Effects of the Wetlands Reserve Program on Waterfowl Carrying Capacity in the Rainwater Basin Region of South-Central Nebraska

A Conservation Effects Assessment Project
Wildlife Component assessment

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Executive Summary

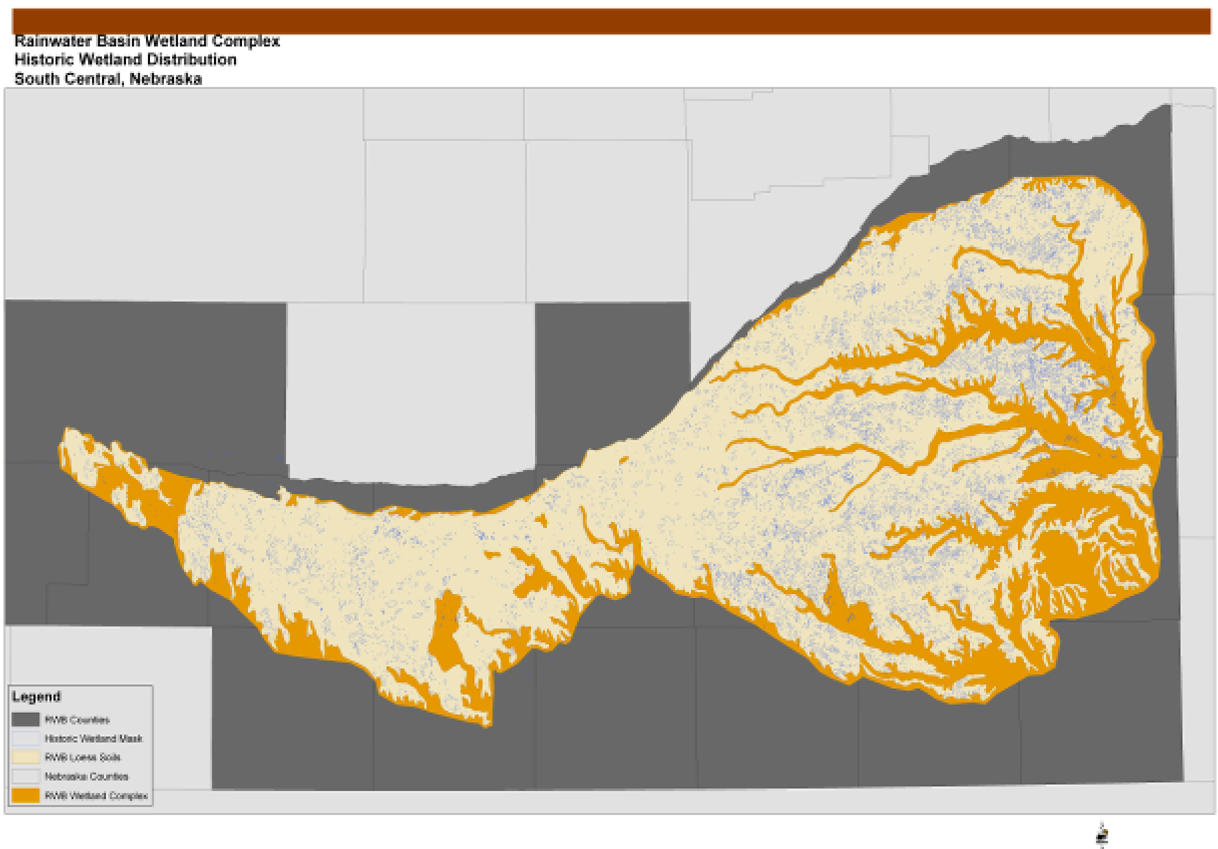
The purpose of this Conservation Effects Assessment Project (CEAP) assessment was to evaluate the energetic contribution of the Wetlands Reserve Program (WRP) for migratory waterfowl using the Rainwater Basin Wetland Complex (RWB). The RWB is located in south central Nebraska and encompasses 6,150 mi^2 that is dominated by row crop agriculture. Historically, > 204,000 acres of playa wetlands were scattered across this region, but currently, just over 40,000 acres of wetlands remain. Annually, an estimated 12.4 million migratory waterfowl use this region during fall and/or spring migrations. Although used with less intensity as a fall stopover, approximately 9.8 million birds use the region during spring migration. This concentration of waterfowl coupled with reduced wetland resources is hypothesized to be causing intense competition between individuals for necessary energetic resources. We developed a bio-energetic model to evaluate the landscape's capacity to provide energetic resources for migrating waterfowl. Two components are necessary to complete a bio-energetic model, the energetic requirements of the individuals using the region and the energy available in primary forage habitats. Once these values were determined the model allowed us to evaluate both landscape capacity and program specific contribution to regional waterfowl foraging capacity. In total the RWB needs to provide 24.1 billion kcal of energy for migratory waterfowl. Currently waste grain can meet all waterfowl energetic requirements using the RWB region. Although sufficient energetic resources exist, research has documented that food resources other than waste grain are required to meet all waterfowl nutritional requirements (essential amino acids, inorganic elements, and vitamins). We used previous research to estimate that 39% (9.5 billion) of the 24.1 billion kcal should be provided by wetland habitats. Prior to delivery of WRP, the RWB could provide 5.9 billion kcal of energy from wetland habitats. The WRP has supported restoration of approximately 3,050 acres of wetland and 1,050 acres of upland habitats in the RWB. These wetland acres represent an 8% increase in the total wetland base and provide an additional 789 million kcal of energy. The WRP program has increased total wetland forage capacity in the RWB by 13% compared to pre WRP conditions. Despite the additional WRP wetland acres, the RWB is still 3.0 billion kcal short of meeting migrating waterfowl wetland forage requirements. Analysis of average (2004), below average (2006), and above average (2007) precipitation years documented 8,900, 3,200, and 12,650 acres of flooded habitat, respectively. These flooded acres could provide approximately 13%, 4%, and 21% of the total wetland forage that would have been required. These results demonstrate that additional habitat from WRP and other conservation programs will be necessary to ensure sufficient habitat becomes available as a result of variable precipitation events. These results also show the importance of management of existing wetlands, including those tracts restored by WRP, to ensure optimal habitat conditions when wetlands become flooded. A hydrologic model documented that off-site hydrologic modifications can have a tremendous negative effect on RWB wetlands ability to pond water. In the future, additional resources will also be needed to restore hydrology to ensure that under average conditions RWB wetlands function.

Introduction

Background

The RWB wetland complex encompasses 6,150 mi^2 including parts of 21 counties in south-central Nebraska (Figure 1). Condra (1939) identified this landscape as the Loess Plains Region of Nebraska. This landscape is characterized by rolling loess plains formed by deep deposits of wind-blown silt with a high density of clay pan playa wetlands. These wetlands are patchy in distribution, but historically the densest areas would have rivaled the Prairie Pothole Region in regard to wetland acres and density. Precipitation from intense summer storms and runoff from winter snowfall fill these playa wetlands providing critical fall and spring habitat for migratory waterfowl.

Figure 1 Rainwater Basin Wetland Complex



Recent Geographical Information Systems (GIS) analysis of the historic soil surveys (1910 - 1917), National Wetland Inventory (NWI 1980 - 1982), and Soil Survey Geographic Database (SSURGO 1961 – 2004) has provided a comprehensive assessment of the historic wetland resources that once were a prominent feature of this landscape. Combined, these datasets delineate approximately 11,000 individual playa wetlands consisting of 1,000 major (Semi-permanent/Seasonal) wetlands comprising 70,000 acres and more than 10,000 minor

(Temporary) wetlands that account for an additional 134,000 acres for a total of 204,000 wetland acres.

The first attempt to quantify the RWB value for waterfowl was done by Nebraska Game and Parks Commission (NGPC) between 1969 – 1972. The McMurtrey survey used 1910 – 1917 soils maps to evaluate the distribution of remaining wetlands and assess their potential value as breeding waterfowl habitat. McMurtrey et al. (1972) reported that 82% of the major wetlands had been converted to agriculture removing approximately 63% of the total wetland acres from the landscape. The agriculture conversion was facilitated by the U.S. Department of Agriculture's (USDA) farm program, road construction, and post-war improvements to earth moving equipment. This fast-paced degradation continued until 1984, when only 10% of the original wetlands remained. These remaining wetlands encompassed only 22% of the original acres and of these, virtually all were hydrologically impacted. These manipulations negatively affected wetland function, size, and value as wildlife habitat (Schildman and Hurt 1984).

Reduced wetland function resulting from hydrologic modification is compounded by the natural and agriculturally induced process of siltation. In addition to the anthropogenic degradations, invasive plant species including reed canary grass (*Phalaris arundinacea*), narrow leaf cattail (*Typha angustifolia*), and river bulrush (*Scirpus pungens*) have deteriorated the quality of wetland habitat in the RWB. The most notable result of this wetland degradation is the loss of wildlife habitat (Smith 1998).

Figure 2 Central Flyway

The RWB resembles the focal point of an hourglass during spring migration (Figure 2). The Central Flyway narrows at the RWB as birds migrate north from their wintering grounds. This constriction results in millions of migratory waterfowl simultaneously using the RWB as a stopover point each spring (Brennan 2006). This congregation of waterfowl includes up to 90% of the mid-continent population of greater white-fronted geese (*Anser albifrons)*, approximately 50% of the mid-continent mallards (*Anas platyrhynchos*), and 30% of continental Northern pintail (*Anas acuta*) breeding population, and an ever- increasing number (>1.5 million) of lesser snow geese (*Chen caerulescens*) (Brennan 2006, Cox and Davis 2005, Traylor 1999).

The recent influx of snow geese during spring migration has increased the density of migratory birds in the RWB, especially in dry years when wetland habitat is limited. This crowding causes elevated stress on the birds, increasing their susceptibility to catastrophic losses from environmental disasters such as severe spring storms and disease (Smith and Higgins 1990). Avian cholera (*Pasteurella multocida*) has been a chronic problem in the RWB since the early 1970s and is confirmed to have killed >200,000 waterfowl there since 1975 (Stutheit 1988). Recent studies in Nebraska and Saskatchewan indicate only a relatively small percentage of waterfowl that die from disease outbreaks are recovered during retrieval operations (Cox and Davis 2005). Consequently, waterfowl mortality from cholera may be much higher than currently estimated.

The elevated numbers of birds using the RWB each spring increases the potential for disease outbreaks, and increases intra- and inter-specific competition between individuals for space and food (Brennan 2006). It has been hypothesized that competition has resulted in the redistribution of birds in recent years and negatively affected the ability of some species to find adequate food resources during migration and initial nesting.

By 1960, the U.S. Fish and Wildlife Service (USFWS) recognized the importance of this region as critical migratory habitat. In 1963 Massie Marsh was acquired and managed as a Waterfowl Production Area (WPA). Presently 59 WPAs totaling 23,300 acres are owned and managed by the USFWS in the RWB. In addition, the State of Nebraska has acquired 35 playa basins totaling 8,400 acres and manages them as Wildlife Management Areas. Management of these properties is very intensive due to the surrounding agriculture land use that causes siltation, and the quick succession of basins from desirable early successional vegetation to monocultures of invasive species that provide little foraging habitat for waterfowl. Both agencies have slowed their pace of acquisition to allow managers to concentrate on managing the existing public land base.

In 1990, Congress authorized the Wetlands Reserve Program (WRP) as part of the Food Security Act (Farm Bill) of 1985. WRP has been reauthorized or amended in every Farm Bill since 1990. WRP is administered by the USDA Natural Resources Conservation Service (NRCS) which provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands through 30-year or perpetual easements. The goal of the program is to achieve the greatest wetland functions and values, along with optimum wildlife habitat (see http://www.nrcs.usda.gov/programs/wrp/). WRP has filled a unique conservation niche in this landscape. WRP completes full hydrologic restoration of enrolled basins and shifts management to the private landowner with assistance from the NRCS. This provides clear benefit for waterfowl as WRP tracts are actively managed for optimal waterfowl habitat and the juxtaposition of WRP tracts complements adjacent public properties.

In 2003, a multi-agency effort initiated the Conservation Effects Assessment Project (CEAP) to quantify environmental benefits of USDA conservation practices supported by programs such as the Conservation Reserve Program (CRP), WRP, and Environmental Quality Incentives Program (EQIP). This report is part of the Wildlife Component of CEAP, which was created specifically to quantify effects of conservation practices and programs on wildlife in agricultural landscapes. The USFWS Region 6 Habitat and Population Evaluation Team (HAPET), Rainwater Basin Joint Venture (RWBJV), Playa Lakes Joint Venture (PLJV), Farm Service Agency (FSA), and NRCS designed this CEAP project to evaluate the effects of WRP in providing migratory waterfowl habitat. To assess the benefits of WRP for migratory waterfowl a bio-energetic model was developed to measure the landscape forage capacity against the estimated energetic requirements of waterfowl that depend on this region during migration.

Justification

The Wetlands Reserve Program is a USDA NRCS program under which private landowners voluntarily enroll marginal lands with degraded wetland features. NRCS acquires a perpetual or 30-year easement and completes wetland and upland restoration of the tract. The main goals of the program are to provide habitat for wildlife, decrease flood damages, improve water quality, enhance cultural opportunities for American Indians, create opportunities for producers to generate alternative incomes, help recover threatened and endangered species, and allow farmers and others to maintain ownership of lands suited for wetland restoration (NRCS 2002).

Currently (as of 2007), >1.9 million acres of wetlands and associated uplands have been enrolled in WRP nation-wide. During the early years of the program a minimalist approach to restoration was taken where limited restoration actions were completed with the expectation that natural wetland and vegetative succession would return wetland function. After 1996 greater emphasis was placed on restoring wetland hydrology and topologic features to ensure that maximum wildlife benefits were achieved, particularly for migratory birds (NRCS 2002).

This CEAP project has provided the opportunity for USFWS and NRCS to collaboratively evaluate the effects of WRP for migratory waterfowl in an area regarded as the focal point of spring migration in the Central Flyway. Many projects have evaluated the benefit of WRP at site specific locations, but no studies have quantified the benefit of WRP in terms of impact on continental waterfowl populations.

METHODS

Previous attempts to quantify conservation success have used measures of acres protected, restored, or enhanced. These measures do not allow us to answer the harder questions of how much is enough or how many acres are needed to meet the population goals for our species of concern. In order to relate acres of habitat to numbers of birds, a common currency must be developed that allows for a direct comparison between conservation actions (acres) and population response (number of individuals). We developed a bio-energetic model to allow us to evaluate conservation actions against target populations. A bio-energetic model is a tool that in the simplest terms compares landscape foraging capacity against the energetic requirements of individuals using that area. To understand a landscapes' carrying capacity two important datasets must be available. A GIS layer representing acres of primary foraging habitat, and data from research that allows for conversion of acres to a caloric measure of resources available to waterfowl using the region.

The other half of a bio-energetic model is an estimate of the energetic requirements of waterfowl using the region. Data from a combination of traditional surveys and existing literature were used to estimate number of individuals, average residency time, and caloric requirements by species. These variables make it possible to estimate the caloric requirements of migratory waterfowl using the region. Once landscape forage capacity and waterfowl energetic estimates were developed both the landscape and program specific questions could be addressed. The RWBJV Conservation Planning Workgroup (CPW) identified priority waterfowl species to guide evaluation of conservation actions within the RWB boundary (Table 1).

Table 1. Waterfowl species and population evaluated.

Common Name	Scientific Name	Population Considered
Mallard	*Anas platyrhynchos*	Mid-continent (MCP)
Northern Pintail	*Anas acuta*	Traditional Survey Area
Blue-Winged Teal	*Anas discors*	Traditional Survey Area
American Green-Winged Teal	*Anas crecca*	Traditional Survey Area
Northern Shoveler	*Anas clypeata*	Traditional Survey Area
American Wigeon	*Anas americana*	Traditional Survey Area
Gadwall	*Anas strepera*	Traditional Survey Area
Light Geese (lesser snow Goose/ Ross goose)	*Chen caerulescens/ C. rossii*	Mid-continent (MCP)
Canada Goose	*Branta canadensis*	Great Plains (GPP)
Canada Goose	*Branta canadensis*	Western Prairie (WPP)
Canada Goose	*Branta canadensis*	Tall Grass Prairie (TGPP)
Greater White-Fronted Goose	*Anser albifrons*	Mid-continent (MCP)

To quantify the benefit of WRP relative to population objectives we compared the energetic carrying capacities of two landscape scenarios. One scenario depicts current landscape configuration with WRP as implemented in the RWB Region, while the alternative landscape depicts WRP parcels as cropland. The underlying assumptions are that: 1) all WRP parcels were once actively cultivated agriculture lands, 2) complete hydrologic restorations have been completed to the extent of the hydric soil footprint, and 3) the basin is being actively managed to maintain the vegetation community in an early successional stage.

To create and compare the scenarios we used five integrated components: 1) delineate WRP easement boundaries, 2) create landcover representing habitats in the RWB, 3) define clear relationships between habitats and forage value, 4) determine energetic requirements of waterfowl utilizing the RWB region annually, and 5) conduct GIS analysis to determine landscape carrying capacity pre and post delivery of WRP.

Component 1: Delineate easement boundary of WRP tracts in RWB.

Before the contribution of a conservation program can be evaluated in a bio-energetic model an accurate boundary and delineation of the habitat types must be created. As of December 2007, there were 71 WRP easements (4,955 acres) on playa wetlands in the RWB. Easement boundaries were created in GIS by USFWS and NGPC private lands biologists that coordinated with NRCS in delivery of these WRP projects. The boundaries were created through photo-interpretation at 1:5,000 scale using the 2005 or 2006 National Agriculture Imagery Program (NAIP) true-color imagery. The SSURGO hydric soil footprint was intersected with the WRP easement boundary to delineate the wetland and upland components of the individual WRP tracts. Results were visually assessed and compared against project information to assure that hydric soils were not over/under representing the extent of restoration completed at each property. If an acreage discrepancy existed greater than 5 acres the wetland and upland components of the project were adjusted using the RWBJV spring 2007 Color Infrared (CIR) imagery to accurately represent the extent of wetland function.

Component 2: Create landcover representing habitats in the RWB.

The most time intensive step in this analysis was developing a spatial dataset that accurately represented landcover types in relation to their energetic forage value for waterfowl. Using a combination of remote sensing (RS) and GIS techniques, HAPET developed a seamless landcover layer for the RWB region that could be analyzed to determine the energetic carrying capacity of the landscape for waterfowl. This dataset was produced through integration of existing data and development of new data representing important forage habitats.

The RWBJV has acquired a substantial amount of GIS data representing the RWB region. However, data gaps still existed in regards to understanding contemporary wetland distribution and vegetation composition. This information is particularly important for evaluating the region's carrying capacity for waterfowl. To develop a suitable landcover for this project, a nine-step mapping protocol was used to streamline data integration and development of new information through RS of CIR imagery. Steps included landcover evaluation & mapping, mapping standards, image acquisition, image processing, sampling design, field data collection, image classification, accuracy assessment, and final landcover development (Appendix B).

The mapping process allowed us to develop a contemporary representation of landcover in the RWB (Figure 3). In summary, the RWB Region encompasses 3,932,585 acres. Seventy percent of the landscape is under cultivation, grassland habitats make up approximately 20% of the region, while 3% of the area is covered by woodland forest communities confined generally to the drainages associated with the Blue River system. River-associated wetlands comprise about 2% of the landscape. Of the historic 204,000 RWB wetland acres, roughly 40,000 acres remain, or about 17% of the historic distribution. Today RWB wetlands make up less than 1% of the total landscape (Table 2).

Table 2. Landcover summary for the Rainwater Basin Region (Including WRP acres)

Agriculture	Acres	Percent Total
CRP	27,637.4	0.7%
Sorghum	36,684.4	0.9%
Alfalfa	53,425.4	1.4%
Wheat	93,248.3	2.4%
Soybeans	1,078,548.2	27.4%
Corn	1,476,608.8	37.5%
Ag Total	**2,766,152.6**	**70.3%**

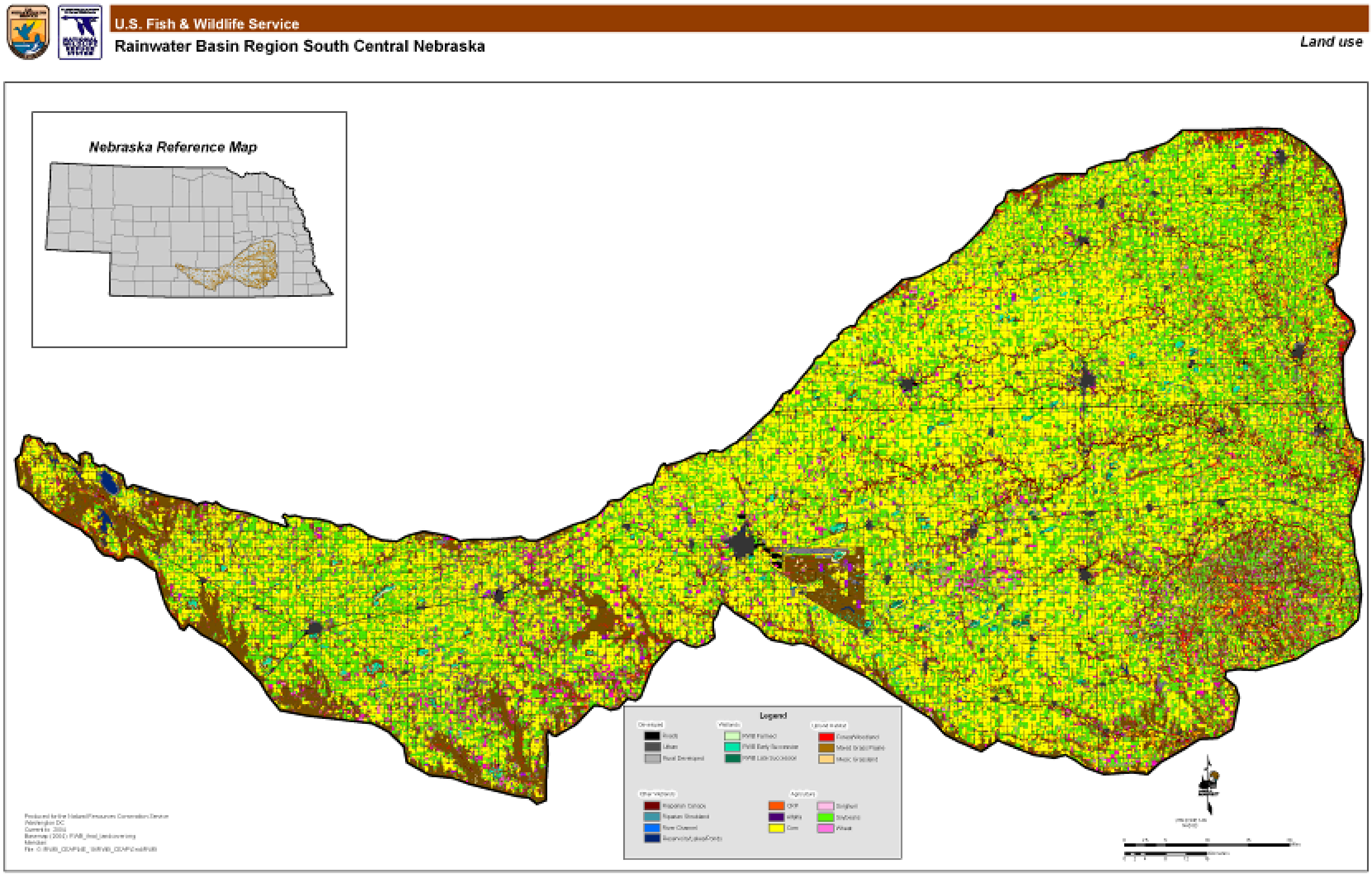
Other Wetlands	Acres	Percent Total
River Channel	56.0	0.0%
Riparian Shrubland	120.1	0.0%
Reservoirs, Lakes, Ponds	23,858.5	0.6%
Riparian Canopy	46,924.4	1.2%
Other Wetlands	**70,959.0**	**1.8%**

Uplands	Acres	Percent Total
Mesic Grassland	8,182.3	0.2%
Woodland/Forest	68,132.8	1.7%
Mixed Grass Prairie	763,039.6	19.4%
Upland Total	**839,354.8**	**21.3%**

RWB Wetlands	Acres	Percent Total
RWB Farmed	7,902.1	0.2%
RWB Late Succession	10,456.1	0.3%
RWB Early Succession	21,856.9	0.6%
RWB Wetlands	**40,215.2**	**1.0%**

Developed	Acres	Percent Total
Urban	36,340.2	0.9%
Roads	98,516.4	2.5%
Rual Developed	81,046.8	2.1%
Developed Total	**215,903.4**	**5.5%**

Figure 3. Landcover for RWB Region



Component 3: Define energetic value of habitats in the RWB.

Large concentrations of waterfowl and the contemporary distribution of RWB wetlands have led to inter-specific and intra-specific species competition for roosting, loafing, and foraging habitat (Smith 1998, Brennan 2006). It is hypothesized this competition has reduced certain species' ability to sequester sufficient lipid reserves that are used during migration and the initial stages of nesting. To understand if forage resources are limited in the RWB, we created an estimate of the energetic resources available from primary foraging habitats in the RWB. To complete this portion of the analysis we converted acres of primary forage habitats (determined from the landcover mapping component) to energetic potential.

Generally habitats are quantified in acres. This unit of measure does not allow us to directly link waterfowl energetic requirements to the habitat. In the RWB, waterfowl primarily acquire energy from waste grain and seeds produced by different wetland vegetation communities. A combination of field and laboratory research is necessary to quantify energy available from these habitats. Field research determines the types and mass of seeds available by a unit area while the laboratory analysis determines the caloric energy that can be metabolized from a known mass of seeds. Combining this research allows us to estimate the kilocalories (kcal) that one acre of habitat could provide. To complete this project we evaluated the landcover to identify the primary forage habitats and then used existing literature to estimate the caloric value these habitats could provide.

The primary foraging habitats in the RWB include: 1) early succession wetland vegetation, 2) farmed wetlands, 3) late succession wetland vegetation, 4) lacustrine wetlands, 5) corn, and 6) soybeans. Early succession wetland vegetation provides the highest forage value of wetland habitats. This moist soil plant community is dominated by smartweed, barnyard grass, and *Carex* species. Preliminary analysis by Rabbe et al. (2004) determined that moist soil plant communities in the RWB could produce between 68 - 210 kilograms of seeds per acre (kg/acre). Haukos and Smith (1993) found that playas in the Southern High Plains of Texas provided between 28 kg/acre and 216 kg/acre depending on the intensity of management. The variability of seed production by playa wetlands is greatly influenced by climatic variables. For this analysis, we set early succession wetland seed production at 121 kg/acre, based on the mid point of the values observed by Haukos and Smith (1993) and professional biological opinion (D. Haukos, USFWS, personal communication).

Farmed wetlands are hydrologically modified wetlands cultivated on an annual basis. Although modified, these basins will often seasonally "flood out" agriculture crops, producing a flush of annual weeds, smartweed and barnyard grass. A production estimate of 61 kg/acre was selected for farmed wetlands, approximately half the value of early-succession dominated RWB wetland production. Herbicide application in agriculture fields for weed control discourages wetland vegetation growth, often resulting in less dense stands of wetland vegetation in farmed wetlands.

Late succession wetland vegetation is characterized by reed canary grass, bulrush, and cattail. Rabbe et al. (2004) found that late succession communities in the RWB produced between 30 and 35 kg/acre of available seeds. There is often an understory of smartweed and barnyard grass associated with these communities. When these communities are disturbed through fire, grazing, or haying, these early succession species dramatically increase the seed production associated with these habitats. For this analysis, 30kg/acre was selected as a representative value for late succession wetland habitats.

Cox and Davis (2005) observed that lacustrine wetlands (reservoirs/stock dams) were often used by migrating waterfowl in the RWB. These habitats are characteristically deeper and only provide suitable foraging habitat for dabbling ducks along the shallower edges. We arbitrarily assumed that 5% of the total area of lacustrine habitats produced moist soil vegetation available during migration. This moist soil habitat was assumed to be in a late succession condition, providing 30 kg/acre of seeds.

In addition to wetland food sources, waste grain also provides an important forage resource in the RWB. Krapu et al. (2004) reported that between 72 – 103 kg/acre of corn was present in harvested corn fields. Due to post-harvest treatments such as grazing, mulching, haying and disking that reduce available waste grain, we set the corn value at 61kg/acre. For soybeans, we utilized 24kg/acre as the available forage value (Krapu et al. 2004).

Waterfowl do not consume all the foods available while feeding. This is due in large part because foraging efficiency declines as resources are depleted (Reinecke et al. 1989). Research to determine a forage threshold or the amount of seeds that are not consumed by foraging waterfowl has been completed in the Lower Mississippi Alluvial Valley and in the Central Valley of California. Results from these projects suggest that at 20 kg/acre of dry seed mass waterfowl can no longer exploit the food resources (Reinecke et al. 1989).

The amount of energy waterfowl can derive from 1 gram of seed is described as true metabolizable energy (TME). TME is represented as kcal of energy per gram of forage (kcal/g). This value is central to a bio-energetic model as it allows the conversion of grams of seed per acre to be represented as energy (kcal) per acre. This conversion allows a bio-energetic model to relate available forage to waterfowl energetic requirements. For example, Kaminski (2003) determined the average TME for moist soil seeds to be 2.47 kcal/gram. To estimate the kcal provided by 1 acre of early succession wetland habitat in the RWB, the following equation would be used:

Energy (kcal/Acre) = (121kg /acre – 20 kg/acre) x (1000 g/kg) x 2.47kcal/gram

Thus, 1 acre of early succession RWB wetland habitat can provide 250,000 kcal of energy compared to late succession habitats that can provide 25,000 kcal of energy (Table 3). Farmed early succession RWB wetland habitats can provide 100,000 kcal of energy (Table 3). Reinecke et al. (1989) reported that corn had a TME of 3.67kcal/g and soybeans TME was 2.65 kcal/g. In the RWB, these forage habitats would provide 148,583 kcal/acre and 10,729 kcal/acre, respectively (Table 3). Finally, reservoir and stock dam habitats in the RWB provide an estimated 25,000 kcal/acre of energy (Table 3).

Table 3. Important waterfowl forage habitats and associated energetic values for the Rainwater Basin region of Nebraska.

Habitat Type	Total Food Available (Kg/acre)	Food - Forage Thershold (Kg/acre)	Food Available (g/acre)	True Metabolizable Energy (kcal/g)	Energy/Acre (kcal/acre)
RWB Moist Soil Early Succession (Managed)	121	101	101,214.6	2.47	250,000
RWB Moist Soil Late Succession (Unmanaged)	30	10	10,121.5	2.47	25,000
RWB Moist Soil Early Succession (Farmed)	61	40	40,485.8	2.47	100,000
Reservoir, Stock Dam	30	10	10,121.5	2.47	25,000
Corn	61	40	40,485.8	3.67	148,583
Soybean	24	4	4,048.6	2.65	10,729

These constants or the energetic value (g/acre) of foraging habitats in the RWB allowed us to determine the landscape foraging capacity. We determined the landscape foraging capacity by multiplying the acres of the primary forage habitats (from the GIS landcover) by the energetic constant. The sum of the energy these habitats provide is the energetic estimate for the region.

The RWB landscape contains approximately 2.6 million acres of suitable primary foraging habitats (Table 4). Based on our assumptions, these habitats provide approximately 237 billion kcal of energy. Wetland habitats provide approximately 6.5 billion kcal of energy while agriculture foraging habitats provide approximately 230.5 billion kcal of energy (Table 4).

Although agricultural habitats provide the vast majority of potential kcal, Krapu et al. (2004) did not find soybeans in the esophageal contents of northern pintails, greater white-fronted geese or lesser snow geese. Furthermore, the value of soybeans as a waterfowl food has not been shown to be advantageous for gaining body mass (Loesch and Kaminski 1989). Conversely, we did not consider other crops (e.g., sorghum) that may be present in the RWB and available to foraging waterfowl but make up a relatively small portion of crop acres in the region.

Table 4. Potential energy available to waterfowl from primary foraging habitats in the Rainwater Basin region of Nebraska.

Wetland Habitats	Acres	Suitable Acres	Energy/Acre (kcal/acre)	Available Energy (kcals) thousands
RWB Early Succession	21,857	21,857	250,000	5,464,236
RWB Late Succession	10,456	10,456	25,000	261,403
RWB Farmed	7,902	7,902	100,000	790,213
Reservoir, Stock Dam (5% of Total Area)	23,858	1,193	25,000	29,823
Total	**64,210**	**41,544**		**6,545,675**

Agriculture Habitats	Acres	Suitable Acres	Energy/Acre (kcal/acre)	Available Energy (kcals) thousands
Soybeans	1,078,548	1,078,548	10,724	11,566,351
Corn	1,476,609	1,476,609	148,253	218,911,689
Total	**2,554,941**	**2,555,157**		**230,478,039**
Total All Habitats	**2,619,151**	**2,596,701**		**237,023,714**

Component 4: Energetic foraging requirements by species utilizing the RWB.

The initial components of this project determined the landscape's energetic carrying capacity. To understand if the energy provided by these habitats is sufficient to support migratory waterfowl using the region we had to establish population based energy demands. Survival and/or recruitment of individuals are the two factors that drive population dynamics. In migration habitats, managers try to provide habitat to maximize survival (Haukos and Smith 1993), but also are aware of "cross seasonal effects" that may influence recruitment on the breeding grounds. The RWBJV partners manage habitats to maintain body condition during fall migration, but also try to provide sufficient resources so waterfowl can increase lipid reserves during spring migration. If migratory waterfowl increase lipid reserves during spring migration, it can positively influence recruitment. Females arriving on the breeding grounds in better physical conditions initiate nesting earlier. Earlier nesting females contribute more to recruitment than later-nesting females (Dzus and Clark 1998). Females arriving on breeding grounds in better physical condition have the propensity to produce larger clutches and are more likely to re-nest if an initial nest is lost (Krapu 1981, LaGrange and Dinsmore 1988, Dubovsky and Kaminski 1994). All of these behaviors have been linked to higher nest success and recruitment.

Duck and goose population objectives from the North American Waterfowl Management Plan (NAWMP) (USFWS and Canadian Wildlife Service 1986) have been stepped down to each Joint Venture. Many Joint Ventures used this data in conjunction with mid-winter surveys as the foundation for developing population-dependent energetic objectives for their administrative boundaries. The use of mid-winter data works well for wintering areas, but does not allow an accurate assessment of waterfowl energetic needs during the migration timeframe. The RWBJV CPW has developed species specific (duck and goose) migration (spring and fall) targets: Fall migration occurs between 1 August–30 November and spring migration occurs between 1

February–15 May. No winter objectives were set for the RWB because the basins traditionally freeze by 1 December and have very limited migratory bird use after that date. Like the wintering Joint Ventures we estimated migration energetic requirements using the following data 1) species population estimates, 2) average residency time by species, and 3) daily energetic requirements by species. These components are multiplied to determine the total energetic requirements of migratory waterfowl. In addition to estimating total energetic requirements we also estimated the amount of energy that should be available from wetland habitats. This was completed using information available in existing literature in regards to food selection by species. Appendix C outlines the process used to estimate energetic requirements of waterfowl using the RWB region.

Using this method, we estimated that 2.6 million waterfowl migrate through the RWB in the fall and 9.8 million waterfowl use the region in spring (Table C-9). These migrants will require 24.1 billion kcal to meet their energetic requirements (Table C-12). To meet the nutritional requirements that cannot be extracted from waste grain, 39% or 9.5 billion kcal should come from wetland derived food sources (Table C-13).

Component 5: GIS analysis to determine landscape carrying capacity.

To determine the contribution of WRP towards waterfowl foraging capacity in the RWB, a GIS analysis was completed. We modified the existing landcover that depicts WRP restorations as early succession wetland habitat and converted the WRP tracts to agriculture (corn). As currently implemented, WRP tracts contain approximately 1,950 acres of upland and 3,050 acres of wetland. The implementation of WRP increased overall forage capacity of the region by 30 million kcal (Table 5). Although total forage only increased slightly the implementation of WRP resulted in wetland forage increasing by 763 million kcal (Table 5). WRP has increased wetland acres by 8% and more importantly resulted in a 13% increase in available wetland forage.

Table 5 Landcover and Forage Statistics Pre and Post Delivery of WRP in the Rainwater Basin.

RWB Pre WRP

Wetland Habitats	Acres	Suitable Acres	Energy/Acre (kcal/acre)	Available Energy (kcals) thousands
RWB Early Succession	18,807	18,807	250,000	4,701,645
RWB Late Succession	10,456	10,456	25,000	261,403
RWB Farmed	7,902	7,902	100,000	790,213
Lake	23,858	1,193	25,000	29,823
Total	**60,535**	**38,358**		**5,783,084**

Agriculture Habitats	Acres	Suitable Acres	Energy/Acre (kcal/acre)	Available Energy (kcals) thousands
Soybeans	1,078,548	1,078,548	10,729	11,571,469
Corn	1,481,501	1,481,501	148,583	220,125,801
Total	**2,560,729**	**2,560,049**		**231,697,269**
Total Pre WRP	**2,621,264**	**2,598,599**		**237,480,353**

RWB Post WRP

Wetland Habitats	Acres	Suitable Acres	Energy/Acre (kcal/acre)	Available Energy (kcals) thousands
RWB Early Succession	21,857	21,857	250,000	5,464,236
RWB Late Succession	10,456	10,456	25,000	261,403
RWB Farmed	7,902	7,902	100,000	790,213
Lake	23,858	1,193	25,000	29,823
Total	**64,210**	**41,544**		**6,545,675**

Agriculture Habitats	Acres	Suitable Acres	Energy/Acre (kcal/acre)	Available Energy (kcals) thousands
Soybeans	1,078,548	1,078,548	10,729	11,571,469
Corn	1,476,609	1,476,609	148,583	219,398,963
Total	**2,554,941**	**2,554,941**		**230,970,432**
Total Post WRP	**2,619,151**	**2,596,485**		**237,516,107**

Results

The goal of this CEAP assessment was to quantify the benefits associated with the WRP in relation to migrating waterfowl in the RWB. To measure WRP's contribution we developed a bio-energetic model. This model allowed us to generate an empirical estimate of the energetic resources the landscape could provide as well as a measure of the energetic requirements of waterfowl using the region. Analysis of the 2004 landcover suggests a total of 237 billion kcal of energy are available from primary foraging habitats in the RWB Region (Table 5). Approximately 12.4 million migratory waterfowl (Table C-9) utilize the RWB annually with 2.6 million (Table C-9) using the region in the fall while 9.8 million (Table C-9) stop during the spring.

In the fall these individuals will require 2.0 billion kcal (Table C-12) of energy during their residency in the RWB, while in the spring approximately 22.1 billion kcal (Table C-12) of energy will be needed. In total 24.1 billion kcal (Table C-12) will be consumed by migratory waterfowl using the RWB during a normal fall and spring migration.

On the surface, these data would suggest that forage resources are not limiting in the RWB. However, when dietary selection and nutritional requirements of waterfowl are considered wetland habitats are limited. Waste grain is high in caloric energy, but lacks important protein and minerals. Waterfowl rely on wetland habitats to acquire these dietary components. In the RWB waterfowl would need approximately 9.5 billion kcal from wetland-derived food sources during the annual migration (fall and spring) (Table C-13). Before delivery of the WRP program the RWB region could provide 5.8 billion kcal of energy from wetland habitats. To date 4,995 acres have been enrolled in the WRP in the RWB region. This includes 3,050 acres of restored wetlands and 1,950 acres of associated uplands. The wetland component (3,050 acres) is being actively managed for migration habitat, and providing an estimated 789 million kcal of energy. This represents a 13% increase in available wetland derived forage compared to pre-WRP conditions. Still, with the implementation of WRP, the RWB is 3.0 billion kcal short of meeting the wetland dependent forage requirements for all migratory waterfowl that use the region (Tables 5 and C-13). We hypothesize that this deficit is causing birds to arrive on the breeding grounds in poorer condition and negatively impacting recruitment.

Discussion

Private lands biologists in the RWB have recognized WRP as one of the most efficient conservation tools available. The long duration of easements (30-year or perpetual) associated with the program ensures that projects will continue to provide wetland habitat for migratory waterfowl despite the uncertain nature of agriculture landscapes.

To fully understand the magnitude of WRP, the landscape has to be evaluated in regards to hypothetical condition verses reality. The vegetation community of wetlands drives their potential to provide energetic resources for waterfowl in the RWB region. If wetlands are restored and consequently "walked away from" as the WRP program was implemented pre-1996, vegetation communities in the RWB quickly shift from early to late succession communities. Late succession communities can be characterized as monocultures of one of several species (bulrush, cattail, or reed canary grass) and provide very limited foraging resources. For example, it would require 378,500 acres of late succession habitat (25,000 kcal/acre) in the RWB to meet the wetland dependent energetic needs of waterfowl. Conversely, it would only require 37,850 acres of early succession habitat (250,000 kcal/acre) to meet the same energetic requirements. In the RWB, NRCS staff have demonstrated a commitment to work with private landowners to manage their WRP projects. Their prescribed management in the form of grazing, haying, or herbicide treatments has maintained early succession communities. This management ensures that WRP tracts in the RWB will continue to provide some quality waterfowl habitat. The value of management should not be overlooked in the administration of the WRP program in the RWB.

As stated it will take approximately 37,850 acres of early succession habitat to meet forage requirements of migratory waterfowl in the RWB region. To meet waterfowl foraging requirements, all these acres would need to be flooded with 6–12 inches of water during spring migration. Because RWB wetlands are ephemeral systems and most wetlands become flooded as a result of intense late summer storms or accumulation of winter precipitation, there can be significant variation in available habitat across the landscape. To account for the climactic variation additional habitat will need to be distributed across the landscape. This will ensure that despite the variation in precipitation, sufficient wetland resources will be available annually. The NRCS has an office in every county in the RWB. This presence and the numerous wetland related farm bill programs provide a great opportunity to deliver this necessary habitat.

The distribution and abundance of spring wetland habitat containing surface water is one of the key uncertainties of the RWB. To better understand the temporal variability of habitat, the RWBJV developed a color-infrared (CIR) aerial photography system to annually map spring habitat. In 2004, a year characterized by average precipitation conditions across the region, approximately 8,800 acres of flooded habitat was available. This included 1,400 acres of farmed wetlands, 4,100 acres of early succession, 2,100 acres of late succession habitats, and 1,200 acres of suitable lacustrine habitat (e.g., stock ponds, irrigation reuse pits, watershed lakes). The total forage value provided by these different habitats was approximately 1.3 billion kcal, approximately 13% of the wetland -derived forage required to support waterfowl that use the region. In 2006, a year characterized by drought conditions, approximately 3,200 acres of habitat was documented. Habitats available were: 120 acres of farmed wetlands, 1,400 acres of early succession, 500 acres of late succession, and 1,200 acres of lacustrine wetlands. These acres provided approximately 400 million kcal, 4.3% of the wetland forage required by migratory waterfowl in the RWB. In 2007, a year characterized as slightly above average precipitation conditions, approximately 12,600 acres of habitat was documented. Habitats available were: 2,500 acres of farmed wetlands, 6,400 acres of early succession, 2,500 acres of late succession, and 1,200 acres of lacustrine wetlands. These acres provided approximately 2.0 billion kcal or 20.6% of the wetland forage target.

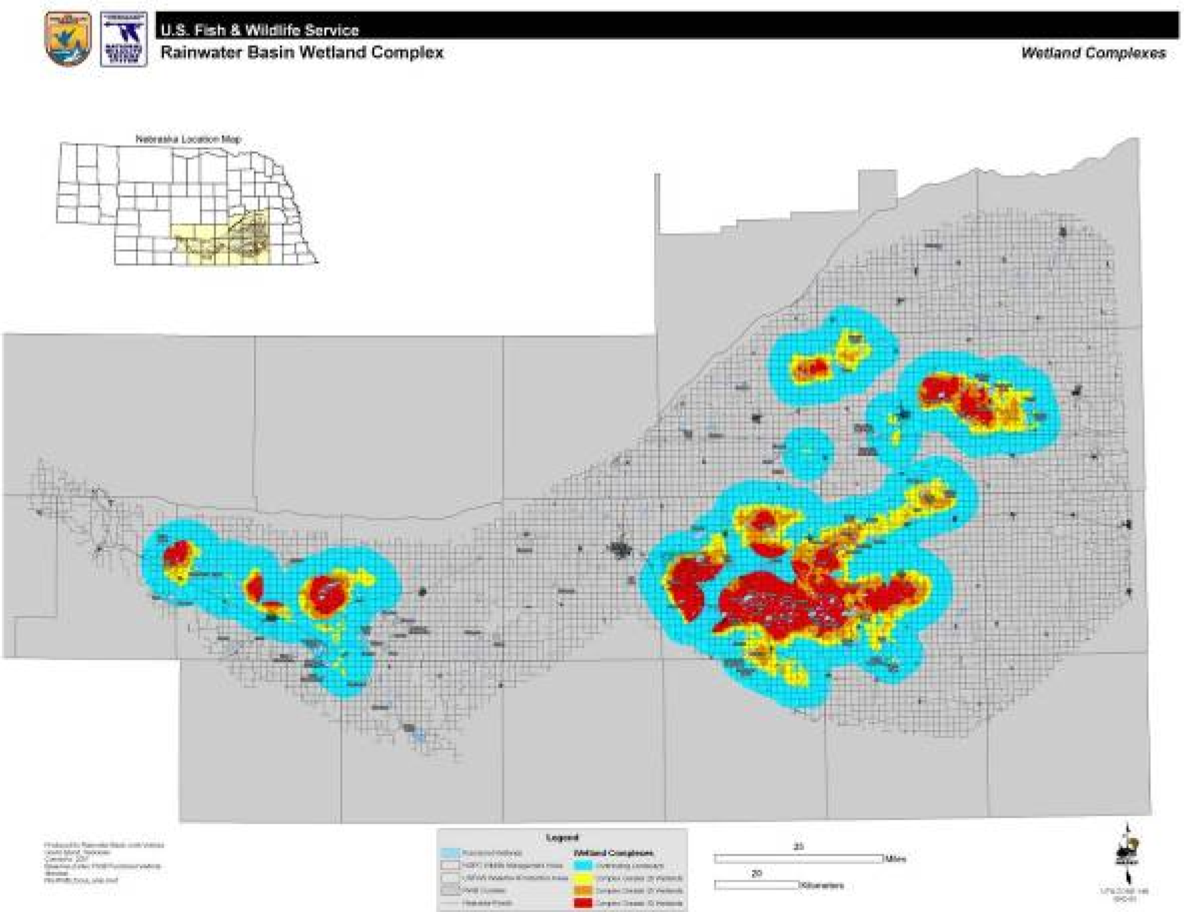
The RWBJV is using these results to evaluate the appropriate acres of habitat that should be protected, restored, and enhanced across the landscape to ensure annual suitable habitat for migratory waterfowl. The RWBJV is also in the process of updating its implementation plan, using foraging habitat as the principle factor limiting waterfowl during spring migration. One potential new habitat goal would be to deliver sufficient habitat so adequate acres would be flooded as a result of 'average' precipitation conditions. Based on the estimate that 40,215 acres of wetland habitat currently exist in the RWB, and in an average precipitation year these acres ponded 8,900 acres (providing 13% of the required foraging habitat) an additional 162,500 acres of early succession wetland acres would be needed to meet waterfowl forage requirements. The restoration goal of 162,500 acres was based on several assumptions. In 2004 roughly 20% of all RWB wetland habitats flooded. This suggests that in an average year a total of 162,500 additional acres of early succession wetland habitat would be required in conjunction with the existing habitats. In addition to the restored acres, management of late succession vegetation (50% conversion of late succession to early succession) will also be required to provide sufficient forage habitat.

The goal of 162,500 acres of total wetland habitat where an additional 100,000 acres (60%) is secured through perpetual easements or fee title acquisition may not be socially or economically possible. This analysis has helped the RWBJV to see that additional acquisitions under a protection strategy will be necessary, but enhancement of existing acres is an equally important strategy. Under current landscape conditions, 26% (10,456 acres) of the existing wetlands are in the late succession vegetation stage (Table 5). If shifted to early succession, and flooded these wetlands would provide 2.4 billion kcal of additional energy. This conversion would allow wetland habitats in the RWB to provide 8.9 billion or 96% of the wetland derived energetic resources needed annually. NRCS restorations of new WRP easements remove any late succession wetland vegetation from the restored area. The drastic disturbance associated with the restoration promotes the growth of early succession wetland vegetation. This not only benefits waterfowl, but also makes vegetation management more cost effective in the future.

Over 70% (2.7 million acres) of the RWB region is under agriculture cultivation, with 65% under irrigation (22.5% gravity, 77.5% center-pivot) (Table 5). Before being converted to pivot irrigation, nearly all of this land was gravity irrigated. Often associated with gravity irrigation is the use of tail water recovery pits that catch runoff and allow the producer to maximize groundwater use for cultivation of crops. These pits not only catch irrigation runoff, but natural precipitation as they are often located in the watershed of RWB wetlands. After irrigation season, these pits continue to fill with runoff from precipitation events and do not allow water to continue to the wetland until the pit reaches full storage capacity. A recent GIS inventory of irrigation tail water recovery pits documented 10,217 pits. Using the hydrogeomorphic (HGM) (Stutheit et al. 2004) model it is estimated that these pits can capture 34,553 acre feet of water at full pool. The HGM model was also used to calculate the total wetland storage volume at 79,274 acre feet based on historic hydric soil footprints. At full saturation, 44% of the water in the RWB would be stored in irrigation tail water recovery pits, while 56% would be available water in wetlands. This crude model helps demonstrate the impact that offsite hydrologic modifications have on RWB wetland function. With the conversion to pivot irrigation systems that no longer use irrigation reuse pits, a tremendous opportunity exists to restore wetland function through off-site hydrologic restoration. These types of off-site restorations would help water fill existing and restored wetlands making these habitats available on a more regular basis.

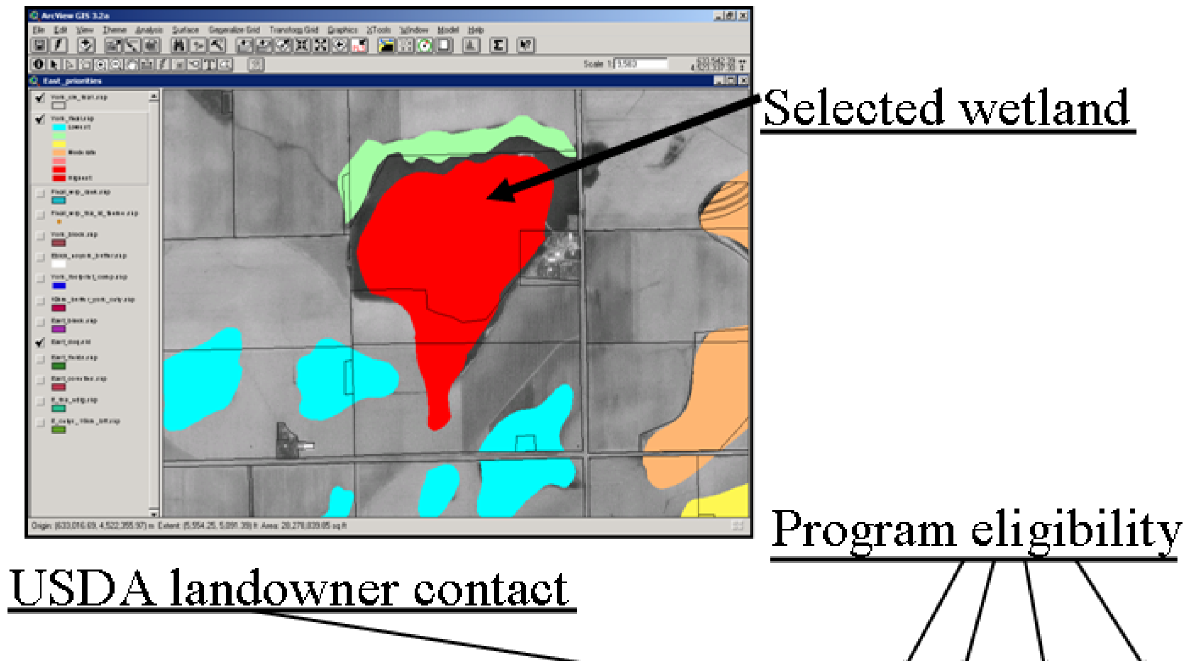
Brennan (2006) suggested that wetland complexes were used at a higher degree compared to isolated wetlands. This research built upon the findings of Gersib et al. (1989) that showed that wetland complexes which included temporary, seasonal, and semi-permanent wetlands were used at a greater intensity by dabbling ducks when compared to areas that lacked one or more of these wetland resources. HAPET has used this information to develop spatial models that identify areas on the landscape that have the potential to provide the highest quality wetland habitats for migratory waterfowl. The product of this analysis has been integrated into Decision Support Tools (DST) to guide wetland conservation actions (Figure 3). Focus areas that have a high density of functioning wetlands with optimal wetland juxtaposition between wetland types should be higher in priority for wetland acquisition, restoration and management activities.

Figure 3 Wetland Focus Areas



In conjunction with the focus area analysis, a program based spatial model was developed. This model evaluated every hydric soil footprint based on program eligibility. A portion of the analysis also used the NRCS-Nebraska WRP criteria to estimate the rank a wetland would receive for enrollment in the WRP. This model allows NRCS and FSA staff to conduct an initial assessment to determine the programs different RWB wetlands may be eligible for (Figure 4). This tool can be used in conjunction with the CLU to help USDA target their wetland programs. Use of these types of tools will help the RWBJV to continue to deliver conservation projects in areas that provide the highest quality waterfowl habitat.

Figure 4 Wetland Conservation Decision Support Tool



Legal	Fpcp	Lndscp_pri	Pcnt_prior	Percent_we	wetland_acres	Farmnbr	Tractnbr	Clunbr	Acres	FWCRP	CREP	WRP<>CREP	Wrp_rankin
T11N R1W Sec18B	york2044 2978	59.5	91.5	17.30	26.2	2987	2041	1	26.239	N	Y	Y	56
T11N R1W Sec18C	york2044 2978	59.5	91.5	100.00	2.0	3682	4206	0	1.957	N	N	Y	51
T11N R1W Sec18C	york2044 2978	59.5	91.5	21.16	31.7	3682	4206	2	31.735	N	Y	Y	39
T11N R1W Sec18B				0.00	0.0	2987	2041	1	122.579	N	N	N	28
T11N R1W Sec18C				0.00	0.0	3682	4206	2	110.391	N	N	N	35
T12N R1W Sec01A	york1674 2460	15.4	23.7	31.63	0.3	4378	1717	0	0.313	N	N	Y	30

Appendix A List of Acronyms

Table A-1. List of acronyms used in this report and their definitions.

Type	**Acronym**	**Definition**
Organization		
	FSA	Farm Service Agency
	HAPET	USFWS Region 6 Habitat and Population Evaluation Team
	NGPC	Nebraska Game and Parks Commission
	NRCS	Nature Resources Conservation Service
	PLJV	Playa Lakes Joint Venture
	RWBJV	Rainwater Basin Joint Venture
	USDA	United States Department of Agriculture
	USFWS	United States Fish and Wildlife Service
RWBJV Workgroups		
	CPW	Conservation Planning Workgroup
	TC	Technical Committee
Region/ Property		
	RWB	Rainwater Basin Wetland Complex
	WMA	Wildlife Management Area
	WPA	Waterfowl Production Area
Waterfowl Population		
	TSA	Traditional Survey Area
	MCP	Mid-Continent Population
	GPP	Great Plains Population Canada Goose
	TPP	Tall Grass Prairie Population Canada Goose
	WPP	Western Prairie Population Canada Goose
Energetic Associated		
	BMR	Basel Metabolic Rate
	DEE	Daily Energy Expenditure
	kcal	Kilocalorie
	TME	True Metabolizable Energy

Type	Acronym	Definition
Data		
	AHM	Adaptive Harvest Management
	CEAP	Conservation Effects Assessment Project
	CIR	Color Infrared Imagery
	CLU	Common land Unit
	CRP	Conservation Reserve Program
	DEM	Digital Elevation Model
	DSS	Digital Sensor System
	DST	Decision Support Tool
	GIS	Geographical Information System
	GPS	Global Positioning System
	HGM	Hydrogeomorphic Model
	HWM	Historic Wetland Mask
	LPS	Leica Photogrammetry Suite
	NAIP	National Agriculture Imagery Program
	NASS	National Agriculture Statistics Service
	NAWMP	North American Waterfowl Management Plan
	NVCS	National Vegetation Classification System
	NWI	National Wetlands inventory
	RS	Remote Sensing
	SSURGO	Soil Survey Geographic Database
	TTA	Testing Training Mask
	WRP	Wetland Reserve Program

Appendix B Mapping protocol used to develop RWB landcover

To estimate potential forage capacity of the RWB landscape for migratory waterfowl an accurate seamless dataset representing important forage habitats was needed. The RWBJV had made efforts to compile spatial data from numerous sources to better understand the landscape. However, many of the existing data layers were not comprehensive in scope or compiled as seamless datasets. In addition specific habitat information necessary to quantify RWB wetlands energetic potential was not present in existing data or not at a fine enough scale. For this project we compiled relevant existing data into a seamless layer then identified required missing data. We used a nine-step process to compile existing data, develop missing components, and assemble a current RWB landcover. These steps were: current landcover evaluation & enhancement, defining a mapping standard, image acquisition, image processing, sampling design, field data collection, image classification, accuracy assessment, and final landcover development.

Landcover Evaluation & Mapping

We created a base dataset from existing spatial data and evaluated its utility in representing key foraging habitats. This allowed us to identify landscape features that were missing in the base dataset, and select features to be added to more accurately evaluate the landscape in terms of waterfowl foraging capacity. By understanding what features were missing from the base dataset, remote sensing techniques could be used to map these features from digital aerial photography. Image analysis allows image classification through unsupervised or supervised classification methods. These methods allow software programs to apply complex algorithms and develop a representation of distinct landcover/habitat types. By using a habitat mask like the base landcover to represent ”known” classes one can reduce confusion between classes of important habitats, thereby increasing the overall accuracy of the final dataset.

For this project we developed the base landcover mask from the Farm Service Agency (FSA) Common Land Unit (CLU) dataset. The CLU is a vector landcover layer created by FSA to administer agriculture programs and contains information on cropping history and conservation program enrollment. The data was created through photo interpretation at 1:5,000 scale. For this project, the individual CLU layers for the 21 counties of the RWB were merged into a seamless dataset retaining the Land Class attribute information. Relevant Land Class information included: Agriculture (cropland), Range/Grass/Pasture, Conservation Reserve Program (CRP), and Non-Agriculture (e.g., rural developed). Once the county datasets were merged together the Land Class descriptions were validated through photo interpretation of multiple years of USDA-National Agriculture Imagery Program (NAIP) aerial photography (2003–2006) and multi-date Color-Infrared (CIR) aerial photography (Fall 2003, Spring 2004, Fall 2004, Spring 2006) collected by the RWBJV. The most recent imagery was primarily used to identify current landcover status, but earlier years were referenced if landcover features were unclear. During the validation process, additional features identifiable from aerial photography and necessary to include in the final landcover, were integrated into the base CLU via heads-up digitizing at 1:5,000 scale. The following features were further delineated because of their value as wildlife habitat, their importance in accurately modeling habitat suitability for priority species, or as an inventory of poorly functioning agriculture fields that may have potential for enrollment in conservation programs.

Landcover/Landuse features further delineated during this process included:
1) Riparian Corridors: tree canopies that follow perennial or intermittent drainages.
2) Upland Woodlands: coniferous or deciduous trees occurring outside of hydrologic drainages/wetlands.
3) Range/Grass/Pasture: all grassland areas.
4) Stock Dams: impoundments created by earthen dams across natural drainages.
5) Irrigation Reuse/Concentration Pits: hydrologic features created by excavating pits on the downslope end of gravity irrigated fields or in wetlands. Irrigation Reuse Pits are features that catch excess irrigation water runoff from gravity-irrigated agriculture fields and recycle the water for continued irrigation. Concentration pits are features built in or near wetlands to concentrate water which would naturally pond in a wetland, thus increasing the farmable area of the field.
6) Stressed Agriculture: portions of agriculture fields that show crop stress due to flooding or poor soils.
7) Urban Developed: cities and towns.
8) Rural Developed: farmsteads, rural industry, any housing or industrial areas outside of city limits.

The next step in enhancing the base landcover was to integrate wetland features. To complete this step the Historic Wetland Mask (HWM) spatial data layer was integrated into the base landcover. The HWM is a comprehensive inventory of contemporary and historic RWB wetlands. The HWM was created by merging: hydric soils data from historic soils surveys (1910 – 1917), SSURGO hydric soils (1961–2004), National Wetlands Inventory (NWI) data (1980–1982), and a satellite-based wetlands inventory completed by Ducks Unlimited in 2005. In the HWM integration process, the wetland data was merged with the landcover to create three additional classes.

1) Agricultural Wetlands: HWM footprints embedded in agriculture fields exhibiting no hydrologic function.
2) Farmed Wetlands: footprints embedded in agriculture fields previously defined as stressed agriculture, or displayed standing water in at least one aerial photography image.
3) Hydrophytes: portions of footprints previously classified as range/grass/pasture.

The final base habitat classes for the RWB mask:
1) Agriculture
2) Agriculture Wetland
3) Farmed Wetland
4) Hydrophytes
5) Stock Dam
6) Irrigation Reuse/Concentration Pit
7) Range/Grass/Pasture
8) CRP
9) Upland Woodland
10) Riparian Woodland
11) Rural Developed
12) Urban Developed

This 12-class landcover provided an adequate assessment of the landscape to determine the distribution of remaining wetlands. However, it was not able to determine wetland vegetation composition. Without vegetation composition we could not assess forage value by wetland or estimate forage capacity of the RWB landscape. A comprehensive inventory of wetland vegetation status was needed to calculate the energetic potential of the landscape.

A site based wetland vegetation mapping effort was undertaken by the USFWS, NGPC, and the RWBJV in 2003. The goal of this project was to complete on-site mapping of vegetation on all public lands in the RWB. This data was collected using handheld Global Positioning System (GPS) units. Technicians traversed the boundary of distinct wetland vegetation communities and created GIS inventory of the community boundaries. The data was collected with sufficient detail to calculate forage potential on public wetlands. This on-site method could not be used to map all of the private basins due to the sheer number of wetlands and the associated large number of landowners, but the data collected on the public areas could be used as training data in a remote sensing project to map wetlands under private ownership.

Mapping Standards

The first step in mapping the wetland vegetation composition was to define the vegetation communities that would be mapped. To define wetland vegetation communities we used the National Vegetation Classification System (NVCS). The NVCS is a hierarchical system that provides a consistent framework for vegetation mapping by federal agencies. Vegetation classes for the CEAP assessment landcover were based on a hybrid of the Formation and Alliance levels of the NVCS. These classes were defined based on the energy availability by vegetation community. The Formation level of the NVCS is the coarsest physiognomic classification, while the Alliance level is the second finest mapping level (the Association is the finest physiognomic classification level). Formations describe basic vegetation communities: (deciduous woodland, seasonally-flooded grassland), Alliances are defined by communities of plant species, while Associations are described by a dominant species representing a specific habitat. Initially, mapping was done to the Alliance level, but after evaluation of available energy by vegetation community several Alliances were grouped to form aggregate communities.

The following Alliances were mapped: 1) Water/Mudflat, 2) Moist Soil vegetation (e.g., Smartweed (*Polygonum* spp.), Barnyard Grass (*Echinochloa* spp.)), 3) Reed Canary Grass, 4) Bulrush (*Scirpus* spp.), 5) Cattail (*Typha* spp.), 6) Wet-Meadow (*Carex* spp.), 7) Upland grass (Big bluestem (*Andropogon*), Indian grass (*Sorghastrum)*, Switch grass (*Panicum*)), 8) Stressed Agriculture and 9) Agriculture (no wetland function). These Alliances were only mapped in the following three base landcover classes: 1) Agricultural Wetlands, 2) Farmed wetlands, and 3) Hydrophytes. All other landcover classes were non-wetland categories not necessitating wetland vegetation mapping.

We evaluated the vegetation Alliances based on the energetic forage potential they could provide for waterfowl. We found several of the classes could be grouped because the communities provided similar energetic value for waterfowl. Five aggregate classes were developed: 1) Late-Succession Hydrophytes (reed canary grass, bulrush, and cattail), 2) Early-Succession Hydrophytes (moist soil vegetation, water/mudflat, and wet meadow), 3) Upland Grass, 4) Farmed Wetland, and 5) Agriculture.

Sampling Design and Image Acquisition

In August 2004, CIR imagery was acquired for the RWB region for the purpose of mapping wetland vegetation in all wetlands across the entire landscape. Based on analysis from a previous 2003 flight, August was chosen as the desired data acquisition timeframe to differentiate wetland vegetation communities. Imagery was acquired using an Applanix Digital Sensor System (DSS) mounted in a Cessna 172 fixed-wing aircraft. Imagery was collected in three spectral bands Red, Green, and Infrared, with a horizontal resolution of 1 meter. Data acquisition was conducted to create a seamless and color-balanced digital dataset.

Image Processing

Imagery was color balanced image-to-image as well as across the geographic region and range of acquisition dates. This removed streaking and variation between acquisition dates and helped maintain constant color and hue for the entire image dataset. Once balanced, images were ortho-rectified using ERDAS Imagine - Leica Photogrammetry Suite (LPS) to a horizontal accuracy of 3 -5 meters, and stitched together into a seamless digital mosaic.

Training data

The 2003 wetland vegetation mapping data collected on the state and federally owned wetlands was used as training data in a remote sensing based vegetation map for the entire RWB area. The 2003 field data was collected by ground crews using GPS units coupled with handheld computers. The GPS unit allowed the technicians to create a digital polygon as they traversed the boundary of each vegetation community. Once the polygon was created, the technician record attribute information associated with mapped feature into the handheld computer. Vegetation communities delineated were: 1) Water, 2) Moist Soil vegetation, 3) Mud Flat, 4) Reed Canary Grass, 5) Bulrush, 6) Cattail, 7) Wet-Meadow, and 8) Upland. These communities were identified due to their differing values for wildlife habitat or management issues associated with the vegetation community. Despite mapping the vegetation for slightly different objectives than for evaluating wetland forage potential, the data collected by this project was easily cross-walked for use as training data in a remote sensing application.

Training data processing

Conversion of the 2003 vegetation mapping project into usable training data for a supervised classification was a multi-step process requiring both eCognition and ArcGIS software. The first step was to load the RWB landcover into eCognition. We used the landcover as a mask to create a class hierarchy. The class hierarchy allowed multi-resolution segmentation parameters to be varied by class to more effectively delineate homogenous vegetation. This increased the software's power to asses the spectral characteristics of the imagery, enhancing the ability to group pixels sharing unique spectral and textural characteristics that coincide with distinct vegetation communities. At this point, eCognition could not differentiate between different mapping classes, but simply recognized groups of pixels that shared similar characteristics (homogenous stands of vegetation). The polygon boundaries were exported out of eCognition into an ArcGIS geodatabase. In the Geodatabase, domains or drop down menus were created corresponding to the appropriate habitat classes. Results from the 2003 USFWS & NGPC vegetation mapping effort were used in ArcGIS to attribute the eCognition polygons. These polygons now contained the information from the 2003 mapping effort and were suitable for use as training data in a supervised classification.

Image Classification

The training data were converted from vector polygons into a raster-based testing and training mask (TTA mask) in ArcGIS. The eCognition software can import ERDAS imagine raster data as a TTA mask for use in a supervised classification. Using the TTA mask a Nearest Neighbor supervised classification was ran on the imagery, with the output exported as a vector dataset. The vector output was imported into a geodatabase with appropriate domains (Early Succession, Late Succession, Agriculture, etc.) for a final photo interpretation. During the photo interpretation process, polygons were classified into finer mapping units than could be easily identified in eCognition. For example, during the photo interpretation phase, the Water class was further defined into: Ponded Water, Stock Dam, or Irrigation Reuse Pit. These finer features are apparent to the naked eye but difficult to train the image classification software to identify. During the final photo interpretation process obvious misclassifications were corrected.

Accuracy Assessment

Accuracy assessment was completed at both the NVCS-Alliance level and aggregated wetland vegetation map. The accuracy assessment was conducted by randomly selecting 20 wetland polygons from the 2003 public lands vegetation map for each of the Alliance classes not previously used as training data. Several mapping classes only occur on private lands (Agriculture wetland and Stressed Agriculture). Therefore, we had to use similarly-timed aerial photography (2004 NAIP) to determine the accuracy of the classification in Agriculture Wetland and Stressed Agriculture categories (Table B-1). Acres were summarized by class to create an error matrix and overall accuracy report (Tables B-2 and B-3). The accuracy results are considered better than average when taking into account the types of landcover classes identified in the classification (Congalton and Green 1999). In wetlands, vegetation community boundaries are not distinct and vary each year. Since the training data and imagery were acquired a year apart it is possible this led to some of the classification error. In addition, RWB wetlands are ephemeral systems and where water occurred during the ground-based public lands mapping effort it could dry out prior to imagery acquisition even if the imagery was acquired the same year. In addition, a moist soil vegetation community can quickly become established after ponded water recedes or management is performed on late succession vegetation. This probably explains much of the error between the water/mudflat and moist soil classes, and between the cattail and bulrush classes. Agriculture and stressed agriculture was classified with a high level of accuracy. This was likely a result of using the CLU to create the preliminary landcover mask, which would have eliminated much of the spectral confusion between agricultural and native vegetation.

Table B-1. Overall accuracy for alliance level and aggregate classification

Alliances	**Producers Accuracy**	**Users Accuracy**	**Overall Accuracy**
Ag	99.9%	99.2%	99.6%
Cattail	73.2%	70.1%	71.6%
Grass	95.9%	82.2%	89.0%
Moist Soil	74.0%	93.1%	83.5%
Reed Canary Grass	82.5%	78.4%	80.5%
Scirpus	90.3%	64.1%	77.2%
Stressed Ag	99.0%	95.0%	97.0%
Trees	84.0%	99.8%	91.9%
Water Mudflat	79.9%	58.3%	69.1%
Wetmeadow	83.2%	74.8%	79.0%

Aggregate Classes	**Producers Accuracy**	**Users Accuracy**	**Overall Accuracy**
Ag	99.9%	99.2%	99.6%
Early Succession	84.5%	94.7%	89.6%
Grass	95.9%	82.2%	89.0%
Late Succession	91.4%	79.0%	85.2%
Stressed Ag	99.0%	95.0%	97.0%
Trees	84.0%	99.8%	91.9%

Table B-2. Error matrix for alliance level vegetation classification

Sum of Acres	Field Veg											
Classified Veg	Ag	Cattail	Grass	Moist Soil	Reed Canary	Scirpus	Stressed Ag	Trees	Water Mudflat	Wet-meadow	Grand Total	Ommission Error
Ag	239.6			0.0			1.8				241.5	99.2%
Cattail		245.1	0.2	80.7	3.6	13.9		0.0	5.7	0.3	349.5	70.1%
Grass		0.0	185.0	12.3	12.0	0.0		3.8	0.0	11.9	225.2	82.2%
Moist Soil		25.5	1.0	1024.0	19.2	7.9		0.1	3.8	18.1	1099.7	93.1%
Reed Canary		4.1	5.1	63.0	349.3	7.8		2.6	4.2	9.3	445.4	78.4%
Scirpus		55.5	1.5	77.8	17.1	292.5			10.9	1.1	456.3	64.1%
Stressed Ag	0.0			9.4			177.3				186.6	95.0%
Trees	0.1			0.0			0.0	63.4			63.6	99.8%
Water Mudflat		4.6	0.0	46.0	9.0	1.5			105.5	14.4	181.0	58.3%
Wet-Meadow		0.1	0.2	71.2	13.0	0.2		5.5	1.8	273.1	365.2	74.8%
Grand Total	239.8	335.0	193.0	1384.3	423.3	323.8	179.1	75.5	132.0	328.2	3614.1	
Comission Error	99.9%	73.2%	95.9%	74.0%	82.5%	90.3%	99.0%	84.0%	79.9%	83.2%		
											Overall Accuracy	81.8%

Table B-3. Error matrix for aggregate classification

Sum of Acres	Aggregate Field							
Aggregate Class	**Agriculture**	**Early Successional**	**Grass**	**Late Successional**	**Stressed Ag**	**Trees**	**Grand Total**	**Ommission Error**
Agriculture	239.6	0.0			1.8		241.5	99.2%
Early Successional		1,558.0	1.2	81.2		5.6	1,646.0	94.7%
Grass		24.3	185.0	12.0		3.8	225.2	82.2%
Late Successional		252.9	6.8	988.9		2.7	1,251.2	79.0%
Stressed Agriculture	0.0	9.4			177.3		186.6	95.0%
Trees	0.1	0.0			0.0	63.4	63.6	99.8%
Grand Total	239.8	1,844.6	193.0	1,082.1	179.1	75.5	3,614.1	
Comission Error	99.9%	84.5%	95.9%	91.4%	99.0%	84.0%		
							Overall Accuracy	**88.9%**

Final Habitat Assessment Map

The final step in landcover development was to integrate all relevant datasets into a seamless data layer. As described, we developed several vector-based datasets to accurately represent the RWB landscape. These datasets included the base landcover derived from the CLU and the wetland vegetation community derived from the aerial photography. Vector datasets are more spatially accurate than raster data, but when completing landscape analysis it is more efficient to use raster data. To develop the seamless raster layer relevant vector datasets were converted to 10 meter resolution raster data and then stacked. This process was completed using the Mosaic tool in ERDAS Imagine. In the mosaic tool, datasets can be ranked in the stacking process. The values from the highest dataset are accepted as the value for the final landcover, which allows the user to prioritize datasets based on their accuracy. Thus, the final data layer uses the most spatially accurate data first, and when that information is not available selects values from the next available dataset. Vector datasets integrated included: the RWB WRP habitat, NWI, RWB hydrologic modifications, RWB wetland vegetation assessment, Nebraska urban areas, Nebraska roads layer, and base landcover mask. The 2004 NASS cropland layer was used to attribute agriculture fields to the appropriate crop type. The stacking order for landcover development, in order of precision, RWB WRP, RWB hydrologic modifications, RWB wetland vegetation, RWB base landcover, Nebraska urban areas, Nebraska roads, RWB NWI, RWB CRP, RWB agriculture cropping, Nature Serve Ecosystem Landcover.

Appendix C Energetic Requirements of Migratory Waterfowl using the RWB Region.

To estimate the amount of habitat required to support migratory waterfowl using the RWB we developed a bio-energetic model. A bio-energetic model provides a method to compare the energetic resources available on the landscape against the energetic requirements of individuals using that region. At the foundation of this bio-energetic model is the caloric estimate of energy required by the individuals using the RWB during each phase of migration. To estimate the energetic requirements of these individuals several model inputs were defined. These include species specific use estimates derived from the continental/population estimates, average residency time, and species specific daily energetic requirements. In addition to the total energetic requirements we also estimated the proportion of diet that should be derived from wetland habitats.

Define species specific migration phase estimates

At the foundation of this model are estimates of number of migratory waterfowl that use the RWB during each phase of migration. To develop the migration specific species estimates, we stepped down the reported continental/population estimates to a local scale. This process allowed us to approximate the number of individuals that migrate through the RWB. We used separate techniques to approximate numbers of ducks and geese due to information available for these separate guilds.

To determine the continental population estimates for ducks we used data in the Waterfowl Population Status Report (USFWS 1997–2006). The Waterfowl Population Status Reports are completed on an annual basis and summarize survey information and habitat conditions each year. We used the Waterfowl Population Status Report (USFWS 1997–2006) to compile breeding population estimates (Table C-1) for the traditional survey area (TSA) for each of the last ten years. This data was then used to calculate the ten year average continental breeding populations for the major duck species that migrate through the RWB Region. To develop fall duck population estimates, we used the breeding population estimates in conjunction with the estimated mallard fall flight. The estimated mallard fall flight is also presented in the Waterfowl Population Status Report. The mallard fall flight estimate is a product of the Adaptive Harvest Management (AHM) model that is completed annually to assist in the hunting regulation process. The AHM model is a complex model that incorporates multiple variables such as: breeding population, age ratios, sex ratios, summer survival, harvest, and May ponds. Sufficient information is available to complete this model for mallards, but not for other species. Therefore, we compared the mallard breeding population against the predicted mallard fall flight to generate a recruitment rate coefficient (Table C-2). We used the mallard recruitment coefficient as a surrogate to estimate fall flight for the other duck species. This calculation was completed for each of the last ten years and used to develop a ten year fall flight average (Table C-3) for the selected duck species.

Table C-1. Spring breeding population estimates for the main species of ducks that migrate through the Rainwater Basin region of Nebraska.

	Breeding Population Estimates for Indicated Species (Thousands)						
Year	Mallard (1)	Northern Pintail (1)	American Widgeon (1)	Gadwall (1)	Northern Shoveler (1)	Green-winged teal (1)	Blue-winged Teal (1)
1997	9,939.7	3,558.0	3,117.6	3,897.2	4,120.4	2,506.6	6,124.3
1998	9,640.4	2,520.6	2,857.7	3,742.2	3,183.2	2,087.3	6,398.8
1999	10,805.7	3,057.9	2,920.1	3,235.5	3,889.5	2,631.0	7,149.5
2000	9,470.2	2,907.6	2,733.1	3,158.4	3,520.7	3,193.5	7,431.4
2001	7,904.0	3,296.0	2,493.5	2,679.2	3,313.5	2,508.7	5,757.0
2002	7,503.7	1,789.7	2,334.4	2,235.4	2,318.2	2,333.5	4,206.5
2003	7,949.7	2,558.2	2,551.4	2,549.0	3,619.6	2,678.5	5,518.2
2004	7,425.3	2,184.6	1,981.3	2,589.6	2,810.4	2,460.8	4,073.0
2005	6,755.3	2,560.5	2,225.1	2,179.1	3,591.5	2,156.9	4,585.5
2006	7,276.5	3,386.4	2,171.2	2,824.7	3,680.2	2,587.2	5,859.6
Average (10 year)	8,467	2,782	2,539	2,909	3,405	2,514	5,710
(1) Breeding Population estimate from the annual Waterfowl Population Status Report							

Table C-2. Estimated mallard recruitment by year determined by dividing mallard breeding population against the estimated fall flight.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Mallard Recruitment	1.39	1.21	1.18	1.18	1.23	1.21	1.3	1.27	1.38	1.36

Table C-3. Fall flight population estimates for the main species of ducks that migrate through the Rainwater Basin region of Nebraska.

	Fall Population Estimate for Indicated Species (Thousands)						
Year	Mallard (1)	Northern Pintail (2)	American Wigeon (2)	Gadwall (2)	Northern Shoveler (2)	Green-winged teal (2)	Blue-winged Teal (2)
1997	13,800	4,940	4,328	5,411	5,721	3,480	8,503
1998	11,700	3,059	3,468	4,542	3,863	2,533	7,766
1999	12,800	3,622	3,459	3,833	4,607	3,117	8,469
2000	11,200	3,439	3,232	3,735	4,164	3,777	8,789
2001	9,700	4,045	3,060	3,288	4,066	3,079	7,065
2002	9,100	2,170	2,831	2,711	2,811	2,830	5,101
2003	10,300	3,315	3,306	3,303	4,690	3,470	7,150
2004	9,400	2,766	2,508	3,278	3,558	3,115	5,156
2005	9,300	3,525	3,063	3,000	4,944	2,969	6,313
2006	9,900	4,607	2,954	3,843	5,007	3,520	7,972
Average (10 year)	10,720	3,549	3,221	3,694	4,343	3,189	7,228

(1) Mallard fall flight estimate from the annual Waterfowl Population Status Report
(2) Estimated fall flight (Species specific breeding populaiton * Mallard recruitment rat

To determine goose estimates for selected species and sub-populations of Canada geese that migrate through the RWB, we again used the data in Waterfowl Population Status Report. We compiled the mid winter surveys for Light geese, sub-populations of Canada geese, and the fall survey information collected to assess the Mid-continent population of Greater White-fronted geese (Table C-4). Using this data, we determined the ten year average for each of the indentified groups. The survey methods for the Tall-grass Prairie Population of Canada goose were modified in 2001. Because previous years were not directly comparable we only have a five year average for this population. Goose populations are not surveyed at the same level or intensity as duck populations. Therefore we could not develop explicit fall and spring continental/population estimates. So for the goose estimates we use these reported averages to step down both the spring and fall objectives for the RWB.

Table C-4. Continental population estimates for the main species and sub-populations of geese that migrate through the Rainwater Basin region of Nebraska.

	Population Estimate for Indicated Species			
Year	Light Geese MCP (1)	Canada Goose GPP/WPP (1)	Canada Goose TGPP (1)	White-fronted Goose (2)
1997	2,850,900	453,400		742,500
1998	2,977,200	482,300		622,200
1999	2,575,700	467,200		1,058,300
2000	2,397,300	594,700		963,100
2001	2,341,300	682,700		1,067,600
2002	2,696,100	710,300	504,700	712,300
2003	2,435,000	561,000	611,900	637,200
2004	2,159,100	622,100	458,700	528,200
2005	2,344,200	415,100	400,800	644,300
2006	2,221,700	444,400	499,800	522,800
Average (10 year)	2,499,850	543,320	495,180	749,850

(1) Based on Mid-winter Survey information, USFWS Waterfowl Status Report

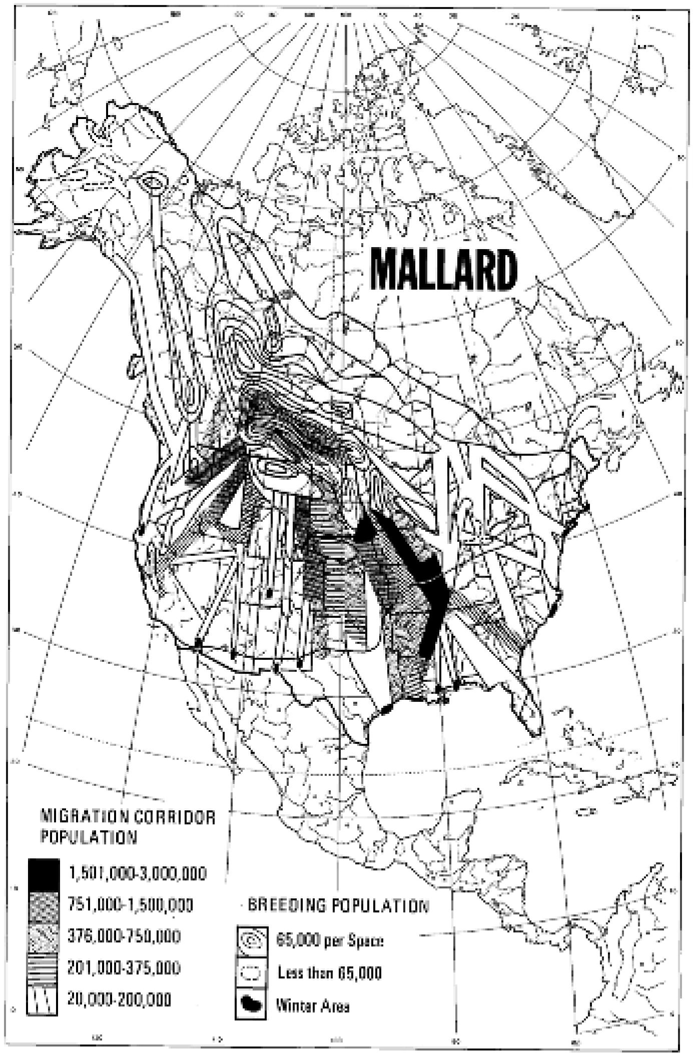
(2) Based on fall survey information, USFWS Waterfowl Population Status Report

Once the continental population estimates were defined, we stepped the populations down to the RWB scale. To estimate the proportion of TSA duck fall flight that migrates through the RWB, a migration corridor assessment was done. This analysis was completed by evaluating species-specific migration corridors that overlap the RWB as outlined in Bellrose (1980). These corridors are geographic migration routes that are characterized by the number of individuals that use the corridor during fall migration (Bellrose 1980) (Figure C-1). The first step in this process was to summarize the high estimates of the migration corridors that originate from the TSA. This value was referenced as the Bellrose Fall TSA Estimate. Next the values associated with the migration corridors that intersect the RWB were summarized. The high value representing the maximum individuals from the dominant corridor was added to the low range of individuals that use peripheral corridors. The migration map value was divided by the fall Bellrose estimate to develop the RWB migration map percentage (Table C-5). The migration map percent was multiplied by the ten year fall flight average (Table C-3) to derive an estimate of the number of ducks that migrate through the region in the fall (Table C-7).

Table C-5 Bellrose Fall flight estimates, estimated number using the Rainwater Basin of Nebraska, and migration percent.

Species	Bellrose Fall TSA Estimate	RWB Migration Corridor	RWB Fall Migration %
Mallard	12,975,000	1,501,000	11.6%
Northern Pintail	5,975,000	1,000,000	16.7%
Wigeon	4,500,000	226,000	5.0%
Gadwall	1,460,000	201,000	13.8%
Northern Shoveler	1,295,000	216,100	16.7%
Green-Wing Teal	2,480,000	300,000	12.1%
Blue-WingTeal	4,165,000	750,000	18.0%

Figure C-1 Mallard migration corridor (Bellrose 1980).



The migration estimates for goose species were developed using a similar method. We estimated the percent of the population that migrated though the region by evaluating the population ranges presented in the Waterfowl Population Status Report (Figure C-2). To complete this analysis we used a GIS to determine the area (Hectacres) of each population range that occurred between the same latitude as the RWB region (North latitude $41^0$20' and south latitude $40^0$10'). The area of the RWB was then divided by the clipped migration range to derive a migration percent for each goose species and sub-population (Table C-6). We used this analysis for the fall migration as no other information is currently available. This type of analysis assumes an even distribution of individuals across the range during migration. This represents the broad distribution of birds during the fall phase of migration. We multiplied the migration percents (Table C-6) by the average goose population estimates (Table C-4) to generate the fall estimates (Table C-7).

Figure C-2. Approximate range of the Great Plains sub-population of Canada geese (Waterfowl Status Report 2006).

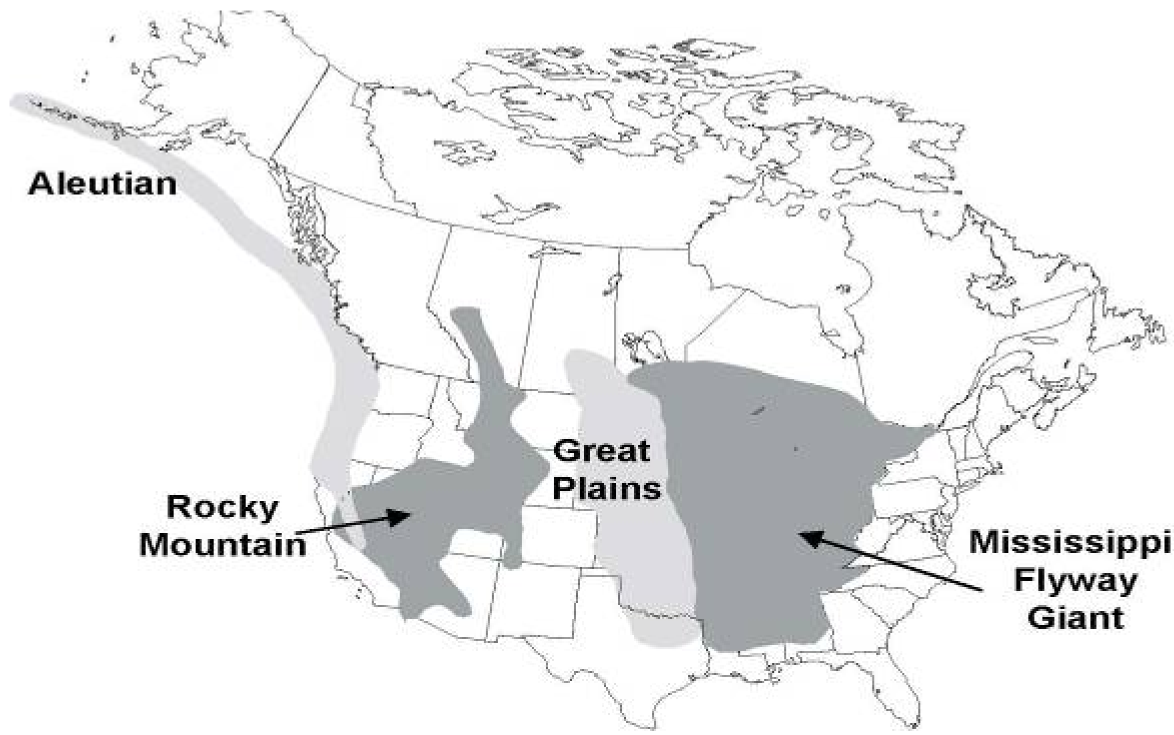


Table C-6 Migration percentages for selected goose species using the Rainwater Basin of Nebraska.

Species	Latitude Range Area (1)	RWB Latitude Area (1)	Percent
Light Geese	29,620,449	3,470,116	12%
Canada Goose GPP/WPP	8,384,481	3,470,116	41%
Canada Goose TGPP	7,606,007	3,470,116	46%
Greater White-fronted Goose	7,786,549	3,470,116	45%
(1) Area determined in GIS using Population range maps from Waterfowl Status Report (Hectacres)			

Table C-7 Estimated waterfowl that migrate through the Rainwater Basin region of Nebraska during fall migration.

Fall Migration			
Ducks Species	**TSA/Continental Estimate**	**Migration Percent**	**Estimated Migrants**
Mallard	10,720,000 (1)	11.6% (2)	1,240,133
Northern Pintail	3,548,774 (1)	16.7% (2)	593,937
Wigeon	3,221,029 (1)	5.0% (2)	161,767
Gadwall	3,694,331 (1)	13.8% (2)	508,603
Northern Shoveler	4,343,183 (1)	16.7% (2)	724,758
Green-Winged Teal	3,189,040 (1)	12.1% (2)	385,771
Blue-Winged Teal	7,228,389 (1)	18.0% (2)	1,301,631
Fall Ducks			**4,916,600**
Goose Species/Populations	**TSA/Continental Estimate**	**Migration Percent**	**Estimated Migrants**
Light Geese	2,499,850 (1)	12% (3)	299,982
Canada Goose GPP/WPP	543,320 (1)	41% (3)	222,761
Canada Goose TGPP	495,180 (1)	46% (3)	227,783
Greater White-fronted Goose	749,850 (1)	45% (3)	337,433
Fall Geese			**1,087,959**
Fall Waterfowl			**6,004,558**
(1) 10 year average derived from Waterfowl Population Status Report (2) Migration percent derived from Bellrose 1980 (3) Migration map percent determined in GIS from Waterfowl Status Report			

To calculate the spring migration estimates for ducks the spring ten-year averages (Table C-1) were multiplied by the migration map percent (Table C-5) for all species except mallards and pintails. Research by Gersib et al. (1989) documented 50% of the MCP mallards and 30% of the continental population of pintails migrate through the RWB in the spring. To calculate the spring migration estimates for the sub populations of Canada geese we multiplied the average population estimates (Table C-4) by the migration percentages determined by GIS (Table C-6). Research by NGPC (NGPC unpublished data 1999) estimated 50% of the light geese use the RWB each spring. Benning (1987) documented that 90% of greater white-fronted geese use the RWB region during the spring.

Table C-8 Estimated waterfowl that migrate through the Rainwater Basin region of Nebraska during spring migration.

Spring Migration			
Species	**TSA/Continental Population**	**Migration Percent**	**Estimated Migrants**
Mallard	8,467,050 (1)	50.0% (2)	4,233,525
Northern Pintail	2,781,950 (1)	30.0% (2)	834,585
Wigeon	2,538,540 (1)	5.0% (3)	126,927
Gadwall	2,909,030 (1)	13.8% (3)	401,446
Northern Shoveler	3,404,720 (1)	16.7% (3)	568,588
Green-Winged Teal	2,514,400 (1)	12.1% (3)	304,242
Blue-Winged Teal	5,710,380 (1)	18.0% (3)	1,027,868
Spring Ducks			**7,497,182**
Species	**TSA/Continental Population**	**Migration Percent**	**Estimated Migrants**
Light Geese	2,499,850 (1)	50% (4)	1,249,925
Canada Goose GPP/WPP	543,320 (1)	41% (5)	222,761
Canada Goose TGPP	406,360 (1)	46% (5)	186,926
Greater White-fronted Goose	749,850 (1)	90% (6)	674,865
Spring Geese			**2,334,477**
Spring Waterfowl			**9,831,659**

(1) 10 year population average from Waterfowl Population Status Report
(2) Gersib (1989) Spring estimates of use by mallards and pintails
(3) Bellrose (1980) estimates migration percent estimates
(4) Nebraska Game and Parks Commission 1999 unpublished data
(5) GIS analysis migration percent for sub populations of Canada Geese
(6) Benning (1987) reported percent of use by White-fronted geese

Proportion of Individuals Utilizing Region by Season

Migration is a climatically driven event and directly influences the use of the RWB region as a stopover site. Fall migration is often influenced by climate and food availability (Bellrose 1980). The fall migration can be a slow, drawn out process or can be a spectacular quick event. Mass migrations are the result of climatic conditions on fall staging areas including strong winds, falling temperatures, and overcast skies and precipitation (Bellrose 1980). Fall mass migrations often result in migrating waterfowl overflying the RWB. Slower paced fall migrations result in birds using the RWB for longer periods of time when sufficient habitat exists. Birds exploit resources in the RWB to replenish nutrient reserves before eventually arriving on the wintering grounds. To account for mass migrations, we assumed that 50% of dabbling ducks, 90% of Canada geese, 90% of light geese, and 85% of white-fronted geese overfly the region annually in the fall.

Climate plays a major role in the spring migration as well. Large concentrations of waterfowl funnel into the RWB region from wintering grounds and stage for an extended period of time waiting for the freeze line to move to northern latitudes. Based on the information presented in Gersib et al. (1989), Benning (1987) and NGPC (1999 unpublished data) we assumed that 100% of the individuals that migrate through the RWB in the spring stop and use the region. Using this information we estimated the total number of waterfowl that use the RWB during the fall and spring phases of migration. To complete this assessment we multiplied the fall and spring migration estimates by the regional-specific migration constant (Table C-9).

Table C-9 Estimated waterfowl use of the Rainwater Basin region of Nebraska during both phases of migration.

Fall Migration species	RWB Estimated Fall Migrants	Percent Stop	Fall Estimate
Mallard	1,240,133	50.0%	620,066
Northern Pintail	593,937	50.0%	296,969
Wigeon	161,767	50.0%	80,884
Gadwall	508,603	50.0%	254,302
Northern Shoveler	724,758	50.0%	362,379
Green-Winged Teal	385,771	50.0%	192,885
Blue-Winged Teal	1,301,631	50.0%	650,815
Light Geese	299,982	10%	29,998
Canada Goose GPP/WPP	222,761	10%	22,276
Canada Goose TGPP	227,783	10%	22,778
White-fronted Goose	337,433	15%	50,615
Spring Migration Species	**RWB Estimated Spring Migrants**	**Percent Stop**	**Spring Estimate**
Mallard	4,233,525	100.0%	4,233,525
Northern Pintail	834,585	100.0%	834,585
Wigeon	126,927	100.0%	126,927
Gadwall	401,446	100.0%	401,446
Northern Shoveler	568,588	100.0%	568,588
Green-Winged Teal	304,242	100.0%	304,242
Blue-Winged Teal	1,027,868	100.0%	1,027,868
Light Geese	1,249,925	100.0%	1,249,925
Canada Goose GPP/WPP	222,761	100.0%	222,761
Canada Goose TGPP	186,926	100.0%	186,926
White-fronted Goose	674,865	100.0%	674,865
Fall Ducks	2,458,300	Spring Ducks	7,497,182
Fall Geese	125,667	Spring Geese	2,334,477
Fall Waterfowl	2,583,967	Spring Waterfowl	9,831,659
	Total Ducks	9,955,482	
	Total Geese	2,460,144	
	Total Waterfowl	12,415,626	

Average Residency Time

Just as regional use varies during migration phase, residency time by waterfowl using the RWB differs during the fall and spring. A season specific residency time was used to represent the average residency time by migration phase. A three day residency time was used as a constant to represent use during the fall .migration. As described earlier, spring migration is climatically driven and waterfowl will follow the freeze line (east-west oriented zone that migrates north as wetlands thaw from south to north in the spring). The shallow nature of RWB wetlands cause them to thaw before other wetland complexes at northern latitudes. Gersib et al. (1989) noted that RWB wetlands were open seven to ten days before any of the lacustrine wetlands in the Sandhills, which are only slightly north of the RWB. This results in large concentrations of waterfowl staging in the RWB before continuing north to the breeding grounds. Fredrickson and Reid (1988) suggested that it would take at least 3 days for waterfowl to replenish nutrient resources after an 8-hour migration and up to 5 days if habitat was limited and weather less than optimal. LaGrange and Dinsmore (1988) hypothesized that stopover sites like the RWB in close proximity to the breeding grounds were critical habitats for female mallards to acquire sufficient nutrients prior to nesting. Cox and Davis (2005) found that radio marked female pintails' spring residency time ranged between 1 – 28 days in the RWB with an average of 9.3 days and the most common (mode) residency time was 6 days. Thus for spring migration, a residency time of 6 days was used for both ducks and geese using the RWB.

Daily Energetic Requirements by Species

To understand daily energetic demand of waterfowl using the RWB we developed estimates of species-specific Daily Energy Expenditure (DEE). DEE is the energy expended by wild birds during a variety of daily activities (e.g., flying, swimming, preening, resting, feeding). Recently, DEE has been calculated by multiplying the Basal Metabolic Rate (BMR) by a factor of three (Miller and Eadie 2006, Reinecke and Kaminski 2006). The BMR is the energy required for normal cellular function and replacement of worn tissue. The average daily turnover rate of protein, the most abundant component of tissue, is 4.4% causing BMR to be directly tied to body mass (Baldassarre and Bolen 1994). To develop a representative species-specific average body mass we used a weighted average incorporating both age and sex ratios (Reinecke and Uhlein 2006). Age ratios were taken from Bellrose et al. (1961). Goose age and sex ratios were derived from Bellrose (1980) with the exception of Greater white-fronted goose, which were taken from the Cornell Lab of Ornithology (www.birds.cornell.edu/). We calculated the species-specific average body mass for all of the target duck and goose species (Table C-10).

Table C-10 Average body mass (kg) for species of waterfowl using the Rainwater Basin region of Nebraska during fall and spring migration.

	Adult Male		Adult Female		Imature Male		Imature Female		
Species	**Av. Mass Kg**	**% Pop**	**Av. Mass Kg**	**% Pop**	**Av. Mass Kg**	**% Pop**	**Av. Mass Kg**	**% Pop**	**Weighted mean kg**
Mallard	1.25	33%	1.11	23%	1.19	22%	1.05	22%	1.16
Pintail	1.03	33%	0.87	23%	0.95	22%	0.80	22%	0.92
Wigeon	0.82	33%	0.77	23%	0.79	22%	0.71	22%	0.78
Gadwall	0.97	33%	0.83	23%	0.86	22%	0.78	22%	0.87
Northern Shoveler	0.68	33%	0.64	23%	0.64	22%	0.59	22%	0.64
Green-winged Teal	0.32	33%	0.31	23%	0.33	22%	0.29	22%	0.31
Blue-winged Teal	0.46	33%	0.38	23%	0.46	22%	0.39	22%	0.43
Light Geese	2.75	37%	2.49	34%	2.18	16%	2.01	14%	2.50
Canada Goose GPP/WPP	4.17	37%	3.49	34%	3.54	16%	3.08	14%	3.73
Canada Goose TGPP	2.77	24%	2.45	23%	2.49	27%	2.18	26%	2.47
Greater White-fronted Goose	2.85	31%	2.51	30%	2.55	20%	2.34	19%	2.59

The species-specific average body mass was used in the BMR equation: αMass^b, where Mass is the species-specific weighted average body weight in Kg, "b" is the slope of the "all waterfowl" regression line, and α is the mass proportionality coefficient (y- intercept at mass = 1 kg; Schmidt-Nielsen 1984). We used the "All Waterfowl" regression for constants "b" and "α" as described in Miller and Eadie (2006). Thus, the All Waterfowl equation can be expressed as $422*\text{Mass}^{0.74}$. The DEE derived from the equation was used to represent the energetic requirements for each species in the fall (Table C-11). For spring DEE, the fall DEE was elevated by three percent to represent the additional energy required to sequester fat reserves and additional body maintenance associated with spring migration (Table C-11).

Table C-11 Basal metabolic rate (BMR), and daily energy expenditure (DEE) for species of waterfowl using the Rainwater Basin region of Nebraska during fall and spring migration.

Species	Weighted mean kg	BMR kcal/Day	DEE kcal/day	DEE + 3% Gain
Mallard	1.16	112.5	337.5	347.6
Pintail	0.92	94.8	284.3	292.8
Wigeon	0.78	83.9	251.6	259.1
Gadwall	0.87	90.9	272.8	281.0
Northern Shoveler	0.64	72.4	217.3	223.9
Green-winged Teal	0.31	42.4	127.1	130.9
Blue-winged Teal	0.43	54.0	161.9	166.8
Light Geese	2.50	198.6	595.7	613.6
Canada Goose GPP/WPP	3.73	267.0	801.0	825.0
Canada Goose TGPP	2.47	196.8	590.4	608.1
Greater White-fronted Goose	2.59	203.8	611.5	629.8

Determine Total Energetic Requirements and Energetic Requirements from Wetland Habitats

By completing above steps we developed estimates of season-specific species use, average residency time, and DEE. These factors allow us to approximate the amount of energy (kcal) that will be required by waterfowl during fall and spring migration. To estimate total energy required by waterfowl that use the RWB during spring and fall migration, we multiplied the migration specific use estimates, seasonal residency time, and species-specific energetic requirement (Table C-12).

Table C-12 Estimated energetic requirements of migrating waterfowl while in the Rainwater Basin Region of Nebraska.

Fall Estimates Species	Estimated Fall Use	Residency Time (Days)	Energetic Requirement (kcal/day)	Total Energy (kcals) thousands
Mallard	620,066	3	337.5	627,783
Northern Pintail	296,969	3	284.3	253,271
Wigeon	80,884	3	251.6	61,050
Gadwall	254,302	3	272.8	208,097
Northern Shoveler	362,379	3	217.3	236,270
Green-Winged Teal	192,885	3	127.1	73,550
Blue-Winged Teal	650,815	3	161.9	316,153
Duck Total	**2,458,300**			**1,776,174**
Light Geese	29,998	3	595.70	53,610
Canada Goose	22,276	3	800.97	53,527
Canada Goose	22,778	3	590.40	40,345
White-fronted Goose	50,615	3	611.50	92,852
Goose Total	**125,667**			**240,334**
Fall Total	**2,583,967**			**2,016,509**
Spring Estimates Species	**Estimated Spring Use**	**Residency Time**	**Energetic Requirement**	**Total Energy (kcals) thousands**
Mallard	4,233,525	6	347.6	8,829,600
Northern Pintail	834,585	6	292.8	1,466,269
Wigeon	126,927	6	259.1	197,353
Gadwall	401,446	6	281.0	676,724
Northern Shoveler	568,588	6	223.9	763,679
Green-Winged Teal	304,242	6	130.9	238,983
Blue-Winged Teal	1,027,868	6	166.8	1,028,594
Duck Total	**7,497,182**			**13,201,202**
Light Geese	1,249,925	6	613.6	4,601,501
Canada Goose	222,761	6	825.0	1,102,666
Canada Goose	186,926	6	608.1	682,032
White-fronted Goose	674,865	6	629.8	2,550,344
Goose Total	**2,334,477**			**8,936,542**
Spring Total	**9,831,659**			**22,137,744**
			Total Duck	**14,977,376**
			Total Goose	**9,176,877**
			Total Energy	**24,154,253**

There is an abundance of waste grain available in the RWB, but waste grains have been shown to be deficient in many nutrients found in natural foods (Baldassare and Bolen 1994, Krapu et al. 2004). Reid (1989) found that naturally occurring wetland plant seeds were a necessary component of duck diets to offset protein and mineral deficiencies associated with agriculture-based food sources. We used values in existing literature to estimate the proportion of waterfowl diets that should be derived from wetland habitats. Heitmeyer et al. (1989) reported that 30% of wigeon and gadwall diets are derived from moist soil seeds, while 51% of northern shoveler diets come from moist soil seeds. Values for the other species were derived from Cox and Davis (2005) and professional opinion when existing literature was not available.

Table C-13 Estimated energetic requirement of migratory waterfowl derived from wetland habitats while in the Rainwater Basin Region of Nebraska.

Fall Estimates Species	Total Energetic Requirement (thousands)	Percent Wetland Diet	Wetland Derived Energy (Thousands)
Mallard	627,783	60%	376,670.0
Northern Pintail	253,271	60%	151,962.9
Wigeon	61,050	30%	18,314.9
Gadwall	208,097	30%	62,429.1
Northern Shoveler	236,270	51%	120,497.8
Green-Winged Teal	73,550	70%	51,484.7
Blue-Winged Teal	316,153	80%	252,922.3
Duck Total	**1,776,174**		**1,034,282**
Light Geese	53,610	5%	2680.49
Canada Goose	53,527	5%	2676.37
Canada Goose	40,345	5%	2017.25
White-fronted Goose	92,852	10%	9285.23
Goose Total	**240,334**		**33,319**
Fall Total	**2,016,509**		**1,067,600**

Spring Estimates Species	Total Energetic Requirement (thousands)	Percent Wetland Diet	Total Wetland Derived Energy (Thousands)
Mallard	8,829,600	60%	5,297,759.7
Northern Pintail	1,466,269	60%	879,761.2
Wigeon	197,353	30%	59,205.9
Gadwall	676,724	30%	203,017.2
Northern Shoveler	763,679	51%	389,476.4
Green-Winged Teal	238,983	70%	167,288.2
Blue-Winged Teal	1,028,594	80%	822,875.5
Duck Total	**13,201,202**		**7,819,384**
Light Geese	4,601,501	5%	230,075.1
Canada Goose	1,102,666	5%	55,133.3
Canada Goose	682,032	5%	34,101.6
White-fronted Goose	2,550,344	10%	255,034.4
Goose Total	**12,617,743**		**574,344**
Spring Total	**25,818,945**		**8,393,728**
		Total Duck	**8,853,666**
		Total Goose	**607,663**
		Total Energy	**9,461,329**

Based on the above calculation during fall migration, waterfowl will use approximately 2.0 billion kcal of energy while in the RWB, while spring energy requirements are approximately 11 times greater (22.1 billion kcal) (Table C-12). Based on species-specific forage requirements, wetland associated food resources should provide about 39% of the required energy or approximately 9.5 billion kcal (Table C-13).

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