

*Appendix N – A Bioenergetic Approach
to Conservation Planning for Waterfowl
at Lower Klamath and Tule Lake
National Wildlife Refuges*

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**A BIOENERGETIC APPROACH TO CONSERVATION PLANNING FOR WATERFOWL AT
LOWER KLAMATH AND TULE LAKE NATIONAL WILDLIFE REFUGE**

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EXECUTIVE SUMMARY

Lower Klamath and Tule Lake National Wildlife Refuges (hereafter abbreviated LKNWR and TLNWR, respectively) are managed by the U.S. Fish and Wildlife Service (Service) as part of the Klamath Basin NWR Complex. The Klamath Basin is recognized as a region of continental significance to North American waterfowl populations (NAWMP Plan Committee 2004). Conservation and management of waterfowl habitats on both refuges is dependent on the availability of water. Increasing competition within the Klamath Basin for water requires that the Service articulate habitat requirements and water needs to support objective waterfowl populations. This report summarizes empirical research and modeling activities designed to assist the Service in efforts to develop biologically sound management plans for waterfowl during fall through spring, the period when waterfowl use is highest on LKNWR and TLNWR. This work is part of an overall Strategic Habitat Conservation approach being developed to design, implement and monitor management actions on both refuges. Our specific objectives were to: 1) use waterfowl survey data to establish spring and fall waterfowl population objectives for TLNWR and LKNWR; 2) estimate biomass and metabolizable energy of key foods in permanent and seasonal wetlands at TLNWR and LKNWR; 3) evaluate current refuge habitat management practices relative to waterfowl food energy needs for each refuge; 4) identify foraging habitat deficiencies that may exist for each refuge; and 5) evaluate a range of potential management alternatives for meeting waterfowl food energy needs.

In Chapter 2, we used bi-weekly aerial counts of waterfowl populations from 1 September to 15 April to characterize waterfowl migration chronology, population size, and species composition and to contrast waterfowl populations between refuges and two time periods (1970-1979 and 1990-1999). We summarized survey data by partitioning waterfowl species into five guilds based on foraging method and diet (dabbling ducks, diving ducks, geese, swans, and coots) and calculated the 10-year mean population estimate for each guild, during each survey for each block of years (1970s vs. 1990s). Finally, we used the survey data to establish guild-specific population objectives. Trends in waterfowl abundance between time periods and seasons varied considerably between refuges. Total mean counts at LKNWR increased from the 1970s to 1990s,

whereas counts at TLNWR have declined since the 1970s. The most striking change has occurred in dabbling and goose abundance. At LKNWR dabbling and goose use has remained constant in fall and increased in spring; in contrast, dabblers at TLNWR in fall have declined from a mean of nearly 500,000 birds in the 1970s to less than 100,000 birds in the 1990s. Goose counts at TLNWR declined during fall from a mean peak of 375,000 in the 1970s to just over 120,000 in the 1990s, peak spring counts declined by over 50% during the same period. Swan counts at LKNWR during winter and spring have increased from the 1970s to 1990s. We used data collected during 1970–1979 to establish dabbling duck, diving duck, and coot population objectives and data from 1990–1999 to establish goose and swan population objectives for conservation planning.

In Chapter 3, we report on field work designed to: 1) estimate moist-soil seed biomass in early v. late seasonal wetlands; 2) estimate tuber and green foliage produced by submerged aquatic vegetation in permanent wetlands; 3) estimate the biomass of macroinvertebrates in seasonal wetlands during spring; 4) estimate the true metabolizable energy value for the seeds of four plants commonly eaten by ducks in the Klamath Basin; and 5) estimate energy production in seasonal and permanent wetland habitats at LKNWR and TLNWR. We sampled foods in 3 of 5 seasonal wetland management units on TLNWR, 9 of 20 seasonal wetlands on LKNWR (representing 4 early and 5 late successional units), 1 permanent wetland at TLNWR 2 of 9 permanent wetlands at LKNWR.

Mean seed biomass estimates ranged from 241 kg/ha in unit 10B to 1,425 kg/ha in unit 5 (Tables 3-3 and 3-4); the mean for early and late successional wetlands was $1,002 \pm 159$ kg/ha and 584 ± 91 kg/ha, respectively. The composite TME value was 2.38 kcal/g for early successional wetlands and 1.59 kcal/g for late successional wetlands. Mean biomass for tubers was 229.7 ± 55.7 kg/ha in fall, higher at Lower Klamath than Tule Lake (Table 3-5). There was no difference in mean invertebrate biomass by wetland type ($F_{2,10} = 3.52$, $P = 0.07$). Cladocerans, Copepods, Oligochaetes, and Chironomids were the numerically dominant macroinvertebrate taxa in all wetlands (Appendix B).

We conducted controlled feeding trials using game-farm male mallards to determine the True Metabolizable Energy value for the seeds of three native species and one invasive exotic. TME_N values differed among seed species ($F_{3,20} = 80.5$, $P < 0.0001$),

being highest for lamb's quarters (2.52 kcal/g), followed by perennial pepperweed (1.31 kcal/g), alkali bulrush (0.65 kcal/g), and spike rush (0.50 kcal/g). The results from this work have been published in a peer-reviewed science journal.

In chapter 4, we incorporated data from Chapter's 2 and 3 into a bioenergetic model and used the model to evaluate current refuge management practices relative to waterfowl food energy needs for each refuge, identify foraging habitat deficiencies that may exist for each refuge, and evaluate potential habitat management alternatives for meeting waterfowl food energy needs. Our modeling indicated deficiencies in energy supplies for one or more guild at each refuge. Current habitats at both refuges were sufficient to meet the energy needs for target populations of swans and diving ducks. LKNWR habitats were also sufficient for meeting the needs of dabbling ducks. However, assuming waterfowl obtain 75% of foods on-Refuge, LKNWR could not meet goose population objectives in spring, and habitats at TLNWR did not meet the needs of dabbling ducks in fall or geese in spring.

We then modeled several alternate management scenarios for each refuge to explore possible options for eliminating habitat deficits. Our options were not exhaustive; rather they provided examples of how a bioenergetic model can be used to explore management options. Our results indicate a variety of habitat scenarios can meet the energy needs of migrating and wintering waterfowl, thus providing flexibility to refuge managers as they consider the broader suite of wildlife species that depend on both refuges to meet their life-cycle needs. We hope our model provides the framework for objectively considering how potential land use changes might impact wintering and migrating waterfowl at both Tule Lake and Lower Klamath Lake National Wildlife Refuges.

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1. INTRODUCTION

Lower Klamath and Tule Lake National Wildlife Refuges (hereafter abbreviated LKNWR and TLNWR, respectively) are managed by the U.S. Fish and Wildlife Service (Service) as part of the Klamath Basin NWR Complex. Of the Complex's six NWRs, Tule Lake and Lower Klamath NWRs support greater than 80% of the Complex's waterfowl populations and, during a typical year, support greater than 50% of the waterfowl in the Upper Klamath Basin. Peak populations of waterfowl approach two million birds in both fall and spring. The Klamath Basin is recognized as a region of continental significance to North American waterfowl conservation (NAWMP Plan Committee 2004). As the two most important wetland habitats in the Basin, TLNWR and LKNWR are among the most important waterfowl migration staging areas in the Pacific Flyway.

Increasing competition within the Klamath Basin for limited water supplies and the ongoing water rights adjudication by the state of Oregon requires that the Service be able to articulate habitat requirements and water needs. From an ecological perspective, the Service wants to establish waterfowl population objectives, and estimate habitats needed to achieve these objectives (e.g., CVJV 2006). Such a plan would guide site specific management and place refuge population and habitat objectives within the larger context of regional and continental waterfowl management objectives as established by the North American Waterfowl Management Plan (NAWMP 1986). Ideally the refuge planning exercise should be flexible enough to permit an objective comparison among a suite of potential habitat management alternatives. This report summarizes empirical research and modeling activities designed to assist the Service in efforts to develop biologically sound management plans for waterfowl during fall through spring, the period when waterfowl use is highest on LKNWR and TLNWR. This work represents the biological planning phase of a Strategic Habitat Conservation Framework being developed for managing habitats at both LKNWR and TLNWR (National Ecological Assessment Team 2006).

Our Approach

Conservation planning for migrating and wintering waterfowl is based on the fundamental premise that food is the resource limiting population performance. Poor habitat conditions reduce food abundance, which can decrease body mass or nutrient reserves (Delnicki and Reinecke 1986, Krapu et al. 2004), increase movements and vulnerability to hunting mortality (Hepp et al. 1986), increase predation risk by altering foraging methods and vigilance behavior (Guillemain et al. 2000a, Fritz et al. 2002), and ultimately decrease survival and breeding potential (Krapu 1981, Kaminski and Gluesing 1987, Raveling and Heitmeyer 1989, Goss-Custard et al. 2006). Recent research has documented food depletion on migration and wintering areas in North America (Rutka 2004, Naylor 2002, Krapu et al. 2004, Greer et al. 2007) consistent with the hypothesis that food is limiting, and other work has documented shifts in bird distribution within and among seasons in response to food depletion (Tubbs and Tubbs 1983, Lovvorn and Baldwin 1986, Sutherland and Allport 1994, Nolet et al. 2006). Thus, for planning, understanding food abundance is one key step towards estimating habitat carrying capacity (Gill et al. 1996, Miller and Newton 1999, Nolet et al. 2006) and understanding the movement, distribution, and habitat use of wintering and migrating waterfowl (Sutherland and Allport 1994, Percival et al. 1996, Guillemain et al. 2000b, Nolet et al. 2001, Stillman et al. 2005, Klaassen et al. 2007).

The most effective tool for using food (i.e., energy) in conservation planning is a bioenergetic model (Sutherland 1996); most habitat joint ventures established under the North American Waterfowl Management Plan (NAWMP) use bioenergetic models to estimate habitat objectives for migrating and wintering waterfowl (e.g., Central Valley joint Venture Implementation Plan 2006). Bioenergetic models rely on four basic types of input data: daily bird energy needs and time-specific population objectives are used to calculate population energy demands, while habitat quantity (how many hectares) and quality (the nutritional value of foods in each habitat type) are used to calculate energy supplies. For LKNWR and TLNWR, detailed information on habitat composition and bird abundance is available from the Service; estimates of daily bird energy needs can be derived from metabolic equations that relate energy needs to body size and activity patterns (Aschoff & Pohl 1970, Miller and Eadie 2006). Data on the nutritional value of

most agricultural foods are available from the literature; data for some, but not all, natural foods occurring in wetlands on LKNWR and TLNWR are also available in the literature (Hoffman and Bookhout 1985, Petrie et al. 1997, Checkett et al. 2002). Estimates of habitat-specific food availability are lacking. We sampled habitats and conducted controlled feeding experiments to gather information needed to populate a bioenergetic model. We then used that model to evaluate past, current, and alternative habitat management scenarios for waterfowl at LKNWR and TLNWR.

Objectives

The specific objectives of this report include:

1. Use waterfowl survey data to establish spring and fall waterfowl population objectives for TLNWR and LKNWR.
2. Estimate biomass and metabolizable energy of key foods in permanent and seasonal wetlands at TLNWR and LKNWR.
3. Evaluate current refuge habitat management practices relative to waterfowl food energy needs for each refuge.
4. Identify foraging habitat deficiencies that may exist for each refuge.
5. Evaluate a range of potential management alternatives for meeting waterfowl food energy needs.

The remainder of this report consists of three chapters. Chapter 2 uses data from aerial surveys of waterfowl populations to summarize population trends for TLNWR and LKNWR and develop waterfowl population objectives for both refuges (Objective 1). Chapter 3 reports on field sampling to estimate the abundance of key foods in wetland habitats and controlled feeding experiments to estimate metabolizable energy for select waterfowl foods (Objective 2). Chapter 4 introduces the bioenergetic model and uses data from Chapters 2 and 3 to evaluate past and current habitat conditions and explore management alternatives for meeting waterfowl food energy needs at TLNWR and LKNWR (Objectives 3-5).

2. WATERFOWL POPULATION TRENDS AND MANAGEMENT OBJECTIVES FOR LOWER KLAMATH AND TULE LAKE NATIONAL WILDLIFE REFUGES

Population objectives for TLNWR and LKNWR are required to establish habitat goals and to evaluate management alternatives using a bioenergetic model. The North American Waterfowl Management Plan (NAWMP) has developed continental population objectives for North American duck species based on environmental conditions and breeding waterfowl numbers from 1970-1979 (North American Waterfowl Management Plan 1986). Most regional Joint Ventures derive population objectives by stepping down continental objectives based on the number and distribution of waterfowl during the 1970's (Central Valley Joint Venture 2006). This approach is less suitable for areas at smaller scales like a specific national wildlife refuge; however, site-specific survey data from the period of years used to generate continental objectives can be used to derive site-specific population objectives that are linked to NAWMP goals. In this chapter, we use data from aerial surveys for both LKNWR and TLNWR to examine population trends and establish population objectives.

Methods

We used waterfowl surveys conducted once every two weeks from 1 September to 15 April to characterize waterfowl migration chronology, population size, and species composition and to contrast waterfowl populations between refuges and two groups of years 1970-1979 and 1990-1999. Aerial surveys were flown from a low flying airplane and birds were identified to species. Survey methods are described by Gilmer et al. (2004). We used data collected during 1970 – 1979 to establish duck and coot population objectives and link duck objectives at TLNWR and LKNWR to the NAWMP. Goose and swan populations have undergone major changes in size and distribution across North America and within the Klamath Basin since the 1970's. While these changes, in part, may be influenced by habitat management at TLNWR and LKNWR they also reflect larger changes within the Pacific Flyway. For example, Cackling Geese (*Branta hutchinsii minima*) no longer use the Klamath Basin in fall and it is unlikely that any habitat management on the refuge can reverse this trend (Pacific Flyway Council

1999). Thus, it made no sense to use data from the 1970's to establish population objectives for geese and swans at either refuge. Rather, we used survey data from 1990-1999 to establish goose and swan population objectives for 24 August to 22 April the period that encompasses the non-breeding season.

We summarized survey data by assigning species to one of four waterfowl guilds based on foraging method and diet; 1) dabbling ducks, 2) diving ducks, 3) geese, and 4) swans. We summarized data for American coot (*Fulica americana*) separate from the other waterfowl. Dabbling ducks included Northern Pintail (*Anas acuta*), Mallard (*A. platyrhynchos*), American Wigeon (*A. americana*), Northern Shoveler (*A. clypeata*), Green-winged Teal (*A. crecca*), Cinnamon Teal (*A. cyanoptera*), and Gadwall (*A. strepera*). Diving ducks included Canvasback (*Aythya valisneria*), Redhead (*A. americana*), and Ring-necked Duck (*A. collaris*). Although TLNWR and LKNWR support large numbers of Ruddy Ducks (*Oxyura jamaicensis*), Bufflehead (*Bucephala albeola*), and scaup (*Aythya* sp.), we did not establish population objectives for these species because we lacked information on the foods consumed by these birds. Geese included Lesser Snow Geese (*Chen caerulescens*), Greater White-fronted Geese (*Anser albifrons*), Cackling Geese, and Canada Geese (*B. canadensis*). We then calculated the 10-year mean population estimate for each guild for each date period. We graphed means to compare guild abundance among time periods and refuges.

We examined population trends at TLNWR and LKNWR to gain insight into how waterfowl use of the refuges has changed and help identify management alternatives that should be considered in the bioenergetic modeling process. We calculated the mean and 75% percentile count for each two-week interval. We graphed trends by date and defined seasons (when using those terms in the text) as 24 August through 22 November (fall), 23 November and 22 January (winter), 23 January through 22 April (spring). These date blocks do not match the calendar seasons, but closely corresponds to phases of the annual life cycle of waterfowl using the Klamath Basin (fall migration, wintering, and spring migration).

We also examined changes in the species composition of the dabbling duck and diving duck guilds among seasons (e.g. fall vs. spring) and among time periods (1970's vs. 1990's). To estimate the relative abundance of each species in a foraging guild, we

first calculated total waterfowl use days for each two-week interval centered on a survey. Waterfowl use days were calculated as total birds counted multiplied by 14 (one week on either side of the survey). For example, if the total waterfowl count on a survey was 100,000 birds, then total waterfowl use days for that two-week period = $100,000 * 14 = 1,400,000$. If Mallards comprised 20% of all dabbling ducks counted, we assigned 300,000 waterfowl days to mallards in that interval ($0.2 * 1,500,000 = 300,000$ mallard days). We calculated use days for all species for each two-week interval included in a season and summed the results across intervals. For example, the fall season included all two-week intervals between 24 August and 22 November. If the sum of all waterfowl days for each of these intervals equals ten million, and the sum of all mallard days in these intervals equals two million, then mallards were assumed to make up 20% of the dabbling duck guild during the fall season.

Finally, we used the survey data to establish guild-specific population objectives. Waterfowl population objectives must consider both abundance and timing of use; consequently, we used count data for each bi-weekly survey and set the population objective for each guild during each date interval as the 75th percentile of the ten counts. We chose the 75th percentile, versus the mean, for several reasons. Philosophically, we feel it is not sound waterfowl management to establish habitat objectives (habitat needs are based on population objectives) that would meet waterfowl food needs in only 50% of years. Practically, population estimates from aerial count data are negatively biased (Caughley 1977: 35) because survey methodology did not correct for detectability (Pollock and Kendall 1987), and our estimates of food production in refuge habitats (Chapter 3) may not be met in all years; during years of relatively low food production our modeling would over estimate habitat carrying capacity.

Results

Population trends

LKNWR and TLNWR combined.— Patterns in waterfowl abundance between the 1970s and 1990s and changes in seasonal use patterns differed among bird guilds. The total number of dabbling ducks using TLNWR and LKNWR in fall and winter was similar between the 1970s and 1990s, but seasonal use was slightly different. Dabbling abundance in fall has declined since the 1970s while spring use has increased (Figure 2-

1). Use days for diving ducks were higher in the 1990's during both fall and spring (Figure 2-2). Swan use was similar in fall, a period when relatively few birds use the refuges, but swan use days in winter and spring were higher during the 1990s than 1970s (Figure 2-3). Total goose use days declined from the 1970s to 1990s with most of the decline occurring during fall (Figure 2-4). Total coot use days were lower during the 1970s with all declines attributable to decreased use in fall (Figure 2-5).

Population trends by refuge.-- Trends in waterfowl abundance between time periods and seasons varied considerably between refuges. Total mean counts at LKNWR increased from the 1970s to 1990s, whereas counts at TLNWR have declined since the 1970s. The most striking change has occurred in dabbling and goose abundance. At LKNWR dabbling and goose use has remained constant in fall and increased in spring; in contrast, dabbling counts at TLNWR in fall have declined from a mean of nearly 500,000 birds in 1970s to less than 100,000 birds in the 1990s. Goose counts at TLNWR declined during fall from a mean peak of 375,000 in the 1970s to just over 120,000 in the 1990s, peak spring counts declined by over 50% during the same period (Figures 2-6 and 2-7). Trends in diver use were similar between refuges with higher counts during fall and spring in the 1990s (Figure 2-8). Swan counts at LKNWR during winter and spring have increased from the 1970s to 1990s and remained unchanged at TLNWR (Figure 2-9). Coot counts at LKNWR were similar between the 1970s to 1990s, but coot counts at TLNWR declined during the same period (Figure 2-10).

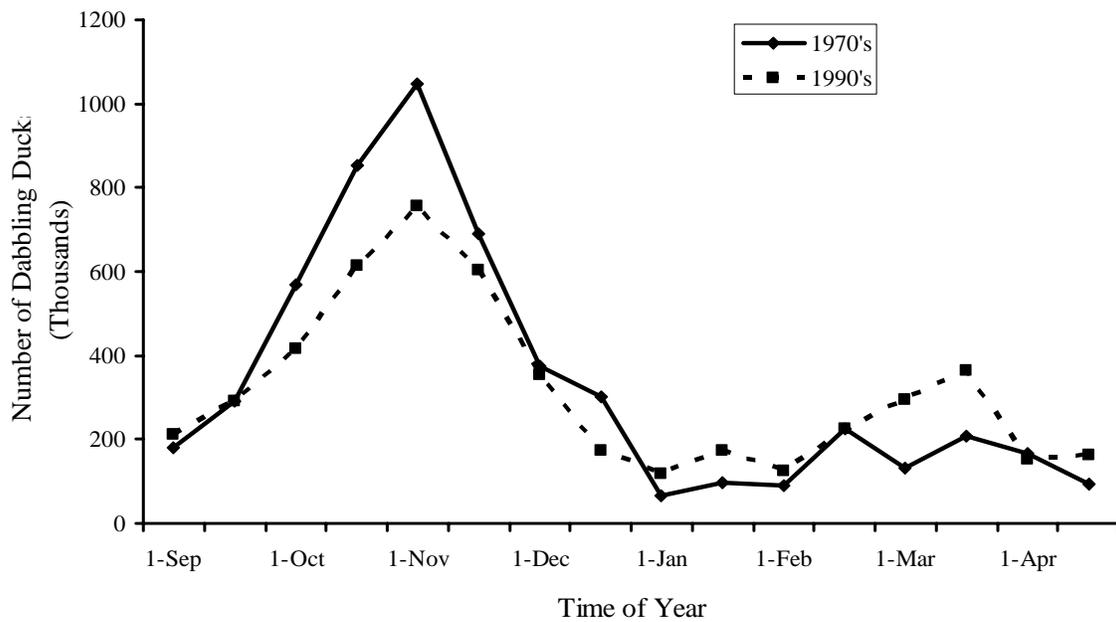


Figure 2-1. Mean counts of dabbling ducks at Tule Lake and Lower Klamath National Wildlife Refuges in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

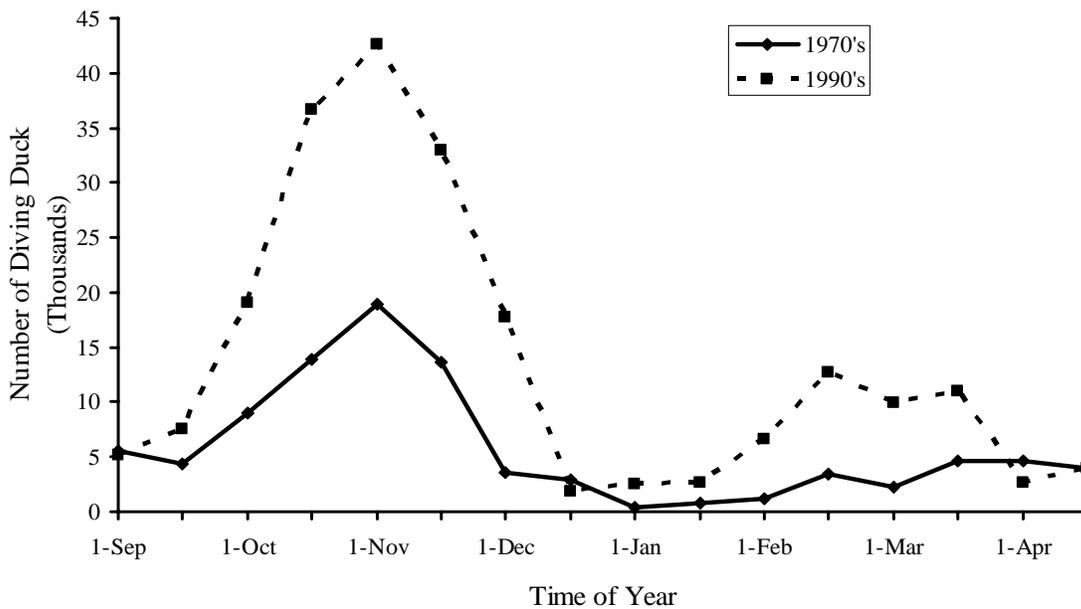


Figure 2-2. Mean counts of diving ducks at Tule Lake and Lower Klamath National Wildlife Refuges in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

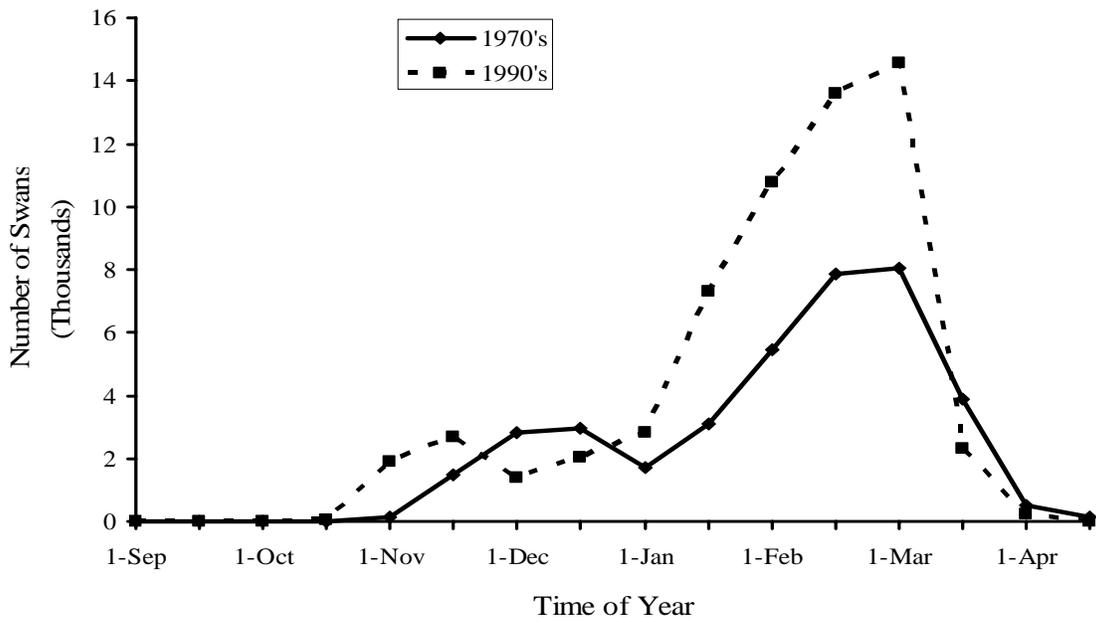


Figure 2-3. Mean counts of swans at Tule Lake and Lower Klamath National Wildlife Refuges in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

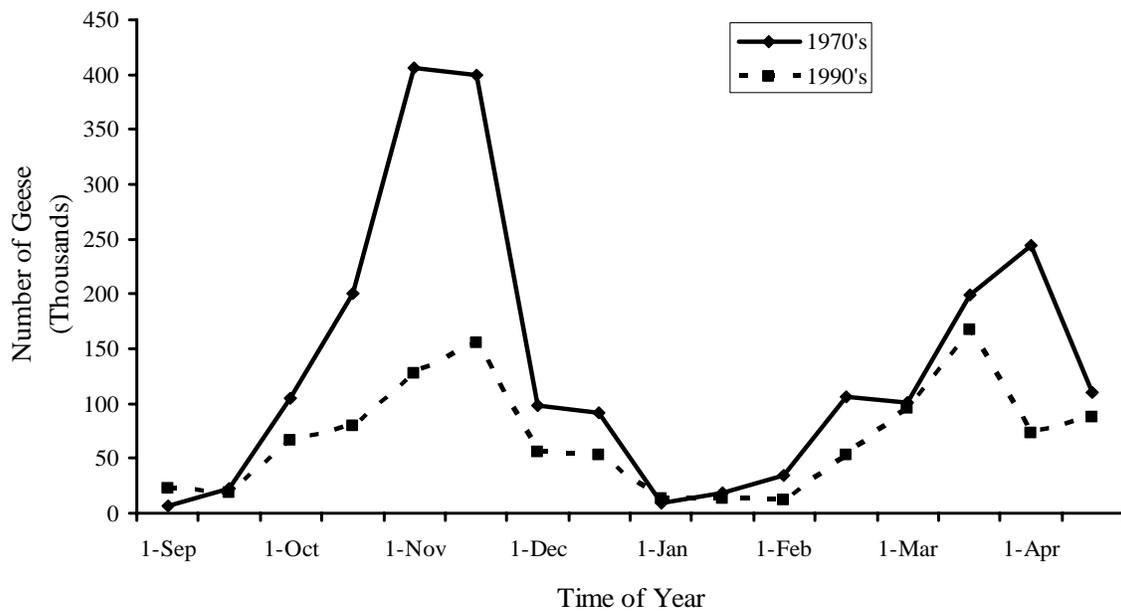


Figure 2-4. Mean counts of geese at Tule Lake and Lower Klamath National Wildlife Refuges in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

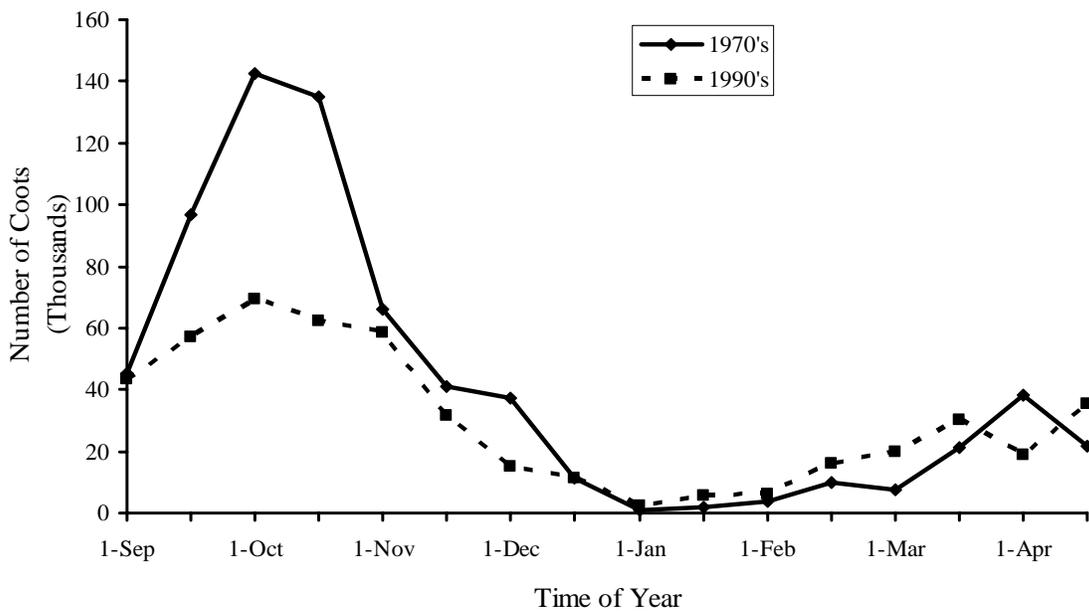
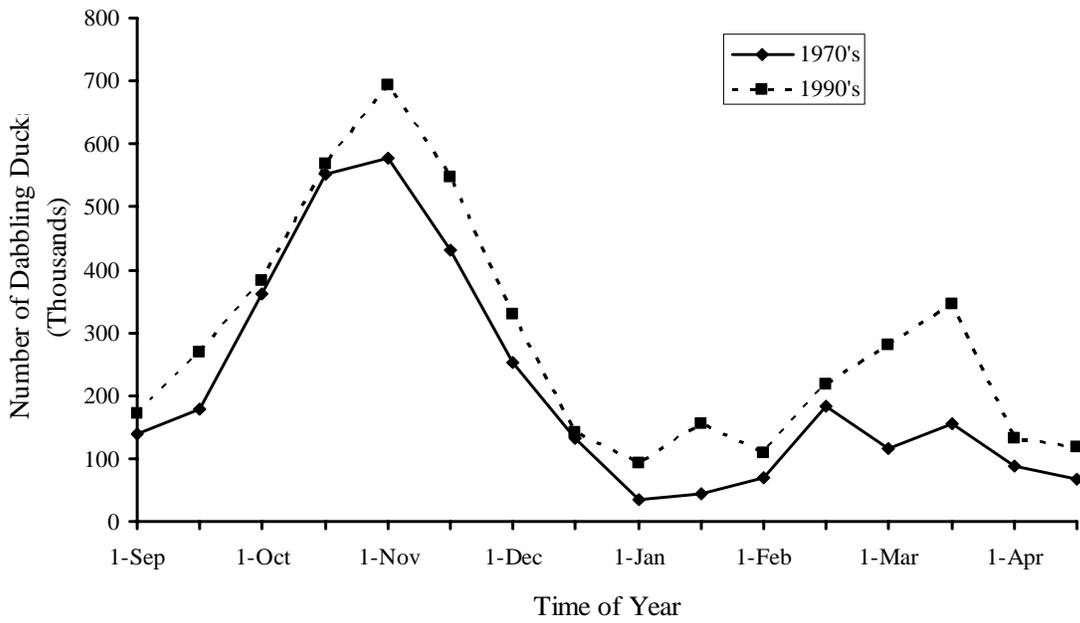


Figure 2-5. Mean counts of coots at Tule Lake and Lower Klamath National Wildlife Refuges in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

a



b

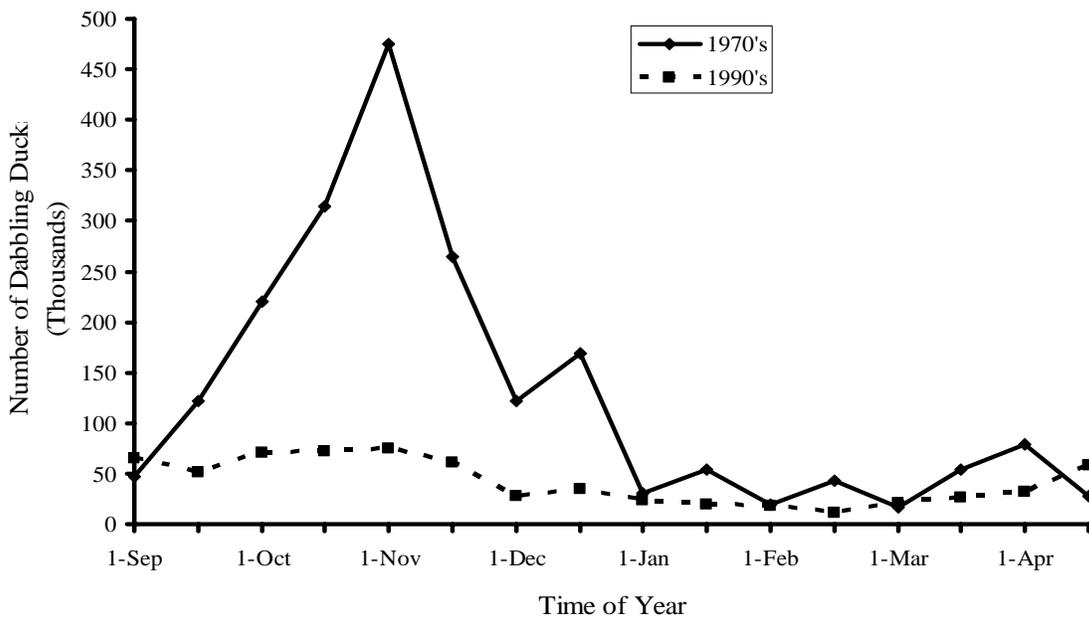
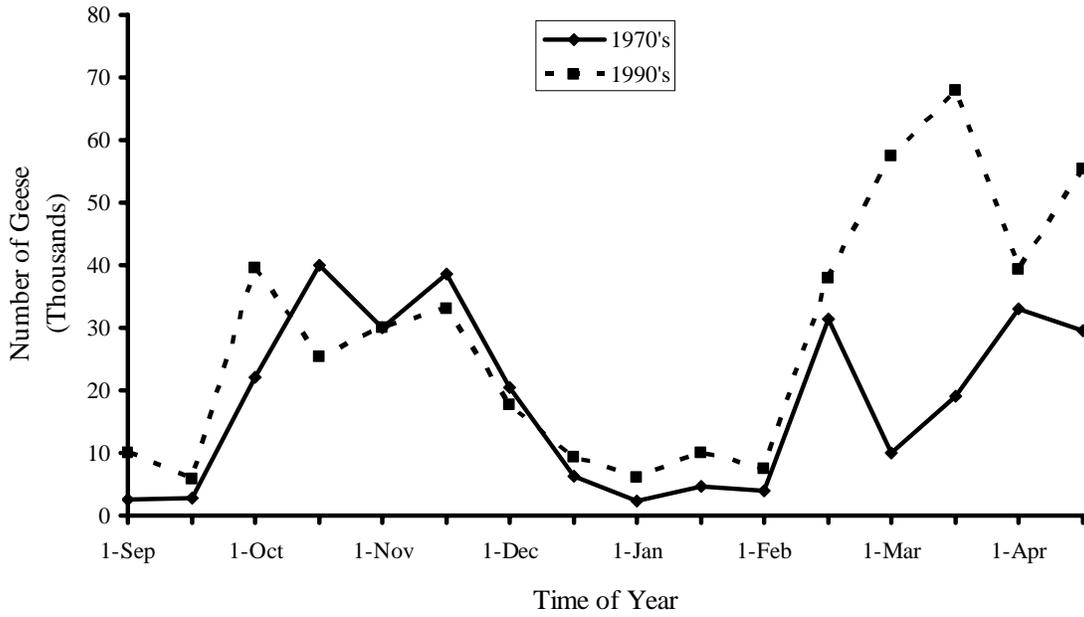


Figure 2-6. Mean counts of dabbling ducks by date at Lower Klamath NWR (a) and Tule Lake NWR (b) in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

a



b

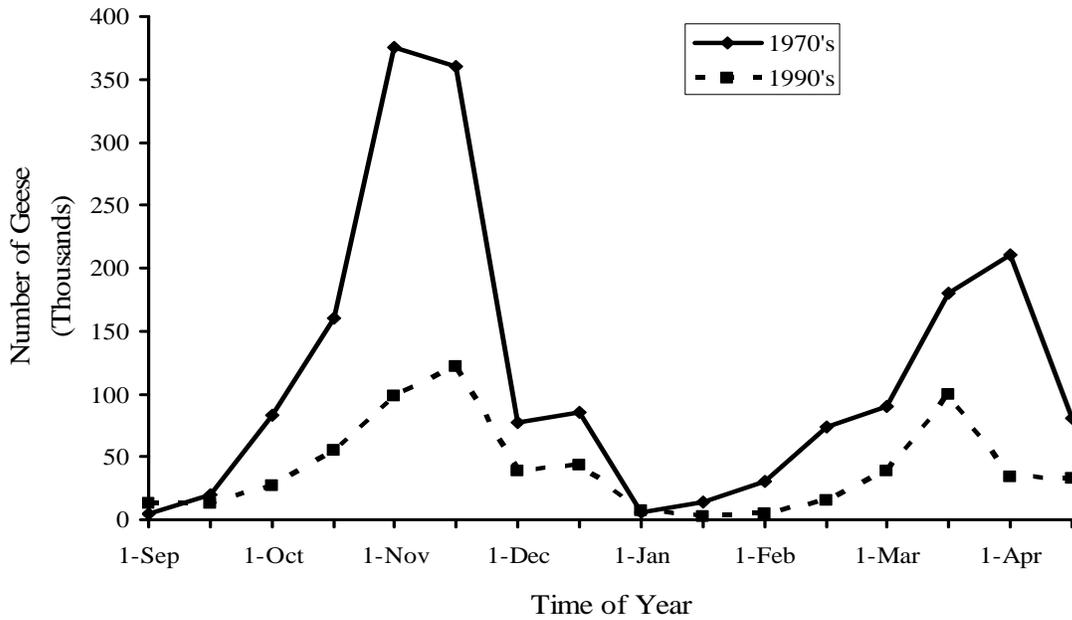
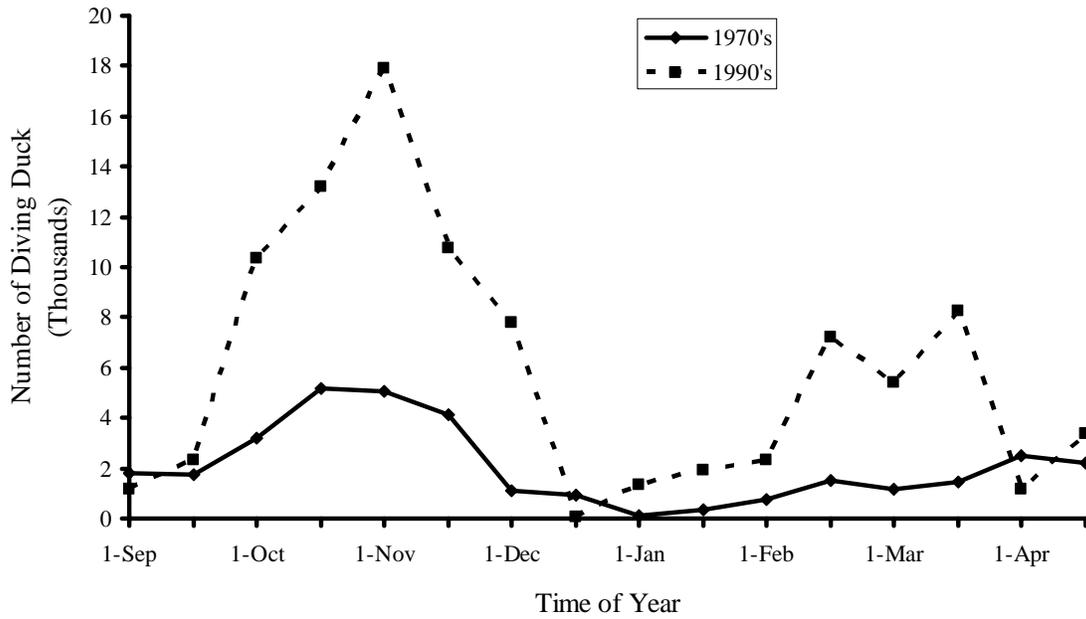


Figure 2-7. Mean counts of geese by date at Lower Klamath NWR (a) and Tule Lake NWR (b) in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

a



b

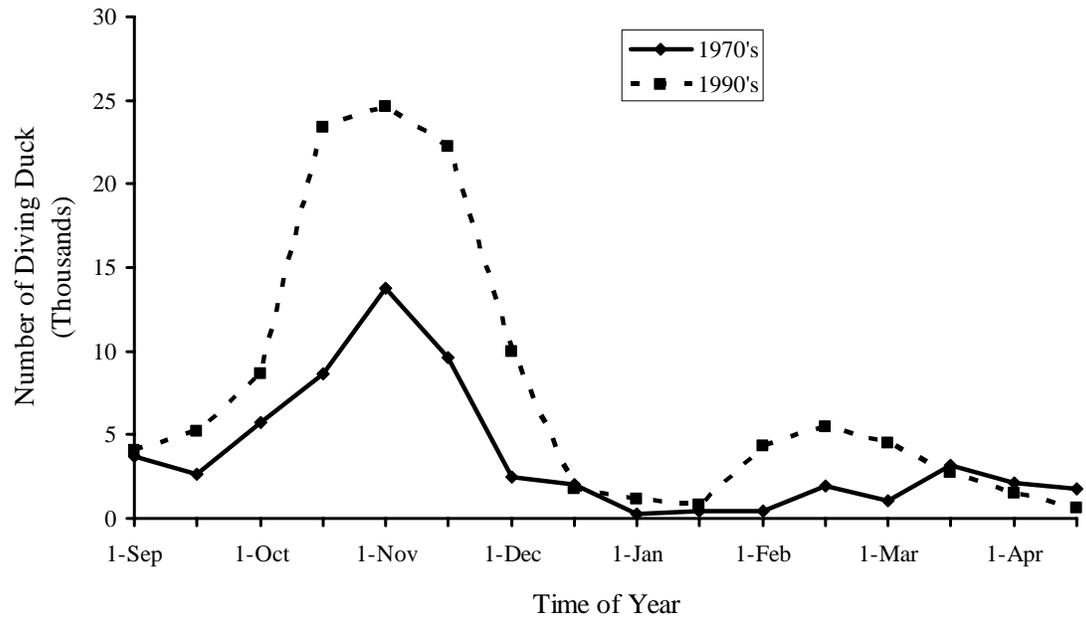
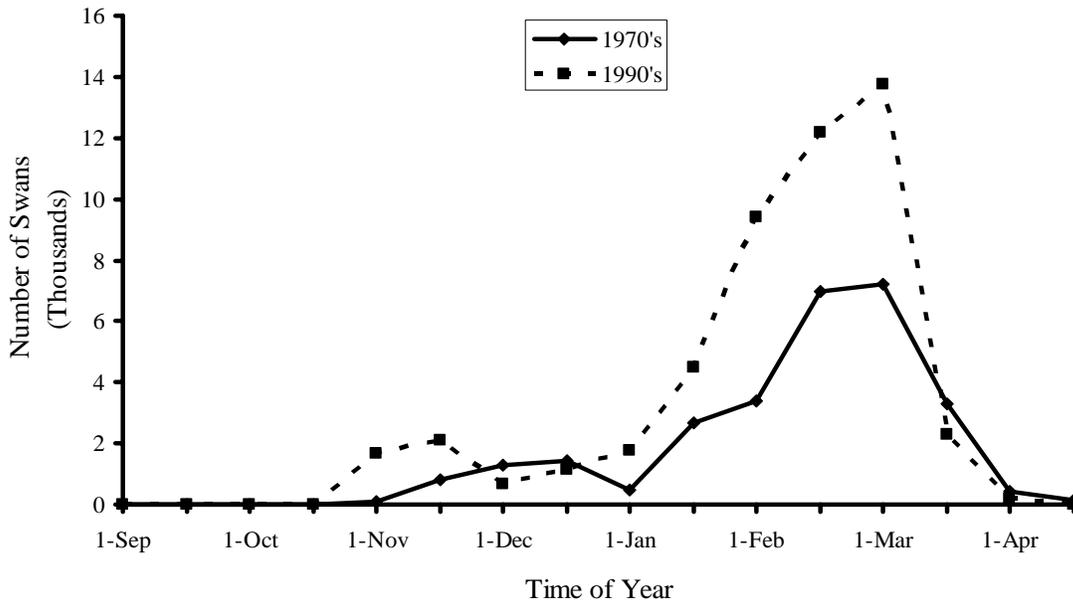


Figure 2-8. Mean counts of diving ducks by date at Lower Klamath NWR (a) and Tule Lake NWR (b) in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

a



b

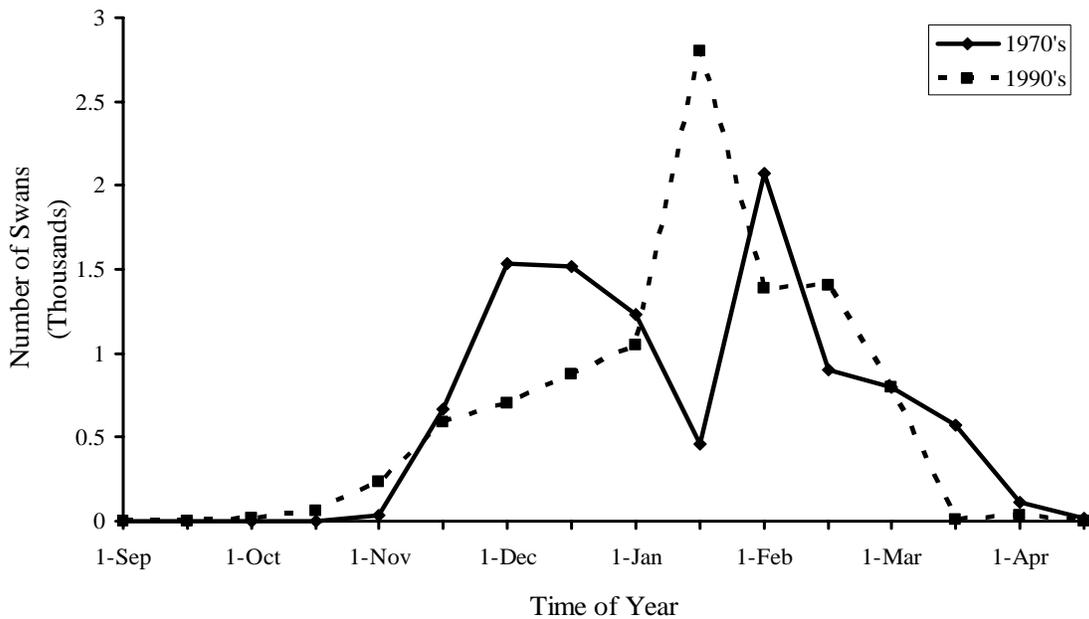
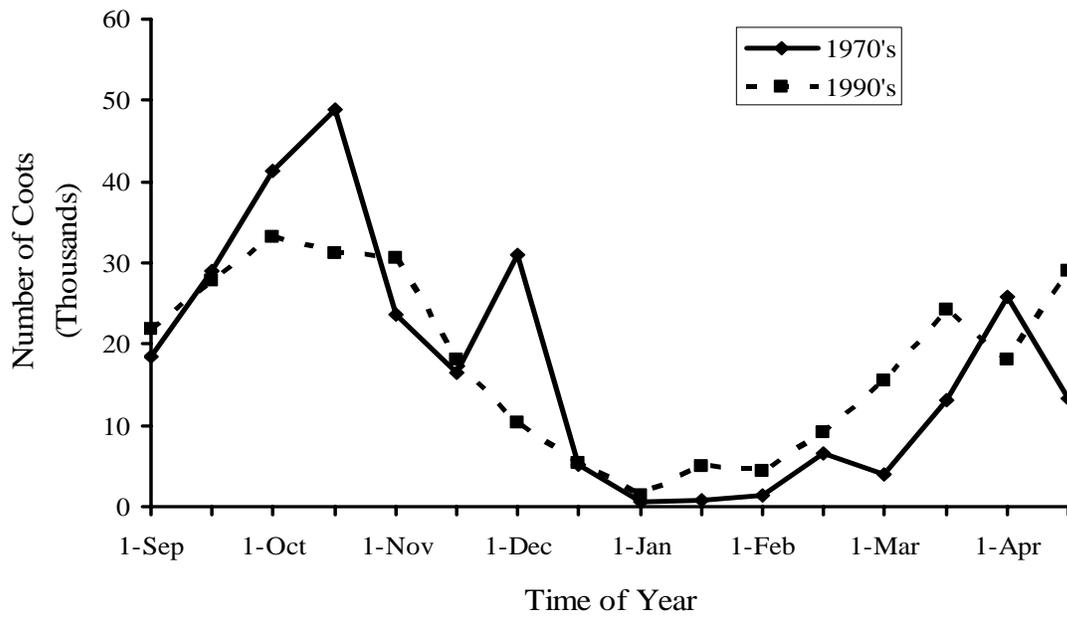


Figure 2-9. Mean counts of swans by date at Lower Klamath NWR (a) and Tule Lake NWR (b) in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

a



b

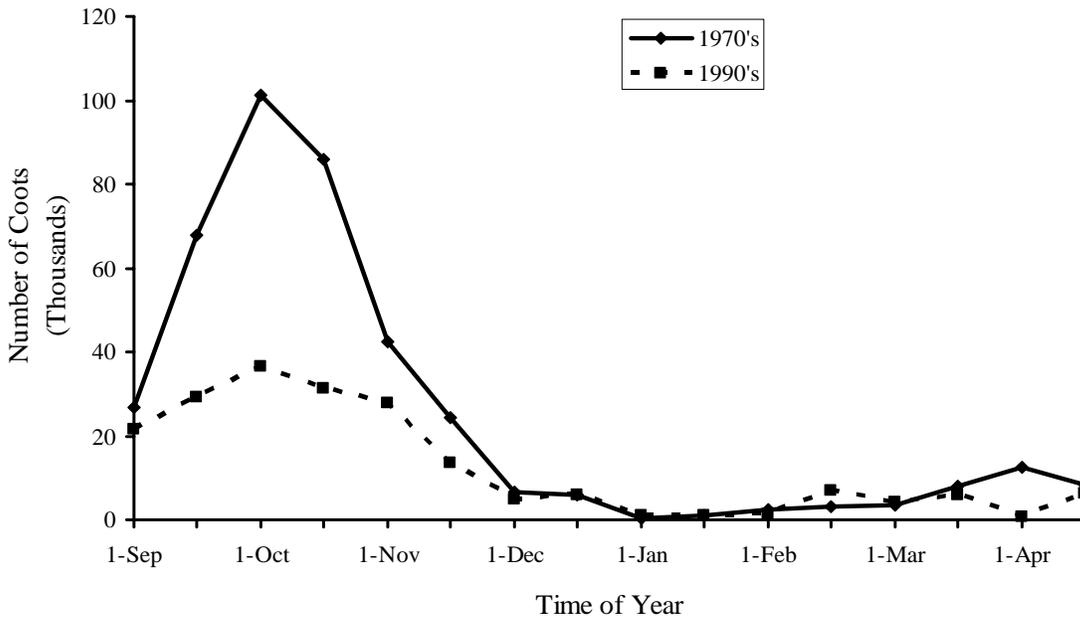


Figure 2-10. Mean counts of coots by date at Lower Klamath NWR (a) and Tule Lake NWR (b) in the 1970's (1970-1979) and 1990's (1990 -1999) determined from aerial surveys.

Comparison of guild composition

The species composition of the dabbling duck guild shifted between the 1970s and 1990s. During the 1970's, pintail was the most abundant dabbling duck at both refuges with estimates ranging between 55-70% at LKNWR and 40-55% at TLNWR for fall, winter, and spring (Figure 2-11 and 2-12). Mallard, wigeon, and shovelers accounted for most of the remaining birds. The relative abundance of pintails declined at both refuges in the 1990's, consistent with declines in continental pintail populations, but declines were more severe at TLNWR where pintail declined to third, fourth, and fourth most abundant dabbling duck during fall, winter, and spring (< 15% of the dabbling duck guild in each season). Mallard were the most abundant dabblers during fall and winter and shoveler most abundant during spring at TLNWR. At LKNWR, pintail were still the most abundant dabblers during fall and spring in the 1990s, while mallards were dominant in winter. Green-winged Teal increased in relative importance during the 1990s at both refuges during all seasons.

Ruddy ducks were the most abundant diving duck at both refuges during all seasons in the 1970s (Figures 2-13 and 2-14). This was followed by some combination of Canvasback, Redheads, Bufflehead and Scaup. Ruddy duck remained relatively most abundant during fall and spring during the 1990s at both refuges; however, during winter, the proportion of Canvasback and scaup were similar to Ruddy Ducks at TLNWR while Bufflehead numbers were similar to Ruddy Ducks at LKNWR. Additional information on waterfowl species composition over time for TLNWR and LKNWR can be found in Gilmer et al. (2004).

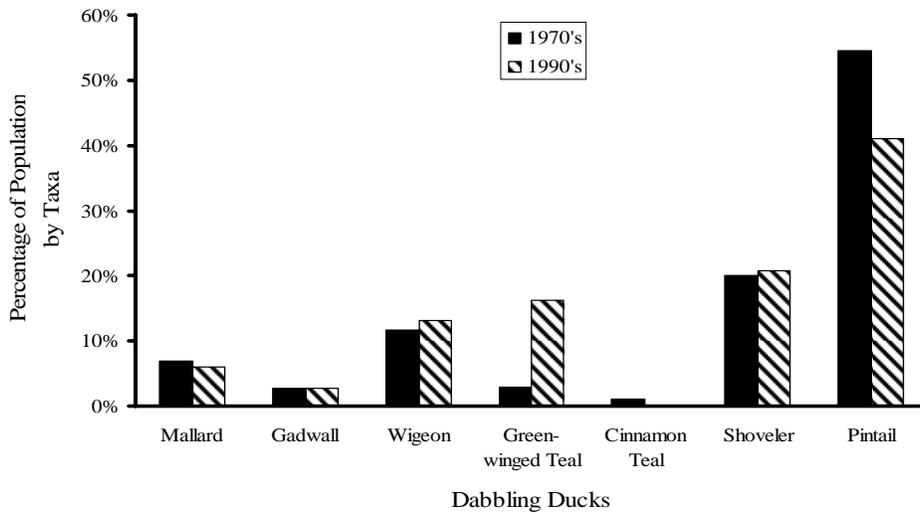
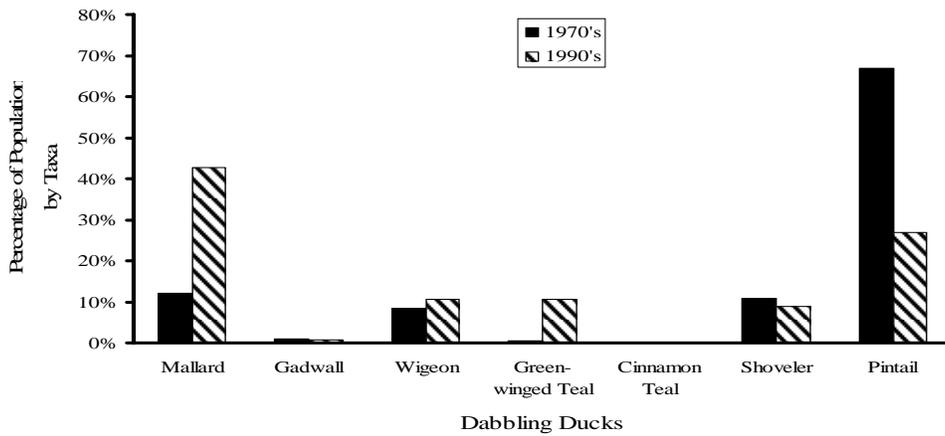
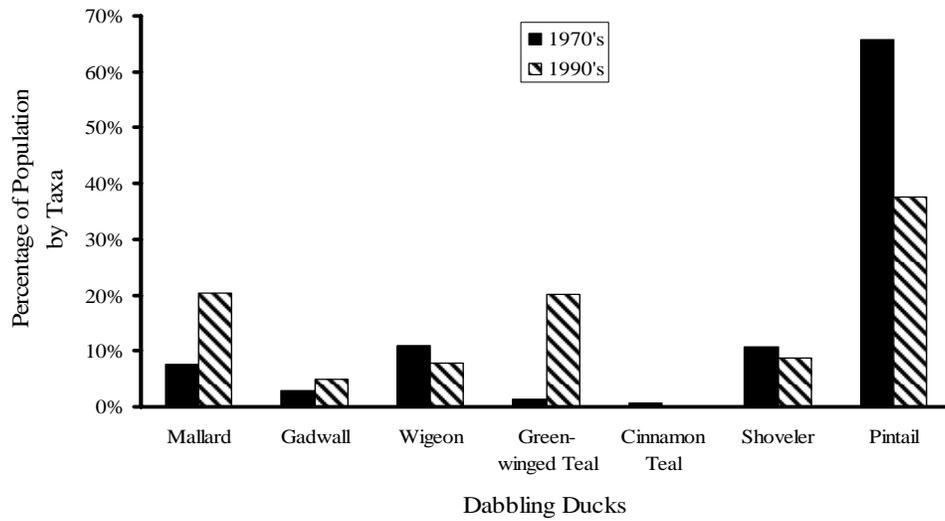


Figure 2-11. Composition of dabbling ducks guild during fall, winter, and spring (top to bottom) at LKNWR during the 1970s (1970-1979) versus 1990s (1990-1999).

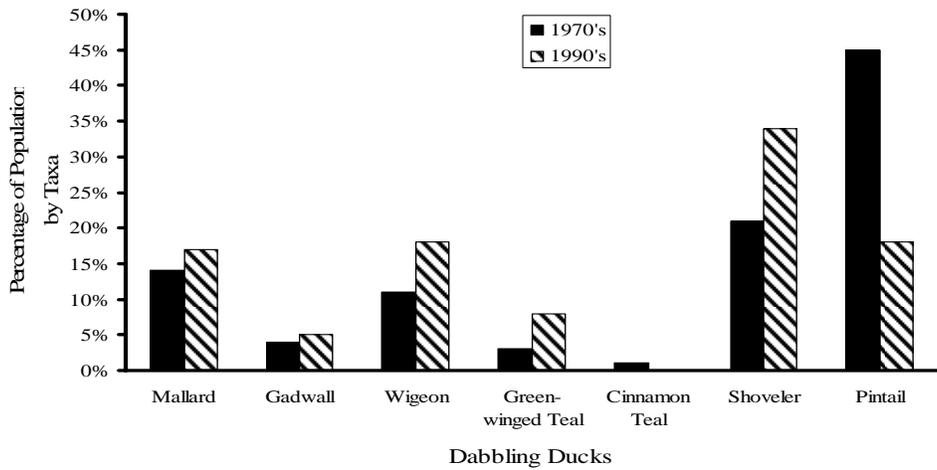
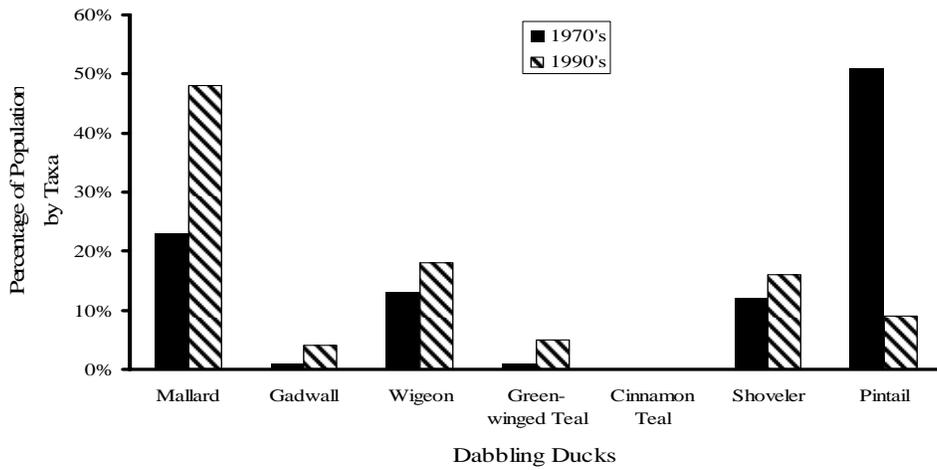
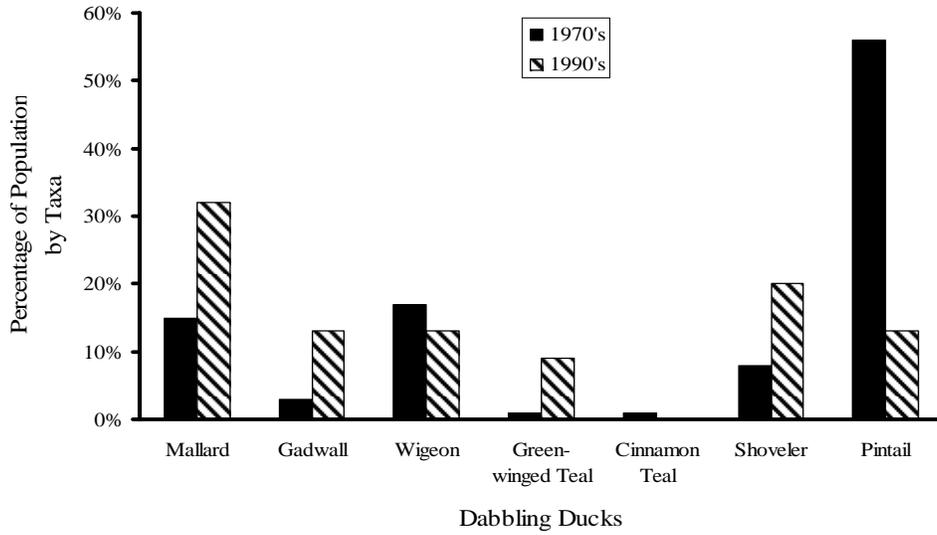


Figure 2-12. Composition of dabbling duck guild during fall, winter, and spring (top to bottom) at TLNWR during the 1970s (1970-1979) versus 1990s (1990-1999).

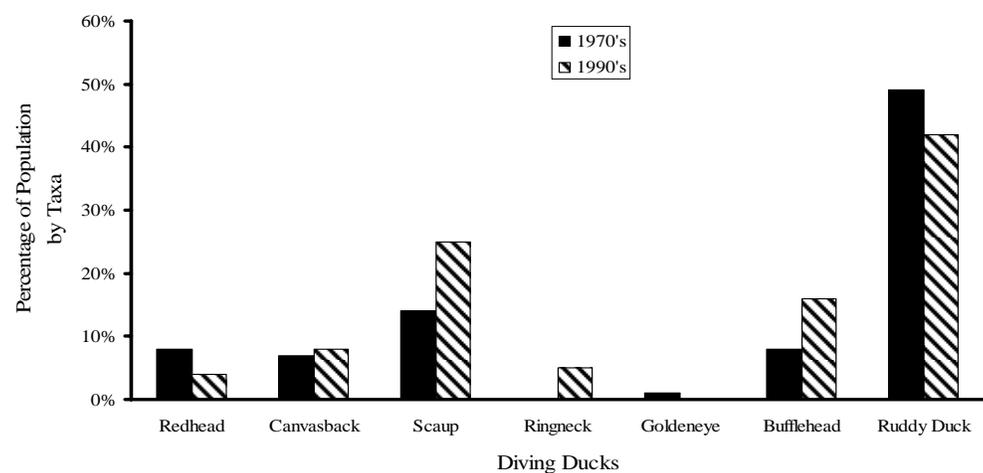
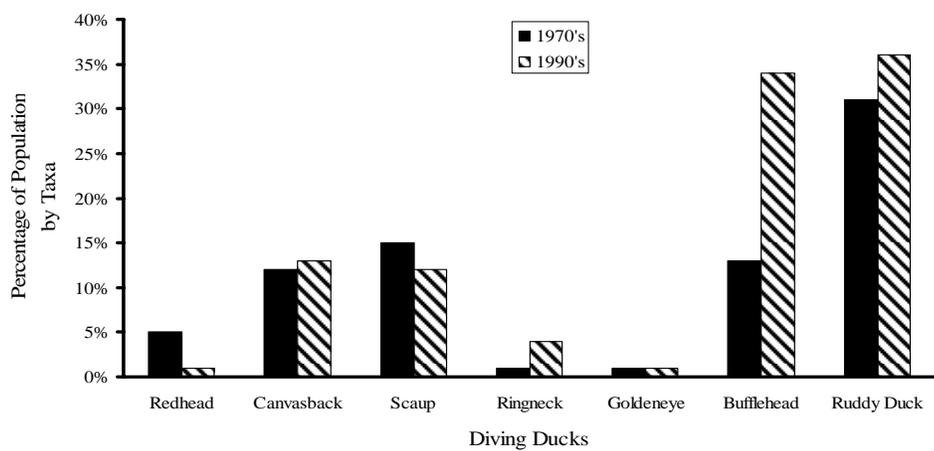
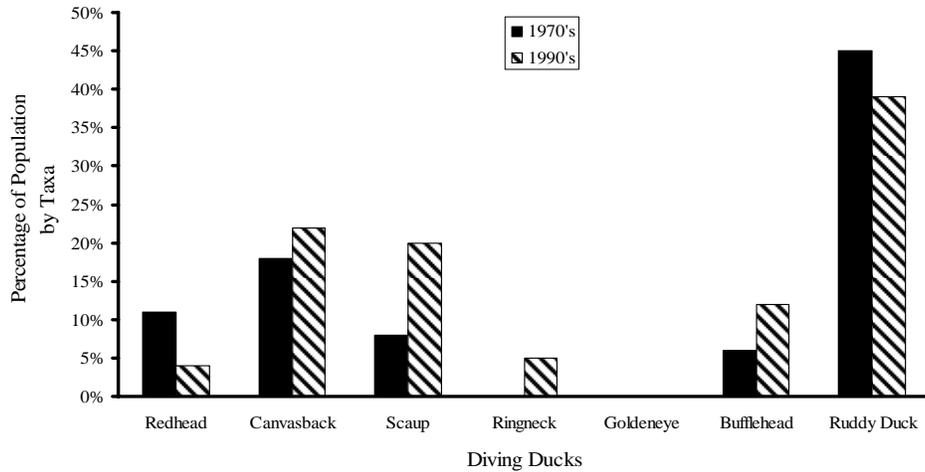


Figure 2-13. Composition of diving ducks guild during fall, winter, and spring (top to bottom) at LKNWR during the 1970s (1970-1979) versus 1990s (1990-1999).

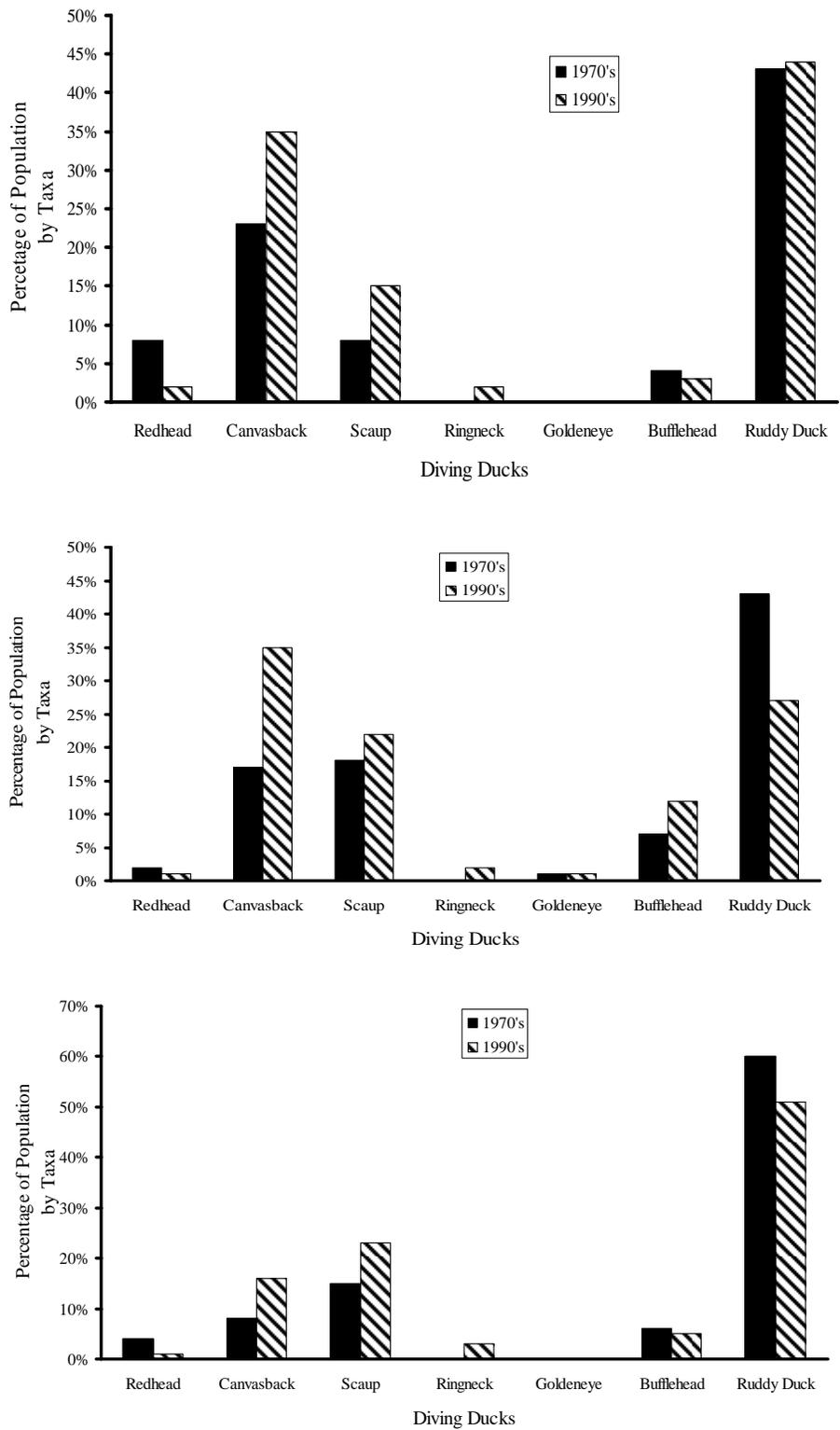


Figure 2-14. Composition of diving ducks guild during fall, winter, and spring (top to bottom) at TLNWR during the 1970s (1970-1979) versus 1990s (1990-1999).

Waterfowl population objectives

The 75th percentile for the 10 years of survey data for each survey period are shown in Tables 2-1 and 2-2. These numbers along with estimates of mean population size (Figures 2-6 through 2-10) were used as waterfowl population objectives for bioenergetic modeling scenarios outlined in chapter 4. For more detailed summary of the count data, see Appendix C.

Table 2-1. Waterfowl population objectives by date for Tule Lake National Wildlife Refuge. Objectives are 75% percentile counts from aerial surveys conducted during a 10 year period.

Date	Waterfowl Taxa or Guild ^a				
	Dabblers ^b	Divers ^c	Geese ^d	Swans	American Coot
Sept 1	53,100	4,270	14,680	0	31,000
Sept 15	54,725	2,990	10,630	0	82,575
Oct 1	292,200	6,998	37,460	0	124,900
Oct 15	281,100	10,730	82,170	0	115,200
Nov 1	765,901	16,440	136,413	260	52,375
Nov 15	268,328	11,088	146,605	713	35,925
Dec 1	193,700	3,825	50,275	1,230	10,650
Dec 15	262,400	2,200	64,608	1,125	8,000
Jan 1	37,015	193	9,240	640	300
Jan 15	91,955	675	4,040	4,205	800
Feb 1	24,635	525	8,350	1,525	2,550
Feb 15	42,850	3,115	13,935	1,530	5,300
Mar 1	16,903	1,308	44,233	1,115	3,750
Mar 15	63,486	3,388	112,708	8	12,375
Apr 1	92,620	2,555	35,705	50	14,500
Apr 15	32,975	2,638	39,595	0	10,250

^aSpecies combined into guilds based on foraging method and diet. Seventy-fifth percentiles calculated for either 1970-1979 (ducks) or 1990-1999 (geese and swans), see methods for explanation.

^bDabblers include Mallard, Gadwall, Northern Pintail, Green-winged Teal, Cinnamon Teal, and Northern Shoveler

^cDivers include Canvasback, Redhead, Ruddy Duck, Bufflehead, Ring-necked Duck, Goldeneye, and Scaup

^dGeese include Canada Goose, Cackling Goose, Greater White-fronted Goose, Lesser Snow Goose, Ross' Goose

Table 2-2. Waterfowl population objectives by date period for Lower Klamath National Wildlife Refuge. Objectives are 75% percentile counts from aerial surveys conducted during a 10 year period.

Waterfowl Taxa or Guild ^a					
Date	Dabblers ^b	Divers ^c	Geese ^d	Swans	Coots
Sept 1	213,521	2,270	7,640	0	28,000
Sept 15	219,869	1,791	5,820	0	33,250
Oct 1	401,738	3,708	51,610	0	52,863
Oct 15	597,010	7,385	36,095	0	59,925
Nov 1	597,536	6,313	34,160	1,545	23,625
Nov 15	487,361	5,783	46,855	3,193	15,925
Dec 1	372,560	1,250	19,475	930	19,500
Dec 15	198,118	855	12,488	1,398	5,500
Jan 1	10,594	160	7,430	2,490	540
Jan 15	27,171	305	12,990	7,211	550
Feb 1	77,714	800	11,431	14,043	1,750
Feb 15	223,459	2,175	56,580	14,960	8,350
Mar 1	148,414	1,560	66,248	18,995	4,850
Mar 15	203,306	1,600	80,433	3,186	11,000
Apr 1	96,775	3,600	49,880	0	45,000
Apr 15	83,339	2,020	70,185	0	16,475

^aSpecies combined into guilds based on foraging method and diet. Means calculated for either 1970-1979 (ducks) or 1990-1999 (geese and swans), see methods for explanation.

^bDabblers include Mallard, Gadwall, Northern Pintail, Green-winged Teal, Cinnamon Teal, and Northern Shoveler

^cDivers include Canvasback, Redhead, Ruddy Duck, Bufflehead, Ring-necked Duck, Goldeneye, and Scaup

^dGeese include Canada Goose, Cackling Goose, Greater White-fronted Goose, Lesser Snow Goose, Ross' Goose

III. FOOD ABUNDANCE AND ENERGETIC VALUE OF KEY FOODS USED BY MIGRATORY WATERFOWL AT LOWER KLAMATH AND TULE LAKE NATIONAL WILDLIFE REFUGE

Developing and using bioenergetic models requires knowledge of the types, abundance, and nutritional value (i.e., metabolizable energy) of individual foods (Central Valley Habitat Joint Venture 2006, Loesch et al. 1994, Miller and Newton 1999, Esslinger and Wilson 2001, and Ballard et al. 2004) found in habitat types included in the model. Estimates of food abundance are available for agricultural habitats at TLNWR and LKNWR (Kapantais et al. 2003), but not for managed seasonal and permanent wetlands. Estimates of wetland seed and tuber production are available for California's Central Valley (Naylor 2002), the Mississippi Alluvial Valley (Kross 2006, Reinecke and Hartke 2005), Missouri (Greer et al. 2007), and New Mexico (Taylor and Smith 2005); however, there are no estimates for wetlands in the intermountain west. While estimates from other areas may provide a reference point for considering food production in the intermountain west, the unique physical properties and distinct plant communities in the region dictate that some site-specific sampling be conducted.

Unlike food production, the metabolizable energy (ME) of a specific food is thought to be more consistent with geography. Despite the value of knowing a food's ME, we know the ME value for only five agricultural foods, four species of acorn, one tuber, and 16 moist soil plant seeds (Hoffman and Bookhout 1985, Petrie et al. 1998, Sherfy 1999, Checkett et al. 2002, Kaminski et al. 2003), and estimates for several foods common at TL and LK are not known. Until an indirect method for estimating metabolizable energy is developed and tested (e.g., Petrie et al. 1998), direct measurements of ME are best. Several methods are available for directly estimating metabolizable energy using controlled feeding experiments; however, estimates of true metabolizable energy (TME) are most accurate (Sibbald 1976, Miller and Reinecke 1984). Unlike estimates of gross energy, TME estimates energy available to birds, and TME is preferable over estimates of apparent metabolizable energy because it accounts for fecal and urinary energy of non-food origin (Sibbald 1976, Miller and Reinecke 1984). To facilitate the development of bioenergetic models for TLNWR and LKNWR, we sampled foods in wetland habitats to achieve the following objectives:

Objectives

1. Estimate moist-soil seed biomass in early v. late seasonal wetlands.
2. Estimate tuber and green foliage produced by submerged aquatic vegetation in permanent wetlands.
3. Estimate the biomass of macroinvertebrates in seasonal wetlands during spring.
4. Estimate the true metabolizable energy value for the seeds of five plants commonly eaten by ducks in the Klamath Basin.
5. Using data from objectives 1-4, estimate energy production in seasonal and permanent wetland habitats at Lower Klamath and Tule Lake NWR.

Methods

Estimating food biomass

Sampling design.-- We estimated food biomass in seasonal and permanent wetlands on both refuges. Seasonal wetlands were classified into two groups based on time since onset of seasonal management, early v. late. Early units had been managed as seasonal wetlands for 1 or 2 years, late wetlands longer than 2 years. We made this initial distinction because plant community and seed production in seasonal wetlands are known to vary with time (Fredrickson and Taylor 1982). Changes with time are generally attributed to plant succession, and qualitative observations by the biological staff at the refuge indicated differences in the plant community did occur; consequently, while we measured plant community composition in each unit prior to sampling, we *a priori* categorized seasonal wetlands early or late successional. We sampled 3 of 5 seasonal wetlands on TLNWR (Lot 5, D-blinds, Sump 1B), and 9 of 20 seasonal wetlands on LKNWR (4A, 4F, 6A, 6B, 6C, 9B, 10B, 13B, White Lake) representing 4 early and 5 late successional units. We sampled the only permanent wetland at TLNWR (Sump 1A; Sump 1B was managed as a seasonal wetland in 2002) and randomly selected 2 of 9 permanent wetlands at LKNWR to sample.

Our sampling goal was to generate relatively precise estimates ($CVs < 0.20$) of food biomass in each management unit for each food type; consequently, we used one of several sampling designs (simple random, stratified random, and double sampling) based on unit-specific vegetative characteristics (Thompson 1992). When it was possible to visually partition a wetland unit into zones of distinct vegetation (habitat patches), we used stratified random

sampling proportional to patch size. We first delineated the boundaries of each patch using a Global Positioning System (GPS) and all-terrain vehicle (ATV) and entered the information into a Geographic Information System (GIS). We delineated borders of vegetation communities where species composition for the selected community appeared to drop below 50%. We then calculated the proportion of each vegetation type within the unit and allocated 40 sample locations proportional to vegetation type patch size. Our sampling effort ($n = 40$ samples per unit) was based on previous experience with sampling moist-soil vegetation (Greer et al. 2007). To choose specific sample locations within each patch, we used GIS to lay a grid (100 m on a side) on top of each habitat patch; each node represented a potential sampling location. We then randomly selected points to sample.

We used double sampling (Thompson 1992) for units when we could visually estimate relative seed or SAV production (Thompson 1992, Reinecke and Hartke 2005). For example, we used this approach for units dominated by a single plant species. Double sampling provided a means of stratifying our sample, but rather than stratify *a priori* based on vegetation community (as above), we stratified based on our estimate of seed production as determined during the first stage of sampling. First, we created a population of possible sample locations by placing a grid onto a digital map of each unit. We varied grid cell size with unit size so there was between 300 and 400 hundred sample points. During the first stage of sampling, we used a GPS unit and either an airboat or ATV to visit each point. At each point, we characterized seed or SAV production as high, medium, or low based on visual inspection (Reinecke and Hartke 2005). For seasonal wetlands (which were dry at the time of sampling) and permanent wetlands with clear water, we visually inspected a 5 m² patch at each sample location. When water clarity prohibited simple visual inspection in permanent wetlands, we ran a two-sided rake (width = 0.38 m) a distance of 1 m through the water column and scored production based on the relative abundance of vegetation on the rake. Sampling effort ($n = 40$) was allocated proportional to estimated food production (low, medium, high) and specific sample locations for the second stage of sampling were selected as described above. We assumed that below ground biomass correlated with above ground biomass.

Finally, we used simple random sampling for units that could not be stratified or double-sampled in a meaningful manner. This was primarily due to fairly homogenous vegetation and seed production or our unfamiliarity with the dominant plants (making it difficult to characterize

seed production using simple visual inspection). A random set of 40 sample locations was selected using the technique described above.

Sampling and processing seeds.-- Seed sampling occurred during late-summer, before flooding in fall. We navigated to sampling locations using a handheld GPS unit and dropped a 0.25 m² open-ended (horse-shoe shaped) sampling frame when the GPS unit indicated we were within 1 m of the location. We recorded percent cover for each species of plant within the sampling frame (within 5%). We then centered a 0.0625 m² frame within the larger sampling frame and clipped all inflorescences occurring within a column defined by that frame (Laubhan and Fredrickson 1992). Inflorescences were separated by species and placed in labeled paper bags. All species producing seeds were collected except aster and biennial wormwood, which were ignored because most seed heads were not developed and they were not utilized by waterfowl in previous food habits studies (Pederson and Pederson 1983). We also collected two soil cores (5.7 cm diameter x 8.0 cm deep) from within the 0.0625 m² sampling frame to account for seeds that might have dropped during clipping. Cores were labeled and frozen to prevent deterioration until processing.

In the lab, we separated seeds from detritus using a modified air separator (USDA 1968) and a series of screens with mesh sizes appropriate for each species (Appendix A). Samples were blown, sifted, and picked through until we visually estimated that $\geq 90\%$ of the chaff mass was removed from the sample. For some species the time required to achieve our 90% standard was too great. For these, we processed a single sample as above for one hour then used that sample as a reference, and processed additional samples of the same species until the proportion of chaff and other detritus resembled the reference. To correct for the detritus, we randomly selected 10% of the samples and processed them to $\geq 90\%$ purity, weighed the detritus that was removed, calculated the mean detritus mass, and subtracted that value from any sample not processed to $\geq 90\%$ purity. All samples were then weighed to the nearest 0.0001 g.

We thawed core samples to room temperature then placed them between a #10 and #45 sieve and rinsed until clear water passed through the bottom sieve (#45); the remaining material was placed in a drying oven (60° C) until dry. Samples were then run through a set of sieves (size #10, #18, #35, and #45) and seeds were sorted by species from the debris remaining on each sieve and weighed to the nearest 0.0001 g.

Seeds on the #45 screen were very small and difficult to identify. Rather than separate by species, we separated seeds into two classes (small black and other). We calculated class-specific biomass of seeds trapped by the #45 screen using the following equation:

$$\text{biomass} = n_s \times m_s \quad (1)$$

where n_s = number of seeds on the screen and m_s = mass of a single seed. We calculated n_s as:

$$n_s = s_v \times s_d \quad (2)$$

where s_v = the sample volume (ml) and s_d = number of seeds in a 1.2 ml subsample from each sample). Using 20 randomly selected samples, we estimated m_s as:

$$m_s = [\sum_{i=1}^{20} (w_i / n_i)] / 20 \quad (3)$$

where w_i equals the mass of a 500 seed or 0.05 g subsample from the sample and n_i was the number of seeds in the subsample.

Sampling and processing submerged aquatic vegetation.-- SAV sampling occurred during fall (Sept-Oct) and late winter (Mar). At each sample location, we firmly pressed a 61 cm² stovepipe sampler into the sediment then used a double-sided rake and sweep-net to remove all above ground SAV. Vegetation was placed in a zip-lock bag, labeled, and refrigerated at temperatures just above freezing for processing. We next extracted a 9.6 cm diameter sediment core (inserted 30.5 cm) from within the area contained by the stovepipe sampler. At the end of each day, roots and tubers were immediately separated from sediments, rinsed, bagged and refrigerated. In the lab, SAV vegetation was separated from algae and invertebrates and all samples were dried to a constant weight at 60°C and weighed to the nearest 0.0001g.

Sampling invertebrates.-- Invertebrate sampling was timed to coincide with peak pintail migration through the basin in spring. To make use of existing site-specific vegetation data, 30 sites/unit were randomly selected for invertebrate sampling from the 40 points sampled per unit during fall seed and SAV sampling. At each location, we drove a 25 cm diameter stovepipe sampler firmly into the sediment. We then pumped all water from the sampler through a #35 sieve using a hand pump (Diaphragm pump; 45 L per minute pumping capacity). We positioned the hose flush with the substrate so the upper layers of benthos were represented in the sample. Water depth was recorded at each location. In areas where sediments were compacted, we forced the hose into the benthos 5 times to dislodge invertebrates. Samples were labeled, preserved in formalin, and transported to the lab for future processing.

In the lab we rinsed each sample through #10 and #35 sieves. All invertebrates captured on the #10 sieve were collected. We spent 30 min picking invertebrates off of the #35 sieve then subsampled anything that remained using a modified spin separator (Waters 1969). After processing, samples were placed in a drying oven at 50°C for ≥ 24 hours then weighed to the nearest 0.0001 g.

We randomly selected 4 samples per unit to characterize taxonomic composition of the invertebrate community. These samples we processed using the same methods discussed while sorting specimens. Taxa were weighed separately and % composition by taxa was averaged across the 4 sites.

Calculations and statistical analyses.-- We calculated biomass using equations appropriate for the sampling design used in each unit (Thompson 1992). We standardized all site-specific biomass estimates to kg/ha. We compared seed and invertebrate biomass among wetland types using single factor ANOVAs (Proc GLM, SAS Inst. 2003).

True Metabolizable Energy

Feeding trials were conducted at Oregon State University in Corvallis, Oregon using game-farm male mallards (*Anas platyrhynchos*) >5 month of age. When not being used in feeding trials birds were confined in an unheated pen, subject to natural temperature and photoperiod, and provided with unlimited access to a commercial game bird ration (crude protein $\geq 20\%$, crude fat $\geq 3.0\%$, crude fiber $\leq 5.0\%$), grit and fresh water (Petrie et al. 1997). Husbandry practices were approved by Oregon State University's Institutional Animal Care and Use Committee (#A3229-01).

We determined TME for the seeds of 3 native species (alkali bulrush [*Scheonoplectus maritimus*], lamb's quarters [*Chenopodium album*], and common spike rush [*Eleocharis palustris*]) and perennial pepperweed (*Lepidium latifolium*), an invasive exotic. We selected the native species due to their common occurrence in wetlands in the intermountain west and presence in the diet of waterfowl (Pederson and Pederson 1983). Perennial pepperweed is eaten by mallard and pintail (*Anas acuta*; Pederson and Pederson 1983) and has invaded seasonal wetlands and riparian areas in the west where it often forms dense, monotypic stands that can effectively exclude native wetland plant species (Young et al. 1995). We obtained seeds from a commercial seed provider because, except for alkali bulrush, seeds were too small to collect a sufficient biomass from natural wetlands.

Feeding trials were conducted mid-February to early June following general procedures outlined in Checkett et al. (2002). Prior to each feeding trial, we randomly selected seven birds ($n = 12$ possible treatment birds) to serve as treatment birds. To provide a measure of endogenous contributions to excreta energy (Sibbald 1976), we selected three additional birds to serve as controls (not fed). We used the same three control birds for all trials. At the beginning of each trial, each bird ($n = 10$) was placed in a metabolic chamber (dimensions: 20 x 20 x 30 cm), provided *ad libitum* water, and fasted for 48 hrs. After fasting, but prior to feeding, we weighed each bird (± 10 g) then fed each treatment bird a known quantity of food (Sibbald 1976). For bulrush and spike rush we fed an amount equal to 1% of the bird's body mass; for perennial pepperweed and lamb's quarters we fed a reduced quantity (0.5%) because most birds regurgitated when fed 1%. Mean mass fed (\pm SE) was 12.5 ± 0.5 g for common spike rush, 12.1 ± 0.5 g for alkali bulrush, 6.5 ± 0.7 g for lamb's quarters, and 5.8 ± 0.2 g for perennial pepperweed. Treatment birds were fed the same species of seed for each trial.

We precision fed birds by inserting a tube (1.2 x 40 cm) into the esophagus and slowly pouring seed into the tube using a funnel and pushing seed down the tube using a wooden dowel. Seeds failing to enter the bird's esophagus (e.g., seeds clinging to the tube wall) were collected, weighed, and subtracted from each bird's original dose (Sherfy et al. 2001, Kaminski et al. 2003). Although TME estimates are theoretically independent of food-intake level (Miller and Reinecke 1984), we removed any bird from a trial if it regurgitated any portion of the test food after feeding, because the small seed size made it difficult to collect all the regurgitated seed. We conducted two trials for each food. For the second trial, only birds not successfully fed in the first trial were available for selection as treatment birds. Thus, no bird contributed more than one TME estimate for any food.

We placed metal funnels under each metabolic chamber that directed fecal and urinary matter into a plastic bag (see picture in Checkett et al. 2002). Excreta were collected from control and experimental cages 48 hrs after feeding (Petrie et al. 1998, Checkett et al. 2002, Kaminski et al. 2003). We removed feathers and grit from each sample, oven-dried the remaining excreta to constant mass at 60°C, weighed the sample to the nearest 0.0001 g, and ground with a mortar and pestle. We estimated gross energy (GE_F ; kcal/g) of whole seeds and excreta using a Parr adiabatic oxygen bomb calorimeter (mean of two, 1.0 g excreta samples for each trial bird or sample of whole seed). We calculated TME (kcal/g) as:

$$\text{TME} = ((\text{GE}_F \times \text{W}_F) - (\text{EE}_F - \text{EE}_C)) / \text{W}_F$$

where GE_F was the gross energy of the whole seed, W_F was the dry mass fed (g) to the treatment bird, EE_F was the energy voided as excreta by the experimental bird (kcal), and EE_C was the energy voided as excreta by control birds (kcal/g; Sibbald 1976). The average energy excreted by control birds was used as the estimate of EE_C . To account for potentially greater catabolism of body tissue by control birds and avoid overestimating energy derived from non-food origin, we corrected TME to zero nitrogen balance (TME_N ; Parsons et al. 1982, Sibbald and Morse 1982).

We determined the nutrient composition for all seeds using proximate analysis. We determined percent moisture by drying samples to a constant mass in a forced air oven at 100°C and percent nitrogen using the Kjeldahl procedure (AOAC 2000). We multiplied percent nitrogen by 6.25 to estimate crude protein. We estimated crude fat using ether extraction, acid detergent fiber (ADF) and neutral detergent fiber (NDF) by the Ankom A200 filter bag technique, and ash content by heating in a cold furnace until 625°C after 15 hr (AOAC 2000). We estimated crude fiber as $\text{ADF} \times 0.80$. Nitrogen Free Extract (NFE) was calculated as $(100\% - \% \text{water} - \% \text{crude fiber} - \% \text{ash} - \% \text{fat} - \% \text{crude protein})$. We expressed TME_N values as a percentage of gross energy [$(\text{TME}_N / \text{GE}_F) \times 100\%$] to estimate digestive efficiency (Petrie et al. 1998).

Because bird mass may influence TME results (Sherfy 1999), we first used single factor analysis of variance (ANOVA; Proc GLM) to compare body mass among months for birds used in feeding trials and for differences in mean treatment bird mass among seed species. Mean body mass of mallards throughout the trial was $1,193.9 \pm 14.1$ g. Body mass did not differ by date ($F = 0.78, P = 0.61$) or seed species ($F_{3,22} = 0.43, P = 0.73$), so mass was not included as a covariate in subsequent TME analyses. We determined whether TME_N of the 4 foods differed by fitting a mixed model ANOVA (Littell et al. 1996). Based on Shapiro-Wilk tests and Levene's test for homogeneity of variance, TME_N values for each seed species were normally distributed ($W_s > 0.86$ and $< 0.96, P_s > 0.23$) with equal variance ($F_{3,22} = 0.45, P = 0.72$). We treated seed species as a fixed effect, and included date of feeding trial and individual bird as random effects. To further examine differences in TME_N between seed species, we conducted pair-wise multiple comparisons using a Tukey multiple comparison test.

Results

Food Abundance

Plant diversity was generally higher in late vs. early successional habitats (Tables 3-1 and 3-2). Species that accounted for > 10% cover for at least one late successional unit that did not occur in early successional units included alkali bulrush, hardstem bulrush, river bulrush, perennial pepperweed, saltgrass, and spikerush. Alkali bulrush and spikerushes were the most commonly occurring dominants in late successional wetlands; whereas, early successional wetlands varied, but were dominated by pigweeds (*Amaranthus spp.*), smartweeds (*Polygonum spp.*), goosefoots and fall panicum (*Panicum dichotomiflorum*).

Seed sampling occurred from 11 September to 7 October 2002. Mean biomass estimates ranged from a low of 241 kg/ha in unit 10B to 1,425 kg/ha in unit 5 (Tables 3-3 and 3-4); the mean for early and late successional wetlands was $1,002 \pm 159$ kg/ha and 584 ± 91 kg/ha, respectively. The composite TME value for early and late successional wetlands was 2.38 and 1.59 kcals/g, respectively. We collected SAV samples during 2 – 7 Oct 2002 (floating vegetation and tubers) and from 4 – 13 Mar 2003 (tubers only). Mean biomass for tubers was 229.7 ± 55.7 kg/ha in fall, higher at Lower Klamath than Tule Lake (Table 3-5). Invertebrate sampling occurred 4 -13 Mar 2003; lot 5 on TLNWR was dry and not sampled. There was no difference in mean invertebrate biomass by wetland type ($F_{2,10} = 3.52$, $P = 0.07$), but the estimate in permanent wetlands was higher than for either early or established wetlands (Table 3-6). Cladocerans, Copepods, Oligochaetes, and Chironomids were the numerically dominant macroinvertebrate taxa in all wetlands (Appendix B).

Table 3-1. Mean percent cover (SE) of plants in early successional seasonal wetland units at Lower Klamath and Tule Lake National Wildlife Refuges, fall 2002.

Species	Wetland Unit (<i>n</i>)			
	5 (40)	9B (40)	DB (40)	S1B (40)
Aster	3.6 (1.2)	17.7 (3.1)	5.9 (1.9)	1.9 (1.3)
Basia	12.3 (3.0)	tr ^a	0	0
Biennial Wormwood	10.0 (2.2)	tr	tr	5.1 (2.1)
Bitter Dock	1.5 (0.6)	0	0	0
Cinquefoil	2.6 (1.0)	0	0	0
Curly dock	2.4 (1.4)	0	0	0
Dock species	4.9 (2.4)	0	0	1.6 (1.1)
Fall Panicum	0	63.9 (6.8)	0	0
Goosefoot sp.	24.3 (4.3)	1.9 (0.7)	6.1 (2.1)	18.1 (3.4)
Pigweed	12.5 (4.0)	0	25.6 (3.0)	0
Pursh Seepweed	2.1 (1.3)	9.4 (4.0)	0	0
Quackgrass	0	0	0	0
Smartweed sp.	5.1 (1.3)	0	0	40.8 (5.0)
Stinging nettle	5.8 (2.6)	0	0	0
Whitetop	0	0	0	0
Willowleaf	0	0	tr	0
Unknown	5.0 (2.1)	0	tr	tr

^a tr < 1.0%

Table 3-2. Mean percent cover (SE) of plants in plots from late successional seasonal wetland units at Tule Lake and Lower Klamath National Wildlife Refuges, fall 2002.

Species	Unit (<i>n</i>)							
	10B (39)	13B (40)	4A (40)	4F (40)	6A (40)	6B (40)	6C (39)	WL (40)
Alkali Bulrush	2.2 (1.9)	12.6 (4.3)	6.4 (2.9)	13.3 (4.2)	10.9 (4.1)	3.4 (2.4)	37.2 (6.3)	25.8 (5.9)
Aster	tr ^a	0	1.3 (0.8)	48.5 (6.4)	1.6 (1.3)	0	7.2 (2.9)	2.1 (2.1)
Atriplex sp.	0	2.9 (2.4)	0	0	tr	2.5 (1.9)	0	0
Baltic Rush	0	0	0	0	0	2.6 (2.2)	0	0
Basia	0	0	0	tr	1.9 (1.9)	1.3 (1.3)	0	2.1 (2.0)
Biennial Wormwood	tr	0	tr	tr	1.4 (0.8)	1.1 (0.6)	1.1 (1.0)	0
Canadian Thistle	0	0	0	0	0	1.6 (1.2)	0	0
Chenopodium sp.	1.5 (1.3)	20.0 (5.2)	1.5 (0.9)	24.3 (5.8)	2.9 (1.5)	tr	3.2 (1.4)	6.8 (1.9)
Foxtail Barley	tr	0	4.4 (2.6)	0	2.6 (1.6)	0	0	0
Hardstem Bulrush	0	9.0 (3.6)	4.6 (2.8)	0	12.0 (5.1)	1.4 (1.3)	1.8 (1.8)	0
Nuttalls' Alkali-grass	11.2 (4.3)	0	0	0	0	0	0	2.1 (2.1)
Panicum	0	0	0	1.9 (1.9)	0	0	0	0
Perennial Pepperweed	0	0	10.2 (4.7)	2.3 (2.3)	0	7.5 (4.2)	0	0
Pursh Seepweed	0	0	0	0	0	0	0	11.3 (3.7)
Quackgrass	0	0	2.6 (1.9)	0	0	tr	0	0
Rabbitfoot Grass	3.2 (1.8)	0	0	0	2.9 (2.5)	1.4 (1.1)	tr	0
River Bulrush	0	48.8 (7.5)	0	0	0	0	4.6 (3.2)	0
Rorripa	tr	0	0	0	0	1.8 (0.7)	0	0
Rumex sp.	tr	2.4 (1.6)	9.5 (3.2)	0	tr	tr	tr	0
Rushes (juncus)	4.9 (2.8)	0	0	0	0	0	0	0
Saltgrass	8.2 (4.0)	0	3.6 (2.5)	0	tr	10.1 (4.4)	1.3 (1.1)	9.8 (4.6)

Table 3-2 cont...

Species	Unit (<i>n</i>)							
	10B (39)	13B (40)	4A (40)	4F (40)	6A (40)	6B (40)	6C (39)	WL (40)
Scratchgrass Muhly	0	0	0	0	0	2.3 (2.3)	0	tr
Smartweeds	tr	0	0	2.0 (1.6)	2.1 (1.0)	0	0	0
Spikerushs	49.8 (7.5)	0	29.2 (6.7)	0	20.5 (5.7)	15.1 (4.8)	21.9 (5.7)	0
Swamp Timothy	0	0	0	0	0	2.4 (1.9)	5.0 (2.2)	1.3 (1.0)
Whitetop	tr	0	0	0	0	4.9 (1.9)	0	0
Wormseed	1.3 (0.8)	0	13.1 (4.5)	0	6.1 (2.5)	tr	0	0
Unknown	2.6 (1.6)	0	8.9 (4.1)	2.5 (2.5)	2.4 (1.9)	8.8 (3.4)	0	0
Unknown forb	0	tr	tr	0	tr	1.3 (0.9)	tr	0

^a tr < 1.0%

Table 3-3. Mean seed biomass (kg/ha) estimated from clip and soil core samples for plant species occurring in early successional seasonal wetland units at Tule Lake and Lower Klamath National Wildlife Refuges, fall 2002.

Species ^a	Unit (<i>n</i>)			
	5	9B	DB	S1B
Alkali bulrush	0	2.1 (2.1)	0	tr ^b
Bulrush sp.	15.1 (3.2)	37.1 (8.5)	3.6 (1.4)	265.7 (125.6)
Dock	193.5 (67.0)	tr	tr	62.9 (27.5)
Smartweeds	91.1 (27.5)	1.5 (0.9)	tr	379.8 (101.4)
Fall Panicum	0	759.6 (116.5)	0	0
Swamp Timothy	0	3.5 (3.5)	0	0
Goosefoot sp.	553.5 (102.9)	48.1 (11.2)	59.4 (25.2)	87.5 (23.0)
Pigweeds	380.4 (143.7)	0	584.6 (80.1)	0
Pursh seepweed	14.4 (13.3)	49.9 (22.6)	0	0
othr45	1.8 (0.7)	tr	tr	6.0 (2.7)
Atriplex	1.5 (1.5)	0	tr	0
Basia	72.7 (26.4)	9.1 (7.5)	0	0
Cinquefoil	7.4 (3.4)	0	0	0
Kochia	67.7 (44.1)	0	0	0
Perennial Pepperweed	0	0	0	2.9 (2.9)
Salt heliotrope	tr	0	0	40.8 (18.2)
Wormseed	1.7 (0.8)	0	0	0
#45 screen, goosefoot	18.3 (3.6)	7.5 (0.8)	2.3 (0.4)	148.3 (33.7)
Unknown forb	3.1 (2.2)	0	0	0
Unknown	3.2 (2.5)	40.5 (23.1)	tr	tr

^a Species whose biomass never exceeded 1 kg/ha in any unit are not shown

^b tr < 1.0 kg/ha

Table 3-4. Mean seed biomass (SE) estimated from clip and soil core samples by plant species in late successional seasonal wetland units (*n*) at Lower Klamath and Tule Lake National Wildlife Refuges, fall 2002.

Species ^a	Wetland Unit							
	10B	13B	4A	4F	6A	6B	6C	WL
Alkali Bulrush	0	68.3 (39.1)	40.1 (25.1)	50.4 (29.5)	22.3 (15.2)	1.3 (0.9)	183.3 (55.5)	227.6 (74.2)
Atriplex sp.	tr ^b	3.2 (3.0)		0	17.6 (13.8)	19.4 (17.4)	2.8 (1.8)	
Baltic Rush	0	0	7.9 (7.9)	0	0	0	1.8 (1.8)	
Basia	0	0		tr	20.0 (20.0)	tr	tr	13.0 (11.9)
Bulrush sp.	6.3 (2.9)	424.2 (54.1)	122.0 (27.4)	240.4 (48.1)	186.7 (38.0)	28.7 (11.0)	238.3 (39.9)	62.9 (19.0)
Dock	53.1 (26.9)	22.7 (8.5)	442.8 (129.1)	19.8 (8.4)	396.5 (102.0)	138.5 (65.8)	38.0 (19.8)	tr
Field Pennycress	tr	tr	2.6 (2.4)	0	4.7 (2.5)	1.3 (1.0)		
Foxtail Barley	3.7 (1.9)	0	6.9 (3.6)	0	33.0 (19.1)	tr		3.4 (3.2)
Goosefoot	8.2 (2.2)	132.7 (32.9)	17.8 (5.3)	124.6 (28.4)	31.5 (8.6)	25.6 (5.7)	46.3 (8.5)	49.6 (11.0)
Hardstem Bulrush	0	16.2 (11.3)	tr	0	3.1 (2.9)	tr	1.1 (1.1)	
Mustard sp.	tr	0	84.5 (42.7)	0	7.4 (6.1)	0		
Nutalls' Alkali-grass	tr	0		0	0	0		tr
Fall panicum	1.3 (0.6)	0		3.6 (1.9)	tr	tr	tr	1.9 (1.9)
Perennial Pepperweed	0	tr	3.7 (2.4)	9.3 (9.3)	0	14.9 (10.5)		
Pigweed	tr	tr	tr	0	1.3 (1.3)	tr	1.1 (1.1)	
Poison Hemlock	0	0		0	0	0	5.8 (5.8)	
Pursh Seepweed	tr	0		tr	0	0		36.4 (12.2)
Rabbitfoot Grass	7.2 (4.2)	0		tr	21.7 (19.4)	2.7 (2.1)	tr	tr
River bulrush	6.6 (6.6)	102.2 (34.4)		0	0	0		
Salt Heliotrope	tr	tr		tr	0	0		1.5 (1.5)

Table 3-4 cont...

Species	Unit							
	10B	13B	4A	4F	6A	6B	6C	WL
Saltgrass	0	1.3 (1.3)	12.9 (12.9)	0	0	tr	tr	tr
Smartweed sp.	1.6 (1.6)	3.7 (1.9)	tr	tr	20.8 (12.7)	tr	tr	tr
Spikerush	118.4 (44.7)	tr	108.7 (39.6)	tr	57.0 (11.6)	51.1 (22.2)	87.6 (28.5)	
Swamp Timothy	tr	0		8.6 (8.6)	0	2.1 (1.5)	10.1 (5.3)	6.8 (4.5)
Whitetop	tr	0		0	0	11.5 (10.2)	tr	
Wormseed	0	0		0	15.0 (13.5)	0		
#45 goosefoot	11.8 (2.2)	40.6 (7.2)	9.9 (2.7)	25.4 (3.4)	24.8 (4.5)	15.1 (4.5)	30.5 (5.0)	19.4 (3.3)
# 45 other	tr	2.9 (1.0)	8.5 (3.4)	1.8 (0.6)	11.1 (2.8)	1.3 (0.7)	3.7 (0.9)	tr
Unknown	22.6 (0.73)	tr	4.9 (3.4)	tr	15.2 (9.1)	9.8 (4.8)	tr	5.3 (4.9)

^a Species whose biomass never exceeded 1 kg/ha in any unit are not shown

^b tr < 1.0 kg/ha

Table 3-5. Mean biomass [kg/ha (SE)] of submerged aquatic vegetation (SAV) in permanent wetlands sampled during October and March during 2003 at Lower Klamath and Tule Lake National Wildlife Refuges.

		SAV				
		leafy vegetation		rhizomes and tubers		
Refuge	Unit	Oct 2002	Mar 2003	Oct 2002	Mar 2003	Depletion (%)
TLNWR	S1A	188 (26)	0	106 (23)	118 (33)	-0.1
LKNWR	3A	371 (56)	0	249 (60)	98 (29)	60.6
	12C	226 (53)	0	334 (53)	112 (26)	66.5
	<i>Mean</i>	<i>261.7 (55.7)</i>		<i>229.7 (66.5)</i>		<i>109.3 (5.9)</i>

Table 3-6. Mean biomass [kg/ha (SE)] of invertebrates in seasonal and permanent wetlands sampled during 4-13 March 2003 at Lower Klamath (LK) and Tule Lake (TL) National Wildlife Refuges.

Wetland type	Refuge	Unit	Biomass
Seasonal early	TL	D-Blinds	7.9 (1.8)
	TL	Sump 1B	12.1 (1.8)
	LK	9B	1.7 (0.6)
	<i>Mean of means</i>		<i>6.0 (2.5)</i>
Seasonal established	LK	4A	1.3 (1.0)
	LK	4F	5.1 (0.6)
	LK	6A	16.4 (4.0)
	LK	6C	15.3 (2.2)
	LK	10B	1.9 (0.6)
	LK	White Lake	5.4 (1.2)
	<i>Mean of means</i>		<i>7.6 (2.7)</i>
Permanent	TL	Sump 1A	10.2 (3.5)
	LK	3A	17.1 (2.8)
	LK	12C	45.6 (5.6)
	<i>Mean of means</i>		<i>24.3 (10.8)</i>

TME values

TME_N differed among seed species ($F_{3, 20} = 80.5$, $P < 0.0001$; Table 3.7). Pair-wise comparisons indicated mean TME_N differed for all pairs of seeds ($P_s \leq 0.002$) except alkali bulrush and common spike rush ($P = 0.49$). TME was highest for lamb's quarters, which was 2.2 times higher than perennial pepperweed, 3.9 times higher than alkali bulrush, and 5.0 times higher than spike rush. Digestive efficiency ranged from lows of 12.0% and 13.0% for common spike rush and alkali bulrush, respectively, to 25.9% for perennial pepperweed, and 57.6% for lamb's quarters. Perennial pepperweed seeds were high protein and fat content, but intermediate metabolizable energy value (Table 3-7). Common spike rush was highest in fiber and ash, while alkali bulrush was highest in carbohydrates (NFE).

Table 3-7. Gross energy (GE), least-squares predicted means (\pm SE) of nitrogen-corrected true metabolizable energy (TME_N), and nutrient composition (% dry mass basis) for the seeds of moist-soil plant species fed to adult, game-farm male mallards February - June 2003.

Plant species ^a	n	GE _F kcal/g	TME _N kcal/g	Nutritional composition (%) ^b					
				Protein	Fat	Ash	NFE ^c	ADF	NDF
alkali bulrush	7	4.42	0.65 \pm 0.080	7.6	4.0	2.7	66.3	24.3	39.2
lamb's quarters	7	4.46	2.52 \pm 0.080	16.6	9.5	4.1	48.4	26.7	27.0
pepperweed	5 ^c	5.32	1.31 \pm 0.090	26.6	20.3	4.9	36.4	14.9	38.6
spike rush	7	3.93	0.50 \pm 0.080	7.5	5.5	12.5	46.5	34.8	47.9

^a alkali bulrush (*Scheonoplectus maritimus*); lamb's quarters (*Chenopodium album*); perennial pepperweed (*Lepidium latifolium*); common spike rush (*Eleocharis palustris*)

^b ADF = acid detergent fiber, NDF = neutral detergent fiber, NFE = 100% - (protein + fat + fiber + ash)

^c reduced sample size caused by regurgitation of food by fed birds

IV. EVALUATING CURRENT HABITAT CONDITIONS AND EXPLORING MANAGEMENT ALTERNATIVES FOR MEETING WATERFOWL FOOD ENERGY NEEDS AT TULE LAKE AND LOWER KLAMATH NATIONAL WILDLIFE REFUGES.

Introduction

Increasing competition in the Klamath Basin for limited water supplies requires that the Service articulate its habitat objectives for waterfowl. Ideally, these objectives are based on explicit population-habitat models that reflect the life history needs of migrating and wintering waterfowl. The establishment of waterfowl population objectives for TLNWR and LKNWR in Chapter 2 is an important step in developing management actions that are biologically defensible. However, the capacity of TLNWR and LKNWR to meet these population objectives under existing and alternative management scenarios must also be evaluated if the resources needed by waterfowl are to be fully justified. Such an approach is consistent with the Service's recent Strategic Habitat Conservation Initiative that encourages a direct link between population objectives and the implementation of conservation programs.

For migrating and wintering waterfowl, food is believed to be the most limiting resource. As a result, conservation planning for waterfowl outside of the breeding season has largely focused on providing sufficient foraging habitat. Within this chapter, we used a bioenergetic model to estimate the food energy supplies available to waterfowl at TLNWR and LKNWR.

Objectives

In this chapter, we address three of the five objectives listed in Chapter 1 including:

3. Evaluate current refuge management practices relative to waterfowl food energy needs for each refuge.
4. Identify foraging habitat deficiencies that may exist for each refuge.
5. Evaluate potential habitat management alternatives for meeting waterfowl food energy needs.

Our intent with objective 5 is not to examine all the management alternatives that the Service may wish to consider. Rather, it is to provide examples of how a bioenergetic model can be used to inform habitat planning for migrating and wintering waterfowl. In

the future, the Service plans to develop and refine a more complete set of management alternatives for evaluation through its Comprehensive Conservation Planning and National Environmental Policy Act (NEPA) process.

Methods

We incorporated data on energy supply and demand into TRUOMET, a bioenergetic model developed for initial use in conservation planning by the California Central Valley Habitat Joint Venture. The model provides an estimate of population energy demand and population energy supply for specified time periods. Population energy demand is a function of period specific population objectives and the daily energy requirement of individual birds during that period. Population energy supply is a function of the foraging habitats available and the biomass and nutritional quality of foods contained in these habitats. A comparison of energy supply vs. energy needs provides a measure of how well refuge habitats meet the energy needs of their target waterfowl populations. Conceptually, TRUMET is a daily ration model (Goss-Custard et al. 2003) with a model structure that assumed birds were ideal free foragers that did not incur costs associated with traveling between foraging patches (e.g., moving between wetland management units). There are seven explicit inputs required for each model run:

1. number of days or time periods being modeled
2. population size for each waterfowl guild being modeled during each time period
3. daily energy requirement of a single bird within a foraging guild
4. acreage of each habitat available for each time period
5. biomass of food in each habitat type on day one
6. nutritional quality of each food type, and
7. percentage of a bird's daily energy needs met on site and the habitats or food types each guild uses to satisfy its daily energy requirements.

Model Inputs

Number and Days Being Modeled.-- Migrating and wintering waterfowl rely on TLNWR and LKNWR in significant numbers between early September and late April

(Gilmer et al. 2004). As a result, we modeled waterfowl food energy needs and food energy supplies for all two-week intervals between 24 August and 22 April.

Daily Energy Requirements of a Single Bird.-- To estimate the daily energy need for a bird in each guild, we multiplied resting metabolic rate (RMR) by three to account for energy costs of free living (Miller and Eadie 2006). We used the following equations for estimating RMR:

$$\text{RMR (kJ/day)} = 433 * (\text{body mass in kg})^{0.785} \text{ (dabblers divers, and coots)}$$

$$\text{RMR (kJ/day)} = 419 * (\text{body mass in kg})^{0.719} \text{ (geese)}$$

$$\text{RMR (kJ/day)} = 413 * (\text{body mass in kg})^{0.689} \text{ (swans)}$$

Because we modeled by guild (a group of species) and species vary in size, we calculated the body mass for a representative bird in each guild as the weighted mean for all species in each guild assuming equal sex ratios for all species. We used body mass values from Bellrose (1980) for ducks, geese, and swans and Alisauskas and Arnold (1994) for coots. We calculated the weighted mean for each two week survey period to account for changes in species composition as indicated by the aerial survey (Gilmer et al. 2004). We held body mass constant across time for dabblers, divers, coots, and swans, but we allowed mass to vary for Ross' Geese, Lesser Snow Geese, Greater White-fronted Geese, and Cackling geese based on data from Ely and Raveling (1989), McLandress (unpublished data), and Raveling (1979). Body mass for Western Canada geese was obtained from Bellrose (1980) and was held constant over time.

Habitat Acreage.-- We modeled six habitat types including harvested and un-harvested grain crops, harvested potato fields, alfalfa/hay, and seasonal and permanent wetlands. Seasonal wetlands are typically flooded in fall or winter with water removal occurring in spring or early summer; permanent wetlands are flooded at least 12 months. Seasonal wetlands were further divided into early and late successional habitats to reflect differences in seed production (Chapter 3) and permanent wetlands were divided into area dominated by submerged aquatic vegetation or robust emergent vegetation (primarily hardstem bulrush and cattail). Food production in permanent wetland areas dominated by robust emergents was set at 0.0 because the dense growth and tall, robust

stature of these plants make foods in these habitats unavailable to waterfowl. Seeds that might have been produced by this plant community that dispersed into other habitats would have been included in food abundance estimates. Refuge personnel provided information on existing habitats at TLNWR and LKNWR (data for 2005). Waterfowl that rely on the refuges were assumed to exploit both agricultural and wetland habitats to meet food energy needs (Tables 4-1 and 4-2); we used these values to reflect current refuge habitat conditions.

Temporal Variation in Habitat Availability.-- Availability refers to the ability of waterfowl to access foods produced in a habitat. Availability varies with flooding conditions and crop harvest practices and can vary among guilds for a specific habitat type. For example, many species of ducks will not feed in dry agricultural fields or wetlands (e.g., diving ducks), but Mallard and Northern Pintail will. We used information provided by refuge staff to determine when and how quickly foods in each habitat type became available. We set foods in permanently flooded wetlands and unharvested grain fields as 100% available at the beginning of our modeling window (September 1 interval). Seasonal wetlands began flooding during the 15 September interval and filled at a constant rate until the 1 January interval when all were filled while grain crops that are to be harvested are assumed to be harvested by September 15. Potatoes became available starting October 1 as harvesting is initiated during the October 1 interval and proceeds at a steady rate until all fields are harvested by the November 1 interval.

Food Densities in TLNWR and LKNWR Habitats.-- We determined food abundance in wetland habitats at TLNWR and LKNWR as part of this study (Chapter 3). We used estimates of food abundance in harvested agricultural crops and pastures as reported by Kapantais et al. (2003). We sampled barley, oats, wheat, and potatoes shortly after harvest in fall, while pasture was sampled in spring. We obtained biomass estimates for unharvested barley, oat, and wheat fields from Dr. Harry Carlson at the University of California's Intermountain Research and Extension Office in Tule Lake (Table 4-2). Waterfowl abandon feeding in habitats before all food is exhausted because the costs of continuing to forage on a diminishing resource exceeds energy gained; this value is called the giving-up-density or foraging threshold (Nolet et al. 2006). For example, Mallards feeding in dry fields in Texas reduced corn densities to 13.2 lbs/acre before abandoning

Table 4-1. Habitat composition (acres) at Tule Lake and Lower Klamath National Wildlife Refuges during 2005.

Habitat Type	Refuge	
	Lower Klamath	Tule Lake
Seasonal Wetlands		
Early Succession	4,834	0
Late Succession	11,280	155
Permanent Wetlands		
Submerged Aquatic Veg.	7,355	11,539
Robust Emergent Veg.	1,839	3,030
Harvested Grains	6,534	8,471
Standing Grains	1,057	249
Harvested Potatoes	0	2,703
Green Browse	2,018	3,405
Total Habitat	34,917	29,552

Table 4-2. Food densities from agricultural and wetland habitats at Lower Klamath and Tule Lake NWRs. Agricultural, seasonal wetland, and permanent wetland food density estimates are reduced by a foraging threshold of 13.2, 30.8, and 44 lbs/acre, respectively.

Habitat Type	Refuge	
	TLNWR (lbs/acre)	LKNWR (lbs/acre)
Harvested Potatoes ^a	437	--
Green Forage (Pasture) ^a	176	176
Harvested Grain ^a		
Barley	77	77
Oats	157	156
Wheat	19	42
Weighted Mean ^b	41.9	56.0
Unharvest Grain ^c		
Barley	4,960	4,960
Oats	4,464	--
Wheat	5,952	--
Weighted Mean	5,675	4,960
Wetlands ^d		
Seeds-Early Succession Seasonal Wetlands	875	875
Seeds-Late Succession Seasonal Wetlands	489	489
Spring Invertebrates - All Wetlands	9	9
Roots / Tubers- Permanent Wetlands	49.4	218
Leafy Vegetation- Permanent Wetlands	121.7	214

^a From Kapantais et al. 2003.

^b Mean value that reflects the proportional contribution of each crop type to the category total

^c Harry Carlson, University of California, Research and Extension Office, Tule Lake, California

^d Data from Chapter 3

fields (Baldassarre and Bolen 1984) and waterfowl abandon rice fields in the Mississippi Alluvial Valley around 50kg/ha (Rutka et al. in review). Consequently, we adjusted our biomass estimates by subtracting published estimates of giving up densities. For grains, we subtracted 13.2 lbs/acre (Baldassarre and Bolen 1984); for seed resources in seasonal wetlands we subtracted 30.8 lbs/acre (Naylor 2002); and for tubers and green foliage in permanent wetlands we subtracted 44 lbs/acre (Reinecke et al. 1989). We report food density data in pounds per acre in this chapter, rather than kg/ha, because this report is intended to be shared with agricultural producers in the Klamath region and lbs/ac is the metric they use when discussing crop yields.

Nutritional Quality of Foods.-- We used data from published sources for estimates of the nutritional value for specific agricultural foods (Table 4-3). When the TME value of a specific food was not known, we used a value for a similar food type. When a comparable species was not available, we estimated TME using a regression relationship between TME value and the proximate composition of a food (Petrie et al. 1998).

Because so little is known about the TME value of specific aquatic invertebrates, we used a single value for this group. In contrast, the seeds of moist soil plants are known to vary considerably in nutritional quality. To estimate the energy content for seeds in early and late successional seasonal wetlands, we calculated a weighted mean by multiplying the TME value for each plant by its proportional contribution to the total seed biomass in the unit (from Chapter 3). We then summed the weighted values for all species in a unit to get the composite TME value for each unit and calculated the mean TME value for units in each seasonal wetland category. We used TME estimates from Chapter 3 as well as those from Petrie et al. (1997) and Checkett et al. (2002). TME values were not available for the seeds of all plants that occurred in our samples. We used estimates from other species in the same genus if they were available (e.g., the TME value for *Rumex crispus*, 2.68 kcals/g was applied to the seeds for all *Rumex* species). For seeds of species collected on the #45 screen from the core samples (Chapter 3), we used a TME value of 2.6 kcals/g, the mean of the species that made up the bulk of the small seeds (*Amaranthus* and *Chenopodium* sp.). For all other seeds we used a TME value of 2.0 kcals/g, the mean for all moist soil seed with known TME values. Using this

Table 4-3. True metabolizable energy (TME) of waterfowl foods at TLNWR and LKNWR.

Food Type or Category	TME Value (kcal/g)
Grains ¹	3.0
Potatoes ²	4.0
Alfalfa Pasture ³	2.4
Seasonal Wetland Seeds (early succession) ⁴	2.4
Seasonal Wetland Seeds (late succession) ⁴	1.6
Leafy Vegetation ³	2.0
Roots / Tubers ⁵	2.5
Aquatic invertebrates ⁶	2.5

¹ from Sugden (1971)

² based on proximate composition (Petrie et al. 1998).

³ from Petrie et al. (1998)

⁴ These metabolizable energy estimates were combined with published TME values of other moist-soil seed resources to generate an average TME value for seeds in early and late succession seasonal wetlands (Checkett 2002).

⁵ based on foods of similar proximate composition

⁶ from Purol (1975)

Table 4-4. Food types used by waterfowl guilds to meet their daily energy demands on LKNWR and TLNWR.

Guild	Standing Grain	Harvested Grain	Harvested Potatoes	SW Seeds	PW Leafy Vegetation	PW Roots and Tubers
Dabbling Ducks	X	X		X		
Diving Ducks						X
Geese	X	X	X	X		
Swans						X
Coots					X	

X – Indicates foraging habitats that are assumed to be used by a waterfowl guild

SW- Seasonal wetland

PW- Permanent Wetland

approach, we estimated the average TME value was 2.38 kcal/g in early successional wetlands and 1.59 kcal/g in late successional wetlands (Table 4-3).

Percentage of a bird's daily energy needs met on-site and the habitats or food types each guild can use to satisfy its daily energy requirements.-- We used information in the published literature and observations of refuge staff to determine what percentage of each guilds daily energy needs must be met on site and the habitats and food types each guild was allowed to use to satisfy their daily energy needs (Table 4-4). We required that diving duck and swans satisfy 100% of their energy needs by foraging on the tubers of submerged aquatic vegetation. The diet of diving ducks differ, but we felt this constraint was appropriate given Canvasback was the most common species in our diver guild. Because of similar food habits and on-site requirements, we combined diving ducks and swans in our modeling even though we generated separate population objectives in Chapter 2. For coots, we required they meet 100% of their energy needs by feeding on the leafy vegetation of submerged aquatic plants, which constrained them to permanent wetlands. We assumed leafy plant material was gone after 1 November (because of senescence); therefore, coot food supplies were effectively zero after this date. We required that geese forage on harvested and unharvested grain crops, (regardless of flooding status), harvested potatoes and pasture (alfalfa). However, because green forage consumption by geese at TLNWR and LKNWR largely occurs during spring migration (D. Mauser personal observation), we assumed that geese only foraged in pasture from 1 March through 15 April.

We required dabbling ducks to feed on seeds and invertebrates in seasonal wetlands and on harvested and unharvested, flooded or unflooded, grain crops. The exception was Gadwall. Although we included Gadwall in the dabbling foraging guild when generating population objectives in Chapter 2, their feeding habitats are similar to coots, both feeding almost exclusively on leafy plant material in permanent wetlands. Thus, we required that 100% of their daily energy needs be met by feeding on leafy vegetation from the 1 September to the 1 November period. During that period, we modeled them separately from other dabblers. After 1 November, we allowed Gadwall to feed on the same foods as other dabblers and included them in the larger dabbling duck

guild. Gadwall were a small fraction of the dabbling guild in general, particularly in winter (Figures 2-11, 2-12).

The extent we required each guild to meet their energy needs on the refuges varied. We required diving ducks, swans, and coots to meet 100% of their needs on refuge for every model. Similarly, we required Gadwall to meet 100% of their needs on refuge up to 1 November. All species of geese and most species of dabbling duck will feed on surrounding private lands, but the extent they require private lands to meet their needs was unknown. We required that geese and dabbling ducks meet from 75-100% of their daily energy needs on refuge. Our decision to use 75% as a minimum reflected a desire by refuge staff to reduce private crop and pasture depredation and provide a higher proportion of the spring diet from refuge habitats.

Model Simulations

We first used TRUOMET to run two models for each refuge: Model 1) current habitat conditions and recent waterfowl populations and Model 2) current habitat conditions and waterfowl population objectives outlined in Chapter 2. We then evaluated five additional models (Models 3-8) that represented several potential management alternatives designed to alleviate food resource deficits identified in Model 2. Because each refuge operates under a unique set of guidelines and infrastructure, we created unique alternative management scenarios for each refuge.

Model 1: Current Conditions

Our first set of simulations compared energy supply based on habitat composition in 2005 and demand based on mean waterfowl population size from surveys conducted 1990-1999. We required all foraging guilds to meet 100% of their daily energy needs from refuge food sources. These simulations provided insight into how well TLNWR and LKNWR can meet the needs of current waterfowl populations in isolation of surrounding private lands.

Outcome.-- Lower Klamath provides enough energy to meet the demands of current diving duck and swan populations (Figure 4-1). Supply exceeded demand considerably all the way through mid-April suggesting additional birds could be

supported; this is consistent with the increasing trend in diver and swan abundance since the 1970s. Carrying-capacity was sufficient despite the fact our estimate of food abundance was likely conservative because we did not allow swans to forage in flooded agricultural fields. Refuge staff have observed this behavior in January and February. Foods for geese were close to meeting fall and winter needs, but were insufficient to meet the large goose populations stopping in the region during spring migration (Figure 4-2). Dabbler foods are exhausted by early March, but come fairly close to meeting current population needs (Figure 4-3). Food was sufficient for coots and Gadwall from the 1 September to 1 November period (Figures 4-4 and 4-5). Considering we required birds to meet 100% of their daily energy demands on-refuges, an assumption that is surely false for many dabblers and geese, habitats at Lower Klamath NWR appear to be meeting the energy needs of current waterfowl populations.

Unlike LKNWR, energy supplies at TLNWR for diving ducks and swans were exhausted by mid-February (Figure 4-6) and food supplies for dabbling ducks run out earlier than LKNWR, being exhausted by early December (Figure 4-8). The relatively poor dabbler habitat at TLNWR compared to LKNWR is consistent with declines in dabbler abundance at TLNWR since the 1970s while dabbler populations at LKNWR have remained steady (Chapter 2). Like LKNWR, food supplies for geese largely meet population demands in fall and winter, but were insufficient to meet spring needs (Figure 4-7). Food resources for Gadwall and coots are sufficient to support current populations through 1 November (Figures 4-9 and 4-10).

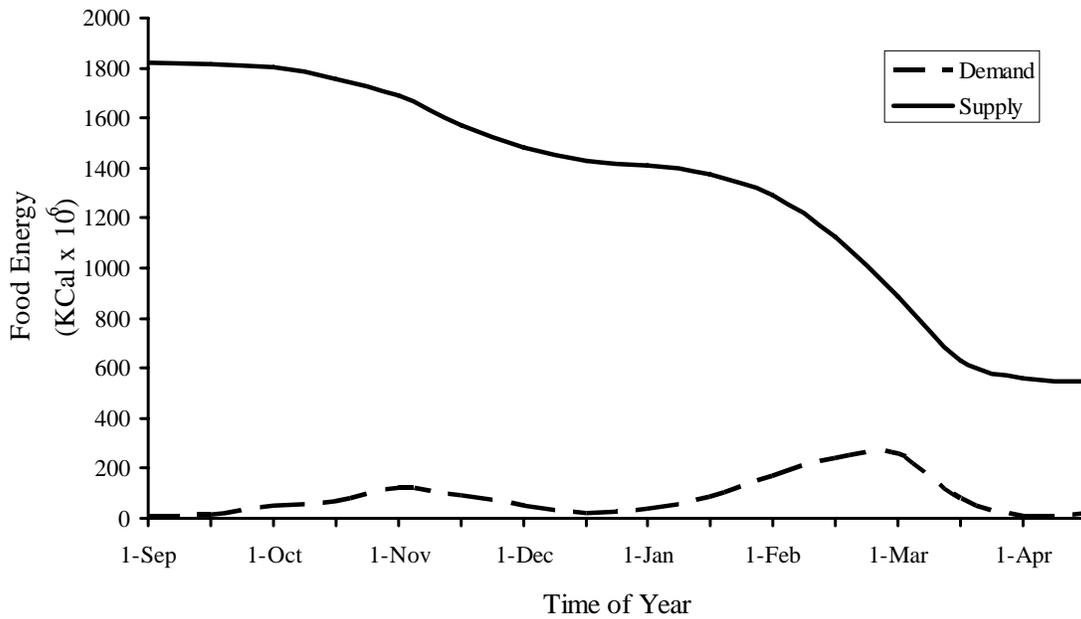


Figure 4-1. Population energy demand vs. food energy supplies for diving ducks and swans (mean 1990s populations) at LKNWR under simulated 2005 habitat conditions.

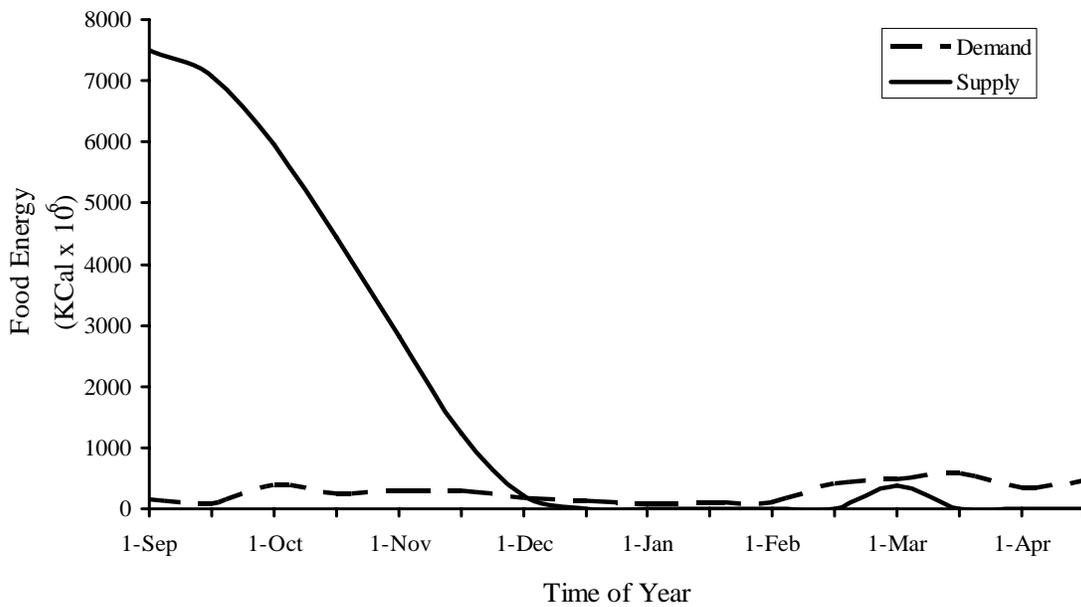


Figure 4-2. Population energy demand vs. food energy supplies for geese (mean 1990s populations) at LKNWR under simulated 2005 habitat conditions.

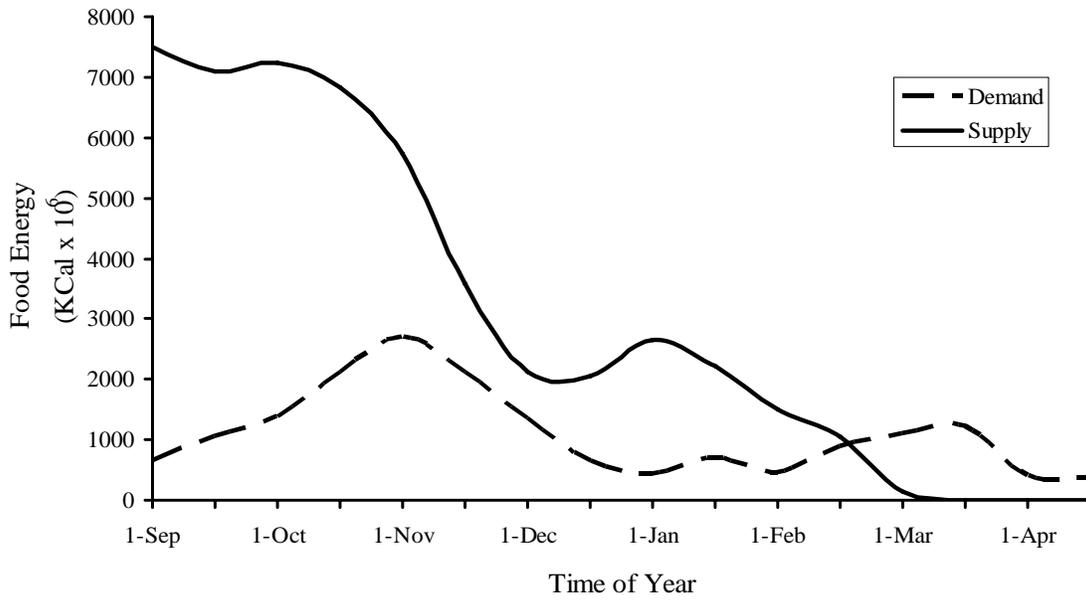


Figure 4-3. Population energy demand vs. food energy supplies for dabbling ducks (mean 1990s populations) at LKNWR under simulated 2005 habitat conditions.

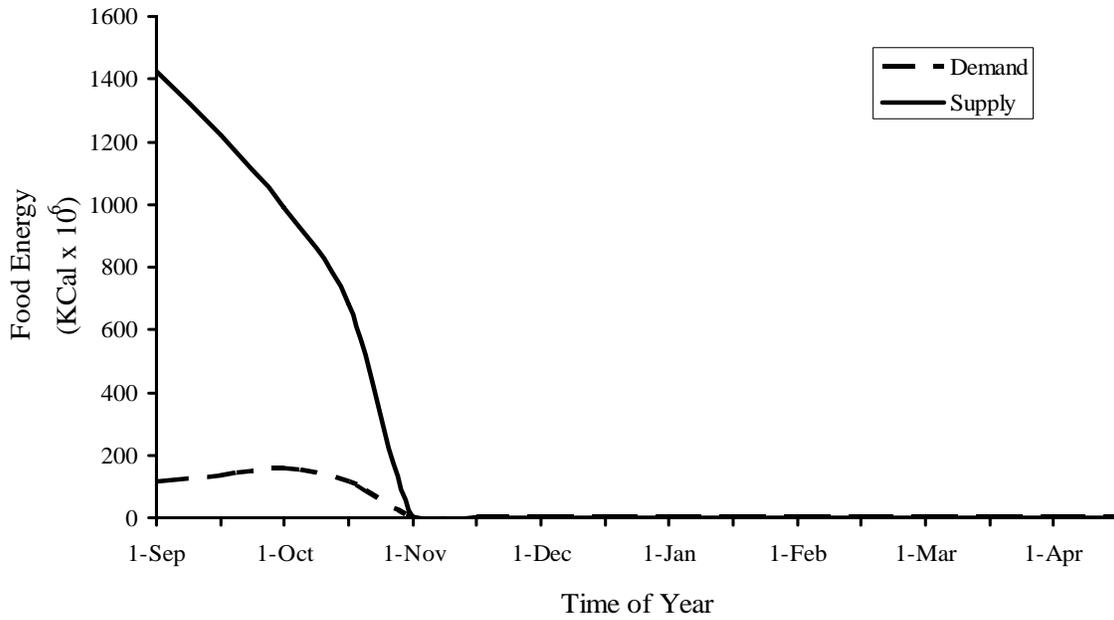


Figure 4-4. Population energy demand vs. food energy supplies for gadwall (mean 1990's populations) at LKNWR under simulated 2005 habitat conditions.

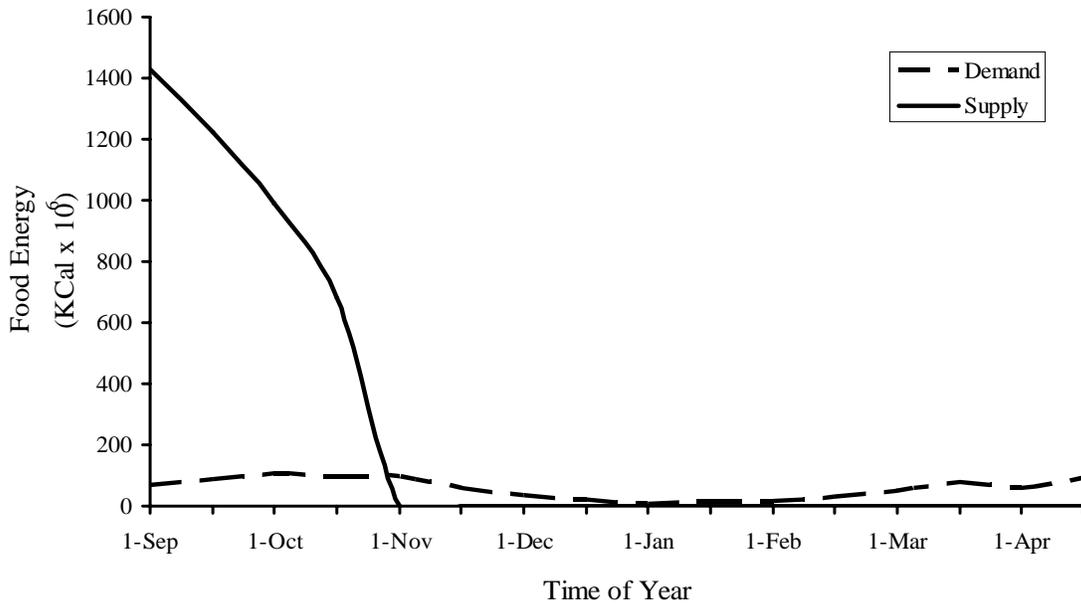


Figure 4-5. Population energy demand vs. food energy supplies for coots (mean 1990's populations) at LKNWR under simulated 2005 habitat conditions.

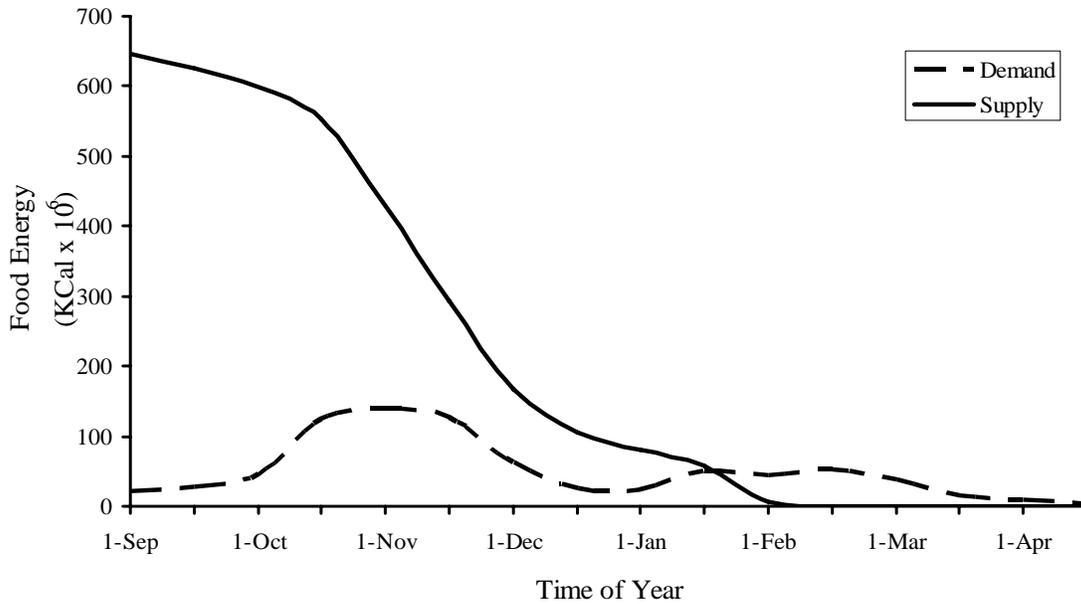


Figure 4-6. Population energy demand vs. food energy supplies for diving ducks and swans (mean 1990's populations) at TLNWR under simulated 2005 habitat conditions.

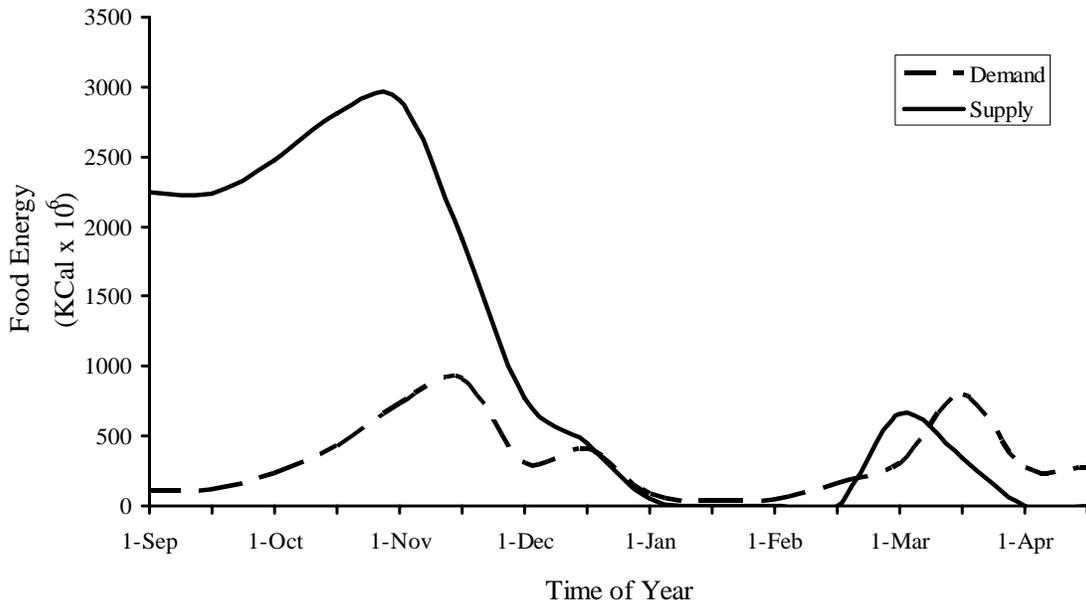


Figure 4-7. Population energy demand vs. food energy supplies for geese (mean 1990's populations) at TLNWR under simulated 2005 habitat conditions.

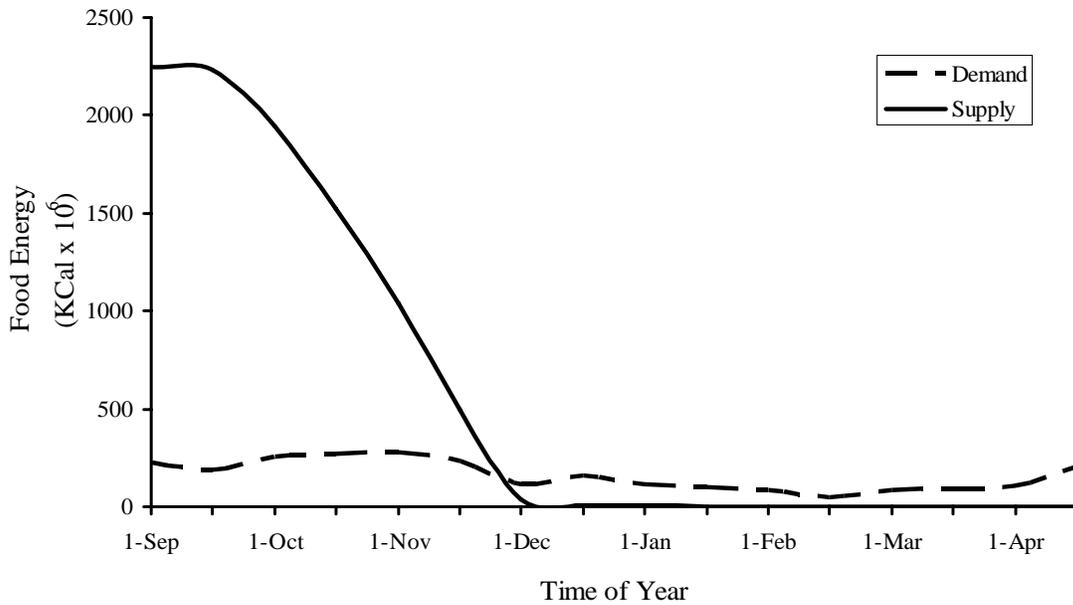


Figure 4-8. Population energy demand vs. food energy supplies for dabbling ducks (mean 1990's populations) at TLNWR under simulated 2005 habitat conditions.

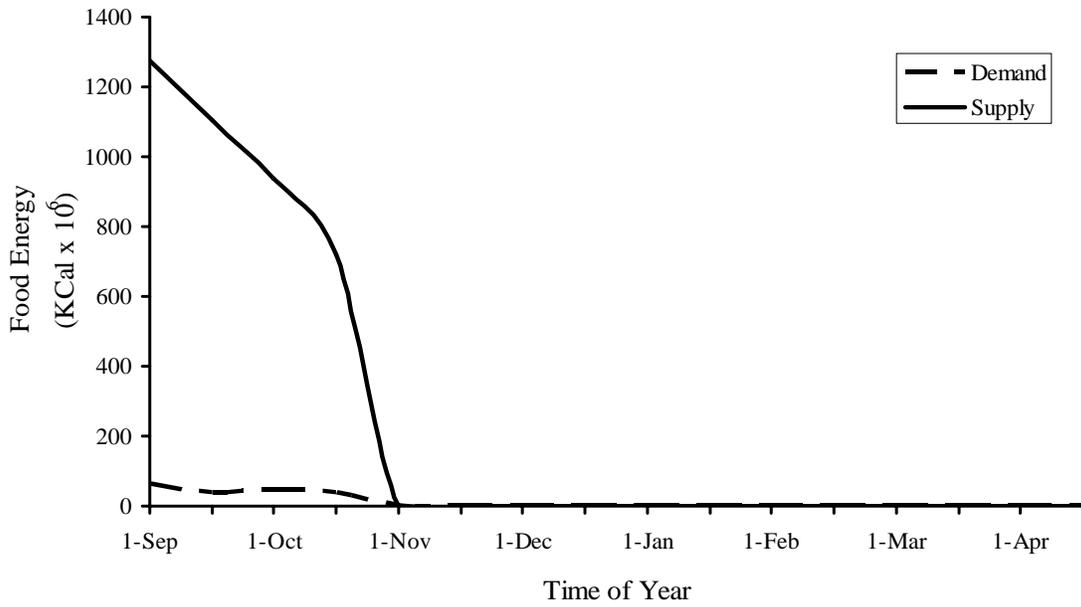


Figure 4-9. Population energy demand vs. food energy supplies for gadwall (mean 1990's populations) at TLNWR under simulated 2005 habitat conditions.

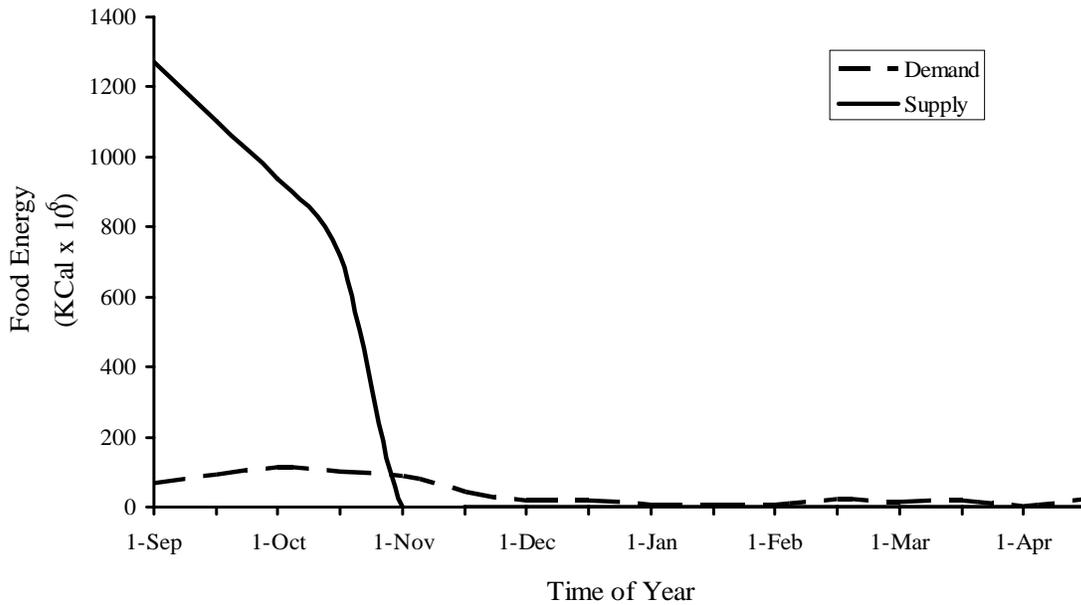


Figure 4-10. Population energy demand vs. food energy supplies for coots (mean 1990's populations) at TLNWR under simulated 2005 habitat conditions.

Model 2: Ability to Meet Waterfowl Population Objectives

Our second set of simulations examined how well existing habitat conditions at TLNWR and LKNWR could meet waterfowl needs given refuge population objectives established in Chapter 2. Rather than use the mean population count like scenario one, we used the 75th percentile, a more conservative number that recognized the desire of the refuge to meet bird needs in greater than 50% of years. This scenario also allowed 25% of goose and dabbling energy needs to be met off refuge.

Outcome.-- Scenario 2 indicated deficiencies in energy supplies for one or more taxa at each refuge. Current habitats at LKNWR provided sufficient food energy to meet population objectives for swans and divers (Figure 4-11) and dabbling ducks (Figure 4-12) all season and gadwall (Figure 4-13) and coots (Figure 4-14) from 1 September to 1 November. However, LKNWR could not support goose population objectives, being exhausted prior to the March 1 interval, 6 weeks before the end of our modeling window (Figure 4-15).

At TLNWR, food resources were adequate to meet the energy needs of diving ducks and swans (Figure 4-16) and gadwall (Figure 4-17) and, but were insufficient to meet the needs of dabbling ducks (Figure 4-18), and geese (Figure 4-19). Dabbling foods were exhausted early in fall, before traditional peak migration in November. Goose needs were met through most of fall and winter but not spring. Although leafy vegetation met coot needs prior to 1 November at TLNWR (Figure 4-20), survey data indicate coots persist at both Tule Lake and Lower Klamath longer than would be predicted. This may reflect persistence of submerged aquatic vegetation beyond 1 November or coot use of other food sources.

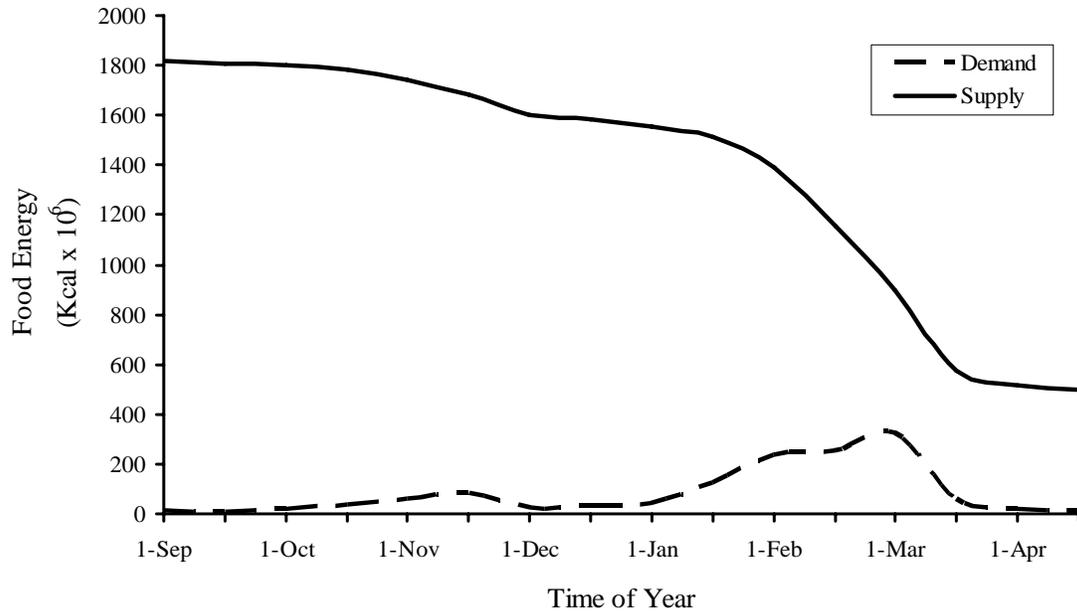


Figure 4-11. Population energy demand vs. food energy supplies (simulated 2005 habitats) for diving ducks and swans at LKNWR relative to refuge population objectives.

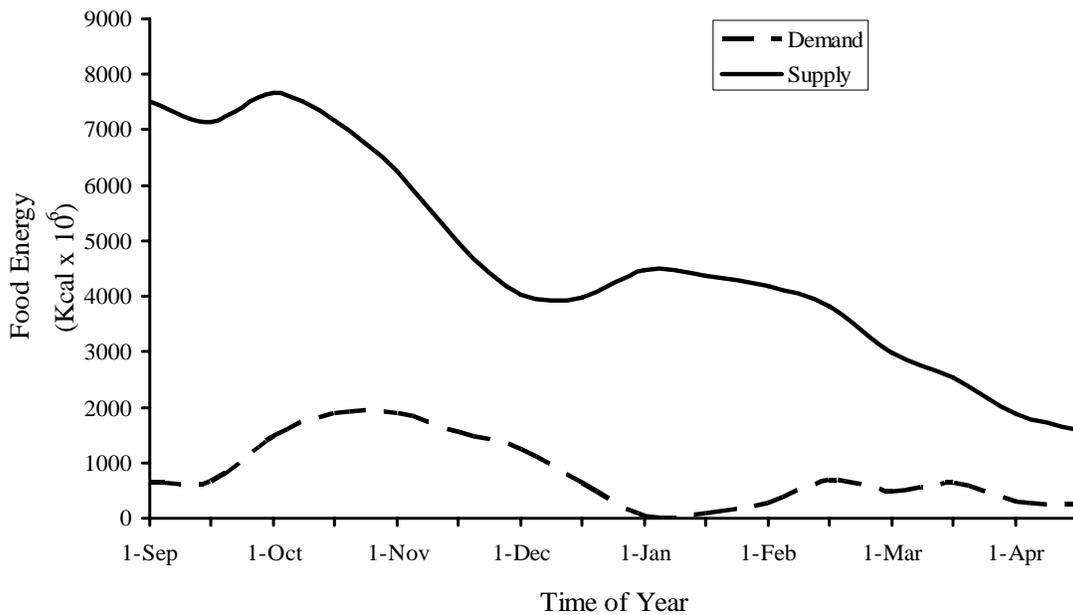


Figure 4-12. Population energy demand vs. food energy supplies (simulated 2005 habitats) for dabbling ducks at LKNWR relative to refuge population objectives.

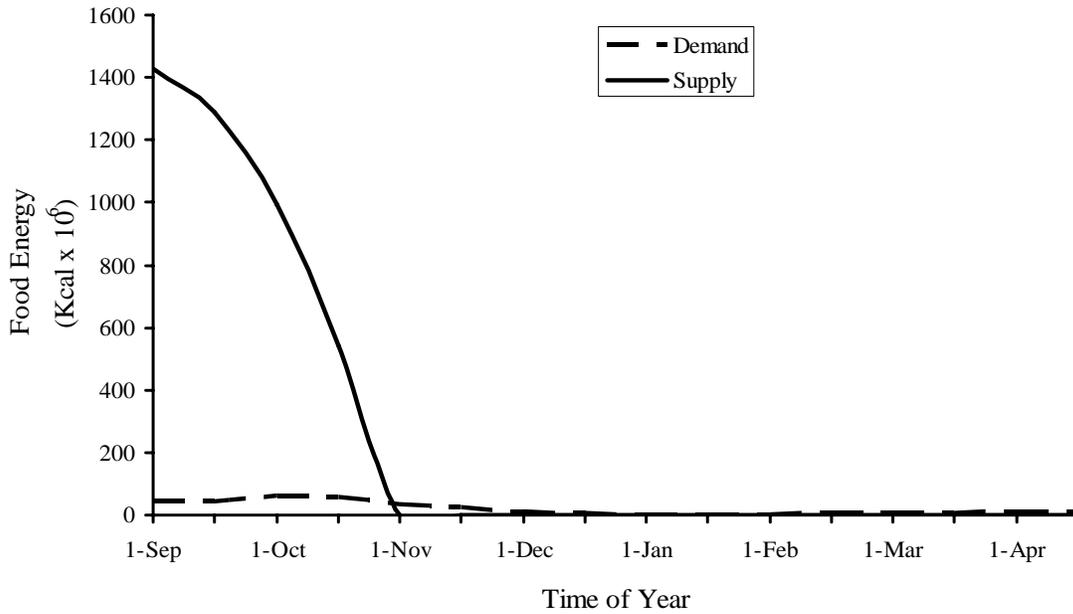


Figure 4-13. Population energy demand vs. food energy supplies (simulated 2005 habitats) for gadwall at LKNWR relative to refuge population objectives.

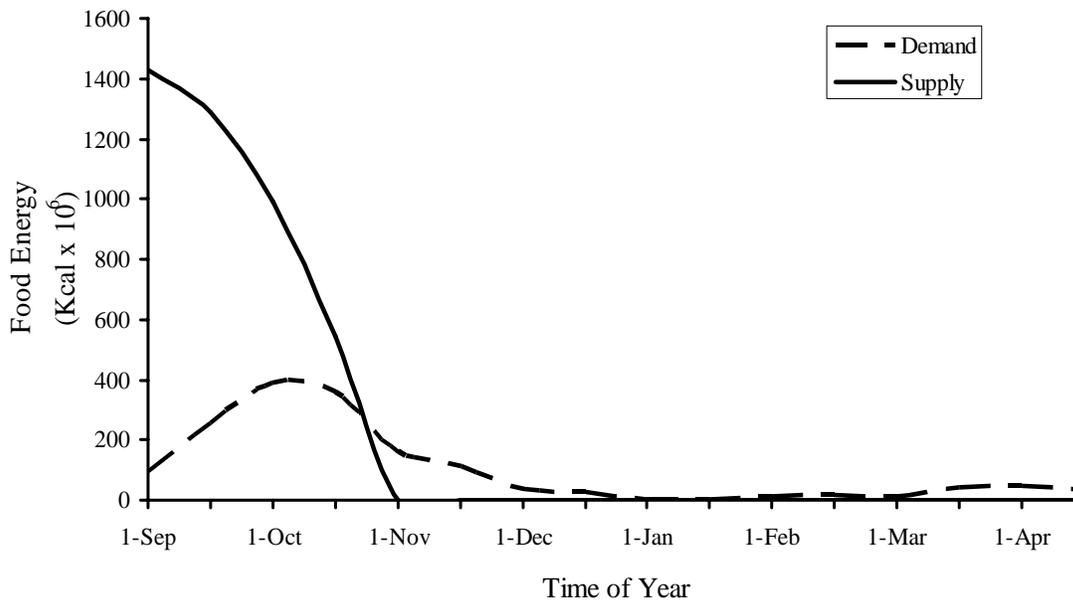


Figure 4-14. Population energy demand vs. food energy supplies (simulated 2005 habitats) for coots at LKNWR relative to refuge population objectives.

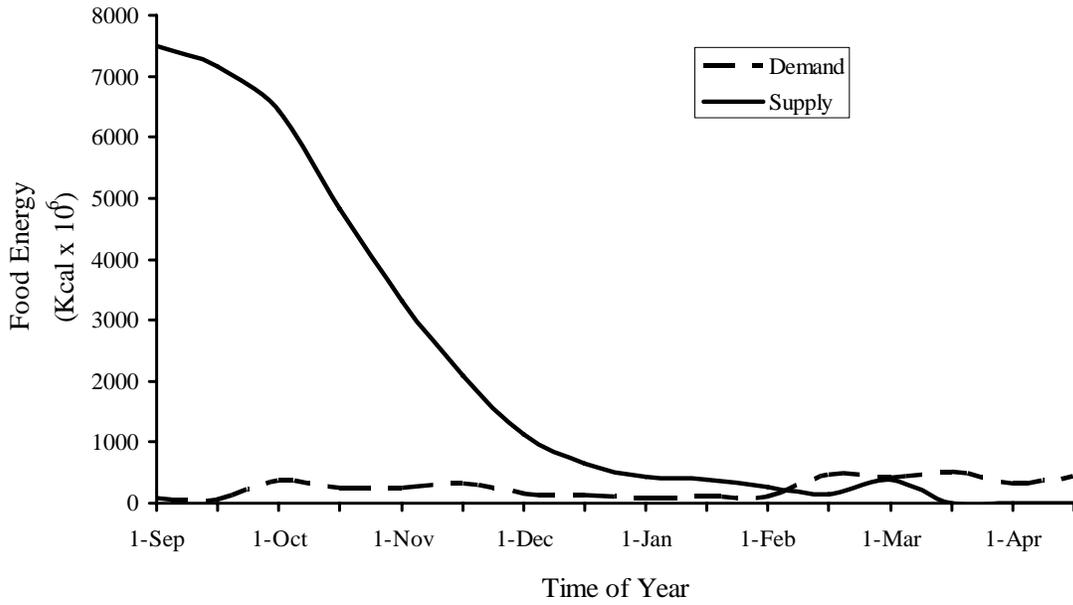


Figure 4-15. Population energy demand vs. food energy supplies (simulated 2005 habitats) for geese at LKNWR relative to refuge population objectives.

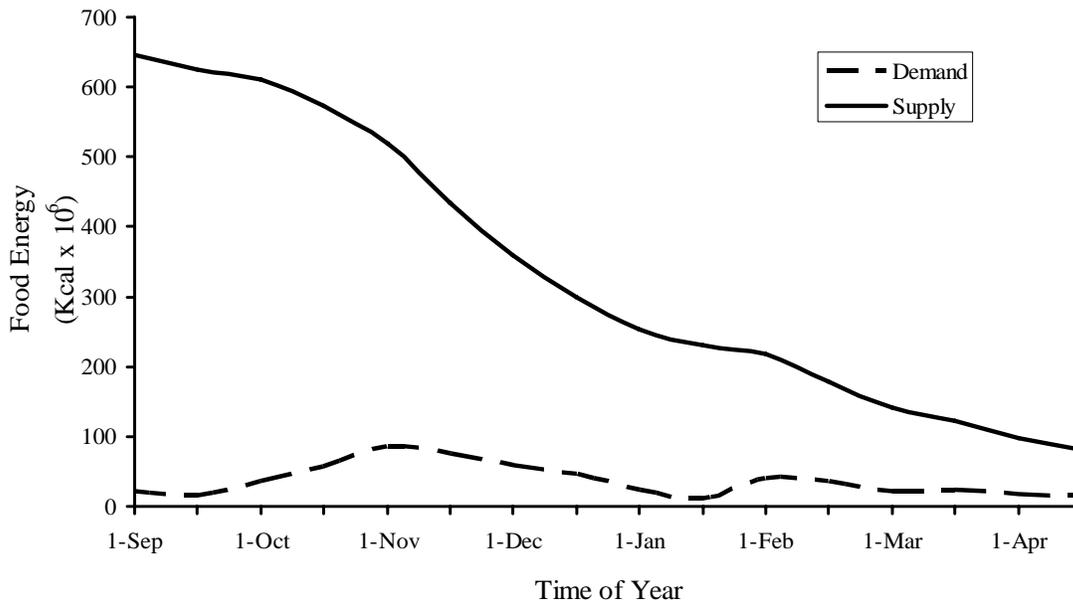


Figure 4-16. Population energy demand vs. food energy supplies (simulated 2005 habitats) for diving ducks and swans at TLNWR relative to refuge population objectives.

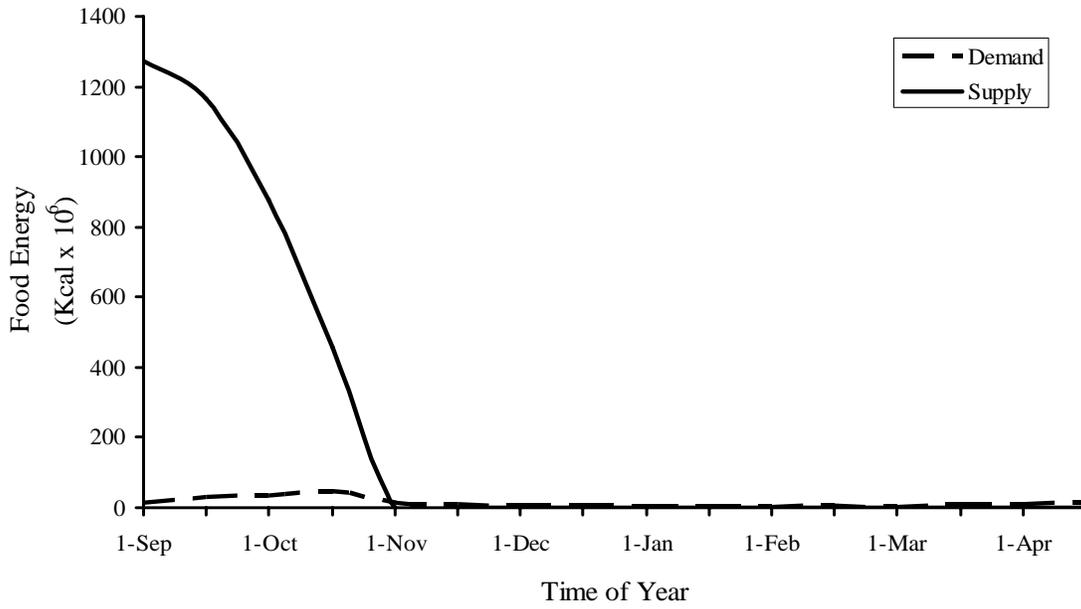


Figure 4-17. Population energy demand vs. food energy supplies (simulated 2005 habitats) for gadwall at TLNWR relative to refuge population objectives.

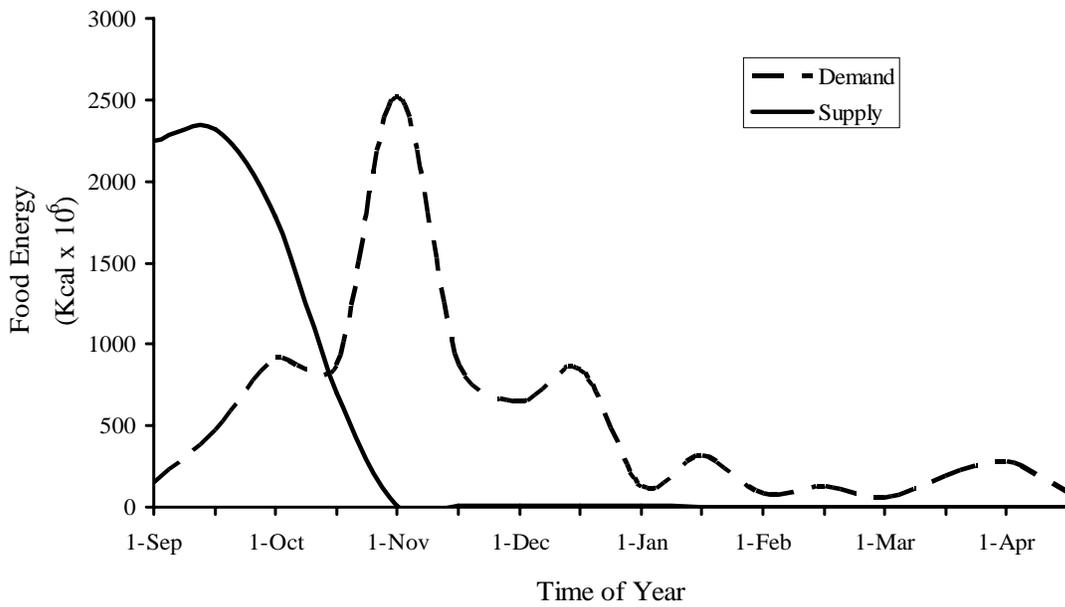


Figure 4-18. Population energy demand vs. food energy supplies (simulated 2005 habitats) for dabbling ducks at TLNWR relative to refuge population objectives.

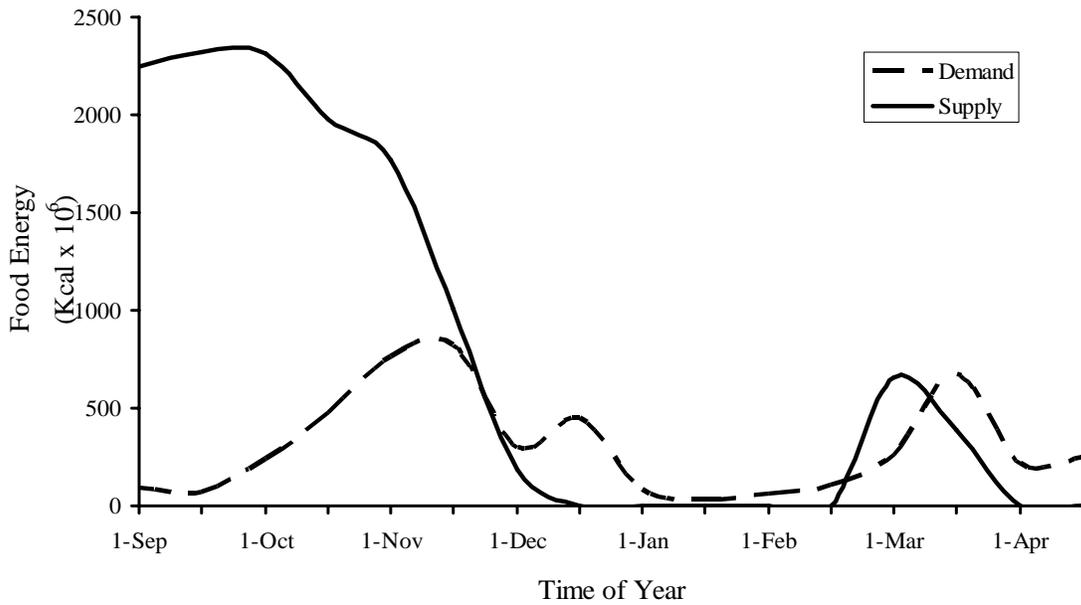


Figure 4-19. Population energy demand vs. food energy supplies (simulated 2005 habitats) for geese at TLNWR relative to refuge population objectives.

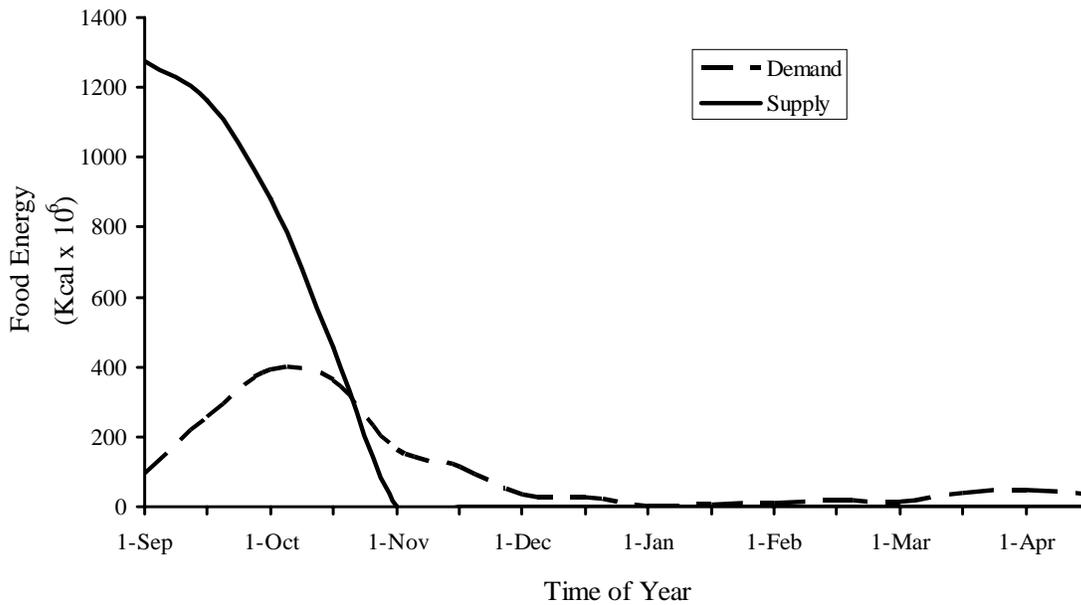


Figure 4-20. Population energy demand vs. food energy supplies (simulated 2005 habitats) for coots at TLNWR relative to refuge population objectives.

Model 3: Meeting LKNWR goose needs

Food supplies for geese at LKNWR were adequate until late winter (Figure 4-15). We asked how many additional acres of unharvested grain and green browse would be needed to meet goose energy demands on LKNWR? Increasing unharvested grain is the most land-efficient option for increasing food for geese in fall and winter (greatest energy gain for least amount of land) while increasing green browse improves foraging conditions for geese in spring, the period when food is currently most limiting. In essence, this scenario reflects a modification in the refuge farming program that left more standing grain and increased acreage of alfalfa or pasture. To answer this question, we incrementally increased the acreage of unharvested grain to meeting winter energy needs and green browse to meet spring energy needs. These increases were offset by a reduction in the amount of harvested grain. In this scenario, acres devoted to wetland habitats were not changed, protecting those acres for waterbirds dependent on wetlands. Altering the ratio of harvested and unharvested grain affects dabbling ducks because they utilize these habitats as well. Therefore, we modeled the affect of this scenario on both dabblers and geese.

Outcome.-- To meet goose energy needs in winter and spring, unharvested grain acreage would need to expand from 1,000 to 1,500 acres and green browse would need to increase from 2,000 to 4,000 acres (Figure 4-21). This results in a reduction of harvestable acres from 6,500 to 4,000. This scenario also increases dabbler energy supply considerably above projected need (Figure 4-22).

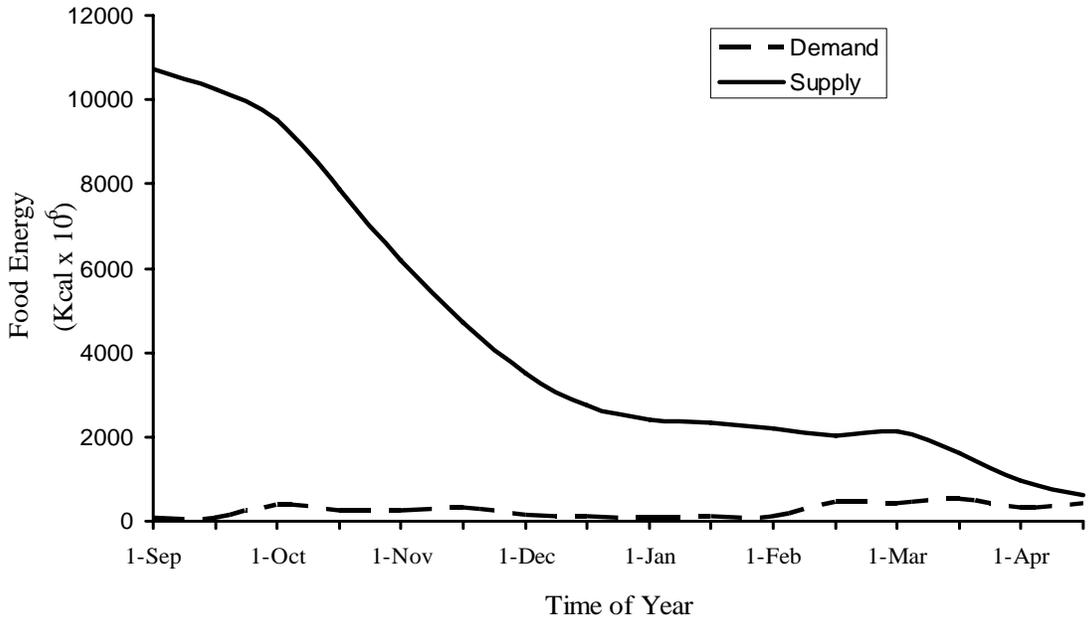


Figure 4-21. Population energy demand vs. food energy supplies for geese at LKNWR after increasing standing grain by 500 acres and green browse by 2,000 acres.

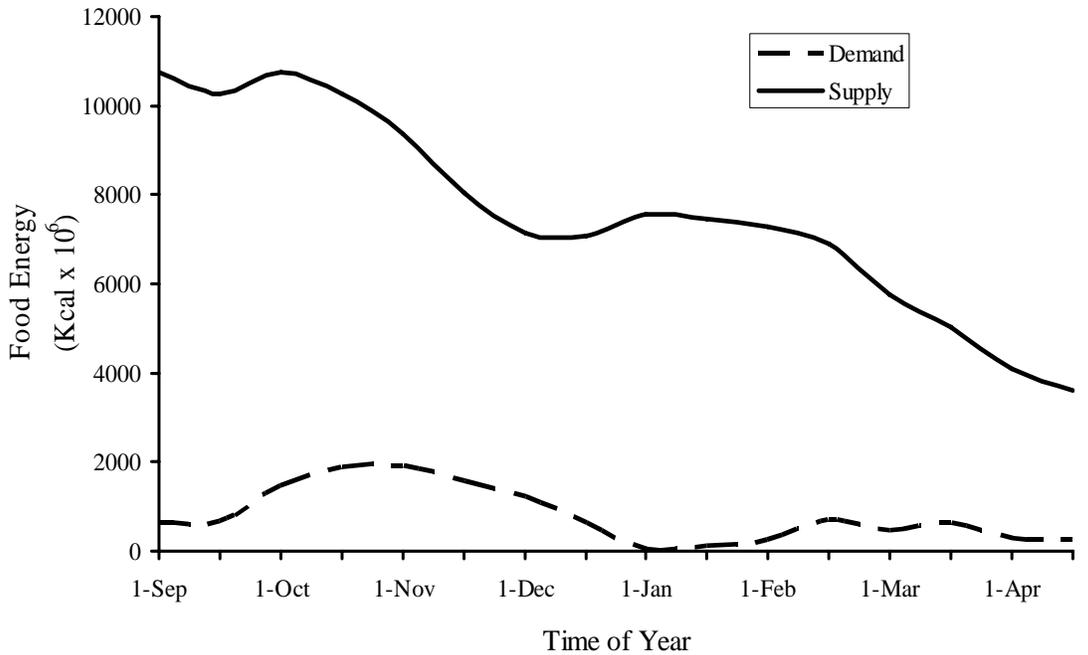


Figure 4-22. Population energy demand vs. food energy supplies for dabbling ducks at LKNWR after increasing standing grain by 500 acres and green browse by 2,000 acres.

Model 4: The “Big Pond” (LKNWR)

Our current conditions model assumed that flooding of seasonal wetlands began in early September and progressed until all wetlands were full by 1 January. This pattern represents the historic management hydroperiod at LKNWR. However, chronic water shortages during summer and fall during the last 15 years have made this flooding schedule increasingly difficult to achieve. In an effort to deal with the possibility of long-term shortages in water availability during summer and early fall, the Refuge is exploring ways to capture water during winter and early spring, a time when water is typically in abundance.

One alternative, called the Big Pond Scenario (BPS), would create a 13,000 acre unit on the southern one-half of the Refuge. Management would focus on capturing water in winter and spring to fill the unit and allow levels to gradually recede during the summer and fall, essentially mimicking conditions on historic Lower Klamath Lake. It would require approximately 50,000 to 70,000 acre-feet of water to “fill” the unit and water depths would range from seven feet to inches at the margins. Preliminary hydrologic analysis indicates there is sufficient water in most years to fill the Big Pond. Even with no water deliveries in summer, the area would support large numbers of colonial nesting waterbirds as well as molting and breeding waterfowl. It is expected that approximately one-half of the surface area of the “Big Pond” would remain flooded during fall migration. Similar management on smaller areas of Lower Klamath NWR has provided an impressive habitat response and high waterbird use.

We used TRUOMET to understand the consequences of the BPS to foraging waterfowl by altering the composition of wetland habitat types on LKNWR. First we had to assign the 13,000 acres associated with the BPS to wetland categories. The hydroperiod for the BPS assumes that half (6,500 acres) of the BP draws down naturally between May and November as a result of evapotranspiration. Thus, we classified half of the BP as a seasonal wetland and the remaining half as permanent wetland. Half of the seasonal wetland component (3,250 acres) would occur at elevations high enough for moist soil plants to germinate and mature (i.e., water would draw down early enough). For these acres, we used food density equal to other LKNWR seasonal wetland habitats; however, because low lake levels will keep these areas dry in fall, we only made these

acres available to foraging waterfowl beginning 1 March when flooding begins. We assumed flooding progressed in a linear fashion from 1 March until the BP is full on 15 April. For the remaining 3,250 acres of the seasonal wetland portion of the BP, we set waterfowl foraging value to zero.

We did not change the number of acres dedicated to agriculture, so all changes in habitat distribution came from existing wetlands acres. The total wetland acreage on LKNWR was 25,308 acres in 2005. After allocating 13,000 to the Big Pond Unit, we allocated the remaining acreage to seasonal wetlands. The final allocation resulted in little change in seasonal wetland acres but a significant decline in permanent wetland acres (Table 4-5).

We simulated how the BPS influenced energy supplies for dabblers, gadwall, divers and swans, and coots. We did not model geese because agricultural habitats were not influenced under the BPS and geese obtain their energy from the agricultural crops. The demand curves for all waterfowl guilds were the same as the Population Objectives model (Model 2).

Table 4-5. Acres dedicated to wetland habitat types during 2005 and under the Big Pond Scenario at Lower Klamath National Wildlife Refuge, California.

Wetland type	2005	Big Pond Scenario
Permanent wetland	9,194	6,500
Seasonal wetland	16,114	15,558
No feeding value ^a	0	3,250
Total	25,308	25,308

^a The number of acres in the Big Pond Unit that will dry during summer but not produce moist soil plants

Outcome

The overall reduction in permanent wetlands under the BPS does negatively impact waterfowl guilds dependent on this habitat type. Resources for diving ducks and swans under the BPS appear to barely meet needs (Figure 4-23) while coot needs exceed refuge capacity earlier than our Population Objective model (Model 2; Figure 4-24). However, the BPS improves conditions for dabbling ducks (Figure 4-25). Delaying the availability of seasonal wetland plant foods on the Big Pond until spring does not compromise fall dabbler needs. Given this situation, delaying flooding until spring may result in higher quality spring habitats as fewer seeds will have been lost to decomposition during winter (Greer et al. 2007). Gadwall were relatively unaffected by the BPS (Figure 4-26). A summary of each model scenario and alternatives relative to LKNWR is provided in Table 4-6.

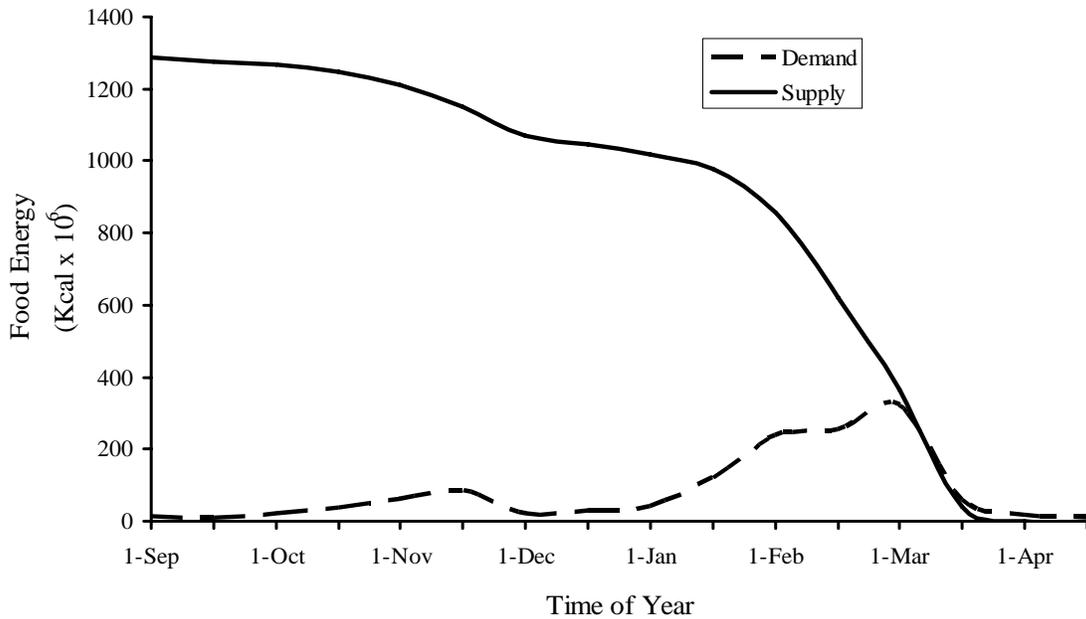


Figure 4-23. Population energy demand vs. food energy supplies for diving ducks and swans at LKNWR under habitat conditions outlined in Big Pond Scenario (Model 4).

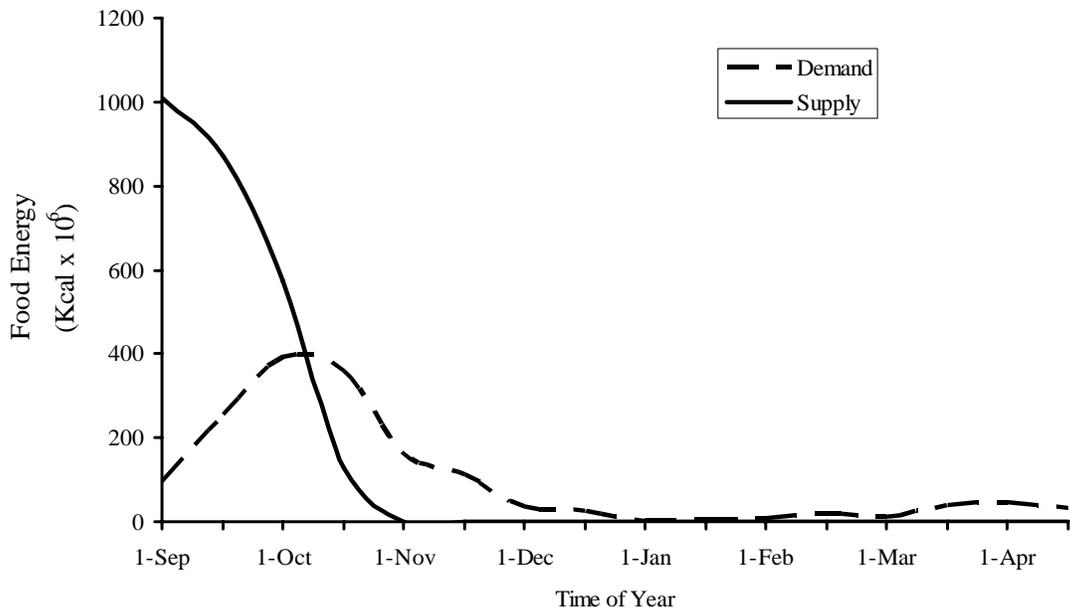


Figure 4-24. Population energy demand vs. food energy supplies for American Coots at LKNWR under habitat conditions outlined in Big Pond Scenario (Model 4).

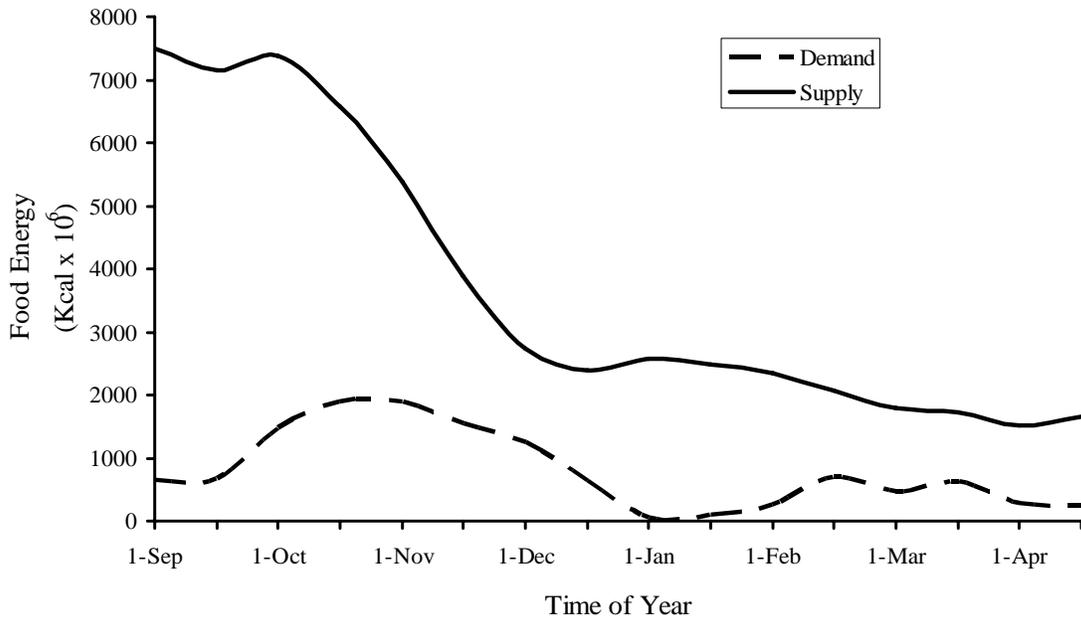


Figure 4-25. Population energy demand vs. food energy supplies for dabbling ducks at LKNWR under habitat conditions outlined in Big Pond Scenario (Model 4).

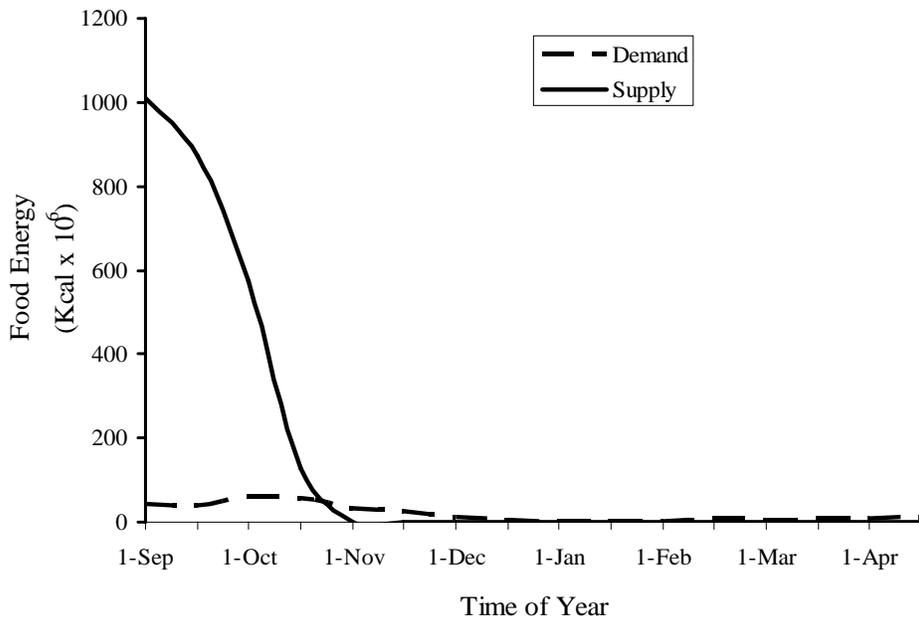


Figure 4-26. Population energy demand vs. food energy supplies for Gadwall at LKNWR under habitat conditions outlined in Big Pond Scenario (Model 4).

Model 5: Increased Standing Grain (TLNWR)

During the 1970's, TLNWR staff farmed approximately 2,000 acres of small grains. This program was intended to provide food for waterfowl and provide waterfowl depredation relief to farmers on private lands. This program was discontinued in the 1980s in favor of a program using cooperating farmers. Under this program, the farmer provided all costs of establishing a crop, harvested two-thirds of the crop, and left one-third standing for waterfowl consumption. This was deemed an acceptable change because populations of waterfowl in the Pacific Flyway (particularly geese) in the 1980s were lower than previous decades, and much of the standing grain was not used. The cooperative farming program was reduced in the 1990s. As a result of changes to the farming program, the acres in unharvested grains declined from about 2,000 acres in the 1970's to 250 acres by 2005.

Dabbling duck and goose populations at TLNWR have substantially declined since the 1970s (see Figures 2-6 and 2-7), as has the acreage of standing grains. We developed this management alternative to determine if increasing standing grain acreage to 1970s levels (2,000 acres) could support desired dabbling duck and goose population objectives.

Outcome.-- Increasing unharvested grains from 250 to 2,000 acres would allow TLNWR to meet the foraging needs of dabbling ducks (Figure 4-27) and geese (Figure 4-28). From a purely energetic standpoint, the decline in dabbling duck and goose populations since the 1970's on TLNWR may in fact be related to this reduction in unharvested grains.

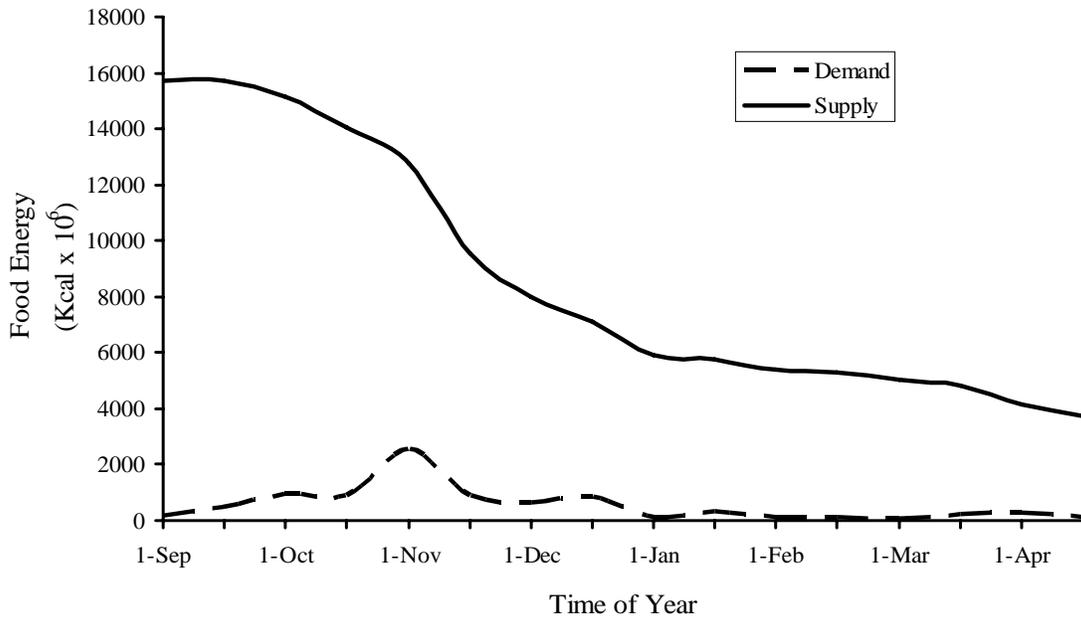


Figure 4-27. Population energy demand vs. food energy supplies for dabbling ducks at TLNWR if standing grain acreage is returned to 1970's level (Model 5).

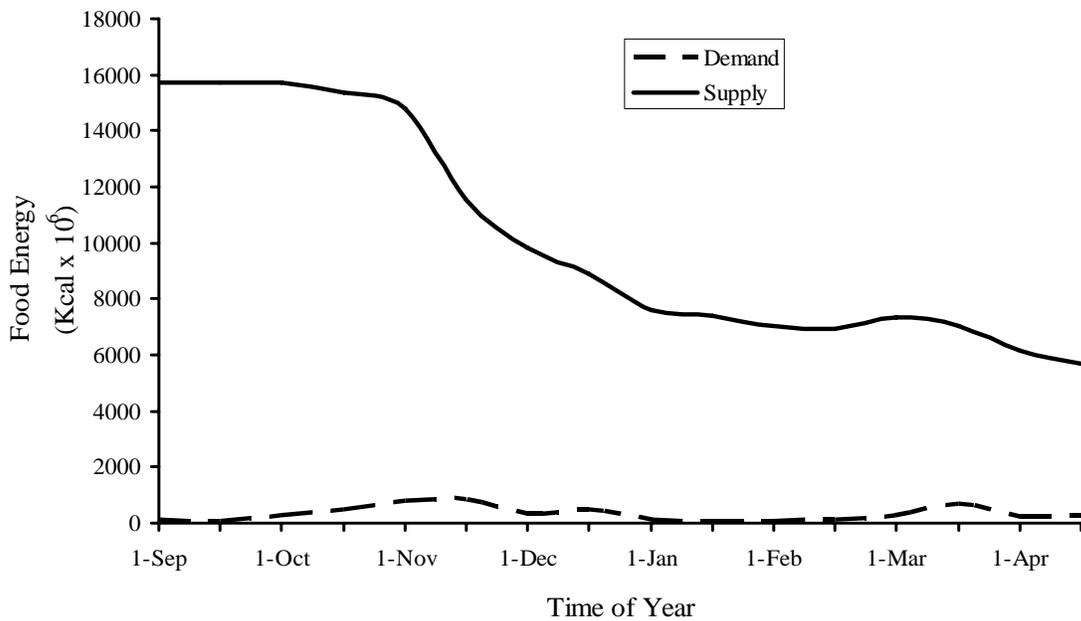


Figure 4-28. Population energy demand vs. food energy supplies for geese at TLNWR if standing grain acreage is returned to 1970's level (Model 5).

Model 6: Seasonal Wetland Emphasis (TLNWR)

The Central Valley of California has also used TRUMET to determine population objectives and habitat needs for wintering waterfowl in this critical area of the Pacific Flyway. Waterfowl managers and biologists have determined, as a goal for the Central Valley, that sufficient wetland habitats are available to meet 50% of waterfowl energy needs. Presently, waterfowl in this area make extensive use of agricultural lands, principally rice; however, it is possible that changes in agriculture policy or farm economics may reduce the acreage of this important food resource. Increasing seasonal wetlands may be desirable because wetland foods are generally more nutritionally diverse and they provide for more species of waterfowl and wetland dependent birds.

Management alternative two asked how many acres of seasonal wetland habitats would be required to meet 50% of dabbling duck energy needs at TLNWR given stated population objectives in Chapter 2. We required that 70% of this seasonal wetland acreage be allocated to early succession habitat and that dabblers meet 75% of their energy needs on refuge. To answer this question, we incrementally increased the acreage of seasonal wetlands and reduced the acres dedicated to harvested grains.

Fifty percent of dabbler energy needs were met when seasonal wetlands totaled 8,000 acres (an increase of 7,350 acres). Converting this much land to seasonal wetlands altered the ability of TLNWR to meet the energy demands for other guilds, especially geese. The refuge could meet all population objectives if the 8,471 acres of harvested grains now existing at TLNWR were converted to 7,845 acres of seasonal wetlands and 626 acres of standing grains (Table 4-7).

Model 7: Minimum Agricultural Footprint (TLNWR)

In this scenario, we altered the habitat composition on TLNWR to estimate the balance of habitat types that could meet the foraging habitat needs for each guild with the minimum amount of agricultural. There are currently 14,828 acres devoted to agriculture on TLNWR. Refuge foraging habitat objectives could still be met for all waterfowl guilds if agricultural acreage is reduced to 6,605 acres and the remaining 8,223 acres is converted to seasonal wetlands. Furthermore, the 6,605 acres of agricultural habitat

would be partitioned to 1,200 acres of standing grains and 5,405 acres of alfalfa pasture (Table 4-7).

Model 8: Minimum Standing Grain (TLNWR)

The last management alternative estimated the minimum amount of standing grain that could be grown at TLNWR while still meeting refuge foraging habitat objectives for each guild. When modeling this alternative, we held the acreage dedicated to permanent wetlands, potatoes, and alfalfa constant at current conditions. Thus, increases in unharvested grain came at the expense of seasonal wetlands and harvested grain fields.

Energy needs for all waterfowl guilds could be met if standing grains are increased to 1,504 acres. This could be achieved by converting all 155 acres of seasonal wetlands at TLNWR to standing grains and converting 1,100 acres of harvested grains to standing grains (Table 4-7).

Table 4-6. Summary of TRUOMET model runs for Lower Klamath National Wildlife Refuge.

	Model			
	Model #1 Current Conditions	Model #2 Population objectives	Model #3 Using agriculture to meet goose needs	Model #4 “Big Pond” Scenario
Goal	Determine if current management is meeting needs of current waterfowl populations.	Determine if current habitat conditions can meet population objectives established in Chapter 2.	Determine acreage of standing grain and pasture needed to achieve goose objectives.	Evaluate whether dedicating 13,000 acres of refuge to winter/spring flooding will meet waterfowl objectives.
Reliance on Refuge foods	100% for all guilds	75% for geese and dabblers 100% for remaining guilds	75% for geese and dabblers 100% for remaining guilds	75% for geese and dabblers 100% for remaining guilds
Waterfowl populations	Mean 1990s abundance for all guilds.	75 th percentile of 1970s duck and 1990s goose populations	75 th percentile of 1970s duck and 1990s goose populations	75 th percentile of 1970s duck and 1990s goose populations
Small grains	6,534 (harvested) 1,057 (unharvested)	6,534 (harvested) 1,057 (unharvested)	4,034 (harvested) 1,557 (unharvested)	6,534 (harvested) 1,057 (unharvested)
Pasture/Hay	2,018	2,018	4,018	2,018
Seasonal Wetland	4,834 (early) 11,280 (late)	4,834 (early) 11,280 (late)	4,834 (early) 11,280 (late)	3,216 (early) 9,648 (late)
gent wetland	1,939	1,939	1,939	1,300
Submergent wetland	7,355	7,355	7,355	5,200
Summarized outcome	Goose foods insufficient winter and spring	Goose foods insufficient winter and spring.	Needs of all waterfowl guilds are met.	dabblers good, increases coot deficit divers and swans sufficient

Table 4-7. Summary of TRUOMET model runs for Tule Lake National Wildlife Refuge

	Model #1 Current Conditions	Model #2 Population objectives	Model #5 Increased Grain	Model #6 Seasonal Wetlands	Model #7 Minimum Ag Footprint	Model #8 Standing Grain
Goal	Determine if current management is meeting needs of current waterfowl populations.	Determine if current habitat conditions can meet population objectives established in Chapter 2.	Verify that standing grain acreage in the 1970's supported observed waterfowl numbers.	Determine seasonal wetland acres needed to supply 50% of dabbling duck needs.	Minimize acreage of agricultural crops while meeting population objectives	Minimum standing grain required while minimally effecting current farm program.
Reliance on Refuge Foods	100% for all guilds	75% for geese 75% for dabblers 100% for others	100% of needs for all guilds met on refuge	75% geese/dabblers 100% for others	75% for geese and dabblers 100% for remaining guilds	75% for geese and dabblers 100% for remaining guilds
Waterfowl Populations	Mean 1990's all guilds.	75 th percentile of 1970s duck 1990s goose populations	Mean populations from the 1970s	75 th percentile of 1970s duck and 1990s goose populations	75 th percentile of 1970s duck and 1990s goose populations	75 th percentile of 1970s duck and 1990s goose populations
Potato acreage	2,703	2,703	2,703	2,703	0	2,703
Small grains	8,471 (harvested) 249 (unharvested)	8,471 (harvested) 249 (unharvested)	6,720 (harvested) 2,000 (unharvested)	875 (unharvested)	0 (harvested) 1,200 (unharvested)	7,370 (harvested) 1,504 (unharvested)
Alfalfa/Hay	3,405	3,405	3,405	3,405	5,405	3,405
Seasonal Wetland	0 (early) 155 (late)	0 (early) 155 (late)	0 (early) 155 (late)	5,600 (early) 2,400 (late)	5,865 (early) 2,513 (late)	0 (early) 0 (late)
Emergent/ Submergent Wetland	3,030/11,539	3,030/11,539	3,030/11,539	3,030/11,539	3,030/11,539	3,030/11,539
Summarized Outcome	Goose and dabbling food resources inadequate	Goose and dabbling foods insufficient	Needs of dabbling ducks and geese met.	8,000 acres of seasonal wetlands take from harvested grain acreage	8,223 acres ag lands converted to seasonal wetlands. Remaining acres in alfalfa/standing grain.	1,504 acres standing grain needed to meet dabbling/goose needs.

Discussion

TRUEMET

The results produced by TRUEMET are a function of model structure and parameter inputs; thus, there are two types of error inherent in any modeling exercise, conceptual (theoretical assumptions used to build the model) and empirical (the availability, precision and accuracy of data used for model inputs). Model structure was determined by the set of rules that dictated how birds foraged. We assumed: 1) birds were ideal free foragers (Fretwell 1972) and were not prevented from accessing food resources due to interference competition; 2) birds switched to alternate foods when preferred foods were depleted below some foraging threshold; 3) the functional relationships that determined population energy demand and population food energy supplies were linear; and 4) that there was no cost associated with traveling between foraging patches. In some cases, empirical work has shown these assumptions to be false (e.g., Nolet et al. 2006); however, in other cases our assumptions are valid (Arzel et al. 2007, Goss-Custard et al. 2003). Additional studies of waterfowl foraging ecology would either improve model structure or confirm the validity of our daily ration approach. However, to date there is no model that can replicate such detail for the range of species that occur on TLNWR and LKNWR.

We had empirical estimates for all key parameters except the extent that waterfowl relied on refuge energy sources to meet their daily energy needs. Our evaluation of carrying-capacity was strongly dependent on energy demand; thus, our assumption that guilds derived 75-100% of their daily energy needs from refuge foods heavily influenced model results. The largest uncertainty was for dabbling ducks and geese. When modeling large landscapes like California's Central Valley, we can reasonably assume those waterfowl groups derive 100% of their needs from the landscape being modeled. At smaller spatial scales like TLNWR and LKNWR, daily observations of birds flying off both refuges indicate this assumption is not true. Estimates of this parameter for geese and dabblers would help improve our understanding of past and current habitat conditions, but ultimately may not be necessary for

conservation planning by refuge staff, who will likely define this parameter based on refuge goals and objectives.

Modeling results can always be improved by better estimates of model inputs. However, our estimates of food abundance were reasonably precise (CV's < 20%) and our calculation of metabolizable energy reflected a composite value derived from TME estimates based on controlled feeding experiments and field sampling that estimated each plant species contribution to seed biomass. Our approach was more detailed than previous efforts in North America that have applied the mean TME for wetland plant seeds (e.g., CVJV 2006).

While we feel model inputs are reasonable, it is prudent to consider the consequences of any parameter estimate being wrong. Because all variables in the model varied with each other in a linear fashion, the impact of an error is directly proportional to the size of the error. For example, if 1,000 diving ducks each required 100 kcal of energy per day to meet their needs this equates to a population energy demand of 100,000 kcal/d. We required that diving ducks meet all their daily energy demands from refuge foods. If only 50% of this demand is met from refuge foods, then refuge energy demand is cut by half. Similarly, if true mean food densities are 25% lower than our estimates, our estimate of total energy is 25% too high. Our assumptions about the habitats used by each foraging guild will also influence our evaluation of refuge carrying capacity. Assumptions that are too restrictive and overlook habitats that provide important food resources to certain guilds will lead to underestimations of carrying capacity, while granting foraging guilds access to habitats not used will produce the opposite result. In general, we believe that the foraging guild – habitat associations described in Table 4-4 do reflect the foods eaten by each guild to meet their energy needs.

Current Conditions

Despite these caveats, results for our “current conditions” model (Model 1) are consistent with waterfowl population differences on both refuges during the 1970s versus 1990s. The decline in dabbling duck abundance at TLNWR from the 1970s to the 1990s is consistent with a drop in food abundance over that period (i.e., the loss of standing grain). In contrast, dabbling duck counts at LKNWR were stable to increasing during

this period (Figure 2-6) consistent with our modeling that showed habitats can meet current dabbler needs for most of the season (Figure 4-3).

Habitat conditions for divers and swans at LKNWR are sufficient to meet 100% of bird energy needs in all time periods, with significant food resources remaining even after birds depart in spring (Figure 4-1). This surplus in food resources is consistent with the substantial increase in diving duck (Figure 2-8a) and swan use (Figure 2-9a) of LKNWR from the 1970's to the 1990's. In contrast, habitat conditions for divers and swans at TLNWR were only able to meet 100% of bird needs until early spring by which time food resources were completely depleted (Figure 4-6). However diving duck use of TLNWR has increased since the 1970's (Figure 2-8b), while swan numbers have remained similar over this time period (Figure 2-9b). Our estimate of energy available to swans and diving ducks was conservative because we did not allow swans to forage in flooded agricultural fields or allow diving ducks to feed on benthic invertebrates. Both foraging behaviors are known to occur. If swans do meet a significant amount of their energy needs from agricultural habitats it would reduce the depletion of root and tuber food resources used by diving ducks and perhaps explain how diving duck populations have increased despite the apparent exhaustion of food resources by spring.

The explanation for low fall goose numbers at TLNWR in the 1990s seems to lie outside refuge habitat conditions. Most notably, the large number of Cackling Geese that historically used the refuge in fall during migration, now winter farther north. However, it does appear that refuge management decisions driven by lower fall goose numbers (reduced the acreage of standing grain) may have influenced dabbling duck use of TLNWR. At LKNWR, habitats meet goose needs farther into winter, but are exhausted by late winter. This in conjunction with increasing goose population size in spring explains the spring energy deficit on the refuge. Given refuge foods are insufficient to support the increasing spring goose population; we would predict that geese are increasingly relying on private lands for food, a prediction supported by recent field observations (D. Mauser).

We did not model carrying capacity for either Ruddy Ducks or scaup as we lacked information on the abundance of benthic invertebrates at both Tule Lake and Lower Klamath. Both species rely heavily on benthic invertebrates to meet their nutritional

needs. Additional field work to sample benthic invertebrate populations is needed to close these gaps.

Ability of Refuges to meet Population Objectives

Lower Klamath and Tule Lake National Wildlife Refuges provide a distinct contrast in their ability to meet population objectives for dabbling ducks. Food supplies for dabbling ducks at LKNWR are well above population energy demand from fall through spring (Figure 4-12). In contrast, food supplies at TLNWR are exhausted by early November (Figure 4-18). Dabbler use of TLNWR traditionally peaked in early November (Figure 2-6b), and the depletion of food resources by this date indicates the refuge is no longer capable of supporting dabbling duck numbers typical of the 1970s.

The difference in the ability of the two refuges to meet population objectives is reflected in the habitats they provide. Dabbling ducks at LKNWR have access to over 15,000 acres of seasonal wetlands and over 1,000 acres of standing grains (Table 4-1). Both of these habitats provide substantial food resources (Table 4-2). Additionally, these seasonal wetlands provide a greater diversity of foods and can therefore meet the dietary needs for a broader range of waterfowl and a greater number of other wetland-dependent species. In contrast, TLNWR provides less than 200 acres of seasonal wetland and less than 300 acres of standing grains (Table 4-1). Outside of permanent wetlands, much of the land base of TLNWR is devoted to harvested grains that provide relatively little food for a relatively small number of duck and waterbird species (Table 4-2).

Food resources at LKNWR were sufficient to meet goose population objectives through mid-March (Figure 4-15), while food resources at TLNWR were exhausted by mid-December (Figure 4-19). Because of their high energy-density values, acreage planted to standing grain and potatoes had the greatest impact on fall and winter geese. We assumed that green browse (alfalfa, pasture) became available as a food for geese by March 1. This provided a significant increase in energy supply at TLNWR with food resources nearly adequate to meet goose population objectives from March 1 onward (Figure 4-19). Although green browse also increased spring food resources for geese at LKNWR, food supplies remained well below population demand because insufficient acres of green browse are planted at LKNWR (Table 4-1).

Finally, both LKNWR and TLNWR can meet population objectives for diving ducks and swans from existing refuge habitats (Figures 4-11 and 4-16). Carrying capacity was higher at LKNWR despite the fact that TLNWR has 4,000 more acres of permanent wetlands than LKNWR (Table 4-1). The quality of permanent habitats at LKNWR was much higher with root and tuber biomass nearly five times greater than at TLNWR (Table 4-2) and shallower water depths that made benthic foods generally more available to swans. This result indicates that rehabilitation of permanent wetland habitats at TLNWR (i.e., drawing down sump 1a) has considerable potential to change carrying capacity for diving ducks in the Klamath Basin.

Management Alternatives

We used our model to evaluate several possible management alternatives to address food deficiencies identified in Model 2. Our suite of alternative models indicated there are likely many possible alternate habitat arrangements that can meet waterfowl food needs. Our suite of models was not exhaustive; but was developed to illustrate how a wide range of different management approaches might alleviate identified foraging deficiencies on TLNWR and LKNWR. In addition, we modeled one potential approach (Big Pond Scenario) that could reduce LKNWR's reliance on summer and early fall water deliveries. We organize the remaining discussion around two central topics, agriculture and water.

Agriculture.-- The most efficient way to increase energy supply on both refuges (i.e., most kcal/acre) to meet the energy needs of dabbling ducks and geese is to increase the amount of standing (unharvested) grain. Converting lands from harvested to unharvested grain fields provides refuge staff with flexibility when thinking about alternate habitat scenarios because the very high energy yields of unharvested crops allows a large number of previously harvested acres to be potentially converted to other more diverse or food rich habitats. For example, the refuge could meet its dabbling duck and goose needs at LKNWR by converting 2,500 acres of harvested grain to 500 acres of standing grain, leaving the remaining 2,000 for other uses (Figure 4-22).

However, agricultural grains lack essential amino acids provided by natural foods and relatively few waterfowl species consume grain, so refuge staff may consider

providing waterfowl with a better balance of natural and agricultural foods, particularly on TLNWR. Converting 7,845 acres of the 8,471 acres of harvested grain fields now present at TLNWR to seasonal wetlands would allow the refuge to provide 50% of dabbler energy needs from natural food resources (Model 6). However, it would also require that all remaining acres of harvested grain fields be converted to standing grain. In essence, this management alternative would eliminate the harvesting of grain crops at TLNWR. Other alternatives could include converting some permanent wetlands to seasonal wetlands. This option is feasible if the quality of permanent wetlands on TLNWR can be improved to meet the needs of diving ducks, swans, and coots.

The amount of food provided by harvested grains at both Tule Lake and Lower Klamath is low (Table 4-1, Table 4-2). Estimates of waste grain abundance in harvested fields on both refuges are from the 1980s and are low compared to work elsewhere (Miller et al. 1989). However, recent work in the Midwest indicates that waste rice (Stafford et al. 2006) and corn (Krapu et al. 2004) available to waterfowl in agricultural fields has significantly declined since 1980. Given the prominence of the agriculture program on both LKNWR and TLNWR, and the sensitivity of model output to estimates of food biomass, the refuge complex has initiated a study to resample waste grain and green browse abundance that is scheduled to begin in spring 2008.

Agriculture is most prominent at TLNWR; occupying 50% of the refuge's approximately 30,000 acres (most of the remaining area is permanent wetlands). In theory, most waterfowl foraging guilds could be sustained solely using wetland habitats. Consequently, one of our alternate models (Model 7) asked the question "what is the minimum amount of TLNWR land that must be devoted to agriculture to meet population objectives for all foraging guilds (with the exception of geese)?" Results indicated that agricultural lands could be reduced from 15,000 acres to 6,600 with agricultural lands partitioned as 1,200 acres of unharvested grains and 5,400 acres of green browse. The balance of lands formally dedicated to agriculture (8,400 acres) would need to be converted to seasonal wetlands. In general, an increase in acres dedicated to green browse is needed to meet the energy needs of geese in spring.

Water availability.-- Potential water shortages in the Klamath Basin now pose the greatest threat to traditional management practices at LKNWR. Shortages are most likely

in summer and early fall and can reduce the summer water deliveries needed to maintain permanent wetland habitats, and delay the flooding of seasonal wetlands that typically begins in September. Variation in food production among habitat types provides one option for dealing with potential water shortages.

Sampling wetland habitats revealed considerable variation in seed biomass between our early and late successional seasonal wetlands and in tuber production between permanent wetlands on TLNWR and LKNWR (Chapter 3). Early successional seasonal wetlands are relatively more important to foraging waterfowl than late successional habitats because they produce more, higher quality seed. Similarly, permanent wetlands at LKNWR produced greater tuber biomass. Both results indicate that more intensive management can improve food production in natural wetlands without increasing the acreage dedicated to those habitats. At TLNWR, Sump 1A has been permanently flooded for decades. Wetland productivity declines under years of static flooding regimes. Submerged aquatic vegetation production would be improved by drawing down the sump, which would dry and consolidate the soils. A drawdown was performed on Sump 1B in 2002 and this did result in improved stands of sago pond weed following flooding in 2003 (D. Mauser pers. obs.). In addition, in the spring when soils were exposed, moist-soil plants produced large quantities of high quality seeds in 2002 (Chapter 3).

Increasing management emphasis on early successional wetlands is more intensive and may require additional staff, equipment, and fuel. Our models did not include cost functions that could be used to identify management scenarios that balance costs with biological function (Rashford et al. 2008). However, proposed expansion of the refuge's Walking Wetlands Program may create the opportunity for expansion of seasonal wetland habitat without significant changes in refuge operating costs.

Traditionally, most seasonal wetlands are flooded starting in early fall. This corresponds to a period when water supplies in the Klamath Basin are often limited. Incurring additional costs to maintain these wetlands in an early succession stage may still be attractive if it reduces the acres of seasonal wetlands needed to meet bird energy needs, and thus the amount of water needed to achieve objectives. Alternatively, Model 2 indicated that food availability far surpasses bird energy needs early in the season. This

suggests it may be possible to delay flooding of some seasonal wetlands until winter without significantly reducing the refuges ability (mostly at LKNWR) to support fall migrating waterfowl. Giving priority to flooding early successional wetlands in early fall would provide the most food for a given amount of water.

Permanent wetlands require water inflows during most months of the year. This habitat type is important to all guilds of waterfowl, but most important to swans, diving ducks, and coots that use this habitat extensively for foraging. Permanent wetlands are also critical to breeding wetland birds. Our sampling of submerged aquatic vegetation on TLNWR suggests it may be possible to reduce the total acres of permanent wetlands needed, thereby saving water, by managing for high quality permanent wetlands like those occurring at LKNWR. However, given the needs of other wetland birds, particularly species that breed in the Klamath Basin, this may not be desirable.

Alternately, the refuge is exploring options to capture water in winter and early spring, when water supplies in the Klamath Project area are generally not limited, by increasing the total acres dedicated to permanent wetlands at LKNWR. This thinking was the basis for Model 4, “The Big Pond Scenario (BPS)”. The BPS would convert 25% of all seasonal wetlands to permanent wetlands, resulting in a total of 13,000 acres when the BP was full. Even if this wetland received no summer water deliveries, approximately half of the 13,000 acres is expected to contain water through summer and fall. The creation of a larger lake may increase the likelihood of providing reliable breeding habitat for colonial waterbirds like American White Pelican, Double-crested Cormorants and Caspian Terns.

Our analysis indicates the BPS may represent an alternative management strategy for meeting waterfowl population objectives if long-term solutions are not found to alleviate summer and early fall water shortages. Converting seasonal wetlands to permanent wetlands will reduce foods for dabbling ducks; however, food resources at LKNWR still appear sufficient to meet population objectives for dabbling ducks because of an existing surplus in dabbling foods. In contrast, the increase in permanent wetlands achieved under the Big Pond alternative actually lowered foods available to diving ducks and swans (but foods were still sufficient to meet the needs of these divers and swans). This resulted from much of the Big Pond’s substrate being exposed on an annual basis

through evaporation, and a subsequent reduction in the submerged aquatic plant communities used by divers and swans. This may be mitigated if some water is available during the irrigation season to offset evapotranspiration. Our analysis of the BPS scenario did not consider water depth. Creation of a much larger lake will create areas of deeper water than currently exist on LKNWR. The growth of submerged aquatic plants generally declines when water depths exceed 1 m and diving ducks and swans may have a more difficult time accessing plant tubers in deeper water.

Our evaluation of current conditions and management alternatives provides insight into how wetland and agricultural habitats can be used to meet waterfowl needs. We recognize that our alternatives are not exhaustive and that there are physical, biological, and legal constraints associated with potential implementation. For example, current water delivery priorities for both refuges are low relative to other water uses in the Klamath Project. In addition, legislation, particularly Public Law 88-567 (Kuchel Act), provides guidance to the Service that directly relates to habitat management on both refuges. We have also not considered the potential effects that management alternatives may have on other non-waterfowl wildlife species. However, we hope this report provides guidance that will help shape the discussion and provide a context for objectively considering how possible land use changes can impact wintering and migrating waterfowl. Our results indicate a variety of habitat scenarios can meet the energy needs of migrating and wintering waterfowl, thus providing flexibility to refuge managers as they consider the broader suite of wildlife species that depend on both refuges to meet their life-cycle needs.

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VI. APPENDICES

Appendix A. Screen sizes and other methodology used to separate seeds from detritus for plants sampled from seasonal wetlands at Tule Lake and Lower Klamath National Wildlife Refuge, fall 2002.

Seed	Screen sizes used	Methodology
Saltbush <i>Atriplex</i> spp.	6 x 38 (0.016 x 0.151 in)	Blower
Five-hook Basia	18 x 18 screen (0.044 x 0.044 in)	Blower
Meadow Fescue	32 x 32 screen (0.023 x 0.023 in) 6 x 50 screen (0.016 x	Blower
Mustard	34 x 34 screen (0.022 x 0.022 in) 6 x 50 screen (0.016 x	Blower
Pepperweed	24 x 24 screen (0.032 x 0.032 in)	Chaff should be ground ≥ 1 additional time
Pigweed	20 x 20 screen (0.040 x 0.040 in) 6 x 42 screen (0.016 x 0.152 in)	Blower
Pursh Seepweed <i>(Suaeda depressa)</i>	12 x 12 heavy screen 18 x 18 heavy screen	

Appendix A. cont...

Seed	Screening	Methodology
Rabbitfoot Grass	36 x 36 screen (0.020 x 0.020 in) 6 x 50 screen (0.016 x	
Red Goosefoot (<i>Chenopodium botryodes</i>)	6 x 50 screen (0.016 x 18 x 18 screen (0.044 x 0.044 in)	Rub sheaths using hands and run back through 6 x 50; blower
Smartweed	18 x 18 screen (0.044 x 0.044 in)	Pick remaining seed by hand
Spikerush (<i>Eleocharis palustris</i>)	20 x 20 screen (0.040 x 0.040 in) 6 x 30 screen (0.021 x 0.150 in)	Blower
Swamp Timothy	34 x 34 screen (0.022 x 0.022 in)	Blower
Whitetop	20 x 18 screen (0.036 x 0.044 in) 4 x 22 screen (0.033 x 0.230 in)	Blower

Appendix B. Taxon-specific composition (%) of invertebrate samples from seasonal and permanent wetlands. Invertebrate order and, in some cases, family are listed with the exception of Copepoda which were not identified beyond class.

Order	Family	Seasonal										Permanent		
		Tule Lake		Lower Klamath								Tule Lake	Lower Klamath	
		DB	S1B	4A	4F	6A	6C	9B	10B	SE	WL	S1A	3A	12C
Hirudinoidea		-	-	-	-	-	-	-	-	-	-	1.3	5.4	T
Oligochaeta		0.2	1.7	55.4	0.7	3.9	19.5	0.3	28.3	0.1	0.2	8.2	1.8	25.8
Gastropoda														
	Physidae	-	-	-	-	-	-	-	-	-	-	0.4	-	-
Amphipoda		-	-	-	-	-	-	-	-	-	-	0.7	4.4	0.6
Copepoda		57.2	55.7	21.2	28.6	32.0	20.0	90.5	24.3	69.2	6.2	30.5	28.3	6.6
Anomopoda														
	Daphniidae	37.6	20.2	3.6	70.5	46.0	56.3	9.2	42.3	24.9	88.2	46.1	53.0	59.8

Appendix B. cont...

		Seasonal										Permanent		
		Tule Lake		Lower Klamath								Tule Lake	Lower Klamath	
Order	Family	DB	S1B	4A	4F	6A	6C	9B	10B	SE	WL	S1A	3A	12C
Levicaudata														
	Lynceidae	-	-	2.1	-	0.3	1.5	-	0.7	5.6	-	0.1	0.7	0.6
Diptera														
	Chironomidae	4.3	21.7	16.9	0.3	15.7	1.8	-	3.7	-	4.0	9.0	2.5	3.9
	Other	-	0.1	0.6	-	0.8	0.1	-	0.4	0.1	-	0.1	0.2	0.4
Coleoptera														
	Amphizoidae	-	-	-	-	-	-	-	-	-	-	0.7	-	-
Ephemeroptera														
		0.5	0.1	-	-	-	0.3	-	-	-	0.9	1.1	3.5	T

Appendix B. cont...

		Seasonal										Permanent		
		Tule Lake		Lower Klamath								Tule Lake	Lower Klamath	
Order	Family	DB	S1B	4A	4F	6A	6C	9B	10B	SE	WL	S1A	3A	12C
Hemiptera														
	Corixidae	-	0.1	-	-	0.1	0.1	-	-	-	0.3	-	-	-
	Notonectidae	T	-	-	-	-	-	-	-	-	-	-	-	-
Odonata														
	Zygoptera	-	T	-	-	-	-	-	-	-	-	2.5	0.2	2.2
	Mecoptera	0.1	0.2	-	-	1.2	0.1	-	0.2	-	0.3	-	-	-
	Plecoptera	T	T	-	-	0.1	0.4	-	0.2	-	0.1	-	-	-

Appendix C. Tables of mean and 75% percentile waterfowl counts for biweekly aerial surveys flown from 1 September to 15 April 1970-1979 and 1990-1999 at Lower Klamath and Tule Lake National Wildlife Refuges.

C-1. Mean counts of dabbling ducks at Tule Lake National Wildlife Refuge during fall, winter, and spring for a 10 year period during the 1970's and 1990's from aerial surveys.^a

Survey Date ^b	1970-1979		1990-1999
	75 th Percentile ^c	Mean (SE)	Mean (SE)
Sept 1	53,100	43,448	50,434
Sept 15	154,725	116,659	42,943
Oct 1	292,200	213,254	59,467
Oct 15	281,100	305,508	63,467
Nov 1	765,901	472,200	69,630
Nov 15	268,328	262,247	56,293
Dec 1	193,700	121,601	25,153
Dec 15	262,400	168,860	34,728
Jan 1	37,015	30,778	23,908
Jan 15	91,955	53,317	19,825
Feb 1	24,635	19,763	18,019
Feb 15	42,850	41,789	11,297
Mar 1	16,903	15,710	20,256
Mar 15	63,486	51,629	25,725
Apr 1	92,620	77,958	29,733
Apr 15	32,975	25,076	57,120

^a dabbling ducks include Northern Pintail (*Anas acuta*), Mallard (*A. platyrhynchos*), American Wigeon (*A. americana*), Northern Shoveler (*A. clypeata*), Green-winged Teal (*A. crecca*), Cinnamon Teal (*A. cyanoptera*), and Gadwall (*A. strepera*).

^b dates are not exact, but surveys were flown approximately every two weeks each year

^c serves as the population objective for dabbling ducks at TLNWR.

Table C-2. Mean counts of diving ducks at Tule Lake National Wildlife Refuge during fall, winter, and spring for a 10 year period during the 1970's and 1990's from aerial surveys.^a

Survey Date ^b	1970-1979		1990-1999
	75 th Percentile ^c	Mean (SE)	Mean (SE)
Sept 1	4,270	3,680	4,034
Sept 15	2,990	2,663	5,217
Oct 1	6,998	5,775	8,678
Oct 15	10,730	8,671	23,407
Nov 1	16,440	13,800	24,660
Nov 15	11,088	9,594	22,250
Dec 1	3,825	2,494	9,969
Dec 15	2,200	2,024	1,750
Jan 1	193	235	1,138
Jan 15	675	413	775
Feb 1	525	439	4,300
Feb 15	3,115	1,936	5,470
Mar 1	1,308	1,035	4,474
Mar 15	3,388	3,171	2,730
Apr 1	2,555	2,154	1,490
Apr 15	2,638	1,786	606

^a diving ducks included Canvasback (*Aythya valisneria*), Redhead (*A. americana*), Ring-necked Duck (*A. collaris*).

^b dates are not exact, but surveys were flown approximately every two weeks each year

^c serves as the population objective for dabbling ducks at TLNWR.

Table C-3. Mean counts of dabbling ducks at Lower Klamath National Wildlife Refuge during fall, winter, and spring for a 10 year period during the 1970's and 1990's from aerial surveys.^a

Survey Date ^b	1970-1979		1990-1999
	75 th Percentile ^c	Mean (SE)	Mean (SE)
Sept 1	213,521	134,261	145,596
Sept 15	219,869	171,458	238,882
Oct 1	401,738	350,455	345,951
Oct 15	597,010	540,087	541,478
Nov 1	597,536	570,513	680,892
Nov 15	487,361	425,122	542,396
Dec 1	372,560	251,754	326,471
Dec 15	198,118	130,697	140,225
Jan 1	10,594	34,050	93,106
Jan 15	27,171	44,688	154,028
Feb 1	77,714	69,457	107,754
Feb 15	223,459	181,406	214,423
Mar 1	148,414	116,286	274,124
Mar 15	203,306	153,040	336,146
Apr 1	96,775	86,086	122,643
Apr 15	83,339	65,183	105,600

^a dabbling ducks include Northern Pintail (*Anas acuta*), Mallard (*A. platyrhynchos*), American Wigeon (*A. americana*), Northern Shoveler (*A. clypeata*), Green-winged Teal (*A. crecca*), Cinnamon Teal (*A. cyanoptera*), and Gadwall (*A. strepera*).

^b dates are not exact, but surveys were flown approximately every two weeks each year

^c serves as the population objective for dabbling ducks at TLNWR.

Table C-4. Mean counts of diving ducks at Lower Klamath National Wildlife Refuge during fall, winter, and spring for a 10 year period during the 1970's and 1990's from aerial surveys.^a

Survey Date ^b	1970-1979		1990-1999
	75 th Percentile ^c	Mean (SE)	Mean (SE)
Sept 1	2,270	1,815	1,150
Sept 15	1,791	1,727	2,318
Oct 1	3,708	3,207	10,348
Oct 15	7,385	5,199	13,189
Nov 1	6,313	5,084	17,909
Nov 15	5,783	4,099	10,764
Dec 1	1,250	1,090	7,791
Dec 15	855	917	38
Jan 1	160	128	1,338
Jan 15	305	369	1,915
Feb 1	800	730	2,310
Feb 15	2,175	1,503	7,206
Mar 1	1,560	1,173	5,393
Mar 15	1,600	1,463	8,284
Apr 1	3,600	2,484	1,158
Apr 15	2,020	2,195	3,381

^a diving ducks included Canvasback (*Aythya valisneria*), Redhead (*A. americana*), Ring-necked Duck (*A. collaris*).

^b dates are not exact, but surveys were flown approximately every two weeks each year

^c serves as the population objective for dabbling ducks at TLNWR.

Table C-5. Mean counts of geese at Tule Lake National Wildlife Refuge during fall, winter, and spring for a 10 year period during the 1970's and 1990's from aerial surveys.^a

Survey Date ^b	1970-1979		1990-1999
	75 th Percentile ^c	Mean (SE)	Mean (SE)
Sept 1	14,680	13,002	4,174
Sept 15	10,630	12,731	20,391
Oct 1	37,460	27,204	82,831
Oct 15	82,170	54,546	160,334
Nov 1	136,413	97,702	375,931
Nov 15	146,605	121,970	360,294
Dec 1	50,275	38,403	77,632
Dec 15	64,608	43,355	84,993
Jan 1	9,240	7,156	6,378
Jan 15	4,040	2,905	13,544
Feb 1	8,350	4,743	30,990
Feb 15	13,935	14,864	74,234
Mar 1	44,233	38,539	90,590
Mar 15	112,708	99,254	180,306
Apr 1	35,705	33,753	210,663
Apr 15	39,595	32,810	80,338

^a geese included Lesser Snow Geese (*Chen caerulescens*), Greater White-fronted Geese (*Anser albifrons*), Cackling Geese (*Branta minima*), and Canada Geese (*B. canadensis*)

^b dates are not exact, but surveys were flown approximately every two weeks each year

^c serves as the population objective for dabbling ducks at TLNWR.

Table C-6. Mean counts of swans at Tule Lake National Wildlife Refuge during fall, winter, and spring for a 10 year period during the 1970's and 1990's from aerial surveys.^a

Survey Date ^b	1970-1979		1990-1999
	75 th Percentile ^c	Mean (SE)	Mean (SE)
Sept 1	0	0	1
Sept 15	0	0	1
Oct 1	0	14	1
Oct 15	0	57	2
Nov 1	260	234	32
Nov 15	713	589	665
Dec 1	1,230	704	1,533
Dec 15	1,125	873	1,520
Jan 1	640	1,052	1,229
Jan 15	4,205	2,803	460
Feb 1	1,525	1,387	2,075
Feb 15	1,530	1,404	901
Mar 1	1,115	799	799
Mar 15	8	13	576
Apr 1	50	33	116
Apr 15	0	0	17

^a swans were almost exclusively Tundra Swans (*Cygnus columbianus*)

^b dates are not exact, but surveys were flown approximately every two weeks each year

^c serves as the population objective for dabbling ducks at TLNWR.

Table C-7. Mean counts of geese at Lower Klamath National Wildlife Refuge during fall, winter, and spring for a 10 year period during the 1970's and 1990's from aerial surveys.^a

Survey Date ^b	1970-1979		1990-1999
	75 th Percentile ^c	Mean (SE)	Mean (SE)
Sept 1	7,640	10,101	2,674
Sept 15	5,820	5,717	2,770
Oct 1	51,610	39,509	22,124
Oct 15	36,095	25,336	40,051
Nov 1	34,160	30,010	29,957
Nov 15	46,855	33,070	38,619
Dec 1	19,475	17,745	20,488
Dec 15	12,488	9,408	6,243
Jan 1	7,430	6,134	2,312
Jan 15	12,990	9,925	4,611
Feb 1	11,431	7,428	4,033
Feb 15	56,580	37,797	31,484
Mar 1	66,248	57,341	9,991
Mar 15	80,433	67,997	19,013
Apr 1	49,880	39,338	32,996
Apr 15	70,185	55,331	29,515

^a geese included Lesser Snow Geese (*Chen caerulescens*), Greater White-fronted Geese (*Anser albifrons*), Cackling Geese (*Branta minima*), and Canada Geese (*B. canadensis*)

^b dates are not exact, but surveys were flown approximately every two weeks each year

^c serves as the population objective for dabbling ducks at TLNWR.

Table C-8. Mean counts of swans at Lower Klamath National Wildlife Refuge during fall, winter, and spring for a 10 year period during the 1970's and 1990's from aerial surveys.^a

Survey Date ^b	1970-1979		1990-1999
	75 th Percentile ^c	Mean (SE)	Mean (SE)
Sept 1	0	0	1
Sept 15	0	0	2
Oct 1	0	0	2
Oct 15	0	0	3
Nov 1	1,545	1,666	86
Nov 15	3,193	2,114	820
Dec 1	930	683	1,305
Dec 15	1,398	1,166	1,454
Jan 1	2,490	1,774	491
Jan 15	7,211	4,496	2,655
Feb 1	14,043	9,388	3,395
Feb 15	14,960	12,187	6,954
Mar 1	18,995	13,748	7,230
Mar 15	3,186	2,295	3,312
Apr 1	0	190	412
Apr 15	0	0	142

^a serves as the population objective for Swans at LKNWR.

^b dates are not exact, but surveys were flown approximately every two weeks each year

^c serves as the population objective for dabbling ducks at TLNWR.

Table C-9. Mean counts of American Coots at Tule Lake National Wildlife Refuge and Lower Klamath National Wildlife Refuge during fall, winter, and spring for a 10 year period during the 1970's from aerial surveys.^a

Interval	Refuge	
	TLNWR	LKNWR
Sept 1	31,000	28,000
Sept 15	82,575	33,250
Oct 1	124,900	52,863
Oct 15	115,200	59,925
Nov 1	52,375	23,625
Nov 15	35,925	15,925
Dec 1	10,650	19,500
Dec 15	8,000	5,500
Jan 1	300	540
Jan 15	800	550
Feb 1	2,550	1,750
Feb 15	5,300	8,350
Mar 1	3,750	4,850
Mar 15	12,375	11,000
Apr 1	14,500	45,000
Apr 15	10,250	16,475

^a numbers serve as the population objective for Coots at TLNWR and LKNWR.

Appendix D. Daily energy requirements by waterfowl guild and date interval for waterfowl on Tule Lake and Lower Klamath National Wildlife Refuges.

Table D-1. Daily bird energy requirements (kcal/day) for a representative bird for each foraging guild at TLNWR for 1970's populations. See methods section of Chapter 2 for list of species in each guild.

Interval	Dabbling Ducks	Diving Ducks	Coots	Geese	Swans
January 1	311	349	208	730	1106
January 15	304	354	208	733	1106
February 1	294	352	208	635	1106
February 15	276	342	208	616	1106
March 1	279	349	208	528	1106
March 15	271	342	208	521	1106
April 1	269	344	208	523	1106
April 15	264	337	208	509	1106
September 1	279	330	208	791	1106
September 15	284	335	208	561	1106
October 1	284	340	208	530	1106
October 15	286	344	208	514	1106
November 1	294	344	208	493	1106
November 15	291	349	208	493	1106
December 1	299	349	208	530	1106
December 15	286	352	208	523	1106

Table D-2. Bird daily energy requirements (kcal/day) for each foraging guild at TLNWR for 1990's populations. See methods section of Chapter 2 for list of species in each guild.

Time of Year	Dabbling Ducks	Diving Ducks	Coots	Geese	Swans
January 1	313	356	208	758	1106
January 15	335	347	208	711	1106
February 1	299	330	208	648	1106
February 15	276	344	208	685	1106
March 1	258	342	208	532	1106
March 15	240	333	208	530	1106
April 1	230	337	208	532	1106
April 15	235	330	208	546	1106
September 1	296	335	208	556	1106
September 15	291	340	208	583	1106
October 1	279	349	208	571	1106
October 15	281	349	208	518	1106
November 1	264	352	208	497	1106
November 15	271	347	208	497	1106
December 1	291	337	208	527	1106
December 15	294	356	208	621	1106

Table D-3. Bird daily energy requirements (kcal/day) for each foraging guild at LKNWR for 1970's populations. See methods section of Chapter 2 for list of species in each guild.

Time of Year	Dabbling Ducks	Diving Ducks	Coots	Geese	Swans
January 1	304	338	208	755	1106
January 15	299	354	208	662	1106
February 1	299	333	208	773	1106
February 15	276	340	208	640	1106
March 1	281	345	208	650	1106
March 15	276	333	208	554	1106
April 1	261	335	208	534	1106
April 15	253	333	208	504	1106
September 1	276	328	208	973	1106
September 15	279	326	208	945	1106
October 1	335	335	208	680	1106
October 15	286	340	208	539	1106
November 1	286	345	208	523	1106
November 15	286	347	208	547	1106
December 1	296	342	208	681	1106
December 15	289	340	208	787	1106

Table D-4. Bird daily energy requirements (kcal/day) for each foraging guild at LKNWR for 1990's populations. See methods section of Chapter 2 for list of species in each guild.

Time of Year	Dabbling Ducks	Diving Ducks	Coots	Geese	Swans
January 1	311	321	208	755	1106
January 15	301	354	208	680	1106
February 1	286	301	208	804	1106
February 15	276	311	208	708	1106
March 1	266	323	208	563	1106
March 15	243	311	208	559	1106
April 1	222	318	208	546	1106
April 15	224	304	208	542	1106
September 1	294	321	208	912	1106
September 15	290	318	208	904	1106
October 1	269	321	208	629	1106
October 15	261	335	208	601	1106
November 1	264	338	208	611	1106
November 15	261	340	208	574	1106
December 1	276	326	208	609	1106
December 15	311	253	208	780	1106

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