WATERFOWL DISTRIBUTION, MOVEMENTS, AND HABITAT USE RELATIVE TO RECENT HABITAT CHANGES IN THE CENTRAL VALLEY OF CALIFORNIA

FINAL REPORT – OCTOBER 2005

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CALIFORNIA WATERFOWL ASSOCIATION
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UNITED STATES BUREAU OF RECLAMATION
UNITED STATES FISH AND WILDLIFE SERVICE
USGS-WESTERN ECOLOGICAL RESEARCH CENTER

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FINAL REPORT
WATERFOWL DISTRIBUTION, MOVEMENTS, AND HABITAT USE RELATIVE TO RECENT HABITAT CHANGES IN THE CENTRAL VALLEY OF CALIFORNIA : A cooperative project to investigate impacts of the Central Valley Joint Venture and changing agricultural practices on the ecology of wintering waterfowl

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EXECUTIVE SUMMARY

The Central Valley of California is one of the most important waterfowl wintering areas in North America. In 1986, the newly formed North American Waterfowl Management Plan (NAWMP) identified the Central Valley as an area of major concern. In 1988, the Central Valley Joint Venture (CVJV) was formed as part of NAWMP, with the goal to restore and enhance Central Valley habitats necessary to support abundance and distribution of waterfowl like during the 1970s. CVJV habitat goals were based upon current knowledge of waterfowl ecology in California. Planners assumed that waterfowl distribution would be like that observed during 1970s midwinter surveys. They used a model to calculate required energy and habitat that assumed waterfowl abundance in each Central Valley basin would gradually build up during fall, peak at the midwinter count in early January, and then decline to desired summer breeding population levels. CVJV goals for wetland and agricultural habitats in each basin were then developed assuming waterfowl would increase use of wetlands as they increased.

In 1996, in light of changing agricultural practices and nearly a decade of CVJV and other conservation activities that altered the Central Valley landscape, waterfowl experts from throughout the Pacific Flyway called for a cooperative study to revisit the assumptions upon which CVJV habitat goals were based. They determined that information was needed on how waterfowl wintering in the Central Valley responded to habitat changes such as increased flooding rather than burning of rice stubble, wetland restoration and enhancement, and establishment of new National Wildlife Refuges, California Wildlife Areas and other preserves in order to update and improve implementation of the CVJV and other programs.

This final report describes that cooperative study. To determine impacts of habitat changes, wintering waterfowl ecology was compared before or during early years of the CVJV vs. 1998-2000 using data on waterfowl distribution, movements, and habitat use collected from aerial surveys of all waterfowl during 1973-1982 vs. 1998-2000 and radio telemetry of northern pintails, mallards, and greater white-fronted geese during 1987-1990 or 1991-1994 vs. 1998-2000.

Three study findings indicate that some CVJV habitat goals need revision: (1) waterfowl use days during 1998-2000 were different than what CVJV habitat goals were based upon. This difference occurred because wintering abundance was below goal (mainly because of low northern pintail abundance), the CVJV assumption that waterfowl abundance peaked in January was not true for all basins, and waterfowl distribution among basins has changed in response to habitat changes; (2) despite increased wetland area, most energy for wintering waterfowl was still acquired in agricultural habitats and the continued high attraction for post-harvest flooded rice has shifted waterfowl use into the Sacramento Valley; (3) daily flight distances and their change over time differed among basins and may require assuming different energetic requirements when modeling habitat requirements for each basin.

The results above indicate that adjustments to habitat goals may be needed to meet CVJV's objective of providing habitat in the amounts and locations necessary to maintain abundance and distribution of waterfowl in the Central Valley like during the 1970s. Thus, we make the following recommendations:

1) Waterfowl use-day goals should be revised to better reflect the percentage of waterfowl use that actually occurred in each basin during the 1970s. Specifically, waterfowl use day goals should be increased in the American, Delta, and Tulare Basins and decreased in Sutter and Colusa Basins.
2) Differences in current vs. 1970s distribution of waterfowl should be considered when prioritizing projects. Dabbling ducks and geese have increased use of the Sacramento Valley and decreased use elsewhere, resulting in the 1998-2000 percentage of total Central Valley waterfowl use in Butte and Colusa Basins well above and in the Delta and Suisun Basins well below 1970s levels. To restore 1970s distribution, the CVJV should place high priority on projects that will attract and maintain wintering waterfowl in the Delta and Suisun. These efforts need to be designed while considering impacts of CALFED and other programs on waterfowl.
3) Differences in current vs. pre-1970s distribution of waterfowl should be considered when prioritizing projects. Habitat changes that occurred before the 1970s were more detrimental to waterfowl populations in the San Joaquin Valley, especially in the Tulare Basin, where wetlands were mostly converted to agriculture having little waterfowl value, than in the Sacramento Valley and Delta where wetlands were mostly converted to rice or other crops with high value for waterfowl. Thus, waterfowl use-day goals should be increased somewhat to account for the fact that 1970s surveys greatly underestimate the greater pre-1970s value of the Tulare and San Joaquin Basins to waterfowl. These southern basins are also especially important for shorebirds, which are now specifically included in CVJV planning.
4) The continued high attraction of many waterfowl species to rice and grain fields, especially of dabbling ducks to flooded fields, should be recognized in design of CVJV implementation. Thus, in addition to ensuring that adequate wetlands are provided for the long-term, enhancement of agricultural habitats should be considered for basins where the portion of Central Valley's waterfowl use has declined since the 1970s if they have potential agricultural lands for enhancement (i.e., Tulare, San Joaquin, and Delta Basins).
5) Research to improve the bioenergetic model upon which CVJV non-breeding waterfowl (and now shorebird) goals are based should continue. For instance, radio tracking shows that average flight distances were greater in the Sacramento Valley than in the San Joaquin Valley, which were greater than in the Delta, which were greater than in Suisun and Mendota WA. In addition, daily flight distances generally declined as habitat availability increased and hunting pressure decreased. Regional differences in daily energy requirements may greatly impact habitat requirements. However, additional research is needed to determine the relationship between daily flight distances and daily energy requirements including whether birds compensate for increased flight energy expenditure by reducing energy expended on other activities or whether increased flight distances require increased food intake.

INTRODUCTION

In 1986, the North American Waterfowl Management Plan (NAWMP) was established with the goal of maintaining the diversity, abundance, and distribution of waterfowl that occurred during the 1970s (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986) and identified the Central Valley of California, as one of their 34 “areas of major concern” in North America. The Central Valley Habitat Joint Venture (re-named the Central Valley Joint Venture [CVJV] in 2004) was formed in 1988 to pursue goals of NAWMP in the Central Valley. Using current knowledge of waterfowl ecology in California, CVJV planners estimated habitat goals that would be necessary to fulfill energetic requirements for goal populations of waterfowl in each of the nine Central Valley basins (Fig. 1). Planners assumed that waterfowl distribution would remain similar to that observed during 1973-1977 midwinter surveys. They used a model to calculate required energy and habitat that assumed waterfowl populations in each basin would gradually build up during fall, peak at the midwinter count in early January, and then gradually decline to desired summer breeding population levels (Heitmeyer 1989a). CVJV goals for wetland and agricultural habitats in each basin were then developed assuming waterfowl would increase their use of wetlands as wetland habitat increased (Heitmeyer 1989a).

In 1996, waterfowl researchers, managers, and other experts from throughout the Pacific Flyway met in California to identify waterfowl research priorities. In light of changing agricultural practices and nearly a decade of CVJV and other conservation activities that altered the Central Valley landscape, they determined that their top information need was a study that revisited some of the assumptions upon which CVJV habitat goals were based. They supported a study to determine how waterfowl wintering in the Central Valley had responded to habitat changes such as increased flooding rather than burning of rice stubble, wetland restoration and enhancement, and establishment of new National Wildlife Refuges, California Wildlife Areas and other preserves.

This final report presents the results of that cooperative study which investigated impacts of the Central Valley Joint Venture (CVJV) and changing agricultural practices on the ecology of waterfowl wintering in California's Central Valley. The goals of the project were to measure the response of waterfowl to habitat changes in the Central Valley and provide information useful for improving implementation of the CVJV and other programs that impact waterfowl and their habitats in the Central Valley. To determine impacts of habitat changes, wintering waterfowl ecology was compared before or during early years of the CVJV vs. 1998-2000 using data on waterfowl distribution, movements, and habitat use collected from aerial surveys (1973-1982 vs. 1998-2000) of all waterfowl species and radio telemetry (1987-1990 or 1991-1994 vs. 1998-2000) of northern pintails, mallards, and greater white-fronted geese.

Preliminary results of this project were periodically provided to the CVJV technical committee and other resource program planners and managers to allow incorporation into program implementation plan updates. In addition, methods, description of accomplishments, additional bird location and movement maps, and other preliminary results were presented in 1999 and 2000 progress reports (Fleskes et al. 1999, 2000) and as posters or oral presentations at several international wildlife conferences (11th North American Artic Goose Conference, 2005, Reno, NV; 3rd International Wildlife Management Congress, 2003, Christchurch, New Zealand; 3rd North American Duck Symposium, 2003, Sacramento, CA; 9th Annual Conference of The Wildlife Society, 2002, Bismark, ND; 8th Annual Conference of The Wildlife Society, 2001, Reno, NV; 2nd North American Duck Symposium, 2000, Saskatoon, Saskatchewan) and other meetings. Both progress reports are available for photocopying from the project leader and the 2000 report and most recent oral and poster presentations are available at www.werc.usgs.gov/dixon/joe.asp.

STUDY OBJECTIVES

This study has four objectives:

1. Assess changes in wintering waterfowl distribution in the Central Valley since the 1970s.
2. Identify changes in wintering northern pintail, mallard, and white-fronted goose movement patterns and use of specific feeding and roosting sites during the last decade.
3. Determine if wintering northern pintails, mallards, and white-fronted geese have changed their use of wetland and agricultural habitat types in the Central Valley during the last decade.
4. Evaluate wetland and agricultural habitat goals of the Central Valley Joint Venture and make recommendations for changes.

STUDY AREA

THE CENTRAL VALLEY LANDSCAPE

The Central Valley of California (including the Suisun Marsh) is composed of 9 basins (Fig. 1) that provide critical wintering habitat for many species of waterfowl in the Pacific Flyway. Central Valley basins range greatly in size, with Tulare (1,449 km^2), San Joaquin (760 km^2) and Delta (540 km^2) Basins larger than the Sacramento Valley (Colusa = 465 km^2, Butte =

261 km^2, American = 223 km^2, Yolo = 208 km^2, Sutter = 91 km^2) and Suisun Marsh (43 km^2) Basins. Agricultural and urban development reduced the estimated 1.6 - 2 million hectares of original wetlands in the Central Valley by over 90% by the early 1900s (U.S. Fish and Wildlife Service [USFWS] 1978, Gilmer et al. 1982), with the magnitude of loss and the types and amounts of waterfowl habitat remaining differing by basin. Historically, about 40% of Central Valley waterfowl habitats occurred in the San Joaquin Valley, comprised of the (northern) San Joaquin Basin and the (southern) Tulare Basin, with the remaining 60% in the Delta, Suisun, and Sacramento Valley basins (USFWS 1978, Fig. 2). The Tulare Basin comprised the largest single block of wetlands historically present in California, but most Tulare Basin wetlands were lost by the early 1900s with the conversion of the Tulare Lake (once the largest freshwater lake west of the Mississippi River) and associated wetlands to agricultural lands such as orchards and cotton fields (Kirk 1994) that are of minimal value to waterfowl (Fleskes 1999). Wetland loss in the Sacramento Valley and Delta Basins during the early 1900s was also severe but many wetlands in the Sacramento Valley were converted to rice, and in the Delta to corn or other grain, that retain high value to waterfowl. Thus, during our 1973-2000 study period, waterfowl habitat occurred throughout the Sacramento Valley (Fig. 1), Delta (Fig. 3), and Suisun Marsh (Fig. 4) in the northern part of the Central Valley. However, in the southern part of the Central Valley, waterfowl habitat was present primarily in 3 distinct blocks separated by agriculture of little waterfowl value: 1) Grassland Ecological Area (EA) in the San Joaquin Basin (Fig. 5); 2) Mendota WA in the northern Tulare Basin (Fig. 1); and 3) Tulare Lake Bed and Kern NWR vicinity in the southern Tulare Basin (Fig. 1). Study area habitats are described further by USFWS (1978), Heitmeyer et al. (1989), and Kadlec and Smith (1989).

METHODS

Change in area and distribution of wetland and agricultural habitats continued during our 1973-2000 study period. We used a variety of methods to measure change in the Central Valley landscape and impacts on distribution, movements, and habitat use of waterfowl wintering there. Datasets and methods that we used to measure change are detailed in the following subsections.

HABITAT AVAILABILITY

We used a variety of methods to track change in availability of wildlife areas, area of managed wetlands, post-harvest flooded rice fields, other agriculture, and habitat conditions. We summarized habitat data during 1973-1982, 1987-1990, 1991-1994 and 1998-2000 to coincide with waterfowl survey and radio telemetry data so habitat and waterfowl ecology change could be compared.

National Wildlife Refuges, State Wildlife Areas, Nongovernmental Preserves

We used data provided by the CVJV (Source International Tracking System 4.0), refuge annual reports, and other files to track when National Wildlife Refuges (NWRs), State Wildlife Areas (WAs), and Nongovernmental Preserves were established or expanded during 1973-2000.

Wetlands

We used data provided by the CVJV (Source International Tracking System 4.0) to track change in area of managed wetlands among Central Valley basins during 1989-2000. Starting with the most recent estimated area of managed seasonal and semi-permanent wetlands (CVJV data summarized by M. Petrie in Table 3-1 of draft CVJV Implementation Plan Update), we subtracted the restored area of wetlands (code 200) and moist soil (code 251) habitats listed for each year to determine estimates for 1989-2000. USFWS (1978) and Gilmer et al. (1982) provided estimates of wetland area in Central Valley basins or regions for the late 1970s but these estimates are inflated because they include associated uplands. We assumed no regional difference in the percentage of uplands included in these 1970s wetland estimates, and used them to represent the distribution of wetlands among basins or regions during 1973-1982 for comparison with later study periods.

Flooded Rice Fields

We used several methods and data sources to determine area and distribution of post-harvest flooded rice fields during the study periods of interest. For 1987-1990, 1991-1994 and 1998-2000, we used satellite imagery to map both total and winter-flooded rice fields in the northern Central Valley (Fleskes et al. 2005). For the 1998-2000 period, we analyzed satellite imagery from 23 July 1999 to determine rice field area and imagery from 30 December 1999 to estimate area of winter-flooded (flooded and saturated soil) and winter-dry rice in Butte, Colusa, American, Sutter, Yolo, and Delta Basins in the northern Central Valley of California. We compared our estimate of winter-flooded area for the 1999-2000 winter with estimates that Spell et al. (1995) reported using identical methods for 1988-1989 (1 August 1988 and 24 January 1989 imagery) and 1993-1994 (30 July 1993 and 6 January 1994 imagery). For the 1973-1982 period, we used data gathered as part of the California Department of Fish and Game (CDFG) duck club survey (CDFG 1979) for estimates of post-harvest flooded rice in the northern Central Valley. To derive estimates of winter-flooded rice for the San Joaquin and Tulare Basins, we used results of aerial mapping for 1998-2000 (this study) and 1991-1994 (Fleskes 1999, Fleskes unpublished data) and refuge, aerial waterfowl survey, and other reports for other years. We used U. S. Department of Agriculture (2004) county reports to derive planted rice acreage estimates for all basins.

Other Agricultural Habitats

We used a variety of methods to estimate post-harvest flooded area of: a) safflower, barley-wheat, seed alfalfa, cotton, and other crop fields (e.g., corn, unidentified) in the Tulare Basin (commonly termed as “preirrigation”); b) corn, wheat, and other crop fields (e.g., sunflower, asparagus, unidentified) in the Delta Basin; and c) fallow and unidentified crops (probably mostly plowed rice fields) in the Sacramento Valley during each study period. In the Tulare Basin, we report the maximum area of “preirrigation” observed during any one aerial waterfowl survey during any one year for each of the study periods of interest (i.e., 21 October 1982 for 1973-1982, 1 September 1989 for 1987-1990, 8 October 1991 for 1991-1994, 18 November 1999 for 1998-2000, USFWS unpublished data). In the San Joaquin Basin, all flooded areas were photographed and/or mapped while conducting aerial telemetry surveys during 1991-1994 (Fleskes 1999) and 1998-2000 (this study). We report the maximum amount of managed-flooded croplands (excludes floodwaters) during any one aerial waterfowl survey during any one year for each of the study periods of interest. For earlier study periods, we relied upon refuge, aerial survey, and other reports (which indicated only slightly more agricultural flooding was present in the San Joaquin Basin than during 1991-1994).

We used satellite imagery, aerial surveys, and a variety of reports to derive estimates of flooded non-rice agriculture in the Sacramento Valley and Delta Basins. To derive an estimate for the 1998-2000 study period for Butte, Colusa, American, Sutter, Yolo, and Delta Basins, we analyzed 23 July 1999 satellite imagery to determine non-rice agriculture and 30 December 1999 imagery to estimate area of non-rice agriculture that was winter-flooded. For the 1991-1994 and 1987-1990 periods, we report the maximum area flooded during any one aerial habitat survey conducted throughout the Sacramento Valley and Delta in 1992-1993 and 1988-1990 (Orthmeyer et al. 1989, 1990; Orthmeyer et al. unpublished data) and ground surveys conducted in 1991-1992 in the Delta (M. Casazza, unpublished data, Miller et al. 1993). For the 1973-1982 study period, we used CDFG (1979) data.

Total Waterfowl Habitat

We summed the area estimates of managed wetlands, winter-flooded rice, and winter-flooded non-rice cropland to calculate the total area of waterfowl habitat for each study period.

Habitat Conditions

Differences in precipitation and water supplies among study periods impacted the availability and quality of waterfowl habitats. We considered this in order to fully evaluate the response of wintering waterfowl to changing landscape conditions. Thus, we report: 1) the Water Year Hydrologic Classification Index (Gehrts 2002); 2) rainfall at Sacramento Metro Airport during October to September (National Oceanic and Atmospheric Administration 2004); and, 3) observer's notes on regional habitat conditions during the early January (i.e., midwinter) aerial waterfowl survey (USFWS Pacific Flyway unpublished reports, Benning et al. 1978 [for 1973-1974]).

HARVEST REGULATIONS

In addition to landscape variables, hunting and related activities can also impact waterfowl ecology. Thus, we summarized waterfowl hunting season length and daily bag limits for ducks and geese (CDFG 1973-2000) during the 1973-1982, 1987-1990, 1991-1994, and

1998-2000 study periods.

WATERFOWL DISTRIBUTION, MOVEMENTS, AND HABITAT USE

To determine impacts of habitat changes on wintering waterfowl ecology, we used data on waterfowl distribution, movements, and habitat use collected from aerial surveys of all waterfowl during 1973-1982 vs. 1998-2000 and radio telemetry of northern pintails, mallards, and greater white-fronted geese during 1987-1990 or 1991-1994 vs. 1998-2000.

Aerial Surveys

We used aerial surveys conducted periodically during September – April to determine daytime abundance and distribution of waterfowl species or species groups (Appendix 1) among Central Valley basins during 1973-1982 and 1998-2000. Survey methodology during the two periods differed somewhat.

1973-1982-Data on waterfowl distribution in the Central Valley were available during the 1973-1974, 1978-1979, 1979-1980, 1980-1981, and 1981-1982 winters from aerial surveys of the entire Central Valley conducted periodically during September – January by CDFG and USFWS biologists (Table 1). We used only these winters to determine pre-CVJV waterfowl distribution because only September and January (i.e., the Midwinter) surveys were conducted or important Central Valley regions were not surveyed during other pre-CVJV winters. The survey consisted of flying all waterfowl use areas in the Central Valley, known from experience and high altitude reconnaissance, with the goal of a complete count for the area covered. Counts were tallied in such a way that required data for the American, Butte, and Sutter Basins to be grouped into a single region called the "East Sacramento Valley". Further, tallying methods and efforts to differentiate species of dark geese varied among surveys and regions. This required us to group geese species into dark (all Canada and white-fronted) and white (i.e., snow and Ross') geese. San Francisco Bay, adjacent to the Central Valley is surveyed only during the January (midwinter) survey. However, because it is a major wintering area for diving ducks, we included San Francisco Bay in a comparison of diving duck distribution at the time of the midwinter survey.

1998-2000-Due to the efforts of numerous cooperators, 7 aerial waterfowl surveys of the Central Valley were conducted between September – March, each in 1998-1999 and 1999-2000 (Table 1). Because the increased availability of flooded habitats (primarily harvested rice, Fleskes et al. 2005) would have made complete survey coverage infeasible, we developed a stratified transect survey method to survey waterfowl abundance in the Butte, Colusa, Sutter, American, Yolo, Delta, and Suisun Basins (Fig. 6). We stratified our survey effort among these basins according to waterfowl abundance and habitat area. We conducted complete surveys of NWRs and WAs and flew transects over rice fields and other wetland and agricultural habitats. We used calculated population densities on transects and estimated population abundances and standard errors across the full coverage of habitat (Cochran 1977). Similar to pre-CVJV surveys, waterfowl habitat in the San Joaquin Basin (mainly in the Grassland Ecological Area and vicinity) and Tulare Basin (mainly Mendota WA and Tulare Lake Bed and Kern NWR vicinity in the Southern San Joaquin Valley) was surveyed completely. Some areas were occasionally missed due to weather or logistical problems, but survey data were adequate to compare waterfowl distribution during 1973-1982 vs.1998-2000.

Data analysis- We plotted the abundance of each waterfowl species or species group by survey date, interpolated abundance between surveys, and estimated waterfowl distribution and use days in each basin or area by year and averaged years to calculate study period averages.

Radiotelemetry

We collected approximately 55,203 day and night duck locations and 1,850 roosting and feeding goose locations in California during the 1998-2000 study period to compare with approximately 95,000 waterfowl locations from the 1987-1994 study period. We used these locations to compare 1987-1994 vs. 1998-2000 weekly or seasonal (i.e., PREHUNT, HUNT1, SPLIT, HUNT2, POSTHUNT) movements and distribution among basins and specific areas, the relative importance of wetland and agricultural habitats for feeding and roosting, and daily flight distances for northern pintails, mallards, and greater white-fronted geese during September - April. We define five seasons: 1) PREHUNT-when the first duck was radiotagged duck in late August (Table 2) to the start of duck hunting season in late October (see “Harvest Regulations” section); 2) HUNT1-the first part of duck hunting season, 3) SPLIT-the 11 to 27 day period after the end of HUNT1 when duck hunting was not allowed or approximately the same period for years when hunting season was continuous; 4) HUNT2-the second part of the hunting season; and, 5) POSTHUNT-the end of HUNT2 to 1 April. To ensure that the 1987-1994 vs. 1998-2000 comparisons reflected study period differences and not differences related to bird age, bird sex, capture location, or tracking intensity, we replicated most 1987-1994 field methodology during 1998-2000 and otherwise tested for or controlled for methodology differences in analysis.

Capture and radiotagging- A total of 1,352 waterfowl during 1987-1994 and 577 waterfowl during 1998-2000 were captured and radiotagged for this study (Table 2). These totals includes ducks and geese for which direct comparisons of ecology across the 1987-1994 vs. 1998-2000 study periods were possible because age class, capture area, and capture period were the same during both study periods. Samples replicated during both study periods included: (1) 527 After-Hatch-Year (AHY) female pintails during 1987-1994 and 305 AHY female pintails during 1998-2000 radiotagged during PREHUNT in the Sacramento Valley (Sacramento and Delevan NWR in Colusa Basin), Suisun Marsh, or San Joaquin Valley (Grasslands EA in San Joaquin Basin and Mendota WA in the extreme northern part of Tulare Basin); (2) 70 female mallards (AHY and Hatch-Year [HY]) during 1988-1990 and 152 female mallards (AHY and HY) during 1998-2000 radiotagged during PREHUNT in Butte Basin in the Sacramento Valley; and (3) 86 adult female white-fronted geese radiotagged in Alaska during 1987-1990 and 120 adult female white-fronted geese radiotagged in Alaska during 1998-2000 (Table 2). The totals also include captures during 1987-1994 that were not replicated during 1998-2000 and were only included when modeling was conducted so that possible impacts of differences among study periods due to bird age, capture location, or capture period could be determined. Captures not replicated during 1998-2000 include: (1) 286 HY female pintails radiotagged during 1991-1994 PREHUNT in Suisun Marsh, Grasslands EA, or Mendota WA (no HY pintails were radiotagged during 1998-2000); (2) 28 HY and 47 AHY female pintails radiotagged during 1991-1994 PREHUNT in the southern part of the Tulare Basin (none radiotagged in the southern part of Tulare Basin during 1998-2000); (3) 19 HY and 6 AHY female mallards radiotagged during 1988-1990 PREHUNT in Sutter Basin (none radiotagged in Sutter Basin during 1998-2000); (4) 26 HY and 18 AHY female mallards radiotagged during the SPLIT between the first and second half of duck hunting season during 1988-1990 in Butte Basin (none radiotagged during SPLIT in 1998-2000); and (5) 220 adult female white-fronted geese radiotagged in the Klamath region of California-Oregon during 1987-1990 (none radiotagged in Klamath during 1998-2000). In addition, not included in the total were HY and male white-fronted geese radiotagged in Alaska and the Klamath region during 1987-1990 (none radiotagged during 1998-2000) and 237 green-winged teal radiotagged in Grasslands EA and Mendota WA during 1997-2000 (none radiotagged during 1987-1994). These were used for other studies but were not included for our study comparing 1987-1994 vs. 1998-2000 waterfowl ecology.

Pintails and mallards-We replicated earlier study field methodology during 1998-2000 for pintails (Miller et al. 1993, 1995, Fleskes 1999) and mallards (Heitmeyer 1989b, Day et al. 1990) including capturing and radiotagging birds on similar dates and in similar locations (Table 2), and distributing day and night tracking effort among regions in a similar manner. We captured pintails with rice-baited and unbaited rocket-nets (Schemnitz 1994) and mallards with grain-baited swim-in traps during late August – early October (additional mallards in Dec in 1988-1990) on public and private wetlands. We weighed (± 5 g), measured (flat wing, culmen 1, total tarsus [Dzubin and Cooch 1992] ± 0.01 mm), aged (HY or AHY; Larson and Taber 1980, Duncan 1985, Carney 1992), and legbanded some male and all females that we captured. Ducks were released at the capture location after processing. We exclusively attached 20-21-g pintail and 23-26-g mallard (2.0-3.2% of body mass) radio transmitters with back-mounted harnesses (Dwyer 1972), except in 1993, we attached 8-g spear-suture transmitters (Fleskes 2003) to 40 of the pintails in the San Joaquin Valley. Each transmitter had a unique signal, a mortality sensor, life expectancy ≥210 days, and an initial minimum range of 3.2 km ground-to-ground using a 150-db receiver and dual 4-element Yagi antennas mounted on the roof of a pickup truck. During both study periods, transmitters were imprinted with contact information and we solicited information from hunters by posting project descriptions at hunting check stations and in statewide media.

White-fronted geese- Methodology for the white-fronted goose radio telemetry study differed somewhat among study periods (1987-1990 vs. 1998-2000). Geese were captured outside the Central Valley during both study periods. However, during 1987-1990, 239 of 325 adult female white-fronted geese were captured and radiotagged in the Klamath Basin and only 13 were radiotagged in the Yukon-Kuskokwim Delta in Alaska (J. Takekawa, unpublished data). During 1998-2000, because the percentage of the white-fronted geese that bypass the Klamath Basin in fall greatly increased (Gilmer et al. 2004), and mortality of geese captured in Klamath during 1987-1990 was high, all 120 adult female white-fronted geese were captured and radiotagged in Alaska before the start of their southern migration. Geese were captured in Alaska near the Kashunuk and Manokinak Rivers on the central Yukon-Kuskokwim Delta (YKD; 61º20'N, 165º20'W) during late summer using aircraft to herd molting geese into corral traps (Cooch 1953). Geese were captured with rocket nets (Dill and Thornsberry 1950) on and near Tule Lake National Wildlife Refuge in the Klamath Basin only during 1987–1990, 221 in early fall during their southern migration towards the Central Valley and 18 in spring during their northern migration towards Alaska. We determined the age and sex of all geese captured, weighed and measured most adults (Orthmeyer et al. 1995), and radiotagged adult females. Geese were marked with USFWS Service leg bands, and either a 45-g radio transmitter attached to a backpack harness (1987 and 1988) or a 30-g solar radio transmitter glued to a yellow plastic neck collar individually identified with black digits (1989, 1999, and 2000; see Ely 1993, Ely and Takekawa 1996). Transmitter life was about 14 months for backpack radio tags and 24 months for solar-powered radio tags. Geese were released at the capture site.

Radiotag tracking- We tracked the movements of pintails and mallards from date of release after radio tagging (i.e., late Aug-early Oct) and white-fronted geese from date of arrival in the Central Valley (i.e., Oct-Nov) until they died, their radio tags failed, or they left the Central Valley in the spring (i.e., through late March or April). Nearly all radiotagged pintails and mallards were tracked in the Central Valley as part of this study. However, mortality and high failure of back-pack harness radio tags reduced the number of white-fronted geese tracked in the Central Valley during 1987-1990 to 100 (87 from Klamath, 13 from Alaska). During 1998-2000, only neck collar radio tags were used on white-fronted geese, and 92 of the 120 tagged in Alaska were tracked in the Central Valley.

We tracked radiotagged waterfowl from trucks and fixed-wing aircraft equipped with dual 4-element Yagi antenna systems; trucks had null-peak systems to accurately determine bearings, whereas aircraft had left-right systems to circle and pinpoint signals on either side of the plane (Gilmer et al. 1981). We recorded status (location, alive, or dead) of each radiotagged pintail, mallard, and goose approximately daily (1-2 times a day during the hunting season and at least every other day during non-hunting intervals) including sequential day and night locations for ducks and feeding and roosting locations for geese. We conducted weekly aerial searches (Gilmer et al. 1981) of waterfowl habitat and urban areas throughout Central California for missing radiotagged waterfowl. Cooperators helped search other areas, including northeastern, coastal, and Salton Sea California; Malheur NWR area, Willamette and Klamath Basins in Oregon; the Carson sink in Nevada; and the western coast of Mexico, 1-10 times each winter for pintails not found in Central California. We censored (i.e., excluded data thereafter) birds equipped with failing radios as evidenced by abnormal signals and any that shed their radios were censored on the date their radios were shed. We excluded any radiotagged bird from analyses if they did not adjust to their radios, as evidenced by their failure to make feeding flights and were killed by predators 1-6 days after marking.

We estimated locations of radiotagged waterfowl from trucks using 2 bearings obtained within several minutes of each other. We used only 2 bearings to minimize error caused by bird movements and because our initial tests indicated >2 bearings did not increase location accuracy in our open, flat study area. Warnock and Takekawa (1995) reported average error rates of 1.5 degrees for bearings, 58 ± 35 (mean ± SE) m for distances between true and calculated locations, and 1.1 ha for error-polygon size with similar truck systems and location distances (e.g. <3 km). We used a modified version of XYLOG and UTMTEL triangulation programs (Dodge et al. 1986, Dodge and Steiner 1986) to calculate Universal Transverse Mercator coordinates for each location.

Data analysis-We conducted a variety of analyses to address each of the study objectives for pintails, mallards and white-fronted geese.

Daily movements among basins- For purposes of estimating energetic needs and habitat requirements for each basin, estimates of waterfowl use of basins for feeding are required. To determine if daytime aerial waterfowl surveys adequately represent feeding distribution of waterfowl, we compared the day and previous or following night location used by pintails and mallards. Too few pairs of sequential roost-to-feed locations were obtained for white-fronted geese, so we simply compared overall distribution of roosting and feeding locations.

Distribution among basins- We used several methods to compare 1987-1994 vs. 1998-

2000 distribution of radiotagged waterfowl among basins. We first estimated weekly distribution among Central Valley basins by species and capture region, restricting study period comparisons to samples of the same aged individuals captured in the same area. Thus, we compared graphs of weekly distribution among basins for: 1) 1991-1994 vs. 1998-2000 for AHY female pintails radiotagged in the San Joaquin Valley (San Joaquin Basin and Mendota Wildlife Area), 2) 1991-1993 vs. 1998-2000 for AHY female pintails radiotagged in the Suisun Marsh, 3) 1987-1990 vs. 1998-2000 for AHY female pintails radiotagged in the Colusa Basin of the Sacramento Valley, 4) 1988-1990 vs. 1998-2000 for AHY and HY female mallards radiotagged in the Butte Basin of the Sacramento Valley, and 5) 1987-1990 vs. 1998-2000 for adult female white-fronted geese radiotagged in Alaska. To reduce bias associated with unequal and multiple sampling of individuals each week, we apportioned multiple weekly locations among areas and used a bird-week as the sample unit. For instance, if a bird was in the San Joaquin Basin during Sunday-Wednesday but in the Delta Basin during Thursday-Saturday, we apportioned 4/7 bird-weeks to San Joaquin Basin and 3/7 bird-weeks to the Delta basin for that week.

In addition to estimating weekly distribution among basins and visually comparing these graphs to determine if there were differences among study periods, we used categorical data modeling (Christensen 1997) to determine the importance of basin *x* study period effects (i.e., did distribution among basins differ among study periods?), relative to the effects of year within study period (i.e., was annual variation greater than variation among study periods?), and other variables that could impact distribution and may have varied among study periods. Variables included capture location, age, and capture mass of individuals in the sample (see Appendix 2 for variables included in models). Because we could control for the effects of bird age and capture location from study period in the analysis, and increased sample size improved model convergence, we included the HY pintails, pintails captured in the southern part of the Tulare Basin during 1991-1994, mallards captured in Sutter Basin or during the SPLIT in 1988-1990, and the adult female white-fronted geese captured in Klamath Basin during 1987-1990 in the appropriate analysis. We selected models using Akaike's Information Criterion (AIC_c) for small sample sizes (Burnham and Anderson 1998, Anderson et al. 2000) and graphed the AIC_c weight of each variable each week to show the relative importance of each factor. We conducted statistical analyses with SAS (SAS Institute Inc. 1999).

In addition, for white-fronted geese, we analyzed all adult females marked from both capture locations (Alaska and Klamath) but only using the first location per bird per month to reduce potential biases associated with varying sampling intensity. We conducted this additional analysis because the graphical comparison of weekly distribution was based on only the 13 birds radiotagged in Alaska and subsequently tracked in the Central Valley during 1987-1990 and the weekly AIC analysis included potential impacts of slightly different tracking intensity of geese among regions during the 1987-1990 vs. 1998-2000 study periods. For this additional modeling effort, we first modeled the relative importance of study period vs. marking location impacts on basin distribution. We conducted a basin distribution analysis on data collected from 1987–1990 and replaced the period effect with the capture location to examine whether differences in marking locations interacted with relative basin use. The best-fitting model contained month and year, but not capture location (log-likelihood=-453.37, N=300, K=30, AICc=973.64, Δ_i=0.0, w_i=0.66). Models that contained a capture location effect had a combined AIC_c weight of only 26%, compared to 74% without these effects, indicating that capture location did not have a large effect on goose distribution among basins. Thus, we pooled all white-front data from the two capture sites. Sparse use of some basins by geese caused all models with a month × basin interaction in our distributional analyses to fail to converge, making it impossible to evaluate month effects on basin distribution. Geese used Yolo Basin infrequently during both study periods, and most locations in Yolo Basin were concentrated in one area just south of the Sutter Basin so we combined Yolo and Sutter Basins to increase statistical convergence for all subsequent distributional analyses.

Distribution among local areas- We used an approach similar to the basin analysis to compare local distribution patterns among study periods. We first estimated and compared weekly distribution of radiotagged waterfowl, regardless of capture location, among local areas. Thus, we graphed and visually compared 1998-2000 weekly distribution of pintails among areas within the Grassland EA (Fig. 5) vs. 1991-1994, pintails among areas within the Suisun Marsh (Fig. 4) and Delta (Fig. 3) vs. 1991-1993, pintails and white-fronted geese among areas within the Sacramento Valley (Fig. 1, Appendix 3) vs. 1987-1990, white-fronted geese among areas within the Delta vs. 1987-1990, and mallards among areas within the Sacramento Valley vs.1988-1990. Because local distribution of pintails on shoot and nonshoot days was known to differ in the Grassland EA (Fleskes et al. 2002), and was not studied in the Suisun Marsh (Casazza 1995), we grouped weekly totals for these areas into shoot and nonshoot days during weeks of the duck hunting season.

Similar to the basin distribution analysis, in addition to visually comparing graphs of weekly local distribution, we used categorical modeling (Christensen 1997) to determine the importance of the local area *x* study period interaction (i.e., did distribution among local areas differ among study periods?) relative to the effects of year within study period (i.e., was annual variation more than variation among study periods?), and other variables that could impact distribution and may have varied among study periods (see Appendix 4 for variables included in models). We graphed the AIC_c weight of each variable each week to show their relative importance over time.

Use of roosting and feeding habitats- Waterfowl select wintering habitats mainly for resting and feeding but the timing when each occurs varies somewhat by species and season.

Pintails and mallards loaf during the day throughout the wintering period (i.e., August - March), but they feed extensively during both day and night before hunting season to replenish fat reserves depleted by breeding and fall migration (Miller 1985, 1986). During the hunting season, most feeding by pintails and mallards is at night, while loafing is the main daytime activity (Euliss 1984, Miller 1985). Daytime feeding increases again after the hunting season as ducks prepare for spring migration and nesting. Thus, habitat use by pintails and mallards at night mainly reflects feeding site selection during all seasons, day use during hunting season mainly reflects loafing site selection, and day use before and after hunting season reflects both feeding and loafing site selection. Therefore, to determine the relative importance of agriculture (vs. wetlands) during 1987-1994 compared to during 1998-2000 for pintails and mallards, we estimated the percentage of feeding locations in agriculture as the percentage of all (day and night) locations during PREHUNT and POSTHUNT and as the percentage of night locations during hunt. To compare importance of agriculture habitats (vs. wetlands) for roosting by pintails and mallards, we compared the percentage of day locations in agriculture during 1987-1990 vs. 1998-2000.

White-fronted geese generally fly from roosting to feeding sites each morning and evening to feed (Ely 1990, Ely 1992, Krapu et al. 1995). Therefore, we classified locations collected during morning (0531 to 1030 hr) and evening (1531 to 2230 hr) as feeding sites and mid-day (1031 to 1530 hr) and night-time (2231 to 0530 hr) as roosting sites. Whenever possible, we verified feeding and roosting locations with direct observations of radiotagged individuals or associated flocks. Waterfowl hunting seasons were ongoing during the start of our study and ended in the third or fourth week of January each year; therefore, November, December, and January data mostly represent hunting conditions whereas February and March data represent post-hunting conditions. We used every location recorded for habitat analyses and assumed that sampling intensity and detection probability were independent of habitat type. Sampling methodologies were similar between decades, so if any sampling biases did exist they would not have affected our assessment of changes in habitat use (i.e., they would be consistent biases). We analyzed habitat use among the 4 major categories and among the 4 rice sub-categories by repeating the same analysis used for basin distribution, except we replaced the basin variable with the habitat category variable or rice habitat sub-category variable, respectively. For the rice habitat sub-category analysis, we combined data from February and March because of low sample sizes in March and our models did not converge when we treated them as separate months.

Daily flight distance-Flight is energetically expensive relative to other activities (Tucker 1974, Norberg 1996) and the distance flown each day may greatly impact the amount of energy, food, and feeding habitat required to sustain goal waterfowl populations. In addition, average daily flight distance directly reflects the average distance between roosting and feeding habitats used by waterfowl, and provides a measure of the distribution of habitats actually used by each species. Thus, in addition to considering current waterfowl use vs. CVJV goal waterfowl use in each basin, the magnitude by which waterfowl flight distances and energetic requirements differ among basins and have changed over time in each basin should be considered when updating CVJV habitat goals.

We estimated daily flight distances for pintails, mallards, and white-fronted geese and compared distances among the 1987-1994 vs. 1998-2000 study periods. For pintails and mallards, we calculated straight-line distances for daily pairs of sequential day-to-night (last day location to first night location) and night-to-day (first day location to last location the previous night) locations within each basin, region (Sacramento Valley, Suisun-Delta), or area (e.g., Mendota WA, Southern San Joaquin Valley) during each season and then calculated an overall winter average for each study period based upon average season distances weighted by season duration (days). Comparisons of overall winter average flight distances provide a useful measure of how energy demands on birds vary among basins and differ among study periods. However, overall winter averages reflects both the impacts of hunting season duration and habitat conditions on flight distances. Because hunting season duration varied among study periods, and flight distance varied among seasons (especially hunting vs. non-hunting seasons), comparisons of seasonal flight distance are more useful than overall winter flight distance for measuring differences among basins and study periods in the distribution or availability of effective habitat.

Data from all seasons were available to compare: a) 1987-1990 vs. 1998-2000 flight distances for pintails in the American, Butte, Colusa, and Sutter Basins and overall Sacramento

Valley, b) 1991-1994 vs. 1998-2000 distances for pintails in Yolo, Delta, Suisun, and San Joaquin Basins and in Mendota WA, and c) 1988-1990 vs. 1998-2000 distances for mallards in Butte and Colusa Basins and Sacramento Valley overall. For white-fronted geese, we used the first feeding and roosting location collected each week for each bird. This reduced the dataset to no more than 5 roosting and 5 feeding locations per bird each month. We then calculated straight-line distances for all possible roosting and feeding location pairings. For example, if a bird had 2 roosting and 3 feeding locations, then there were 6 total pairings. We then averaged those distances for each bird, month, and roosting basin to calculated roost-to-feed distances.

RESULTS AND DISCUSSION

HABITAT AVAILABILITY

Changing or undefined methodology used to measure waterfowl habitat made definitive comparisons of habitat availability across study periods difficult. However, information was adequate to clearly show that the northerly shift in distribution of waterfowl habitats, which started well before the 1970s when Sacramento and Delta wetlands were mostly converted to rice and corn but San Joaquin wetlands were mostly converted to croplands of lower waterfowl value (Dasmann 1966, Gilmer et al. 1982), continued during our 1973-2000 study period.

Wetlands

Managed wetland area increased throughout the Central Valley during 1973-2000, but the increase was greater in the Sacramento Valley than in other regions (Fig. 7). Comparing 1987-1990 vs. 1998-2000, the proportion of total Central Valley managed wetlands present in the Sacramento Valley increased from 28% to 34%, whereas the proportion in the San Joaquin

Valley decreased from 44% to 42% (Fig. 7). Comparing 1979-1985 vs.1998-2000, the proportion of total Central Valley wetlands present in the Sacramento Valley increased from 26% to 34%, whereas the proportion in the San Joaquin Valley decreased from 49% to 42% (Fig. 7). However, wetland estimates for 1979-1985 included an unknown proportion of uplands. The greater difference between the 1979-1985 and 1987-1990 estimates (which were derived using GIS and do not include uplands) for the San Joaquin Valley compared to the Sacramento Valley (Fig. 7) indicates that uplands may have comprised a greater proportion of the 1979-1985 San Joaquin wetland estimate. Thus, the 1979-1985 vs.1998-2000 comparison probably exaggerates the true northerly shift in wetland distribution.

The largest area of wetland habitat restored by the CVJV and others during 1987-2000 included: (1) Llano Seco NWR, Upper Butte Basin WA (Llano Seco, Howard Slough, and Little Dry Creek units), Esquon Ranch, and Wattis Audubon Sanctuary in Butte Basin; (2) Vic Fazio WA in Yolo Basin; (3) Island Slough WA in Suisun Marsh (Fig. 4); (4) Stone Lake NWR and Consumnes Preserve in the Delta (Fig. 3); (5) San Joaquin River NWR, Arena Plains and North Units of Merced NWR, Bear Creek Units of San Luis NWR, and China Island, Gadwall, Salt Slough and Mud Slough WAs in the San Joaquin Basin, and; (6) additional units of Mendota WA in the northern Tulare Basin (Fig. 1).

Agricultural Habitat

The proportionate northerly shift of waterfowl-friendly agricultural habitat was greater than the relatively modest change in distribution of wetland habitat between 1973 and 2000. Total area of croplands that were intentionally winter-flooded increased 157% in the Sacramento Valley and 58% in the Delta but declined 23% in the San Joaquin Valley between 1973 and 2000

(Fig. 8). Thus, between 1973-1982 and 1998-2000, the percentage of Central Valley's total winter-flooded agricultural lands increased from 73.2% to 84.2% in the Sacramento Valley but declined from 18% to 12.7% in the Delta and from 8.9% to 3.1% in the San Joaquin Valley (Fig. 8). This large increase in winter-flooded agriculture in the Sacramento Valley resulted almost exclusively from a 146% increase in post-harvest winter-flooded rice (32,000 ha in 1979 [CDFG 1979] vs. 78,725 ha in 1999 [Table 3, Fleskes et al. 2005]). The increase in winter-flooded rice in the Sacramento Valley occurred for two main reasons. First, there was a return in the late 1990s of the large acreage of planted rice (e.g. 201,512 ha in 1999-2000), last seen during the 1970s (Fig. 9). Second, the percentage of Sacramento Valley rice acreage that was flooded after harvest increased (Table 3). In contrast, the area of planted rice in the San Joaquin Valley declined from an annual average of 36,180 ha during 1973-1982 to 4,533 ha during 1999-2000 (Fig. 9) and winter-flooded rice area in the San Joaquin Valley declined to <100 ha. Further, the maximum area of post-harvest flooded crops in the Tulare Basin (i.e. preirrigation) declined from 3,367 ha in 1982 and 4,452 ha during 1987-1990 to 2,475 ha in 1991-1994 and 2,792 ha in 1998-2000.

The increase in winter-flooded rice area in the northern Central Valley averaged 777 ha per year between 1988-1989 and 1993-1994, and 3,523 ha per year between 1993-1994 and 1999-2000. However, change in total and winter-flooded rice between 1988-1989 and 1999-2000 varied among northern Central Valley basins. Between 1988 and 2000, both total area of rice and winter-flooded rice increased in Butte (total +20%, flooded +62%), Colusa (total +30%, flooded +108%), American (total +40%, flooded +14%) and Sutter (total +14%, flooded +4%) Basins but declined in Yolo (total -10%, flooded -37%) and Delta (total -70%, flooded -1982%)

Basins (Table 3). The increases in winter flooded rice area in Butte and Colusa Basins were due to increases in both total rice area and percentage of rice that was winter-flooded, whereas in American and Sutter Basins, area of planted rice increased but the percentage that was winter-flooded declined. Both planted rice area and the percentage winter-flooded in Yolo and Delta Basins declined between 1988 and 2000.

Waterfowl Habitat Area

With wetland area increasing slightly more in the Sacramento Valley, and agricultural flooding increasing primarily in the Sacramento Valley, waterfowl habitat (wetlands + winter-flooded rice and other croplands) distribution shifted to the north (Fig. 10). Comparing 1987-1990 vs. 1998-2000, the percentage of total Central Valley flooded waterfowl habitat that occurred in the Sacramento Valley increased from 55% to 63% while the percentage in the San Joaquin Valley decreased from 24% to 20%. An even greater northerly shift in waterfowl habitat distribution is indicated by comparing 1979-1985 vs.1998-2000 totals (i.e., increased from 43% to 63% in Sacramento Valley and decreased from 35% 20% in San Joaquin Valley). However, with uplands likely comprising a greater proportion of the 1979-1985 wetland estimate for the San Joaquin Valley than for the Sacramento Valley, the 1979-1985 vs.1998-2000 comparison probably exaggerates the northerly shift in waterfowl habitat.

Timing of Flooding

Timing of flooding varied among habitat types, basins, and years. Most Central Valley wetlands were dry during the summer, except for periodic irrigations to promote seed production, and flooded during fall and winter. Most initial flooding of wetlands occurred from mid-August to late October, varying somewhat depending upon the opening date of duck hunting. Due to higher water costs, a smaller portion of wetlands received summer irrigation in Tulare than in other basins. Also, fall flooding of some wetlands was delayed in the south part of the Tulare Basin (excluding Mendota WA) to reduce evapotranspiration and coincide with the later opening date of the "Southern San Joaquin" duck hunting zone during 1991-1994 (see Harvest Regulations section below).

Timing and duration of post-harvest flooding of crop fields also varied among basins and years. Prior to 1992, flooding of harvested rice fields in the Sacramento Valley was almost exclusively for the purpose of duck hunting. These fields were flooded soon after harvest and were kept flooded until the end of waterfowl hunting season; exact timing of flooding depended upon timing of rice harvest and waterfowl hunting season dates. However, with increasing restrictions on rice straw burning beginning in 1992, an increasing portion of post-harvest flooded rice was for straw decomposition purposes. Flooding in all of these fields was not maintained throughout the winter (Fleskes, unpublished data). Managed post-harvest flooding of cropland in the Delta included fall flooding of harvested wheat fields to control johnsongrass (*Sorghum halepense*) and winter flooding of harvested corn and small amounts of rice and other crops for waterfowl hunting. Although fall flooding of Delta wheat fields declined between 1991-1994 (M. Casazza, unpublished data) and 1998-2000, and winter flooding of harvested rice declined between 1988-2000 in the Delta (Fleskes et al. 2005), peak estimates of winter flooding of corn and other non-rice crops in the Delta increased slightly during the study (Fig. 8). Little managed post-harvest flooding of croplands occurred in the Suisun or San Joaquin Basins during any period (Fig. 8), although significant late-winter flooding occurred in the San Joaquin Basin in some years due to precipitation (Fleskes 1999). In the Tulare Basin, post-harvest flooding of fields peaked during August – early November, when mostly safflower and other non-cotton fields were flooded. Cotton was the main crop type flooded after November (Fleskes et al. 2003). Unlike the Sacramento Valley and Delta, where most flooded fields were maintained throughout the duck hunting season, most fields in the Tulare Basin were flooded for only a few weeks. Further, since the early 1990s, the practice of very briefly (e.g., $\leq$1 day) flushing water across narrow bands of fields to remove salts and increase soil moisture has increasingly replaced post-harvest flooding.

Weather and Water Availability

Weather and water availability differed among study periods. During 1973-1982, water availability was adequate to allow normal fall flooding of managed habitats all years except 1981-1982, and midwinter rains provided additional habitat in all years except 1980-1981 (Table 4). During 1987-1994, dry-to-extreme drought conditions prevailed during most years, with low water availability restricting fall flooding in all years except 1993-1994, and little winter-rain flooding except during 1992-1993. During 1998-2000, water availability was adequate both to allow normal fall flooding of managed habitats but below-average winter precipitation produced little or no lowland or bypass flooding (Table 4).

HARVEST REGULATIONS

Waterfowl hunting season length and daily bag limits for ducks and geese varied during the 1973-2000 study period. Almost all of the Central Valley study area was included in the "Balance of the State" (BOS) zone. However, a "Southern San Joaquin Valley" (SSJ) zone that included the part of the Tulare Basin south of Mendota WA began with the 1991-1992 season, and sometimes had season dates that differed from the BOS zone. Although regulations allowed hunting on any day during the hunting season, nearly all duck clubs in the Grassland EA (main wintering area in the San Joaquin Basin) and wildlife areas and national wildlife refuges throughout central California, only allowed hunting on Wednesdays, Saturdays, and Sundays (i.e., shoot days). Merced NWR in the Grassland EA and Kern NWR in the southern part of the Tulare Basin only allowed hunting on Wednesdays and Saturdays, and many clubs in the Kern NWR vicinity adopted Wednesdays and Saturdays as their only hunting days. Many clubs outside the San Joaquin Valley allowed hunting any day of the season. Hunting season dates and bag limits differed for ducks and geese.

Ducks

Duck harvest regulations changed from liberal during 1973-1982, to restrictive during 1987-1994, to very liberal (except for restrictive bag limit for pintails and female mallards) during 1998-2000. Duck hunting season in the BOS zone ran a consecutive 93 days (mid Oct – mid Jan) during 1973-1982, 79 days (24 Oct – 10 Jan) during 1987-1988, but was shortened to 59 days during 1989-1994, with a 22-23-day late October to mid-November first season (HUNT1) and a 36-37-day second season (HUNT2) starting after an 11- to 27-day closure (i.e., SPLIT). The season in SSJ was the same as in BOS, except during 1991-1994, when the SSJ season ran 58 consecutive days from early or mid November to early or mid January. During 1998-2000, the season in both zones was extended to 100 consecutive days (10 or 16 Oct to 17 or 23 Jan), with an additional 1-2 days for junior hunters the first weekend after the regular season ended (CDFG 1973-2000).

The daily bag limit was the same in the BOS and SSJ zones. The daily bag limit was 6 – 7 ducks with no more than 5 – 7 mallards or 6 – 7 pintails during 1973 -1982, 5 ducks with $\leq$ 4 mallards [≤1 hen] or 4 pintails [≤1 hen] or 5 in aggregate during 1987-1988, 4 ducks with ≤ 3 mallards [≤1 hen] and 1 either-sex pintail during 1988-1994, and 7 ducks with ≤ 7 mallards [≤ 2 hens] and 1 either-sex pintail during 1998-2000. Thus, there was no difference in the daily bag limit of mallards and pintails during 1973-1982 and 1987-1988 (except 2 additional pintails were allowed in the 1974-1975 season), but 2 more mallards than pintails were allowed during 1988-1994, and 6 more mallards than pintails were allowed during 1998-2000 (CDFG 1973-2000).

Geese

Goose season length and bag limits varied among species and study periods. The general goose hunting season in BOS ran 93 days (mid Oct – mid Jan) during 1973 – 1980 and 79 days (late Oct – mid Jan) during 1980 – 2000. The season in SSJ was the same as in BOS except in 1991-1992 when the SSJ season was 65 instead of 79 days. After 1974, Canada goose seasons were reduced in special management areas that included all San Joaquin Basin and most Sacramento Valley WAs and NWRs to protect the Aleutian Canada goose (recently named the Aleutian cackling goose). After 1986, Canada goose season was closed entirely and white-fronted goose season reduced in special management areas that included most WAs and NWRs in the Sacramento Valley. Daily bag limits were revised as the status of populations changed, with restrictions placed on take of Ross', snow, Canada subspecies, or white-fronted geese. The daily bag limit varied during 1973 – 1982, with 6 geese allowed during 1973 – 1979 (≤ 3 dark during 1973 – 1975, ≤ 3 dark or white during 1975 – 1979), 2 geese during 1979 - 1980 (≤ 1 dark or 1 white), 4 geese during 1980 – 1981 (≤ 2 dark or 2 white), and 5 geese during 1981 – 1982 (≤ 2 dark or 3 white). The daily bag was 3 geese during 1987 – 1990 and 1998 – 2000 (≤ 1 dark unless both were large Canada geese during 1987 – 1990, ≤ 2 dark during 1998 – 2000).

OBJECTIVE 1. ASSESS CHANGES IN WINTERING WATERFOWL DISTRIBUTION IN THE CENTRAL VALLEY SINCE THE 1970s.

Comparisons of results of 1973-1974 and 1978-1982 (hereafter 1973-1982) vs. 1998-2000 aerial waterfowl surveys and 1987-1990 and 1991-1994 (hereafter 1987-1994) vs. 1998-2000 radio tracking of pintails, white-fronted geese, and mallards indicate that the distribution of waterfowl among Central Valley basins has changed.

Percentage of Total Central Valley Waterfowl Counted During Aerial Surveys in Each Basin, 1973-1982 vs. 1998-2000.

Comparisons of aerial waterfowl surveys during 1973-1982 vs. 1998-2000 indicate that distribution of waterfowl among Central Valley basins changed (Fig. 11), but changes differed among species and species groups.

Dabbling ducks- Dabbling ducks comprised the majority of waterfowl in the Central Valley, and pintails were by far the most abundant dabbling duck species, even during 1998-2000 though pintail populations failed to recover like other dabbling ducks. Thus, distribution graphs for waterfowl, dabbling ducks, and pintails were very similar and showed increased percentages of each in Sacramento Valley basins, especially after early winter, and decreased percentages in other basins (Figs. 11-12). In Tulare Basin, early winter use declined but late winter use did not. In the San Joaquin Basin, use was greater in 1998-2000 than 1973-1982 before mid-November but lower thereafter. The percentage of Central Valley pintails in Suisun, Delta, and Yolo Basins was lower during 1998-2000 than 1973-1982, especially in the Delta and Yolo Basins during late winter. The percentage of Central Valley pintails occurring in the East

Sacramento Valley increased greatly after early winter between 1973-1982 and 1998-2000. The percentage of pintails in the Colusa Basin increased slightly between 1973-1982 and 1998-2000. Distribution changes of most other dabblers also showed a northerly shift into Sacramento Valley basins, but distribution among Central Valley basins varied somewhat among pecies.

Similar to pintails, the percentage of total Central Valley green-winged teal occurring in Sacramento Valley basins increased between 1973-1982 and 1998-2000, with the percentage increasing in both the East Sacramento Valley and the Colusa Basin (Fig. 12). Although the percentage of green-winged teal in the San Joaquin Valley was similar in 1973-1982 and 1998-2000 during early winter, the percentage declined as winter progressed during 1998-2000. Even so, a higher percentage of total Central Valley green-winged teal ($\geq$35%) than pintails ($\geq$8%) were in San Joaquin or Tulare Basins throughout October-December even in 1998-2000 (Fig. 12).

The pattern of northern shoveler distribution among Central Valley basins was similar to green-winged teal, including the late-winter decline in the San Joaquin and corresponding increase in the East Sacramento Valley during 1998-2000 but not 1973-1982 (Fig. 12). However, unlike green-winged teal, the percentage of total Central Valley northern shovelers occurring in the Tulare and Yolo Basins was slightly greater during 1998-2000 than during 1973-1982.

Similar to pintail and green-winged teal, the percentage of total Central Valley mallards present in the San Joaquin, Yolo, and Delta Basins declined and the percentage in the East Sacramento Valley and Colusa Basins increased between 1973-1982 and 1998-2000. However, unlike for pintail and green-winged teal, the percentage of total Central Valley mallards in

Suisun and Tulare was slightly greater (mostly during early winter) during 1998-2000 than 1973-1982 (Fig. 12).

Similar to other dabbling ducks, gadwall also showed the pattern of decline in San Joaquin Basin and increase in East Sacramento Valley and Colusa Basins between 1973-1982 and 1998-2000, especially during late winter (Fig. 12). Similar to mallards, the percentage of total Central Valley gadwall present in Suisun Basin during early winter was greater during 1998-2000 than 1973-1982.

Cinnamon teal, American wigeon, and wood duck distribution patterns were not like other dabbling ducks (Fig. 12). In contrast to other dabbling ducks, cinnamon teal distribution did not shift north and the Tulare Basin increased in importance while the East Sacramento Valley declined in importance between 1973-1982 and 1998-2000 (Fig. 12). Sacramento Valley basins remained the main use area for American wigeon during both 1973-1982 and 1998-2000 (Fig. 12). Wood ducks are difficult to count using aerial surveys and the highly variable estimates did not provide strong indication of any shift in distribution between 1973-1982 and 1998-2000 (Fig. 12).

Diving Ducks- In contrast to dabbling ducks, the percentage of diving ducks during October – January in the San Joaquin and Tulare Basins was much greater during 1998-2000 than during 1973-1982 (Fig. 13). This percentage increase in the San Joaquin Valley corresponded to a decrease in the percentage of diving ducks in the Delta, Suisun, and Yolo Basins. The percentage of divers in Colusa and East Sacramento Valley Basins in 1998-2000 was lower than in 1973-1982 during early but not late winter. Canvasback, redheads, ringnecks, and ruddy ducks all strongly showed the increased importance of the San Joaquin Valley;

distribution of less common divers was highly variable (Fig. 13).

Most diving ducks in Central California (i.e., Central Valley and San Francisco Bay) winter in the San Francisco Bay (Fig. 14), where only the January "midwinter" survey was conducted. The percentage of total Central Valley divers in San Francisco Bay in January declined from 87% in the 1960s to 58% in 1970s but changed only slightly thereafter (60% in 1980s, 54% in 1990s; Fig. 14). The proportion of all Central California divers increased in all Central Valley basins except Tulare between 1960s and 1970s, mostly in the Yolo and Delta between the 1970s and 1980s, and almost exclusively in the San Joaquin and Tulare Basins between the 1980s and 1990-2001 (Fig. 14).

Geese- The percentage of all geese in the Delta, San Joaquin, and Colusa Basins declined and the percentage in East Sacramento Valley and Yolo Basins increased between 1973-1982 and 1998-2000 (Fig. 15). This distributional shift was most drastic for dark geese (all white-fronted and Canada species and subspecies). For instance, almost 50% of Central Valley's dark geese were in the Delta in late December during 1973-1982 but <10% were there during 1998-2000; the late December percentage in the East Sacramento Valley increased during the same period from <20% to 60%. Few Ross' and snow geese arrived before mid-November, after which distribution was similar during 1973-1982 and 1998-2000 (Fig. 15).

Swans- Similar to white geese, few swans arrived before mid-November. After mid-November, the percentage of Central Valley swans in the East Sacramento Valley was greater but the percentage in the Delta and Yolo Basins lower in 1998-2000 compared to 1973-1982.

Sandhill cranes- The percentage of Central Valley sandhill cranes surveyed in East Sacramento Valley and Colusa Basins was greater and in San Joaquin and Tulare Basins was lower during 1998-2000 than 1973-1982 (Fig. 15). However, because sandhill cranes regularly use uplands and other dry habitats, are less visible than large concentrations of geese, and were not the main focus of surveys, many were probably missed.

Change in Waterfowl Use Days in Each Central Valley Basin from Aerial Surveys, 1973-1982 vs. 1998-2000.

A comparison of waterfowl use days reflects not only changes in waterfowl distribution reported above, but also changes in the total abundance of waterfowl migrating to and wintering in the Central Valley.

Dabbling ducks- Total dabbling duck abundance during September - January (Fig. 16) and use days during October - December (Fig. 17) in all Central Valley basins combined were lower during 1998-2000 than during 1973-1982, primarily because of the decline in pintail abundance (Fig. 18). Dabbling duck and pintail abundance patterns varied among years during 1973-1982 in some basins but were fairly similar during both 1998-1999 and 1999-2000.

Except for pintails, which were less abundant in all basins during 1998-2000 compared to 1973-1982 (Fig. 18), use days (Fig. 19) and abundance patterns (Figs. 20-25) for other species differed greatly among basins and years. Mallards were more abundant in the Tulare Basin during 1998-2000 than 1973-1982 but counts were within range of earlier estimates in other basins (Fig. 20). Green-winged teal abundance was greater in the Central Valley during 1998-2000 than 1973-1982 but the timing of use in some basins varied between the early and later study periods (Fig. 21). For instance, similar to pintails, green-winged teal abundance peaked earlier in the (northern) San Joaquin Basin during 1998-2000 compared to earlier years. Abundance of American wigeon and northern shoveler during 1998-2000 was similar to 1973-

1982 in most basins (Figs. 22-23). Abundance of gadwall and cinnamon teal was greater during 1998-2000 than most years during 1973-1982 (Figs. 24-25). In the Tulare Basin, all ducks except pintails were more abundant during 1998-2000 than during 1973-1982 (Figs. 18, 20-25).

Diving ducks- Overall diver abundance in the Central Valley during 1998-2000 was greater than during 1973-1982 (Fig. 26), with 1 October – 31 December use days in 1998-2000 averaging 274% (annual avg. = 6,872,147; SE = 182,770) of the diver use days during 1973-1982 (annual avg. = 2,511,386; SE = 493,503) (Fig. 19). This increase was primarily because diver use during 1998-2000 in the San Joaquin Basin was 847% (annual avg. = 4,139,779, SE = 747,409) of the use during 1973-1982 (annual avg. = 488,454, SE = 78,493) and in the Tulare Basin was 823% (annual avg. = 989,084, SE = 321,739) of the use during 1973-1982 (annual avg. = 120,130, SE = 45,666). Diving duck use in 1998-2000 was also 430% of the 1973-1982 use in the Colusa Basin but was only 11% of the 1973-1982 use in the Delta and 63% of the 1973-1982 use in the Suisun Basin; diver abundance during 1998-2000 in Yolo Basin and the East Sacramento Valley was similar to most years during 1973-1982 (Fig. 26). The increase in diving duck abundance and percentage of all Central California (Central Valley and San Francisco Bay combined) divers that occurred within the Central Valley correlated with a decline in diver abundance in the San Francisco Bay between the 1960s and 1970s. However, the increase in diving ducks in the San Joaquin Valley and the Central Valley overall between the 1980s and 1990-2001 did not coincide with any consistent decrease in diver abundance in San Francisco Bay (Figs. 14, 27). Thus, the increase in divers in the San Joaquin Valley after the 1980s does not appear to be the result of diving ducks shifting out of the San Francisco Bay. Instead, abundance of diving ducks wintering in Central California increased between the 1980s and 1990-2001 and this increase occurred mainly in the San Joaquin Valley.

Geese- Overall goose abundance in the Central Valley during 1998-2000 was greater than during 1973-1982 (Fig. 28), with 1 October – 31 December total use days in 1998-2000 averaging 221% (annual avg. = 48,727,555; SE = 3,568,250) of the use during 1973-1982 (annual avg. = 22,092,225; SE = 2,655,809) (Fig. 19). This increase was primarily because 1998-2000 goose use in the East Sacramento Valley was 353% (1998-2000 annual avg. = 25,416,449; SE = 330,342) of the use there during 1973-1982 (annual avg. = 5,609,507; SE = 1,448,096) and goose use in the Colusa Basin was 152% of use during 1973-1982. Goose use also increased greatly in the Yolo Basin but the magnitude of use was only 10% of that in the East Sacramento Valley and had little impact on overall Central Valley abundance. The increase in goose use in the Colusa Basin occurred primarily during October (Fig. 28).

The increase between 1973-1982 and 1998-2000 in Central Valley abundance of dark geese was much greater than for white geese (Figs. 29-30). Total 1 October – 31 December dark goose use days in 1998-2000 (annual avg. = 48,727,555; SE = 3,568,250) averaged 221% of the use during 1973-1982 (annual avg. = 22,092,225; SE = 2,655,809) whereas white goose use days in 1998-2000 (20,854,987, SE = 5,819,408) averaged 130% of the use during 1973-1982 (16,011,898; SE = 1,979,363) (Fig. 19). Most of the increase in dark geese use occurred in the East Sacramento Valley where 1998-2000 use was 1,930% (annual avg. = 16,913,618; SE = 1,142,244) of the use during 1973-1982 (annual avg. = 876,245; SE = 204,803) and in the Colusa Basin where 1998-2000 use (annual avg. = 8,844,616; SE = 1,739,481) was 321% of the use during 1973-1982 (annual avg. = 2,757,402; SE = 629,210). The increase in dark goose use in the Colusa Basin primarily occurred during October (Fig. 29). Dark goose use also increased greatly in the Yolo Basin but the magnitude of use was only 10% of that in the East Sacramento Valley. Dark goose use during 1998-2000 in the Delta (annual avg. = 752,193; SE = 466,543) was 60% of the use during 1973-1982 (annual avg. = 1,250,504; SE = 453,366); October-December goose use in other basins was minimal during both periods.

Distribution of Radiotagged Pintails, Mallards, and White-fronted Geese Among Central Valley Basins, 1987-1994 vs. 1998-2000.

Pintails- Comparisons of 1987-1994 vs.1998-2000 weekly distribution of adult female pintails radiotagged in late August-early October in the Colusa Basin, Suisun Marsh, or San Joaquin Valley (Grasslands EA in San Joaquin Basin and Mendota WA in Tulare Basin) indicated that, while distribution of pintails radiotagged in Colusa Basin was similar during 1987-1990 and 1998-2000, distribution and timing of movements among Central Valley basins for pintails radiotagged in Suisun Marsh and the San Joaquin Valley differed somewhat during 1991-1994 and 1998-2000 (Fig. 31). Changes include: 1) an earlier northerly exodus of San Joaquin Valley pintails into the Delta and Sacramento Valley during 1998-2000 than during 1991-1994; 2) reduced percentage of Suisun pintails going to the San Joaquin Valley during 1998-2000 compared to during 1991-1993; 3) increased early-season use of Suisun Marsh and reduced early-season use of Yolo and Delta by Suisun Marsh pintails; and 4) increased late-season use of the Yolo Basin by all pintails (Fig. 31). Most pintails from Suisun Marsh and San Joaquin Valley moved to the Sacramento Valley by December, and once there, had distribution similar to pintails radiotagged in the Sacramento Valley (Fig. 31).

Modeling of basin distribution that included all radiotagged pintails (i.e., in addition to above, includes 1991-1994 HY pintails tagged in Suisun and San Joaquin Valley and HY and

AHY tagged in the southern Tulare Basin), indicated study period differences during only a couple of weeks (e.g., week 16 day locations or week 9 night locations) for pintails tagged in the Sacramento Valley but during several (day) or most (night) weeks for pintails tagged in Suisun Marsh and San Joaquin Valley (Fig. 32). Year-within-study period was important during most weeks for pintails tagged in Sacramento Valley but not other areas. Basin distribution differed by capture location during the first few weeks after capture for Sacramento (Sacramento vs. Delevan NWR) and San Joaquin Valley pintails (Grassland EA vs. Mendota WA vs. south Tulare Basin). It also differed by age (HY vs. AHY) during mid-winter for Suisun Marsh pintails and during late-winter for San Joaquin Valley pintails. Distribution differed by capture mass during only a few weeks.

Mallards- Except for decreased late-winter use of the Delta and Yolo Basins and increased late-winter use of the Butte Basin during 1998-2000, weekly distribution of mallards that were radiotagged in Butte Basin was similar to during 1988-1990 (Fig. 33). Most mallards tagged in the Butte Basin remained in Sacramento Valley basins September – February during both periods with ≥76% remaining in the Butte Basin through December each year.

Modeling of mallard distribution among basins that included all mallards radiotagged (i.e., in addition to above, includes mallards tagged in 1988-1990 during PREHUNT in Sutter Basin and Nov-Dec. in Butte Basin) indicated that basin distribution differed among study periods during a few early- and most late-winter weeks (Fig. 34a). This reflected the decreased late-winter use of Yolo and Delta Basins and the increased late-winter use of Butte Basin. Mallard distribution among basins differed by capture location (i.e., Butte vs. Sutter Basin) during the first half of the winter. Age, capture body mass, and capture season did not have a large impact on distribution of mallards among basins.

White-fronted geese— Distribution of greater white-fronted geese differed drastically between 1987-1990 and 1998-2000. Comparison of weekly distribution of all locations of adult female white-fronted geese radiotagged in Alaska shows increased use of the Sutter, Yolo, and American Basins, decreased use of Butte Basin, and greatly decreased late-winter use of the Delta during 1998-2000 compared to during 1987-1990 (Fig. 35). Distribution based only on the first roosting and feeding location each month of adult female geese radiotagged in Alaska or Klamath Basin (only in 1987-1990) indicates an even greater shift out of the Delta and into the American Basin in 1998-2000 compared to 1987-1990 (Table 5, Fig. 36). The AIC model weights indicated a strong study period effect, with the 3 most parsimonious models explaining distribution of white-fronted geese among basins including a basin × study period interaction; models that contained basin × study period interactions had a combined AIC_c weight of 99% (Ackerman et al. 2005). The study period effect was most prevalent during early and late winter (Fig. 34b), corresponding with reduced early-winter use of Butte Basin, reduced late-winter use of the Delta, and increased use of American, Sutter, and Yolo Basins (Figs. 35-36). Very few geese (<1%) were located in the San Joaquin Valley or Suisun Marsh during either study period.

OBJECTIVE 2. IDENTIFY CHANGES IN WINTERING PINTAIL, MALLARD, AND WHITE-FRONTED GOOSE MOVEMENT PATTERNS AND USE OF SPECIFIC FEEDING AND ROOSTING SITES DURING THE LAST DECADE.

Distribution and Movements of Radiotagged Pintails in the Grassland Ecological Area,

1991-1994 vs. 1998-2000.

Although general patterns of pintail distribution and movements within the Grassland EA were similar during 1991-1994 and 1998-2000, there were many changes in pintail use of individual areas. During both study periods, pintail distribution and movements in the Grassland EA differed among seasons (PREHUNT, HUNT1, HUNT2, POSTHUNT), diurnal periods (day, night), and for shoot and nonshoot days (See Fig. 37 for percent in each area each week, Fig. 38 for maps of pintail locations, and Fig. 39 for maps of day-night movements by season and shoot-nonshoot days).

PREHUNT use of private areas during both day and night was greater during 1998-2000 than during 1991-1994. This increase in PREHUNT use of private clubs was due to an increase in PREHUNT flooding on clubs, and may also reflect that a greater percentage of our Grassland EA sample was captured on private areas in 1998-2000 (92%) than during 1991-1994 (47%). The increase in PREHUNT flooding of private wetlands was due to several factors including improved water supplies and response of duck hunting clubs to research that showed pintails were more likely to use areas during hunting season that they used during PREHUNT (Fleskes et al. 2002). In addition, the Grassland Habitat Management Coordination Committee encouraged PREHUNT flooding of private areas, restored wetlands, and established the Gadwall WA sanctuary unit in the south grasslands to distribute waterfowl more widely throughout the Grassland EA. During 1991-1992, 4 previous years of below-normal precipitation throughout California (California Department of Water Resources 1991; National Oceanic and Atmospheric Administration, Asheville, North Carolina, USA, unpublished data) resulted in record low water deliveries to the Grassland Water District. This prevented irrigation during May-July and delayed fall flood-up of many private wetlands in the Grassland EA for 2 weeks (Grassland Water District, Los Banos, California, USA, unpublished data). WAs and NWRs in the Grassland EA received more normal water deliveries. Grassland EA wetland conditions improved after January 1992 because of above average precipitation and higher water levels in reservoirs. Conditions in the Grassland EA were further improved after the 1992-1993 season, when the Central Valley Project Improvement Act (Davis 1992) nearly doubled the amount of water delivered to the Grassland Water District (Grassland Water District, Los Banos, California, USA, unpublished data). Mean weekly availability of wetlands in the Grassland EA during PREHUNT increased from 5,385 ha in 1991-1992, to 6,698 ha in 1992-1993, 9,603 ha in 1993-1994 (Fleskes 1999), and ≥10,000 ha during 1998-2000. Changes in water delivery patterns and the locations where we radiotagged pintails caused other differences in pintail use of individual areas. For instance, during 1999, work on water delivery canals delayed flooding and reduced early use of Kesterson NWR.

Day and night distribution during HUNT differed during 1991-1994 and 1998-2000. During HUNT in both study periods, most pintails followed a pattern of roosting on sanctuaries on shoot days and flying to duck clubs in the evening. More pintails remained on clubs on nonshoot than shoot days (Figs. 37-39). However, because duck hunting season was closed during the SPLIT during 1991-1994, but there was no hunting closure "split" during 1998-2000, pintails spent more days during the winter on San Luis NWR and other NWR and WA sanctuaries during 1998-2000 (Fig. 37). Restoration of wetlands on the newly established Arena Plains NWR increased pintail use of this area, especially at night. Arena Plains NWR was the third most important shoot day roost site during early-hunt in 1998-1999 whereas, during 1991-

1994, use was minimal except during PREHUNT. Most of the pintails that roosted on Arena Plains went to North and East Clubs at night. Pintail use of Kesterson NWR was lower during 1998-2000 than 1991-1994, probably due to delayed flooding and reduction in size of Kesterson's "Gadwall" sanctuary unit when the "Gadwall" WA unit sanctuary in the South Grasslands was established. The "Gadwall" WA unit sanctuary in the South Grasslands received use throughout PREHUNT and early-hunt during 1999-2000 and was likely one of the reasons for the increase in use of the South Grasslands by pintails that year. Pintail use of Los Banos WA was lower during 1998-2000 than 1991-1994. Earlier analysis of 1991-1994 pintail movements indicated a link between Merced NWR and the South Grasslands (Fleskes et al. 2002). A review of day-night movements shows this link was still evident during 1998-2000, but there was also an increase in movement of pintails roosting on Merced NWR to east grassland areas. During the late-hunt season of 1993-1994, the recently created watergrass wetlands of Salt Slough WA began to receive use by pintails at night. Although some night use of Salt Slough WA was still evident during 1998-2000, most pintails flying out of San Luis NWR at night still went to North or South Clubs.

Although there was wide annual variation in pintail distribution during POSTHUNT, there was no consistent change between 1991-1994 and 1998-2000. During POSTHUNT in both 1991-1994 and 1998-2000, most pintails abandoned public areas and went to private wetlands, where they reduced their movements and used the same areas during both day and night.

AIC analysis indicated that pintail distribution among Grassland EA areas was related to study period during 3 (day) or 6 (night) weeks; all factors combined including study period were important during 9 weeks (Fig. 40a). Capture (sub)area (e.g., San Luis NWR, South Grassland

Clubs, etc.) combined with year was related to distribution among Grassland EA areas during the first few weeks after capture but capture subbasin (e.g., Mendota WA, Tulare, Grassland EA, Suisun Marsh, other) was not. Capture weight combined with year were related to distribution in the Grassland EA during a few weeks.

Distribution of Radiotagged Pintails in Suisun Marsh, 1991-1993 vs 1998-2000.

Day- Daytime use of Suisun Marsh areas by pintails differed greatly between 1991-1993 and 1998-2000. (See Fig. 41 for percent of pintails in each area each week; Fig. 42 for maps of day and night locations; and Fig. 43 for maps of day-night movements by season and shoot-nonshoot days). During 1991-1993, Grizzly Island WA received the bulk of the early winter daytime use, and use of private duck clubs increased as they flooded. In 1998-2000, Island Slough WA, the area where we captured most of our sample, received most early PREHUNT use. Grizzly Island WA provided PREHUNT habitat during both study periods, but private clubs were much more important in 1998-2000 than 1991-1993. Once hunting season began, daytime use shifted almost exclusively to Joice Island WA in 1991-1992, with Hill Slough WA also important in 1992-1993 (the west side of Hill Slough WA was not flooded in 1991). During 1998-2000, daytime hunting season use of Joice Island WA was much lower and pintails were more evenly distributed among Hill Slough, Joice Island, Grizzly Island, and private clubs. Day use in 1999-2000 increased for the West Side WA Units compared with previous years. Pintails began to use private wetlands again during the day after hunting season ended during both study periods.

Night- Nightime distribution in Suisun Marsh was fairly consistent between the two study periods. Grizzly Island WA received much of the early winter use at night while private wetlands received most of the night use thereafter. Grizzly Island WA was more important at night during 1999-2000 than 1991-1993. Night use of Island Slough WA was also evident during 1998-2000.

Distribution of Radiotagged Pintails (1991-1993 vs. 1998-2000) and White-Fronted Geese (1987-1990 vs. 1998-2000) in the Delta.

Pintails—Pintail distribution in the Delta was somewhat different during 1991-1993 and 1998-2000. During both study periods, Mandeville Island, Rindge Tract, Bouldin Island, Venice Island, and Webb Tract in the central Delta received the bulk of pintail use and Mandeville Island was the major hunting season day roost site (See Fig. 44 for weekly distribution, Fig. 45 for maps of locations, Fig. 46 for maps of day-night movements). However, changing management, habitat restoration, or other factors increased pintail use of Prospect Island and the Consumnes Preserve in the north Delta and Twitchell Island in the central Delta. In addition, pintails use of duck clubs in the lower Yolo Bypass and Staten Island in the upper-mid Delta during PREHUNT and early weeks of HUNT declined drastically between 1991-1993 and 1998-2000. There was little daily interchange of pintails between Suisun Marsh and the Delta as most pintails that roosted in either region remained there at night (Fig. 46).

AIC ranking of models indicated that distribution among Delta areas between the 1991-1993 vs. 1998-2000 study periods differed more during the day than at night (Fig. 40b). Pintail distribution within the Delta did not vary greatly by capture region (Suisun Marsh, San Joaquin Valley) or age-class of individuals (Fig. 40b).

White-fronted geese— Distribution of white-fronted geese within the Delta was generally similar during 1987-1990 and 1998-2000 with a few changes (Fig. 47). During both study periods, most white-fronts roosted and fed on Mandeville and other central Delta islands. Similar to pintails, there was an indication that white-fronted goose use of Staten and other upper-mid Delta islands was lower during 1998-2000. However, comparisons with 1987-1990 are tentative because few of our radiotagged white-fronts went to the Delta during 1998-2000. Data were insufficient to test for study period impacts using AIC ranking of models.

Distribution of Radiotagged Pintails, Mallards, and White-fronted Geese in the Sacramento Valley, 1987-1990 vs. 1998-2000.

Pintails- In general, pintail distribution and movement patterns in the Sacramento Valley were similar during 1987-1990 and 1998-2000. However, there were some differences (Figs. 48-50).

Daytime- Pintail day use in September was concentrated on Delevan, Sacramento (where we captured pintails), and Colusa NWRs (i.e., WESTNWRS, Fig. 48) in the Colusa Basin during both the 1987-1990 and 1998-2000 study periods. Pintails dispersed easterly into Butte, American, and Sutter Basins as winter progressed during both study periods, but use of WESTNWRs during October-January remained slightly higher during the 1998-2000 than the 1987-1990 study period. Day use of lands where Llano Seco NWR, Upper Butte Basin WA, and Wattis Sanctuary were established in the Butte Basin during the 1990s (i.e., NEWWANWRs, Fig. 48) was much higher during 1998-2000 than 1987-1990. These new Butte Basin areas didn't appear to have attracted an increased portion of Central Valley pintails into Butte Basin (based upon a similar percent of radiotagged pintails using Butte Basin during 1998-2000 and 1987-1990 [Fig. 31]). Rather, the new areas have apparently dispersed day use of pintails within Butte Basin among more public areas, thus decreasing the proportion using MIDWANWR (i.e., Graylodge WA, Butte Sink NWR and Sutter NWR; based upon percentage of use in MIDWANWR in 1987-1990 approx. equal to percentage of use in MIDWANWR + NEWWANWR in 1998-2000, Fig. 48). We speculate that the reason for the decline in pintail day use of the upper "District 10" portion of the American Basin (DISTRICT, Fig. 48]) was because several hundred acres of non-hunted flooded rice was available in the lower part of the American Basin (i.e., OTHAMERI, Fig. 48) during 1998-2000 but not 1987-1990. This may have reduced the percentage of pintails using District 10. Unlike in the Grassland EA, distribution in the Sacramento Valley on shoot and nonshoot days during the hunting season was similar, as most pintails in the Sacramento Valley returned to sanctuaries on both shoot and nonshoot days (Fig. 51).

Nighttime- Pintail night use in September during both 1987-1990 and 1998-2000 was similar to day use and was concentrated on WESTNWRS (Fig. 48). However, unlike day use, night use of WESTNWRs declined to <5% by mid-October during both study periods. Most night use occurred on private lands in the Colusa, Butte, and American Basins (i.e., OTHCOLUS, OTHBUTTE, OTHAMERI, and OTHLCSCUT, Fig. 48), reflecting pintail selection of rice fields for nocturnal feeding. Similar to day use, night use of District 10 was lower during 1998-2000 than 1987-1990. We speculate this resulted from the large increase in flooded rice lands, providing feeding areas near day roost sites and reducing the need to fly to District 10 to forage at night. Night use of NEWWANWRs increased only slightly, whereas night use of OTHCOLUS during October-December and OTHAMERI during February was drastically greater in 1998-2000 than in 1987-1990 (Fig. 48). Modeling indicated that daytime distribution of pintails radiotagged in the Sacramento Valley among Sacramento Valley areas differed more weeks among study periods than did night distribution (Fig. 52a), reflecting greater impact of NEWNWRs on daytime roost distribution (Fig. 48).

Mallards—Use of Sacramento Valley areas by mallards radiotagged in the Butte Basin differed during 1988-1990 and 1998-2000 (See Fig. 53 for weekly distribution, Fig. 54 for location maps, Fig. 55 for day-night movement maps). Changes in daytime distribution included greatly increased use of NEWWANWR and MIDWANWR, greatly decreased use of BSNKCLUB, and slightly decreased use of WESTNWRS (Fig. 53). Changes in night distribution included decreased use of WESTNWRS, greatly increased early-winter use of MIDWANWR, increased late-winter use of OTHBUTTE, and decreased late-winter use of OTHCOLUS (Fig. 53). The large early-winter increase in day and night use of MIDWANWR and early-winter decrease in BSNKCLUB was likely because a greater percentage of the 1998-2000 radiotagged sample was captured on MIDWANWRs (74% in 1998-2000 vs. 16% in 1988-1990) and a lower percentage were captured on BSNKCLUBs (0% in 1998-2000 vs. 42% in 1988-1990) (Table 2). However, while trapping location differences explain the early-winter decline in day use of BSNKCLUB, the mid- and late-winter decline in day use of BSNKCLUB clubs was probably due to the attraction of NEWWANWRs and/or unknown changes in BSNKCLUB that reduced day use there (e.g., habitat changes, increased hunting pressure, loss of private sanctuaries). Similar to pintails, during both 1988-1990 and 1998-2000, most mallard day use was on NWRs and WAs (e.g., MIDWANWR) reflecting their need for sanctuary from hunting disturbance and most night use was on private areas (e.g., OTHBUTTE, OTHCOLUS, Fig. 53) reflecting nocturnal foraging in rice fields. AIC ranking of models that included all radiotagged mallards, including those captured in Sutter and during the SPLIT, indicated that day distribution differed among study periods during most weeks during mid- to late-winter but night distribution did not change (Fig. 52b). Capture location impacted distribution among Sacramento Valley areas for several weeks after capture (Fig. 52b).

White-fronted geese—Roosting and feeding distribution among Sacramento Valley areas of white-fronted geese radiotagged in Alaska and Klamath in 1998-2000 differed somewhat from 1987-1990 and changes were unlike those for ducks.

November-January white-fronted goose roost and feeding use of DISTRICT increased greatly, OTHLCSCUT increased slightly, and WESTNWRS decreased slightly between 1987-1990 vs. 1998-2000. These changes were most evident during November (Fig. 52c and 56). Feeding use of WESTNWR declined more than roosting use (Fig. 56). In contrast to increased use by pintails and mallards, white-front use of NEWWANWR for roosting declined to near zero in 1998-2000 (Fig. 56). Also, unlike for pintails and mallards, >50% of white-fronted goose roost locations during both 1987-1990 and 1998-2000 were outside NWRs and WAs (Fig. 56).

OBJECTIVE 3. DETERMINE IF WINTERING PINTAILS, MALLARDS AND WHITE-FRONTED GEESE HAVE CHANGED THEIR USE OF WETLAND AND AGRICULTURAL HABITAT TYPES IN THE CENTRAL VALLEY DURING THE LAST DECADE.

General Habitat Use Patterns

The percentage of pintail, mallard, and white-fronted goose locations in agricultural habitats varied by species, feed and roost intervals, seasons, basins, and study years (Figs. 57 and 58). In the four Sacramento Valley basins (American, Butte, Colusa, Sutter) where we had data for all three species during HUNT and POSTHUNT seasons, use of agriculture habitats (averaged across basins, seasons, feed and roost intervals, and years) was greater by white-fronted geese (73% of locations) than by pintails (64%) or mallards (53%). Agricultural habitats in the Sacramento Valley (averaged across basins, HUNT and POSTHUNT seasons, and years) were used more during feeding than roosting intervals (white-fronted geese = 82% vs. 63%; pintails = 80% vs. 48%; mallards = 66% vs. 36%) and (averaged across basins, feed and roost intervals, and years) less during PREHUNT vs. HUNT and POSTHUNT by pintails (34% vs. 58% and 59%) and mallards (17% vs. 51% and 56%). Too few white-fronts were in the Central Valley during PREHUNT to compare with HUNT (74%) and POSTHUNT (72%) use. Among basins, agriculture was used primarily for feeding by pintails in Sacramento Valley and Delta Basins (except during PREHUNT in Butte and Colusa Basins) but used little in Suisun and the San Joaquin Valley basins (except agriculture primarily used during PREHUNT in the southern part of Tulare Basin). Pintails primarily roosted in agriculture only in the American, Yolo, and Delta Basins, as well as during POSTHUNT in Butte and Sutter Basins in some years. Agriculture use by mallards and white-fronted geese was greater in the American Basin than in other Sacramento basins.

Change in Habitat Use, 1987-1994 vs. 1998-2000

Overall, the relative importance of agricultural (vs. wetland) habitats for pintails, mallards, and white-fronted geese wintering in the Central Valley was greater during 1998-2000 than during 1987-1994. However, the change varied by basin, species, season, and feeding or roosting interval (Tables 6-198, Figs. 57-58). Among basins, pintail use of agriculture increased in Sacramento Valley basins, decreased slightly in the Delta, and changed little in Suisun and

San Joaquin Valley Basins. Within Sacramento Valley basins, agriculture use generally increased more for mallards and pintails than for white-fronted geese. Agricultural use increased during all seasons and for both feeding and roosting. Both feeding and roosting use of agriculture by mallards and pintails increased more between study periods during POSTHUNT than during PREHUNT or HUNT (Tables 6-7). Specific changes varied by species.

Pintails-The use of agriculture by pintails increased in the Sacramento Valley, decreased slightly in the Delta, and changed little in Suisun and San Joaquin Valley Basins (Table 6, Figs. 57-58). The percentage of pintail locations in agricultural habitats was greater in 1998-2000 than 1987-1990 during both feeding (day and night in PREHUNT and POSTHUNT, night during hunt) and roosting periods (day all seasons) in all four Sacramento Valley basins (American, Butte, Colusa, Sutter) during all seasons. The one minor exception was that roosting in agriculture in Colusa Basin during PREHUNT declined slightly from 6% in 1987-1990 to 2% in 1998-2000 (Table 6). There were too few PREHUNT locations in Sutter Basin to compare use among years. During both 1991-1994 and 1998-2000, agriculture received <1% of the pintail use in the Suisun Basin, 1-7% of the pintail use in the North San Joaquin Basin, and <1% in Mendota WA in the northern part of the Tulare Basin. In the southern part of the Tulare Basin (mostly in Tulare Lake Bed and Kern NWR vicinity), 85% of pintail locations during PREHUNT and 7-15% during HUNT and POSTHUNT were in agriculture during 1991-1994 (too few locations during 1998-2000 to compare).

Mallards-Similar to pintails, mallard use of agricultural habitats was greater in 1998-2000 than 1987-1990 in Sacramento Valley basins during most periods and seasons (Table 7, Figs. 57-58). During PREHUNT, feeding use of agriculture increased in Sutter Basins, but did not change in American, Butte, or Colusa Basins. PREHUNT roost use of agriculture increased in Butte and Sutter but decreased in Colusa (too few locations in American Basin in 1998-2000 for comparison). During HUNT, feeding use of agriculture increased greatly in all 4 Sacramento Valley basins and roost use increased somewhat in Butte and Colusa Basins. Feeding and roosting use of agriculture increased in all 4 Sacramento Valley basins during POSTHUNT.

White-fronted geese-Use of agricultural habitats by white-fronted geese was greater in 1998-2000 than 1987-1990 in only some Sacramento Valley basins (Table 8, Figs. 57-58). Use of agriculture during HUNT and POSTHUNT feeding periods increased in Colusa and Sutter Basins but was similar in American and Butte Basins. Likewise, roosting use of agriculture in Colusa and Sutter Basins during HUNT and POSTHUNT was greater in 1998-2000 than in 1987-1990, but roost use of agriculture in the American Basin during HUNT and POSTHUNT was similar among years (>97% of locations) and roost use in Butte Basin declined in HUNT and POSTHUNT.

Among the 4 main habitat type categories (rice, wetland, upland, and other crops), white-fronted geese roosted primarily within rice habitat (1987–1990: 40% and 1998–2000: 54%) and also fed within rice habitat (1987–1990: 57% and 1998–2000: 72%; Table 9). Use of rice habitat increased between decades, whereas use of wetlands declined for both roosting and feeding. Within each decade, a higher proportion of feeding sites were in rice habitat compared to roosting sites, whereas a higher proportion of roosting sites were in wetlands compared to feeding sites.

Within rice habitats, geese roosted primarily in post-harvest burned rice during 1987–1990 (43%), whereas they roosted primarily in post-harvest flooded rice during 1998–2000

(78%; Table 10). Similarly, geese fed mainly in post-harvest burned rice during 1987–1990 (34%) and post-harvest flooded rice during 1998–2000 (64%; Table 10). Use of post-harvest burned rice decreased by 40% for roosting and 28% for feeding sites between decades, whereas use of post-harvest flooded rice increased by 53% for roosting and 54% for feeding sites (Table 10). Although we did not measure change in availability of burned rice fields among study periods, the California Rice Straw Burning Reduction Act of 1991 increasingly restricted rice-straw burning after 1991 reducing the availability of burned fields (Hill et al. 1999). During the same time, post-harvest flooding of rice fields as an alternate straw decomposition method greatly increased (Fleskes et al. 2005).

OBJECTIVE 4. EVALUATE WETLAND AND AGRICULTURAL HABITAT GOALS OF THE CVJV AND MAKE RECOMMENDATIONS FOR CHANGES IF APPROPRIATE.

Results of this study indicate that some revision of CVJV habitat goals is appropriate because: 1) improved estimates of historic waterfowl use are available, 2) waterfowl distribution has shifted into the Sacramento Valley in response to habitat changes, 3) waterfowl daily energy requirements have declined in some basins, 4) waterfowl daily energy requirements may differ among basins, and 5) waterfowl continue to obtain most of their energy in agricultural habitats despite increased wetland area.

Day-time Surveys Adequately Represented Feeding Basin

Radiotracking showed that nearly all pintails (86-100%) and mallards (92-100%) used the same basin during the day (mostly roosting during winter) and night (mostly feeding during winter) (Table 11). Likewise, for white-fronted geese, the percentage feeding in each basin was either identical or very similar to the percentage roosting in that basin (Table 5). Thus, daytime aerial surveys adequately represented pintail, mallard, and white-fronted goose use of basins for feeding. Because these species are among the most wide-ranging of waterfowl, it is likely that day-time surveys also adequately represent feeding use of basins by all waterfowl species. Thus, these data are appropriate to estimate waterfowl use-days and calculate energy requirements and habitat needs in each basin.

Waterfowl Use Days during 1998-2000 Different Than CVJV Goals

Use days during 1998-2000 in some basins for some species differed greatly from CVJV goals (Figs. 59-60). This occurred for three reasons: 1) abundance of waterfowl wintering in the Central Valley during 1998-2000 was below CVJV goals; 2) CVJV basin goals were estimated assuming waterfowl abundance in each basin peaked at the time of the midwinter survey, whereas 1998-2000 periodic surveys show that peak abundance for some basins occurred well before (e.g., San Joaquin, Fig. 61) or after (e.g., American Basin, Fig. 61) the midwinter survey and probably did during the 1970s as well; and 3) waterfowl distribution among basins has changed since the 1970s (Fig. 11). The importance of each factor varied among basins.

1) Wintering waterfowl abundance in 1998-2000 different than goal- Wintering waterfowl abundance and use-days in the Central Valley during 1998-2000 were below CVJV goals mainly because of the lack of northern pintails. Northern pintail breeding populations in North America during 1998 and 1999 continued to be well below NAWMP goals (Wilkins and Cooch 1999) and resulted in pintail wintering abundance (Fig. 62) and use days (Fig. 59) in the Central Valley that were about a third of CVJV goal levels. In contrast, breeding populations of most other waterfowl species were at or above NAWMP goals, and although individually less abundant than pintails in the Central Valley during winter, were at or above CVJV goals during 1998-2000 (Figs. 63-74). Winter abundance and use days of dark geese in the Central Valley during 1998-2000 were greater than CVJV goals (Fig. 72), mainly because of the recovery of white-fronted goose populations. After declining from (fall) peak estimates of 480,000 in 1966-68 to a low of 73,100 in 1979, harvest restrictions and the Yukon-Kuskokwim Delta Goose Management Plan helped to restore the Pacific population of white-fronted geese to an average of 174,900 during 1987-1990 and 390,700 during 1998-2000 (Pacific Flyway Council 2003). Harvest restrictions and the Yukon-Kuskokwim Delta Goose Management Plan also helped to restore cackling Canada goose populations. However, unlike white-fronts, which continued to winter mainly in the Central Valley, the abundance of cackling Canada geese in the Central Valley declined drastically during the 1990s. Cacklers had shifted from wintering mostly in the Central Valley to wintering almost exclusively in Oregon and Washington (Trost and Drut 2004). Aleutian Canada goose populations have increased and continue to winter primarily in the Central Valley. However, even at their current abundance levels, Aleutians are far less numerous in the Central Valley than cacklers once were. Thus, the species composition of dark geese wintering in California changed during the study. Overall, waterfowl (i.e., ducks, geese, and swans combined) use days in the Central Valley during 1998-2000 were below CVJV goals, approximately in magnitude equal to the pintail “deficit” (Fig. 59). Pintails are the most common waterfowl species wintering in the Central Valley and are especially important in the San Joaquin Valley, whereas geese, mallards, and some of the other species that were at or above CVJV goal levels are less common. Thus, the lack of pintails contributed to much lower than planned use in the San Joaquin Basin, whereas in the Colusa and Butte Basins the pintail deficit was mitigated by above-goal abundance of other species.

2) Peak abundance actually occurred before or after the midwinter survey- The CVJV calculated waterfowl use day goals for each basin based upon the assumption that waterfowl abundance during the 1970s peaked in each basin at the time of the midwinter survey in early January. However, periodic surveys show that, although overall Central Valley waterfowl abundance does peak in early January, peak abundance and use in some basins occurs well before or after early January (Fig. 61). In basins where peak waterfowl use did not coincide with the midwinter survey, use was underestimated and habitat goals were set too low.

Although surveys were not conducted after early January (i.e., the midwinter survey) during the 1970s, our 1998-2000 surveys showed that waterfowl abundance in the American Basin was much greater after the midwinter survey some years, with the trend especially strong for pintails (Figs 61-62). High late-winter use of the American Basin likely occurred because no public area sanctuary was present in the basin. During hunting season, birds mainly utilized food resources in basins that had sanctuaries and took full advantage of the American Basin's food resource only after hunting season ended (Figs. 48-50). Thus, it is likely the trend for peak waterfowl use in the American Basin to occur after the mid-winter survey, that we saw during 1998-2000 was even stronger during the 1970s, because pintails were much more numerous and the closest sanctuary was even farther away (i.e., in Sutter NWR in 1970s rather than in Yolo WA or lightly hunted rice fields in the Yolo and American Basins during 1998-2000). Thus, actual waterfowl use in the American Basin during the 1970s was likely much greater than modeled in the original CVJV plan (which assumed a peak at the time of the midwinter survey) and explains why waterfowl abundance and use days in the American Basin during 1998-2000 far exceeded the CVJV goal use days (Fig. 59-61). Because the assumed mid-winter peak underestimated actual historic waterfowl use and habitat needed to maintain that use, habitat goals for the American Basin should be increased.

Post midwinter surveys during 1998-2000 also showed a late-winter peak in waterfowl use in the Yolo Basin. However, historic surveys also showed the timing and magnitude of use in the Yolo Basin were highly variable (Fig. 16-17), probably because use varied directly with the timing and magnitude of Yolo Bypass flooding from the Sacramento River over flow (Gilmer et al. 1982, 1989). Thus, current goals for managed habitat are likely within the wide range needed to maintain highly variable historic and current use days.

Periodic surveys were conducted before the mid-winter survey during 1973-1982. These surveys show that peak waterfowl use in the Tulare Basin often occurred during September – November, not at the time of the midwinter survey (Fig. 16). This early peak in use some years was due to large concentrations of pintails using the expanses of post-harvest flooded agricultural fields that sometimes occurred in the Tulare Lake Bed region (Fig. 18, Houghten et al. 1985, Barnum and Euliss 1991). Use later in the winter depended on whether precipitation was adequate to flood parts of the Tulare Lake Bed. Thus, on average, an assumed mid-winter peak underestimated peak waterfowl use in the Tulare Basin and habitat needed to maintain historic use are likely greater than current goals.

3) Waterfowl distribution among basins has changed since the 1970s- Aerial surveys and radio tracking revealed that the percentage of waterfowl use days occurring in Sacramento Valley basins has increased and the percentage occurring in the Delta, Suisun Marsh, San

Joaquin, and Tulare Basins has declined since the 1970s. The trend varied by species, with use by most dabbling ducks and geese shifting north to the Sacramento Valley, but diving duck use increasing in the San Joaquin Valley. This northerly shift in distribution was a major factor affecting waterfowl use in all basins and lessened the impact of low pintail populations on overall waterfowl abundance in the Sacramento Valley but compounded the impact elsewhere.

Daily Flight Distance Differed Among Basins and Study Periods

Radio tracking indicated that distances flown by pintails and mallards between day and night locations and by white-fronted geese between feeding and roosting sites differed among basins and study periods. In addition, pintails flew farther than mallards (differences in tracking methods preclude duck vs. white-fronted goose comparisons) and all three species flew farther during hunting than non-hunting seasons (Table 12, Figs. 76-78). Flight distances of all three species declined between study periods during most seasons in the Sacramento Valley and pintail flight distances declined more in the Sacramento Valley than in the San Joaquin Valley (data for San Joaquin Valley not available for mallards or geese) (Figs. 76-78). For white-fronted geese, both seasonal and overall winter average (seasonal averages weighted by season duration) flight distances were shorter during 1998-2000 than earlier study periods (Table 12, Fig. 79). However, because duck hunting season was longer during 1998-2000 (100 d consecutive [i.e., hunting open during “SPLIT” weeks]) than earlier study periods (79 d consecutive [i.e., hunting open during “SPLIT” weeks] during 1987-1988; 59 d SPLIT [i.e., no hunting during “SPLIT” weeks] during 1988-1990 and 1991-1994), whereas goose hunting season duration remained at 79 days throughout the study, and daily flights averaged longer during hunting than non-hunting seasons (Figs. 76-79), overall winter average flight distances during 1998-2000 for ducks did not decline as much as for geese, and in some basins even increased, compared to during earlier study periods (Table 12). Thus, even in the Sacramento Valley where availability of roost and feeding sites increased the most, and flight distances during hunting seasons declined the most between study periods (Fig. 76), overall winter average flight distances for pintails increased (+1%) between study periods (Table 12). Daily flight distances within each region or basin and the change in distances between study periods for each species are described in more detail below.

Northern Pintails- Within the 3 regions of similar size for which we had adequate data to compare, overall winter average pintail flight distance between sequential day and night locations was greater in the 1,248 km^2 Sacramento Valley region (flights within or between Colusa, Butte, American, Sutter, and Yolo Basins) than in the 791 km^2 Suisun-Delta-Yolo region (flights within or between Suisun, Delta, and Yolo Basins) or the 761 km^2 San Joaquin Basin (Fig. 76, Table 12). For instance, during 1991-1994, winter flight distances averaged 5.63 $\pm$ 0.93 km (avg $\pm$ SE) in the Sacramento Valley, 3.25 $\pm$ 0.12 km in the Suisun-Delta-Yolo region, and 3.96 $\pm$ 0.08 km in the San Joaquin Basin for pintails radiotagged in Suisun Marsh or San Joaquin Valley (Table 12). During 1998-2000, winter flight distances averaged 7.00 $\pm$ 0.11 km in the Sacramento Valley, 4.72 $\pm$ 0.13 km in the Suisun-Delta-Yolo region, and 4.47 $\pm$ 0.13 km in the San Joaquin Basin for pintails radiotagged in Suisun Marsh, San Joaquin Valley, or Sacramento Valley (Table 12).

Overall winter average flight distances of pintails also varied greatly among individual basins (Table 12). The shortest overall winter average flight distance was in Suisun Basin, the smallest basin (42 km^2). Thus, basin size obviously impacted average flight distance. However, the longest winter average flight distance was in Butte Basin, which at 261 km^2 was smaller than Colusa (465 km^2), Delta (540 km^2), and San Joaquin Basins (760 km^2). Thus, factors other than basin size, such as distribution of suitable sanctuaries and feeding areas within basins, also obviously impacted daily flight distance.

Overall, winter flight distances (season averages weighted by season duration) between sequential day and night locations for pintails differed during 1998-2000 and 1987-1994 in some areas (Table 12). The change between study periods differed for the 3 regions of similar size for which we had data. Overall average winter pintail flight distance in the Sacramento Valley region (flights within or between Colusa, Butte, American, Sutter, and Yolo Basins) was similar during 1998-2000 and 1987-1990. However, overall winter flight distance during 1998-2000 was 45% greater in the Suisun-Delta-Yolo region (flights within or between Suisun, Delta, and Yolo Basins) and 20% greater in the San Joaquin Basin (similar in area as Sacramento Valley and Suisun-Delta-Yolo region) than during 1991-1994 (Table 12). Change between study periods in overall average winter flight distance for pintails within individual basins differed even more greatly than for regions, ranging from a 22% decline in Sutter Basin and a 18% decline in Butte Basin between 1987-1990 and 1998-2000 to a 97% increase in the Yolo Basin between 1991-1994 and 1998-2000 (Table 12).

Distances between sequential day and night pintail locations varied greatly among seasons, with greater average flight distances during seasons when duck hunting was open (HUNT1, HUNT2, "SPLIT" weeks in 1987-1988 and 1998-2000) than when duck hunting was closed (PREHUNT, POSTHUNT, SPLIT weeks in 1988-1994) (Fig. 76). In addition, distances during hunting season were much greater on shoot days (Wednesdays and weekends when hunting on NWRs and WAs was allowed) than on nonshoot days in the San Joaquin Basin and southern part of the Tulare Basin, but only slightly greater on shoot than on nonshoot days in the Sacramento Valley overall. The shoot vs. nonshoot difference was minimal or not consistent in individual Sacramento basins, the Delta, Suisun Marsh, or Mendota WA (Fig. 77). This regional disparity in the impact of shoot vs. non-shoot days on flight distance was likely due to regional differences in hunting patterns. In the San Joaquin Valley, few hunters went into the field on non-shoot days and most pintails spent the day on the same private wetland in which they fed at night (Fleskes 1999). In the Sacramento Valley, Delta, and Suisun Marsh, hunting pressure on flooded fields and other private areas during both shoot and non-shoot days was apparently more similar, so the percentage of pintails that flew back to public and private sanctuaries was similar.

Changes between study periods in seasonal flight distances for pintails varied among regions and seasons (Figure 76). For the Sacramento Valley region, 1998-2000 flight distances were consistently shorter than 1987-1990 distances during hunting seasons but slightly greater than 1987-1990 distances during nonhunting seasons. In the Suisun-Delta-Yolo region, 1998-2000 flight distances were slightly shorter than 1991-1994 distances during HUNT1 but greater than 1991-1994 distances during other seasons (only some differences significant). In the San Joaquin Basin, 1998-2000 flight distances were shorter than 1991-1994 during HUNT2 (significant only on shoot days) and similar during all other season except SPLIT, where the greater distance in 1998-2000 than in 1991-1994 was because hunting season was open during the “SPLIT” weeks of 1998-2000 but not 1991-1994.

Change in seasonal flight distances for pintails varied greatly among individual basins (Figure 77). Distances in 1998-2000 were less than 1987-1990 during all seasons (most differences significant) for pintail flights within Butte and Sutter Basins but were greater or equal to 1987-1990 distances during most seasons for flights within Colusa and American Basins. In Yolo, Delta, and Suisun Basins, distances in 1998-2000 were greater than or equal to 1991-1994 distances during all seasons except HUNT1 when 1998-2000 distances were shorter (not all differences significant; difference during "SPLIT" because hunting open in 1998-2000 but not in 1991-1994). Except for lower flight distance on nonshoot days during HUNT1, flight distance changed little in Mendota WA.

Mallards- Distances between sequential day and night mallard locations were shorter than for pintails (Table 12, Figs. 76-78). However, similar to pintails, mallard overall winter average flight distance between sequential day and night locations in the Butte Basin during 1998-2000 was significantly shorter (-25% for mallards vs. 18% for pintails) than during 1988-1990 (Tables 12). However, unlike pintails, most mallard locations were in the Butte Basin and thus mallard flight distance for the overall Sacramento Valley region also declined 25% between 1988-1990 and 1998-2000 (compared with a +1% change for pintails between 1987-1990 and 1998-2000). Mallard flight distances during 1998-2000 were 8% longer in Colusa Basin and 1% longer in Sutter Basin than during 1988-1990; winter averages were not calculated for other basins because radiotagged mallards were located in each during only a few seasons.

Seasonal trends for mallard flight distances among areas and seasons (Fig. 78) were similar to pintails (Fig. 76-77). Similar to pintails, mallards in the Sacramento Valley flew farther during hunting than nonhunting seasons and only slightly farther on shoot than non-shoot days. For the overall Sacramento Valley region, 1998-2000 flight distances were shorter than 1988-1990 distances during all seasons except during SPLIT. (Flight distances were greater during SPLIT in 1998-2000 than 1988-1990 because hunting season was open during the "SPLIT" weeks in 1998-2000 but not 1988-1990.) Trends in change within individual basins for mallards were also similar to pintails. Distances in 1998-2000 were less than in 1988-1990 for mallard flights within Butte Basin, except during the SPLIT and on shoot days of HUNT2, and within Sutter Basin except during PREHUNT and POSTHUNT. Similar to pintails, mallard flight distances in 1998-2000 were greater or equal to 1988-1990 distances during most seasons for flights within Colusa Basin. There were too few mallard locations in other basins to compare study periods.

White-fronted geese- Similar to mallards, the average winter distance between roosting and feeding sites for white-fronted geese was shorter (26%) during 1998–2000 than 1987–1990 (Table 12). Similar to both pintails and mallards, the distance traveled by geese was generally greater when hunting season was open (i.e., Nov – Jan) than during POSTHUNT (i.e., Feb) (Fig. 79) and both the distances and change among years varied among basins (Table 12). However, in contrast to pintails and mallards, white-fronted geese traveled shorter distances from roosting to feeding sites in Butte and Sutter Basins than in other basins. Also, unlike for pintails and mallards, because goose hunting season duration was the same during both 1987-1990 and 1998-2000, overall average winter flight distances for geese also were shorter during 1998-2000 than during 1987-1990 in all basins in the Sacramento Valley and Delta.

Ranking flight distance changes-Rankings of regions and basins based upon the magnitude of flight distance change (i.e., from greatest decline to greatest increase) between study periods varied somewhat among species (Table 12). For all three species, flight distances in the Sacramento Valley region consistently declined between 1987-1990 and 1998-2000 during most seasons (and also for the entire winter for mallards and white-fronted geese). Pintail flight distance did not decline as consistently during most seasons in the Delta-Suisun-Yolo region or San Joaquin Basin as in the Sacramento Valley (data for the San Joaquin Basin was available only from pintails). Among the four Sacramento basins for which data was available for 1987-1990, Butte Basin ranked 1st or 2nd in flight distance decline and Colusa Basin ranked last for all 3 species. However, Sutter Basin ranked 1st or 2nd for ducks but last for white fronted geese and American ranked first for white fronted geese but third for pintails. Among the six basins used by both our radiotagged pintails and white-fronted geese, Butte and American ranked 2nd or 3rd, Colusa 4th and Yolo 6th for both species. However, Delta Basin ranked 1st for white-fronted geese and 5th for pintails whereas Sutter ranked 1st for pintails but 5th for white-fronted geese.

Change in Distribution, Movements, and Habitat Use Related to Habitat Change

In general, wetland acreage increased significantly in all basins except the Suisun (Fig. 7), and acreage of winter-flooded agriculture increased greatly in the Sacramento Valley but declined slightly or changed little in other basins (Fig. 8). Waterfowl distribution, movements, and habitat use changed between 1973-1982 and 1998-2000 in apparent response to habitat changes.

Waterfowl distribution- Coincident to increases in acreage of planted and winter-flooded rice in the Sacramento Valley, the percentage of Central Valley’s dabbling ducks and geese occurring in the Sacramento Valley increased and northerly winter movements from the San Joaquin to the Sacramento Valley occurred earlier. For most Sacramento Valley basins, this northerly shift in wintering use largely mitigated for the impact of lower continental pintail populations, resulting in overall waterfowl use near that during 1973-1982. However, elsewhere in the Central Valley, the shift in distribution and use to the Sacramento Valley compounded the impact of the lower pintail populations and resulted in greatly reduced waterfowl use days during 1998-2000 compared to 1973-1982.

Changes in pintail distribution correspond to increased flooding of harvested rice fields in the Sacramento Valley starting in the early 1990s, indicating that the Sacramento Valley now provides food and sanctuary for pintails displaced due to reduced wetland and agricultural flooding in southern Tulare Basin (Houghten et al. 1985, Barnum and Euliss 1991). Drought conditions in the Central Valley during 1987-1991 (California Department of Water Resources 1991; National Oceanic and Atmospheric Administration, Asheville, North Carolina, USA, unpublished data) probably exacerbated impacts of changing habitat distribution by increasing movement of San Joaquin Valley dabbling ducks to the less arid Sacramento Valley, where better-established water rights (Gilmer et al. 1982, Heitmeyer et al. 1989) maintained better habitat conditions. Habitats in San Joaquin Basin have apparently remained more attractive to pintails, at least during early winter.

Changes in distribution were not consistent for all waterfowl species. For instance, cinnamon teal, which are associated more with wetland than agricultural habitats (Heitmeyer and Raveling 1988, Barnum and Euliss 1991) and have a more southerly distribution in California (Bellrose 1980), did not shift north like most other dabbling ducks. Also, improved wetland habitats attracted an increased percentage of Central Valley's diving ducks to the San Joaquin Valley, but this only slightly mitigated the decline in use by dabbling ducks.

AIC analysis using data from radiotagged white-fronted geese shows the relationship between habitat changes and changes in distribution of this species. The best-fitting models explaining differences between the 1987-1990 and 1998-2000 study periods in both roosting and feeding distributions among basins for white-fronted geese contained the change in total basin area in rice production, with the regression being forced through the origin (Table 13). The next best model contained the first principal component of changes in total rice area, flooded rice area, and wetland area within basins, with the regression being forced through the origin (Table 13). This indicates feeding and roosting distributions of geese shifted between study periods into basins that had the greatest increases in the amount of area in rice production, but changes in the amount of flooded rice and wetland habitat also influenced changes in goose distributions to a lesser extent (Table 14). For example, the greatest percentage increase in basin area rice production was American Basin (40%) and the greatest percentage decline in rice production was in the Delta Basin (-70%). Correspondingly, geese increased their use of the American Basin for roosting by 128% and for feeding by 129%, whereas they decreased their use of the Delta Basin for roosting by 82% and for feeding by 88% (Table 14).

Flight distance- Flight distances decreased during most seasons in most basins but declines were greatest in the Sacramento Valley, which had the greatest increase in habitat availability. For white-fronted geese, change in flight distance was most closely related to change in roosting sites. The most parsimonious model explaining study period changes in distances white-fronted geese traveled between roosting and feeding sites among basins contained the change in wetland habitat, with the regression being forced through the origin (Table 13). This indicates that declines in white-fronted roost-to-feed distances between decades were greater in those basins with the largest increases in wetland area. For example, the Delta Basin had the greatest increase among northern Central Valley basins (excludes San Joaquin

Valley) in wetland habitat between decades (129%) and also the largest decline in the distance traveled from roosting to feeding sites by geese (-44%). Similarly, the Colusa Basin had the smallest increase in wetland habitat (20%) and one of the smallest declines between decades in roost-to-feed distances (-199%; Table 12). However, a model excluding habitat variables (including only the intercept) also fit the data well (Table 13), indicating that the relationship between the change in distance traveled from roosting to feeding sites and changes in wetland habitat was weak.

Summary of Significant Results

Five study findings indicate that some assumptions upon which CVJV habitat goals were based are not valid:

(1) Actual historic waterfowl use in some basins was different than what CVJV modeled because the model used only the January midwinter count and assumed waterfowl abundance peaked at that time, which periodic surveys show was not true in all basins.

(2) Distribution of waterfowl use among basins has not remained the same as during 1970s because habitat has increased most in the Sacramento Valley region and dabbling duck and goose use has shifted to the Sacramento Valley.

(3) Despite recovery of most populations of waterfowl that winter in the Central Valley, waterfowl use days remain well below goal because of continued low abundance of northern pintails, the most common wintering species in the Central Valley.

(4) Despite increased wetland area, most energy for wintering waterfowl is still

acquired in agricultural habitats.

(5) Daily flight distances, and their change over time, differed among basins and may require assuming different energetic requirements when modeling habitat requirements for each basin.

Summary of Recommendations for CVJV Habitat Goals

The results above indicate that adjustments to habitat goals may be needed to meet CVJV's objective of providing habitat in the amounts and locations necessary to maintain abundance and distribution of waterfowl in the Central Valley like during the 1970s. Thus we have the following recommendations:

1) Waterfowl use-day goals should be revised to better reflect the percentage of waterfowl use that actually occurred in each basin during the 1970s. Specifically, waterfowl use day goals should be increased in the American, Delta, and Tulare Basins and decreased in Sutter and Colusa Basins (Table 15).

2) Differences in current vs. 1970s distribution of waterfowl should be considered when prioritizing projects. Dabbling ducks and geese have increased use of the Sacramento Valley and decreased use of other areas. This has resulted in the 1998-2000 percentage of total Central Valley waterfowl use in Butte and Colusa Basins well above, and in the Delta and Suisun Basins well below, 1970s levels. To restore the 1970s distribution, the CVJV should place high priority on projects that will attract and maintain wintering waterfowl in the Delta and Suisun. These efforts will need to be designed while considering impacts of the CALFED Ecosystem Restoration Program and other

management activities on waterfowl.

3) Differences in the current vs. pre-1970s distribution of waterfowl should be considered when prioritizing projects. Numerous sources have noted that habitat changes that occurred before the 1970s were more detrimental to waterfowl populations in the San Joaquin Valley, especially in the Tulare Basin, where wetlands were mostly converted to agriculture having little waterfowl value, than in the Sacramento Valley and Delta where wetlands were mostly converted to rice or other crops with high value for waterfowl. Thus, waterfowl use-day goals should be increased somewhat to account for the fact that 1970s surveys greatly underestimate the greater historic value of the Tulare and San Joaquin Basins to waterfowl (Table 15). These southern basins are also especially important for shorebirds, which were not examined in our studies, but are now specifically included in CVJV planning.

4) The continued high attraction of many waterfowl species to rice and grain fields, especially of dabbling ducks to flooded fields, should be recognized in design of CVJV implementation. Thus, in addition to ensuring that adequate wetlands are provided for the long-term, enhancement of agricultural habitats should be considered for basins where the portion of Central Valley's waterfowl use has declined since the 1970s, if the basin has potential agricultural lands for enhancement (i.e., Tulare, San Joaquin, and Delta Basins).

5) Research to improve the bioenergetic model upon which CVJV non-breeding

waterfowl (and now shorebird) goals are based should continue. For instance, radio tracking shows that average flight distances were greater in the Sacramento Valley than in the San Joaquin Valley, which were greater than in the Delta, which were greater than in Suisun and Mendota WA. In addition, daily flight distances generally declined as habitat availability increased and hunting pressure decreased. Regional differences in daily energy requirements may greatly impact habitat requirements. However, additional research is needed to determine the relationship between daily flight distances and daily energy requirements, including whether birds compensate for increased flight energy expenditure by reducing energy expended on other activities, or whether increased flight distances require increased food intake.

6) The Central Valley landscape continues to change as a result of the CVJV, changing agricultural practices, urban development, and other activities. Thus waterfowl abundance, distribution, movement patterns, flight distances, habitat use, survival, and body condition should be monitored periodically to measure the effectiveness of the CVJV and provide updated information that is necessary for informed CVJV implementation plan revisions.

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Table 1. Approximate dates of aerial waterfowl surveys during 1970 – 2000 for winters where more than September and January surveys that included all or most of the Central Valley of California were conducted[a].

WINTER	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
1973-1974	18	10 24	7 21	5[b]	7--16			
1978-1979	20		1 29	13	2--------24			
1979-1980	11	31	14	12	3-------22			
1980-1981	23	22	5 17		4-8			
1981-1982	22	21	4 18	16	4-8			
1998-1999	16----29	14[b]	18	15	6--------28	18[c]	10--17[b,d]	
1999-2000	15	13	17	13	4-7	17	20[c]	

[a]First date of 1-3 day complete Central Valley survey listed; date range listed for longer surveys.
[b]Southern San Joaquin Valley not surveyed.
[c]Northern San Joaquin Valley not surveyed.
[d]West Sacramento Valley not surveyed.

Table 2. Locations, dates, and numbers of after-hatch-year (AH) and hatch-year (HY) female waterfowl radio-tagged during 1987-1994 and 1998-2000.

SPECIES-AREA COHORT	EARLIER STUDIES				CURRENT STUDY			
	DATE	AH	HY	LOCATION	DATE	AH	HY	LOCATION
PINTAIL-SACVAL	8/23-9/7/87	33		SACRAMENTO NWR	8/27-8/31/98	50		SACRAMENTO NWR
		21		DELEVAN NWR	8/31-9/2/99	50		SACRAMENTO NWR
	8/21-8/30/88	48		SACRAMENTO NWR				
		12		DELEVAN NWR				
	8/22-8/30/89	73		SACRAMENTO NWR				
PINTAIL-SUISUN	8/29-9/23/91	55	40	SUISUN MARSH	9/12-9/15/98	50		SUISUN MARSH
	8/28-9/16/92	61	38	SUISUN MARSH	9/7-9/22/99	50		SUISUN MARSH
PINTAIL-SANJVAL	8/29-10/6/91	44	37	GRASSLAND EA	9/4-9/22/98	20		GRASSLANDEA
		22	4	MENDOTA WA		30		MENDOTA WA
		12	2	TULARE LAKE BED	9/6-10/5/99	33		GRASSLAND EA
	8/31-10/5/92	30	48	GRASSLAND EA		22		MENDOTA WA
		17	4	MENDOTA WA				
		18	6	TULARE LAKE BED				
	8/28-9/25/93	64	57	GRASSLAND EA				
		47	58	MENDOTA WA				
		17	20	TULARE LAKE BED				
MALLARD-SACVAL	9/29-10/14/88	4	5	GRAYLODGE WA	8/30-9/15/98	11		GRAYLODGE WA
	9/29-10/14/88	9	13	BUTTE SINK CLUBS		39		UP. BUTTE BAS. WA
	9/29-10/14/88	1	13	SUTTER NWR	8/28-9/13/99	57	45	GRAYLODGE WA
	11/16-11/25/88	13	3	BUTTE SINK CLUBS				
	9/7-9/16/89	3		GRAYLODGE WA				
	9/7-9/16/89	14	15	BUTTE SINK CLUBS				
	9/7-9/16/89	2	5	UP. BUTTE BAS. WA				
	9/7-9/16/89	5	6	SUTTER NWR				
	11/25-12/16/89	3	5	BUTTE SINK CLUBS				
	11/25-12/16/89	2	18	GRAYLODGE WA				
WHITE-FRONTED GOOSE[a]	6/22-7/01/87	9		ALASKA	6/21-7/31/98	59		ALASKA
	9/27-10/17/87	76		KLAMATH	7/8-8/5/99	61		ALASKA
	3/22/88	5		KLAMATH				
	7/04-7/29/88	33		ALASKA				
	9/25-11/3/88	63		KLAMATH				
	3/19/89	13		KLAMATH				
	6/28-8/9/89	44		ALASKA				
	10/16-10/31/89	82		KLAMATH				

[a]A total of 100 (87 from Klamath) were tracked in the Central Valley during Nov-Feb 1987-1990 and 92 during 1998-2000.

Table 3. Total area of rice and area and percentage that was winter-flooded in each northern Central Valley basin during 1999-00 vs. 1993-94, and 1988-89 [a].

	1999-00			1993-94			1988-89		
Basin	Total ha	Flooded ha	Flooded %	Total ha	Flooded ha	Flooded %	Total ha	Flooded ha	Flooded %
Butte	54,669	30,659	56	47,408	24,718	52	45,399	18,977	42
Colusa	80,528	24,381	30	65,752	13,674	21	61,858	11,742	19
American	39,232	15,564	40	34,764	12,158	35	27,942	13,701	49
Sutter	20,956	6,624	32	18,374	5,444	30	18,442	6,399	35
Yolo	4,694	1,497	32	3,425	1,590	46	5,206	2,359	45
Delta	1,433	116	8	2,195	118	5	4,739	638	13
All	201,512	78,841	39	171,918	57,702	34	163,586	53,816	33

[a] Winter-flood values for 30 December 1999, 6 January 1994, or 24 January 1989. Values for 1999-00 from this study, values for 1988-89 and 1993-94 from Spell et al. (1995).

Table 4. Water Year Hydrologic Classification Index for the Sacramento (SACV) and San Joaquin Valley (SJV), Sacramento Metro Airport rainfall during October-September, and description of water conditions in early January during winters waterfowl ecology was studied.

		HYDRO-INDEX[a]			
PERIOD	WINTER	SACV	SJV	RAIN[b]	EARLY JANUARY CONDITIONS[c]
Pre-CVJV	1973-1974	+Avg	+Avg	21.2	Above average rain, bypass flooding
	1978-1979	+Avg	Wet	18.0	Good, minor lowland-bypass flooding
	1979-1980	-Avg	+Avg	23.9	Good, extensive lowland-bypass flooding
	1980-1981	+Avg	Wet	12.4	Dry fall and winter, only managed flooding
	1981-1982	Dry	Dry	31.9	Above normal rain caused extensive flooding
Early-CVJV	1987-1988	Dry	Critical	14.5	Some rainfall flooding except in South SJV
	1988-1989	Critical	Critical	16.6	Below average in SACV, Average in SJV
	1989-1990	Dry	Critical	12.3	Below average rainfall
	1991-1992	Critical	Critical	13.0	Drought conditions
	1992-1993	Critical	Critical	25.5	Widespread flooding from heavy rains in Dec
	1993-1994	+Avg	Wet	12.0	Only managed wetlands flooded
Decade-CVJV	1997-1998	Wet	Wet	31.9	Rain flooding in SACV, SJV good conditions
	1998-1999	Wet	Wet	13.8	Little unmanaged flooding
	1999-2000	Wet	+Avg	21.6	Dry with no unmanaged flooding

[a] Water Year Hydrologic Classification Index. The HYDRO-INDEX (Wet, +Avg, -Avg, Dry, Critical) is a measure of water availability during a water year (Oct-Sept) based upon natural water production of a river basin, unaltered by diversions, storage, and water exports during the current and previous year (Gehrts 2002).

[b] Rainfall in inches at Sacramento Metro Airport during October-September.

[c] Summarized from California Winter Waterfowl Survey (USFWS, Pacific Flyway Unpublished Reports) for all years except Waterfowl Status Report-1974 (USFWS, Special Scientific Report-Wildlife No. 211) was used for 1973-1974.

Table 5. Roosting and feeding distributions of white-fronted geese among basins from 1987–1990 to 1998–2000 in the Central Valley of California, USA.

	Roosting basin use			Feeding basin use		
Basin	1987–1990	1998–2000	difference	1987–1990	1998–2000	difference
American	10%	22%	12%	8%	19%	11%
Butte	24%	20%	-4%	22%	21%	-1%
Colusa	28%	34%	6%	34%	34%	0%
Delta	23%	4%	-19%	23%	3%	-20%
Sutter	11%	16%	5%	10%	16%	6%
Yolo	5%	5%	0%	5%	7%	2%

(From: Ackerman, J. T., J. Y. Takekawa, D. L. Orthmeyer, J. P. Fleskes, J. L. Yee, and K. L. Kruse. In Press. Spatial use by wintering greater white-fronted geese relative to a decade of habitat change in California's Central Valley. Journal of Wildlife Management).

Table 6. Percentage of northern pintail feeding and roosting locations in agriculture by season and basin, 1987-1994 vs. 1998-2000.

FEEDING[a]

	PREHUNT			HUNT			POSTHUNT		
Basin	87-94[b]	98-00	Difference	87-94	98-00	Difference	87-94	98-00	Difference
American	58	88	+30	85	94	+9	81	92	+11
Butte	23	37	+14	76	86	+10	63	87	+24
Colusa	11	16	+5	77	91	+14	45	70	+25
Sutter	.[c]	.	.	82	92	+10	68	90	+22
Yolo	.	.	.	85	94	+9	80	82	+2
Delta	80	74	-6	80	80	0	71	60	-11
Suisun	0	0	0	0	0	0	0	0	0
San Joaquin	2	2	0	2	2	0	4	5	+1
Tulare[d]									
Mendota WA	0	0	0	0	0	0	0	0	0
South San J	85	.	.	15	.	.	10	.	.

ROOSTING[e]

	PREHUNT			HUNT			POSTHUNT		
Basin	87-94	98-00	Difference	87-94	98-00	Difference	87-94	98-00	Difference
American	48	82	+34	67	84	+17	80	94	+14
Butte	3	26	+23	21	23	+2	50	83	+33
Colusa	6	2	-4	2	10	+8	20	48	+28
Sutter	.	.	.	10	18	+8	57	88	+31
Yolo	.	.	.	70	65	-5	77	80	-3
Delta	71	76	+5	67	69	+2	67	60	-7
Suisun	0	0	0	0	0	0	0	0	0
San Joaquin	1	2	1	1	1	0	4	7	+3
Tulare									
Mendota WA	0	0	0	0	0	0	0	0	0
South San J	85	.	.	7	.	.	10	.	.

[a] Day and night locations during prehunt and posthunt, night locations during hunt.
[b] 1987-1990 for American, Butte, Colusa, Sutter basins, 1991-1994 for other basins and areas.
[c] A point indicates to few locations to estimate use.
[d] Separate estimates for Mendota Wildlife Area (WA) in the northern part of Tulare Basin and the southern part of Tulare Basin (South San J).
[e] Day locations all seasons.

Table 7. Percentage of mallard feeding and roosting locations in agriculture by season and basin, 1988-1990 vs. 1998 –2000.

FEEDING[a]

	PREHUNT			HUNT			POSTHUNT		
Basin	88-90	98-00	Difference	88-90	98-00	Difference	88-90	98-00	Difference
American	10	10	0	72	88	+16	70	87	+17
Butte	21	22	+1	51	72	+21	43	66	+23
Colusa	29	29	0	47	81	+34	33	73	+40
Sutter	13	36	+23	63	85	+22	36	84	+48

ROOSTING[b]

	PREHUNT			HUNT			POSTHUNT		
Basin	88-90	98-00	Difference	88-90	98-00	Difference	88-90	98-00	Difference
American	5	.[c]	.	.	83	.	58	85	+27
Butte	6	18	+12	12	22	+10	30	48	+18
Colusa	26	16	-10	4	7	+3	34	53	+19
Sutter	6	25	+19	16	16	0	17	75	+58

[a] Day and night locations during prehunt and posthunt, night locations during hunt.
[b] Day locations all seasons.
[c] Point indicates too few locations to estimate use.

Table 8. Percentage of white-fronted goose feeding and roosting locations in agriculture by season and basin, 1987-1990 vs. 1998 –2000.

FEEDING

	PREHUNT[a]			HUNT			POSTHUNT		
Basin	87-90	98-00	Difference	87-90	98-00	Difference	87-90	98-00	Difference
American	.[b]	.	.	99	98	-1	96	99	+3
Butte	.	.	.	88	88	0	84	81	-3
Colusa	.	.	.	52	82	+30	68	88	+20
Sutter	.	.	.	43	76	+33	64	88	+24
Yolo	.	.	.	99	94	-5	98	.	.
Delta	.	.	.	98	99	+1	94	.	.

ROOSTING

American	.	.	.	93	97	+4	97	100	+3
Butte	.	.	.	89	83	- 6	64	40	-24
Colusa	.	.	.	25	34	+9	39	48	+9
Sutter	.	.	.	56	62	+6	28	64	+36
Yolo	.	.	.	.	40	.	77	.	.
Delta	.	.	.	100	.	.	82	.	.

[a]Too few radio-tagged geese in Central Valley during PREHUNT to estimate use.
[b]Point indicates too few locations to estimate use.

Table 9. Habitat used by radio-marked white-fronted geese for feeding and roosting during the 1987–1990 and 1998–2000 winters in the Central Valley of California, USA. Number of telemetry locations are in parentheses.

Behavior/Habitat type	1987–1990	1998–2000	difference
Roosting Locations (*N* =2044)			
Rice	40%	54%	14%
Wetland	36%	31%	-5%
Upland	2%	5%	4%
Other crop	23%	10%	-12%
Feeding Locations (*N* =2505)			
Rice	57%	72%	15%
Wetland	22%	12%	-10%
Upland	2%	3%	1%
Other crop	19%	13%	-6%

(From: Ackerman, J. T., J. Y. Takekawa, D. L. Orthmeyer, J. P. Fleskes, J. L. Yee, and K. L. Kruse. In Press. Spatial use by wintering greater white-fronted geese relative to a decade of habitat change in California's Central Valley. Journal of Wildlife Management).

Table 10. Rice habitat used by radio-marked white-fronted geese for feeding and roosting during the 1987–1990 and 1998–2000 winters in the Central Valley of California, USA. Number of telemetry locations are in parentheses.

Behavior/Habitat type	1987–1990	1998–2000	difference
Roosting Locations (*N* =681)			
Burned	43%	3%	-40%
Dry post-harvest	14%	9%	-5%
Flooded post-harvest	25%	78%	53%
Puddled post-harvest	19%	11%	-9%
Feeding Locations (*N* =1186)			
Burned	34%	6%	-28%
Dry post-harvest	32%	18%	-14%
Flooded post-harvest	10%	64%	54%
Puddled post-harvest	24%	12%	-12%

(From: Ackerman, J. T., J. Y. Takekawa, D. L. Orthmeyer, J. P. Fleskes, J. L. Yee, and K. L. Kruse. In Press. Spatial use by wintering greater white-fronted geese relative to a decade of habitat change in California's Central Valley. Journal of Wildlife Management).

TABLE 11. Night destination of pintails and mallards from each basin during prehunt, hunting season, and posthunt, 1998-1999.

a) Northern Pintails

PERCENT IN EACH BASIN AT NIGHT

PREHUNT

DAY BASIN	Colusa	Butte	Sutter	American	Yolo	Suisun	Delta	NSJV	SSJV
Colusa	**98.0892**	1.9108	.	.	.	.	.	.	.
Butte	2.0408	**97.9592**	.	.	.	.	.	.	.
Sutter	.	.	.	.	.	.	.	.	.
American	.	.	.	**100**	.	.	.	.	.
Yolo	.	.	.	.	.	.	.	.	.
Suisun	.	.	.	.	.	**99.576**	0.42373	.	.
Delta	.	.	.	.	.	.	**100**	.	.
NSJV	.	.	.	.	.	.	.	**100**	.
SSJV	.	.	.	.	.	.	.	.	**100**

HUNTING SEASON

DAY BASIN	Colusa	Butte	Sutter	American	Yolo	Suisun	Delta	NSJV	SSJV
Colusa	**92.3214**	6.5179	0.5357	0.4464	0.0893	.	.	0.0893	.
Butte	1.7760	**93.7158**	2.1858	1.9126	0.2732	.	0.1366	.	.
Sutter	.	3.4188	**94.0171**	1.7094	0.8547	.	.	.	.
American	.	4.1420	2.3669	**91.1243**	2.3669	.	.	.	.
Yolo	0.6803	1.3605	.	4.0816	**88.4354**	0.6803	4.7619	.	.
Suisun	.	.	.	.	1.4894	**97.8723**	0.6383	.	.
Delta	0.2028	.	0.2028	.	1.0142	1.0142	**97.5659**	.	.
NSJV	.	.	.	0.1227	.	.	0.1227	**99.7546**	.
SSJV	.	.	.	.	.	.	.	3.4483	**96.5517**

POSTSEASON

DAY BASIN	Colusa	Butte	Sutter	American	Yolo	Suisun	Delta	NSJV	SSJV
Colusa	**96.2963**	.	1.2346	1.2346	.	.	1.2346	.	.
Butte	2.5641	**89.7436**	.	2.5641	2.5641	.	2.5641	.	.
Sutter	.	.	**92.1569**	5.8824	.	.	1.9608	.	.
American	.	.	0.9804	**97.0588**	1.4706	.	0.4902	.	.
Yolo	.	.	.	2.2472	**86.5169**	.	11.2360	.	.
Suisun	.	.	.	.	.	**100**	.	.	.
Delta	.	.	.	3.2258	9.6774	.	**87.0968**	.	.
NSJV	.	.	.	.	.	.	.	**98.1818**	1.818
SSJV	.	.	.	.	.	.	.	.	**100.000**

b) Mallards

PREHUNT

DAY BASIN	Colusa	Butte	Sutter	American	Yolo	Suisun	Delta	NSJV	SSJV
Colusa	.	.	.	.	.	.	.	.	.
Butte	.	**100**	.	.	.	.	.	.	.
Sutter	.	.	.	.	.	.	.	.	.
American	.	.	.	**100**	.	.	.	.	.
Yolo	.	.	.	.	.	.	.	.	.
Suisun	.	.	.	.	.	.	.	.	.
Delta	.	.	.	.	.	.	.	.	.
NSJV	.	.	.	.	.	.	.	.	.
SSJV	.	.	.	.	.	.	.	.	.

HUNTING SEASON

DAY BASIN	Colusa	Butte	Sutter	American	Yolo	Suisun	Delta	NSJV	SSJV
Colusa	**97.0732**	2.9268	.	.	.	.	.	.	.
Butte	0.1235	**99.6914**	0.0617	0.123	.	.	.	.	.
Sutter	.	7.6923	**92.3077**	.	.	.	.	.	.
American	.	.	.	**100**	.	.	.	.	.
Yolo	.	.	.	.	**100**	.	.	.	.
Suisun	.	.	.	.	.	.	.	.	.
Delta	.	.	.	.	.	.	.	.	.
NSJV	.	.	.	.	.	.	.	.	.
SSJV	.	.	.	.	.	.	.	.	.

POSTHUNT

DAY BASIN	Colusa	Butte	Sutter	American	Yolo	Suisun	Delta	NSJV	SSJV
Colusa	**100**	.	.	.	.	.	.	.	.
Butte	.	**98.0296**	1.478	0.493	.	.	.	.	.
Sutter	.	.	**100**	.	.	.	.	.	.
American	.	.	.	**100**	.	.	.	.	.
Yolo	.	.	.	.	**94.4444**	.	5.5560	.	.
Suisun	.	.	.	.	.	.	.	.	.
Delta	.	.	.	.	.	.	**100**	.	.
NSJV	.	.	.	.	.	.	.	.	.
SSJV	.	.	.	.	.	.	.	.	.

Table 12. Average (±SE) winter flight distances (km) between sequential day and night locations for radio-tagged pintails and mallards and between all possible combinations of up to five (first weekly) roost and feeding locations each month for radio-tagged white-fronted geese in each Central Valley basin, 1987-1994 vs. 1998-2000. Differences in methods account for the greater flight distances for geese and preclude direct comparison with duck flight distances.

	Northern Pintail			Mallard			White-fronted goose		
Basin	1987-94[a]	1998-00	change	1988-90	1998-00	change	1987-90	1998-00	change
Butte	7.16±0.13	5.87±0.16	-18%	4.83±0.24	3.63±0.07	-25%	23.0±3.9	18.6±3.0	-19%
Colusa	4.17±0.11	5.48±0.13	+31%	4.22±0.51	4.55±0.28	+8%	25.7±4.2	23.5±2.8	-9%
Amer	2.92±0.12	2.97±0.12	+2%		2.60±0.09		30.5±4.0	22.5±3.5	-26%
Sutter	4.32±0.21	3.36±0.17	-22%	2.84±0.29	2.86±0.22	+1%	20.4±4.0	18.6±2.3	-9%
Yolo	2.28±0.15	4.49±0.16	+97%				41.1±6.9	37.8±6.3	-8%
SACV	6.94±0.11	7.00±0.11	+1%	4.77±0.19	3.60±0.06	-25%			
Delta	3.51±0.11	5.08±0.27	+45%				69.9±17	39.1±14	-44%
SACV +Delta				4.77±0.19	3.61±0.06	-24%	32.5±3.4	24.2±2.2	-26%
Suisun	2.19±0.11	2.52±0.09	+15%						
SanJoa	3.96±0.08	4.47±0.13	+20%						
MWA	1.71±0.10								
S. TB	2.50±0.21								

[a]For pintails, data from 1987-90 for Butte, Colusa, American (Amer) and Sutter Basins and for the Sacramento Valley combined (SACV) and 1991-94 for Delta, Suisun, and San Joaquin (SanJoa) Basins, Mendota Wildlife Area (MWA) on the northern border of Tulare Basin and the southern Tulare Basin (S. TB) south of Mendota Wildlife Area.

Table 13. Ranking of candidate models describing the response of white-fronted geese to changes in habitat within basins between 1987–1990 and 1998–2000 in the Central Valley of California, USA. All candidate models with Akaike weights ≥0.05 are shown. The number of candidate models are shown in parentheses.

Model type/structure[a]	log-likelihood	*N*	*k*[b]	AIC*c*	ΔAIC*c*[c]	Akaike weight[d]
Change in Roosting Basins (5 models)						
Total Rice Change	-2.98	6	2	13.95	0.0	0.68
prin1	-4.24	6	2	16.47	2.5	0.20
Flooded Rice Change	-5.60	6	2	19.21	5.3	0.05
Change in Feeding Basins (5 models)						
Total Rice Change	-4.43	6	2	16.85	0.0	0.59
prin1	-5.61	6	2	19.21	2.4	0.18
intercept	-6.21	6	2	20.41	3.6	0.10
Flooded Rice Change	-6.45	6	2	20.90	4.0	0.08
Wetland Change	-6.66	6	2	21.32	4.5	0.06
Change in Distance Traveled from Feed to Roost Sites (5 models)						
Wetland Change	5.18	6	2	-3.37	0.0	0.59
intercept	4.77	6	2	-2.54	0.8	0.40

[a] Total Rice Change=change in the total rice area in production within a basin between decades, Flooded Rice Change=change in the flooded rice area within a basin between decades, Wetland Change=change in the wetland area within a basin between decades, prin1=first principal component of Total Rice Change, Flooded Rice Change, and Wetland Change. All models have the intercept excluded, except for the intercept model which has the intercept and no covariates.

[b] The number of estimated parameters in the model including the variance.

[c] The difference in the value between AIC*c* of the current model and the value for the most parsimonious model.

[d] The likelihood of the model given the data, relative to other models in the candidate set (model weights sum to 1.0).

(From: Ackerman, J. T., J. Y. Takekawa, D. L. Orthmeyer, J. P. Fleskes, J. L. Yee, and K. L. Kruse. In Press. Spatial use by wintering greater white-fronted geese relative to a decade of habitat change in California's Central Valley. Journal of Wildlife Management.)

Table 14. Change in habitat availability between 1987–1990 and 1998–2000 and the corresponding change in roosting and feeding use and distance traveled between roosting and feeding sites among basins by white-fronted geese in the Central Valley of California.[a]

	Change between decades					
	Habitat type			Goose behavior		
Basin	Total rice[b]	Flooded rice[b]	Wetlands[c]	Roost-to-feed distance	Roosting basin use	Feeding basin use
American	40%	14%	40%	-26%	128%	129%
Butte	20%	62%	156%	-19%	-17%	-4%
Colusa	30%	108%	20%	-9%	18%	3%
Delta	-70%	-82%	129%	-44%	-82%	-88%
Sutter	14%	4%	48%	-9%	48%	70%
Yolo	-10%	-37%	62%	-8%	11%	56%
Total	23%	47%	67%	-26%	na	na

[a]Table From Ackerman, J., J. Y. Takekawa, D. L. Orthmeyer**,** J. P. Fleskes, J. L. Yee, and K L. Kruse. In Press. Spatial use by wintering greater white-fronted geese relative to a decade of habitat change in California's Central Valley. Journal of Wildlife Management XX:xxx-xxx.
[b]Data from Fleskes, J.P., W. M. Perry, K.L. Petrik, R. Spell, and F. Reid. 2005. Change in area of winter-flooded and dry rice in the northern Central Valley of California determined by Satellite Imagery. California Fish and Game 91:207-215.
[c]Data from Central Valley Joint Venture.

Table 15. PERCENT OF CENTRAL VALLEY TOTAL WATERFOWL

Basin	Midwinter Abundance 1973-77[1] Avg	Sep15-Feb15 Use Days 1973-1980[2] Range	Avg	Sep15-Feb15 Use Days 1998-2000[3] Range	Avg	CVJV Plan 1990[4] Goals	CVJV Plan revised Goals	Rationale for revised Goals[5]
Butte	25	17-25	20	29-32	31	23	20	a,b
Sutter	7	2 - 3	2	3 - 4	4	7	3	a,b
American	1	8 - 11	9	10-12	11	5	9	a,b
Colusa	17	9 - 15	12	23-23	23	15	12	a,b
Yolo	5	5 - 34	14	4 - 4	4	5	5	a,b,c
Suisun	2	4 - 6	5	2 - 3	3	5	5	a,b
Delta	9	5 - 20	13	3 - 4	3	10	13	a,b
SanJoaquin	30	17-25	20	16-19	17	25	25	a,b,d,f
Tulare	4	3 - 6	5	4 - 5	5	5	8	a,b,d,e,f

[1]U.S. Fish and Wildlife Service 1977. Central Valley Concept Plan For Waterfowl Habitat Preservation. Table 1 - Summary of U.S. Fish and Wildlife Service and California Department of Fish and Game midwinter surveys 1973-77. American Basin percentage interpolated from East Sacrament Valley counts.

[2]U.S. Fish and Wildlife Service and California Department of Fish and Game unpublished data from periodic surveys during Sept - Jan, 1973-74, 1977-78, and 1979-80. East Sacramento Valley Basins tallied together so breakdown into percentages for Butte, Sutter and American predicted from 1998-2000 distribution among East Sacramento Valley basins. Calculated from actual 1973-1979 counts for Sept - Jan and assuming the portion of total winter use days in each basin that occurred during late January and Feb, was like during 1998-99.

[3]Fleskes et al., unpublished data from September - March Surveys.

[4]Central Valley Habitat Joint Venture Implementation Board. 1990. Central Valley Habitat Joint Venture Implemenation Plan. Goals based on 1973-77 midwinter counts (i.e., first column) that were "adjusted to reflect present (i.e. 1990) and desired future abundance" (Heitmeyer 1989).

[5]Rationale for 2002 Goals:

a) Maintaining the historic distribution of waterfowl in the Central Valley is an important goal of the CVHJV that promotes management of privately-owned and public habitats in all basins, distributes recreational access to the waterfowl resource, and may reduce risk of catastrophic losses of waterfowl to disease.

b) Surveys conducted periodically during winter provide a more complete picture of waterfowl distribution and more accurate estimate of waterfowl use days than a single midwinter survey.

c) Yolo Basin average is skewed high because it received 34% of waterfowl use in 1973-74 due to extended flooding of the Yolo Bypass; other years with periodic surveys indicate much lower use (i.e., 5% in 1978-79 and 1979-80, 4% in 1980-81; 9% in 1981-82; 4% in 1998-99 and 1999-00.)

d) Habitat changes that occurred before the 1970s were more detrimental to waterfowl populations in the San Joaquin Valley where wetlands were often converted to cotton agriculture than in the Sacramento Valley where wetlands were often converted to rice agriculture.

e) Distribution estimates based on surveys after 15 Sept do not account for high historic use of Southern San Joaquin by pintails and other waterfowl during August and early September (USFWS 1977).

f) San Joaquin Valley wetland habitat restoration is especially crucial for meeting goals of U. S. Shorebird Conservation Plan (Shuford et al. 1998).

Central Valley of California

NWRs, WAs, and NGO areas added during 1988-2000 named in red

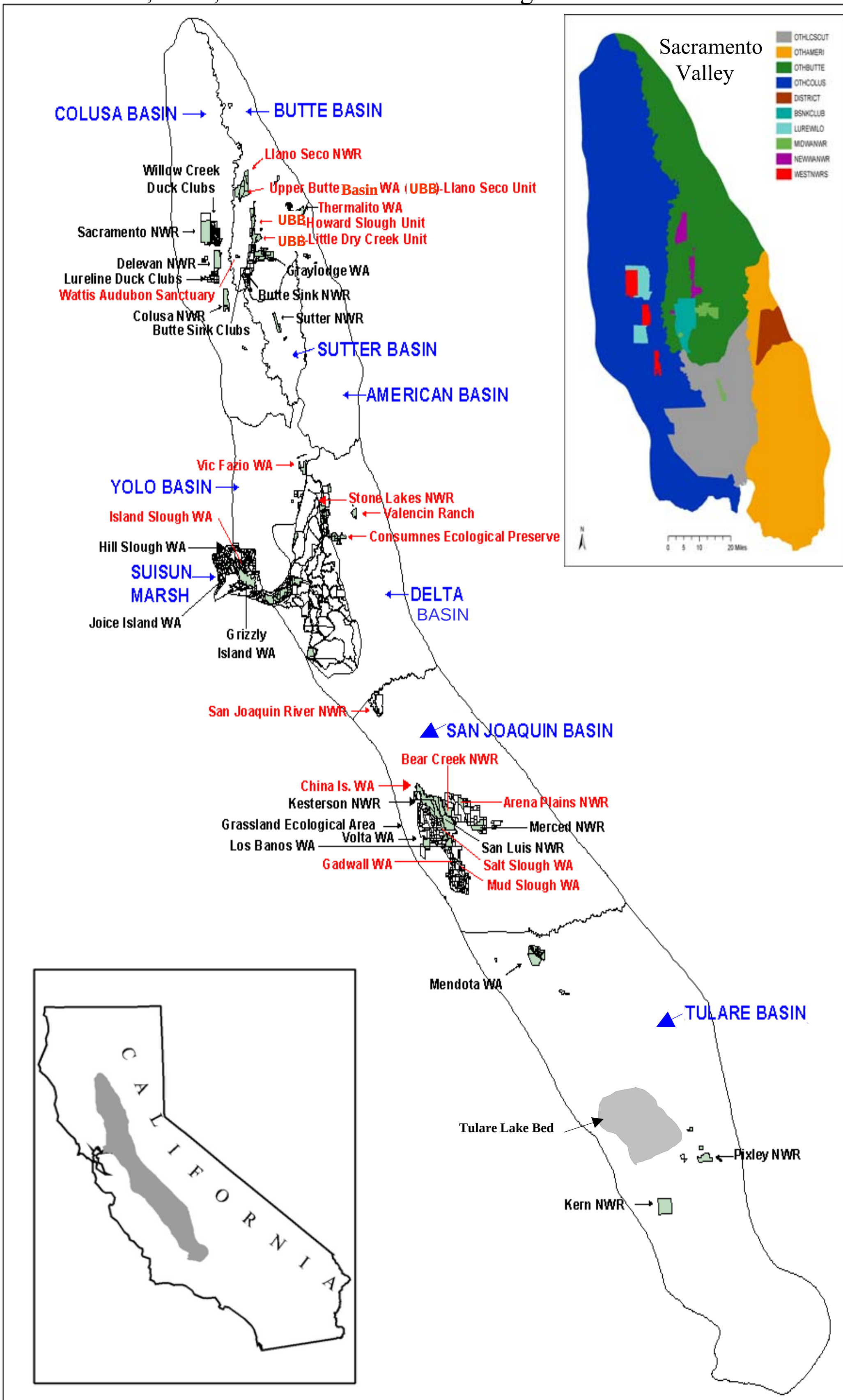


Figure 1

HISTORIC VS. EXISTING WETLANDS

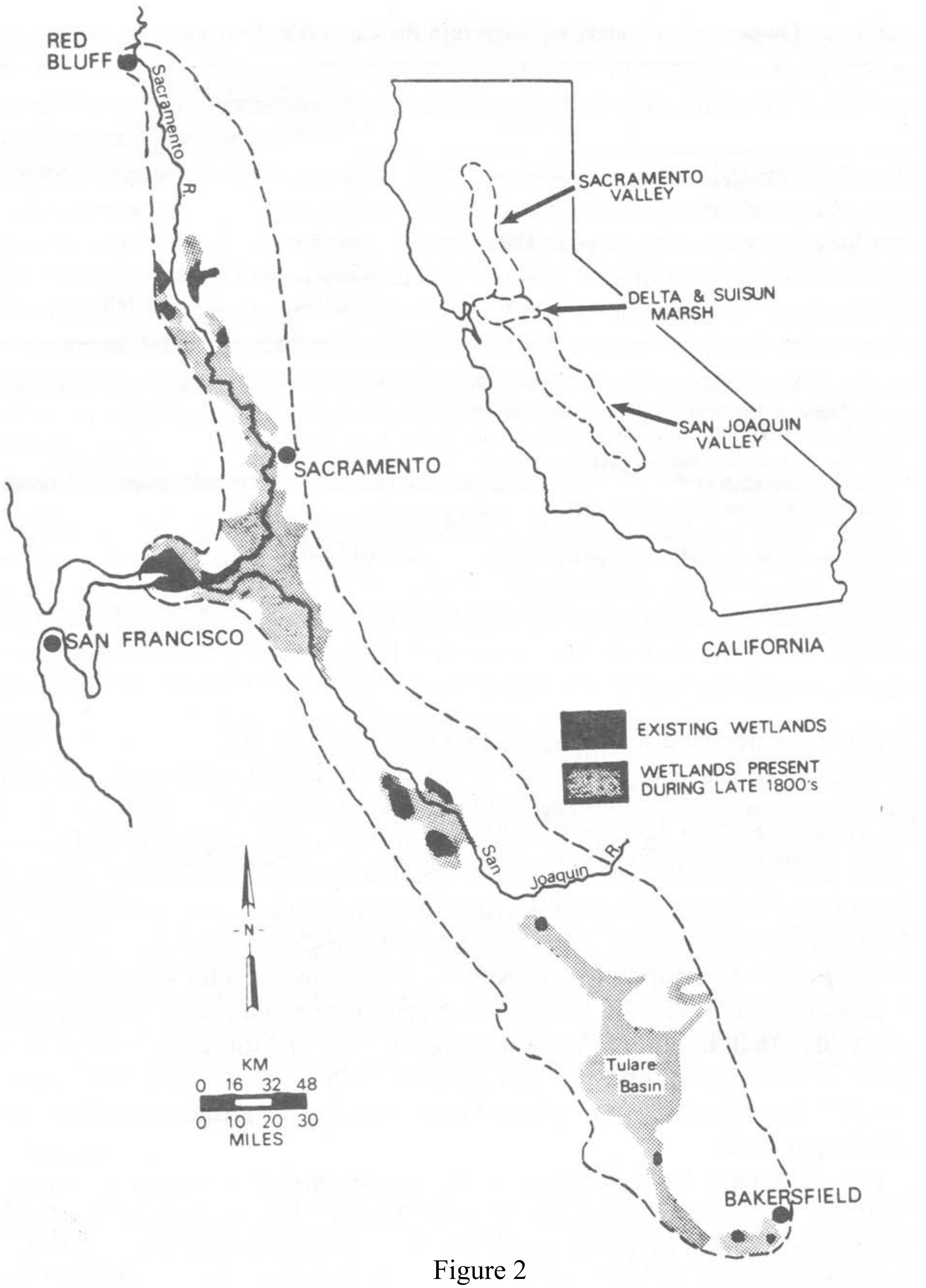


Figure 2

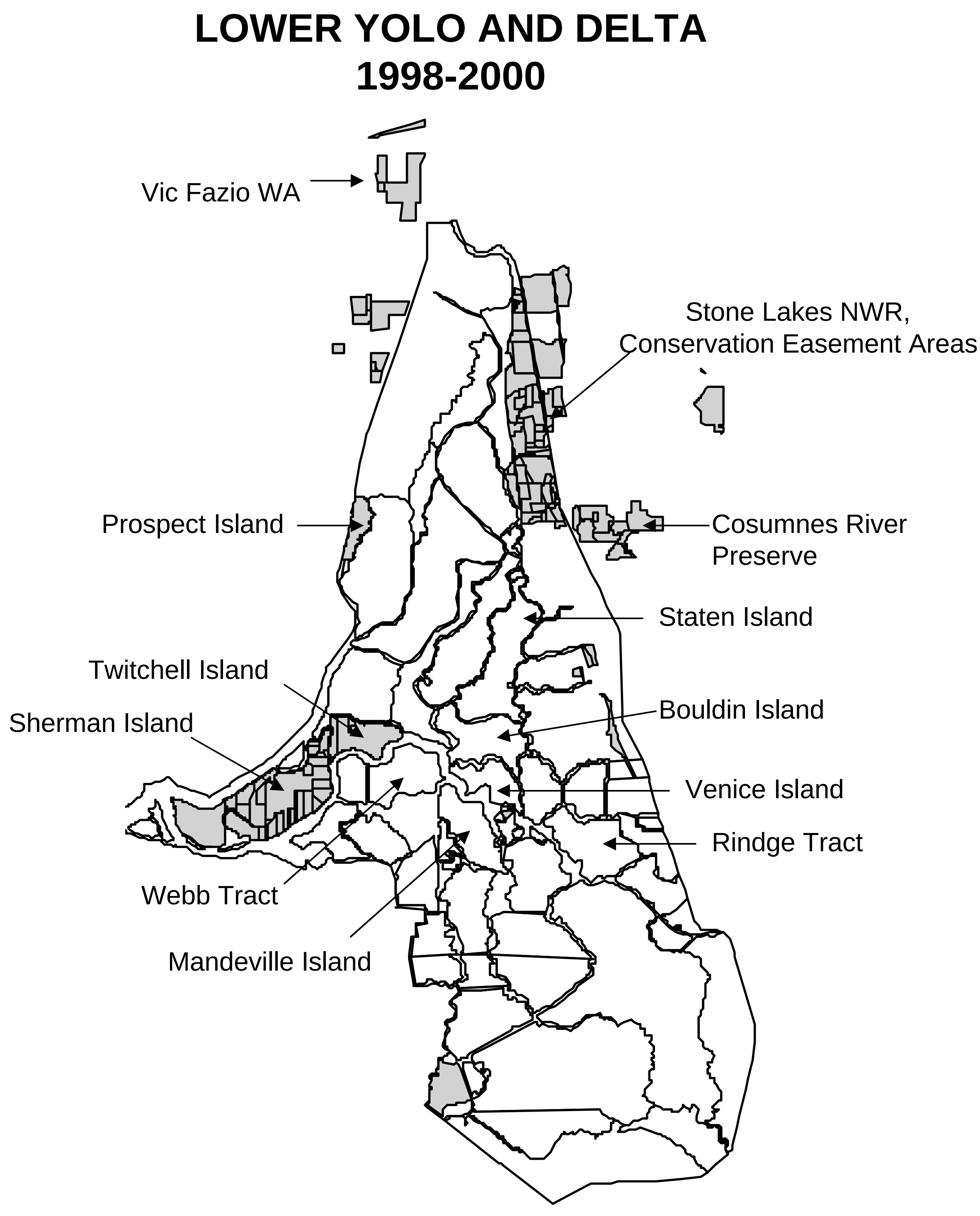
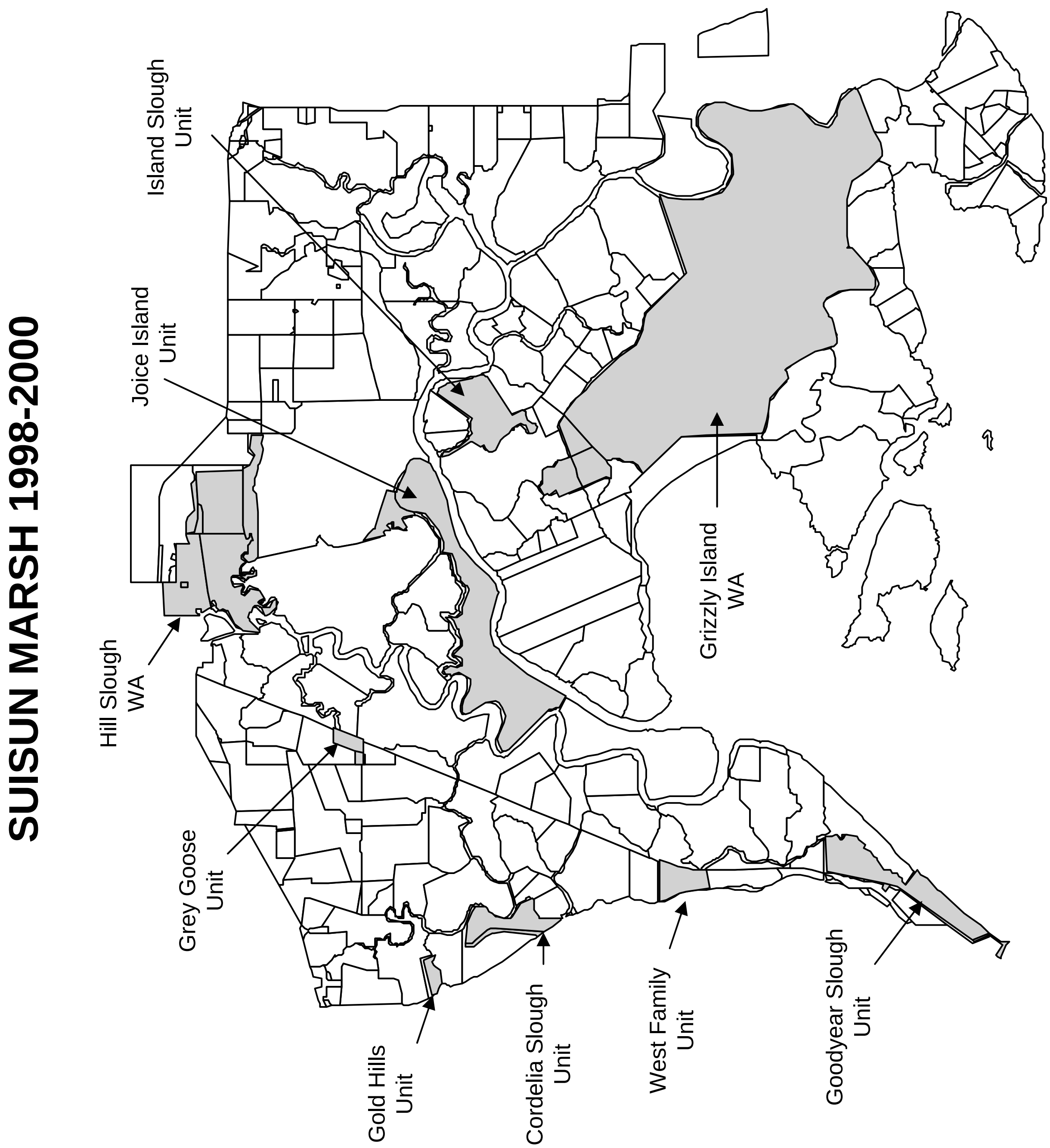

LOWER YOLO AND DELTA
1998-2000
Vic Fazio WA
Stone Lakes NWR,
Conservation Easement Areas
Prospect Island
Cosumnes River
Preserve
Staten Island
Twitchell Island
Sherman Island
Bouldin Island
Venice Island
Rindge Tract
Webb Tract
Mandeville Island

Figure 3



SUISUN MARSH 1998-2000
Island Slough Unit
Joice Island Unit
Hill Slough WA
Grey Goose Unit
Gold Hills Unit
Cordelia Slough Unit
West Family Unit
Goodyear Slough Unit
Grizzly Island WA

Figure 4

GRASSLAND ECOLOGICAL AREA 1998-2000

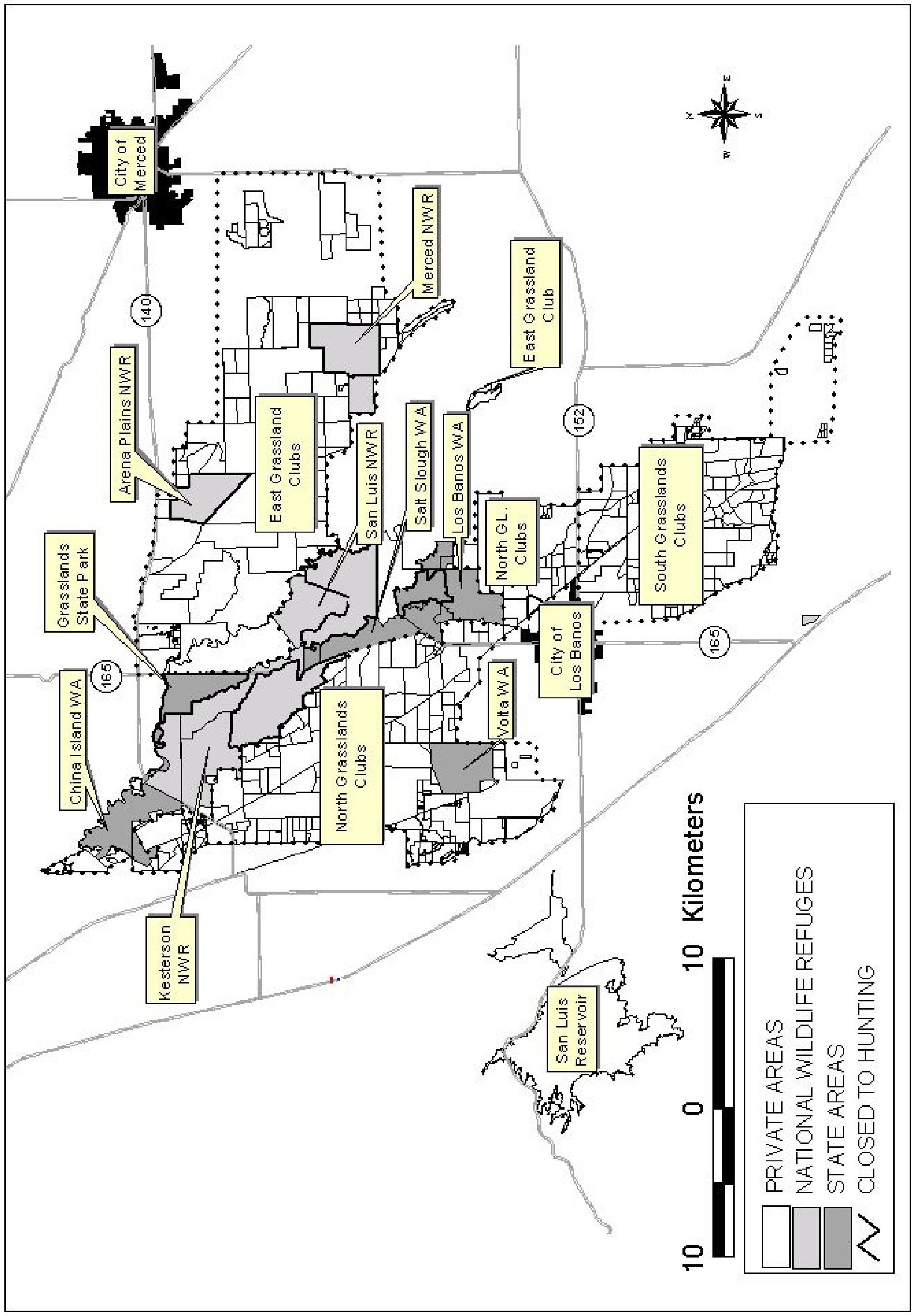


Figure 5

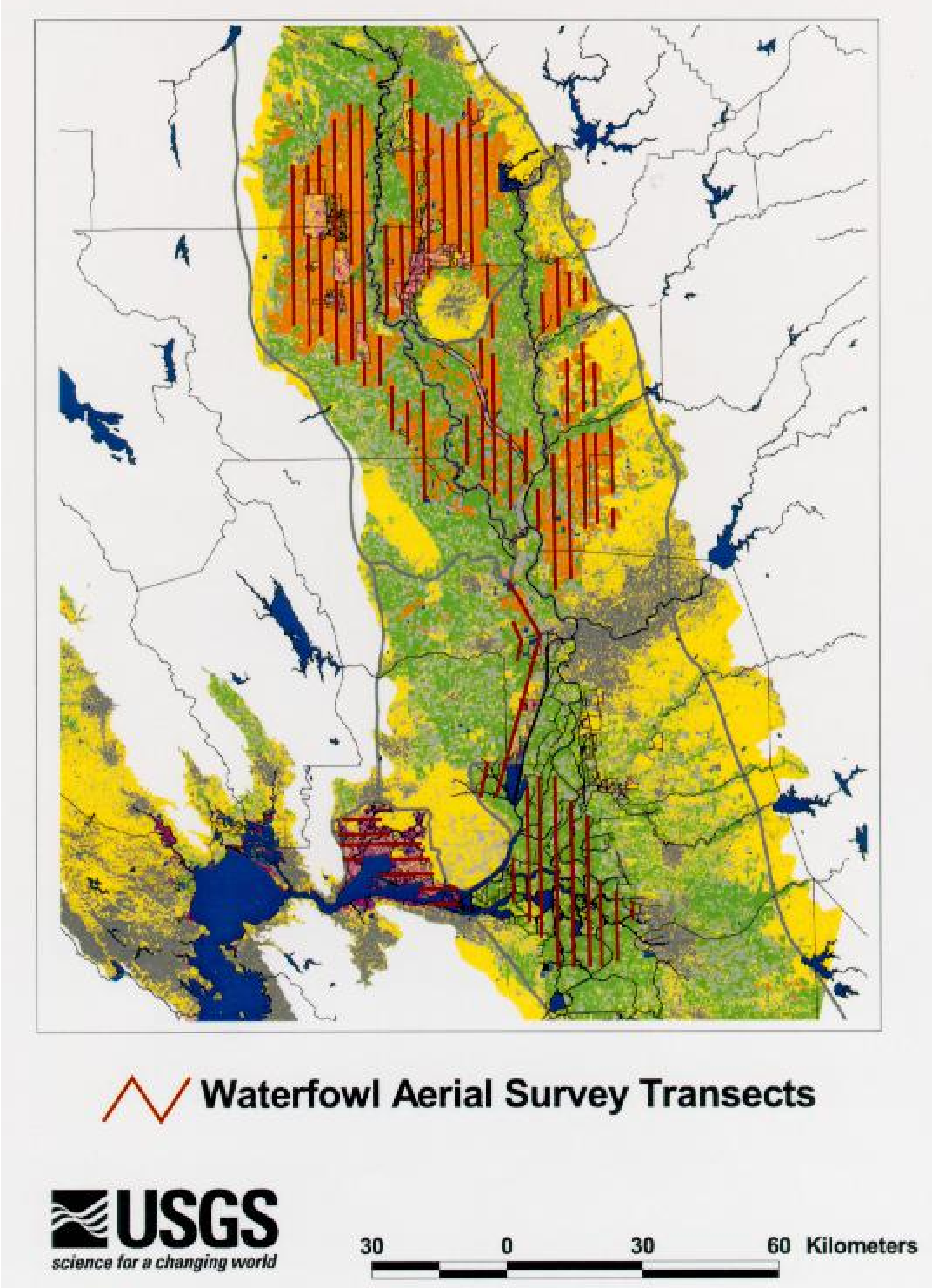
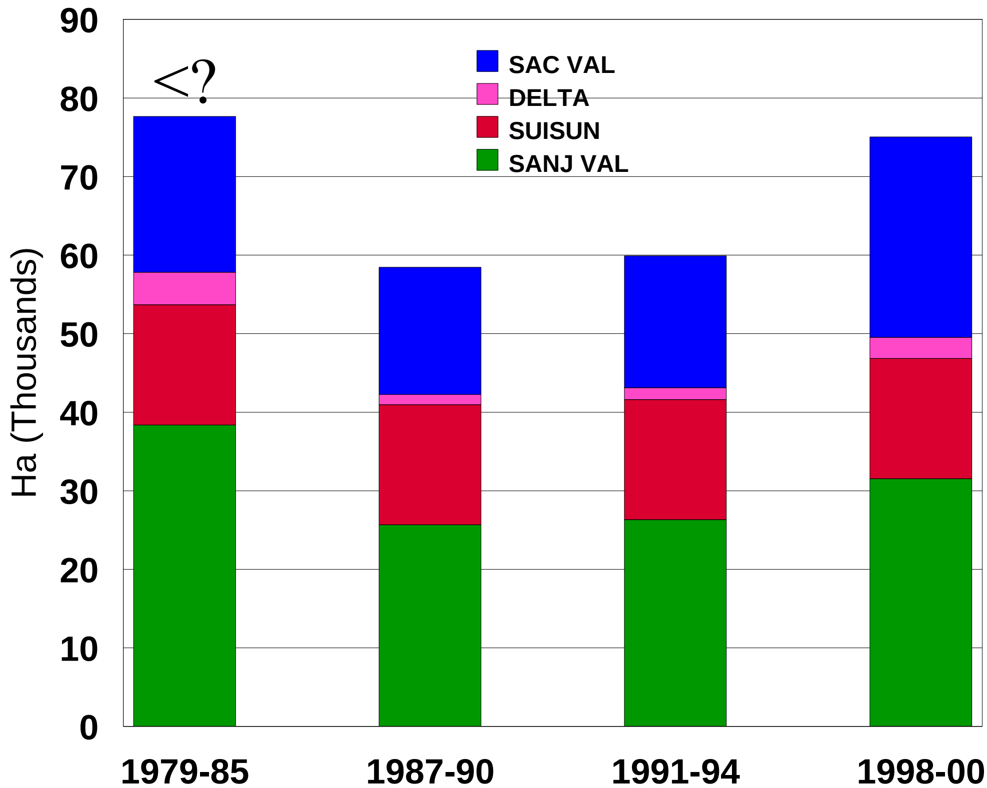

Waterfowl Aerial Survey Transects
USGS
science for a changing world
30 0 30 60 Kilometers

Figure 6

WETLANDS



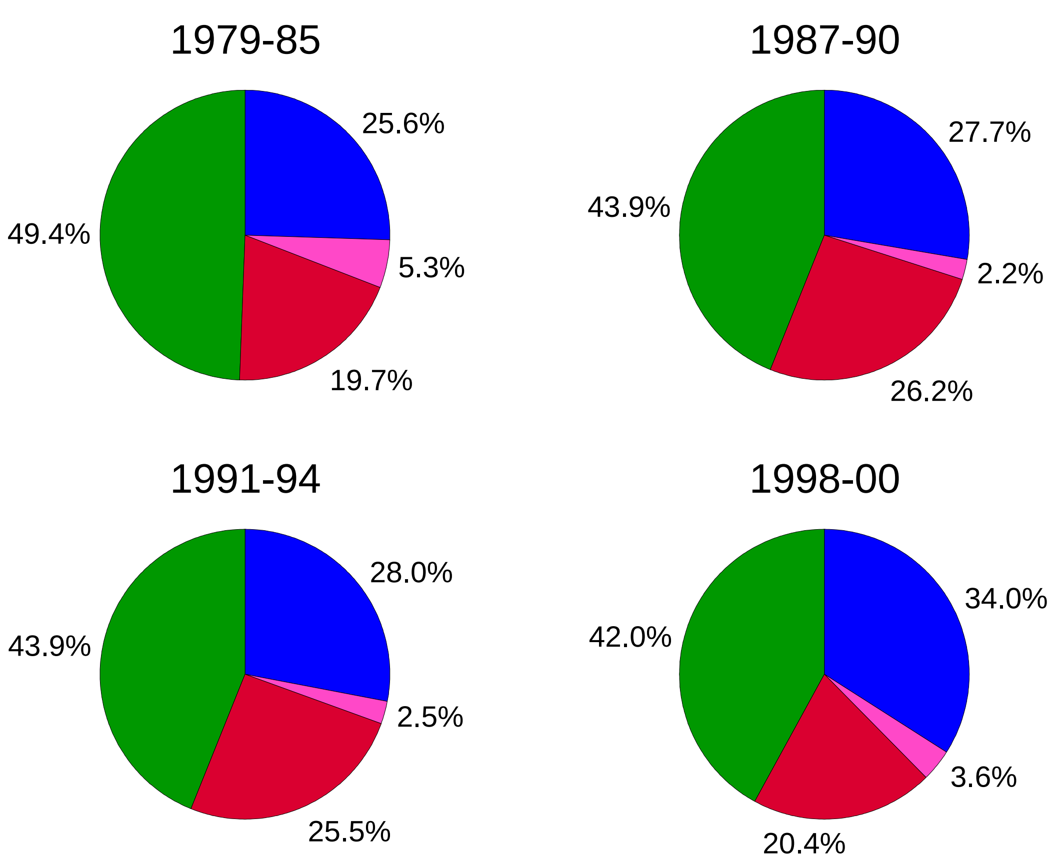
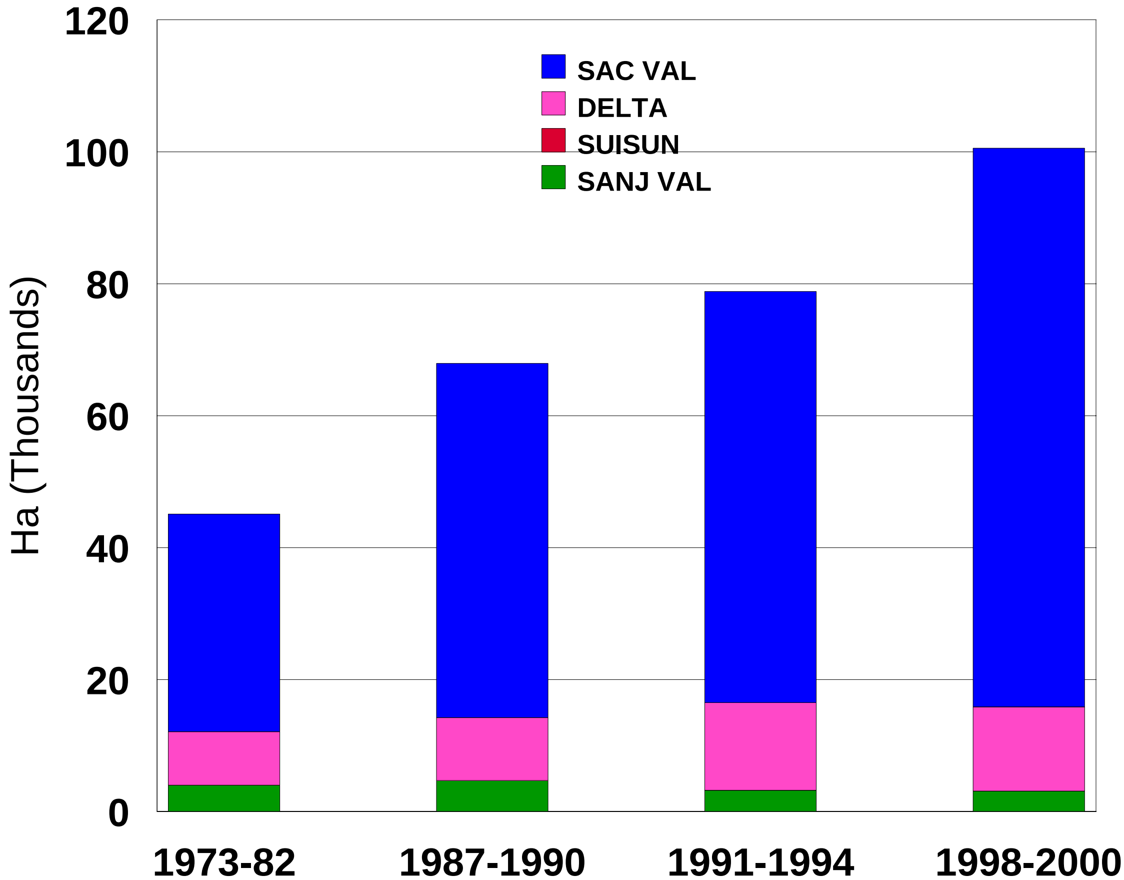


Figure 7

FLOODED AGRICULTURE



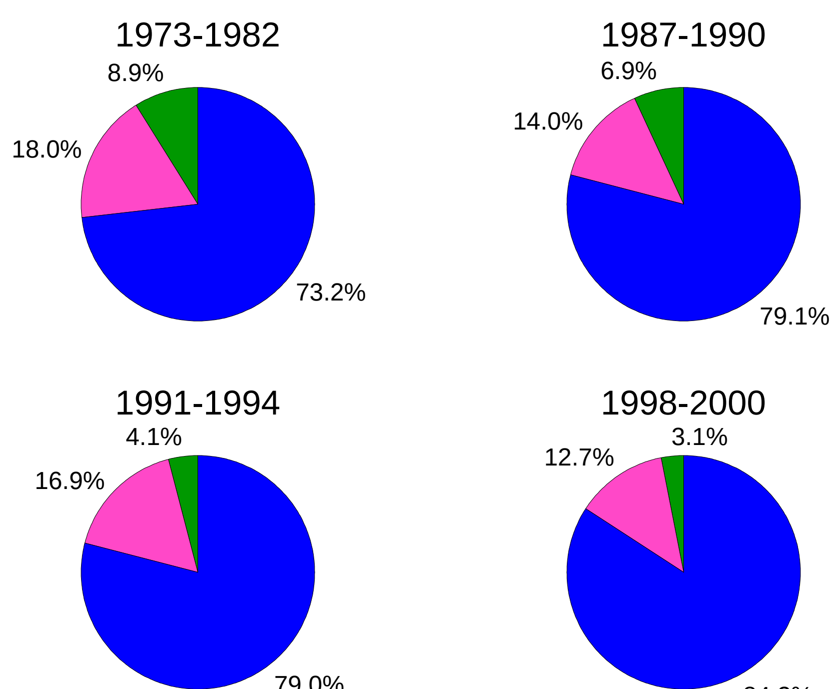


Figure 8

PLANTED RICE

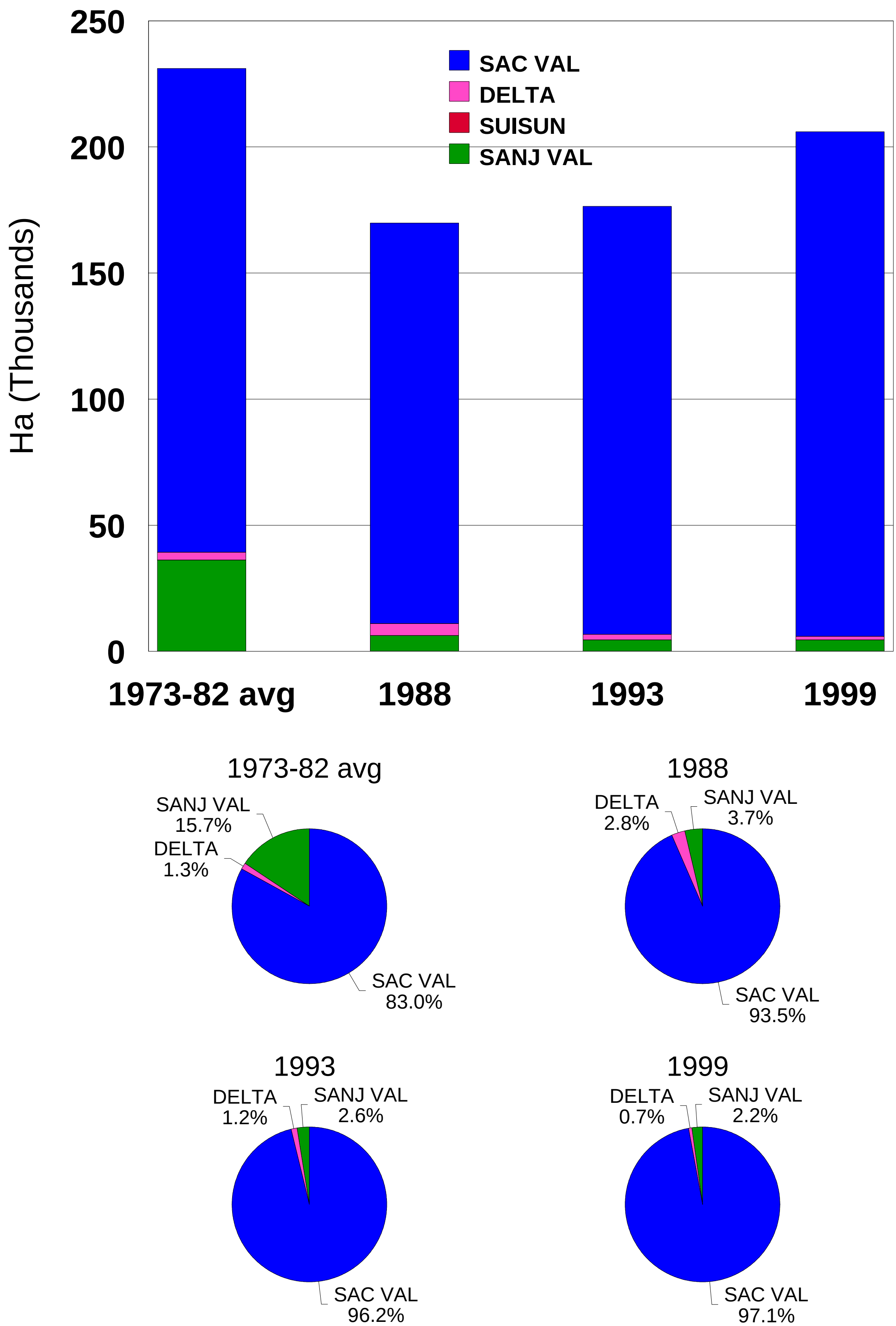


Figure 9

FLOODED HABITAT

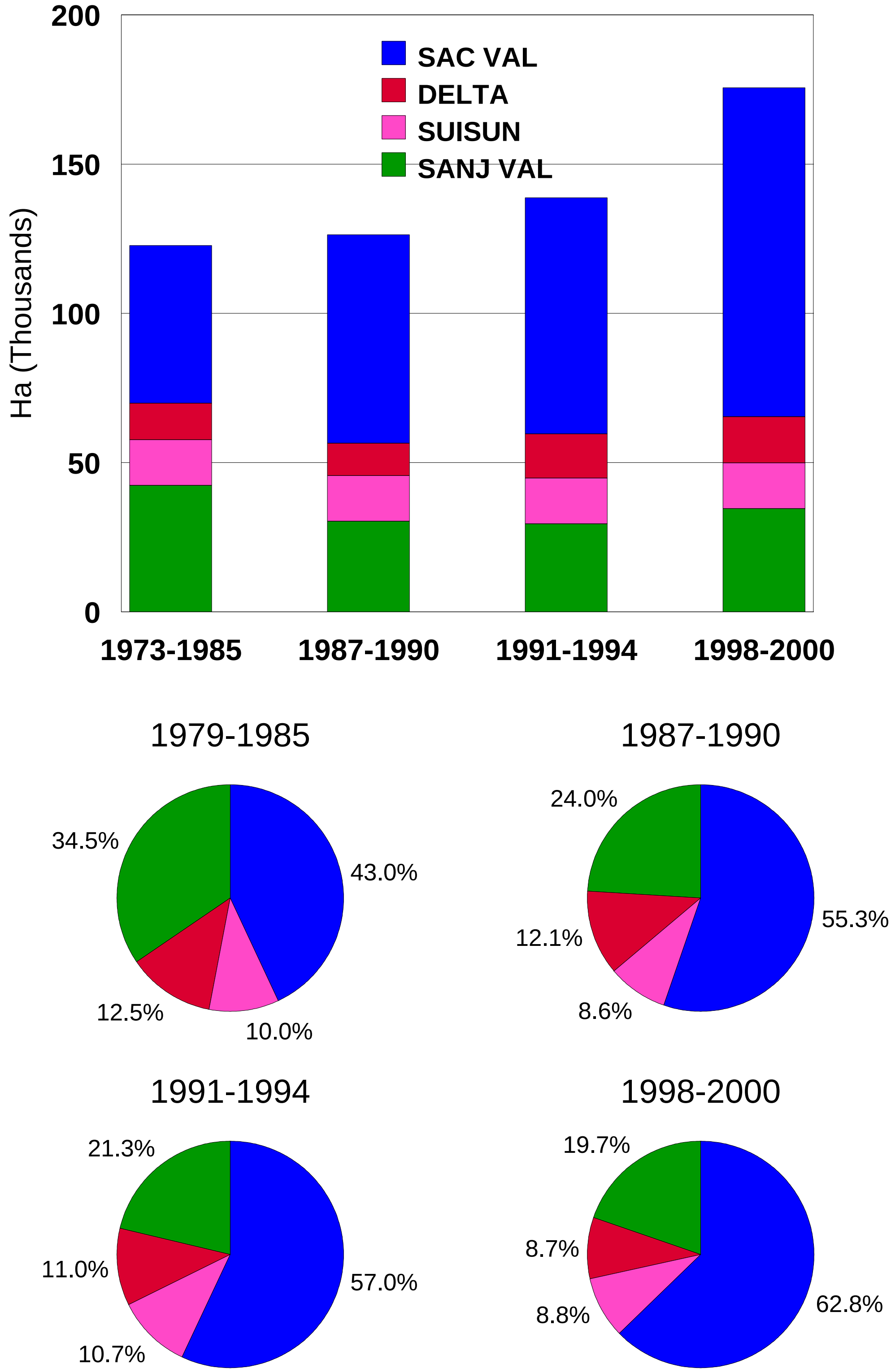


Figure 10

Distribution of All Waterfowl

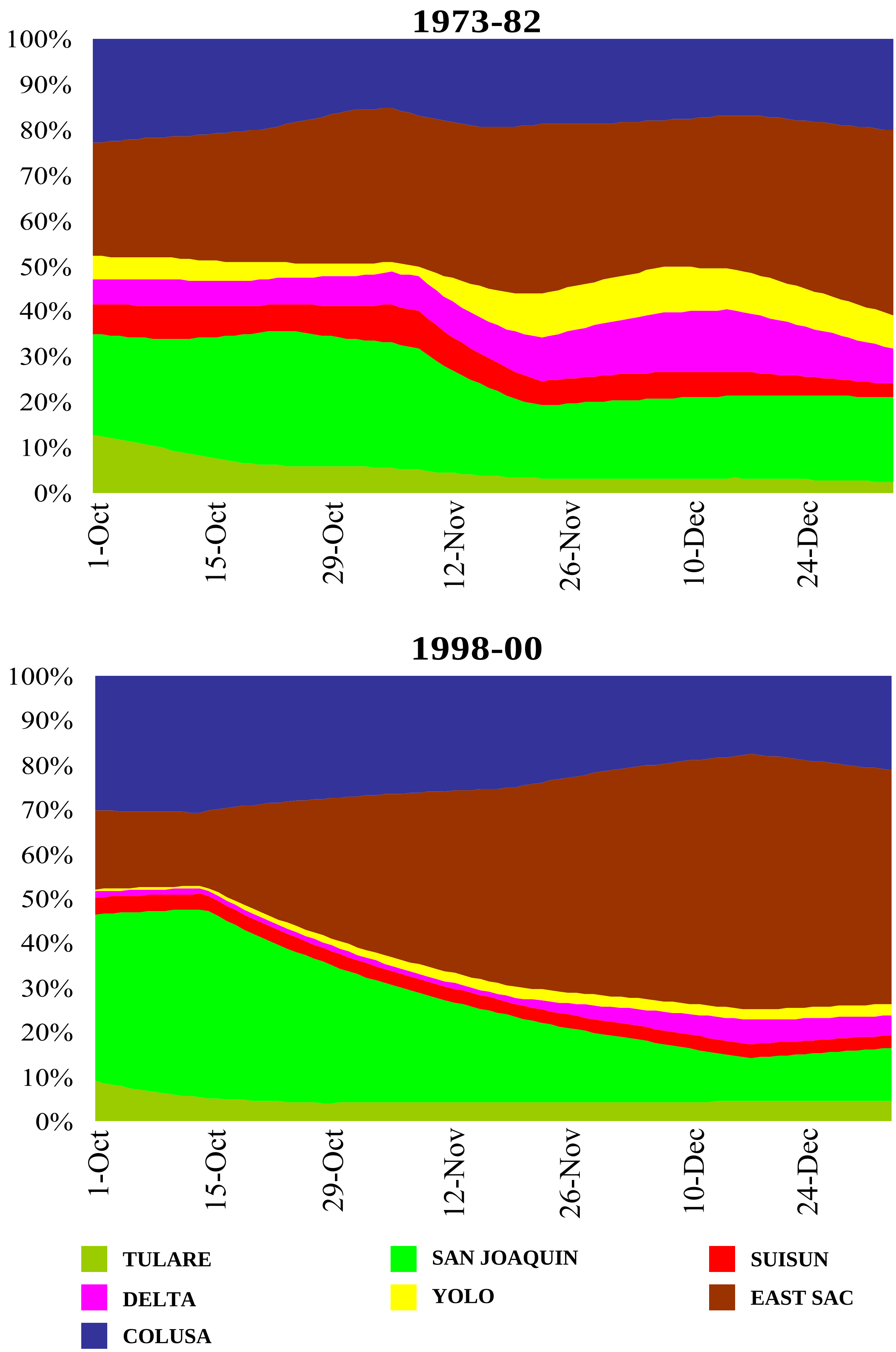


Figure 11

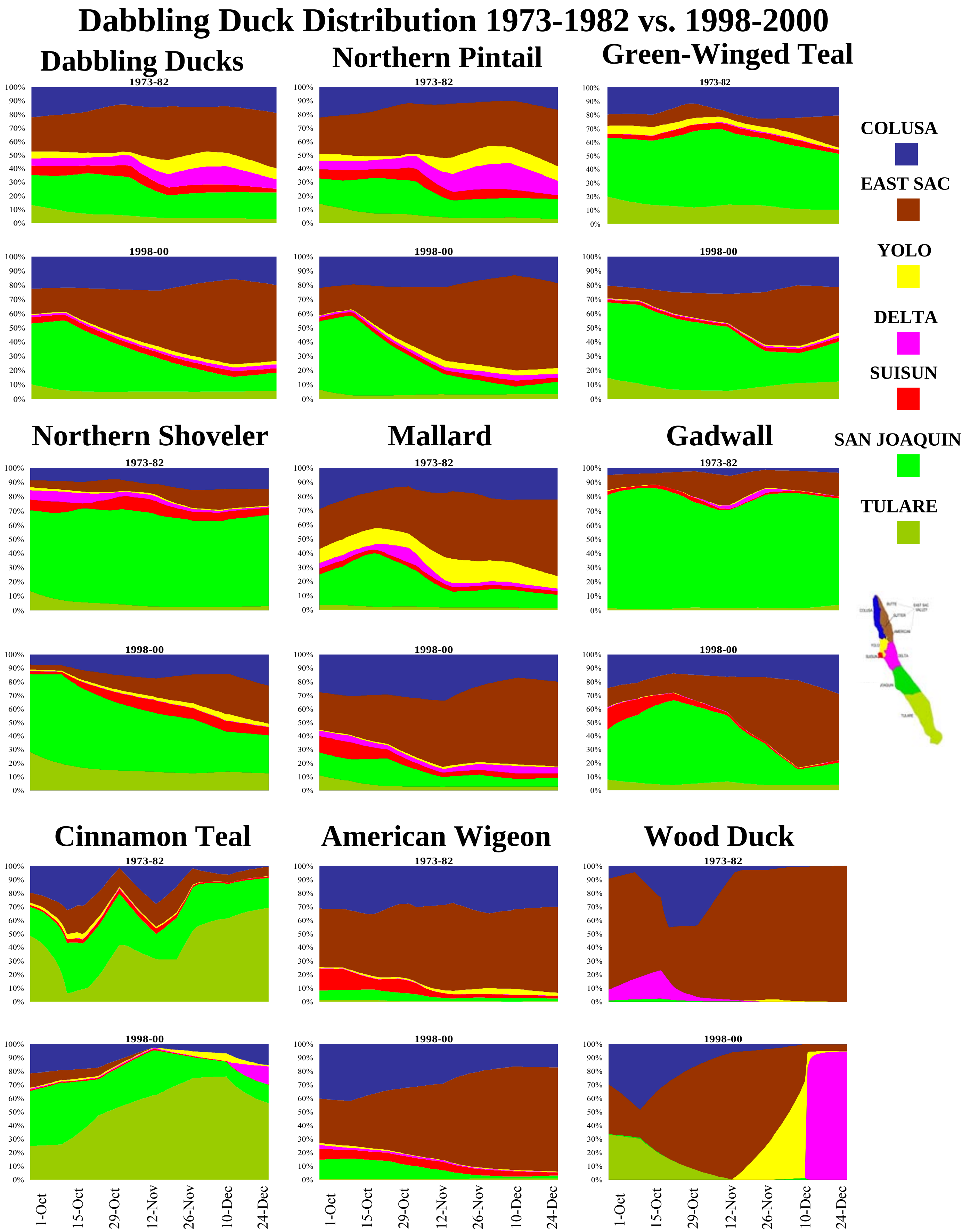

Dabbling Duck Distribution 1973-1982 vs. 1998-2000
Dabbling Ducks
Northern Pintail
Green-Winged Teal
Northern Shoveler
Mallard
Gadwall
Cinnamon Teal
American Wigeon
Wood Duck
1973-82
1998-00
COLUSA
EAST SAC
YOLO
DELTA
SUISUN
SAN JOAQUIN
TULARE
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
1-Oct
15-Oct
29-Oct
12-Nov
26-Nov
10-Dec
24-Dec

Figure 12

Diving Duck Distribution 1973-1982 vs. 1998-2000

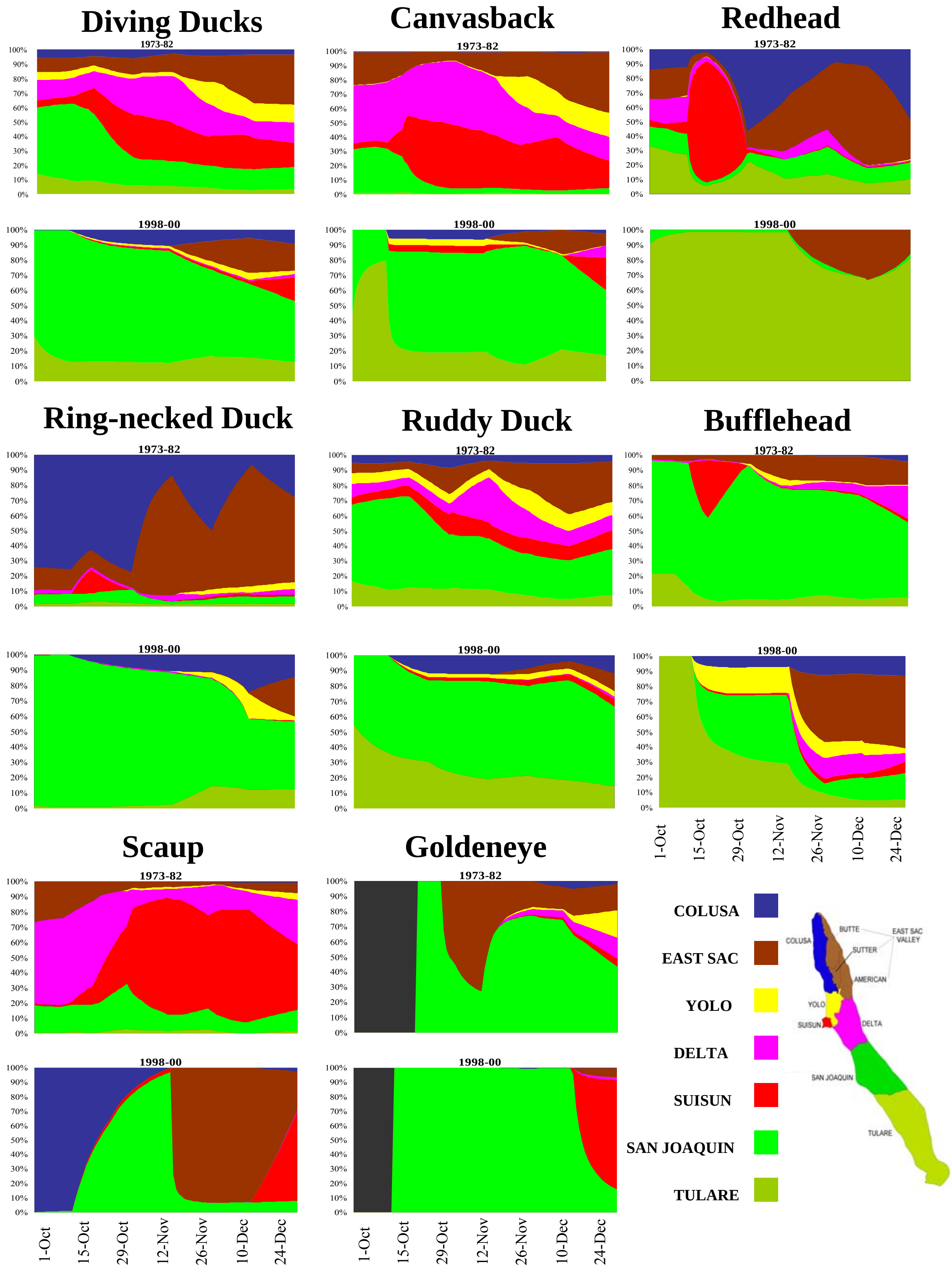


Figure 13

Diving Duck Distribution in January

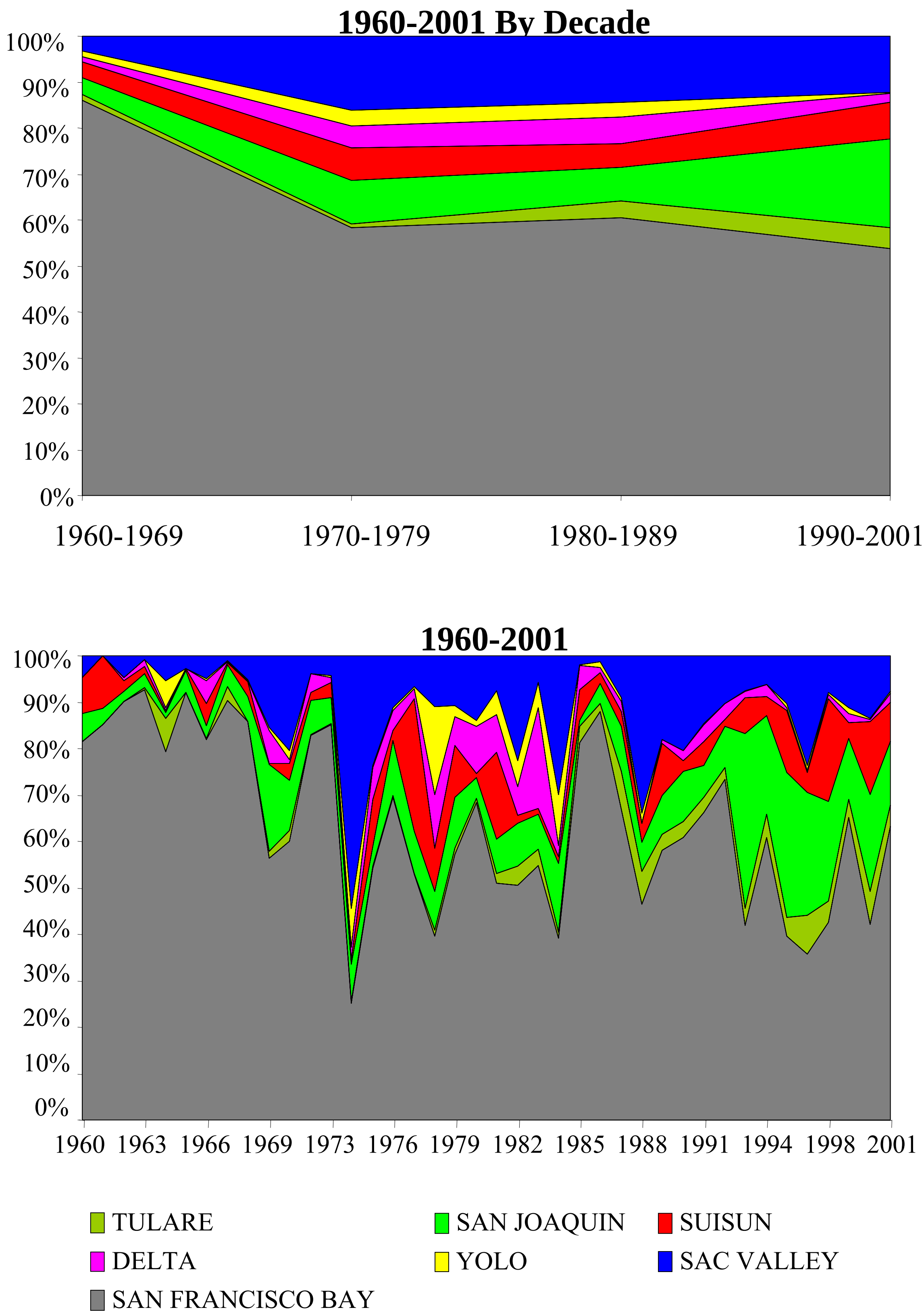


Figure 14

Distribution of Geese, Swans, and Cranes

1973-1982 vs. 1998-2000

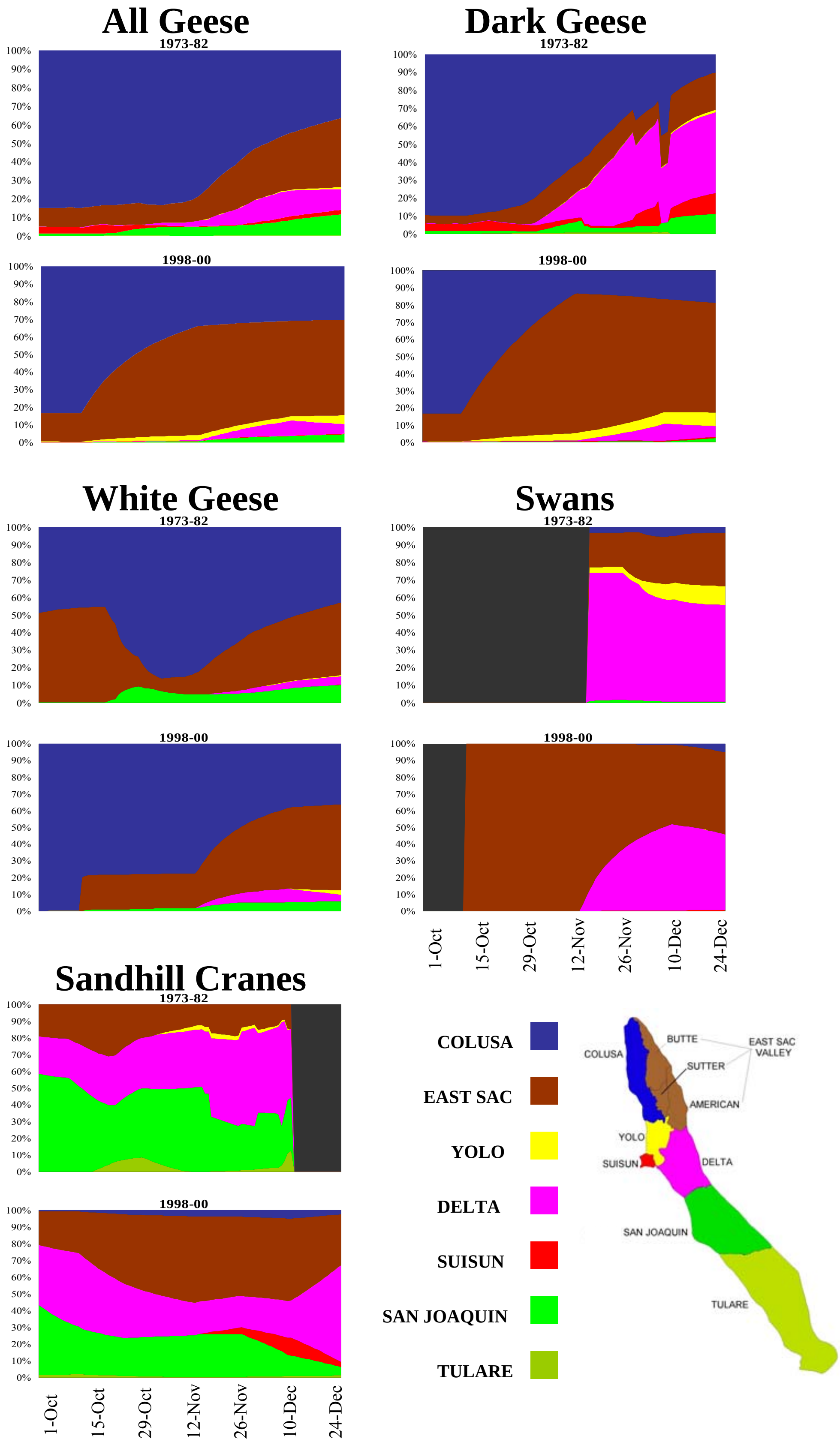


Figure 15

Dabbling duck abundance during September - January

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick gray) and 1999-2000 (thick black)

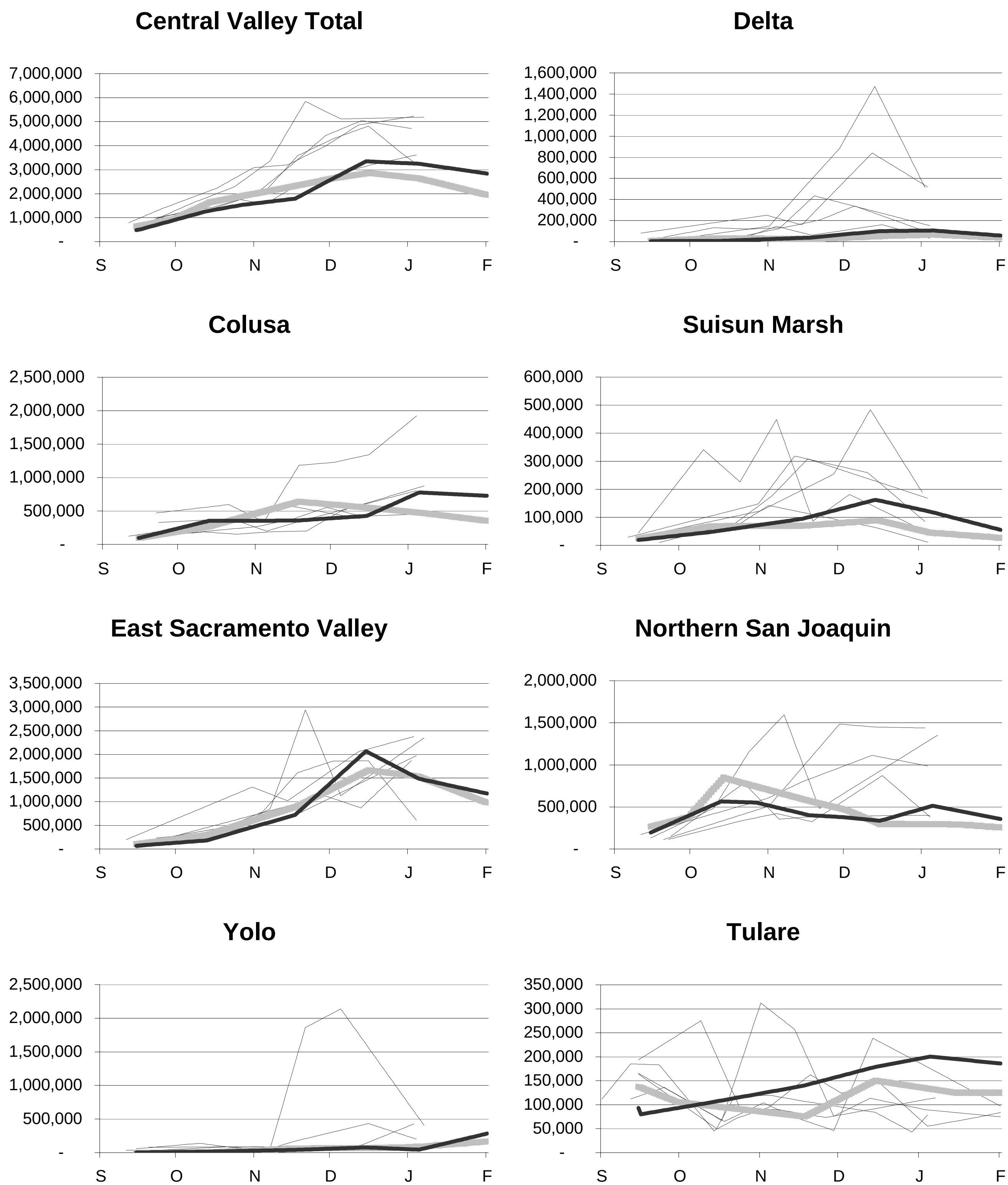


Figure 16

OCT 1 - DEC 31 WATERFOWL USE DAYS
1973 & 1978-81 VS 1998-99 & 1999-00

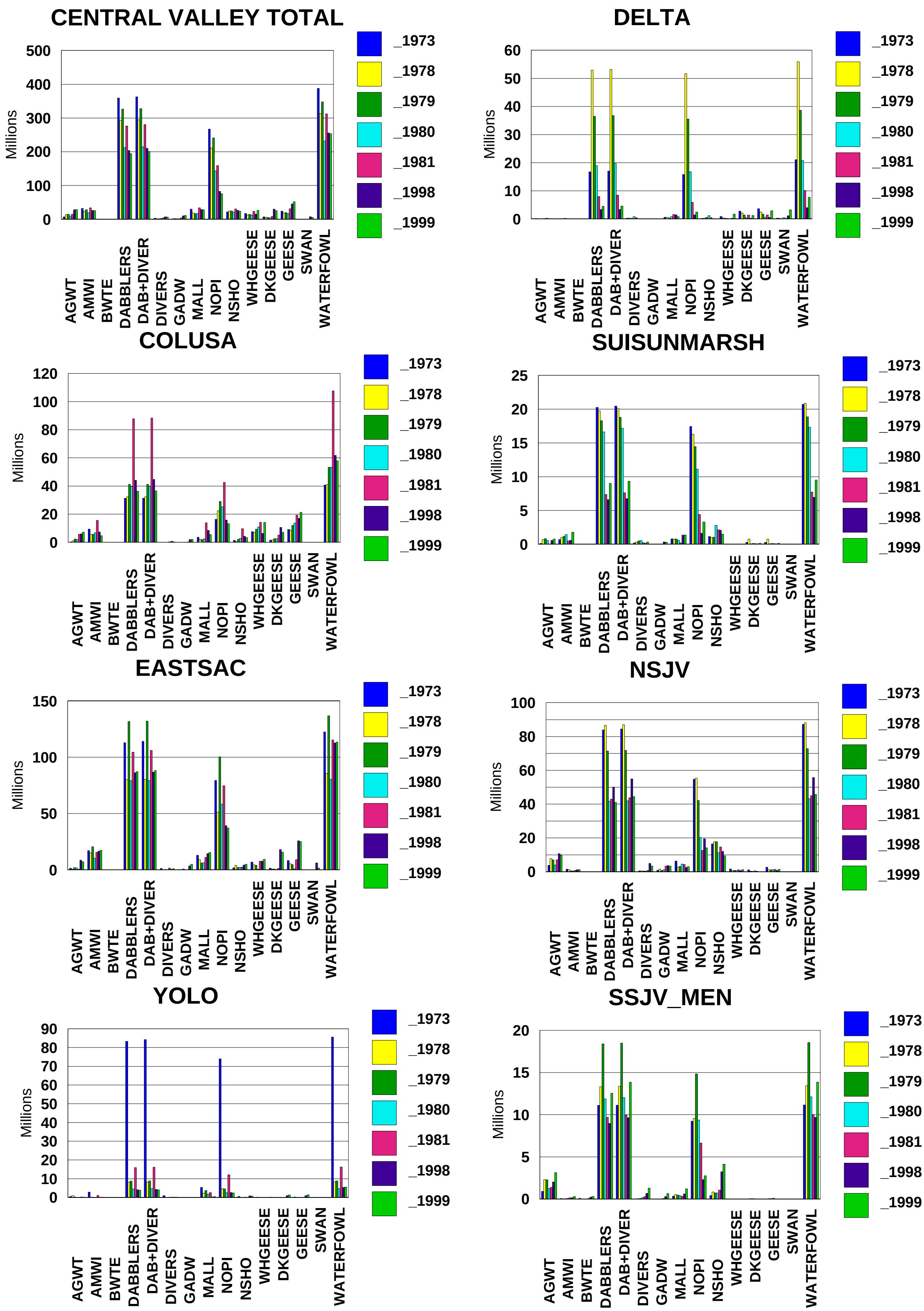


Figure 17

Northern Pintail abundance during September - January

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick gray) and 1999-2000 (thick black)

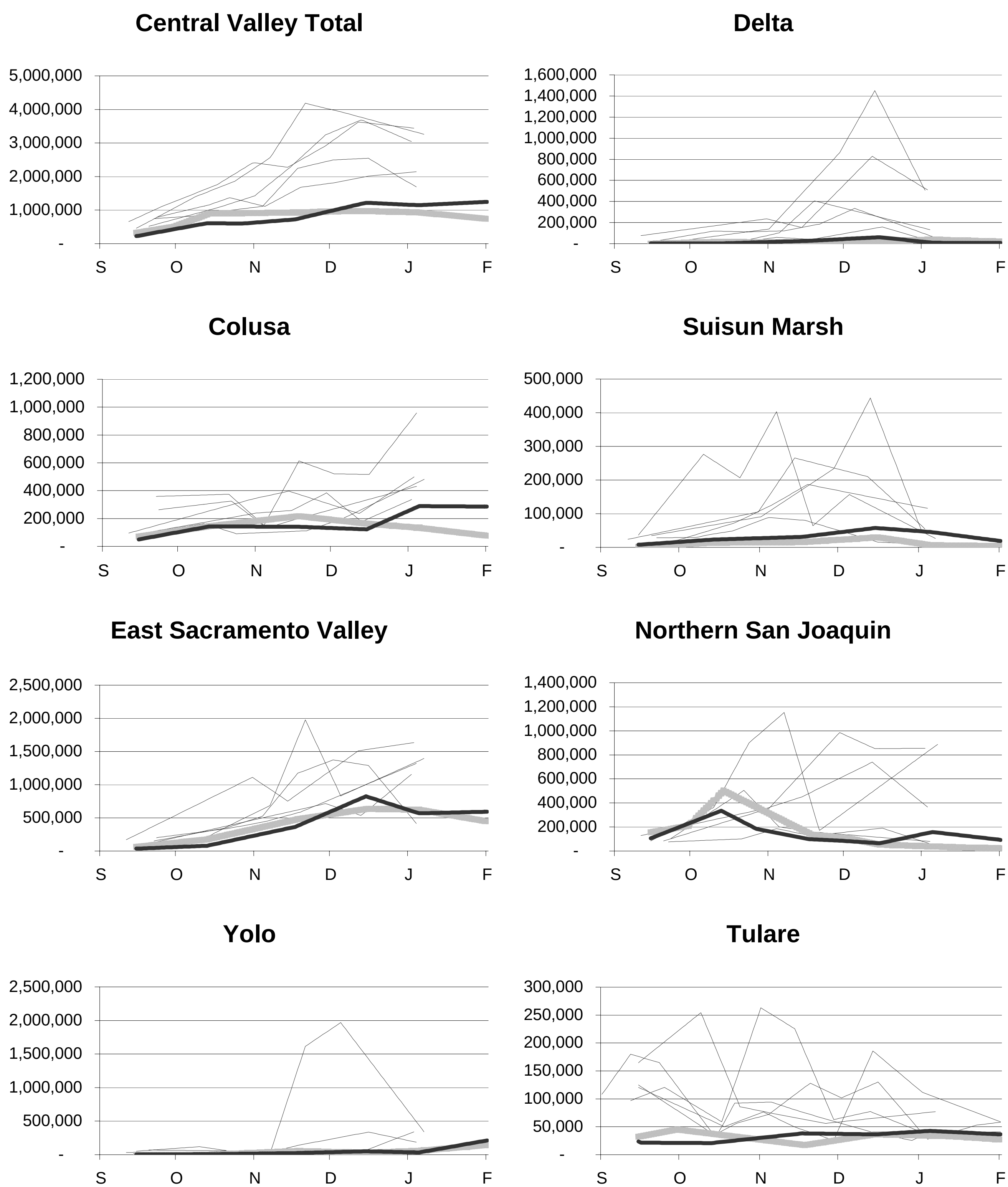


Figure 18

OCT 1 - DEC 31 WATERFOWL USE DAYS

1973 & 1978-81 VS 1998-99 & 1999-00 (Pintails and Totals Not Shown)

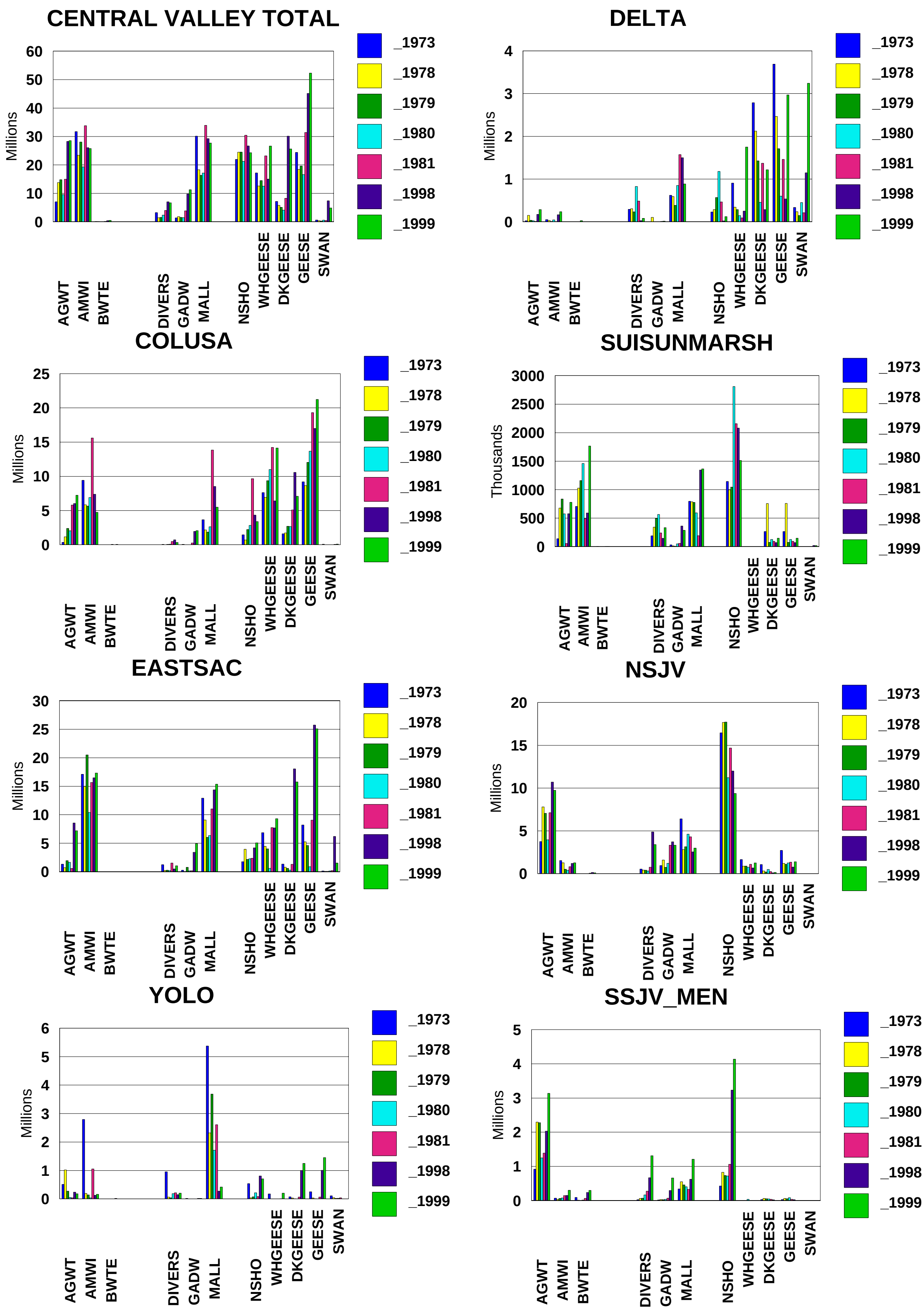


Figure 19

Mallard abundance during September - January

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick gray) and 1999-2000 (thick black)

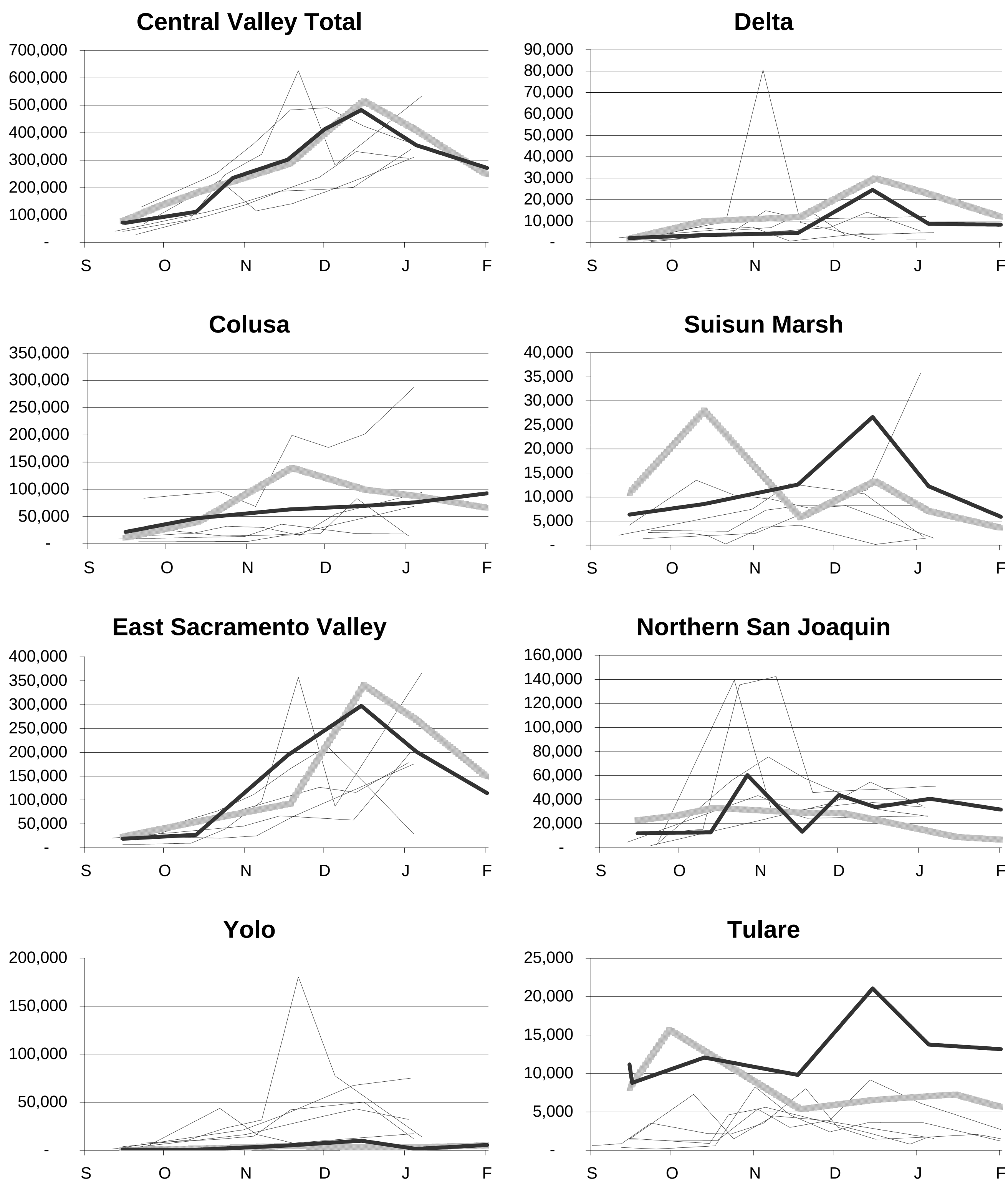


Figure 20

Green-winged Teal abundance during September - January

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick gray) and 1999-2000 (thick black)

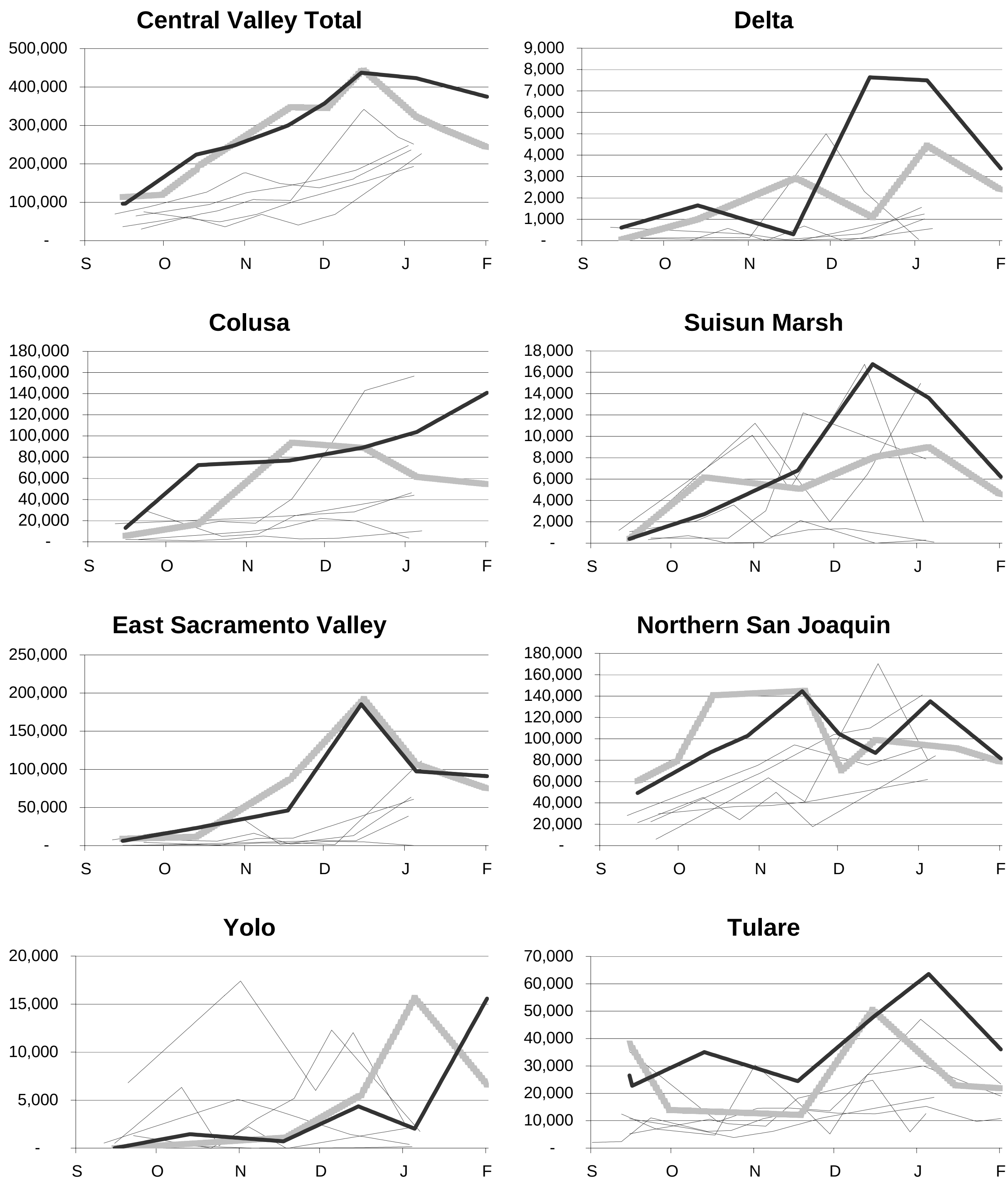


Figure 21

American Wigeon abundance during September - January

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick gray) and 1999-2000 (thick black)

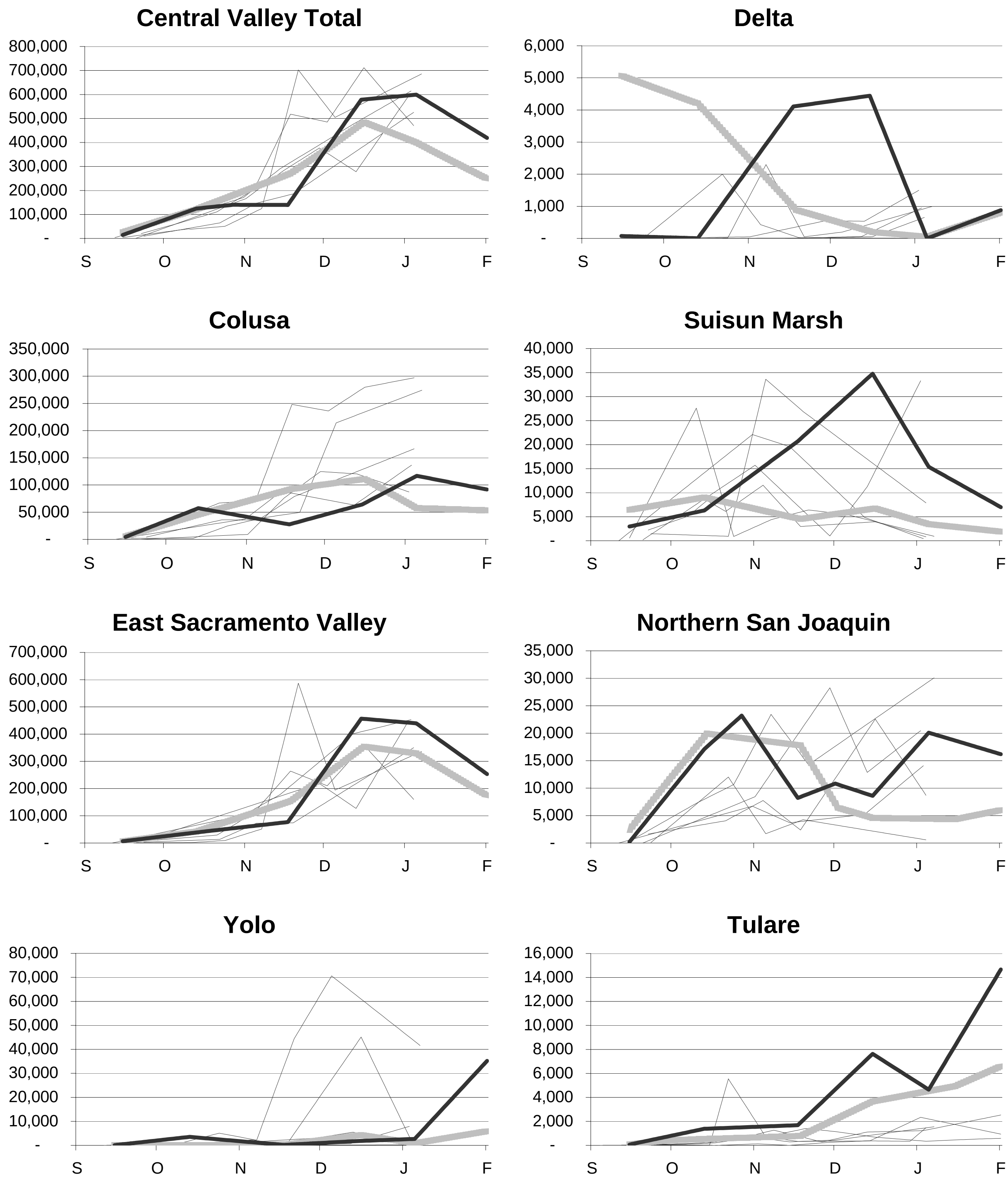


Figure 22

Northern Shoveler abundance during September - January

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick gray) and 1999-2000 (thick black)

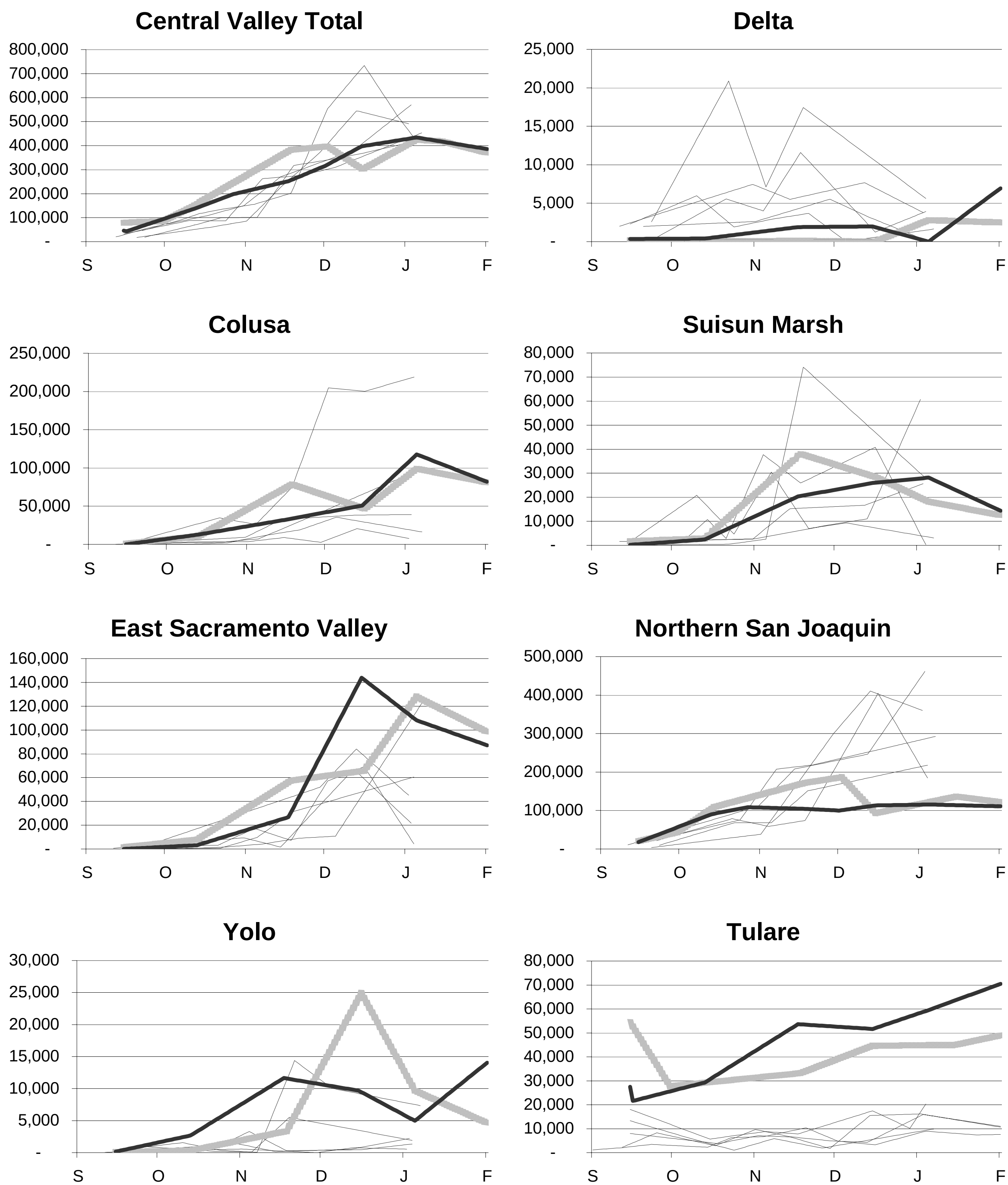


Figure 23

Gadwall abundance during September - January

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick gray) and 1999-2000 (thick black)

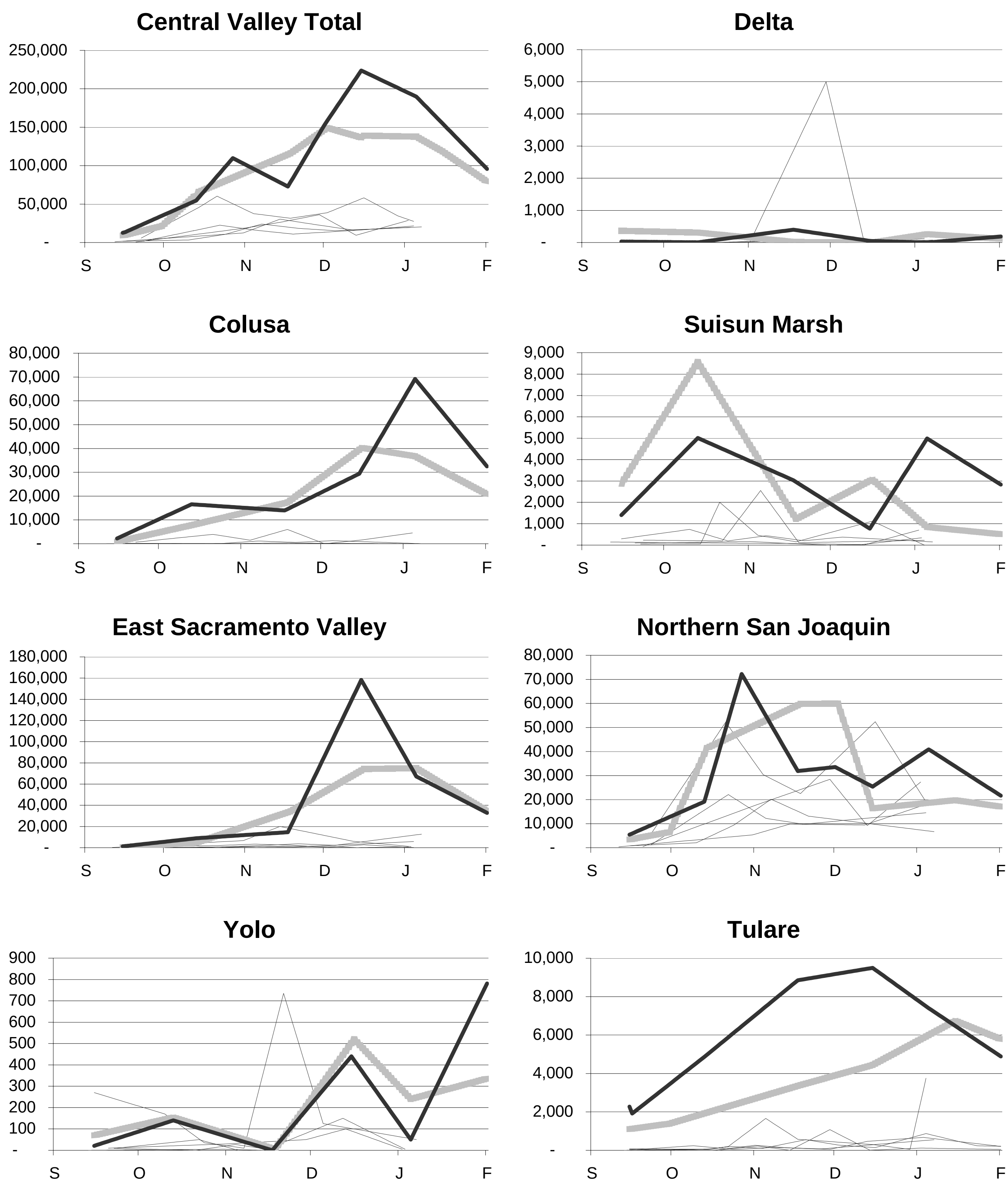


Figure 24

Cinnamon Teal abundance during September - January

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick gray) and 1999-2000 (thick black)

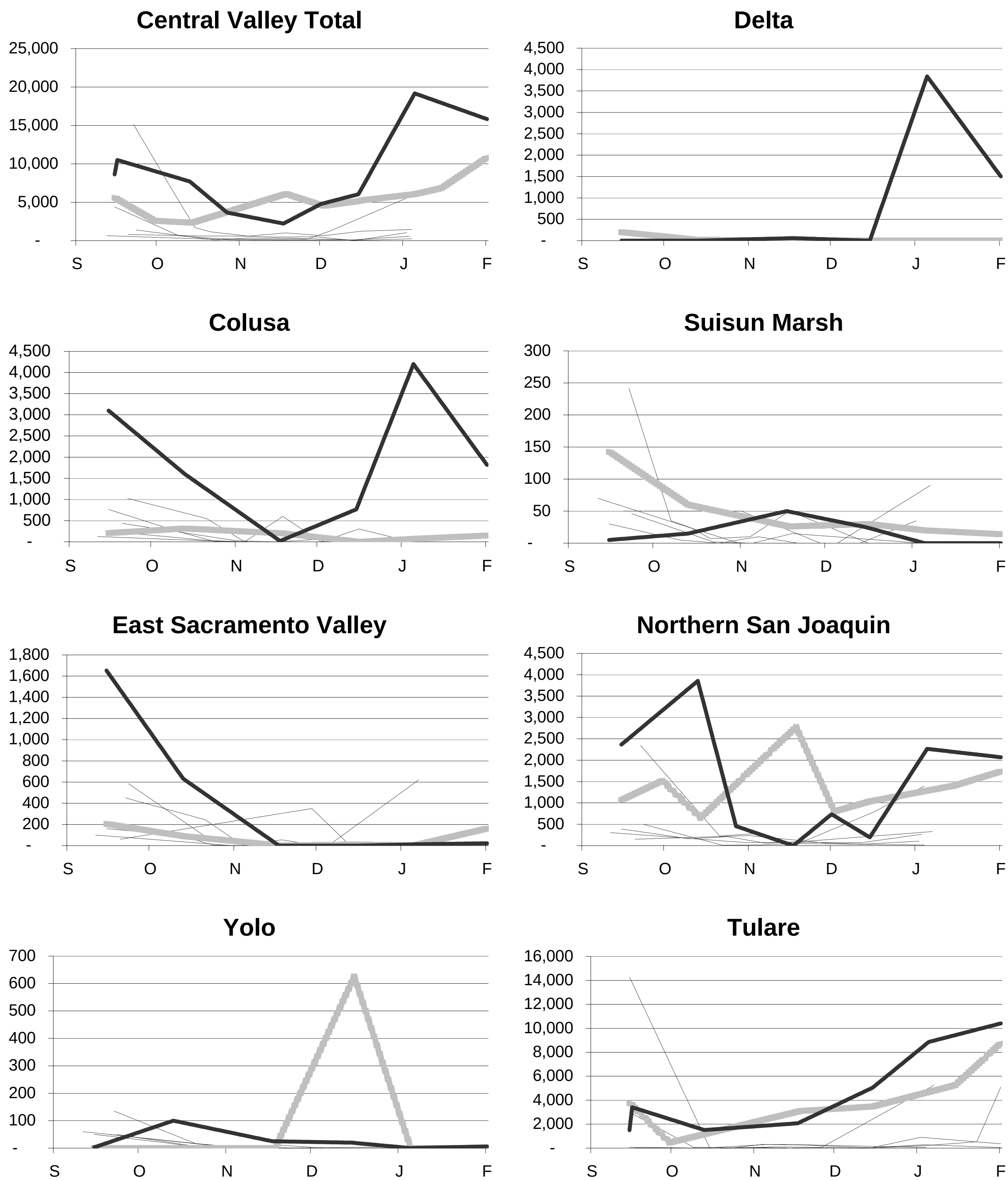


Figure 25

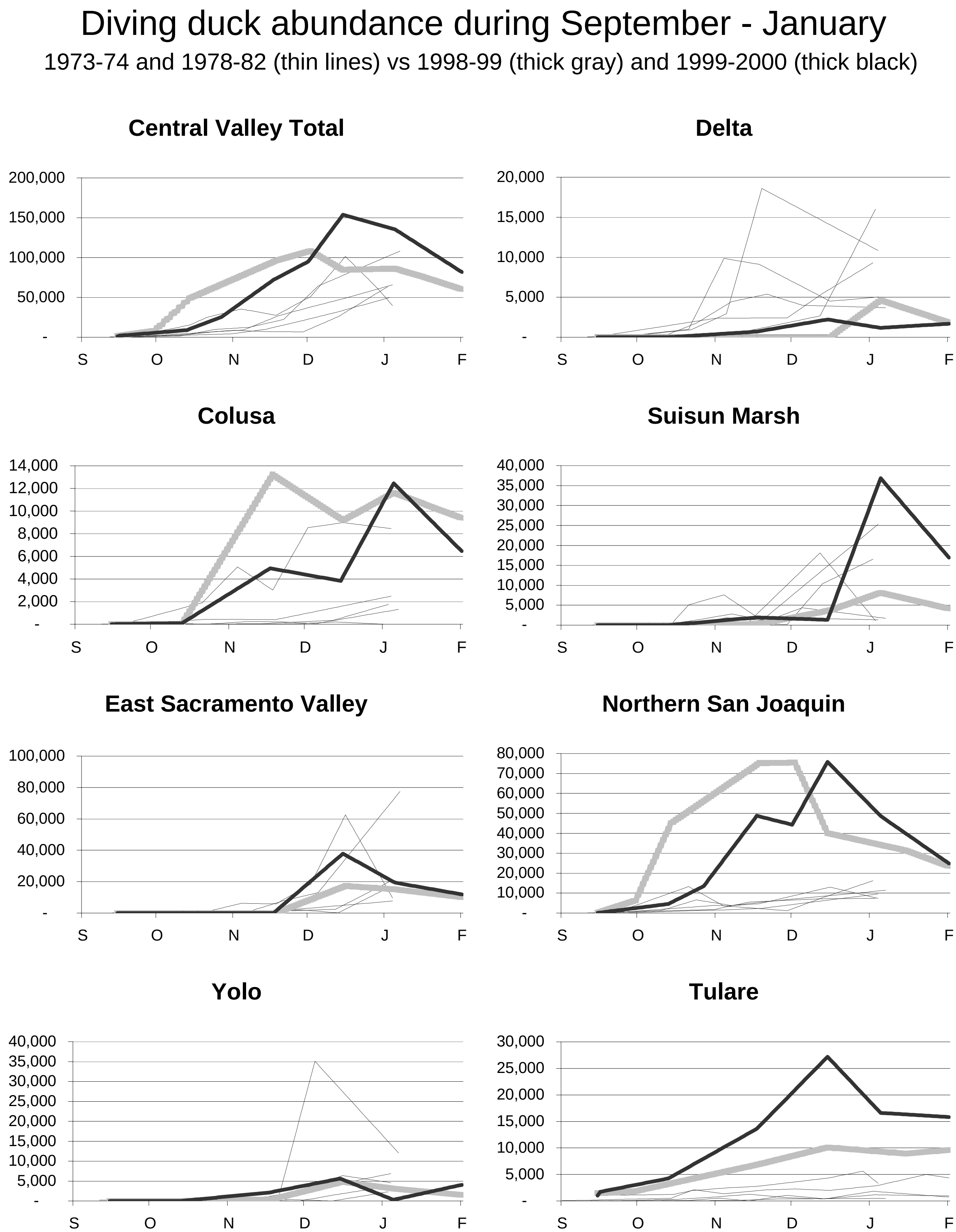

Diving duck abundance during September - January
1973-74 and 1978-82 (thin lines) vs 1998-99 (thick gray) and 1999-2000 (thick black)
Central Valley Total
200,000
150,000
100,000
50,000
-
S O N D J F
Delta
20,000
15,000
10,000
5,000
-
S O N D J F
Colusa
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
S O N D J F
Suisun Marsh
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
S O N D J F
East Sacramento Valley
100,000
80,000
60,000
40,000
20,000
-
S O N D J F
Northern San Joaquin
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
S O N D J F
Yolo
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
S O N D J F
Tulare
30,000
25,000
20,000
15,000
10,000
5,000
-
S O N D J F

Figure 26

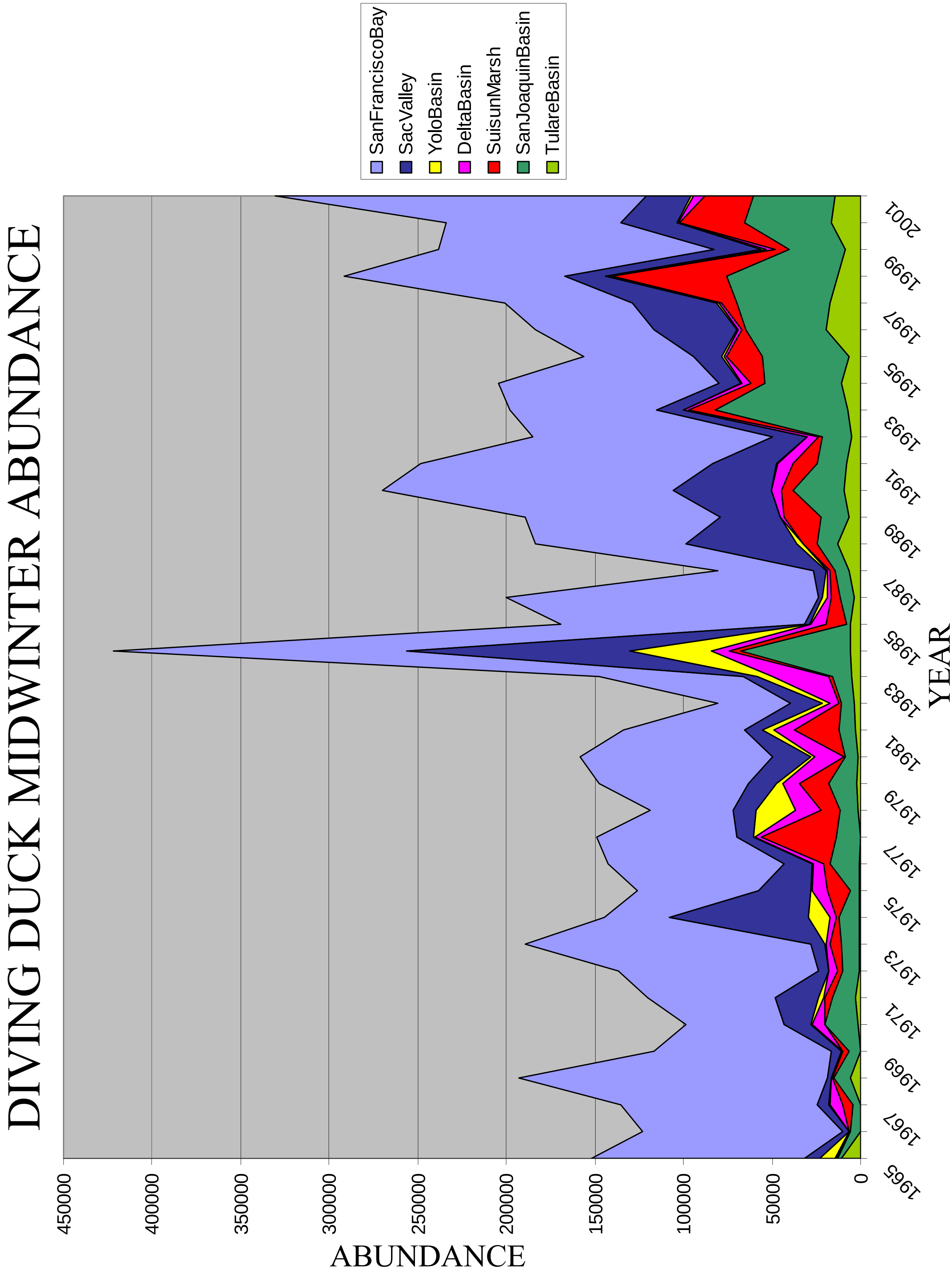

DIVING DUCK MIDWINTER ABUNDANCE
SanFranciscoBay
SacValley
YoloBasin
DeltaBasin
SuisunMarsh
SanJoaquinBasin
TulareBasin
ABUNDANCE
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
YEAR
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001

Figure 27

Goose abundance during Sep - Jan

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick blue) and 1999-2000 (thick red)

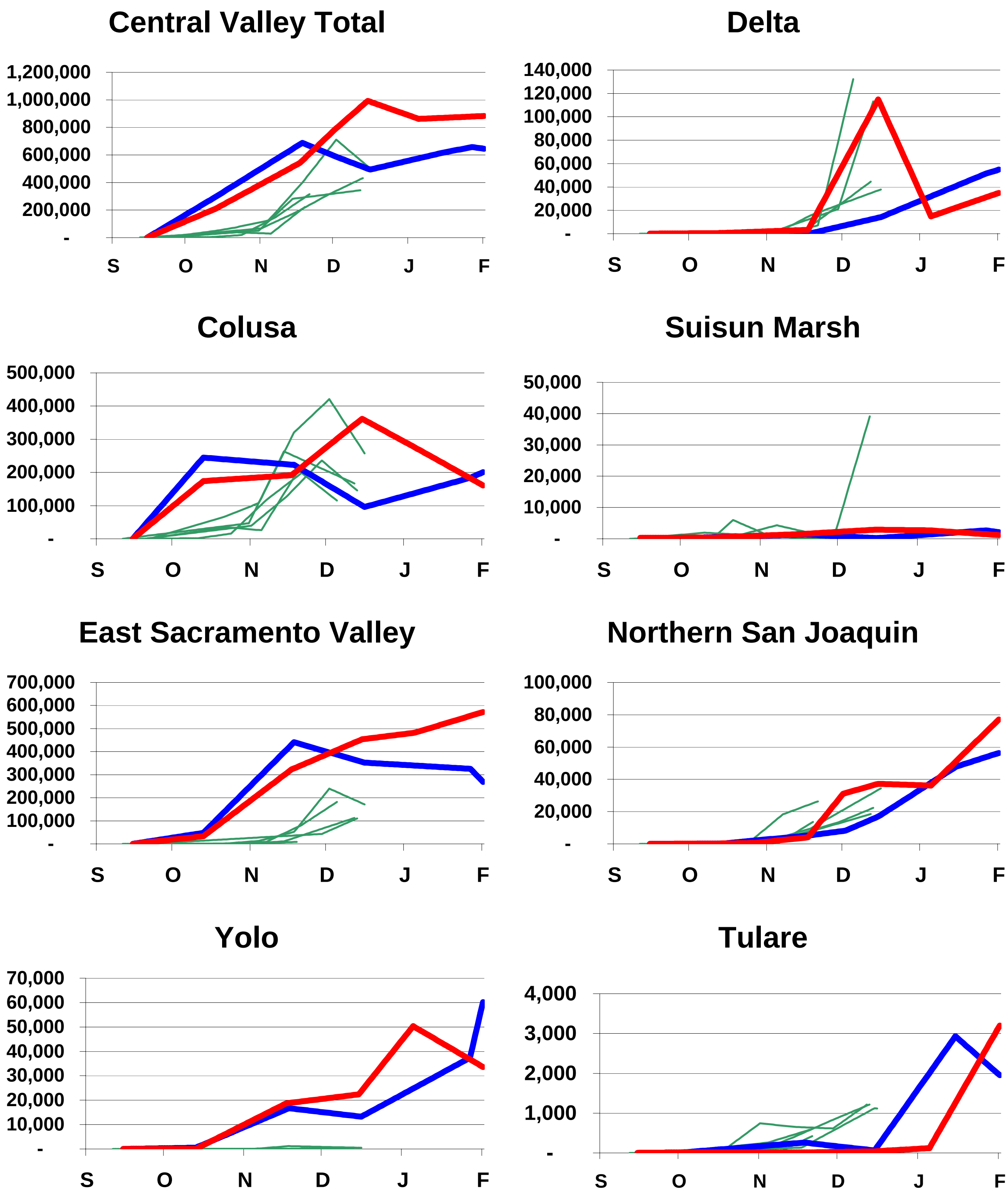


Figure 28

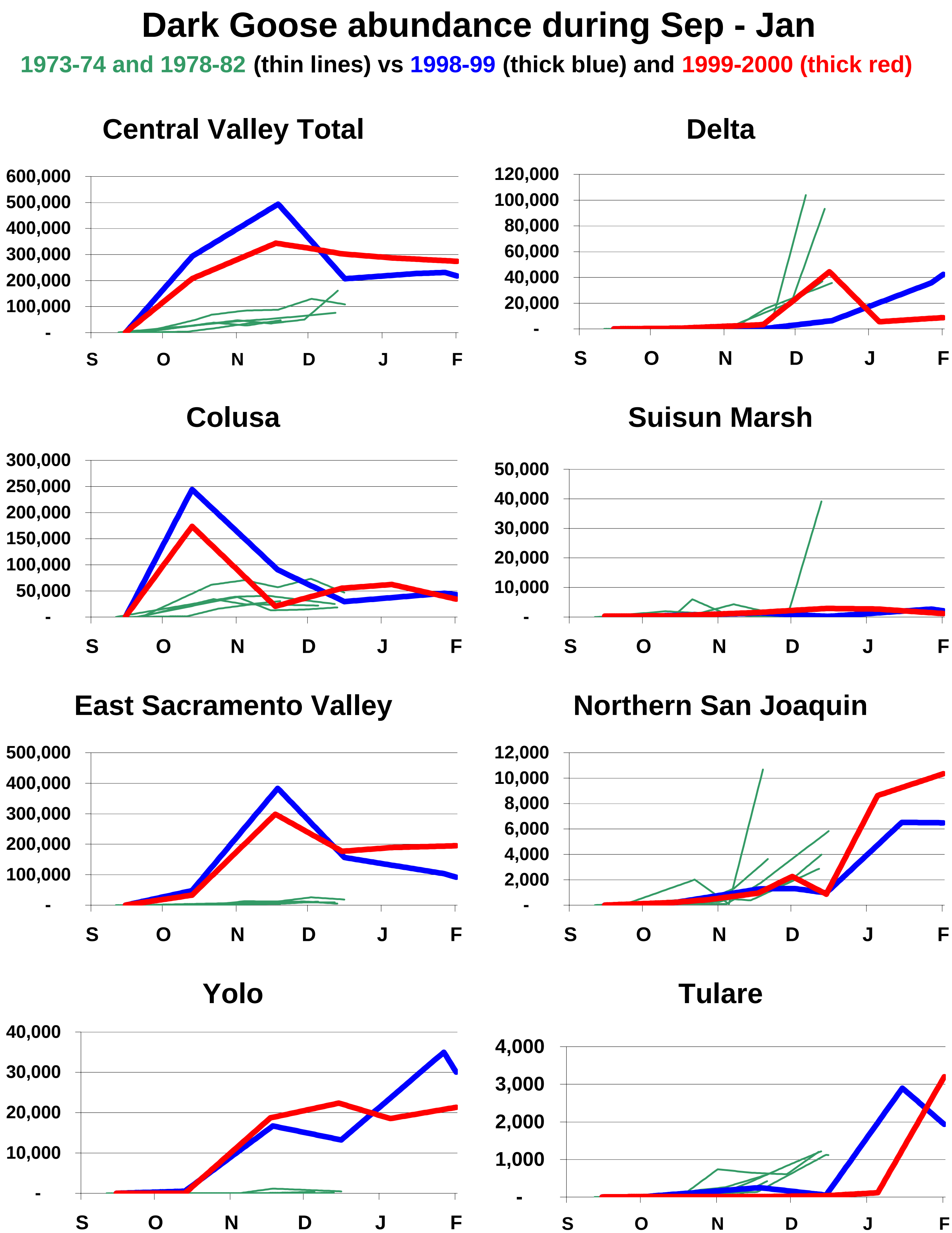

Dark Goose abundance during Sep - Jan
1973-74 and 1978-82 (thin lines) vs 1998-99 (thick blue) and 1999-2000 (thick red)
Central Valley Total
600,000
500,000
400,000
300,000
200,000
100,000
-
S O N D J F
Delta
120,000
100,000
80,000
60,000
40,000
20,000
-
S O N D J F
Colusa
300,000
250,000
200,000
150,000
100,000
50,000
-
S O N D J F
Suisun Marsh
50,000
40,000
30,000
20,000
10,000
-
S O N D J F
East Sacramento Valley
500,000
400,000
300,000
200,000
100,000
-
S O N D J F
Northern San Joaquin
12,000
10,000
8,000
6,000
4,000
2,000
-
S O N D J F
Yolo
40,000
30,000
20,000
10,000
-
S O N D J F
Tulare
4,000
3,000
2,000
1,000
-
S O N D J F

Figure 29

White Goose abundance during Sep - Jan

1973-74 and 1978-82 (thin lines) vs 1998-99 (thick blue) and 1999-2000 (thick red)

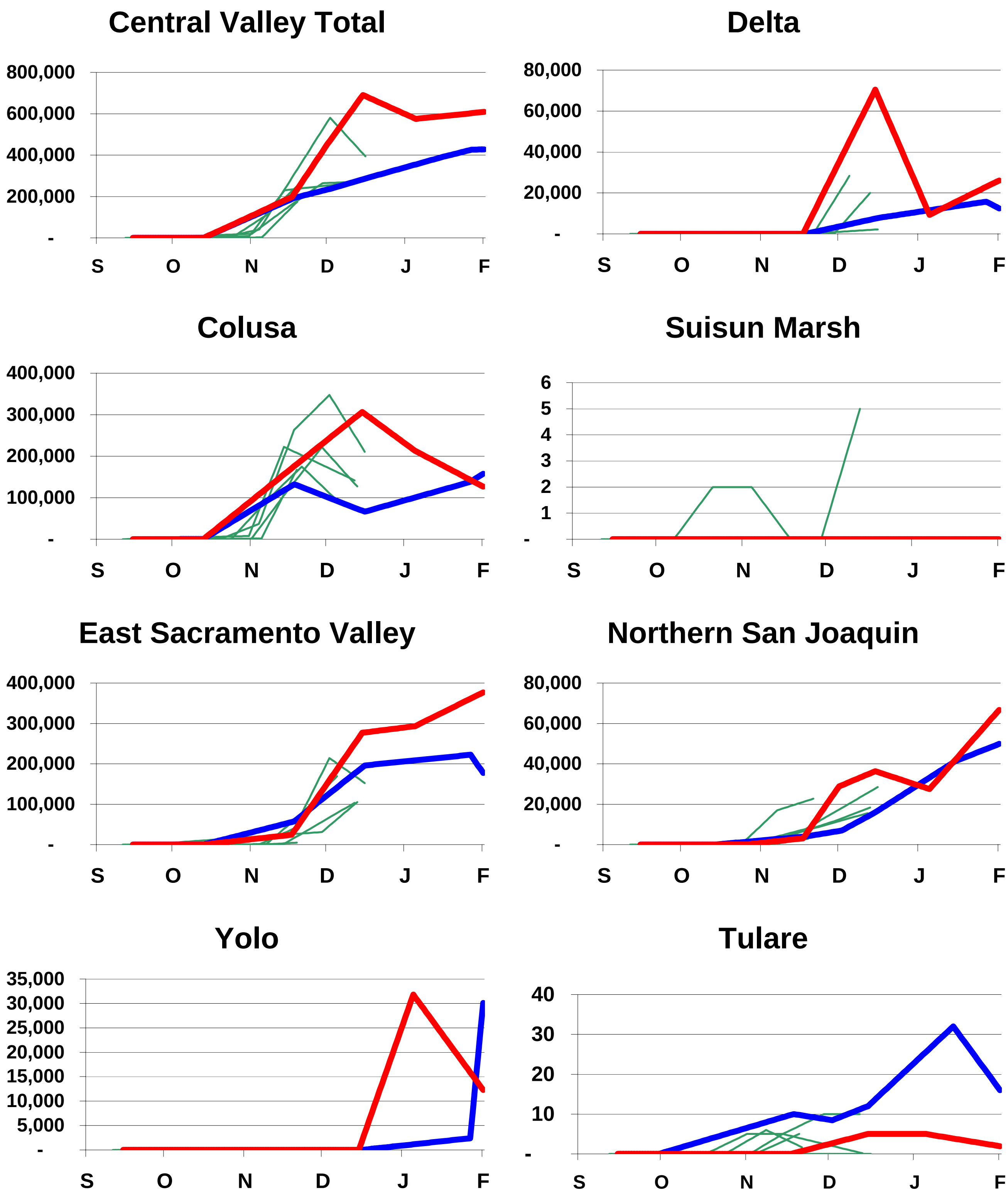


Figure 30

DISTRIBUTION OF RADIOTAGGED PINTAILS
1987-1994 vs. 1998-2000

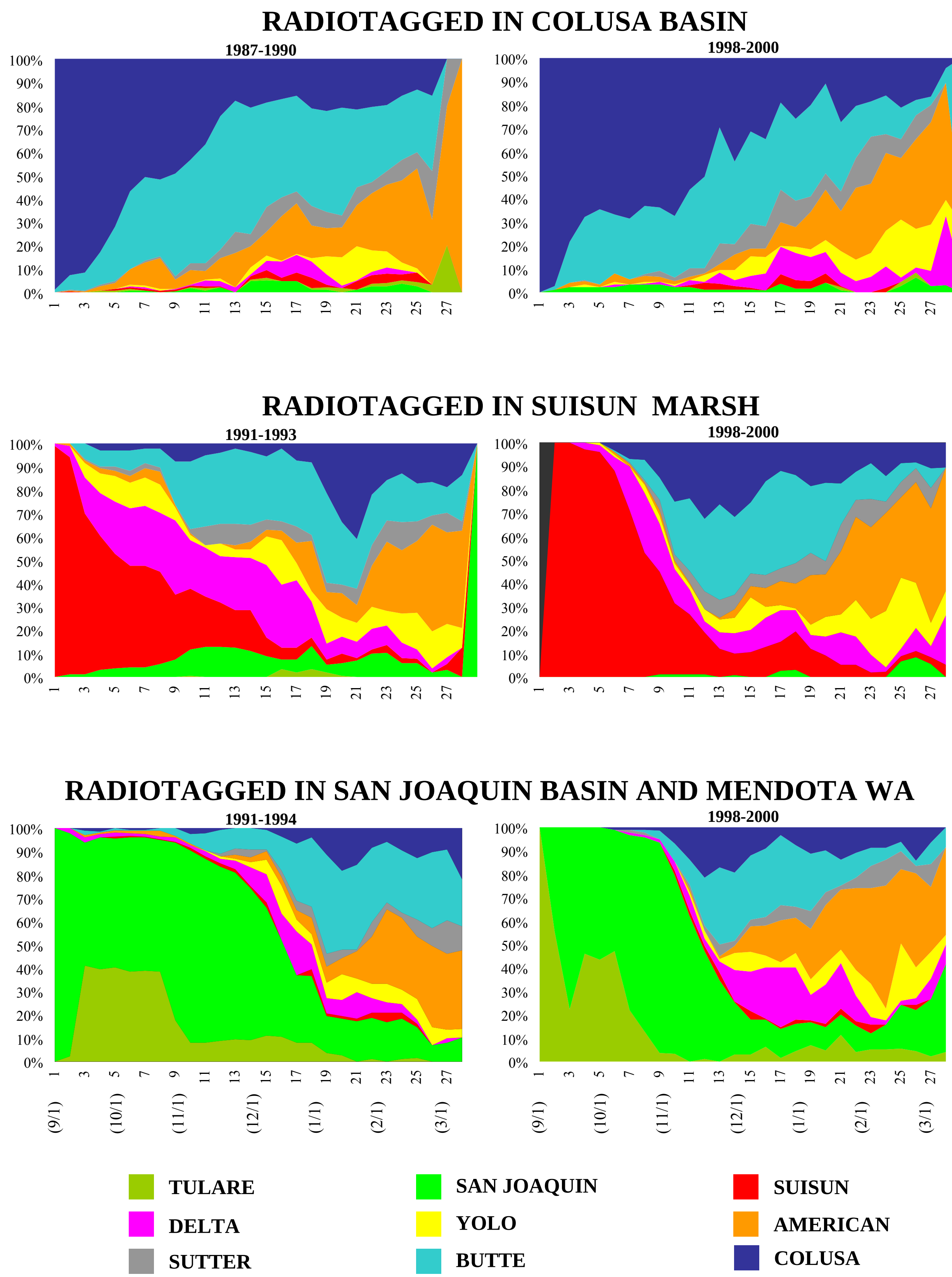


Figure 31

AIC WEIGHTS OF FACTORS RELATED TO WEEKLY PINTAIL DISTRIBUTION AMONG BASINS

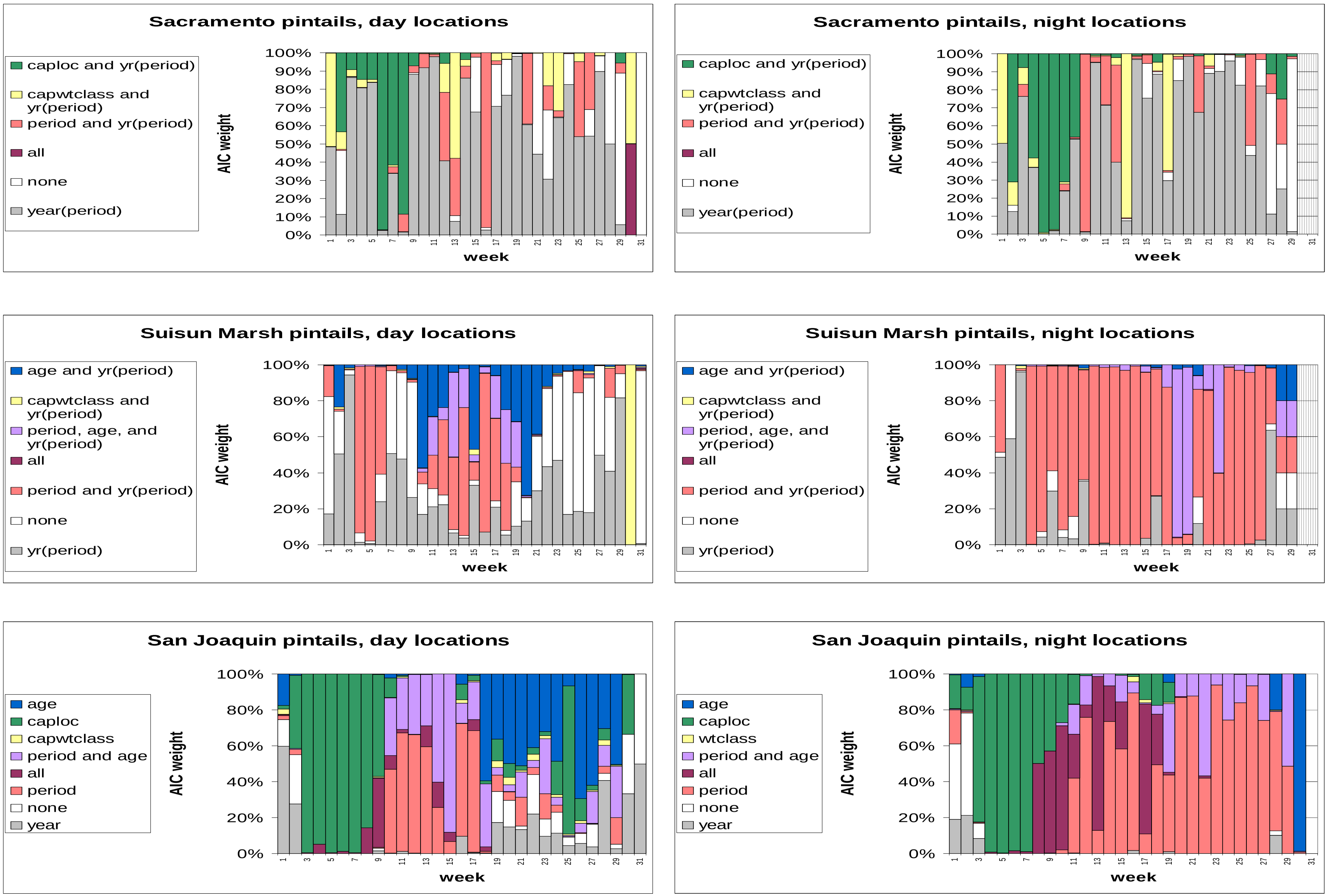


Figure 32

Distribution of All Mallards Radiotagged in Butte Basin

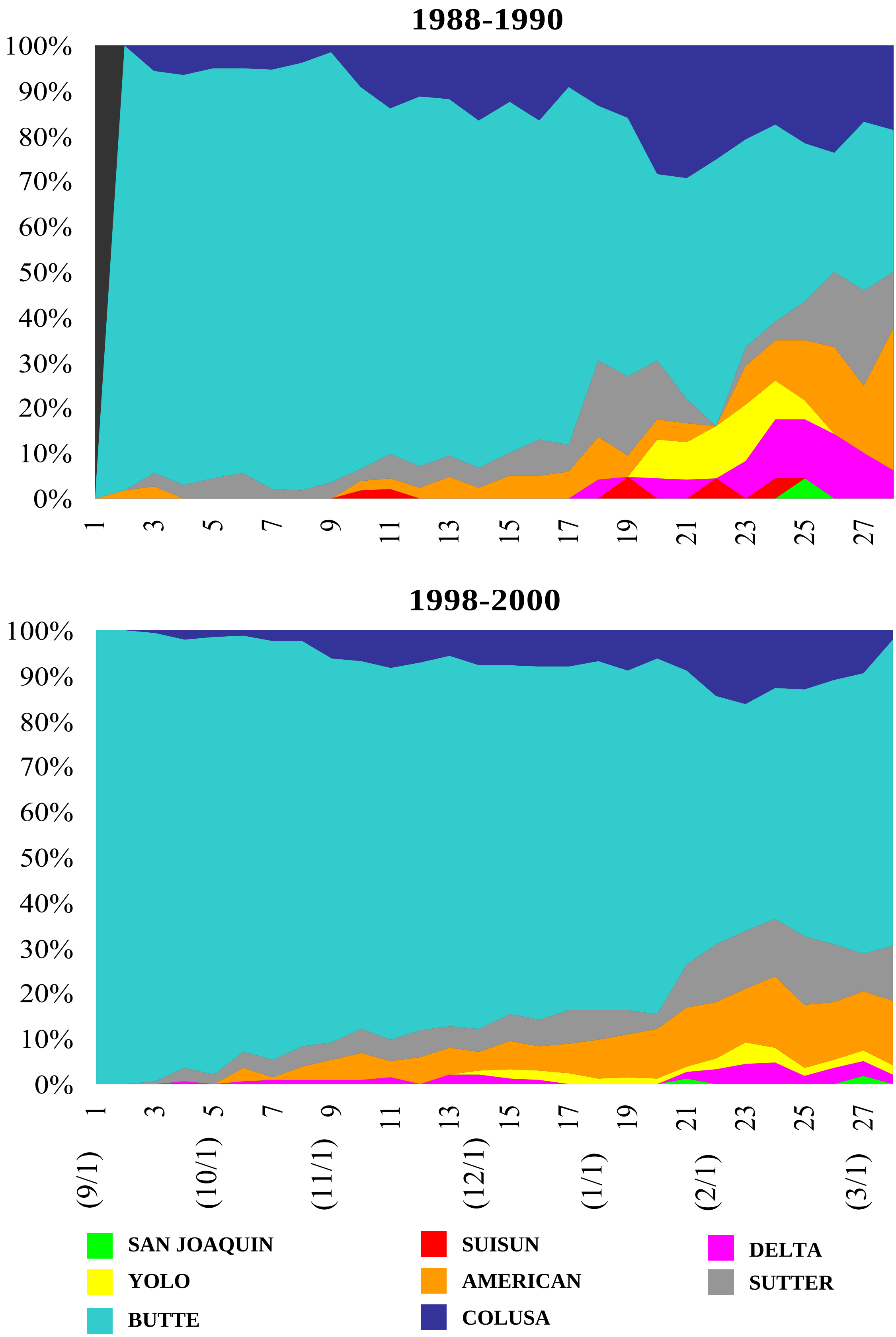
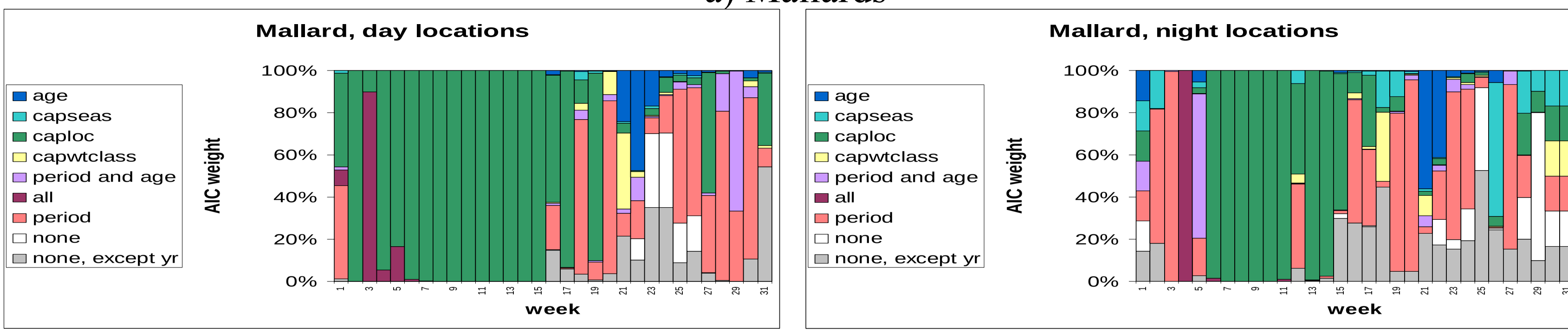


Figure 33

AIC WEIGHTS OF FACTORS RELATED TO WEEKLY MALLARD AND WHITE-FRONTED GOOSE DISTRIBUTION AMONG BASINS

a) Mallards



b) White-fronted Geese

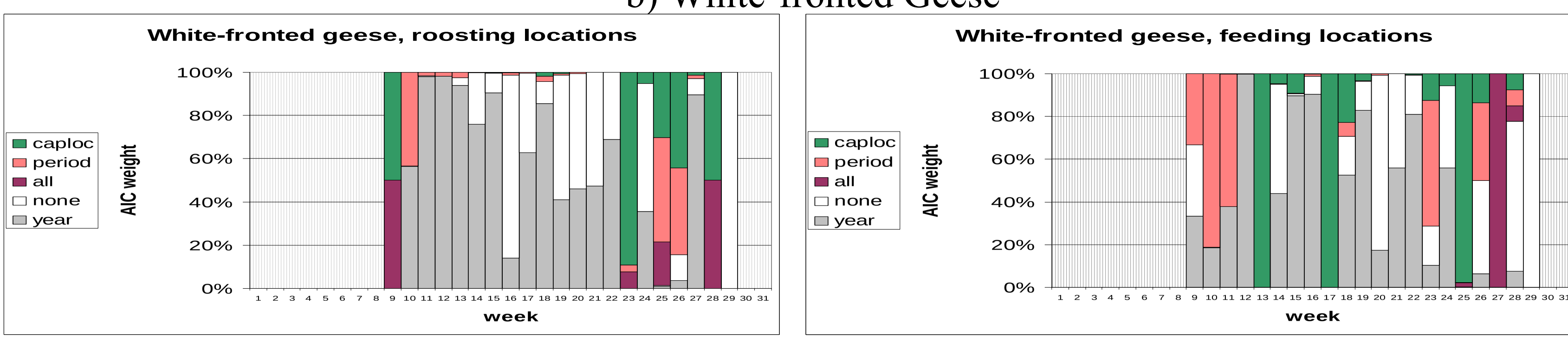


Figure 34

Distribution of White-Fronted Geese Radiotagged in Yukon-Kuskokwim Alaska

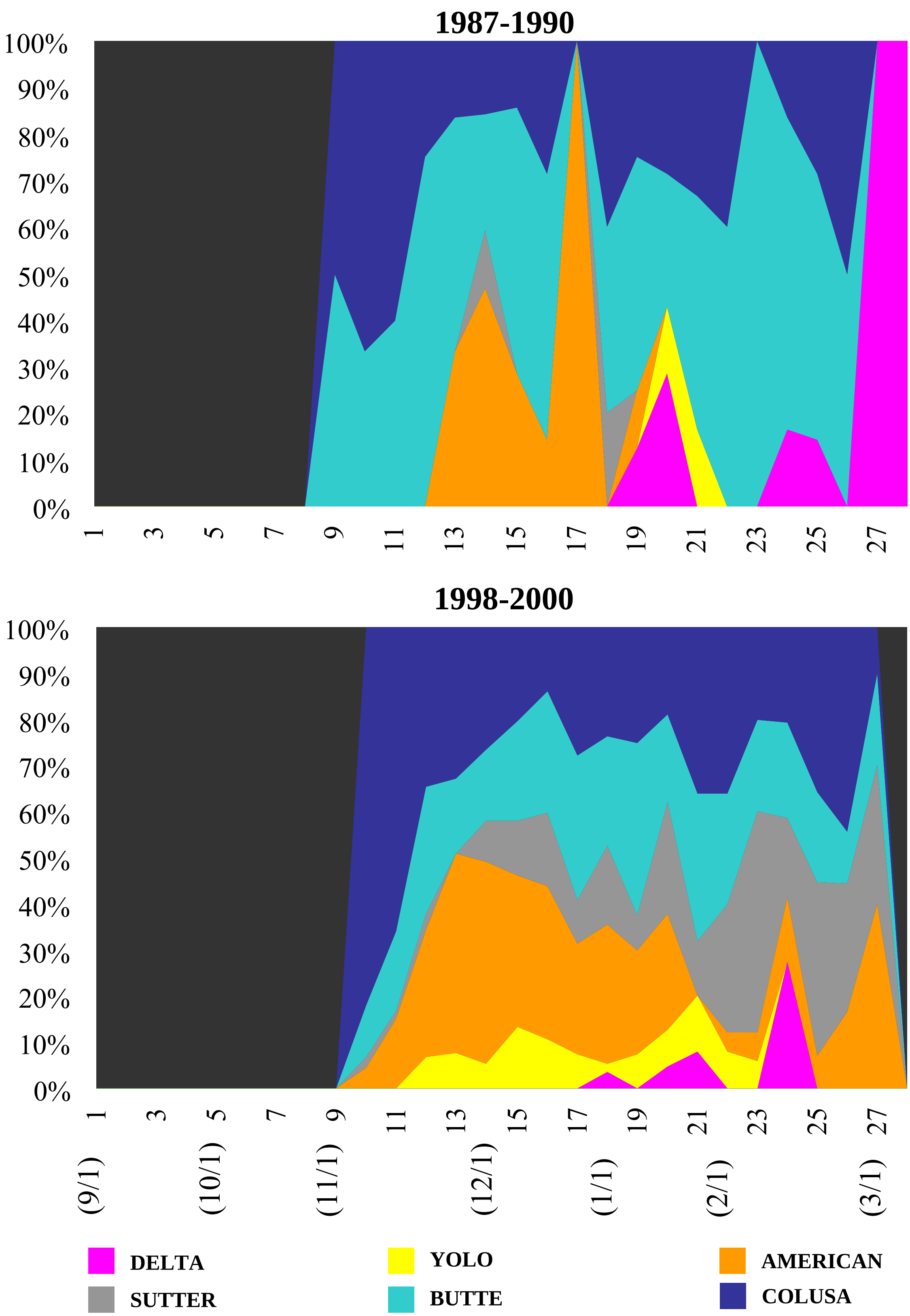


Figure 35

DISTRIBUTION OF RADIO-TAGGED WHITE-FRONTED GEESE

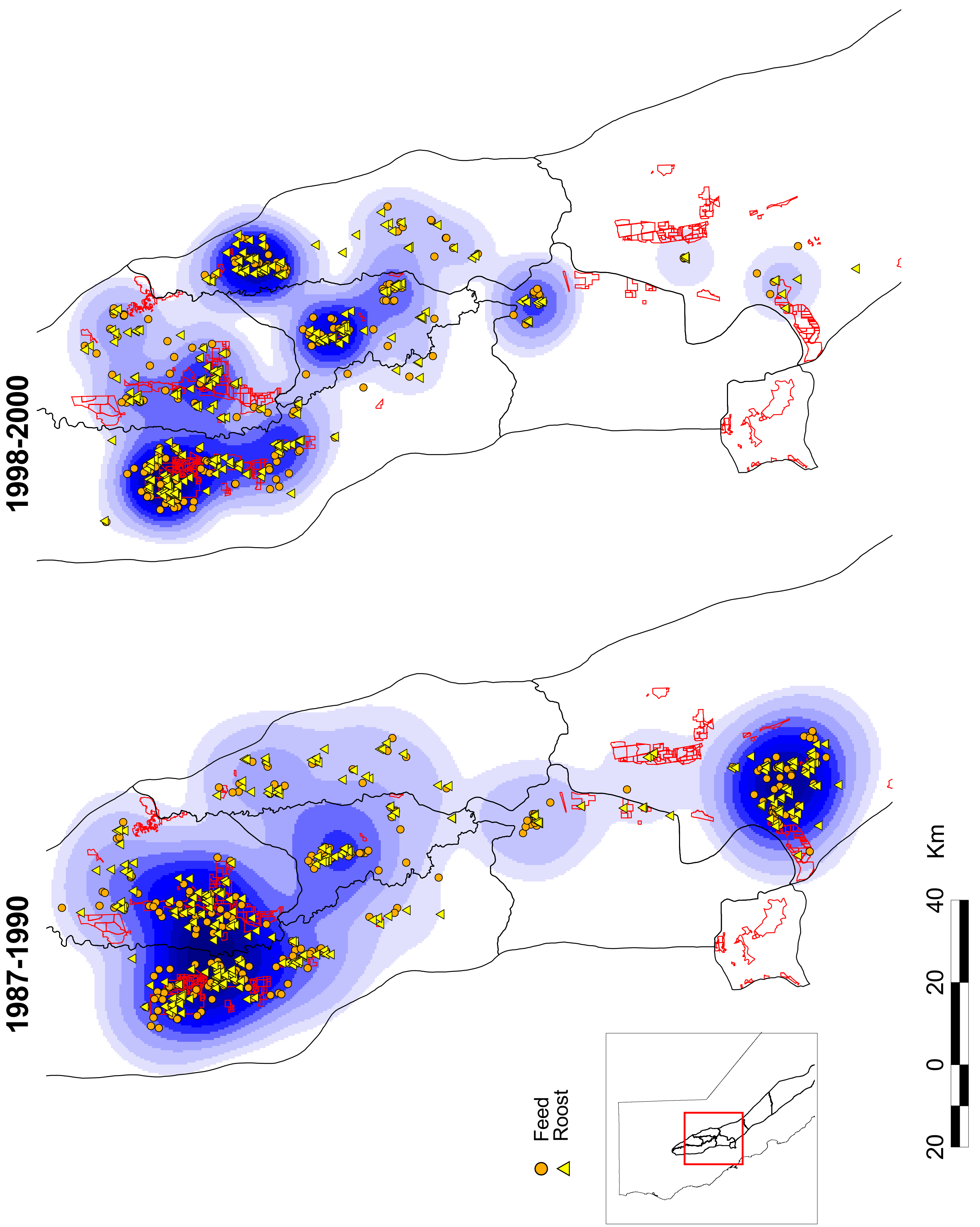


Figure 36

PINTAIL DISTRIBUTION IN THE GRASSLAND EA 1991-1994 VS. 1998-2000

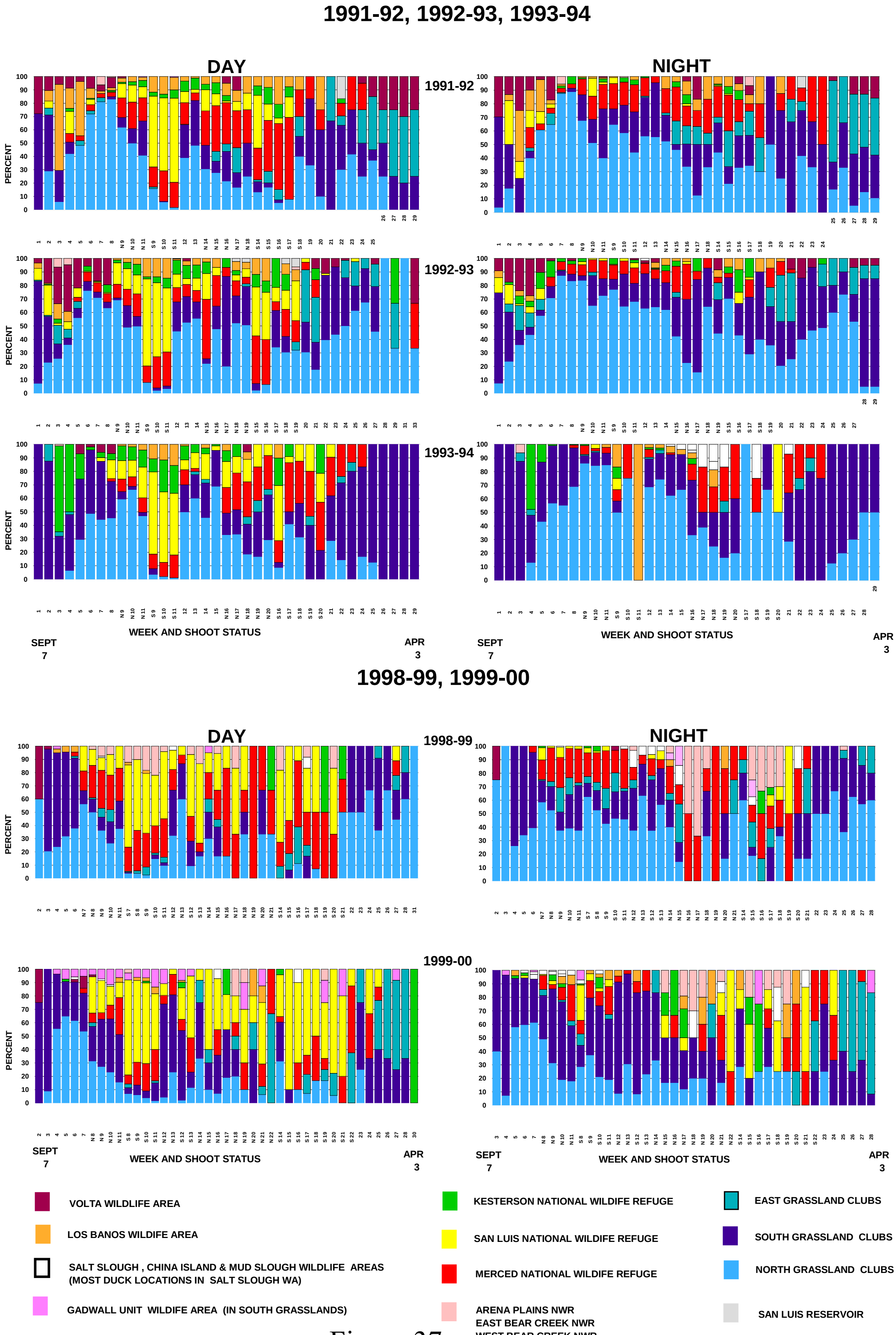


Figure 37

PINTAILS IN THE GRASSLAND EA

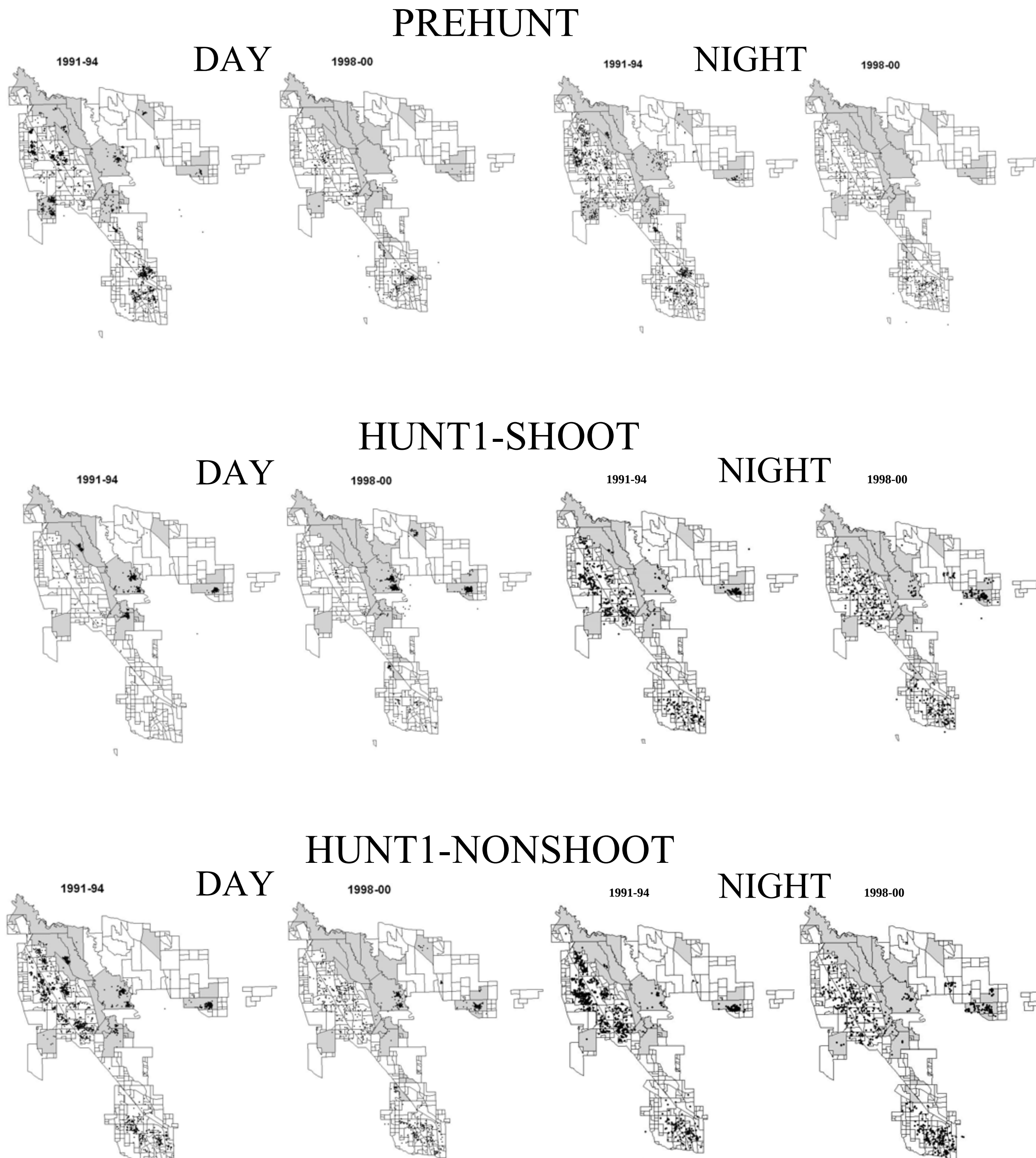


Figure 38 (a)

PINTAILS IN THE GRASSLAND EA

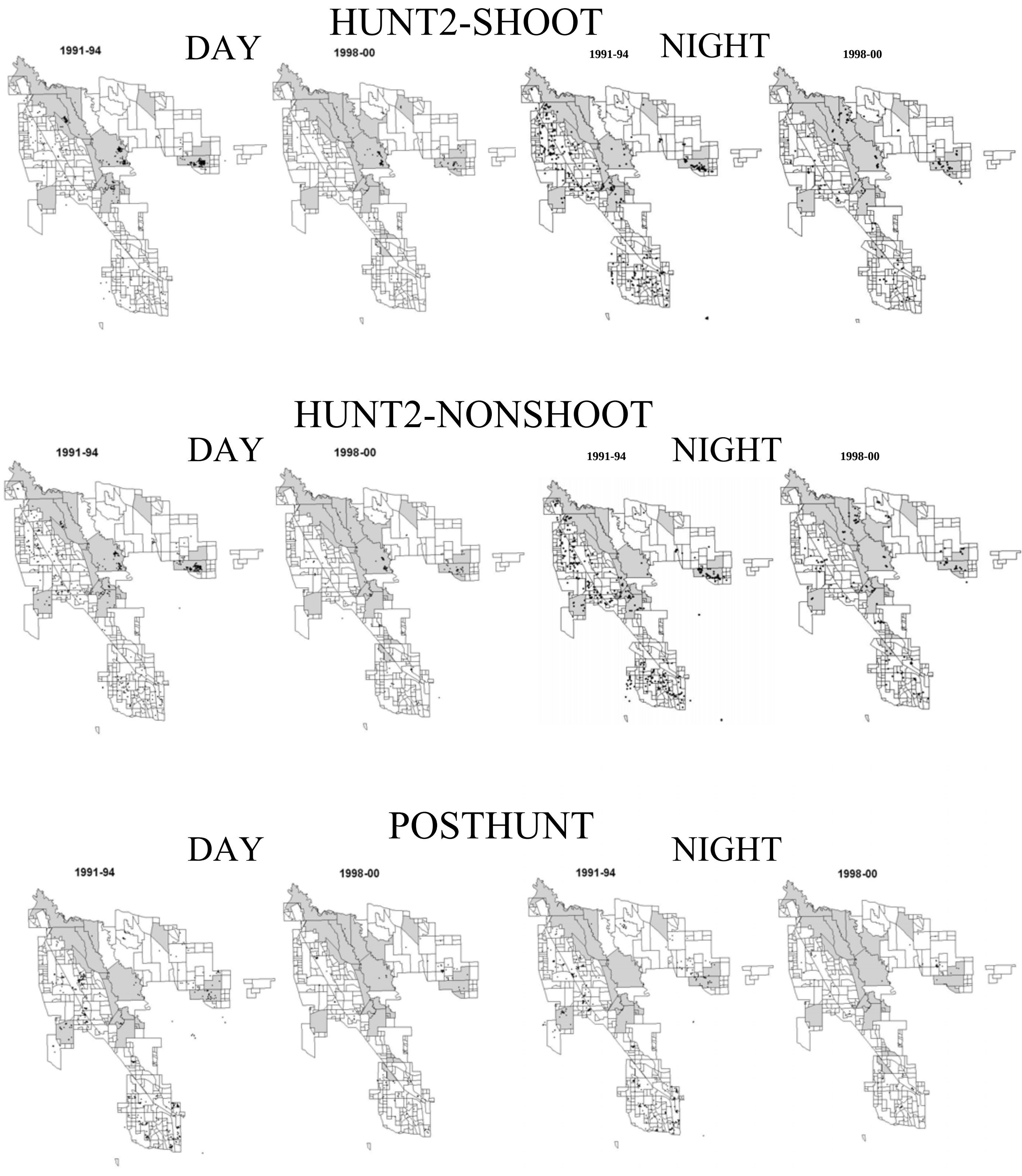


Figure 38 (b)

PINTAIL DAY-NIGHT MOVEMENTS IN THE GRASSLAND EA

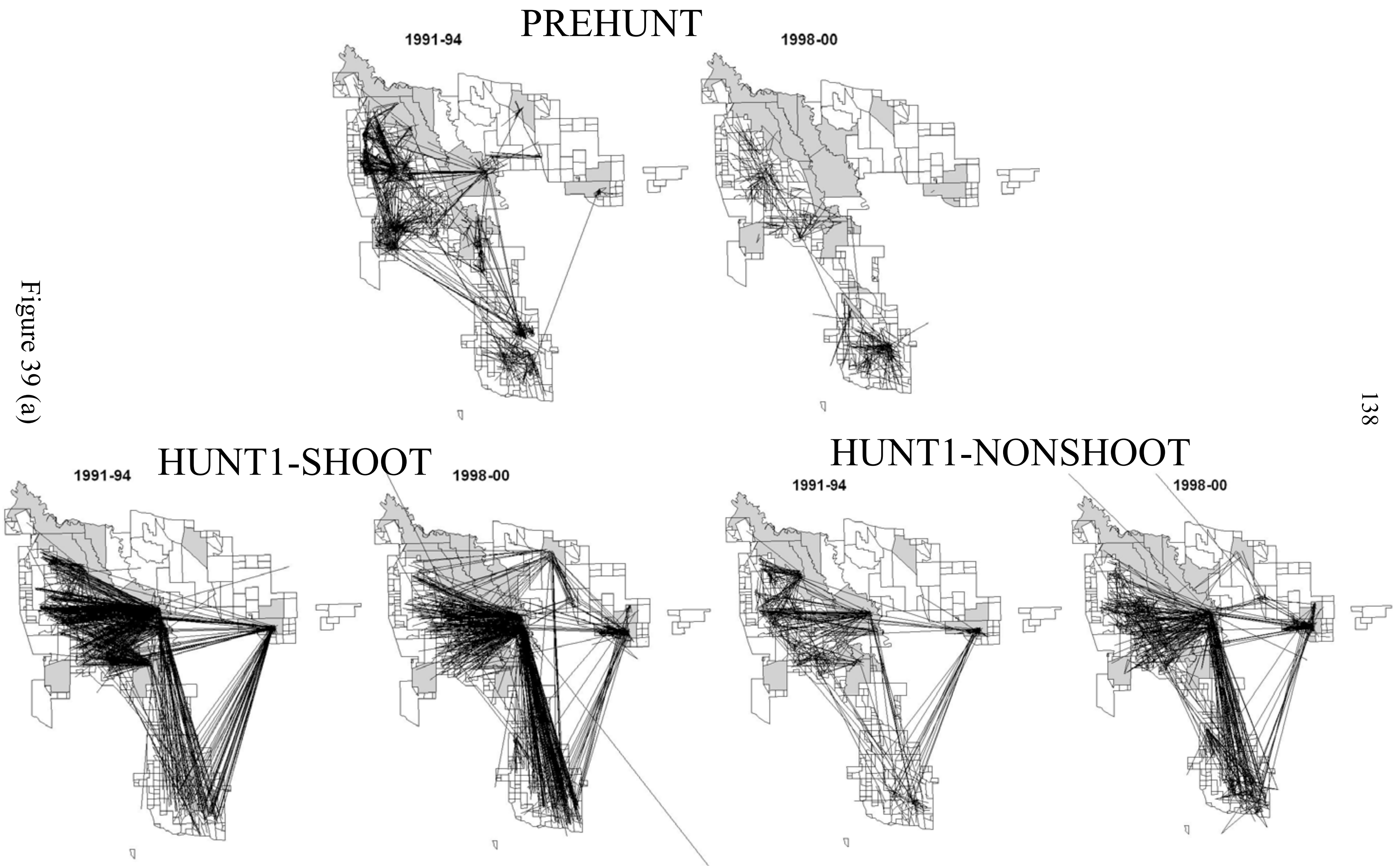


Figure 39 (a)

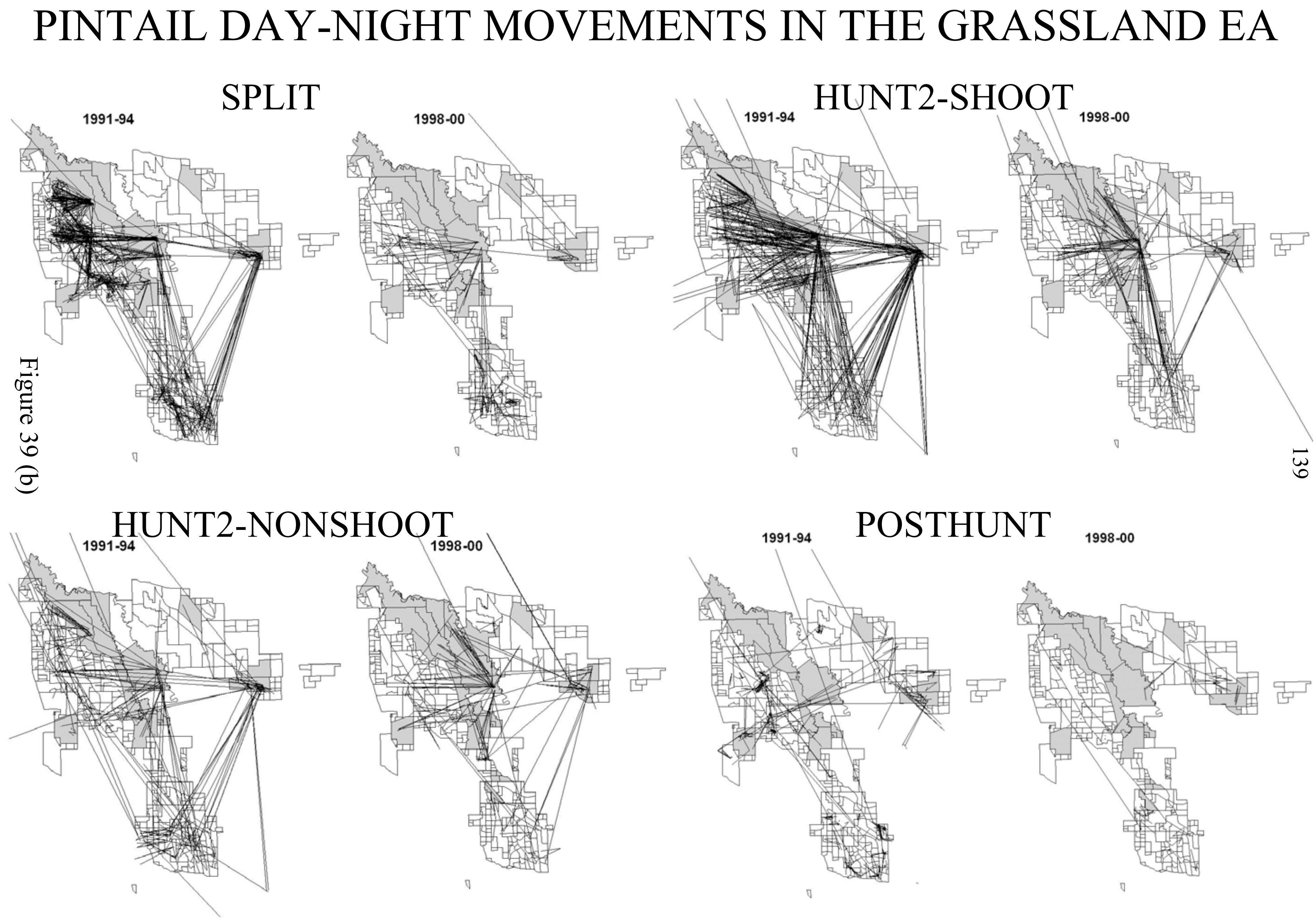
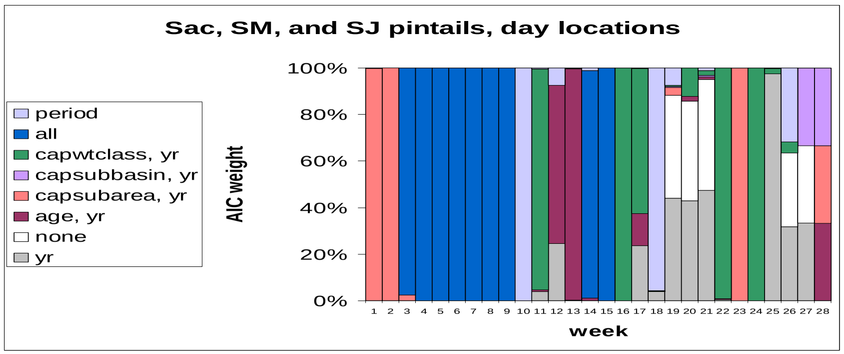
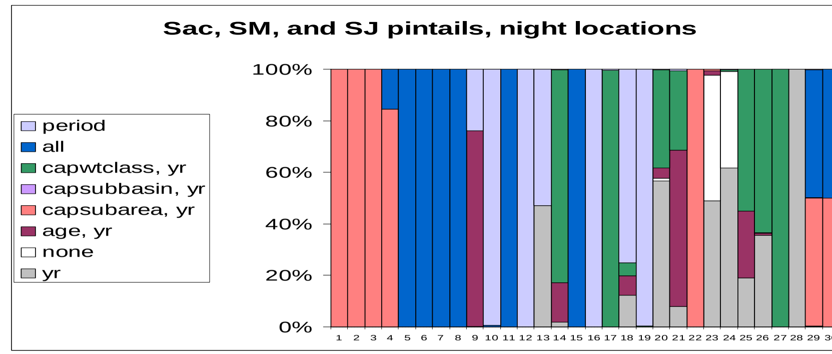

PINTAIL DAY-NIGHT MOVEMENTS IN THE GRASSLAND EA
SPLIT
1991-94
1998-00
HUNT2-SHOOT
1991-94
1998-00
HUNT2-NONSHOOT
1991-94
1998-00
POSTHUNT
1991-94
1998-00

Figure 39 (b)

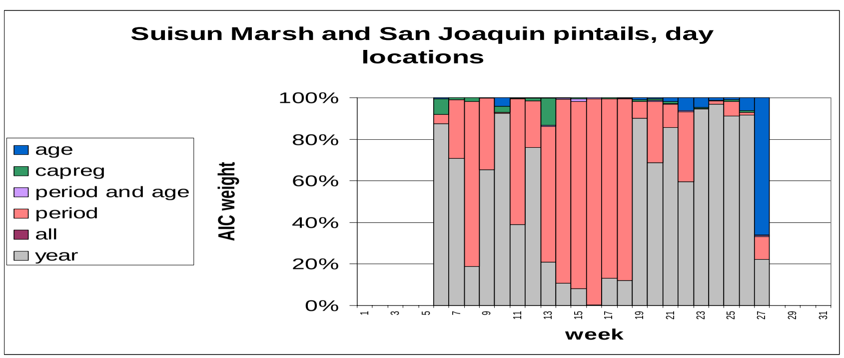
AIC WEIGHTS OF FACTORS RELATED TO WEEKLY PINTAIL DISTRIBUTION AMONG GRASSLAND EA AND DELTA AREAS

a) Grassland Ecological Area





b) Delta



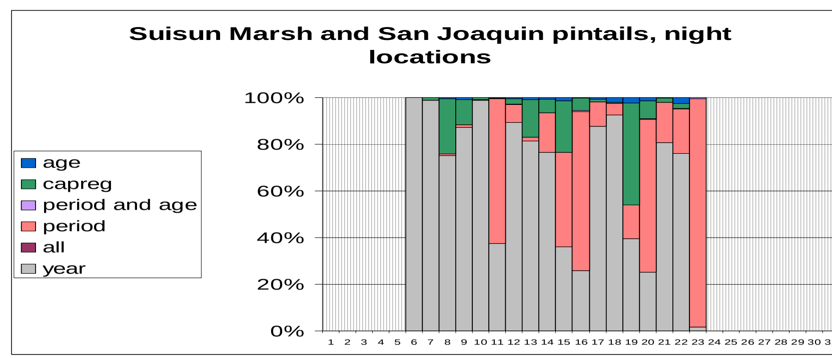


Figure 40

PINTAIL DISTRIBUTION IN SUISUN MARSH 1991-1993 VS. 1998-2000

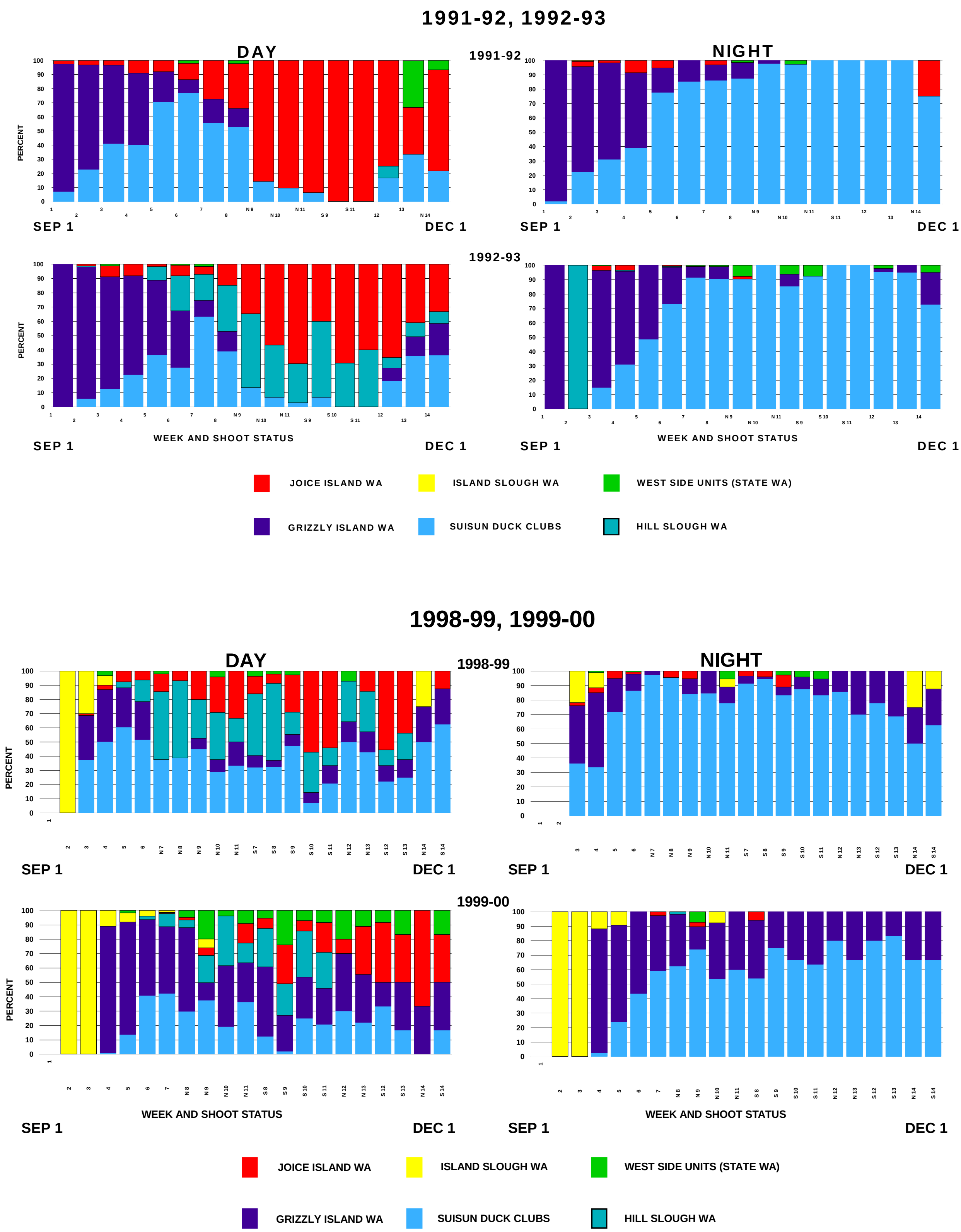


Figure 41

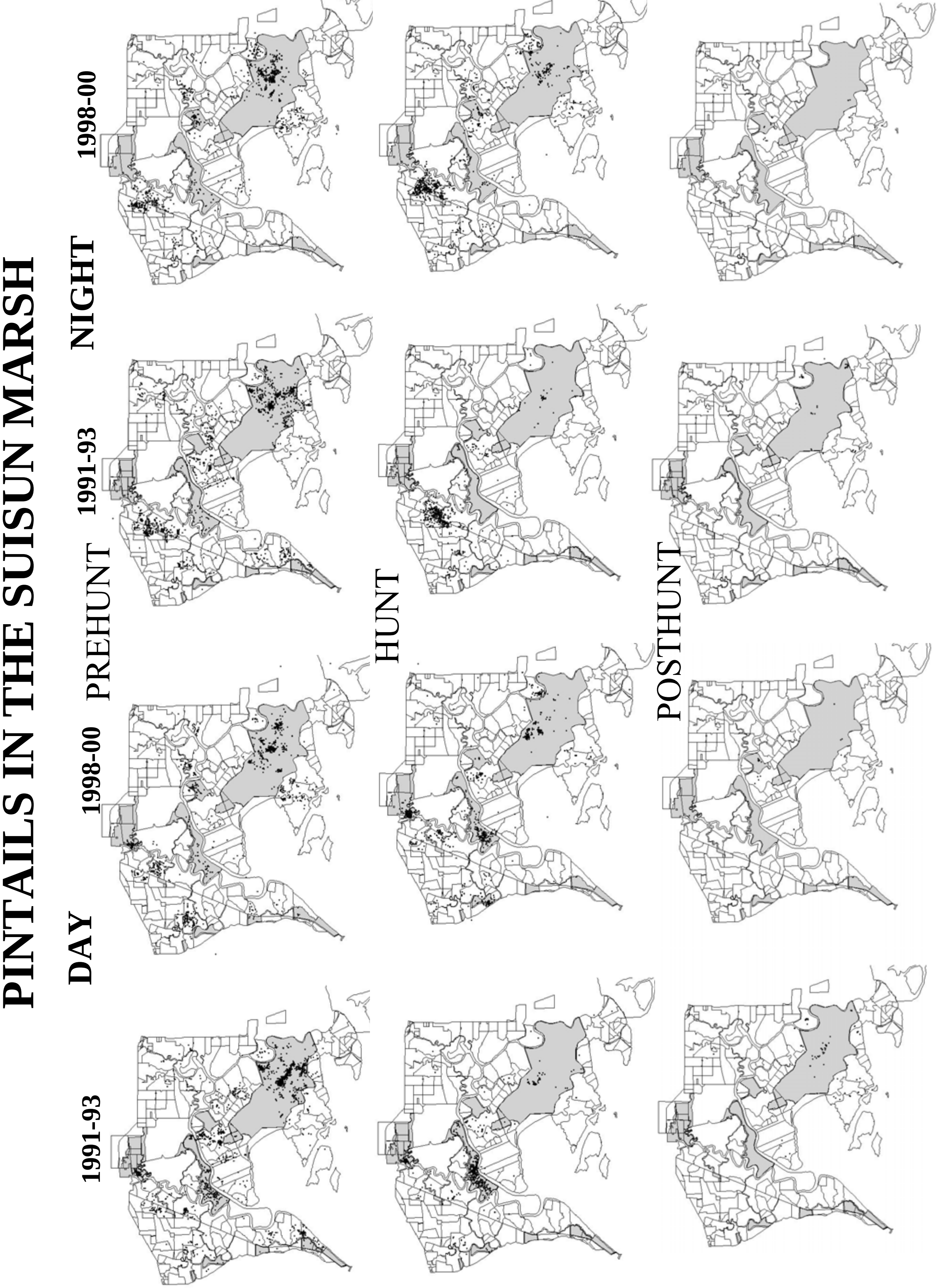

PINTAILS IN THE SUISUN MARSH
DAY
NIGHT
1991-93
1998-00
1991-93
1998-00
PREHUNT
HUNT
POSTHUNT

Figure 42

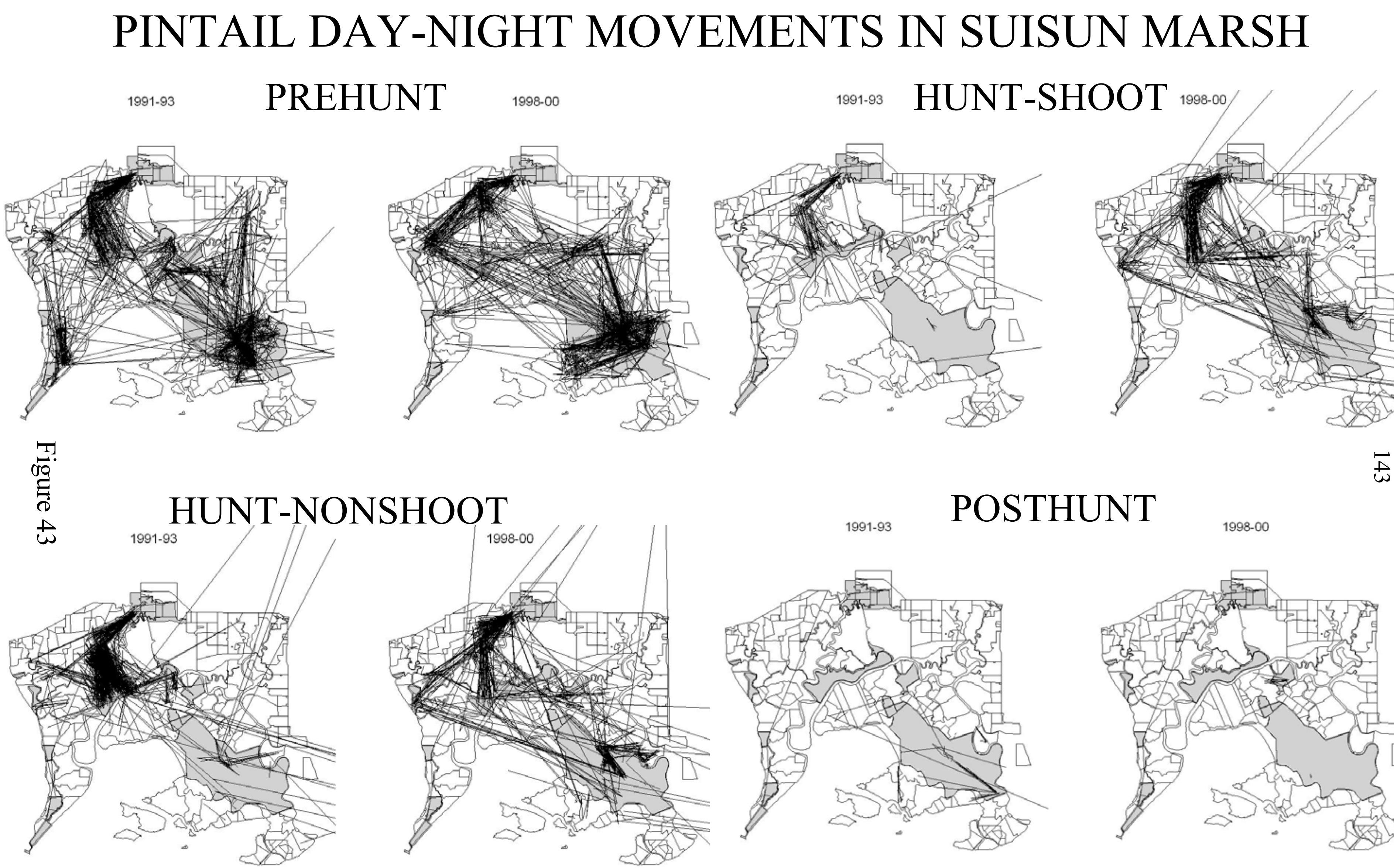

PINTAIL DAY-NIGHT MOVEMENTS IN SUISUN MARSH
PREHUNT
1991-93
1998-00
HUNT-SHOOT
1991-93
1998-00
HUNT-NONSHOOT
1991-93
1998-00
POSTHUNT
1991-93
1998-00

Figure 43

PINTAIL DISTRIBUTION IN THE DELTA
1991-1993 VS. 1998-2000

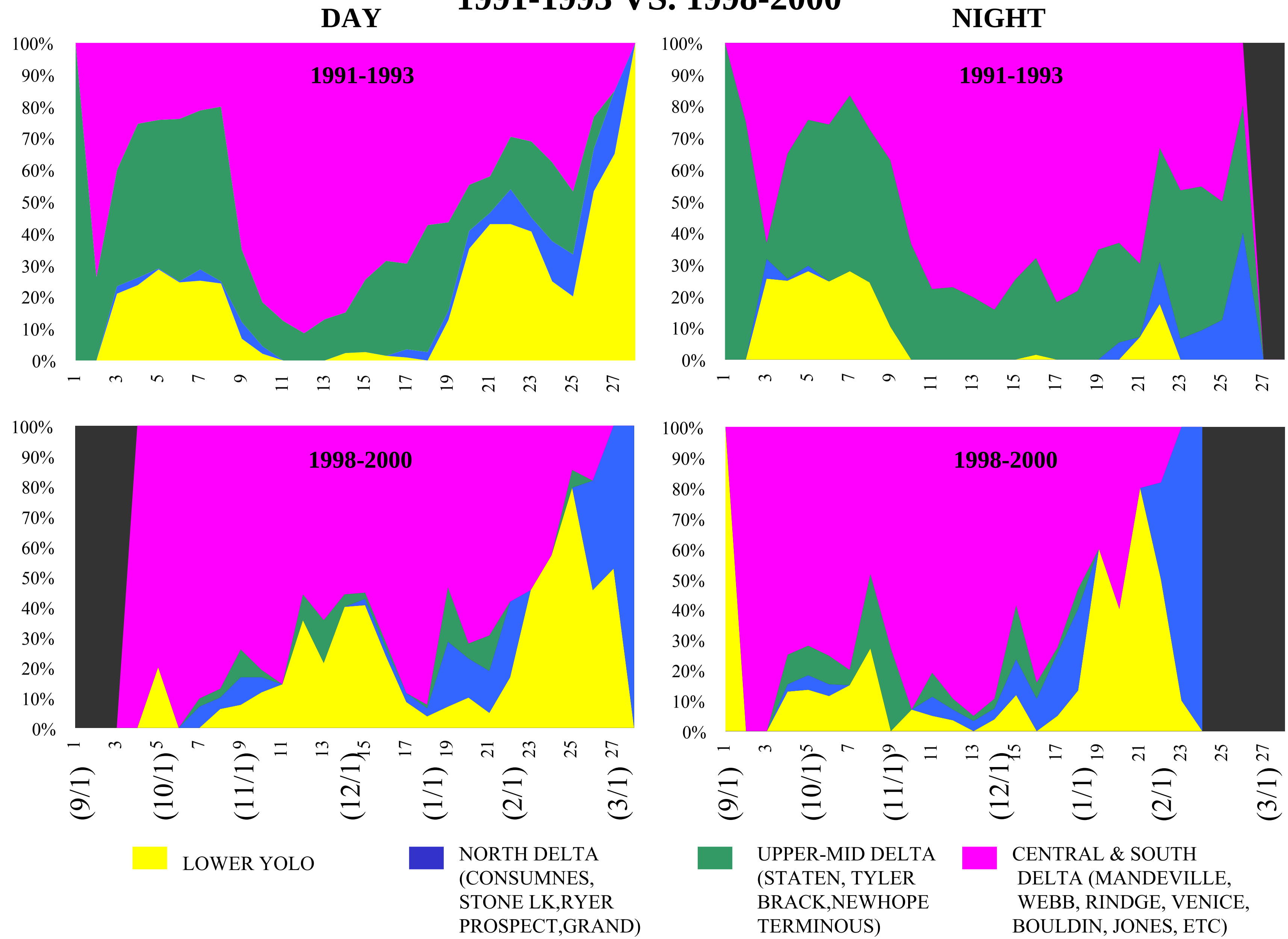


Figure 44

PINTAILS IN THE DELTA REGION DURING PREHUNT

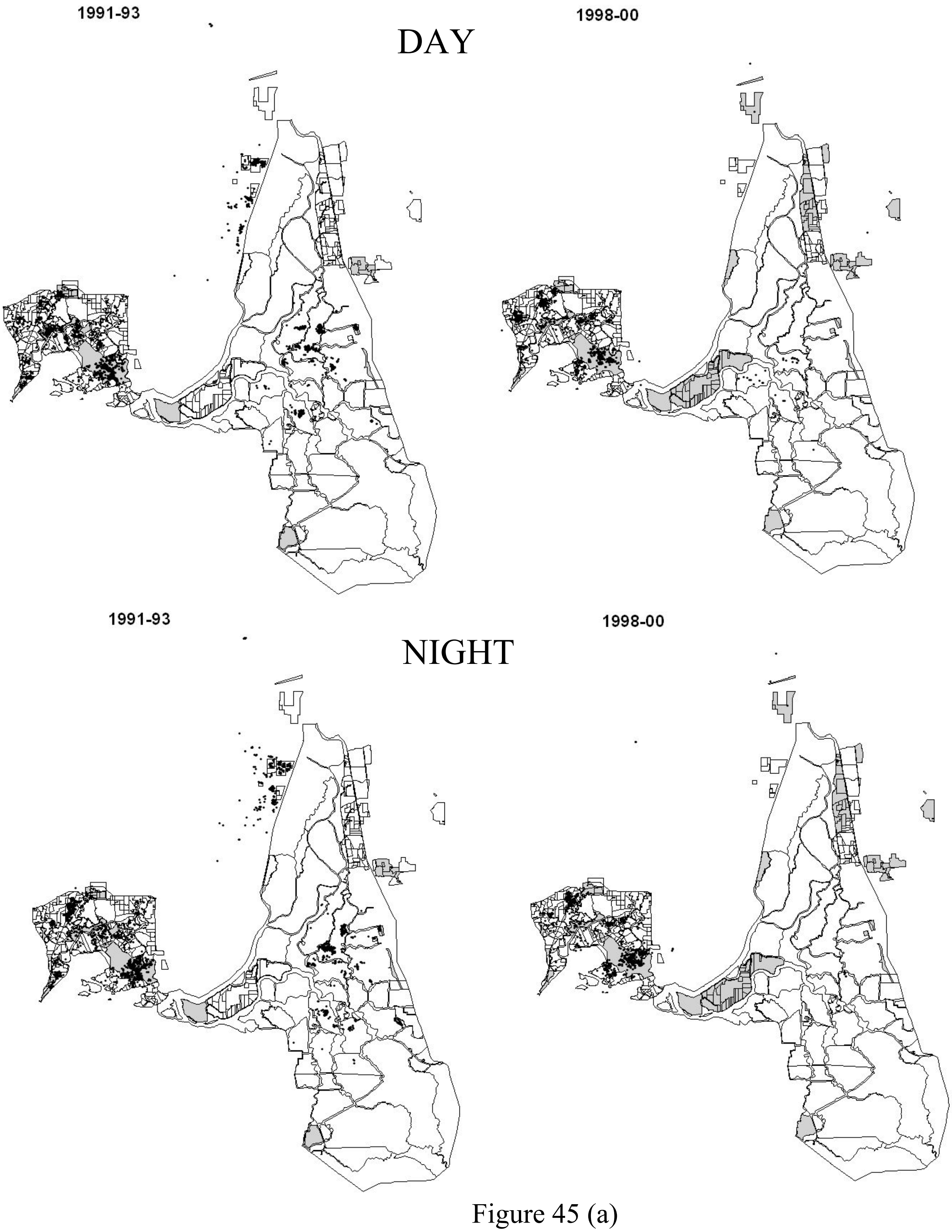


Figure 45 (a)

PINTAILS IN THE DELTA REGION DURING HUNT

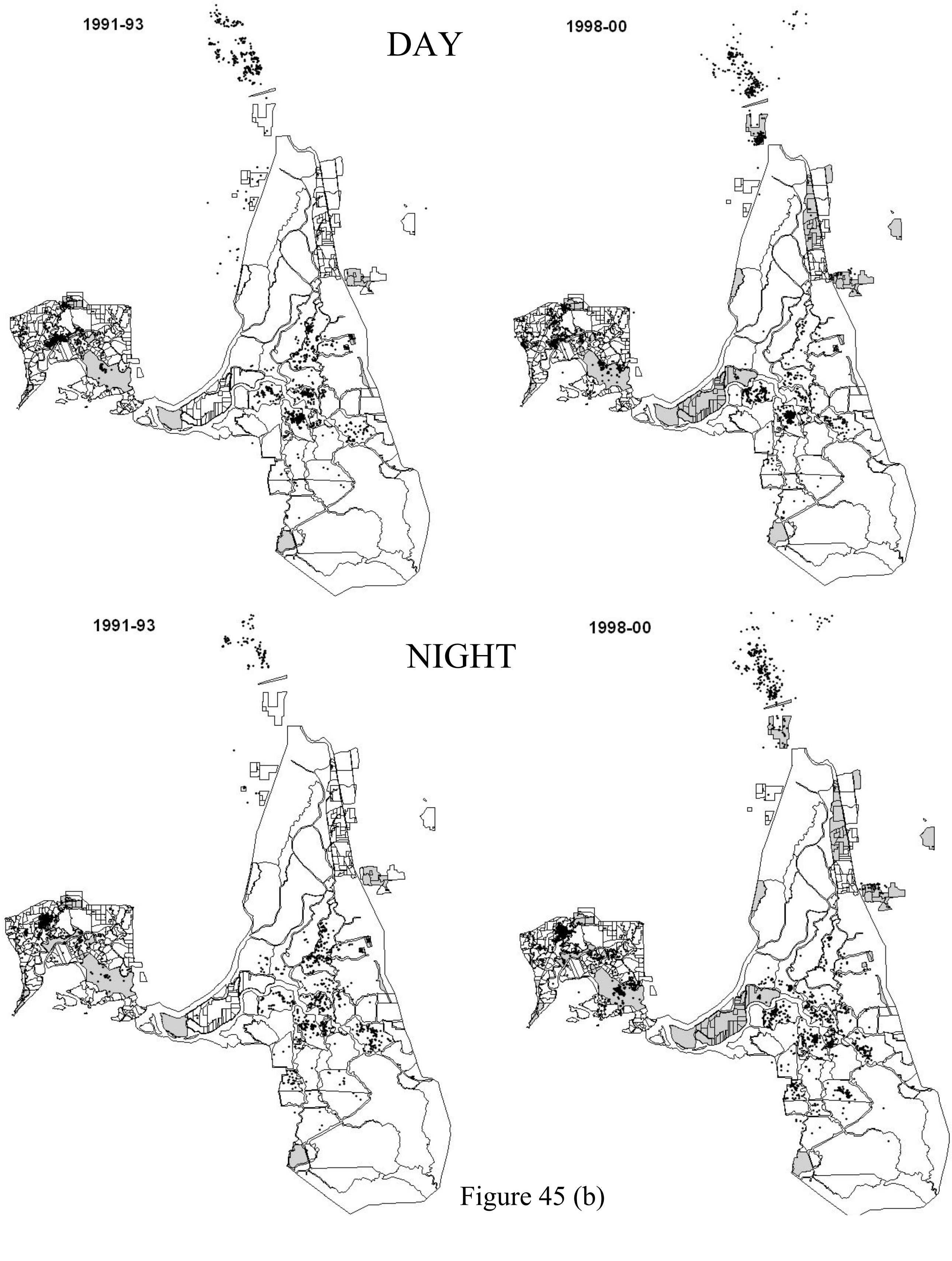


Figure 45 (b)

PINTAILS IN THE DELTA REGION DURING POSTHUNT

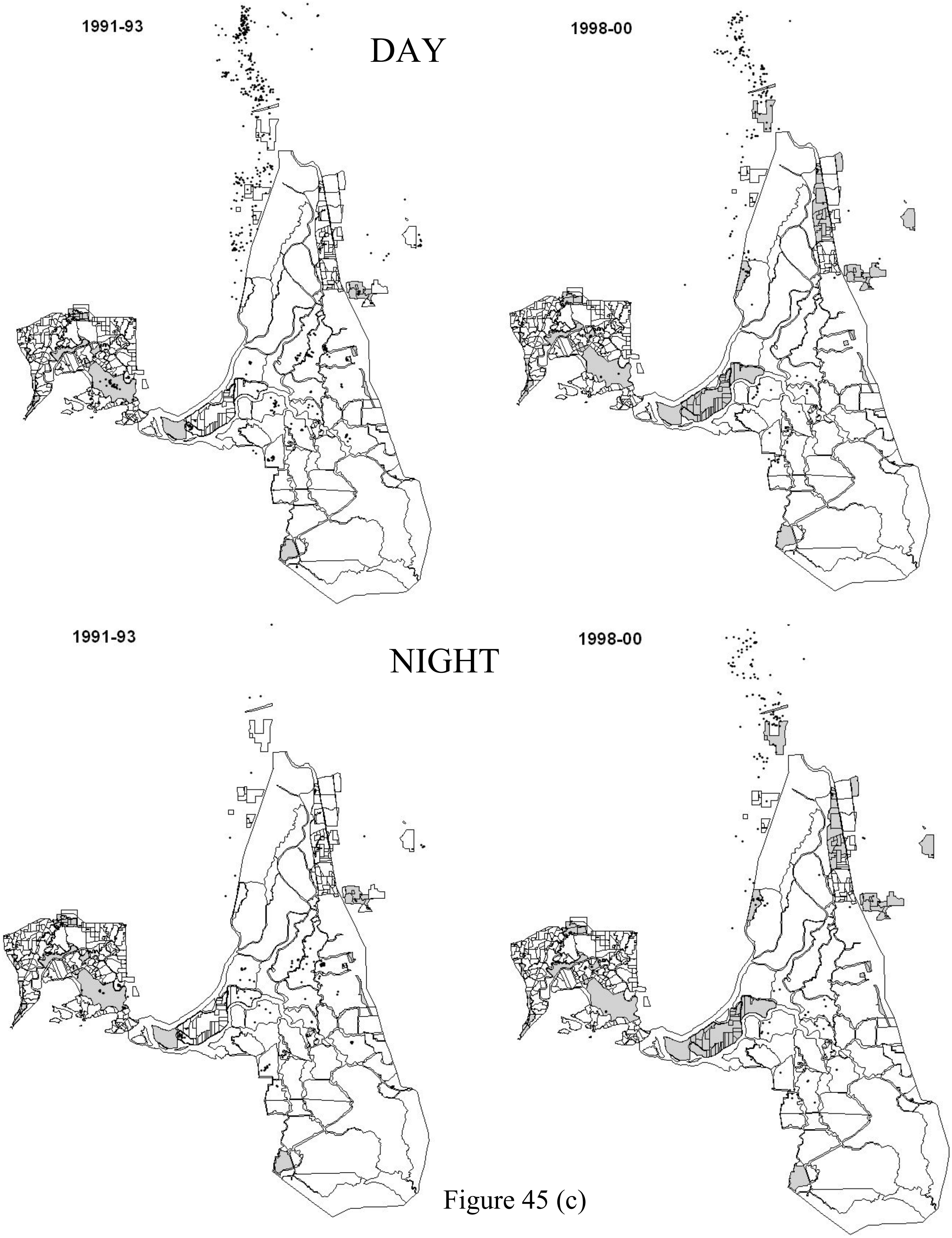


Figure 45 (c)

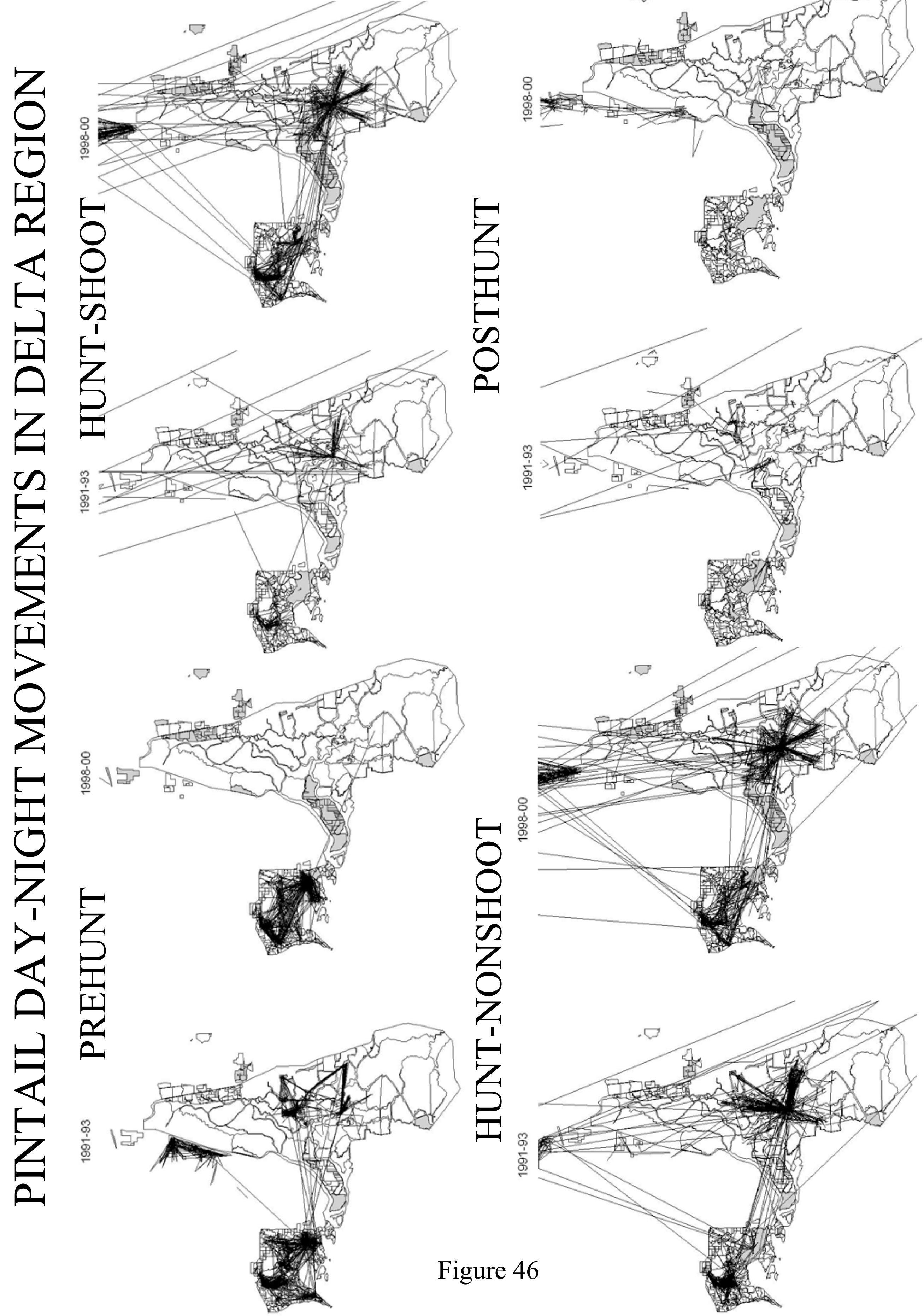

PINTAIL DAY-NIGHT MOVEMENTS IN DELTA REGION
PREHUNT
HUNT-SHOOT
HUNT-NONSHOOT
POSTHUNT
1991-93
1998-00
1991-93
1998-00
1991-93
1998-00
1991-93
1998-00

Figure 46

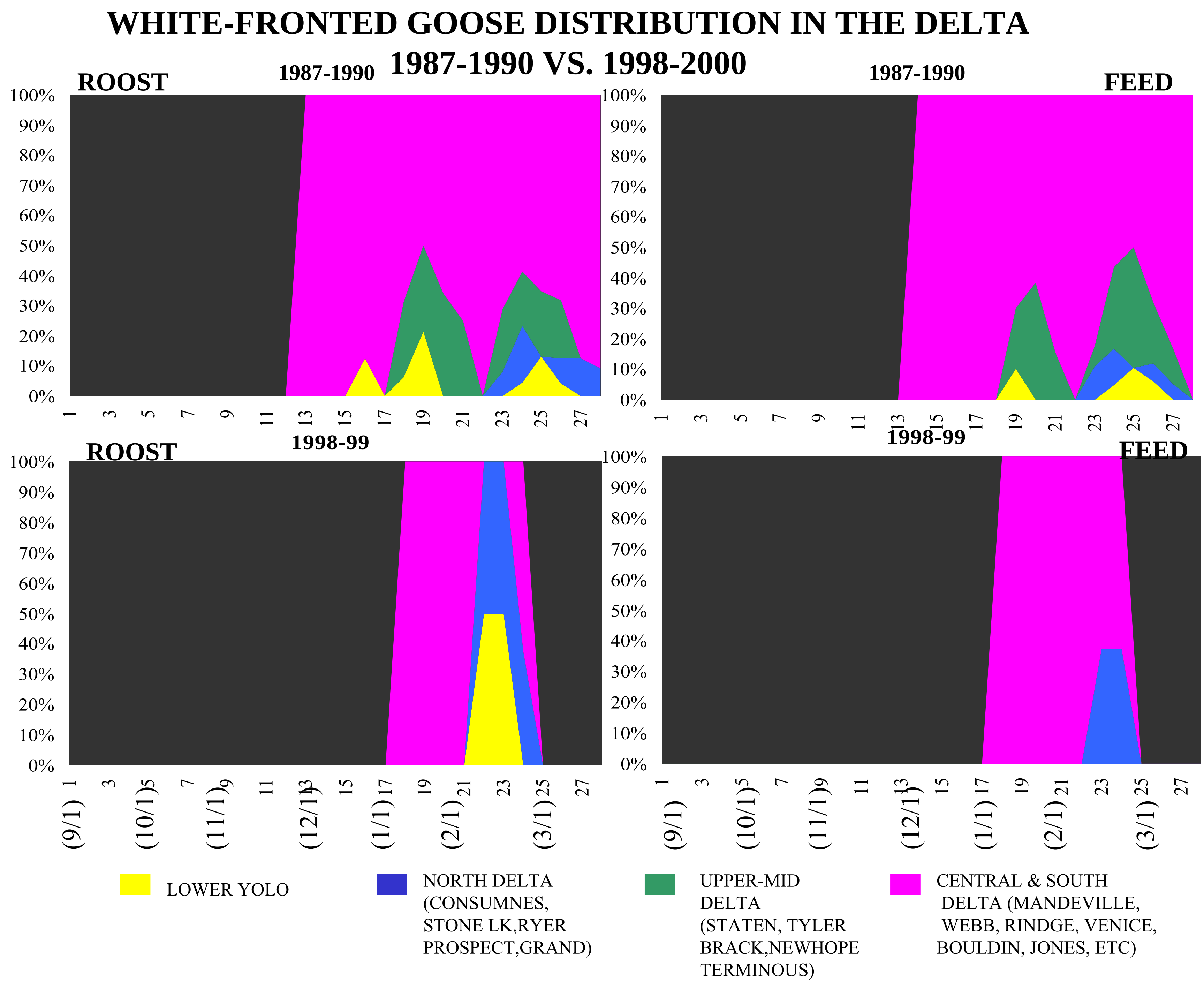

WHITE-FRONTED GOOSE DISTRIBUTION IN THE DELTA
1987-1990 VS. 1998-2000
ROOST
1987-1990
FEED
1987-1990
ROOST
1998-99
FEED
1998-99
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1 3 5 7 9 11 13 15 17 19 21 23 25 27
(9/1) (10/1) (11/1) (12/1) (1/1) (2/1) (3/1)
LOWER YOLO
NORTH DELTA (CONSUMNES, STONE LK,RYER PROSPECT,GRAND)
UPPER-MID DELTA (STATEN, TYLER BRACK,NEWHOPE TERMINOUS)
CENTRAL & SOUTH DELTA (MANDEVILLE, WEBB, RINDGE, VENICE, BOULDIN, JONES, ETC)

Figure 47

PINTAIL DISTRIBUTION AMONG SACRAMENTO VALLEY AREAS 1987-1990 VS. 1998-2000

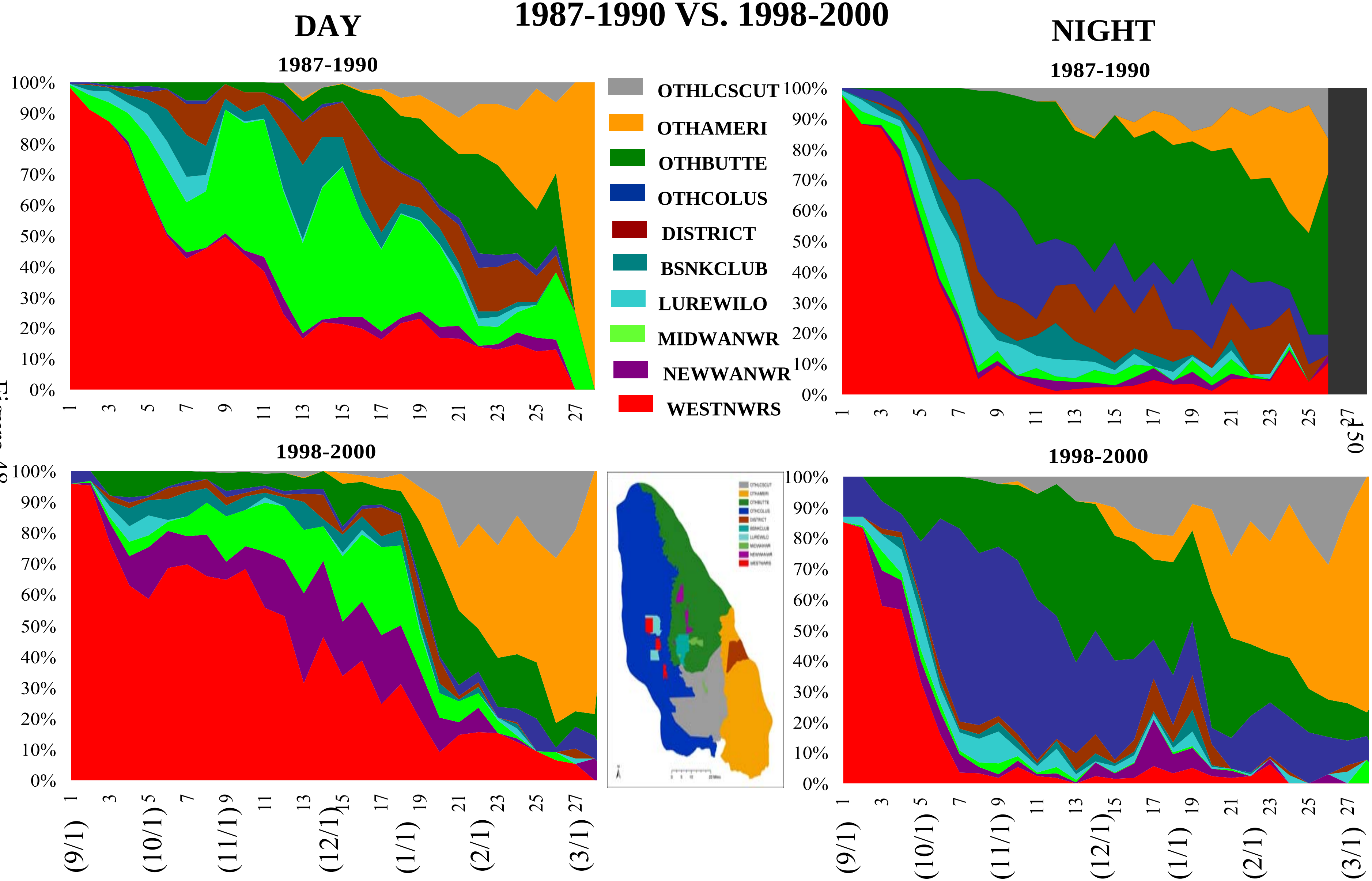


Figure 48

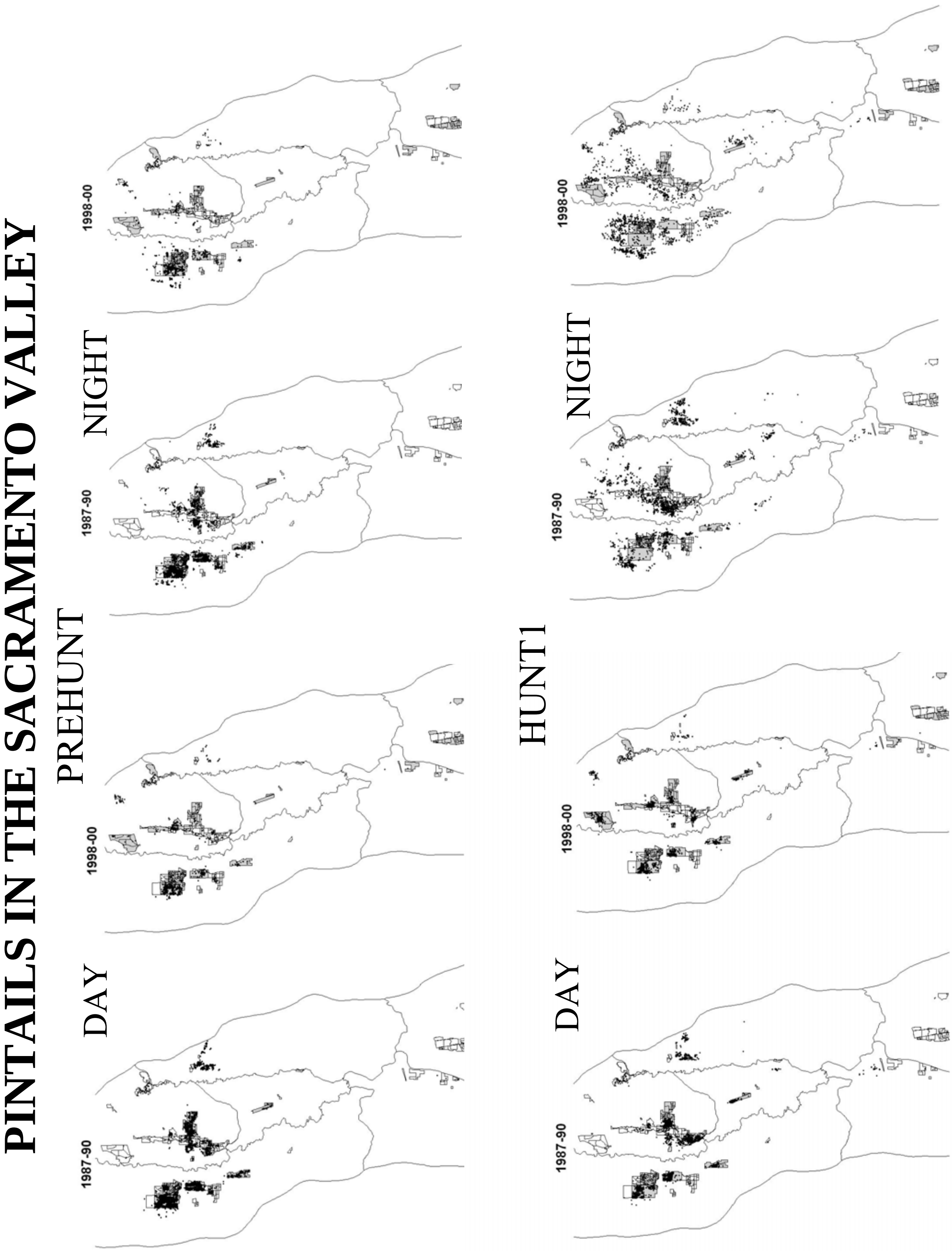

PINTAILS IN THE SACRAMENTO VALLEY
PREHUNT
DAY
NIGHT
1987-90
1998-00
HUNT1
DAY
NIGHT
1987-90
1998-00

Figure 49 (a)

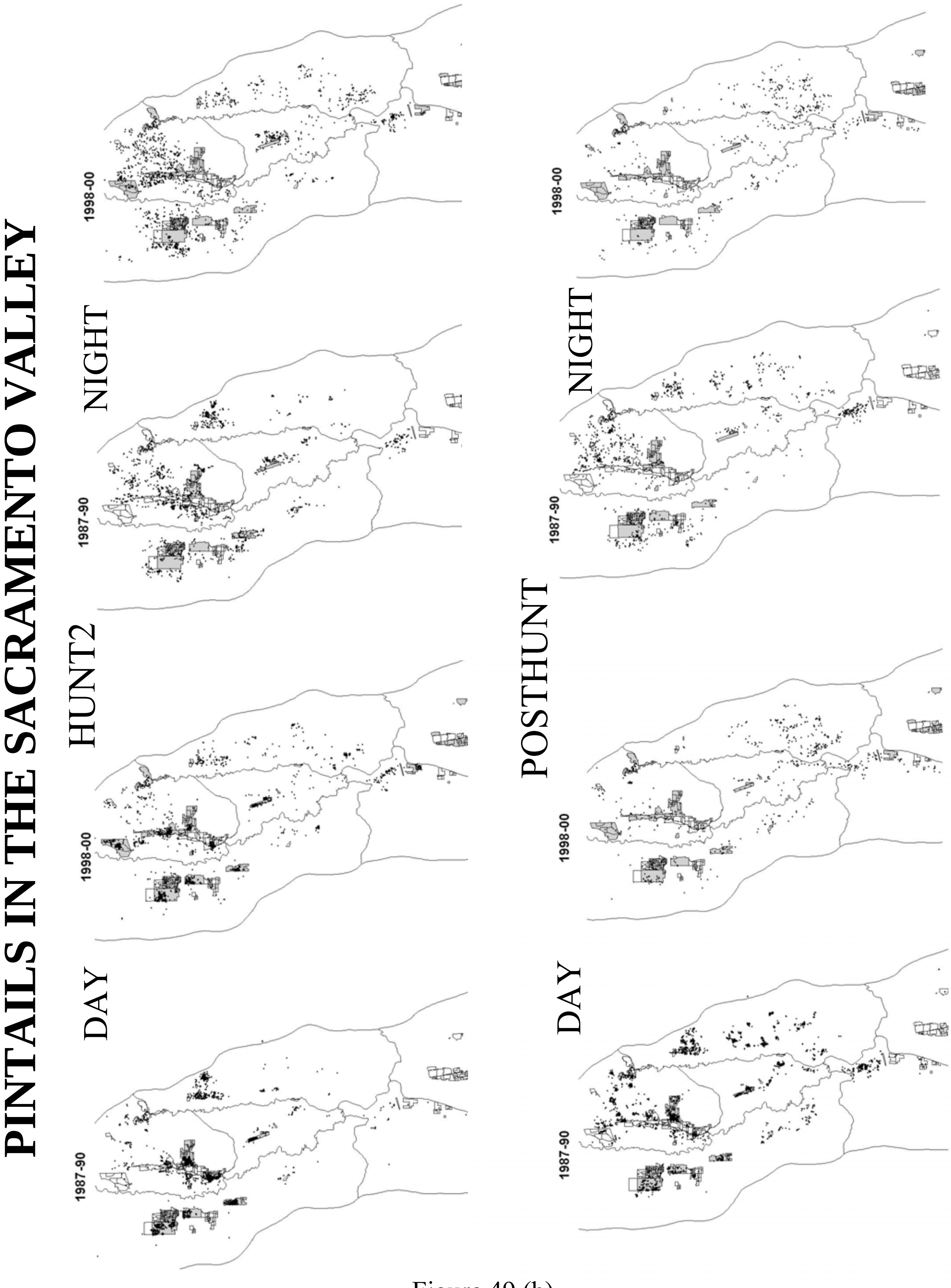

PINTAILS IN THE SACRAMENTO VALLEY
HUNT2
DAY
1987-90
1998-00
NIGHT
1987-90
1998-00
POSTHUNT
DAY
1987-90
1998-00
NIGHT
1987-90
1998-00

Figure 49 (b)

PINTAIL DAY-NIGHT MOVEMENTS IN THE SACRAMENTO VALLEY

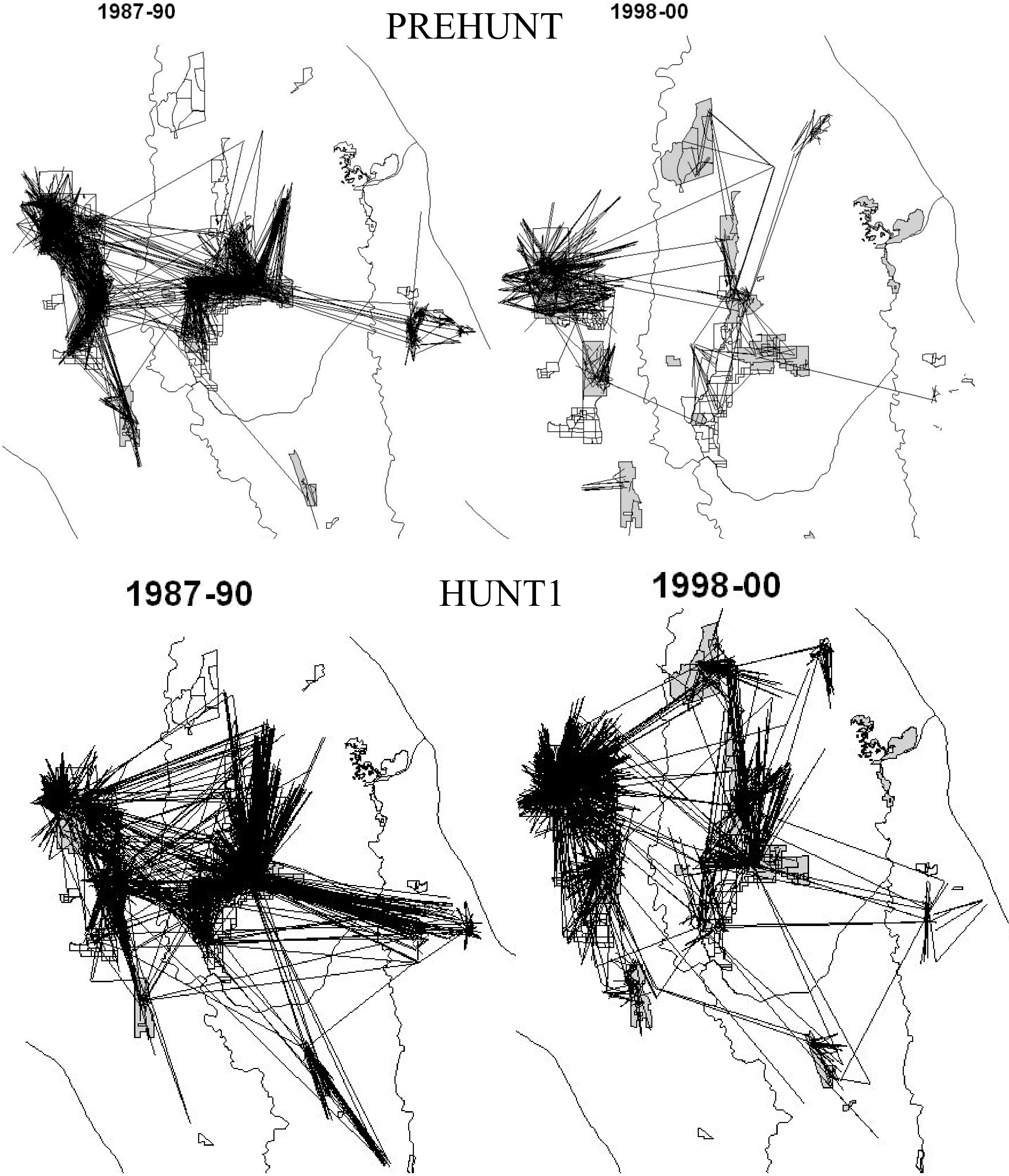


Figure 50 (a)

PINTAIL DAY-NIGHT MOVEMENTS IN THE SACRAMENTO VALLEY

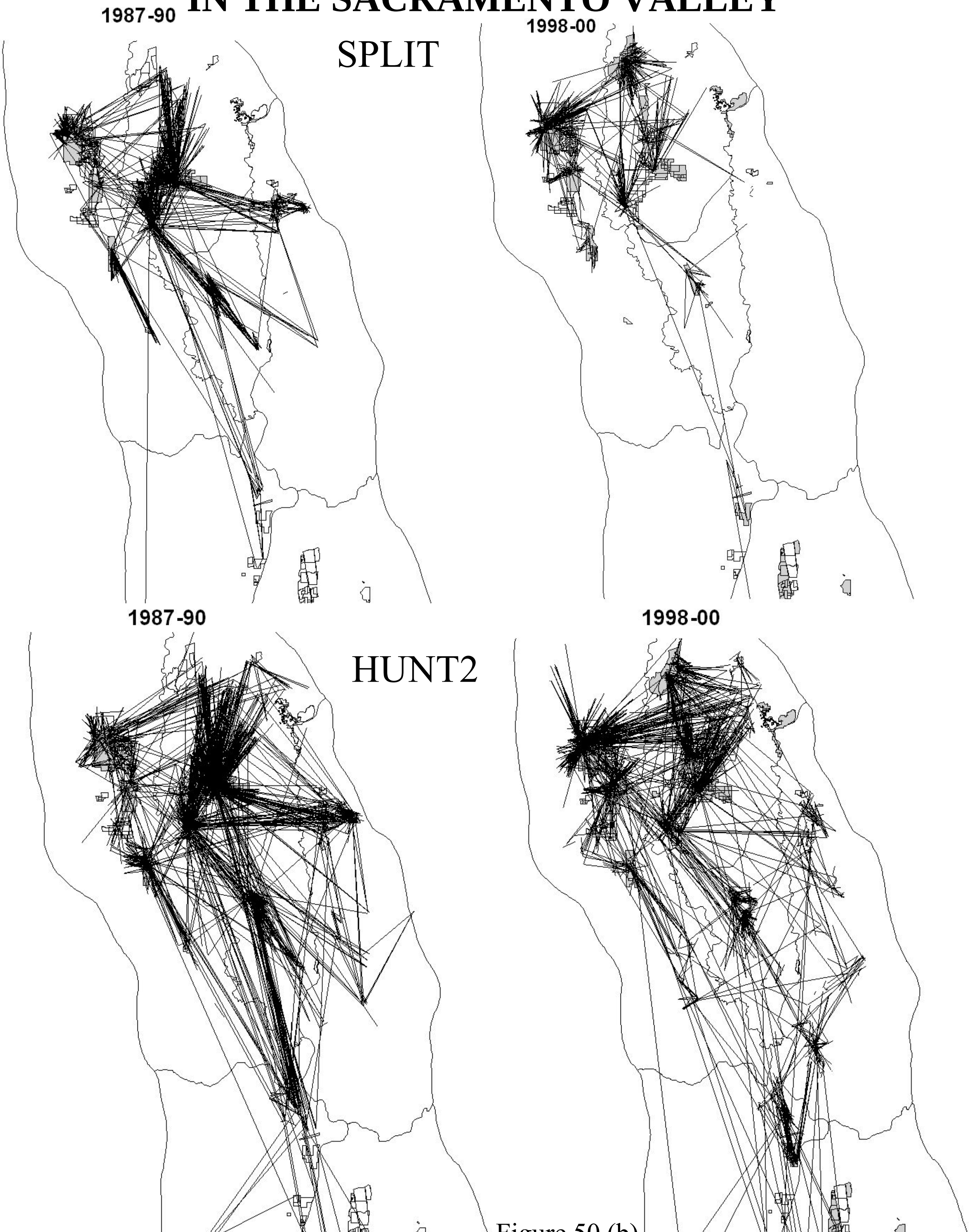


Figure 50 (b)

PINTAIL DAY-NIGHT MOVEMENTS IN THE SACRAMENTO VALLEY

POSTHUNT

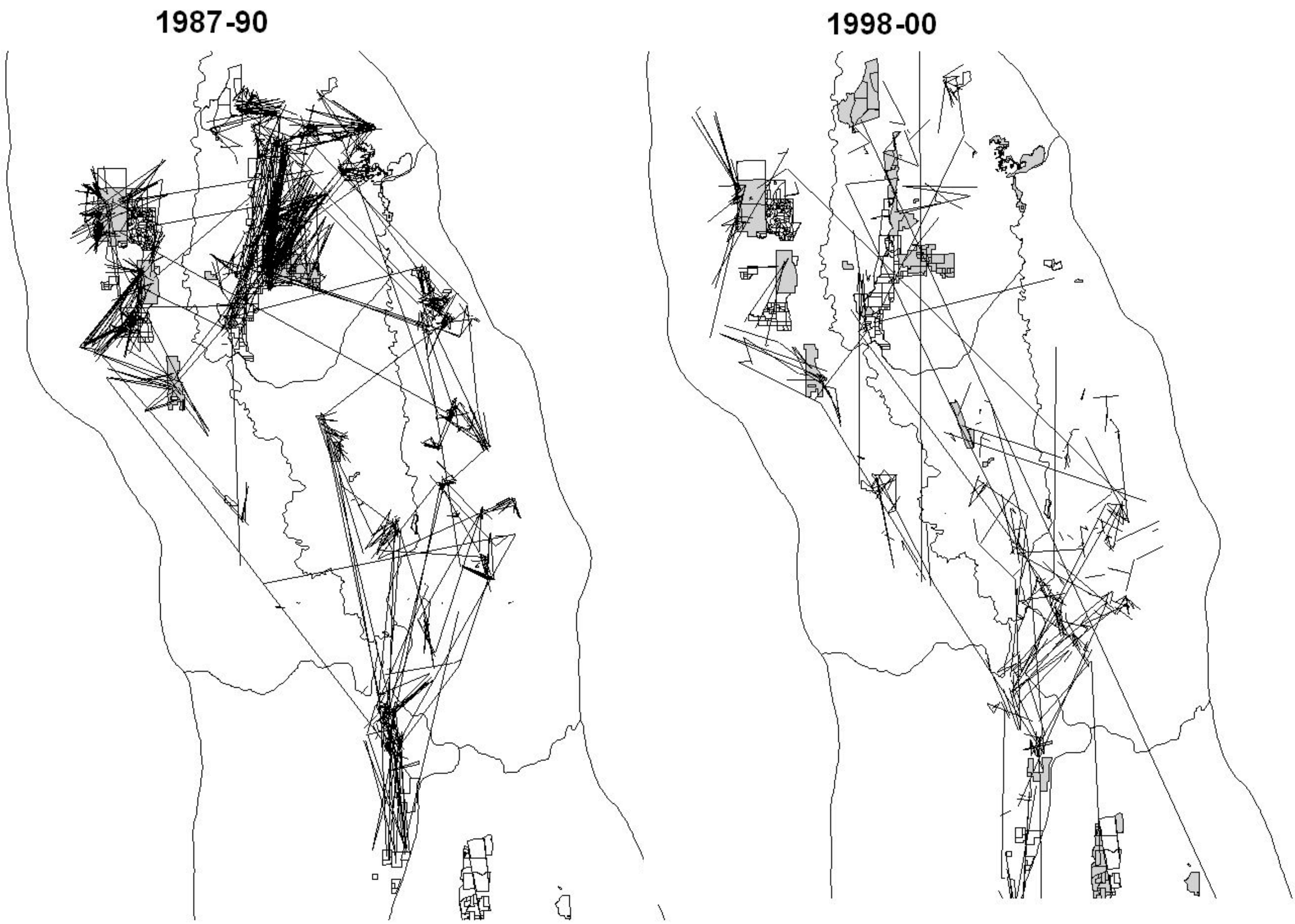


Figure 50 (c)

HUNTING IMPACT ON PINTAIL DISTRIBUTION DIFFERED AMONG BASINS

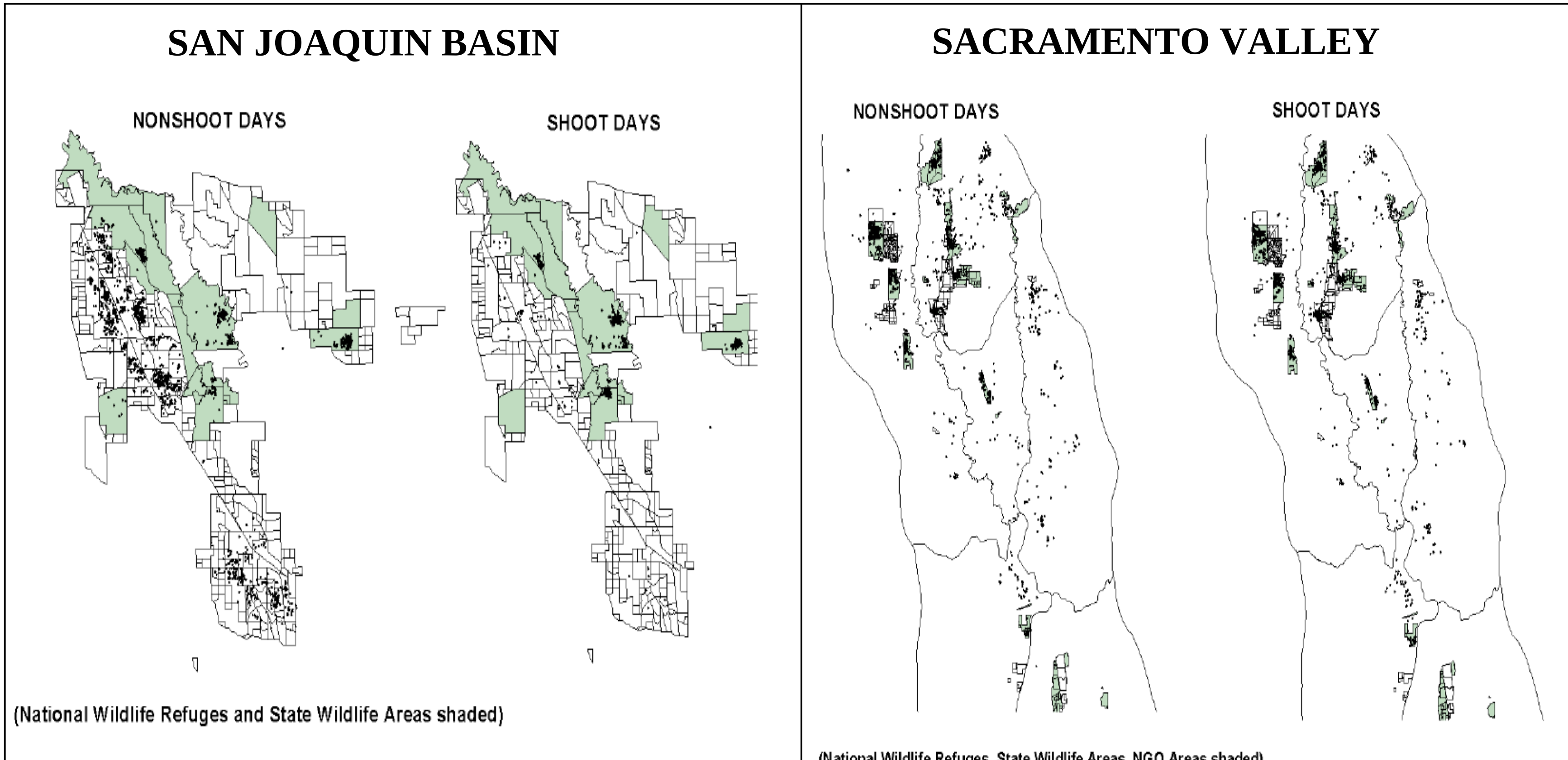
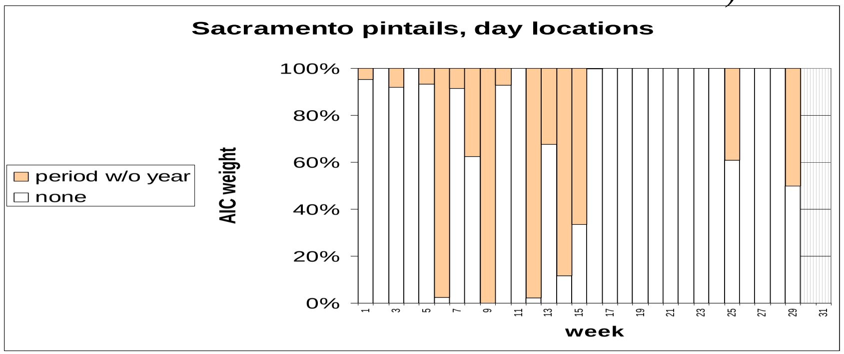
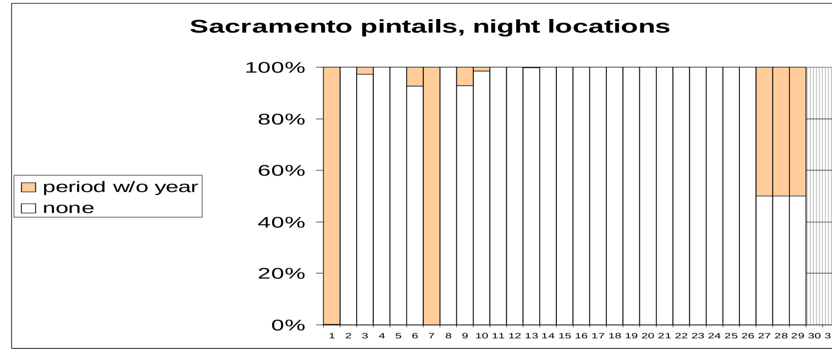


Figure 51

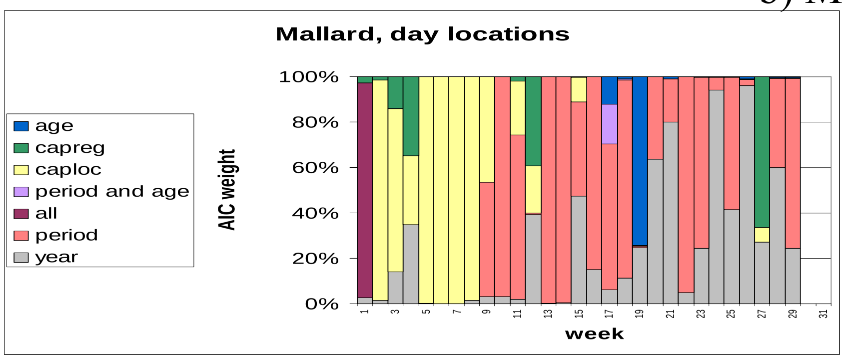
AIC WEIGHTS OF FACTORS RELATED TO WEEKLY WATERFOWL DISTRIBUTION AMONG SACRAMENTO VALLEY AREAS

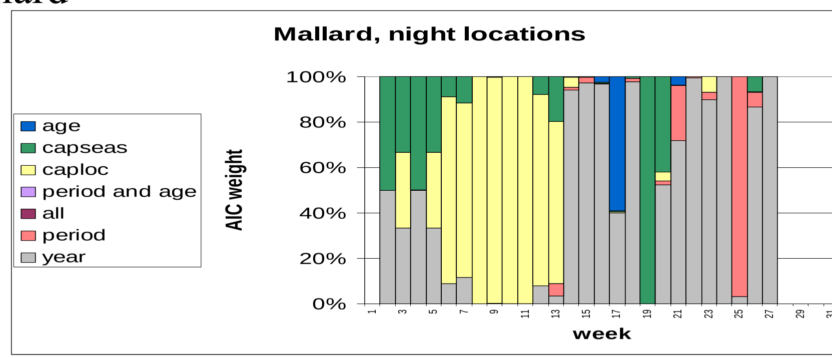
a) Northern Pintail



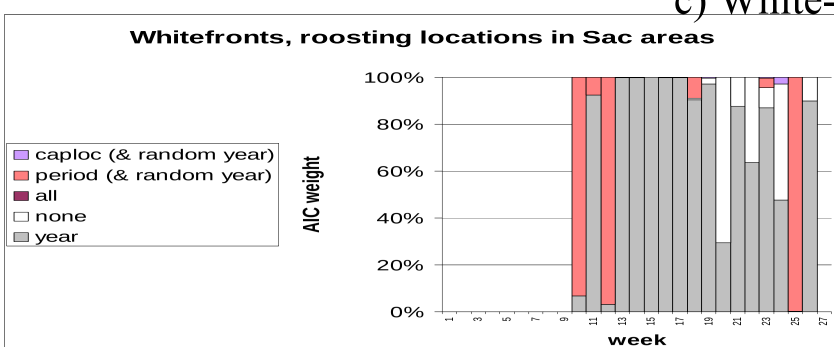


b) Mallard





c) White-fronted Goose



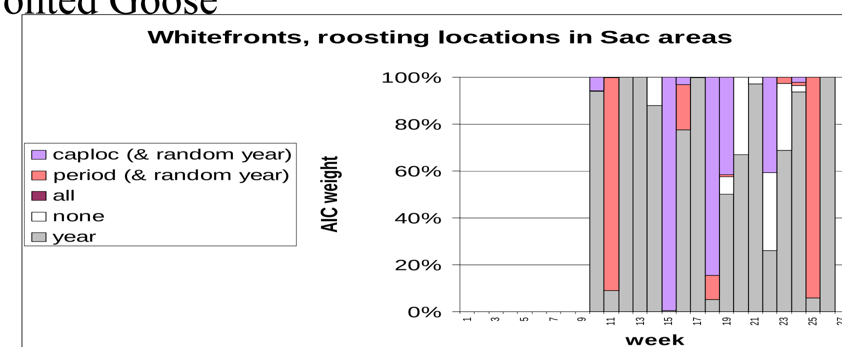


Figure 52

MALLARD DISTRIBUTION AMONG SACRAMENTO VALLEY AREAS 1988-1990 VS. 1998-2000

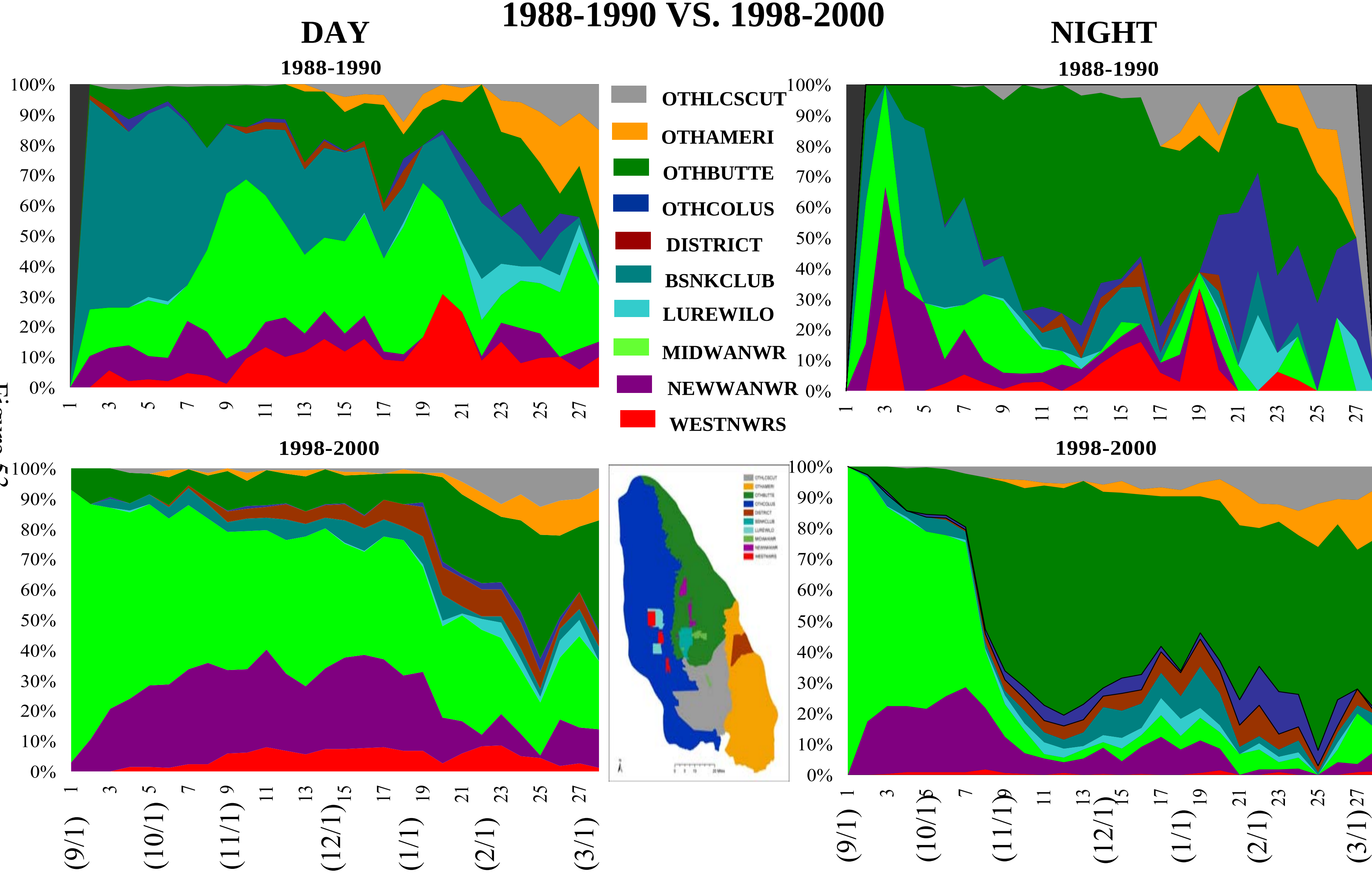


Figure 53

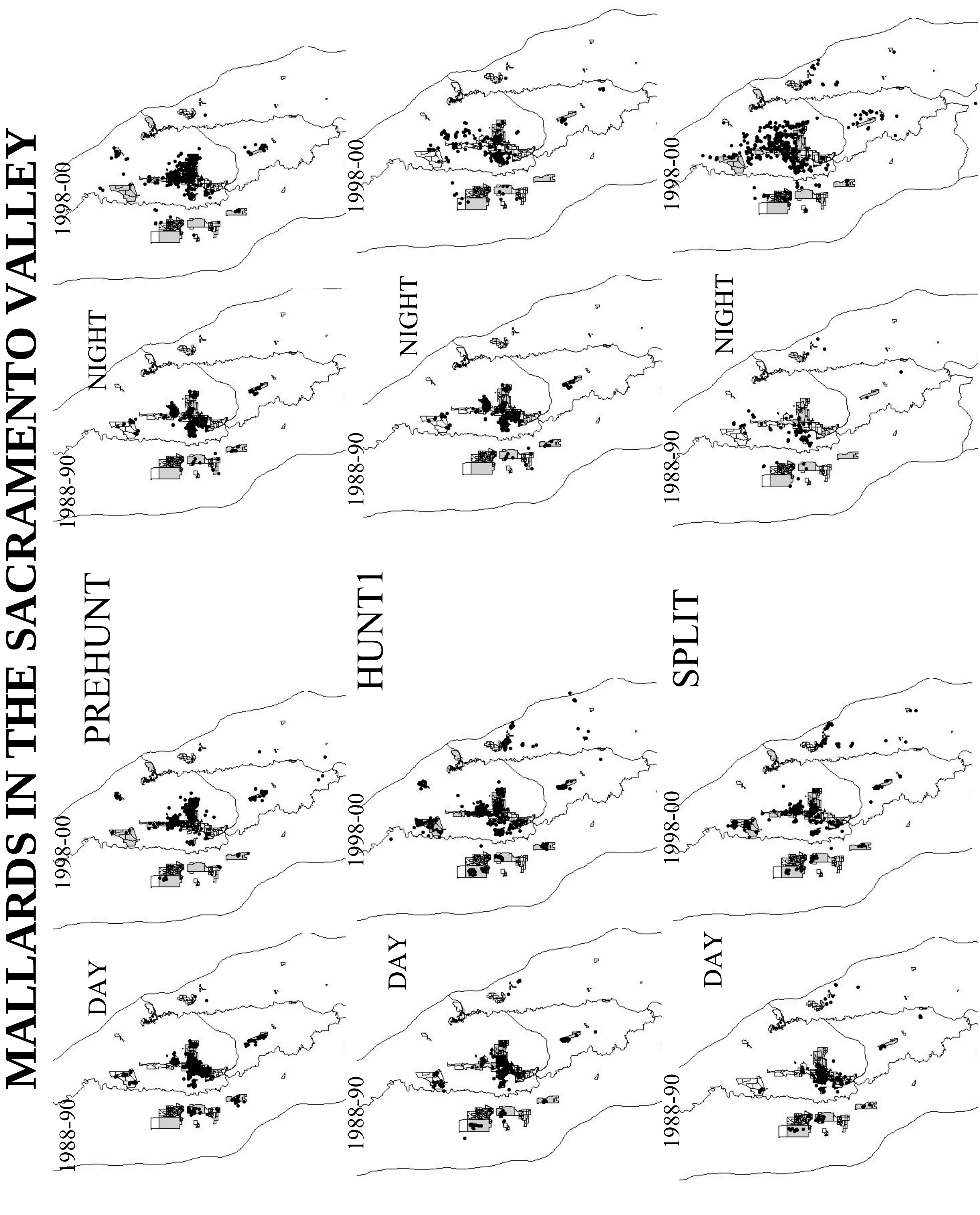

MALLARDS IN THE SACRAMENTO VALLEY
PREHUNT
HUNT1
SPLIT
DAY
NIGHT
DAY
NIGHT
DAY
NIGHT
1988-90
1998-00
1988-90
1998-00
1988-90
1998-00
1988-90
1998-00
1988-90
1998-00
1988-90
1998-00

Figure 54 (a)

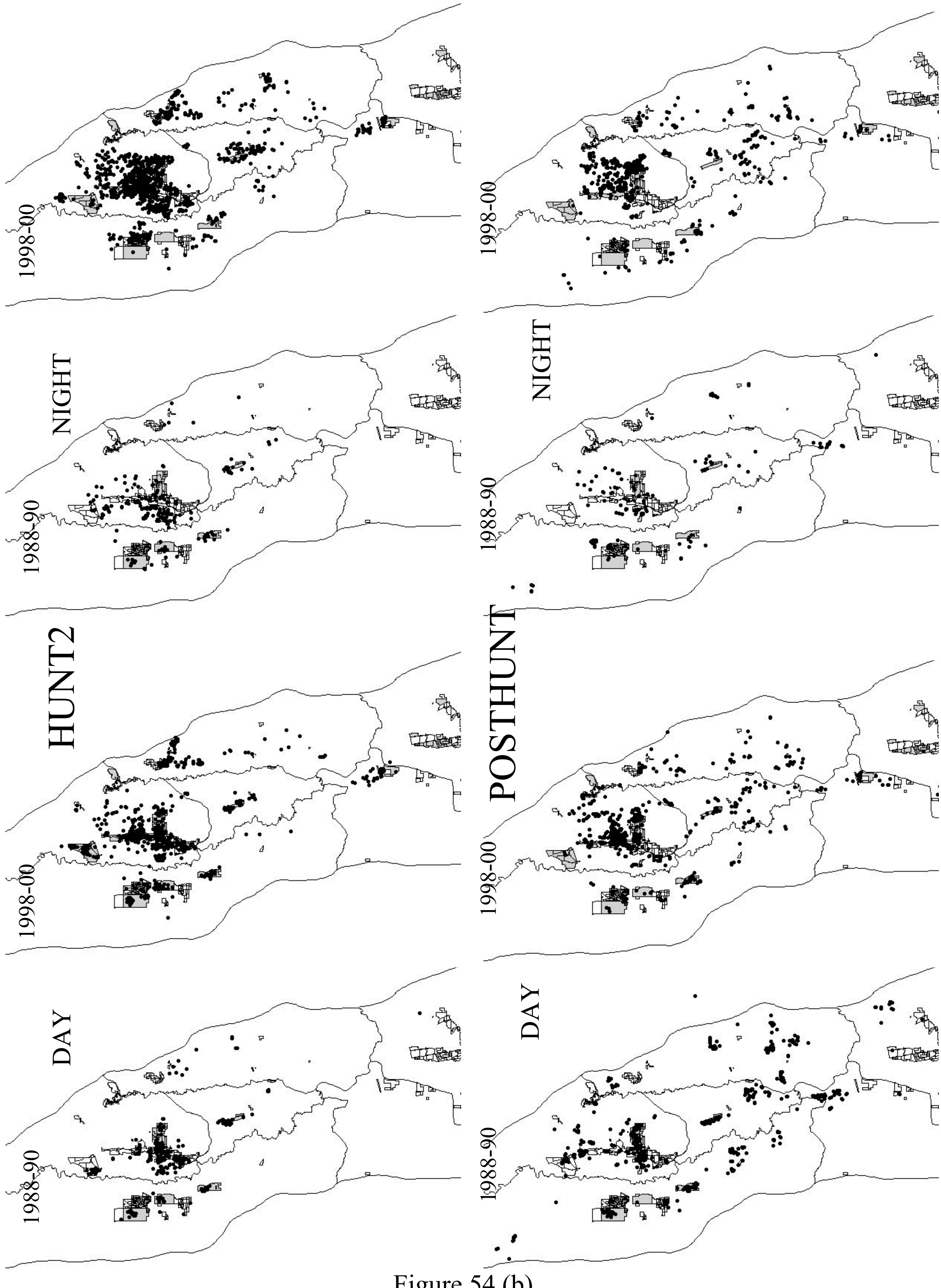

MALLARDS IN THE SACRAMENTO VALLEY
HUNT2
POSTHUNT
DAY
NIGHT
DAY
NIGHT
1988-90
1998-00
1988-90
1998-00
1988-90
1998-00
1988-90
1998-00

Figure 54 (b)

MALLARD DAY-NIGHT MOVEMENTS

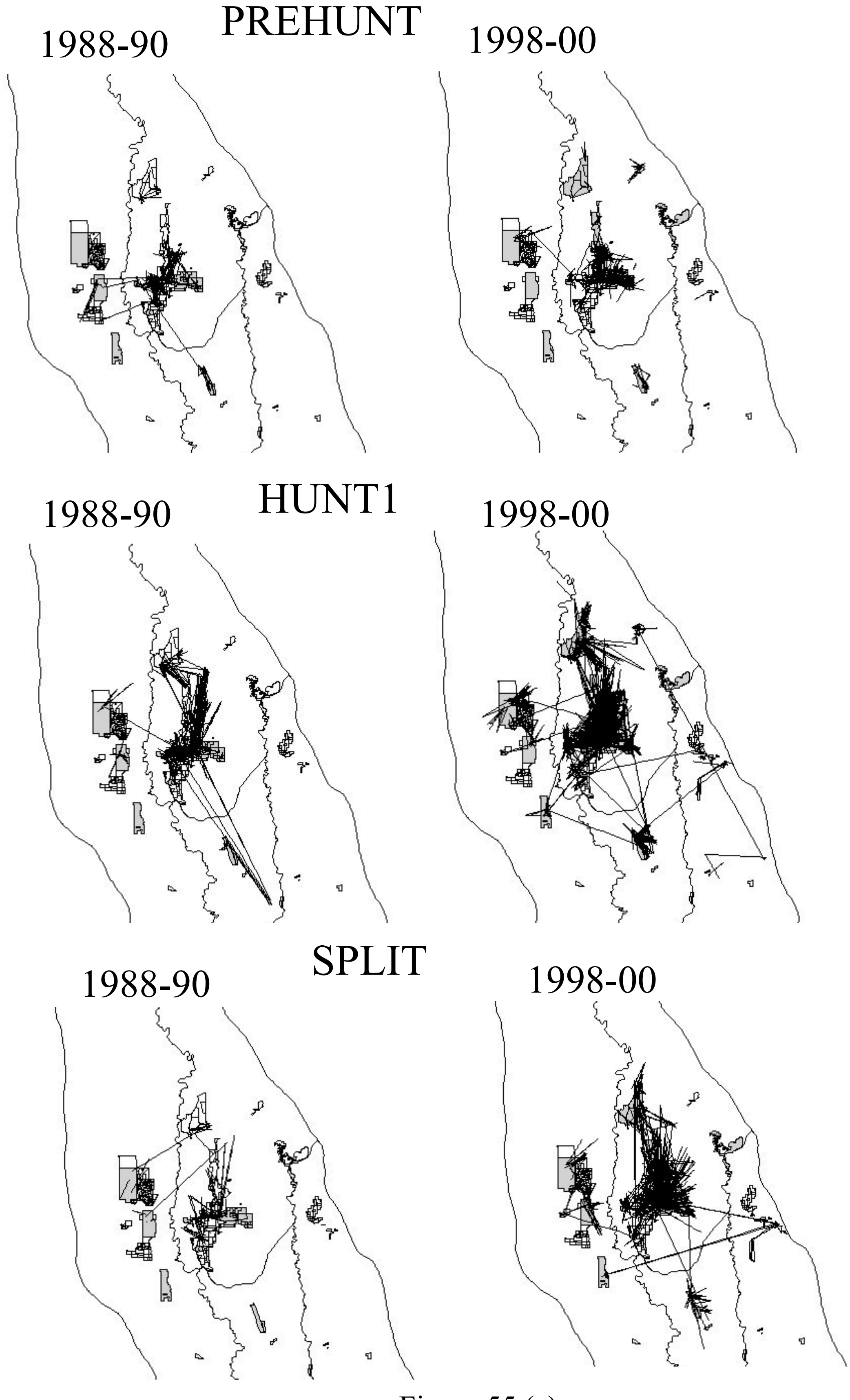


Figure 55 (a)

MALLARD DAY-NIGHT MOVEMENTS

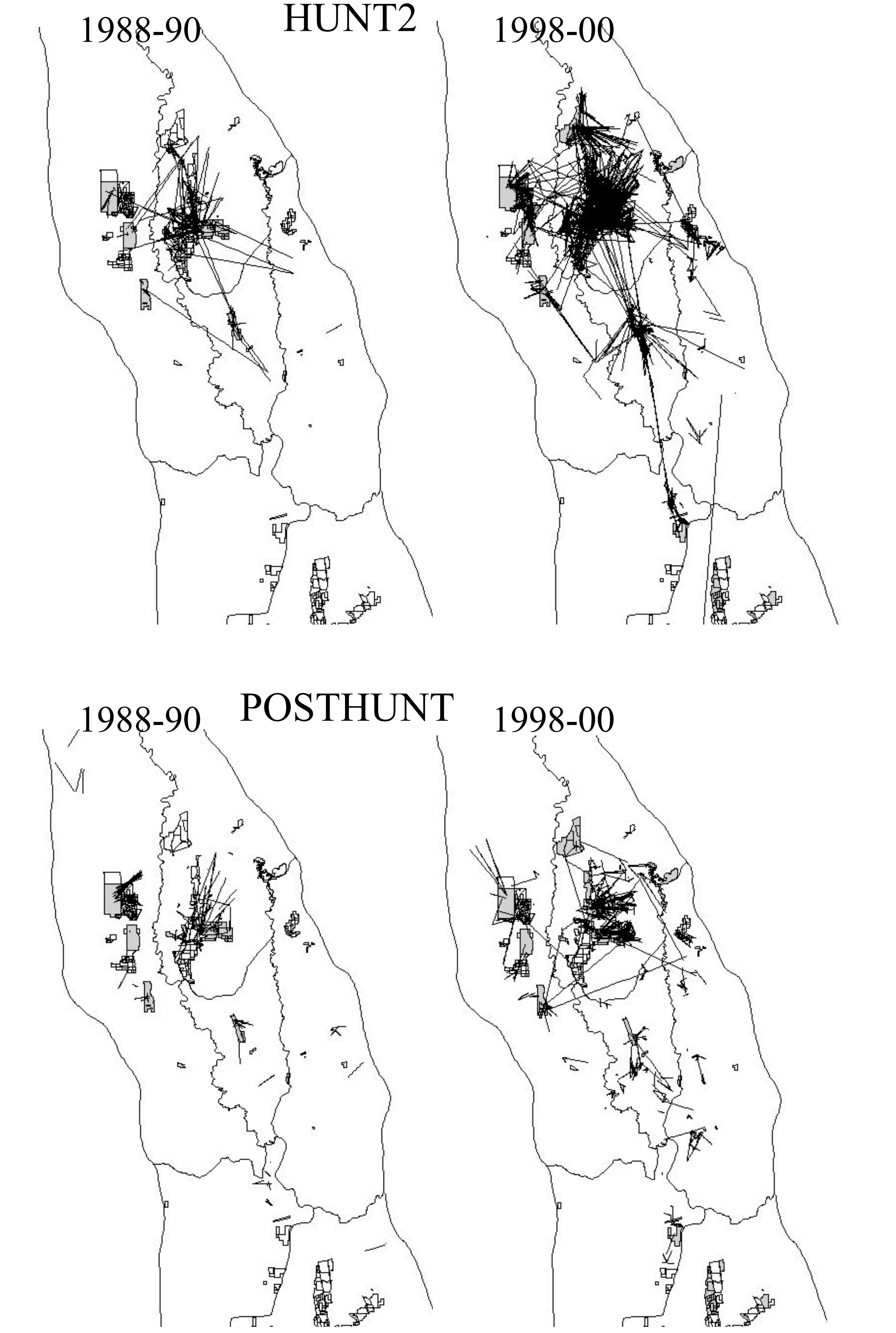


Figure 55 (b)

WHITE-FRONTED GOOSE DISTRIBUTION AMONG SACRAMENTO VALLEY AREAS, 1987-1990 VS. 1998-2000

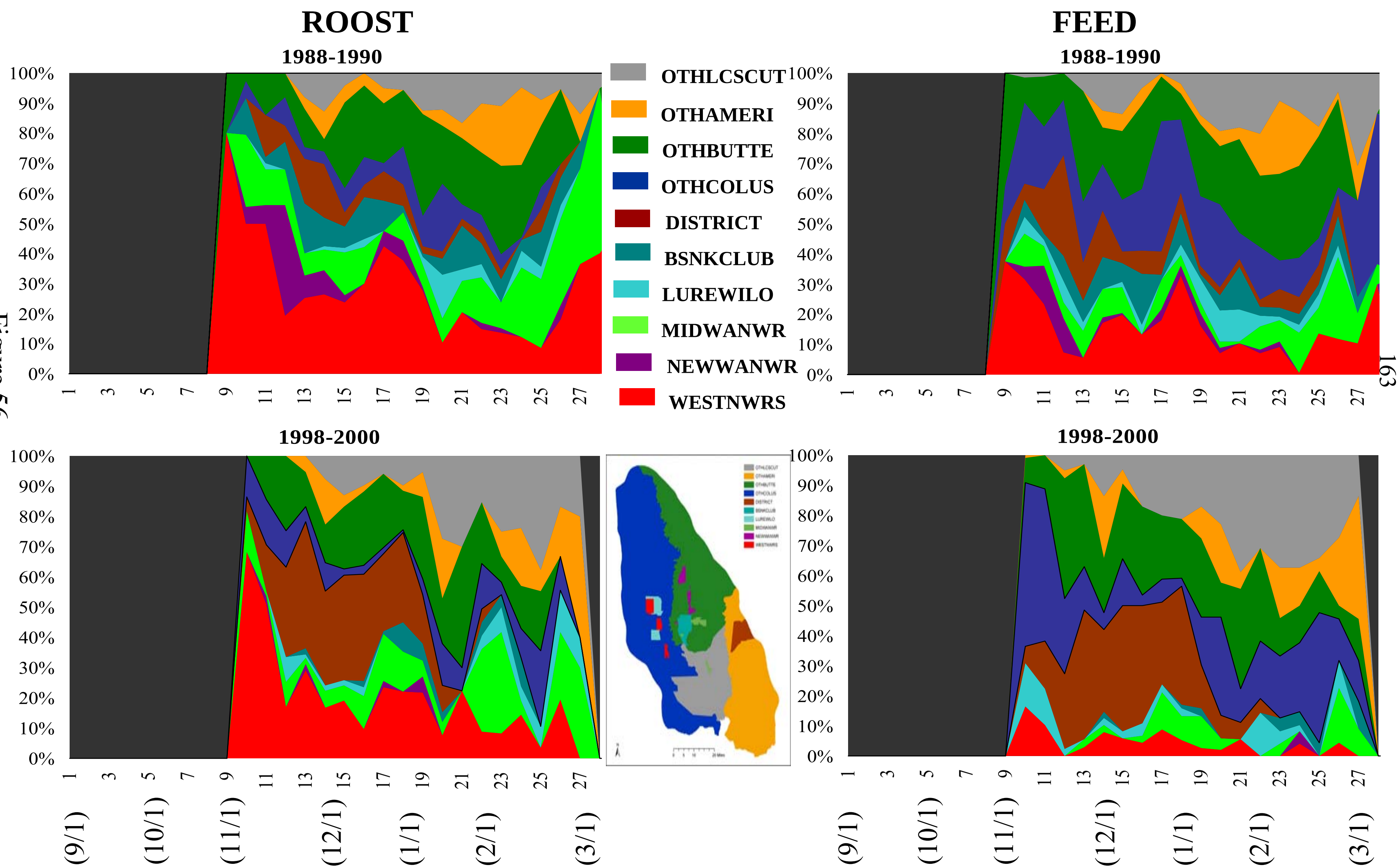


Figure 56

PERCENT OF ROOST LOCATIONS IN AGRICULTURE DURING 1987-1994 VS. 1998-2000

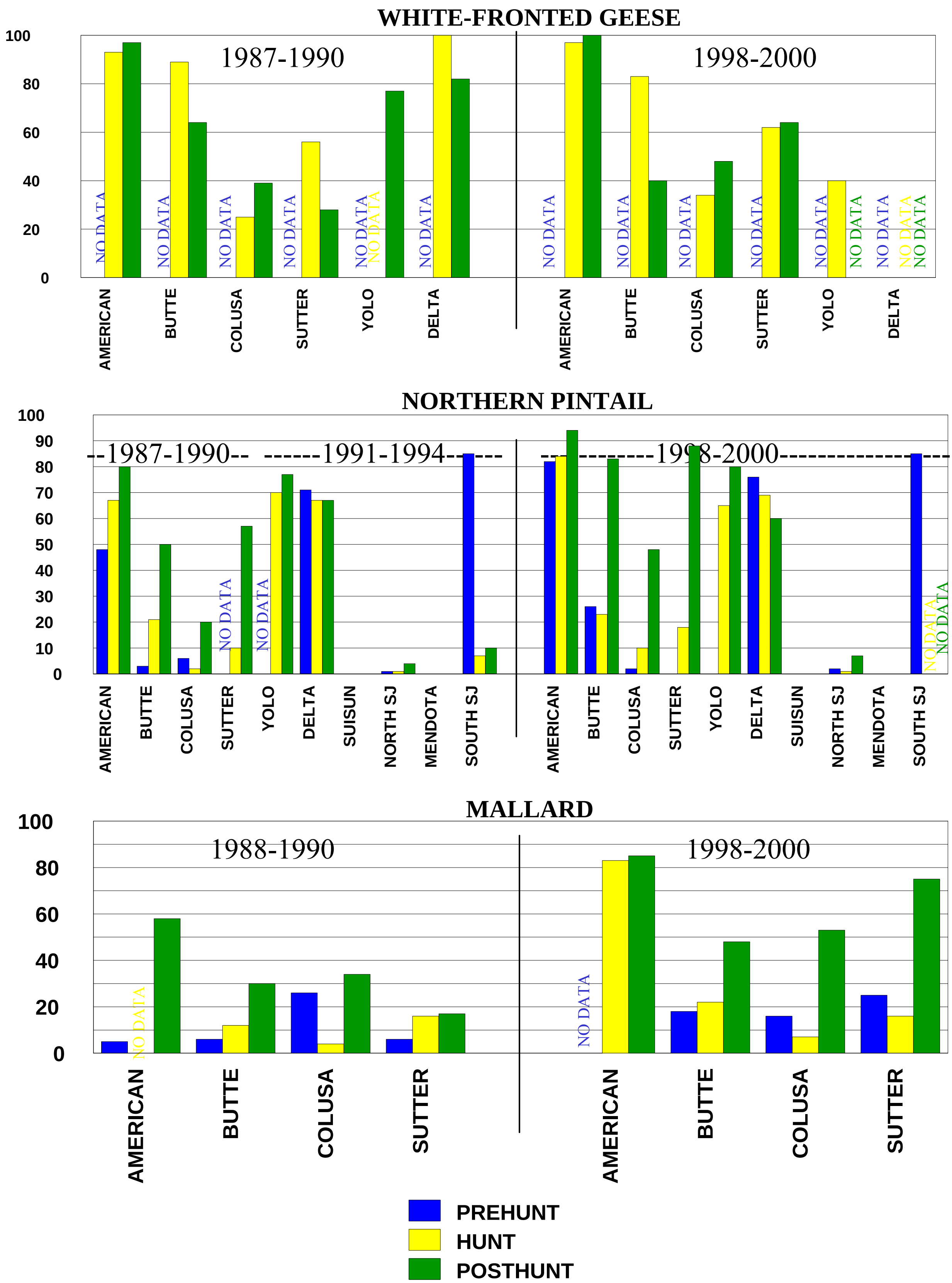


Figure57

PERCENT OF FEEDING LOCATIONS IN AGRICULTURE DURING 1987-1994 VS. 1998-2000

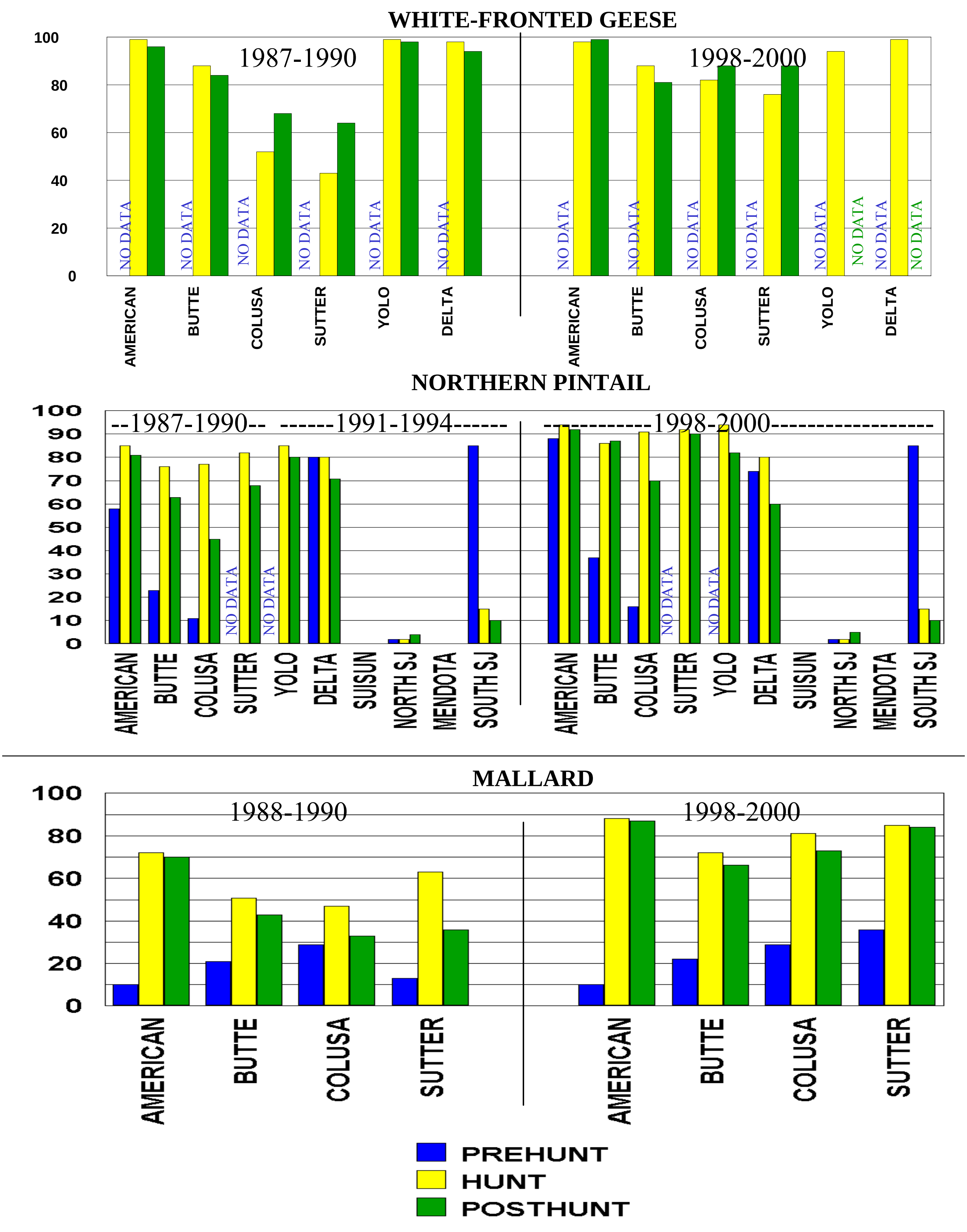


Figure 58

SEPT 15 - FEB 15 WATERFOWL USE DAYS
CVHJV GOAL VS 1998-99 & 1999-00

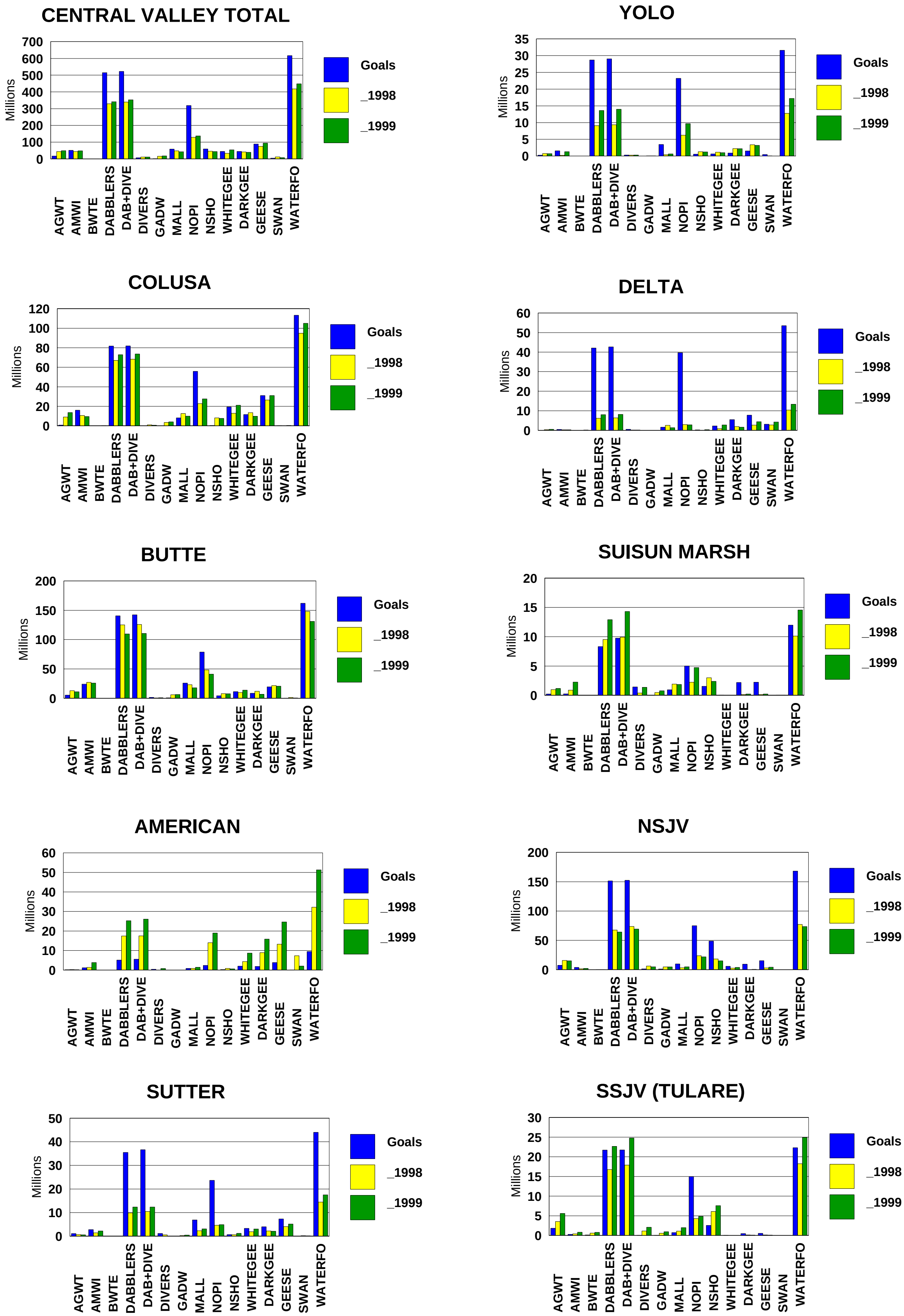


Figure 59

SEPT 15 - FEB 15 WATERFOWL USE DAYS
CVHJV GOAL VS 1998-99 & 1999-00 (Pintails & Totals Not Shown)

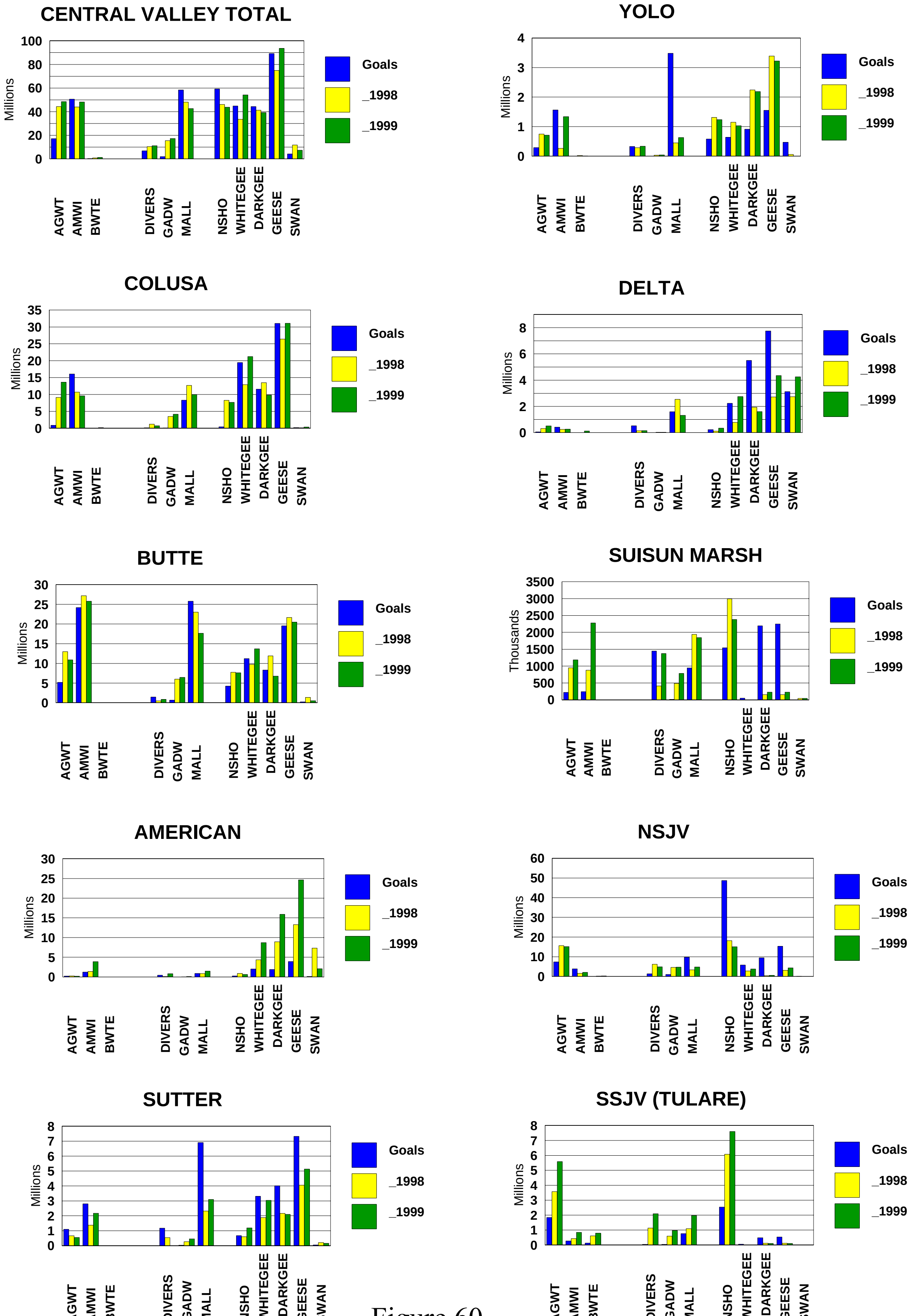


Figure 60

Duck, Geese, and Swan abundance during Sep - Jan

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

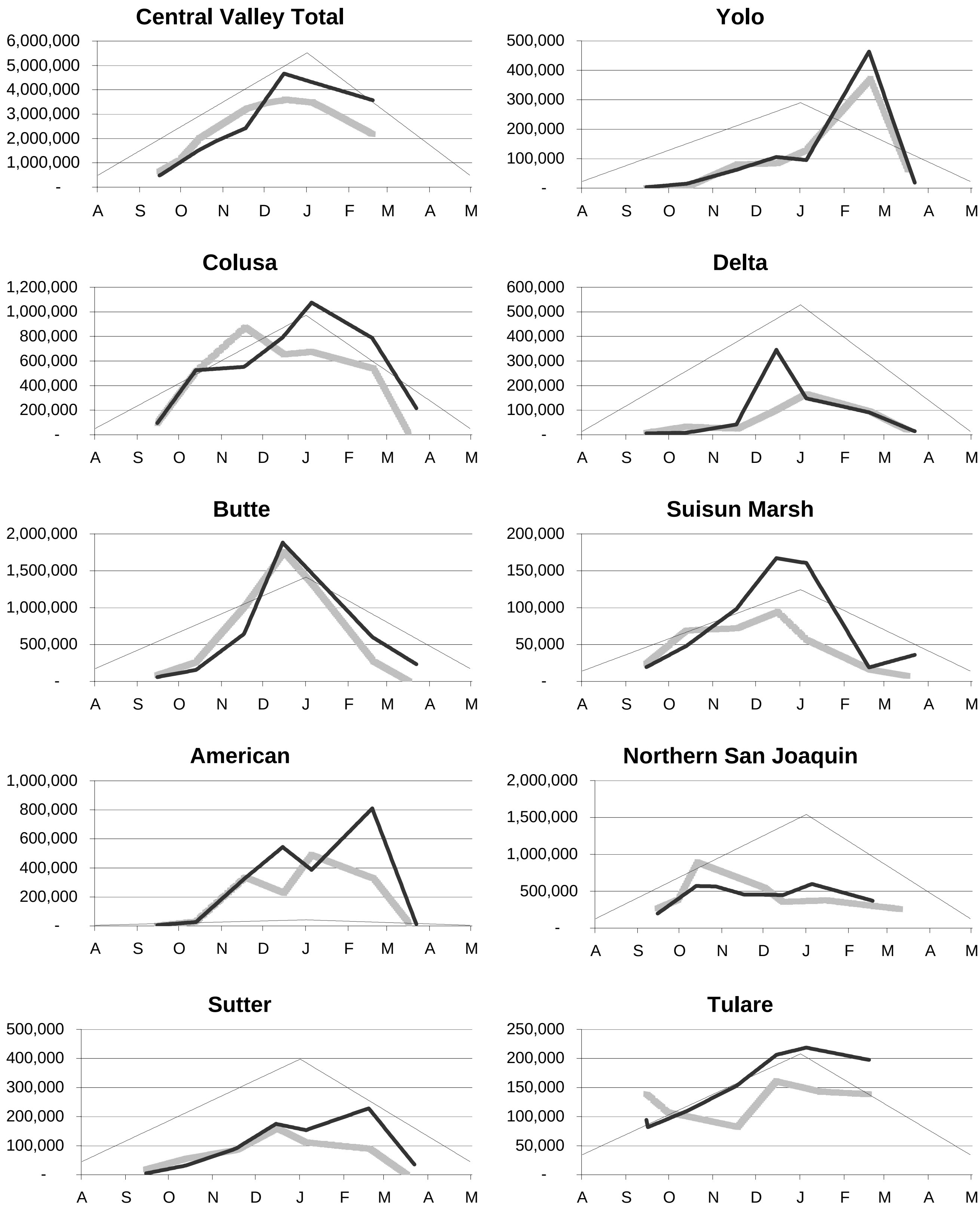


Figure 61

Northern Pintail abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

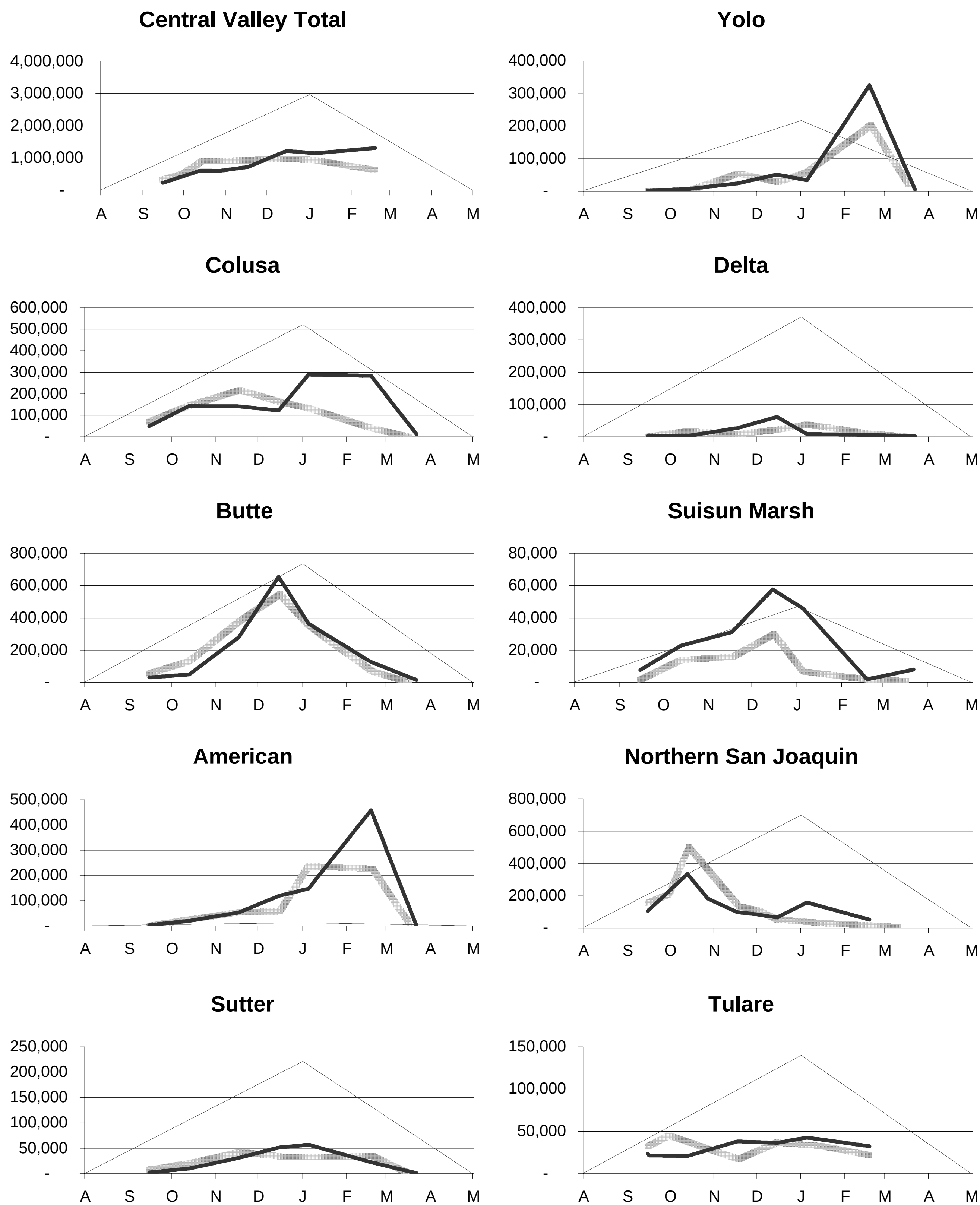


Figure 62

Mallard abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

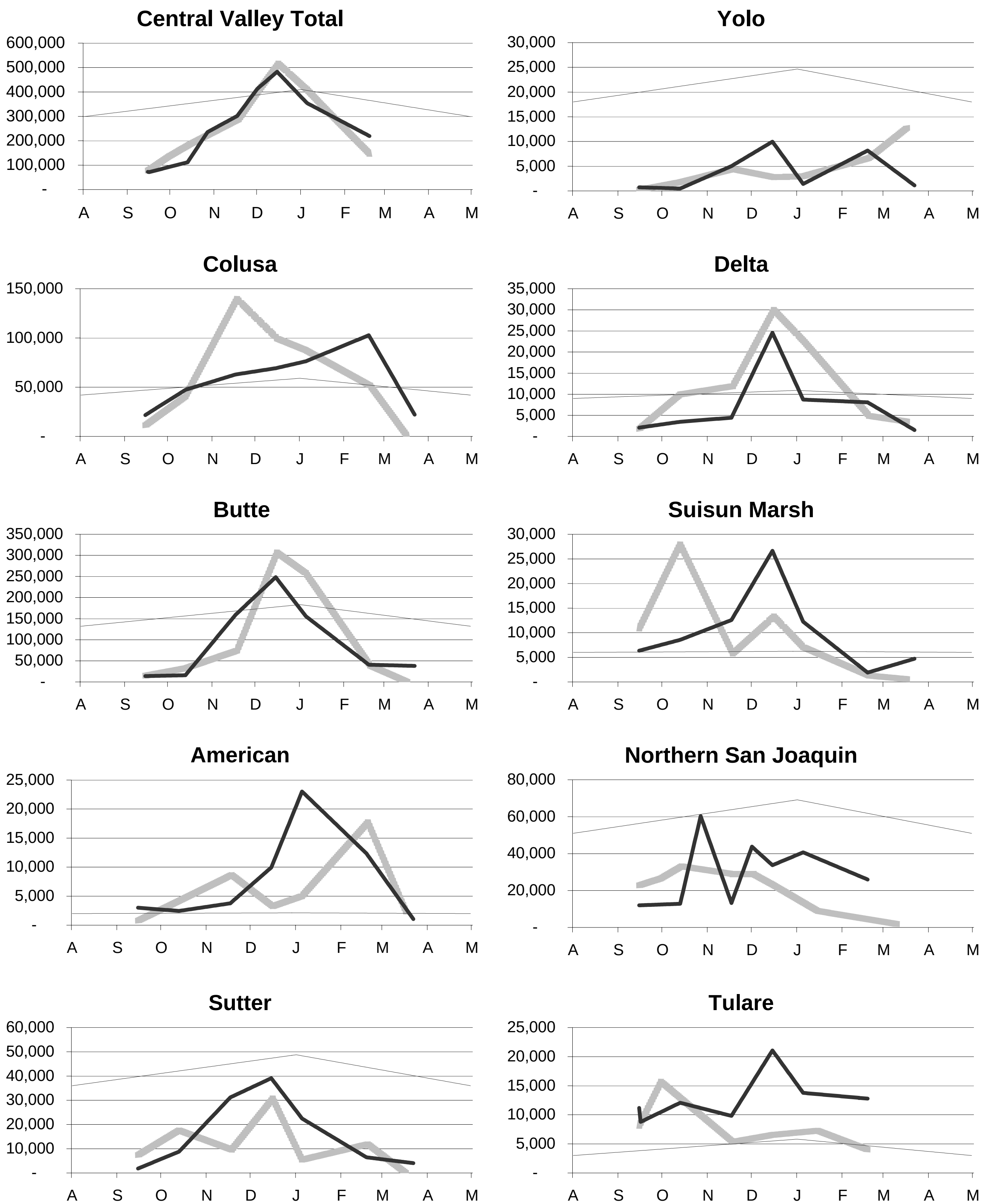


Figure 63

Green-winged Teal abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

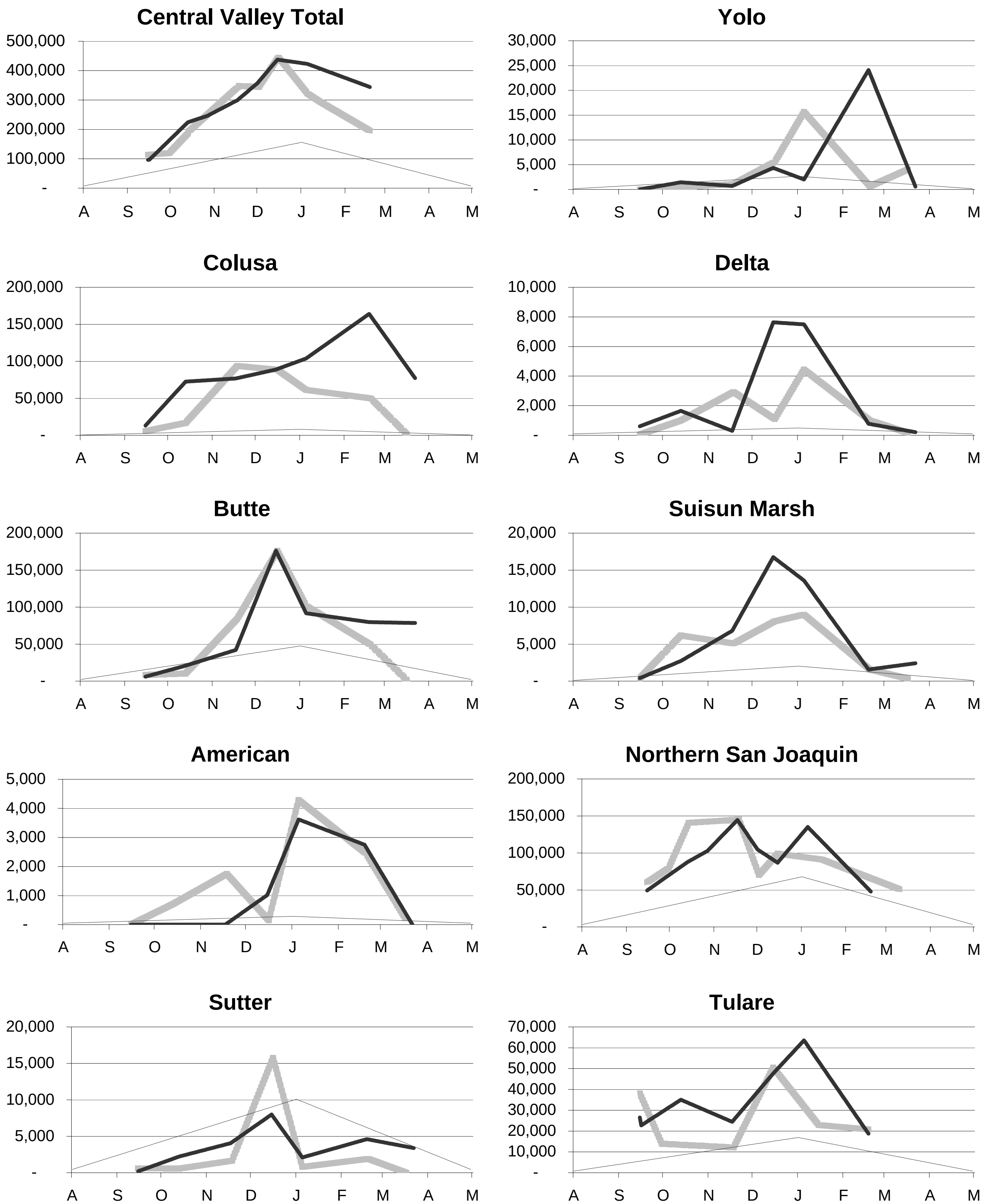


Figure 64

Gadwall abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

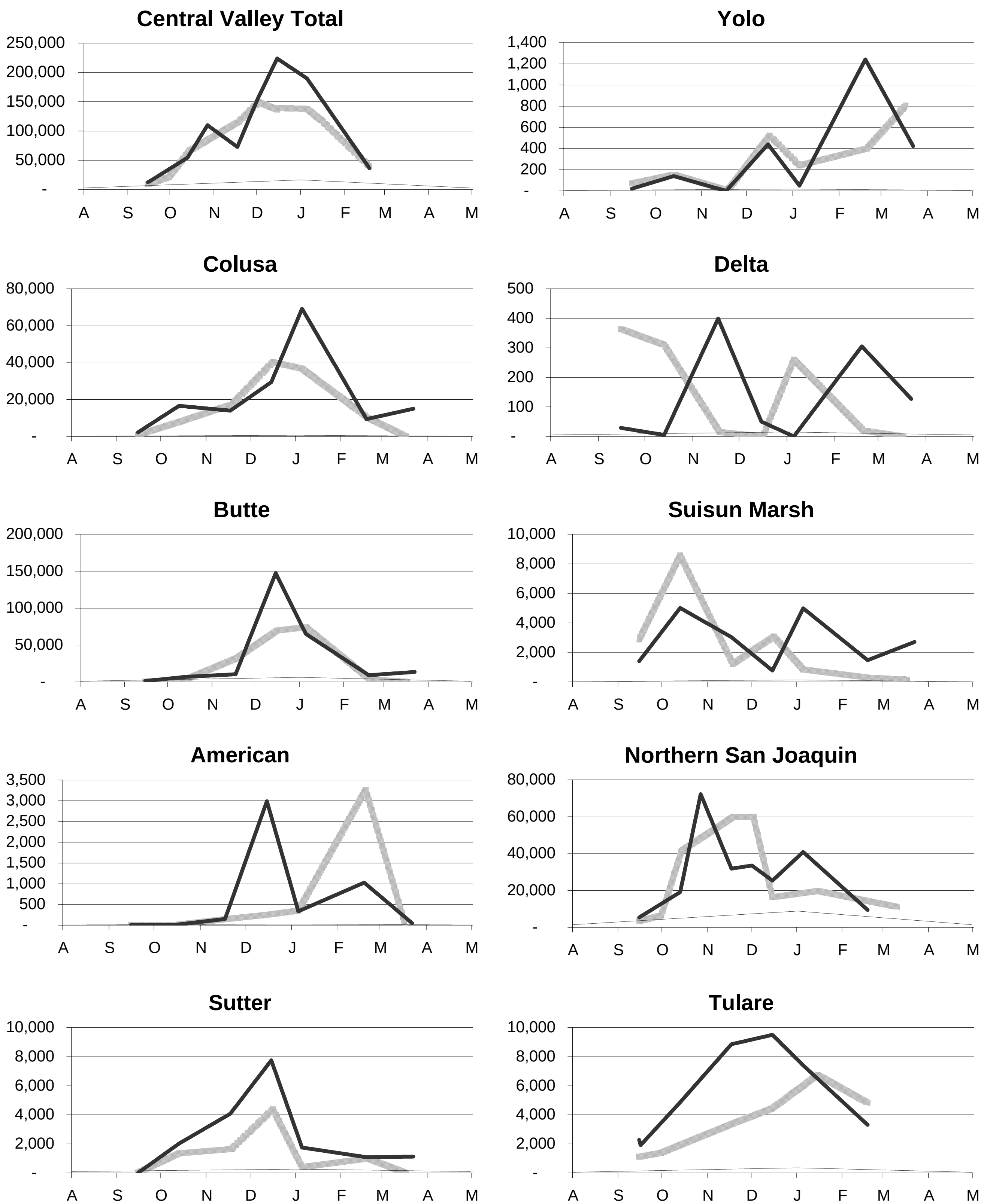


Figure 65

American Wigeon abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

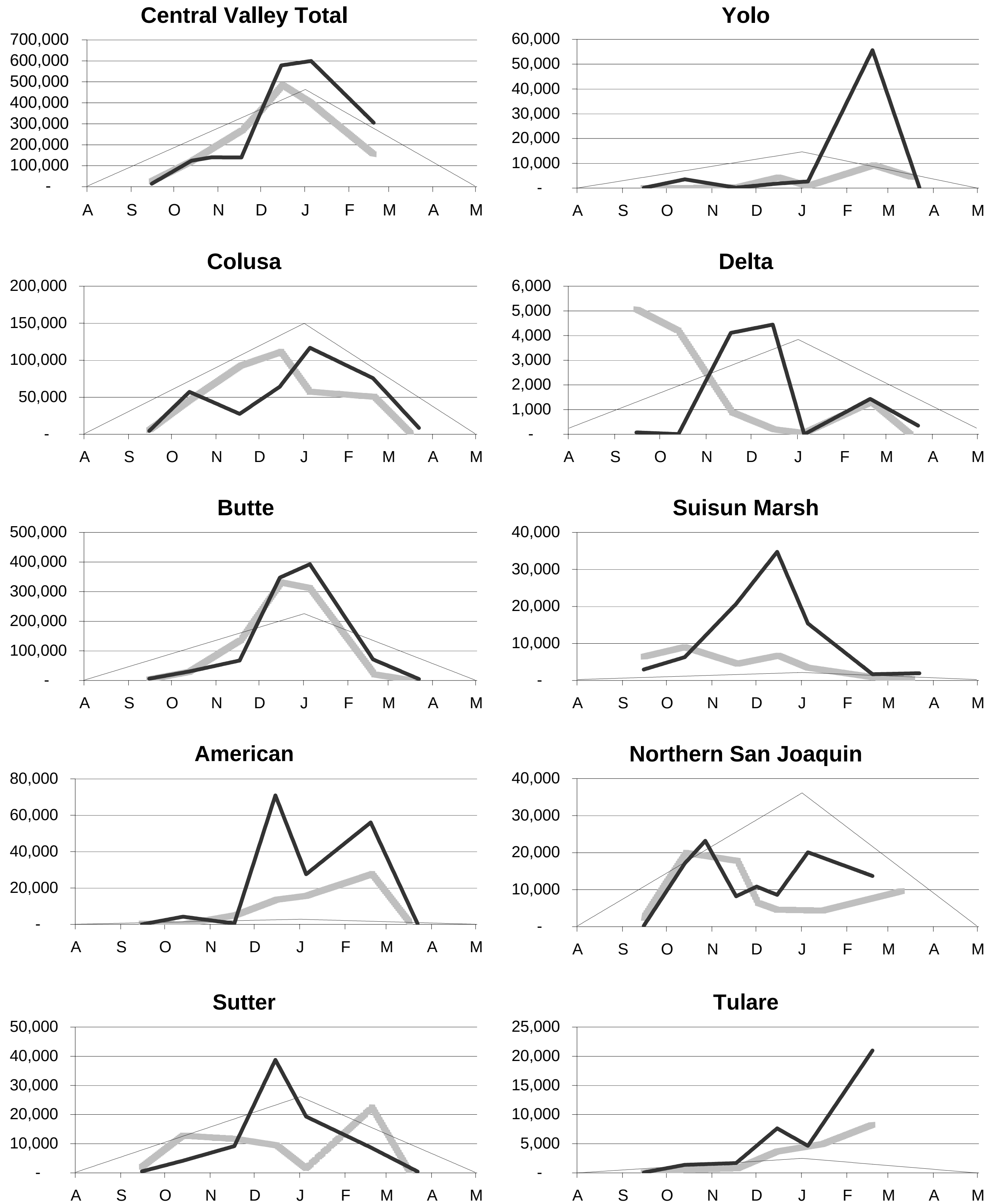


Figure 66

Cinnamon Teal abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

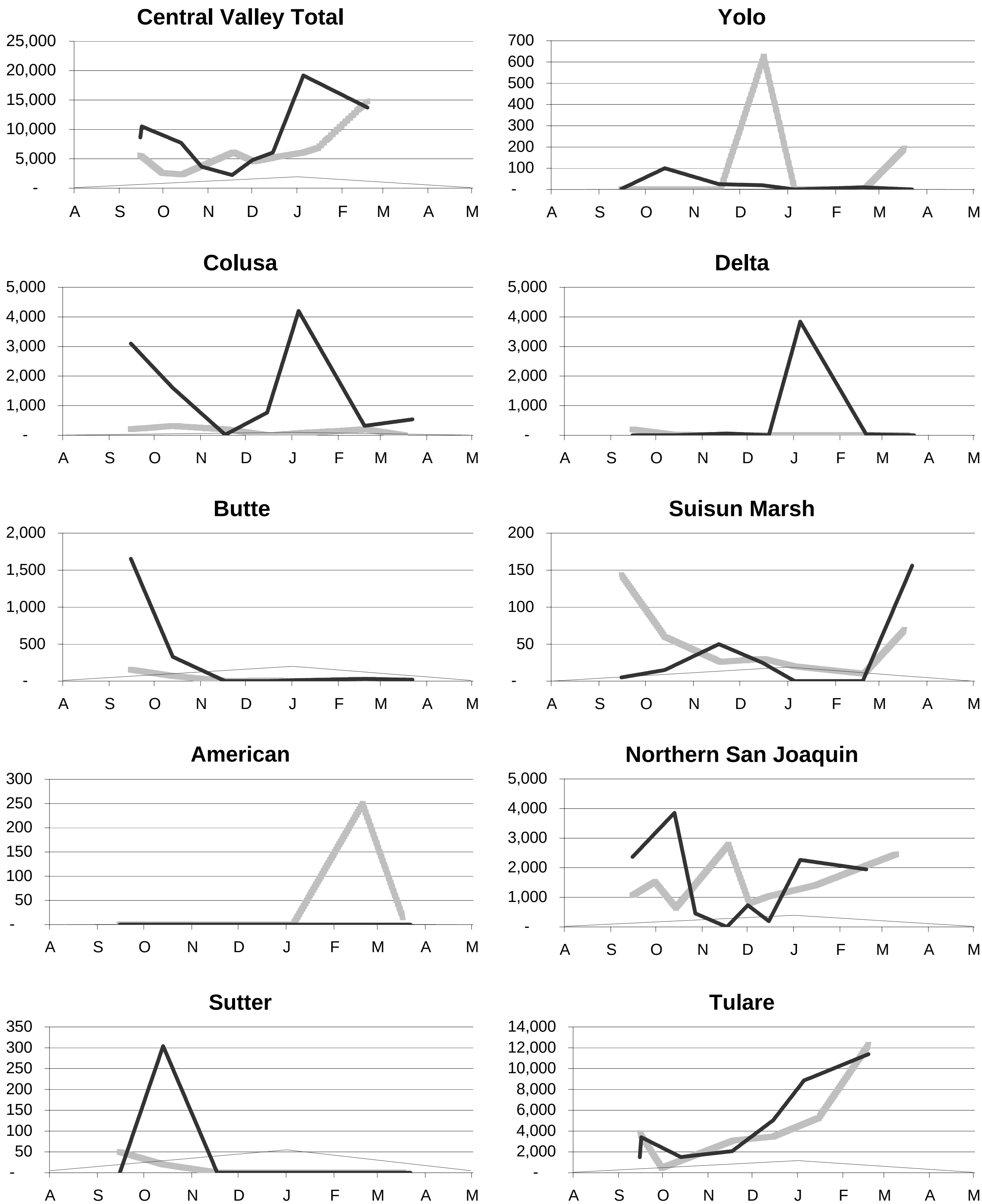


Figure 67

Northern Shoveler abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

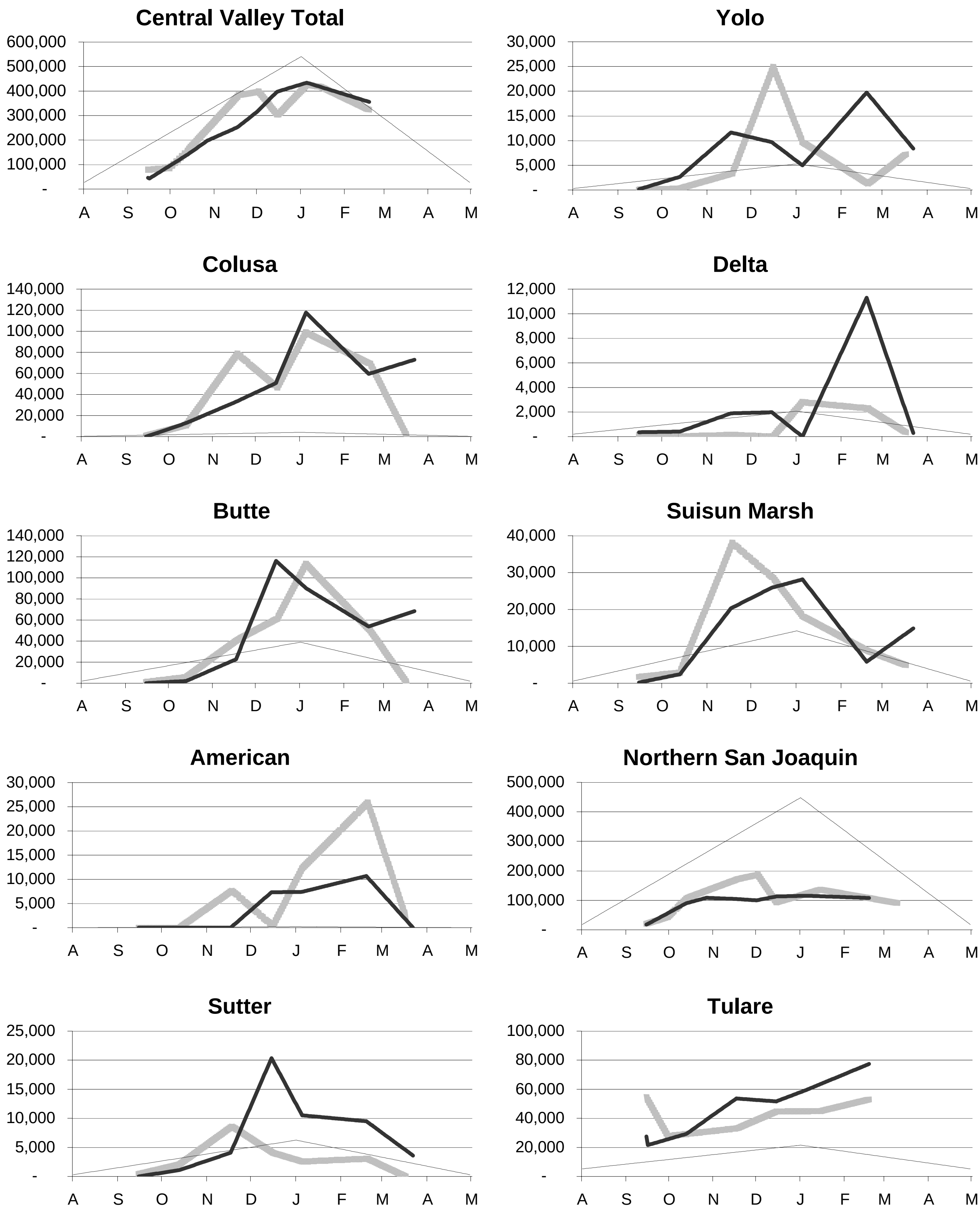


Figure 68

Dabbling duck abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

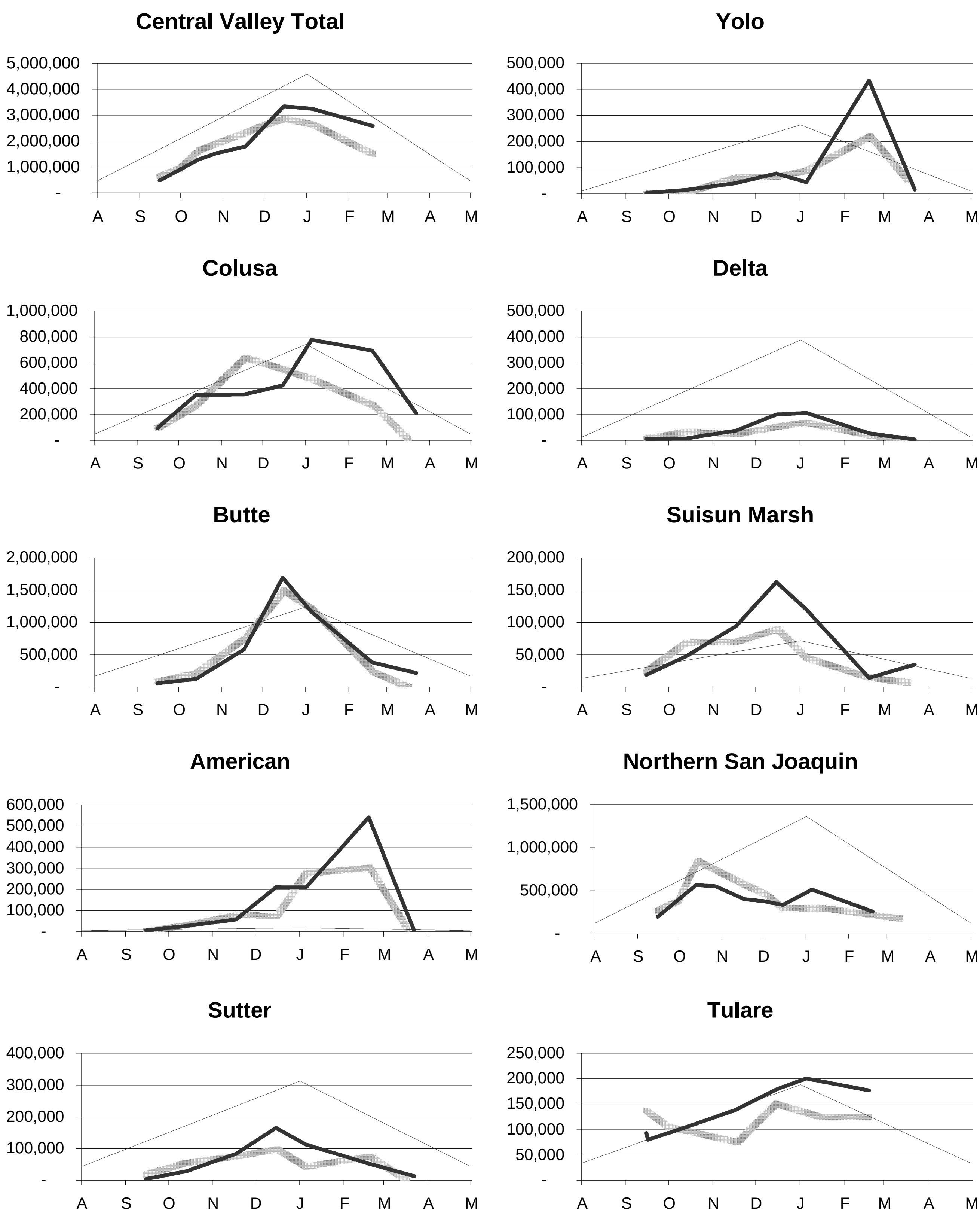


Figure 69

Diving duck abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

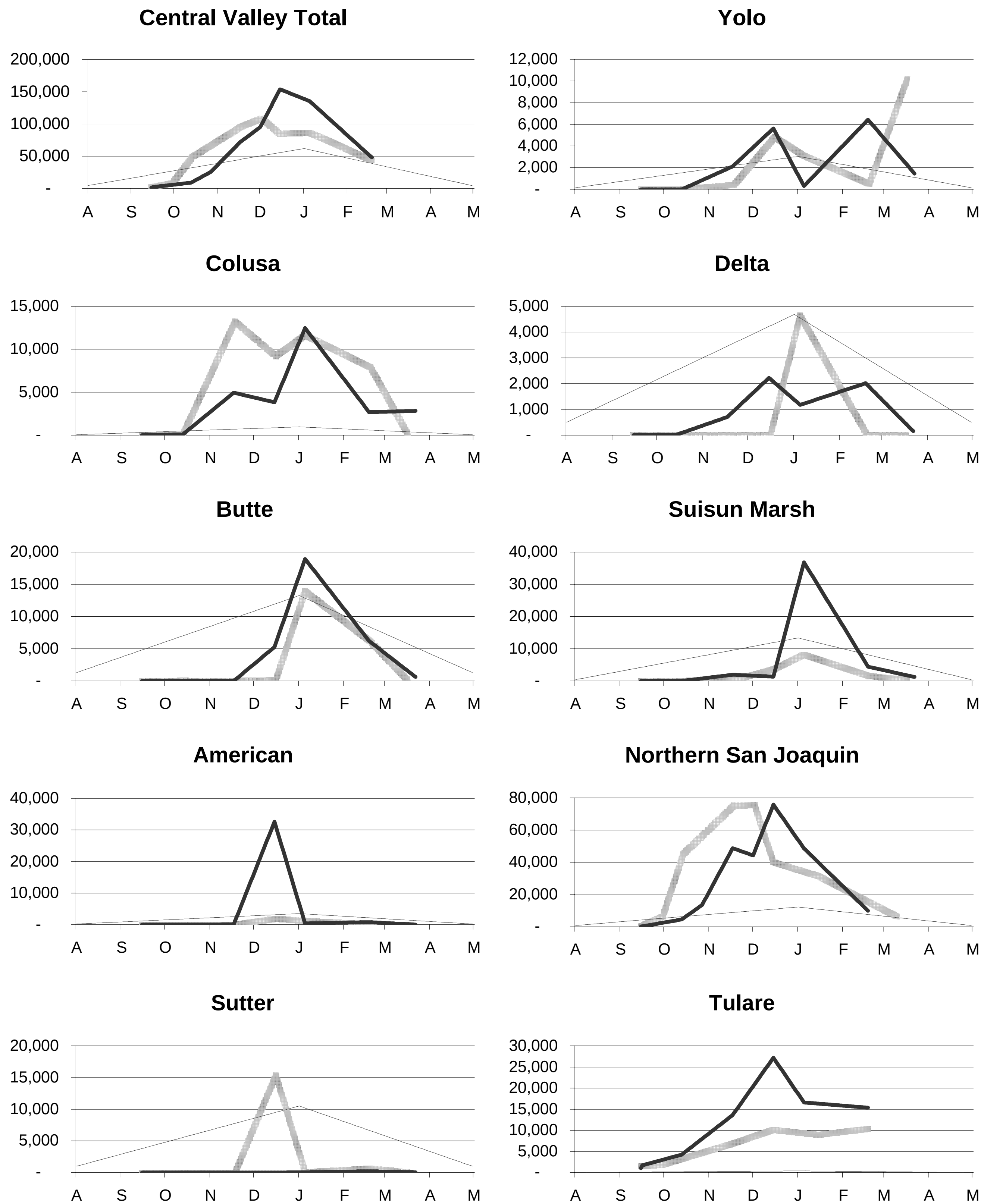


Figure 70

White Goose abundance during Sep - Jan

Goals (thin line) vs 1998-99 (thick blue) and 1999-2000 (thick red)

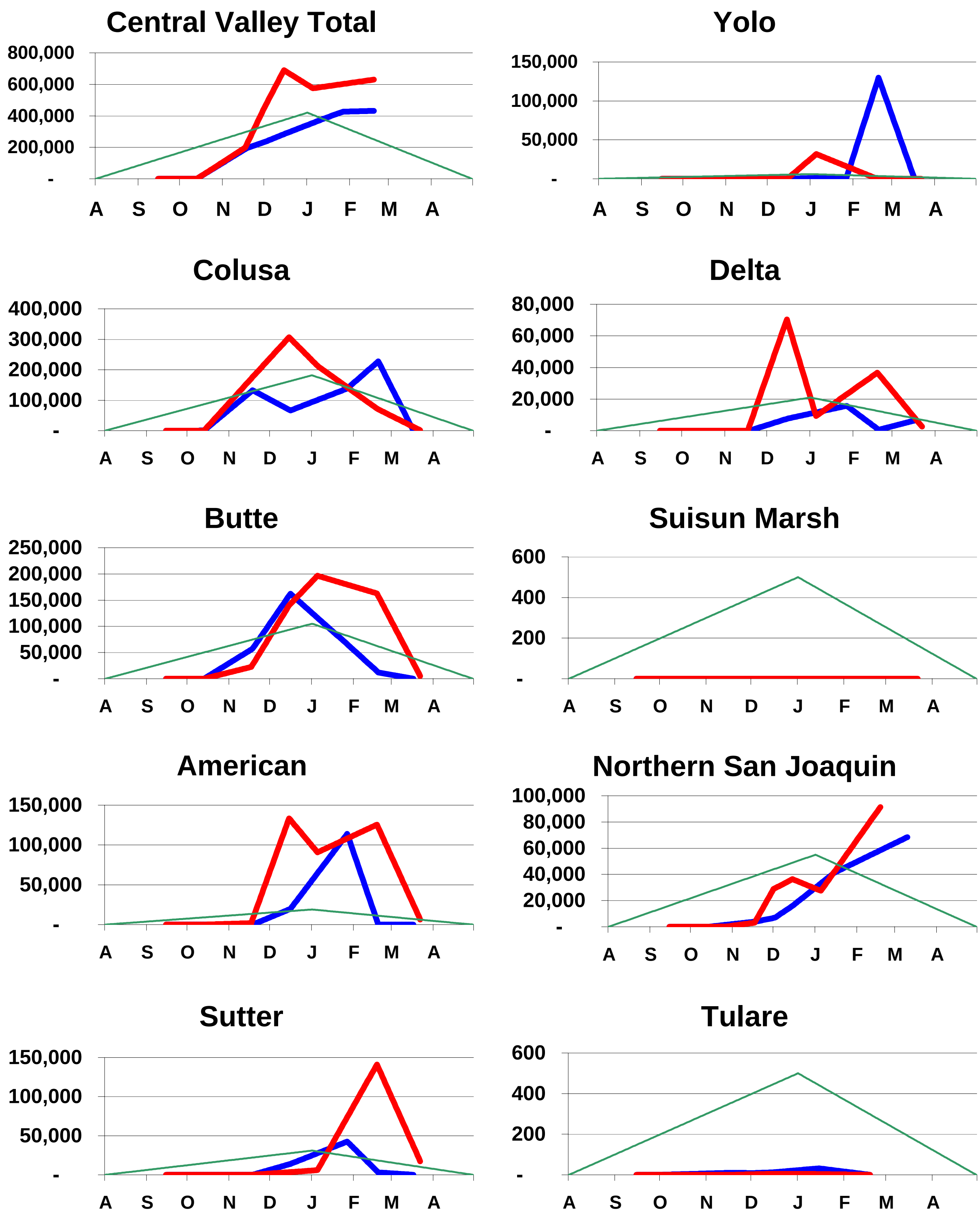


Figure 71

Dark Goose abundance during Sep - Jan

Goals (thin line) vs 1998-99 (thick blue) and 1999-2000 (thick red)

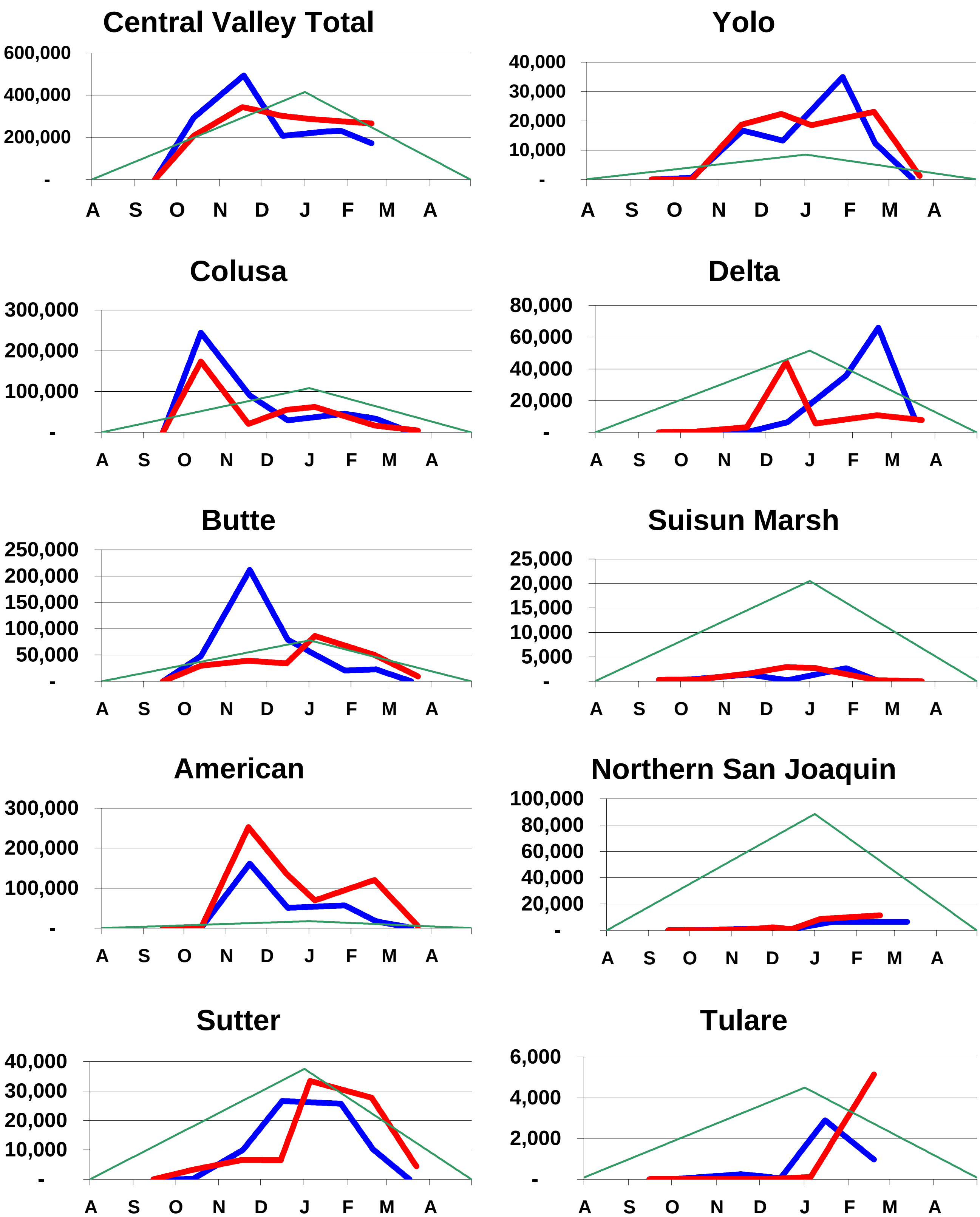


Figure 72

Goose abundance during Sep - Jan

Goals (thin line) vs 1998-99 (thick blue) and 1999-2000 (thick red)

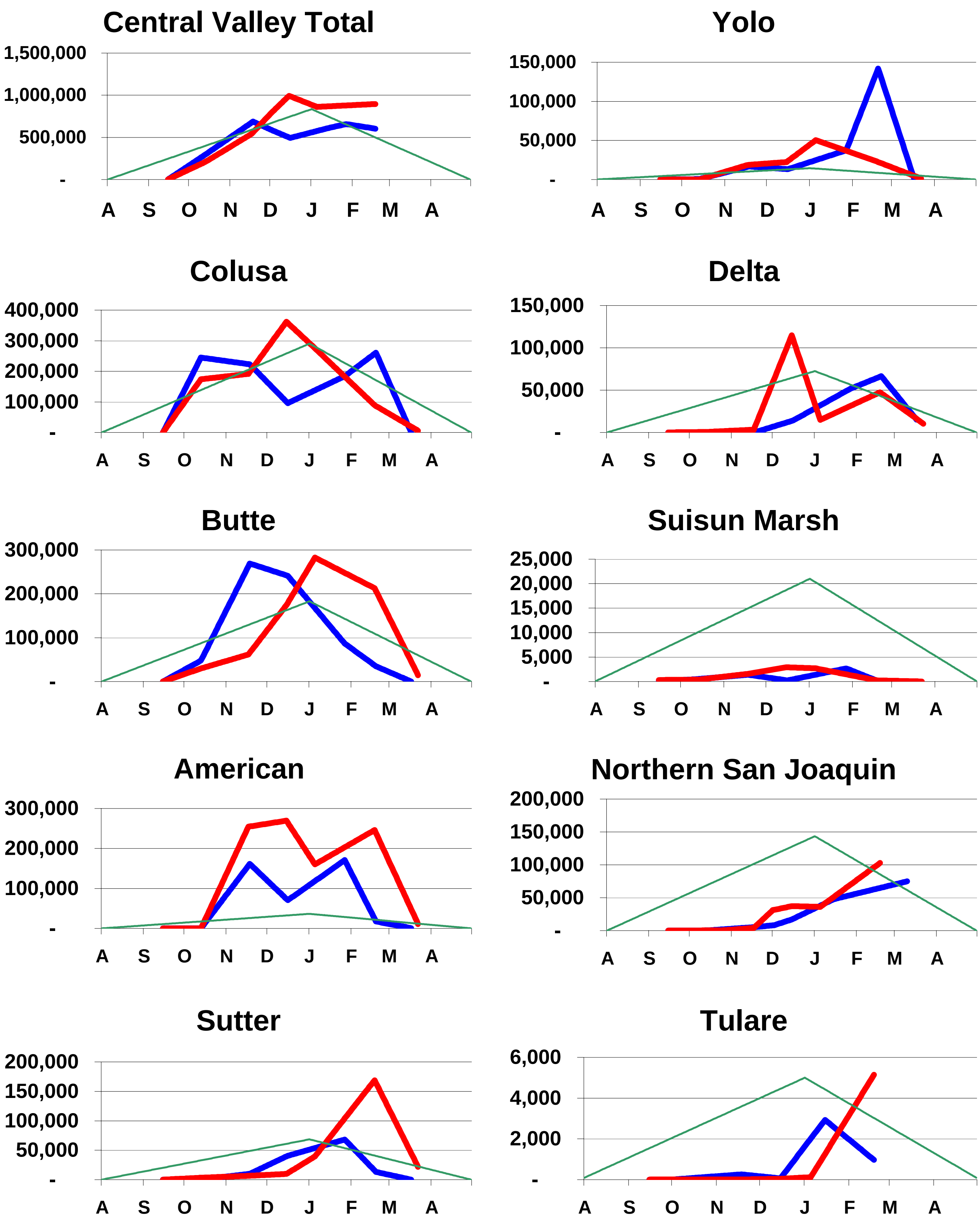


Figure 73

Swan abundance during September - January

Goals (thin line) vs 1998-99 (thick gray) and 1999-2000 (thick black)

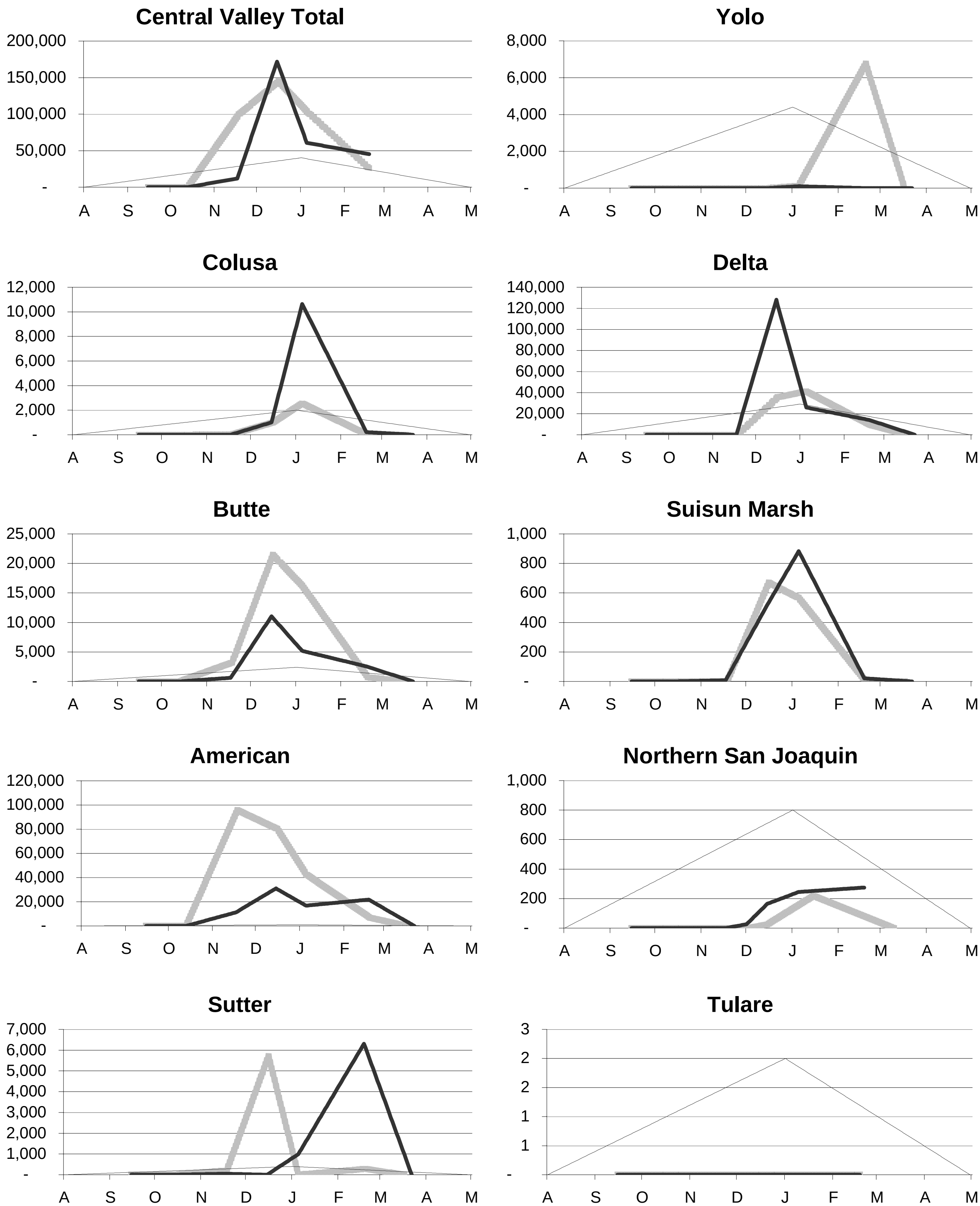


Figure 74

American Coot abundance during September - January

1998-99 (thick gray) and 1999-2000 (thick black)

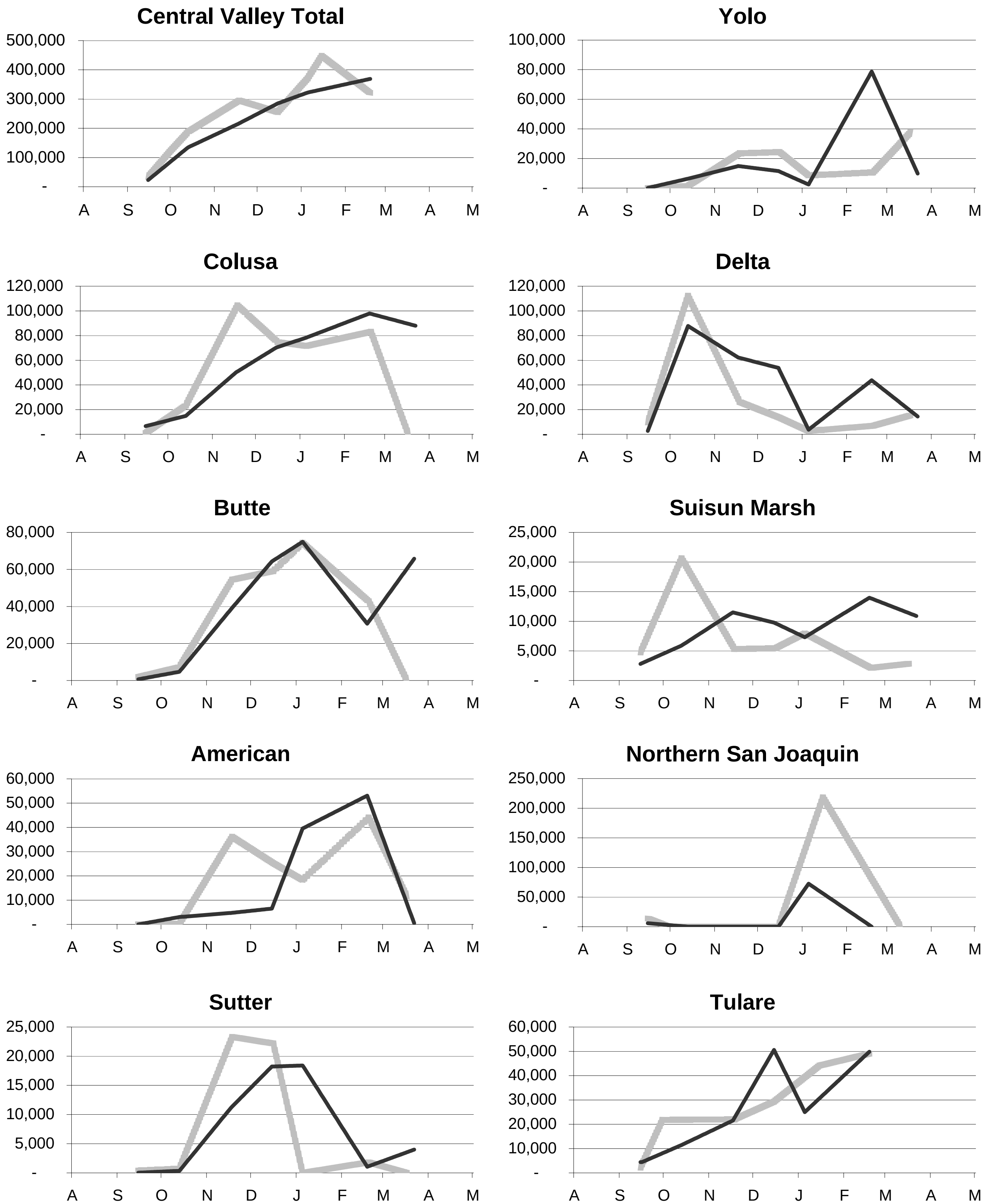


Figure 75

PINTAIL FLIGHT DISTANCES

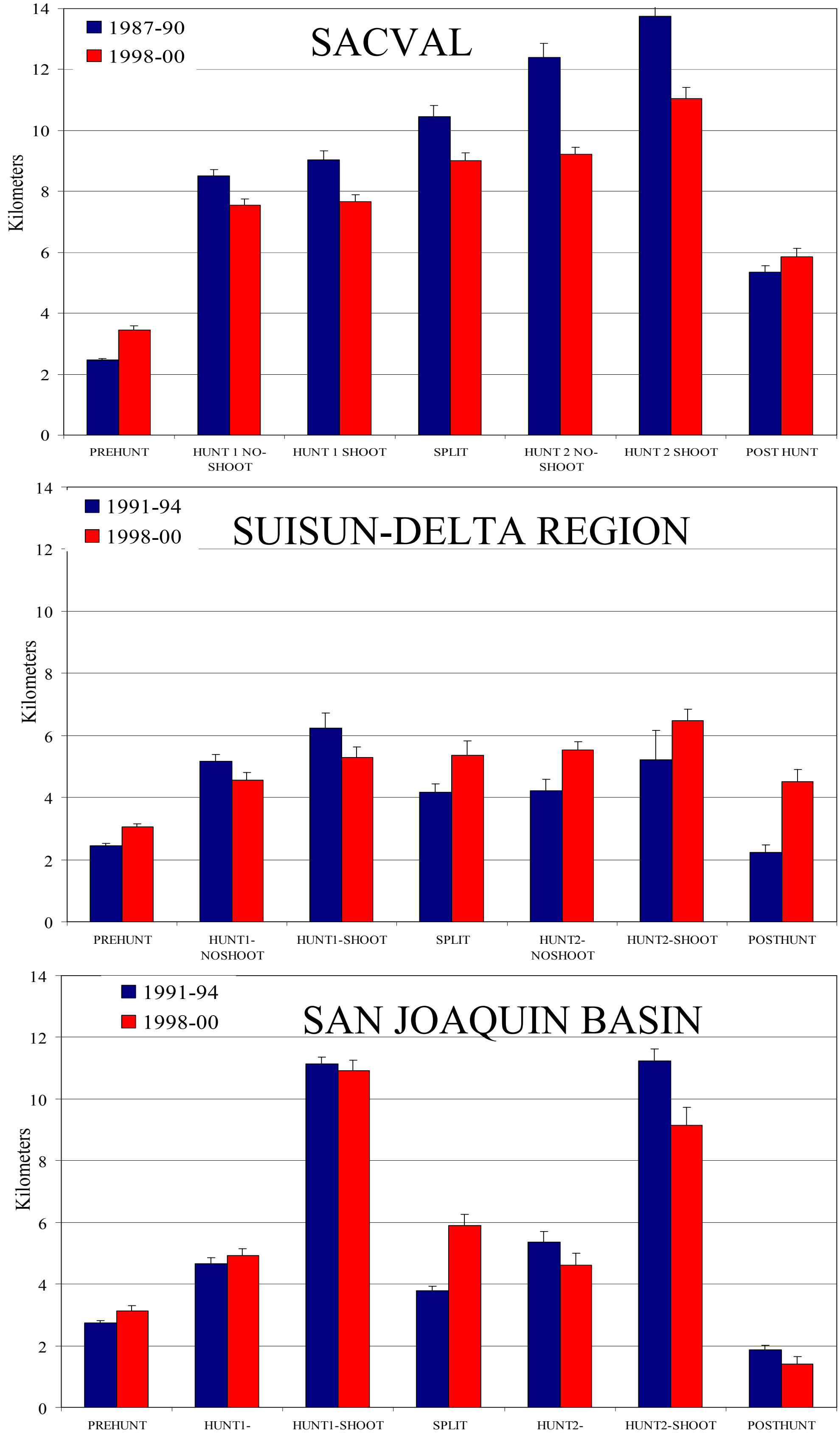


Figure 76

PINTAIL FLIGHT DISTANCES

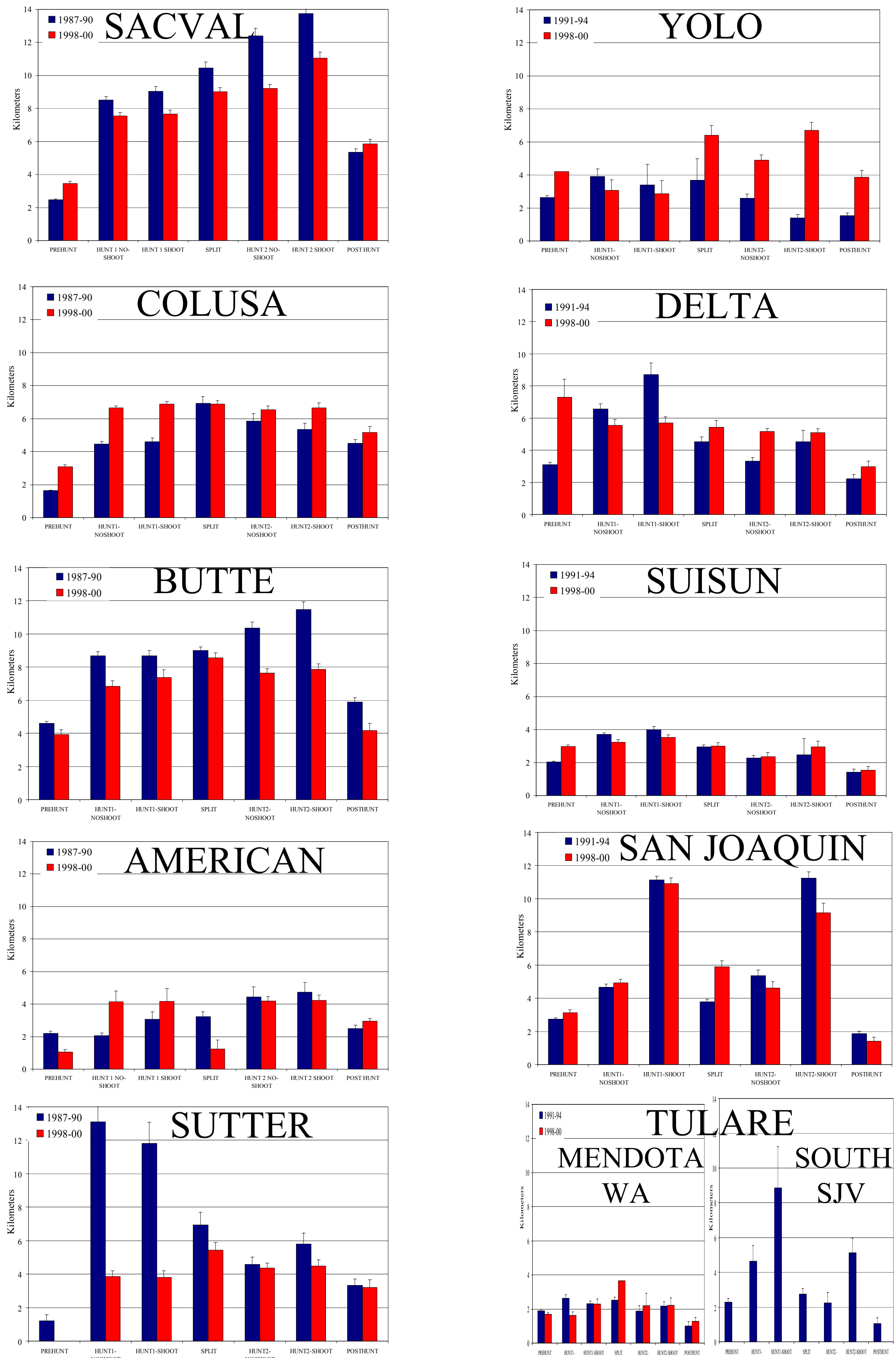


Figure 77

MALLARD FLIGHT DISTANCES

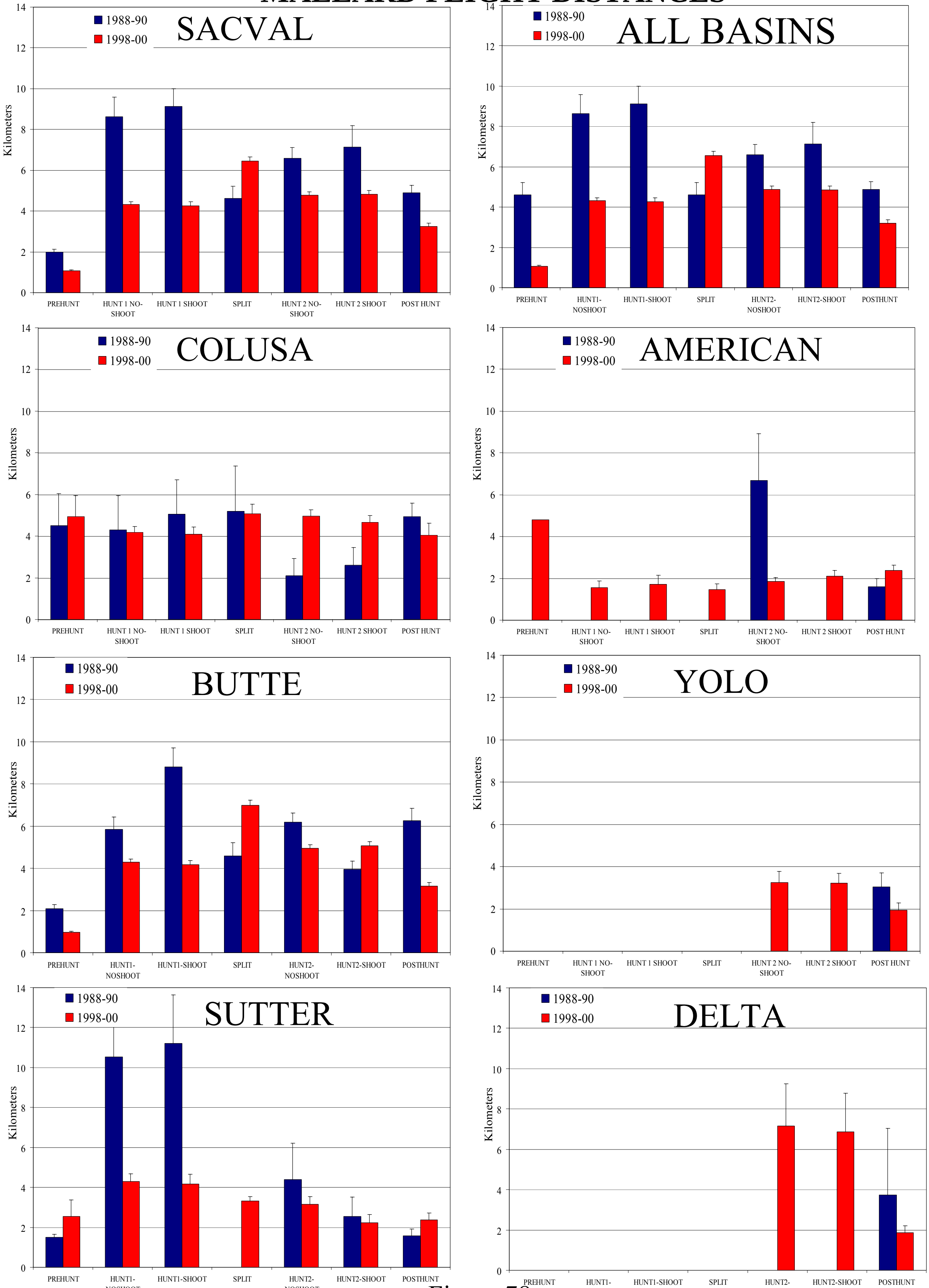


Figure 78

WHITE-FRONTED GOOSE FLIGHT DISTANCE

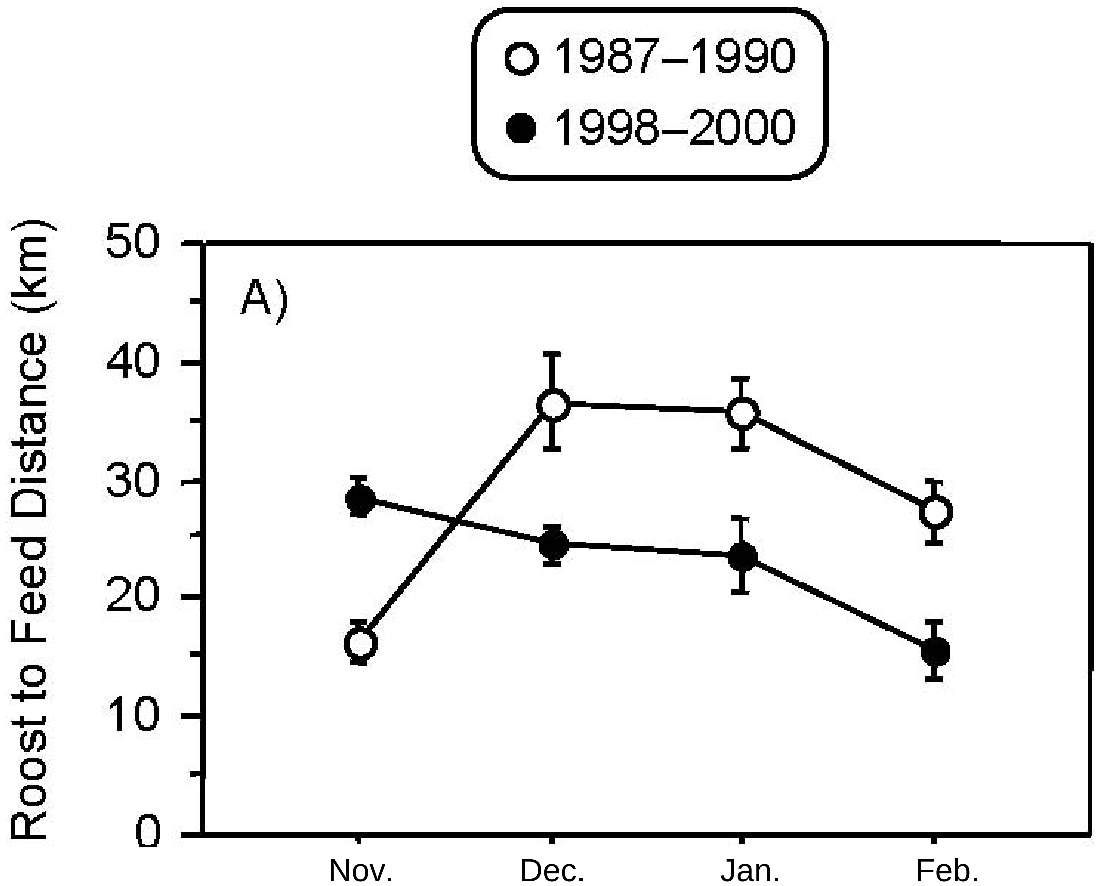


Figure 79

Appendix 1. Common names and genus-species of waterfowl and other birds counted during aerial surveys in the Central Valley of California during 1973-2000[a].

Common name	Genus-species
WATERFOWL SPECIES	
Dabbling Ducks	
Green-winged teal	*Anas crecca*
American wigeon	*Anas americana*
(Probably includes a few Eurasian wigeon, *Anas penelope*)	
Cinnamon teal	*Anas cyanoptera*
(Probably includes a few Blue-winged teal, *Anas discors*)	
Gadwall	*Anas strepera*
Mallard	*Anas platyrhynchos*
Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Woodduck	*Aix sponsa*
Diving Ducks	
Bufflehead	*Bucephala albeola*
Canvasback	*Aythya valisineria*
Goldeneye	*Bucephala clangula, B. islandica*
Merganser	*Mergus merganser, Lophodytes cucullatus*
(Probably also some Red-breasted mergansers, *M. serrator*. COME-Common merganser, *M. merganser*, tallied separately in one survey added into MERG).	
Redhead	*Aythya americana*
Ring-necked duck	*Aythya collaris*
Ruddy duck	*Oxyura jamaicensis*
Scaup	*Aythya affinis*, *A. marila*
Dark Geese[b]	
Canada goose[c]	*Branta canadensis, Branta hutchinsii*
Greater white-fronted goose[d]	*Anser albifrons*
White Geese[b]	
Lesser snow	*Chen caerulescens*
Ross' Goose	*Chen rossii*
Swans	
Tundra swan	*Cygnus columbianus*
NON-WATERFOWL SPECIES	
American coot	*Fulica americana*
Sandhill crane	*Grus canadensis*
White-faced ibis	*Plegadis chihi*
American white pelican	*Pelecanus erthrorhynchos*

[a]In some surveys uncommon species were not differentiated by species.
[b]In some surveys dark geese were not differentiated by species or were tallied as "Honkers" and other dark geese. White geese rarely differentiated by species.
[c]In some surveys Canada geese were tallied as Cackling (*Branta hutchinsii*) and other; or as Western (*B. canadensis moffitti*), Lesser (*B. c. parvipes*) /Taverner (*B. h. taverneri*), Cackling, Aleutian (*B. h. leucopareia*), and undifferentiated Canada.
[d]In some surveys Tule (*A.a.gambelli)* white fronts differentiated from greater White-fronted geese.

Appendix 2. Variables for each species-marking region included in categorical modeling of distribution among basins.

<u>Sacramento Valley Pintails</u>
Year: 1987-1988, 1988-1989, 1989-1990, 1998-1999, 1999-2000
Period: 1987-1990, 1998-2000
Caploc: Sacramento NWR, Delevan NWR
Capwtclass: < mean mass at capture, > mean mass at capture

<u>Suisun Marsh Pintails</u>
Year: 1991-1992, 1992-1993, 1998-1999, 1999-2000
Period: 1991-1993, 1998-2000
Capwtclass: < mean mass at capture, > mean mass at capture

<u>San Joaquin Valley Pintails</u>
Year: 1991-1992, 1992-1993, 1993-1994, 1998-1999, 1999-2000
Period: 1991-1994, 1998-2000
Caploc: Grassland Ecological Area, Mendota Wildlife Area, Tulare Lake Basin
Capwtclass: < mean age class mass at capture, > mean age class mass at capture
Age: Hatch-Year (HY), After-Hatch-Year (AHY)

<u>Sacramento Valley Mallards</u>
Year: 1988-1989, 1989-1990, 1998-1999, 1999-2000
Period: 1988-1990, 1998-2000
Caploc: Butte Basin, Sutter Basin
Capwtclass: < mean age class mass at capture, > mean age class mass at capture
Age: HY, AHY
Capseas: Prehunt, Split

<u>White-fronted Geese</u>
Year: 1987-1988, 1988-1989, 1989-1990, 1998-1999, 1999-2000
Period: 1987-1990, 1998-2000
Caploc: Alaska, Klamath

Appendix 3. Sacramento Valley area abbreviations and description.

WESTNWRS- Delevan, Sacramento, and Colusa National Wildlife Refuges (NWRs) in the Colusa Basin in the western part of the Sacramento Valley.

LUREWILO-Lureline and Willow Creek Duck Clubs in Colusa Basin (near Sacramento and Delevan NWRs).

OTHLCSCUT-All Sutter Basin and lower Colusa Basin (all Private).

OTHCOLUS - Private lands in upper and mid Colusa Basin (i.e., Colusa Basin minus OTHLCSCUT, LUREWILO, and WESTNWRS)

NEWWANWRs -Lands where Llano Seco NWR, Llano Seco, Howard Slough and Little Dry Creek units of the Upper Butte Basin (UBB) Wildlife Area (WA), and Wattis Audubon Sanctuary were established in the Butte Basin during the 1990s.

MIDWANWRs -Graylodge WA, Butte Sink NWR and Sutter NWR in the middle part of the Sacramento Valley.

BSNKCLUBs – Butte sink duck hunting clubs (Private lands in the Butte Sink to west and southwest of Gray Lodge WA that surrounds Butte Sink NWR).

OTHBUTTE – All other areas in Butte Basin (all private) (i.e., Butte Basin minus NEWWANWRs, MIDWANWRs, and BSNKCLUBS).

DISTRICT- Upper portion of the American Basin known as District 10.

OTHAMERI – All the rest of the American Basin (mostly south of District 10), includes Yuba River area, Olivehurst area, and lower American Basin.

Appendix 4. Variables included in categorical modeling of northern pintail, mallard, and white-fronted goose distribution among local areas.

Pintails Among Grassland Ecological Areas
Year: 1991-1992, 1992-1993, 1993-1994, 1998-1999, 1999-2000
Period: 1991-1994, 1998-2000
Capsubbasin: Grassland Ecological Area, Mendota Wildlife Area, Tulare Lake Bed; Outside San Joaquin Valley
Capsubarea: North Grassland Clubs, South Grassland Clubs, Kesterson NWR, San Luis NWR, Los Banos WA, Volta WA, Outside of Grassland EA
Capwtclass: < mean age class mass at capture, > mean age class mass at capture
Age: HY, AHY

Pintails Radio tagged in Suisun Marsh or San Joaquin Valley Among Delta Areas
Year: 1991-1992, 1992-1993, 1998-1999, 1999-2000
Period: 1991-1993, 1998-2000
Capreg: Suisun Marsh, San Joaquin Valley
Age: HY, AHY

Pintails Radio Tagged at Sacramento NWR Among Sacramento Valley Areas
Year: 1987-1988, 1988-1989, 1989-1990, 1998-1999, 1999-2000
Period: 1987-1990, 1998-2000

Mallards Radio Tagged in Sacramento Valley Among Sacramento Valley Areas
Year: 1988-1989, 1989-1990, 1998-1999, 1999-2000
Period: 1988-1990, 1998-2000
Caploc: Butte Basin, Sutter Basin
Capseas: Prehunt, Split
Age: HY, AHY

White-fronted Geese Among Sacramento Valley Areas
Year: 1987-1988, 1988-1989, 1989-1990, 1998-1999, 1999-2000
Period: 1987-1990, 1998-2000
Caploc: Alaska, Klamath