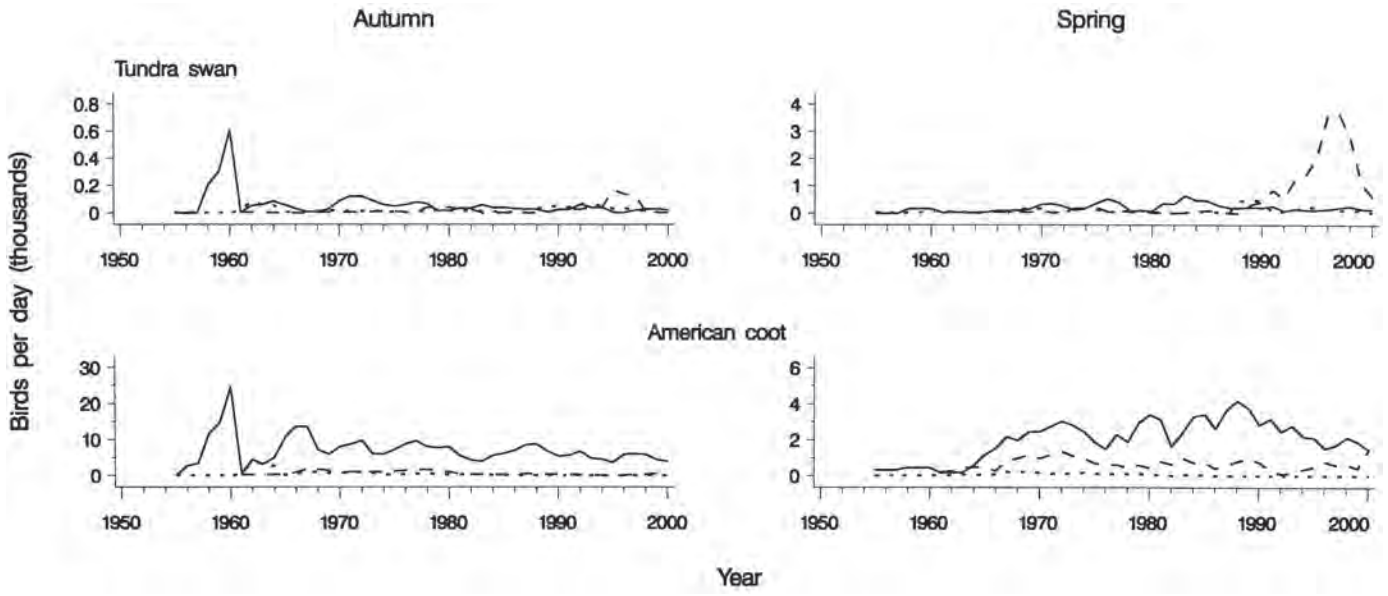

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Appendix 4

The following appendix tables show correlation between California midwinter survey counts and abundance in the Klamath Basin National Wildlife Refuge complex, 1953-76 (early period) and 1977-2001 (recent period).

Table 4a. California midwinter survey counts regressed from the previous autumn average abundance on the Klamath Basin NWR complex for the early period (1953-76) and the recent period (1977-2001).

[Bold type indicates the regression is significant at the 0.05 level. Closely related species were tallied as groups. For an explanation, see Identifying and Counting Waterfowl, p. 6]

	Early period (1953-76)				Recent period (1977-2001)			
Species	**Slope**	**SE**	***P*-value**	**r^2**	**Slope**	**SE**	***P*-value**	**r^2**
Northern pintail	-0.19	0.11	0.09	0.13	**0.89**	**0.19**	**0.00**	**0.51**
Mallard	0.23	0.20	0.27	0.06	0.10	0.19	0.58	0.01
American wigeon	0.30	0.15	0.06	0.16	**0.63**	**0.23**	**0.01**	**0.26**
Northern shoveler	0.14	0.44	0.76	0.00	**0.36**	**0.14**	**0.02**	**0.23**
Gadwall	0.19	0.26	0.46	0.03	**1.06**	**0.25**	**0.00**	**0.47**
Green-winged teal	**0.27**	**0.10**	**0.01**	**0.27**	**0.16**	**0.06**	**0.01**	**0.29**
Wood duck	0.01	0.08	0.88	0.00	-0.21	0.16	0.23	0.08
Ruddy duck	-0.10	0.16	0.55	0.02	0.00	0.17	1.00	0.00
Canvasback	**0.20**	**0.09**	**0.04**	**0.19**	-0.16	0.18	0.39	0.04
Redhead	0.68	0.40	0.10	0.12	0.21	0.23	0.36	0.04
Scaup	0.32	0.22	0.15	0.10	0.06	0.20	0.78	0.00
Ring-necked duck	0.09	0.12	0.45	0.03	**0.66**	**0.10**	**0.00**	**0.68**
Goldeneye	-0.05	0.15	0.74	0.01	0.09	0.09	0.29	0.05
Bufflehead	0.22	0.15	0.14	0.10	0.43	0.32	0.20	0.08
Mergansers	-0.02	0.08	0.83	0.00	**0.32**	**0.08**	**0.00**	**0.41**
White-fronted geese	0.02	0.19	0.92	0.00	-0.29	0.31	0.36	0.04
Cackling Canada goose	0.06	0.20	0.76	0.00	**0.78**	**0.26**	**0.01**	**0.29**
White geese	0.05	0.08	0.56	0.02	-0.18	0.26	0.51	0.02
Tundra swan	0.05	0.15	0.71	0.01	**-0.25**	**0.09**	**0.01**	**0.28**
American coot	**0.33**	**0.10**	**0.00**	**0.36**	**0.92**	**0.40**	**0.03**	**0.20**
Total	-0.08	0.09	0.36	0.04	**0.68**	**0.25**	**0.01**	**0.26**

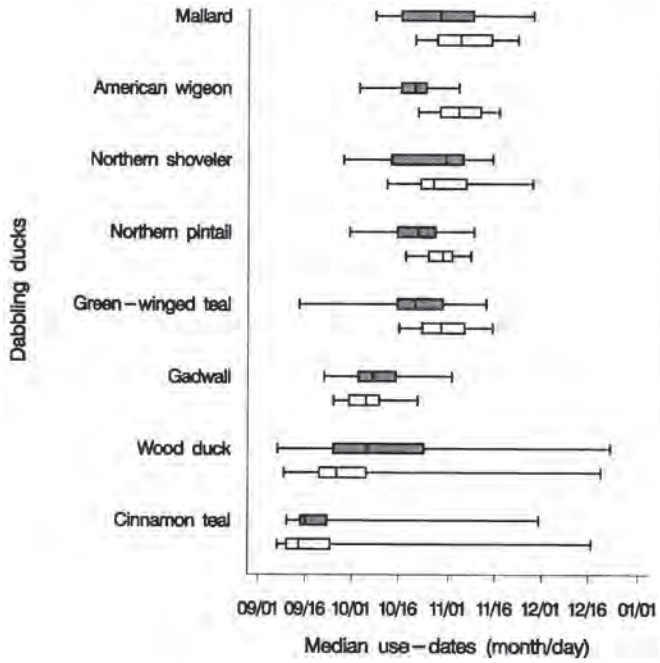
Table 4b. Spring average abundance on Klamath Basin NWR complex regressed from California midwinter survey counts for the early period (1953-76) and the recent period (1977-2001).

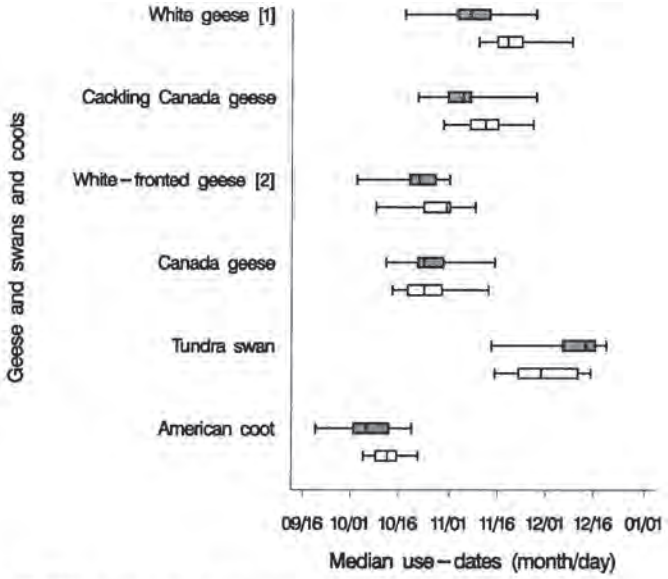
[Bold type indicates the regression is significant at the 0.05 level. Closely related species were tallied as groups. For an explanation, see Identifying and Counting Waterfowl, p. 6]

	Early period (1953-76)				Recent period (1977-2001)			
Species	**Slope**	**SE**	***P*-value**	**r^2**	**Slope**	**SE**	***P*-value**	**r^2**
Northern pintail	-0.06	0.51	0.91	0.00	**0.50**	**0.21**	**0.02**	**0.21**
Mallard	0.17	0.42	0.69	0.01	0.57	0.32	0.09	0.13
American wigeon	-0.97	0.55	0.09	0.14	**0.72**	**0.22**	**0.00**	**0.32**
Northern shoveler	0.55	0.31	0.10	0.13	0.15	0.31	0.63	0.01
Gadwall	0.48	0.35	0.19	0.08	**0.38**	**0.14**	**0.01**	**0.25**
Green-winged teal	0.92	0.57	0.12	0.11	1.11	0.60	0.08	0.13
Wood duck	0.02	0.89	0.98	0.00	0.54	0.56	0.35	0.04
Ruddy duck	**0.93**	**0.32**	**0.01**	**0.30**	-0.14	0.20	0.49	0.02
Canvasback	0.73	0.38	0.07	0.15	-0.06	0.28	0.85	0.00
Redhead	-0.33	0.19	0.10	0.13	0.33	0.17	0.07	0.15
Scaup	-0.16	0.24	0.50	0.02	0.01	0.19	0.98	0.00
Ring-necked duck	0.01	0.56	0.99	0.00	**0.68**	**0.12**	**0.00**	**0.61**
Goldeneye	-0.13	0.17	0.45	0.03	**0.51**	**0.23**	**0.04**	**0.19**
Bufflehead	-0.15	0.24	0.53	0.02	0.18	0.17	0.28	0.05
Mergansers	0.20	0.38	0.60	0.02	0.10	0.25	0.69	0.01
White-fronted geese	0.14	0.24	0.57	0.02	**0.68**	**0.14**	**0.00**	**0.51**
Cackling Canada goose	0.50	0.37	0.19	0.08	**0.73**	**0.20**	**0.00**	**0.37**
White geese	0.93	0.57	0.12	0.12	0.11	0.07	0.15	0.09
Tundra swan	0.54	0.27	0.06	0.16	**0.65**	**0.30**	**0.04**	**0.18**
American coot	0.59	0.32	0.08	0.15	0.16	0.13	0.25	0.06
Total	-0.10	0.51	0.85	0.00	**0.40**	**0.16**	**0.02**	**0.21**

Appendix 5

The following appendix figures show the distribution of median use-dates of waterfowl on Klamath Basin NWR complex during autumn and spring.





[1] White geese = lesser snow goose and Ross's goose.
[2] White-fronted geese = greater tule white-fronted goose and Pacific greater white-fronted goose.

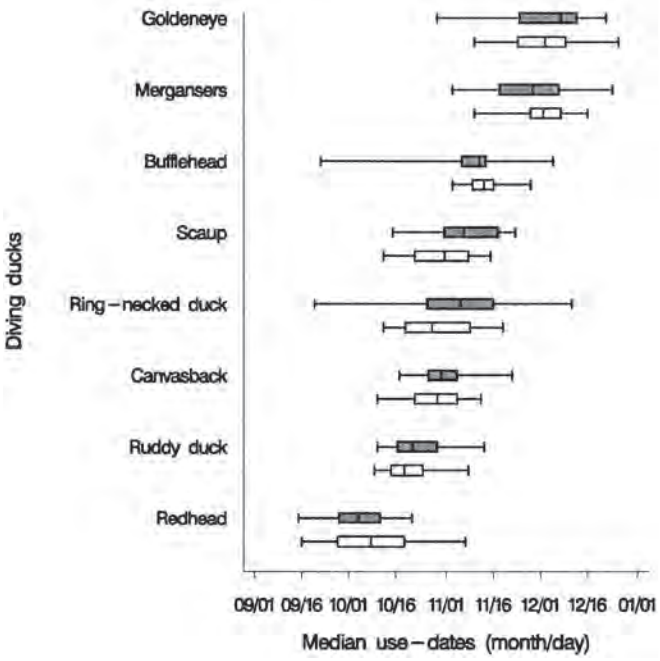
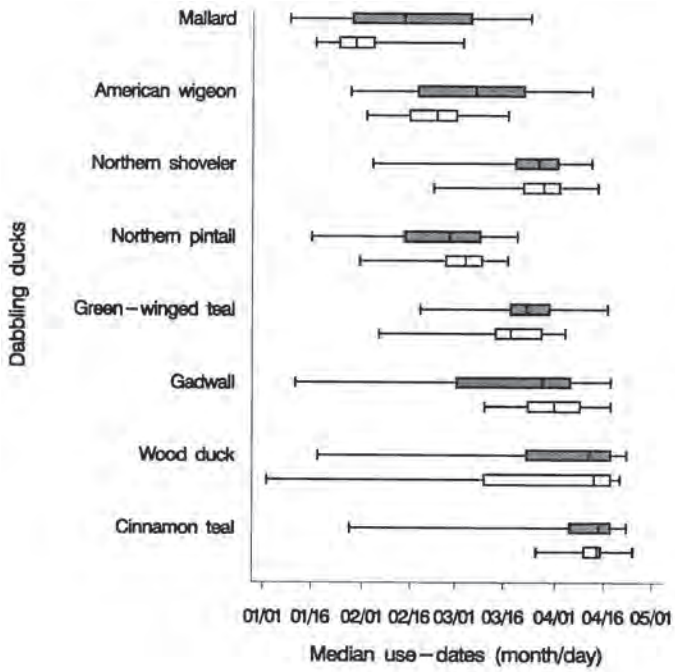
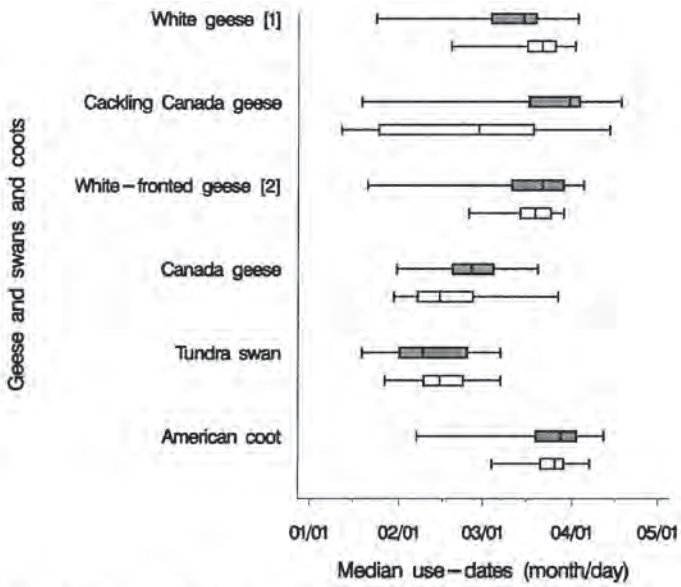


Figure 5a. Box plots show the distribution of median use-dates of waterfowl on the Klamath Basin NWR complex during autumn over the early period (1953-76; shaded) and the recent period (1977-2001; open). The left and right edges of a box represent the interquartile range of median use-dates, or the middle range in which 50% of all median use-dates occurred. Lines extend from the box to span the full range of median use-dates over all years.





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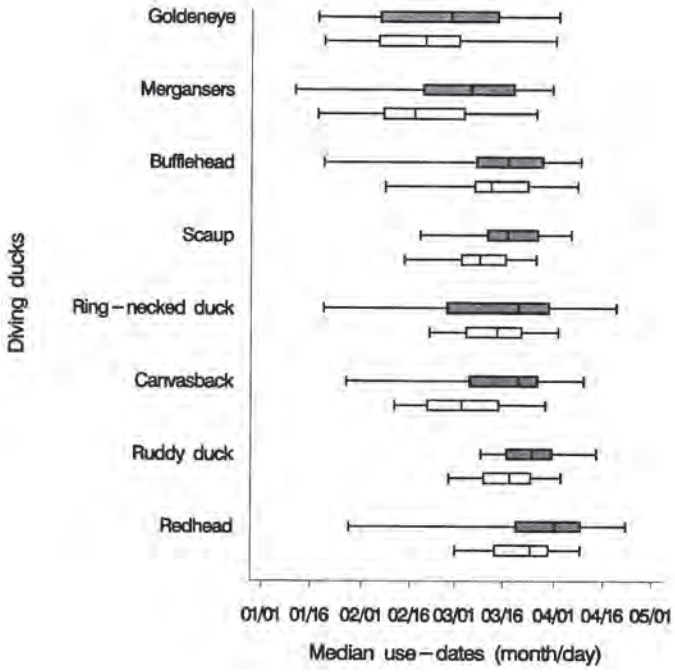

Figure 5b. Box plots show the distribution of median use-dates of waterfowl on the Klamath Basin NWR complex during spring over the early period (1953-76; shaded) and the recent period (1977-2001; open). The left and right edges of a box represent the interquartile range of median use-dates, or the middle range in which 50% of all median use-dates occurred. Lines extend from the box to span the full range of median use-dates over all years.

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