# Is Cover Type Use by Dabbling Ducks at Bald Knob National Wildlife Refuge, Arkansas, Related to Energy Availability?

By

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**Abstract**

Managers of U. S. Fish and Wildlife Service's Bald Knob National Wildlife Refuge (Refuge) in central Arkansas want to provide sufficient habitat resources to meet its population objectives for wintering waterfowl. Nutrient reserves acquired during the wintering period appear to support spring migration and subsequent reproductive success for some species, and Refuge managers have prioritized habitat provision for three species of dabbling ducks (mallards, northern pintails, and green-winged teal). Dabbling duck use of a flooded parcel is hypothesized to relate to the energetic value of food provided by each cover type, but such comparative use has not previously been evaluated for the Refuge. Primary and secondary literature were reviewed to describe waterfowl management and the application of bioenergetics in habitat modeling.. The case study used survey data from fourteen wintering seasons from 2006-07 to 2019-20. Duck use days (DUDs) and duck energy days (DEDs) were analyzed for correlation in ten cover types. The study found a strong correlation in rice and a weak correlation in moist-soil; DEDs in all other cover types appeared to be unrelated to duck use. Duck use was highest in wooded wetlands, despite a low DED/acre value. Based on these results, duck use may not be an effective tool for the Refuge to estimate energy availability, except perhaps in rice and moist-soil. Variation in migration, disturbance, population size, and life history strategies related to habitat resources other than food density likely affect duck use of the Refuge. Limitations to this study were identified which may have affected the results (e.g., decision to exclude hunting areas, daytime surveys, etc.). Recommendations for the Refuge include provision of wooded wetlands, rice, and moist-soil vegetation, limiting water depths to that of optimal foraging depth for dabbling ducks, and adjusting the timing of surveys to more closely coincide with when ducks are actively foraging. Varieties of habitat resources are likely ideal to support species diversity.

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## INTRODUCTION

The wintering waterfowl population objective for the Mississippi Alluvial Valley (MAV) is 4.2 million birds, with Arkansas comprising 46.6% of that total (Reinecke and Loesch 1996; LMVJV 2015). Managers of U.S. Fish and Wildlife Service's Bald Knob National Wildlife Refuge (Refuge) in central Arkansas have an objective of providing sufficient wintering habitat to meet the goals of the North American Waterfowl Management Plan (NAWMP 1986, 2004) through which the Refuge was established. Waterfowl population targets of 260,234 birds for the Refuge are distributed across dabbling ducks (81%), diving ducks (6%), and geese (13%) (Hagy *et al.* 2020). Habitat management activities in agricultural allotments and vegetation/cover types on the Refuge are undertaken to meet and sustain these population goals of waterfowl and other water birds. Typical management techniques for waterfowl involve the use of levees, water control structures, disking, burning, and herbicide application to manage both vegetation and water levels (Gray *et al.* 2013). While managed parcels may not sufficiently accommodate the needs of different species simultaneously or equally, gaining a better understanding of dabbling duck usage and movement amongst cover types may help to inform which cover types the Refuge managers could provide to help meet dabbling duck population targets. Dabbling ducks are important to the regional economy as game species and for continued public support of Refuge operation (R. Crossett, pers. comm. 2020), with three species of dabbling ducks of primary interest to the Refuge: mallards (*Anas platyrhynchos*), northern pintails (*A. acuta*), and green-winged teal (*A. crecca).*

Waterfowl (ducks, geese, and swans) response to changes in vegetation, habitat dynamics, and wetland restoration has been documented in other areas (Hagy *et al.* 2017; Herbert *et al.* 2018; Stafford *et al.* 2006; Fredrickson and Reid 1988), but these studies have been conducted in areas different from the Refuge. Based on previous studies, dabbling duck use of a flooded area is hypothesized to relate to the energetic value of food provided by each cover type (LMVJV 2015), but such comparative use has not yet been evaluated on the Refuge.

Duck Energy Days (DEDs) are defined as "the number of ducks that can obtain daily energy requirements from an acre of foraging habitat in a day" (LMVJV 2015). State energy objectives are set based on estimating the energy demands for wintering waterfowl populations (LMVJV 2015). As stepped down from the LMVJV (2015) objectives for Arkansas, the Refuge aims to provide 13.5 million duck energy days, to meet population objectives of 210,610 dabbling ducks, by using cover types of high energetic values per acre (Hagy *et al.* 2020). At present, the managers have been unable to determine the effectiveness of current resource management in meeting the population objectives. In developing a management plan, the Refuge managers have speculated that ducks may be using the cover types based on the energetic value of the flooded acreage; this assumes that individual ducks are distributing in an ideal-free manner based on the distribution and availability of energy (per acre) of that cover type over space and time[1]. The energetic values of various cover types are being considered by Refuge managers in planning the number of acres which will achieve the desired effect size for dabbling duck (and other waterfowl) populations. The goal of this study is to address the question: Is cover type use by dabbling ducks at the Refuge related to energy availability?

This report has two major components: a literature review and a case study. Primary and secondary literature were reviewed to assess past work on waterfowl use of different cover types and the relationship of use over time to energy availability associated with each cover type in

[1] Ideal free distribution is the concept that individuals in a group are 'ideal' by recognizing the quality of the cover type and sharing resources equally (i.e., *n* individuals will consume 1/*n*th of the available food), and the individuals are "free" because they can move freely amongst sites without cost (Fretwell 1972, Fretwell and Lucas 1970).

areas other than the Refuge. In the context of this report, DEDs are the number of mallard-sized ducks (requiring 294.35 kcal/day) (LMVJV 2015) that an area (measured in acres) could potentially support for one day, while DUDs represent duck use and are the number of ducks observed in an area extrapolated across the survey season. The case study assesses the degree to which dabbling duck use is related to energy availability in each cover type, over fourteen wintering periods (November–March 2006–2020). The null hypothesis is that there is not a strong association between duck use and available energy in each cover type. The null hypothesis will be rejected if cover types with higher available energy have higher duck use relative to cover types with lower available energy.

The availability of cover types to dabbling ducks for foraging varies from year-to-year as crops rotate, and within each season as flooding conditions change and waterfowl deplete food resources. Dabbling duck count data will allow me to assess if patterns in use by dabbling ducks are related to available energy in each cover type. If data suggests that dabbling ducks are using a certain cover type more than another based on the energetic value of the cover type, Refuge managers may be able to strategically increase or redistribute the number of ducks by providing more or fewer parcels of the various cover type(s) based on the energetic capacity to support certain use.

The significance of this study is to address the main study question and to potentially aid in the development of a more robust waterfowl management plan for the Refuge by identifying whether dabbling duck use is useful for measuring performance relative to Refuge objectives. The utility of such a plan would need to be based on a better understanding of the methods being used, the variability in the data over time and across years, and the desired effect size that refuge management wishes to detect.

## LITERATURE REVIEW

### History of Waterfowl Management in North America

The need for waterfowl management in North America became recognized in the early twentieth century, as waterfowl numbers had notably declined (Nelson 1927). In 1935, one bird biologist observed that "heavy overshooting throughout the country, agricultural activities, and drought… have reduced the numbers of migratory waterfowl over the entire continent, but the decrease has been much more rapid in the [Mississippi/Central] and Pacific [flyways]" (Lincoln 1935). By 1948, Lincoln (1945) and other waterfowl researchers had identified and documented the four major flyways of North America (Gabrielson 1944, Baldassarre and Bolen 2006:9-10, USFWS 2018a) (Figure 1). The declines in waterfowl were primarily attributed to hunting and anthropogenic habitat loss (through land use/cover change), as well as droughts of the 1930s (Hawkins and USFWS 1984, Baldassarre and Bolen 2006:7-9).

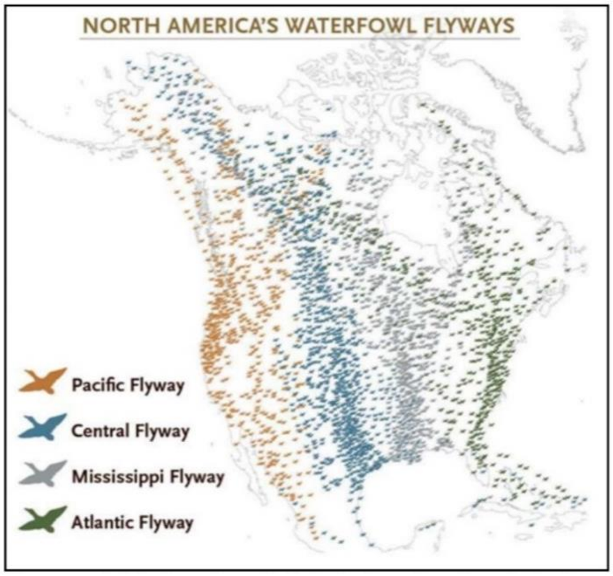


Figure 1. Map depicting four major waterfowl migration flyways in North America (Credit: Humberg, n.d.).

Numerous mechanisms have been implemented to address the observed declines in migratory birds across the continent, including the Agricultural Appropriation Act (1885), Weeks-McLean Law (1913), Canada's Migratory Bird Convention Act (1917), Migratory Bird Treaty Act (1916, 1918), Migratory Bird Conservation Act (1929), Migratory Bird Hunting and Conservation Stamp Act ("Duck Stamp Act" of 1934), Federal Aid in Wildlife Restoration Act (1938), Mid-Winter Waterfowl Survey (1938), NAWMP (1986), North American Wetlands

Conservation Act (1989), Mexico's declaration of 34 Wetlands of International Importance (2004), America's Conservation Enhancement Act (2020), and several others (Hawkins and USFWS 1984:376, USFWS 2018a, NAWMP 2020). Many of these acts, such as the Duck Stamp Act, focused on funding for establishment of waterfowl refuges, but did not dictate the means and methods for managing waterfowl (Hawkins and USFWS 1984:374-7).

Declines in waterfowl observed in the early 20th century were partly attributed to loss of habitat (Hawkins and USFWS 1984, Baldassarre and Bolen 2006:7-9). As Euro-American human populations moved westward into the Mississippi Alluvial Valley (MAV), wetlands were considered obstacles to settlement (Baldassarre and Bolen 2006:7). Fertile river valleys provided the most productive soils, while wetlands were viewed as impediments to be reclaimed and drained to make way for agriculture (Carr *et al.* 1996). Since 1860, more than 53% of wetlands (64.9 million acres) have been converted to agricultural cropland (Dahl and Johnson 1991, Dahl 2000), mostly in the Mississippi and Central flyways (Dahl and Johnson 1991). Despite provision of funding for drainage engineering to farmers, Congress passed the Migratory Bird Hunting and Conservation Stamp Act in 1934, to initiate the federal acquisition of wetlands for restoration. Five more decades would pass before the Food Security Act (Farm Bill) of 1985 set up "Swampbuster" provisions to curtail the conversion of wetlands for agricultural use, successfully reducing the conversion of 235,000 ac (95,000 ha) per year down to 59,000 ac (24,000 ha) per year by the 1990s (Dahl 2000, NRCS, n.d.). This Act also encouraged farmers to remove highly erodible soils from crop production and instead protect fields using various cover types, which then provided waterfowl habitat (Baldassarre and Bolen 2006:13). Grassland ecosystems, another important habitat type for waterfowl, had declined to less than 0.1% of pre-European settlement of North America by the 1990s (Baldassarre and Bolen 2006:178).

Although likely important to the native Quapaw ("Akansas") people who inhabited the river valleys (Tucker 1942, Cox and Dye 1990), duck hunting in Arkansas was not common amongst early European-American (Euro-American) settlers due to the abundance of other species such as deer, turkeys, and bears (Smith and Lehman 2014). However, around the turn of the twentieth century, duck hunting in the state increased, with annual duck harvests in Arkansas reported to be approximately 120,000 birds (Cooke 1906). In the mid-1920's, a rice farmer near Stuttgart, Arkansas, had constructed a 750-acre (ac; 303-hectare (ha)) reservoir, with colloquial observations that it seemingly attracted "all the ducks in the country" (Taylor 2012). Within ten years and numerous new farm ponds/reservoirs, Stuttgart and several other towns in Arkansas had each proclaimed themselves to be the "Duck Capital of the World" (Harris 2010, Taylor 2012), and duck hunting became an important part of the state's economy and were harvested in ever increasing numbers with few restrictions (Baldassarre and Bolen 2006:5, Green and Krementz 2008). Arkansas remains a major area for duck hunting, comprising as much as 21% of mallard harvests in North America (Anderson and Henny 1972, USFWS 2003, Green and Krementz 2008). Across the continent, hunting accounts for more than 50% of waterfowl mortality (Bellrose 1980), with annual harvests of approximately 17 million ducks (Baldassarre and Bolen 2006:307).

Fueled by friction between hunters, private landowners, conservationists, and government regulators, the task of devising methods for meeting waterfowl population goals was assigned to federal "flyways biologists" at the U.S. Bureau of Biological Survey, which later become the U.S. Fish and Wildlife Service (USFWS) (Hawkins and USFWS 1984). As the ecosystems and climate of the four major flyways varies, a council was formed for each flyway (comprised of federal, state, university, and other partners) responsible for devising its management plan; in the

Mississippi flyway, the first waterfowl management plan was adopted in 1958 and updated in 1970 (Hawkins and USFWS 1984:390-1). Though the four flyway councils still remain, their respective management plans were consolidated into the NAWMP to foster a continent-wide approach; the NAWMP was signed by the United States and Canada in 1986 and joined by Mexico in 1994 (Baldassarre and Bolen 2006:499). The Lower Mississippi Valley Joint Venture (LMVJV) group (which includes Arkansas) is one of 20 such joint ventures established for the continent under the NAWMP to facilitate step-down conservation planning for species and habitat resources (Baldassarre and Bolen 2006:499). The NAWMP is updated approximately every five years, and it has set specific population targets for 37 species of waterfowl and protection of over 2.4 million acres (971,245 ha) in the United States (NAWMP 1986, Baldassarre and Bolen 2006:499).

**Habitat Management Planning for Waterfowl**

Between 1911 and 1939, waterfowl management strategies had emphasized study of the foods being consumed by ducks (McAtee 1911, 1914, Cottam 1939, Martin and Uhler 1939). Pirnie (1935) focused on relating marsh and aquatic vegetation with waterfowl food habits. Capture and banding were regular practices for tracking migrating waterfowl (Hawkins and USFWS 1984:2). Volunteers across the continent began performing waterfowl surveys (counts) in 1935 (Hawkins and USFWS 1984:15). Various surveying methods ensued, such as the mail-in questionnaires for hunters purchasing stamps under the “Duck Stamp Act” of 1934 (Fronczak and USFWS 2003) from 1961 to 2001. Over time, surveying methodology became more sophisticated and consistent amongst all the flyways, with uniform data gathered by aerial and ground crews to include counts, species, age, and sexes of birds (Hawkins and USFWS 1984:389, USFWS 2020a).

Drought and economic issues in the 1930s had persuaded decision-makers that permanent marshes and open water were best for waterfowl management (Hawkins and USFWS 1984:434). The U.S. Army Corps of Engineers had ownership and entered into cooperative agreements with the U.S. Fish and Wildlife Service for many inland impoundments, and artificial wetlands began to proliferate on waterfowl refuges (Hawkins and USFWS 1984:434-435). Hunting regulation had been the main method of conserving waterfowl until such time that management plans were developed (Hawkins and USFWS 1984:374-6). By the time more refuge lands were acquired in the late twentieth century, scientific training on waterfowl had improved considerably in higher institutions of learning (Hawkins and USFWS 1984:376, Baldassarre and Bolen 2006:10), contributing to the development of new plans and strategies to sustain waterfowl populations.

**Habitat Use vs. Availability Studies in the Non-breeding Season**

A literature review in 1980 of about 900 citations brought attention to a knowledge gap in wintering waterfowl studies, reporting that only 5.5% of those publications dealt with waterfowl outside of the breeding season (Bellrose 1980). Most studies had focused on nesting and breeding (Baldassarre and Bolen 2006:200-2;211-4). Many localized studies on habitat management for attracting migrating and wintering waterfowl had actually been conducted but were not being reported in published literature (Weller and Batt 1988). Studies pertaining to habitat management for wintering waterfowl slowly began to emerge indicating that food and environmental conditions during the winter (non-breeding) period regulated waterfowl and other bird populations (Lack 1966, Fretwell 1972, White and James 1978, Frederickson and Drobney 1979, Kaminski and Gluesing 1987, Baldassarre and Bolen 2006:250-1). Even so, Calicutt *et al*. (2011) reported that only 5% of published articles reliably determined food selection based on use and availability, and no previous studies were found which determined food use at a scale appropriate for winter home ranges. Nutrient reserves acquired during the wintering period appear to support spring migration and subsequent reproductive success for some species of dabbling ducks (Nummi and Pöysa 1995, Devries *et al.* 2008; Guillemain *et al.* 2008; Sedinger and Alisauskas 2014, Arzel *et al.* 2014), and more recent studies on non-breeding periods are emerging (e.g., Klimas *et al.* 2020).

Waterfowl response to changes in vegetation, habitat dynamics, wetlands and grassland restoration has been well researched (Frederickson and Reid 1988, Stafford *et al.* 2006, Hagy *et al.* 2017a, Herbert *et al*. 2018, Ackerman *et al.* 2019). Migratory waterfowl will select habitat types for food, water, shelter, and rest (Baldassarre and Bolen 2006:352). Heitmeyer (1988) reported that the energetic requirements of dabbling ducks change from protein-rich invertebrates in the spring and summer months to the carbohydrate-rich seeds and tubers (and opportunistically, agricultural grains) during the fall migration and winter.

Weather patterns may also affect diet options, as availability of invertebrates is higher in wet winters than in dry, increasing the protein source and resulting in an observed, earlier molting (of breeding plumage) and the associated energy expenditure (Anderson *et al*. 2000). One study in managed moist-soil wetlands in the MAV reported that local precipitation was inversely related to waterfowl density, and this relationship was stronger than other factors such as weather severity and temperature (Hagy *et al.* 2014). Miller *et al*. (2014) suggested that bioenergetic models must also consider other factors which likely affect duck abundance and distribution. For example, water depth limits energy availability (Poysa 1983), and dabbling ducks may focus their feeding in shallower portions of flooded parcels where the substrate is reachable (Johnson and Rohwer 2000, Hagy and Kaminski 2015), regardless of cover type or energetic value. Hagy and Kaminski (2015) reported that dabbling ducks decreased feeding by

10% for each 10.7 centimeters (cm (4.2 inches; in)) increase in water depth, and optimal depth was less than 50 cm (19.7 in), and Euliss and Harris (1987) found that green-winged teal and northern pintails used significantly different water depths when foraging versus while resting. Such information demonstrates that food availability is dynamic during the non-breeding period, due to competition amongst species and larger flocks, plant senescence and decomposition, timing and level of flooding (Behney 2020), and other factors (Brasher *et al.* 2007; Arzel *et al.* 2009; Greer *et al.* 2009; Hagy and Kaminski 2012; Straub *et al.* 2012).

Habitat modeling for waterfowl has continued to develop over time, giving rise to the Integrated Waterbird Management & Monitoring (IWMM) program which sought to close the information gap of the non-breeding period to optimize the entire life cycle of waterfowl and other waterbirds (IWMM 2020). The aim of the program is providing a multi-scale, adaptive framework for data collection and tools to guide decision-makers in the acquisition, restoration and enhancement of wetlands for waterfowl, shorebirds, and wading birds during the non-breeding season (IWMM 2015).

In the early twentieth century, studies meant to inform waterfowl management in North America had involved analysis of foods consumed by ducks using necropsies (McAtee 1911, 1914, Cottam 1939, Martin and Uhler 1939). It was only more recently that studying bioenergetics of the foods themselves has gained momentum (Baldassarre and Bolen 2006:9). Managing habitat to meet migrating and wintering waterfowl population objectives has been accepted as part of modern management plans, but implementation has relied upon several assumptions despite few actual parameters to accurately estimate carrying capacity of particular habitat (cover) types (Hagy and Kaminski 2015). On refuges with cooperative farming agreements[2], rice is presumed to be the best energy-source for dabbling ducks and flooded rice fields in the LMAV comprises over eleven percent (11%) of managed habitat (Petrie *et al.* 2014).

Several assumptions have been made regarding using bioenergetics for managing duck populations on southeastern U.S. refuges (USFWS and Ducks Unlimited staff 2019). These assumptions include that a) ducks are free to move about the landscape and all or most of energy provided is completely consumed, b) energy is limiting in non-breeding populations (Soulliere *et al.* 2007, 2012; Arzel *et al.* 2009), c) managers have more control over habitat than they do over duck abundance, d) energy can be a means of achieving population objectives, and e), many of the existing joint ventures (such as the LMVJV) already use energy objectives during planning (USFWS and Ducks Unlimited staff 2019). Ongoing studies and compilations of literature pertaining to duck use and energy availability are therefore important in the development of waterfowl and refuge management.

Some research has been conducted on the effects of food resource availability and landscape energetics for dabbling ducks (e.g., Cramer *et al.* 2012; Beatty *et al.* 2015; Calicutt *et al.* 2011), and comparisons between duck use and rice production areas in Europe (e.g., Pernollet *et al.* 2015, 2017). Many of these studies focus on mallards and assumed that mallards represent other dabbling duck species due to overlapping habitat requirements (Reinecke and Loesch 1996, Davis *et al*. 2014, Herbert *et al*. 2018), although Herbert *et al*. (2021) noted that this assumption of similarity has not been well tested.

Herbert *et al*. (2018) used spatio-temporal models to explain the abundance and

[2] Cooperative agreements are agreements "with persons for crop cultivation, haying, grazing, or the harvest of vegetative products, including plantlife, growing with or without cultivation on wildlife refuge areas may be executed on a share-in-kind basis when such agreements are in aid of or benefit to the wildlife management of the area" (50 CFR 29.2).

distribution of mallard ducks in relation to landscape variables in the MAV. That study found that mallard presence in rice fields was disproportionately higher than in soybean fields (Herbert *et al.* 2018). However, mallards also use other cover types when rice fields are less available, as long as the field is flooded (Delnicki and Reinecke 1986). Beatty *et al.* (2015) found that energy resources from wetlands and open water were more important predictors of mallard use than were non-flooded agricultural plots. Fox *et al.* (2017) suggested that herbivorous waterfowl may select for an agricultural landscape if the crop type provides opportunity for high food intake rates. Herbert *et al*. (2021) noted that waste soybeans decompose much more quickly than waste rice once exposed to water (Nelms and Twedt 1996), implying that depletion of food availability over time affects duck movement. Davis and Afton (2010) found that female mallards remained in the same cover type for roosting as long as food resources were stable. As waste rice availability declined through the winter (Stafford *et al*. 2006), availability of other types of plant seeds was associated with the female mallards switching cover types (Davis and Afton 2010).

Baldassarre *et al.* (1986) noticed an adaptive behavior of minimal foraging in mid-winter, attributed to an accumulation of lipids (energy storage) in late fall which are used during periods where natural forage/energy resources might be less available (such as when water is frozen) and conservation of body temperature is important. In a 2015-2016 study of wintering mallards in the MAV of Ohio, Shirkey *et al*. (2020) concluded that food-rich but intensively hunted areas encouraged nocturnal foraging activity and decreased diurnal movement. Several species of dabbling ducks have been found to redistribute during the day to avoid predators and hunting pressure (Euliss and Harris 1987, Dooley *et al*. 2010, Casazza *et al.* 2012, Herbert *et al.* 2021). Prior to the hunting season, mallards have been observed to frequently switch cover types diurnally and less at night, reversing that pattern once hunting season commenced (Shirkey *et al.*

2020). The authors suggested that this apparent switch to nocturnal foraging may counter the typical refuge management objective of providing duck hunting opportunities, since fewer ducks are functionally available for harvest.

**Using Bioenergetics in the Context of Waterfowl Management**

Dabbling ducks utilize a variety of habitat types to consume different seeds and tubers from both natural and agronomic sources (Hagy and Kaminski 2012), and it is assumed that factors influencing duck use and selection of different habitat types include duck species' morphology, plant nutrient composition, and seed/grain particle size (Fritz *et al.* 2001, Gurd 2006, Klaassen *et al.* 2007, Heitmeyer 2010). Understanding the energy requirements of the species for cellular function and replacement of tissue is central to the study of energetics (Baldassarre and Bolen 2006:118). Nutritional needs and habitat selection of migratory waterfowl vary according to recurring biological events such as breeding, nesting, egg-laying and incubation, growth, molting, general survival, energy needed for migration, and thermal regulation (Frederickson and Reid 1988; McWilliams *et al.* 2004). Flight consumes the most energy resources for waterfowl, thus reducing flight distance (between rest and forage areas) for wintering birds potentially would help to conserve energetic resources in colder temperatures (Frederickson and Reid 1998). Molting (of breeding plumage into non-breeding plumage) is another energy intensive event, and it occurs in dabbling ducks after arrival at the wintering site (Anderson *et al.* 2000). Frozen wetlands and temperatures below 7°C (45°F) (Herbert *et al.* 2021) can simultaneously decrease food availability and increase energy expenditure for thermal regulation (body heat retention), respectively, for dabbling ducks (Schummer *et al.* 2010, Guillemain *et al*. 2013), potentially explaining both relocation to more southern areas of the MAV during late winter and decreased evening flight distances (Hepp 1985). The flooding of agricultural fields can maximize food availability while minimizing flight distance between a) roosting areas and available forage, and b) available patches of different cover types as energy resources decline over time (Fretwell and Lucas 1970, Frederickson and Reid 1998).

Determining actual energetic expenditures of ducks in the field is difficult, so the emphasis has switched to the energetic values of plants and rates of consumption for estimating energy needs (Frederickson *et al*. 1998). The dietary benefit derived from each cover type depends on its gross energy (GE) from protein, carbohydrates, fat, fiber, vitamins, and minerals (ash) (Baldassarre and Bolen 2006:149). Not all of the GE is metabolized, so some energy is lost to excretion (Sibbald 1976), and the true metabolizable energy (TME) can be estimated (Baldassarre and Bolen 2006:149).

The expression of TME in avian energetics was reviewed by Miller and Reinecke (1984). The authors concluded that TME estimates are less sensitive than apparent metabolizable energy (AME) to variation in wild bird food intake, due to the impracticality of collecting quantities of natural foods large enough to supply the test birds with energy requirements. Erratic or even negative AME estimate values may result (Miller and Reinecke 1984). Sibbald (1976) reported a TME assay to be rapid, to require smaller quantities of test diets, and have a lower variance in interpretable results. Despite the higher potential variance and its impractical applicability to wild bird foods, AME has been used in most of the earlier modeling calculations for avian energetic requirements (Miller and Reinecke 1984). Miller and Eadie (2006) refined these earlier studies of non-passerines for application to winter habitat requirements for waterfowl, by examining the allometric relationship between resting metabolic rate (RMR) and body mass and devising an equation specific to waterfowl. More recent studies have begun to utilize species-specific TME estimates in bioenergetic models for wild waterfowl (e.g., Gross *et al.* 2020a).

Hagy and Kaminski (2012) surveyed food-use literature from studies in the MAV to identify foods potentially used by dabbling ducks. Their method was to compare estimated seed decline rates from core samples based on published measured estimates of decomposition. On a spatial scale, seed use was inferred when declines in mass were higher than predicted decomposition rate. For known seed types used by ducks, it was assumed that consumption by ducks was the cause of such a rapid decline in mass (Hagy and Kaminski 2012). Other methods for energy estimates involve the collection of soil core samples to calculate biomass of waterfowl foods, then multiplying the biomass by the TME value (Livolsi *et al.* 2015). This estimation method and the decline in mass method used by Hagy and Kaminski (2012) are considered less invasive than earlier diet studies, which had relied on necropsies and dissection of duck gizzards (Frederickson *et al*. 1998). Hagy and Kaminski (2015) attempted to demonstrate the parameter of a foraging threshold using foraging patches of different food/prey densities and monitored the depletion of foods and responses of waterfowl in winter. Even when seed reduction ceased after two weeks, ducks neither abandoned the wetlands nor did they distribute according to ideal-free predictions (Hagy and Kaminski 2015); dabbling duck use of the experimental plots was observed to be unrelated to initial seed density.

Gray *et al.* (2013) compiled tables of duck energy days (DEDs), defined as “the number of ducks that can obtain daily energy requirements from an acre of foraging habitat for a day” (LMVJV 2015) for various cover types used in wetland management, pulling bioenergetic information from the Hagy and Kaminski (2012) study and numerous others (See Table 2 in METHODS section). While there are variances amongst energetic values for cover types in different regions of North America (for example, relating to latitudinal and climatic differences in growing season), Hagy *et al*. (2014) supported using fixed estimates of food density in the

MAV for simplistic daily ration models, and a simplified table of DED values has been incorporated into the IWMM (2020). Recent studies have utilized region-specific energy-use day (EUD) values to estimate foraging carrying capacity (e.g., Vonbank *et al.* 2016, McClain *et al.* 2019, Marty *et al.* 2020), but for the purpose of the case study in this report, the simplified table of DED values will be used.

**Early Conclusions**

Availability of food can affect duck abundance and distribution by attracting ducks to food-rich sites (Brasher 2010, Hagy *et al.* 2017b, Osborn *et al*. 2017), and it also influences stopover duration (O'Neal *et al.* 2012). This suggests that increasing energy-rich food/cover types to attract dabbling ducks at wildlife refuges may be an effective strategy. Using the refined "waterfowl equation" for the allometric relationship between RMR and body mass, Miller and Eadie (2006) suggested that wetland habitat/energetic requirements for supporting winter waterfowl populations were likely to be 37% to 50% higher than previously predicted using the earlier models. Hagy and Kaminski (2015) appear to agree with this assessment, noting that foraging threshold values for moist-soil units used in carrying capacity models are greater than in rice fields, and "could significantly affect estimates of food availability, change habitat requirements, and result in increased habitat conservation goals".

From their experiment of parameterizing a foraging threshold, Hagy and Kaminski (2015) had concluded that foraging effort and numerical responses of non-breeding dabbling ducks were influenced by factors other than total food densities, foraging thresholds may vary by location, and numerical response of dabbling ducks may be an inconsistent predictor of habitat quality as it relates to seed and tuber density. The researchers emphasized that accurate and nonbiased parameters should be used in habitat conservation models to avoid overestimation of seed availability in energetic carrying capacity models (e.g., Kross *et al*. 2008) and inefficient habitat conservation efforts. They concluded that environmental factors and external influences on duck foraging (such as predation risk and opportunity cost) may contribute to waterfowl habitat use and food availability (Hagy and Kaminski 2015).

Even with recent interest in using bioenergetics for waterfowl management in North America, European studies have instead focused on agent-based models which focus on inter-individual differences in behavior of foraging ducks, with an emphasis on individual efficiency (e.g., methods, intake rate, patch choice) and the optimal foraging theory (Guillemain *et al.* 2017) based on foraging thresholds. This indicates that strategies for waterfowl management are still evolving.

Based on the increased interest and prevalence of bioenergetics studies and models, there is a growing recognition of the potential utility of such models in waterfowl management in North America (Miller *et al*. 2014). Provision of cover types for waterfowl based on energetics may be confounded by climate change, and simple bioenergetic models may not capture important impacts from land reallocation and other large-scale environmental changes on individual duck behavior, such as changes in metabolic costs due to increased travel-time and reduced food accessibility (Miller *et al.* 2014). Another potential challenge in studying outcomes of various waterfowl management strategies is that daytime duck surveys may be an inaccurate representation of total duck use of those sites because nocturnal foraging is common for dabbling ducks (McNeil *et al.* 1992, Cox and Afton 1997, Anderson *et al.* 2000, Guillemain *et al.* 2002, Fleskes *et al.* 2002, Parejo *et al.* 2019, Shirkey *et al*. 2020). Assessing the utility of

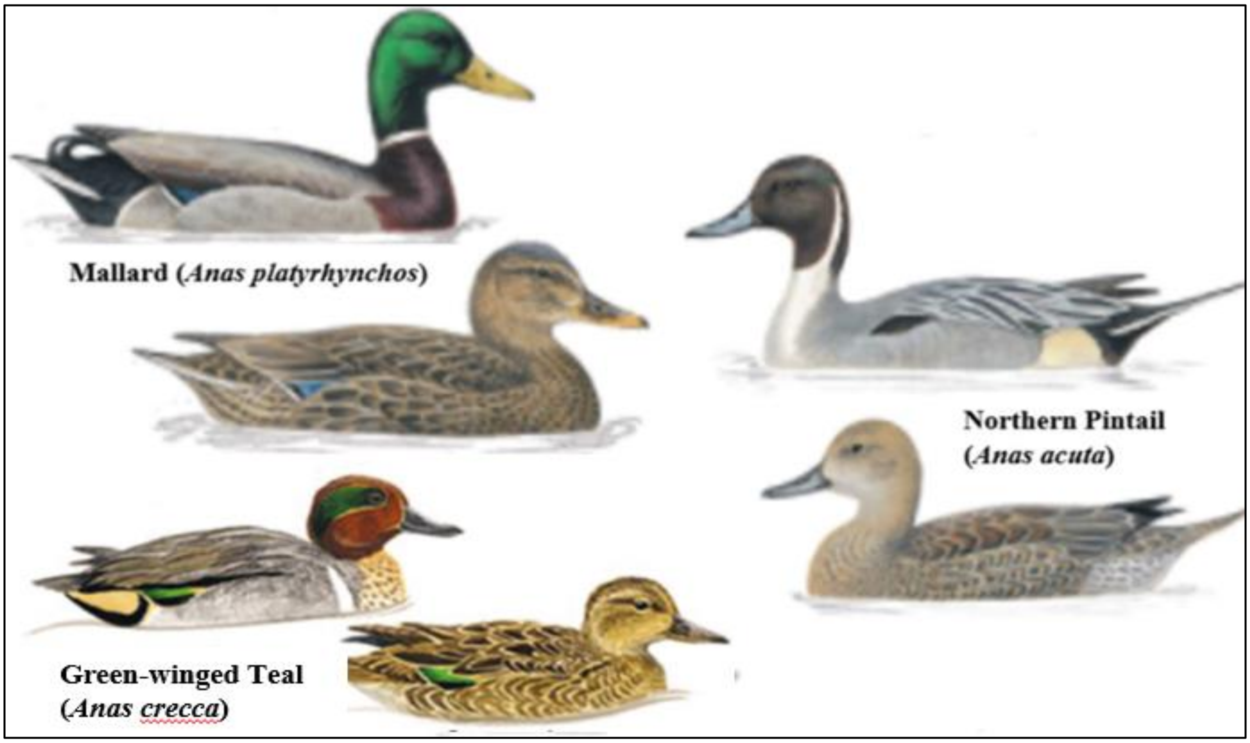


Figure 2. Illustrations of the focal species (mallard, northern pintail, and green-winged teal) for dabbling duck management at Bald Knob National Wildlife Refuge, Arkansas, USA (Credit: Norman and Langman 2019).

bioenergetic/energetic carrying capacity models as an effective tool for meeting waterfowl population goals will likely continue to develop as more studies are conducted.

**Focal Species**

Gray *et al.* (2013) asserted that to manage wetland wildlife effectively requires a basic understanding of the life history and habitat requirements of target species. Focal species for the Bald Knob National Wildlife Refuge (which is the subject of this paper's case study) are mallard (*Anas platyrhynchos*), northern pintail (*A. acuta*), and green-winged teal (*A. crecca*) (R. Crossett, pers. comm. 2020) (Figure 2). General characteristics of dabbling ducks, including morphology and life histories, are described in Baldassarre and Bolen (2006). Most North American dabbling ducks migrate north to breeding grounds between February and April, migrating southward between August and December to spend the winter (Ringelman 1992, Gray *et al.* 2013). Mallards are often used as a surrogate species in conservation planning for other dabbling ducks in the MAV (Herbert *et al*. 2021), but energy requirements (and therefore habitat selection and foraging activity) may vary, due to differences in species' morphology, body size, timing of migration, and other behavior. Brief life histories of the three focal species are provided below in an attempt to consider behaviors or morphology which may influence the effectiveness of using bioenergetics in the management of wintering duck populations in Arkansas.

**Mallard (*Anas platyrhynchos*)** – The mallard is a large-bodied duck which can be found in almost any wetland habitat in North America (Drilling *et al.*2018). Male and female mallards pair up to mate each year, migrating in the spring to breeding grounds and nesting sites (Guillemain *et al.* 2002). This dabbling species is a generalist forager whether in the water or on land. During breeding periods, a mallard's diet consists mostly of invertebrates, while in non-breeding periods, seeds and plant material comprise most of the diet (Johnson and Lockwood 2013). Diet studies in Texas indicated that wintering mallards consumed between 61 to 94 percent acorns, with other natural plants, seeds, and crops comprising the rest (Johnson and Lockwood 2013).

Perhaps the most recognizable due to a bright green head (drakes), yellow beak and blue patch on both wings (both sexes), mallards are the most hunted duck in North America (Drilling *et al.* 2018). Despite being a popular game species, mallards are prolific (with total population estimated at over 10 million individuals) and of little conservation concern (USFWS 2019; Drilling *et al.* 2018). Green and Krementz (2008) reported that a majority of the continental mallard population winters in the Mississippi Alluvial Valley (MAV), in which Bald Knob National Wildlife Refuge is situated. Mallards are economically and culturally important for Arkansas (Green and Krementz 2008); duck hunters and related organizations have financially supported easements, water impoundments, and wintering habitat for waterfowl throughout

Arkansas' public lands and wildlife management areas (Vidal 2018). Public support and patronage of waterfowl refuges is largely maintained via relationships with duck hunters, so increasing and stabilizing the number of mallards is one of the management priorities for the Refuge (R. Crossett, pers. comm., 2019).

As generalist foragers, mallards may use a variety of habitats. Herbert *et al.* (2018) observed mallards to disproportionately utilize rice fields more than soybean, but Delnicki and Reinecke (1986) and Beatty *et al*. (2015) reported flooding to be the more important predictor than cover type. In the MAV, bottomland hardwood forests have been considered an important wintering area for mallards (Tiner 1984, Reinecke and Baxter 1996, Davis *et al.* 2009). Flooded bottomland hardwood forests (BHF) may be important source of mast (from acorns) (Leach *et al.* 2012, Straub *et al.* 2016) and invertebrates during energy-intensive activities such as pair bonding and prebasic (and prealternate) molt, which occur during the winter for several species in the Anatidae family, including mallards (Allen 1987, Heitmeyer 1987, Combs and Frederickson 1985, 1986). Wintering mallards appear to use microhabitats within these bottomlands with low tree density (open canopy) (Kaminski *et al*. 1993). The rapid peak and subsequent decline of invertebrates in short-term, flooded BHF may explain several observations of high early season use of bottomlands by wintering mallards, followed by a gradual decline in use (Allen 1987). Herbert *et al*. (2021) found a higher abundance of mallards compared to other dabbling duck abundances in BHF during December and January when those areas were temporarily flooded. Otherwise, long-term or sustained flooding in these areas results in an inverse relationship with invertebrate density and biomass (Heitmeyer 1985, Batema *et al*. 1985), and lower use by mallards is expected (Allen 1987). BHF have been reduced in the Mississippi Alluvial Valley by over 80% of pre-European settlement, largely due to land conversion to agriculture and anthropogenically-altered hydrologic processes (King *et al.* 2012). Heitmeyer and Frederickson (1981) asserted that losses of southern BHF have resulted in mallards being forced to concentrate into fewer and lesser-quality wintering grounds. Several studies have surmised that while agricultural grains can be considered an important supplement, they should not completely substitute natural foods (Baldassarre *et al.* 1983, Heitmeyer 1985); a variety of cover types for mallards is therefore recommended (Allen 1987).

At higher latitudes, in colder climates, and during the winter months, mallards are primarily nocturnal feeders (Guillemain *et al.* 2002; McNeil *et al.* 1992). Mallards may spend more time on pair formation rather than on foraging (Tamisier *et al.* 1995) even at night (Shirkey *et al.* 2020), intensifying their foraging efforts just prior to the spring migration (Guillemain *et al.* 2002) and its associated energy expenditure (McWilliams *et al.* 2004).

**Northern Pintail (*Anas acuta*)** – The northern pintail is a medium-sized dabbling duck, typically smaller than a mallard but larger than a green-winged teal. This species occurs in Europe, North America, and Asia (Clark *et al.* 2014), remaining almost entirely north of the equator (Birdlife International 2020). This species migrates in flocks southward each autumn to winter in warmer climates, returning to cooler climates in the spring to breed. The primary breeding areas in the central flyway include the prairie pothole region of north-central United States and Canada (Clark *et al*. 2014). In North America, the largest concentrations of wintering pintail occur on the U. S. Gulf Coast and the Pacific Coast of Northern California and Oregon (Bagstad *et al.* 2018). Despite having such a large range and distribution, northern pintail has experienced a decline over the recent four decades due to diminished availability of springtime ponds (Bartzen and Dufour 2017). Particularly apparent in breeding grounds, pintail populations have not recovered to levels observed prior to the 1980s (Fleskes *et al.* 2002, Rice *et al*. 2010), and determining factors confounding the recovery of this species remains a priority for waterfowl management in North America (USFWS 2010, NAWMP 2019).

Several studies in Texas during the 1970s indicated wintering habitat for pintails to be grain fields, marshes, and impoundments (Chabreck 1979, Suchy and Anderson 1988). Other known habitats used by pintails during the non-breeding period include wetlands, ponds, lakes, bays, tidal marshes, and flooded agricultural fields (Cornell Lab of Ornithology 2019). In the breeding season, pintails utilize primarily wetlands and potholes in short-grass to mixed-grass prairie (Bellrose 1979, Suchy and Anderson 1988). Northern pintails dabble their bills near the surface of the water to filter out seeds and other food items such as plants, snails, crustaceans, and aquatic insects (Suchy and Anderson 1988, Cornell Lab of Ornithology 2019). Diet studies have reported that non-breeding northern pintails consume foliage, rhizomes, seeds, amphipods, crustaceans, and agricultural grains (Johnson and Lockwood 2013).

Multiple studies have observed female pintails foraging nocturnally and roosting during the daylight hours (Cox and Afton 1997, Fleskes *et al.* 2002, Parejo *et al.* 2019). Hypotheses proposed to explain this diel movement include that a) nighttime is safer for foraging (Casazza *et al.* 2012), b) additional food is being sought at night to supplement deficiencies from daytime feeding (McNeil *et al*. 1992), and c) social behaviors unrelated to feeding or roosting drive the daytime gatherings of pintails (Tamisier 1976). Supporting the first hypothesis, other studies suggest that hunting may also influence pintail movement as the birds seek sanctuary (Cox and Afton 1997, Casazza *et al.* 2012). Perejo *et al*. (2019) studied the day-to-night movements of female pintails during the winter in the rice-growing region of Iberia. The variables considered to have the most influence on pintail movement were proximity to food availability, water depth and substrate. Pintails were observed in Iberia to select most strongly for flooded rice fields with water depths 9 to 21 cm (3.5 to 8.2 in), standing rice stubble 25 to 45 cm (9.8 to 17.7 in), and substrate with pebbles smaller than 0.5 cm (0.2 in) in diameter (Perejo *et al*. 2019). The authors also surmised that pintails were roosting shorter distances away from rice fields as availability of such fields decreased or the quality of the nutrients available diminished over time.

**Green-winged Teal (*Anas crecca*)** – The green-winged teal is the smallest duck species in North America (Johnson and Lockwood 2013, Baldassarre 2014) and the second most harvested (Baldassarre & Bolen 2006). Population objectives from the NAWMP have been met or exceeded by this species since 1994 (Johnson and Lockwood 2013). This species breeds throughout much of Canada and migrates southward along all four major flyways to spend winter in the United States and Mexico (Devineau *et al.* 2010, Johnson *et al.* 2020).

Winter habitat for the green-winged teal includes vernal pools, wetlands, forested wetlands, rice fields, and mudflats (Johnson and Rowher 2000, Johnson and Lockwood 2013). This species may prefer to forage in very shallow water compared to other dabbling duck species, frequently walking rather than swimming (Johnson and Lockwood 2013). Green-winged teal have been observed resting in sparsely vegetated areas during the daytime, moving to densely vegetated areas for nocturnal foraging (Anderson *et al*. 2000). Additionally, this species is known to use flooded bottomland forests for portions of the winter (Frederickson and Heitmeyer 1987).

Diet studies during the non-breeding period have reported consumption of natural moist-soil plants and seeds (Anderson *et al*. 2000), agricultural grains, and invertebrates (especially midge larvae) (Johnson and Lockwood 2013). Anderson *et al*. (2000) observed that consumption of invertebrates by green-winged teal remains high in the non-breeding season based on availability, with seeds consumed at a lower level than expected based on availability. Earlier studies on wintering green-winged teal reported that agricultural grains and seeds were most important (Rollo and Bolen 1969, Sell 1979, Sheeley and Smith 1989), but this was attributed to bias since these diet studies were from hunter-killed teal from agricultural fields (Anderson *et al.* 2000). Additionally, Gaston (1992) observed that this species forages on macroinvertebrates more than mallards, which are more generalist feeders (Johnson and Rowher 2000). Diet of green-winged teal during the breeding period has been less studied, attributed to its small body size and nest concealment in dense vegetation (Johnson and Lockwood 2013). It is inferred from other dabbling duck species that invertebrates are important food items during the breeding season (Johnson and Lockwood 2013).

**SUMMARY**

Based on this review of the literature, I would expect mallards to demonstrate a high use of wooded wetlands during the wintering period, but to move to other cover types as energy resources were available. Based on the above information, northern pintails would be expected to utilize rice fields or areas in close proximity to rice and higher available energy. Due to their foraging behavior of walking while feeding, the small-bodied green-winged teal would be expected to demonstrate usage of more dense vegetation (higher percent cover and less open water) such as wooded wetlands, parcels flooded at a shallower depths, and agricultural fields. All three species are expected to be foraging nocturnally during the winter, and especially during open hunting periods at which time they may be seeking shelter from predation and harvest.

**CASE STUDY**

**Study Area**

Bald Knob National Wildlife Refuge (Refuge) is located on approximately 15,020 acres (ac; 6,078 hectares (ha)) in central Arkansas (Figure 3), situated at the convergence of two major watersheds: Arkansas-White-Red (watershed unit 11010014) and Lower Mississippi-Lower White-Cache (watershed unit 08020302) in the Lower Mississippi Alluvial Valley (LMAV) (U.S. Geological Survey 2020) (Figure 4). Little Red River forms the southern boundary of the Refuge, flowing in a southeastern direction into the White River. At a landscape level, the MAV is a floodplain spanning approximately 500 miles (mi; 800 kilometers (km)) which is ecologically important to resident, migrating and wintering waterfowl and other water birds (La Sorte *et al.* 2014; King *et al.* 2006) as part of the Mississippi flyway in North America. The water resources of the Refuge are under the jurisdiction of the U.S. Army Corps of Engineers and managed by the U. S. Fish and Wildlife Service (USFWS) via a memorandum of understanding which follows the Refuge's comprehensive conservation plan for stewardship of wildlife (USFWS 2009). Based on aerial imagery, the Refuge is surrounded on three sides by cleared forest which has been converted to agricultural fields. Henry Gray Hurricane Lake, a state-managed wildlife area, is adjacent with the eastern boundary of the Refuge and is mostly forested.

**History and Current Management**

Historically, approximately 9,500 ac (3,845 ha) of bottomland hardwood forests bordered the Little Red River until its confluence with the White River (Hamel *et al.* 2001), 3,900 ac (1,578 ha) were open waters (Service 2001), and the remaining 1,600 ac (648 ha) were a blend of mudflats, marsh, moist soil vegetation, and uplands (Hamel *et al*. 2001). Vegetation in the bottomlands was mostly oaks (*Quercus* spp.) and bald cypress-tupelo brake (*Taxodium distichum* and *Nyssa aquatica*) (Hamel *et al.* 2001), which served as a buffer to flood inundation, provision of wildlife habitat, and heat regulation in this subtropical region (Ellison *et al*. 2017). According

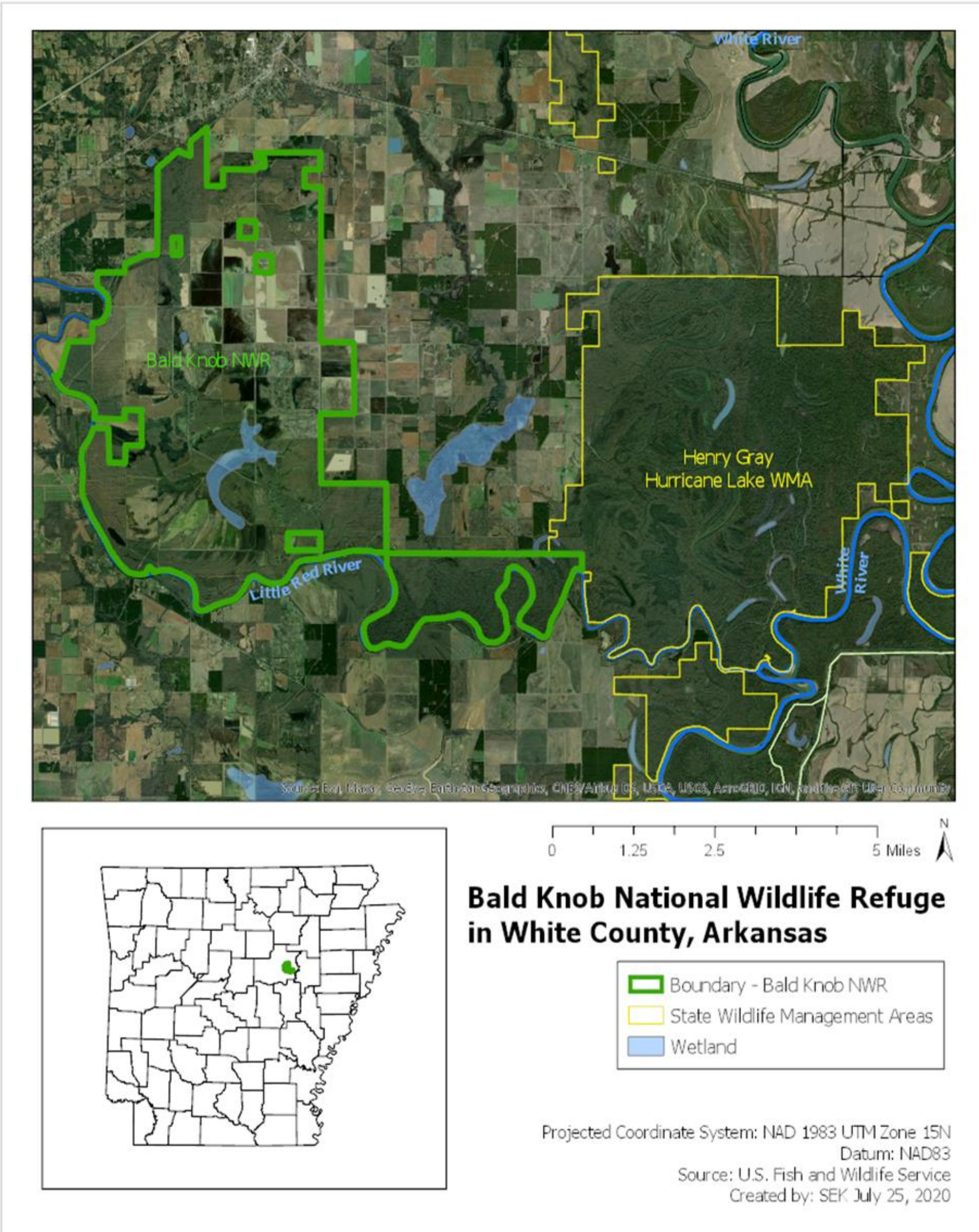


Figure 3**.** Map showing location of Bald Knob National Wildlife Refuge in White County, Arkansas, USA (Credit: S. Kreisler).

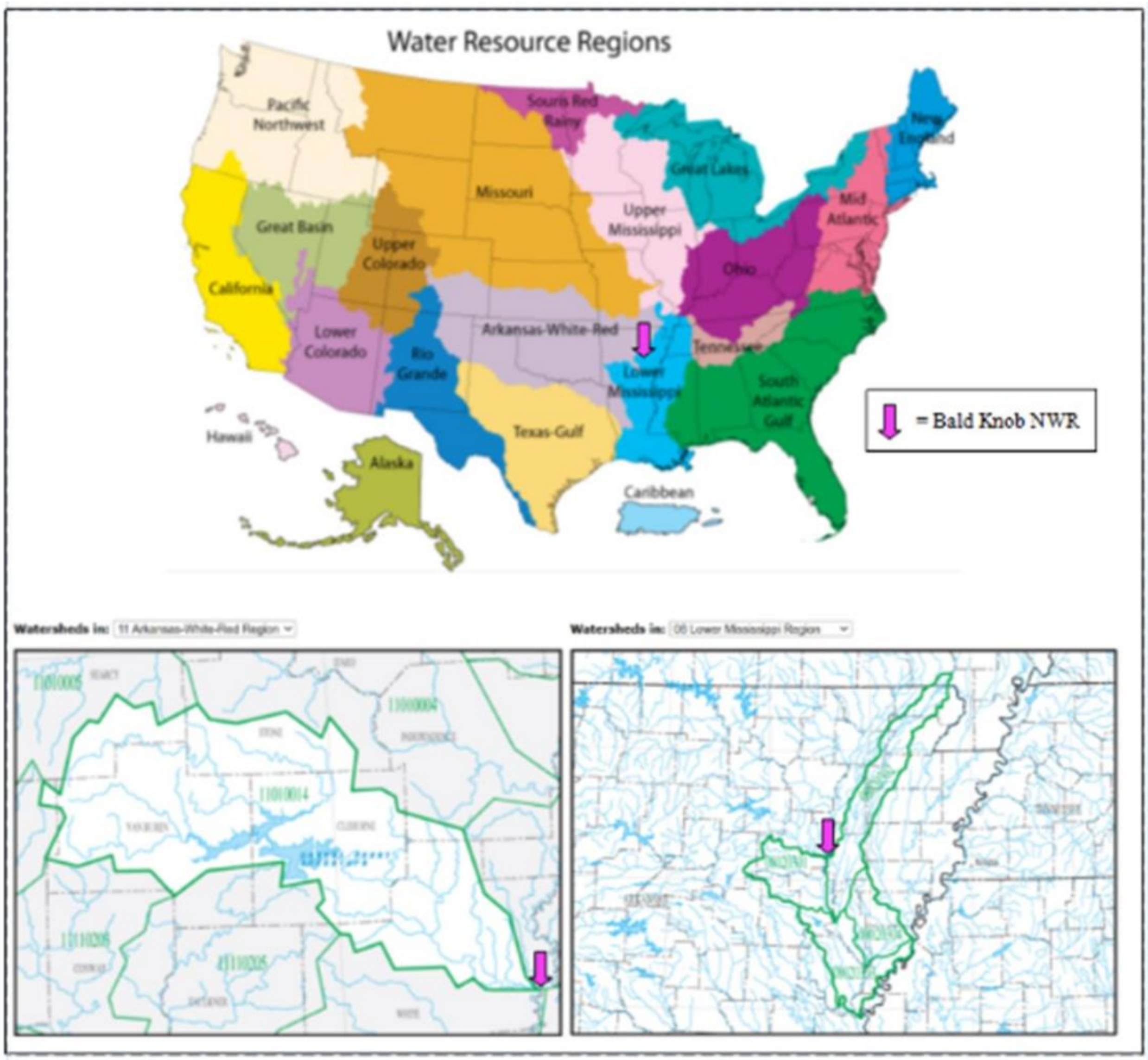


Figure 4. Map of location of Bald Knob National Wildlife Refuge in relation to major watersheds (adapted from USGS 2021).

to the University of California at Davis' soils' mapping application, the soils on the Refuge are Jackport, Kobel, Dewitt, Oaklimeter, Gore, Rexor, Tichnor, and Commerce (NRCS 2021). Each of these soil types contains some percentage of a very fine sand, characteristic of areas periodically inundated with water, such as floodplains, backswamps, stream terraces, and depressions (NRCS 2021). Native vegetation found on these soils usually consists almost entirely of mixed hardwoods, which corroborates with survey data dating back to 1837 (Hamel *et al.* 2001).

As a growing European population in North America settled into the LMAV in the nineteenth century, wetlands were drained, and land was cleared for agriculture (Carr *et al*. 1996). By the late twentieth century, approximately 24 million hectares (ha) of bottomland forests in the LMAV had been reduced to less than 2 million ha (Forsythe 1985; Hamel *et al.* 2001, USFWS 2018b). In 1927, a federal biologist observed decreased waterfowl across the converted areas, a result of heavy overshooting, agricultural activities, and drought (Nelson 1927). By 1985, the “Swampbuster” Act of the Farm Bill had begun to restore wetlands (NRCS, n.d.), and by 1993, rigorous migratory waterfowl habitat initiatives resulted in the establishment of numerous refuges (including Bald Knob) in the LMAV, as was recommended by the North American Waterfowl Management Plan (NAWMP) (U.S. Department of the Interior and Environment Canada. 1986). The Refuge’s goals include the protection and restoration wetlands and bottomland hardwood forests, provision of wintering habitat for waterfowl, and provision of breeding and non-breeding habitat for songbirds (USFWS 2009). In addition to providing habitat for waterfowl, the Refuge supports habitat for plants, other birds, and other wildlife species such as deer, large and small mammals, amphibians, reptiles, and aquatic organisms (USFWS 2009, Johnson 2018). Additionally, the Refuge provides the public with opportunities such as hunting, fishing, birdwatching and photography (USFWS 2020b), and three extractive gas wells have become operational within the Refuge boundary (Crafton *et al.* 2018).

As stated previously, most of the bottomland forests in the LMAV were converted to agriculture (Dahl 1990, Forsythe 1985, Service 1998, Hamel *et al.* 2001, Johnson 2018), and less than half of the Refuge currently supports restored or retained bottomland hardwoods (Service

2001). Subjected to new water management regimes and impoundments of nearby rivers, the parcels of the Refuge are connected by a network of constructed sloughs and reservoirs, while silt deposition restricted water circulation and depth (Carr *et al.* 1996). Since most of the bottomland forest was cleared for agriculture, the site of the present Refuge was chosen for providing managed wetlands for waterfowl via artificial irrigation rather than relying on unpredictable flooding events in the Little Red River and backflow from the White River (R. Crossett, pers. comm. 2019).

At present, the Refuge participates in a cooperative farming program, providing annual leases to farmers for growing rice, soybean, sorghum (milo), millet and corn on approximately 4,500 acres (18.2 $km^2$) (Edwards and Crossett 2008, USFWS 2020b). Under this farming program, portions of the crops (approximately 25 percent) may be left unharvested to provide food for the wintering birds. Each autumn, water from the Little Red River is pumped into these agricultural fields and other cover types to create wetlands (Johnson 2018).

Cover types on the Refuge include harvested and unharvested crops, wooded wetlands, moist-soil vegetation, marsh, and mudflats. In the non-agricultural areas, the Refuge land consists mainly of bottomland forests of predominantly oak, cypress brake, buttonbush (*Cephalanthus occidentalis*) scrub-shrub, marsh, moist-soil vegetation (Edwards and Crossett 2008, R. Crossett, in litt. 2020). The moist-soil vegetation is mostly endemic varieties of *Polygonum* spp., wild millet, grasses, sedges, forbs, shrubs, and other aquatic and wetland-obligate plants (Devall *et al*. 1995, Johnson 2018, R. Crossett, pers. comm. 2019). Other areas of the Refuge include a blend of mudflats, uplands, and non-vegetated surfaces like roads and buildings. Agricultural production on the Refuge has permitted the use of pesticides (including insecticides), artificial fertilizers, and mechanical tillage of the soil (R. Crossett, pers. comm.

2019). As the parcels are flooded, seeds, grains and tubers become accessible to foraging waterfowl and other species.

As detailed in the Structured Decision-Making Process document (Appendix A) for fulfilling the 2009 Comprehensive Conservation Plan (USFWS 2009), the Refuge intends to provide 750-1,000 ac (300-400 ha) of (flooded) unharvested cropland, 570 ac (230 ha) of harvested cropland, 500-650 ac (200-263 ha) of moist-soil habitat with percent cover greater than 50%, 800 ac (325 ha) of wooded wetlands, and other cover types totaling at least 3,125 ac (1,265 ha) of flooded habitat throughout the winter. The flooding schedule would be adjusted accordingly to meet these objectives. An assumption of this plan is that provision of sufficient DEDs per acre will achieve waterfowl population objectives, but the effectiveness of the plan for achieving these targets has not yet been tested, and it is unknown if the objectives are being met. The objective of this study is to assess if cover type use by dabbling ducks at the Refuge may be related to energy availability. In this way, this study may help the Refuge managers in evaluation of the effectiveness of using energetic values of cover types in providing habitat for dabbling ducks on the Refuge.

**METHODS**

All field data were collected by Refuge staff. Each species of waterfowl was counted in each cover type at the Refuge for 14 consecutive winters (mid-November to early-March) from 2006-2007 to 2019-2020. The surveyor(s) drove a vehicle along a specific route during the season, between 10am and 2pm, on a selected weekday for each survey date. Survey dates are listed in Appendix B. The survey route (Figure 5) allowed duck counts in all flooded parcels within visual range of the vehicle using scopes and binoculars.

The surveyor recorded waterfowl and other waterbirds in each parcel, counting individuals of each species or estimating the number of birds in larger each species or estimating the number of birds in larger flocks (i.e., rounding to the nearest 50, 100, or 1,000 as flocks increase in size). The calendar date and the number of surveys each year varied (Table 1), depending on the availability of the surveyor and drivable conditions of the survey route (R. Crossett, pers. comm. 2020). Each parcel identification number, its cover type and percentage flooded were recorded. The surveyor recorded the time, weather conditions (air temperature, precipitation, relative humidity), and hunting open or closed status for each parcel. The data were recorded manually on paper, and later entered into a Microsoft Access 2010 database.

Table 1. Duck survey day occurrence by month at Bald Knob NWR during wintering seasons 2006-07 to 2019-20 (Credit: S. Kreisler).

| | **Survey Day** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| *n* | *14* | *14* | *14* | *14* | *14* | *13* | *12* | *9* | *1* | *1* |
| **November** | 14 | 12 | 1 | | | | | | | |
| **December** | 0 | 2 | 12 | 7 | 2 | | | | | |
| **January** | | | 1 | 7 | 10 | 7 | 1 | 1 | | |
| **February** | | | | | 2 | 5 | 8 | 3 | 1 | |
| **March** | | | | | | 1 | 3 | 5 | | 1 |

A combination of Microsoft products (Access, Excel, Presenter, Word) and ArcGIS Pro by ESRI (and related geoprocessing tools and extensions) was used to sort data, analyze, and produce tables, figures, and maps to address the central project questions. Survey data were downloaded into a Microsoft Excel database, then sorted by survey date and cover type. Cover types at the Refuge were grouped into categories based on descriptions from an energy matrix (Appendix C) compiled from various sources (Table 2). Each year was sorted separately by parcel number, to ensure consistency throughout each season, and any clerical errors were corrected once identified. Dabbling duck count information was separated from other species.

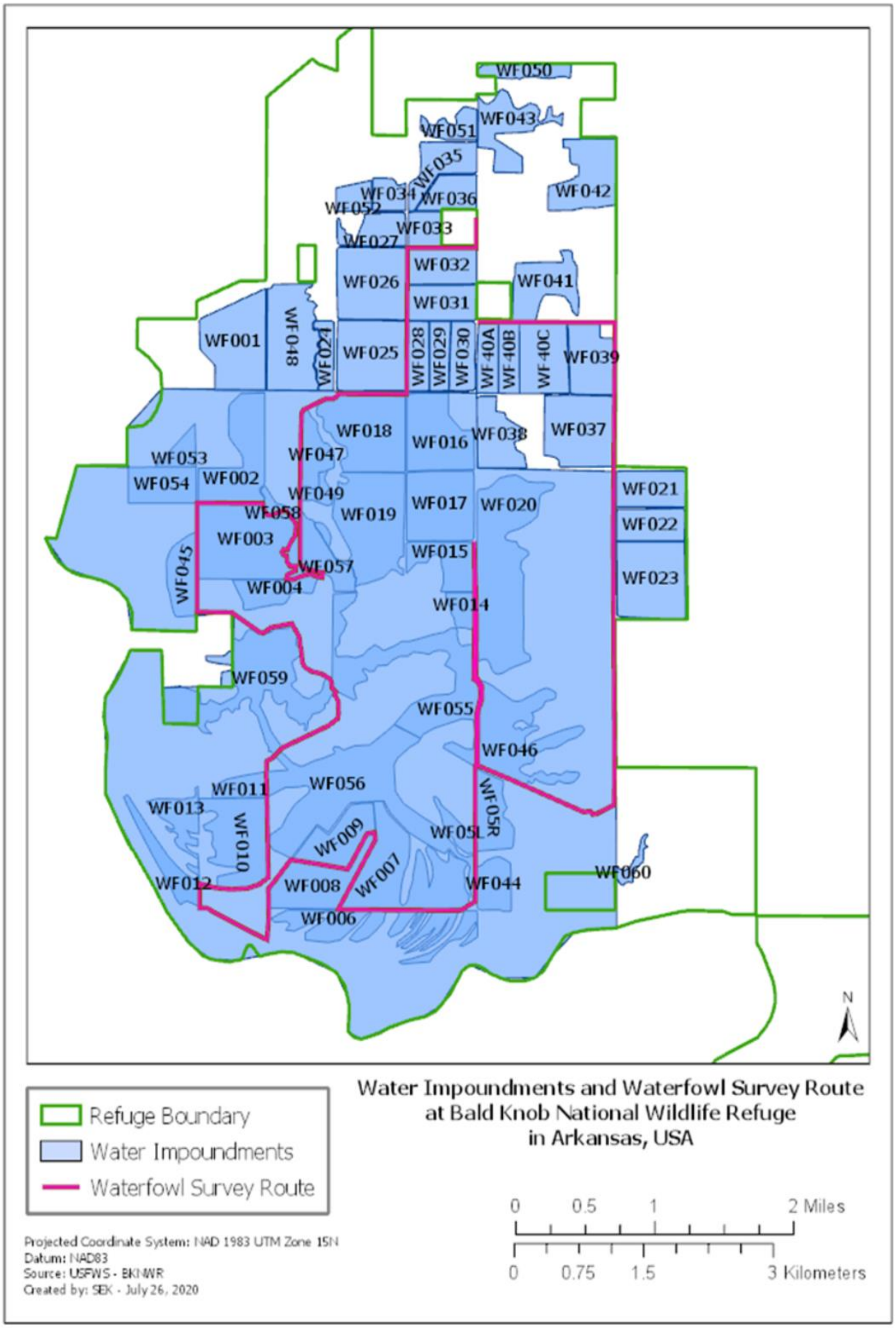


Figure 5. Map of waterfowl survey route and water impoundments at Bald Knob National Wildlife Refuge, Arkansas (Credit: S. Kreisler).

Table 2. Cover types at Bald Knob National Wildlife Refuge, Arkansas, with corresponding duck energy days (DEDs) as derived from an energy matrix (IWMM 2020) for the Mississippi Alluvial Valley compiled from the following sources: 1. (Bowyer *et al.* 2005), 2. (Feaga 2013), 3. (Foster *et al.* 2010), 4. (Foth *et al.* 2012), 5. (Gray *et al.* 2013), 6. (Greer *et al.* 2009), 7. (Hagy *et al.* 2011), 8. (Hagy *et al.* 2012), 9. (Kross *et al*. 2008), 10. (Manley *et al.* 2004), 11. (Marty 2017), 12. (Merkens *et al.* 2012), 13. (Osborn *et al.* 2017), 14. (Ringelman *et al.* 2018), 15. (Stafford *et al*. 2006), 16. (Stafford *et al.* 2011), 17. (Straub *et al*. 2012), 18. (Tapp 2013), 19. (Weegman 2013), 20. (Whittington 2005). The energy matrix is depicted in Appendix C.

| Cover Type | Availability | DED/ac | DED/ha | Classification |
|---|---|---|---|---|
| Mudflats | 75% | 100 | 247 | Mudflat (13,14) |
| Bottomland Hardwood | 25% | 200 | 494 | Seasonal Wooded Wetlands (4,6,17) |
| Afforestation | 25% | 200 | 494 | Semi-permanent Wooded Wetlands (4,6,17) |
| Cypress Brake | 25% | 200 | 494 | Semi-permanent Wooded Wetlands (4,6,17) |
| Scrub-Shrub Swamp | 25% | 200 | 494 | Semi-permanent Wooded Wetlands (4,6,17) |
| Corn, Harvested | 75% | 500 | 1235 | Harvested Crop (3,5,6,11,15) |
| Millet, Harvested | 75% | 500 | 1235 | Harvested Crop (6) |
| Milo, Harvested | 75% | 500 | 1235 | Harvested Crop (6) |
| Rice, Harvested | 75% | 500 | 1235 | Harvested Crop (6,15) |
| Soybean, Harvested | 75% | 500 | 1235 | Harvested Crop (6) |
| Marsh | 50% | 700 | 1729 | Freshwater Persistent Emergent Marsh (18,19) |
| Moist-soil vegetation | 95% | 1800 | 4446 | Freshwater Non-persistent Emergent Marsh (1,8,9,15) |
| Layout (Green) | 50% | 1900 | 4693 | Green Browse (12) |
| Millet | 95% | 5000 | 12350 | Unharvested Millet (3,5) |
| Soybean | 95% | 9600 | 23712 | Unharvested Soybean (20) |
| Milo | 95% | 15000 | 37050 | Unharvested Sorghum (5) |
| Rice | 95% | 25000 | 61750 | Unharvested Rice (3,6,10) |
| Corn | 95% | 33000 | 81510 | Unharvested Corn (7) |

Included as dabbling ducks were mallard, northern pintail, green-winged teal, blue-winged teal (*Spatula discors)*, northern shoveler (*Spatula clypeata)*, gadwall (*Mareca strepera)*, American wigeon (*Mareca americana*), and wood duck (*Aix sponsa)*. To remove hunting activities as a variable in cover type avoidance by ducks, parcels which were open to hunting on the survey date were excluded from this analysis. “Available” acres were calculated based on the approximate number of acres in the parcel multiplied by the estimated percentage of flooding in that parcel on a survey date. DEDs per acre were multiplied by the number of available acres, resulting in a total energetic value available in a parcel on a given survey date. If more water had been pumped into a field, the DED value for that parcel would increase based on the new percentage of flooded acres. Similarly, if the impounded water became frozen due to weather, or the water was drawn down, the DED value for that parcel would decrease. DED value thus increased and decreased over the season independent of duck consumption of the energy (DED/acre x flooded acres) – DUD ± flooding/frozen acres = DEDs remaining). While DEDs are the number of ducks an area could potentially support, duck use days (DUDs) are the number of ducks observed on a survey date multiplied by the number of days since the previous survey date in the same season (Survey date – previous survey date) x bird count = DUD).

I assessed if maximum duck energy days ($DED_{max}$) available during a wintering season were associated with the cumulative DUDs during a wintering season by running separate regression analyses for each cover type over the 14 years. Maximum DEDs ($DED_{max}$) are the energetic values (DEDs/acre) of each cover type multiplied by the maximum flooded acres in that cover type during each wintering season. Cumulative DUDs represents the estimated cumulative duck use from each wintering season. To assess if the total energy available to ducks from all the managed parcels on the Refuge was associated with the total cumulative DUDs, $DED_{max}$ was summed over all cover types within a season and a separate regression analysis was run for these totals.

Charts for all cover types for each survey season were compiled onto a single page, for side-by-side comparison. Each cover type was then ranked in order of percentage of total DEDs available, per survey day, and the average ranking for each cover type was compared and ranked for survey day duck counts, cumulative DUDs, and DED values. For each cover type, all fourteen years of charts were placed on a single page to assess similarities across all years.

To test the assumption that mallards are representative of other dabbling ducks in conservation planning in the MAV (Herbert *et al.* 2021), relative percentages of mallards observed in each cover type over the fourteen wintering seasons were graphed. Correlations were also run to test the relationship between counts of mallards and pintails, mallards and green-winged teal, mallards and all other dabbling ducks (including pintails and teal), and mallards and all other dabblers (excluding pintails and teal); each regression analysis was run for each cover type independently and combined.

In ArcGIS Pro, maps were created to display year-to-year changes in cover types in the survey area. Polygons were cleaned to ensure consistency in acreage for each parcel across all fourteen survey seasons. New fields were added as needed within the attribute table, and acreage was calculated for each polygon/parcel. These acreages were compared with the information from the Access database. Each parcel was assigned a cover type based on the information from Access, with a distinct color/shade gradient assigned to each cover type. The survey route was applied as a polyline feature. A new feature class was created for each year. Year-to-year changes in cover types were illustrated in a layout file depicting all fourteen survey seasons (Appendix D).

**RESULTS**

To assess if the Refuge is achieving its population targets for dabbling ducks, and the average amount of DEDs being provided, I calculated the average cumulative DUDs and maximum duck energy days ($DED_{max}$) over all years that each cover type was available. Cumulative duck use averaged 6,963,861 (± 2,710,150, *n*=14) DUDs per year and available energy averaged 13,008,103 (± 6,475,014, *n*=14) DEDs per year. The total $DED_{max}$ per year (all cover types combined) were not associated with the total cumulative DUDs per year ($R^2$ = 0.0245; P=0.5933).

The cover types available in all fourteen survey seasons (2006-07 to 2019-20) were wooded wetlands, harvested crops (rice, millet, milo, and soybeans), marsh, moist soil vegetation, and unharvested rice. Mudflats were available in 11/14 seasons and green browse in 4/14 seasons. Green browse is food which management sets out for ducks in times of food scarcity, and may consist of layout grains, seeds, “winter wheat”, or other temporary cover. Unharvested corn was available in some years, but no dabbling ducks were reported so this cover type was excluded from the analysis. Other unharvested grains were available as follows: millet in 3/14 seasons, milo in 2/14 seasons, and soybeans in 1/14 seasons.

The degree to which maximum duck energy days ($DED_{max}$) available per year in each cover type during a wintering season were associated with the cumulative DUDs per year varied among cover types: rice ($R^2 = 0.31$, P=0.04), moist-soil vegetation ($R^2 = 0.22$, P=0.09), mudflats ($R^2 = 0.22$, P=0.15), wooded wetlands ($R^2 = 0.15$, P=0.17), harvested crops ($R^2 = 0.02$, P=0.63), and marsh ($R^2 = 0.02$; P=0.69) (Table 3). Green browse and unharvested grains (milo, millet, and soybeans) were available in fewer than 10 years, so no analyses were conducted for those cover types. DEDs were significantly associated with DUDs in rice fields ($P<0.05$), and a weak association was observed for moist-soil vegetation ($P<0.10$); all other relationships were not statistically significant ($P>0.05$).

The cover types in descending order of average DUDs (for all years the cover type was available) are wooded wetlands (3,121,771), harvested crops (1,426,544), moist-soil vegetation (1,382,762), millet (802,810), milo (737,071), unharvested rice (603,592), green browse

**Table 3.** Number of years of availability (n = 14), DED value per acre (and hectare), average maximum DUDs, average maximum DEDs, and coefficients of determination for each cover type at Bald Knob NWR, Arkansas during survey seasons 2006-07 to 2019-20.

| Cover Type | No. of years available (n) 2006- 2020 | DED/ac | DED/ha | Average Cumulative DUDs | Average $DED_{max}$ | Coefficient of Determination ($R^2$) | *P* value (P) |
|---|---|---|---|---|---|---|---|
| **Mudflat** | 11 | 100 | 247 | 34,815 | 9,321 | 0.2163 | 0.1494 |
| **Semi-permanent Wooded Wetland** | 14 | 200 | 494 | 3,121,771 | 362,723 | 0.1535 | 0.1659 |
| **Harvested Crop** | 14 | 500 | 1,235 | 1,426,544 | 486,602 | 0.0199 | 0.6308 |
| **Marsh** | 14 | 700 | 1,729 | 1,609 | 96,408 | 0.0182 | 0.6945 |
| **Moist-soil** | 14 | 1,800 | 4,446 | 1,382,762 | 889,077 | 0.2236 | 0.0877 |
| **Green Browse (Layout)** | 4 | 1,900 | 4,693 | 364,758 | 226,435 | n <10 | n <10 |
| **Unharvested Millet** | 3 | 5,000 | 12,350 | 802,810 | 1,083,705 | n <10 | n <10 |
| **Unharvested Soybean** | 1 | 9,600 | 23,712 | 261,593 | 370,920 | n <10 | n <10 |
| **Unharvested Milo (Sorghum)** | 2 | 15,000 | 37,050 | 737,071 | 2,261,690 | n <10 | n <10 |
| **Unharvested Rice** | 14 | 25,000 | 61,750 | 603,592 | 10,439,975 | 0.3084 | 0.0392 |
| | **TOTAL of Averages of Each Cover Type:** | | | **8,737,325** | **16,226,856** | | |
| | Combined Total Annual Average: | | | 6,963,861 | 13,008,103 | 0.0245 | 0.5933 |

(364,758), soybeans (261,593), mudflats (34,815), and marsh (1,609) (Table 4). The relative distribution of available DEDs from each cover types varied (Figure 6), and the average maximum DEDs in descending order are unharvested rice (10,439,975), milo (2,261,690), millet (1,083,705), moist soil (889,077), harvested crops (486,602), soybeans (370,920), wooded wetlands (362,723), green browse (226,435), marsh (96,408), and mudflats (9,321).

**Table 4.** Total cumulative DUDs and maximum DEDs per cover type for all survey seasons 2006-07 to 2019-20 at Bald Knob NWR, Arkansas.

| Year | Total Maximum Type | MUDFLATS | WOODED WETLAND | HARVESTED | MARSH | MOIST-SOIL | GREEN BROWSE | MILLET | BEANS | MILO | RICE | *Maximums* *ALL* | | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | DUDs | 905 | 1,861,667 | 1,610,608 | 1,000 | 889,320 | | | | 415,232 | 540,011 | *5,318,743* | DUDs | 2006 |
| | DEDs | 4,800 | 305,295 | 428,167 | 37,640 | 607,590 | | | | 3,205,630 | 24,264,304 | *28,853,426* | DEDs | |
| 2007 | DUDs | 7,776 | 1,911,180 | 2,779,840 | 4,684 | 293,268 | | 662,634 | | 1,058,910 | 599,125 | *7,317,417* | DUDs | 2007 |
| | DEDs | 11,530 | 308,650 | 915,307 | 48,075 | 399,800 | | 224,500 | | 1,317,750 | 13,850,750 | *17,076,362* | DEDs | |
| 2008 | DUDs | 1,900 | 2,672,414 | 1,285,804 | 10,590 | 2,230,345 | 207,020 | 167,946 | | | 872,744 | *7,448,763* | DUDs | 2008 |
| | DEDs | 8,400 | 320,295 | 842,075 | 48,280 | 263,500 | 353,850 | 418,574 | | | 10,408,886 | *12,663,860* | DEDs | |
| 2009 | DUDs | 30,640 | 1,886,548 | 461,313 | 157 | 1,977,100 | 467,420 | | 261,593 | | 107,380 | *5,192,151* | DUDs | 2009 |
| | DEDs | 14,600 | 311,920 | 441,639 | 38,635 | 1,280,450 | 449,290 | | 1,483,680 | | 7,266,250 | *11,286,464* | DEDs | |
| 2010 | DUDs | 6,128 | 1,873,004 | 485,323 | - | 643,597 | | | | | 1,007,640 | *4,015,692* | DUDs | 2010 |
| | DEDs | 4,590 | 224,261 | 605,050 | 99,149 | 734,050 | | | | | 13,775,155 | *15,442,255* | DEDs | |
| 2011 | DUDs | 118,688 | 3,678,185 | 1,484,260 | 6,100 | 148,919 | | 1,577,849 | | | 80,330 | *7,094,331* | DUDs | 2011 |
| | DEDs | 9,053 | 298,939 | 316,760 | 162,359 | 1,743,317 | | 2,608,041 | | | 5,123,400 | *10,261,869* | DEDs | |
| 2012 | DUDs | 136,324 | 3,518,599 | 4,612,511 | - | 1,207,212 | 25,962 | | | | 1,330,310 | *10,830,918* | DUDs | 2012 |
| | DEDs | 14,390 | 453,573 | 783,400 | 48,300 | 365,395 | - | | | | 19,385,051 | *21,050,109* | DEDs | |
| 2013 | DUDs | 31,425 | 2,233,745 | 1,018,156 | - | 446,657 | 758,630 | | | | 422,197 | *4,910,810* | DUDs | 2013 |
| | DEDs | 7,900 | 355,130 | 458,338 | 2,415 | 499,480 | 102,600 | | | | 1,793,766 | *3,219,629* | DEDs | |
| 2014 | DUDs | 4,104 | 2,405,638 | 269,449 | - | 1,062,570 | | | | | 458,557 | *4,200,318* | DUDs | 2014 |
| | DEDs | 7,965 | 404,715 | 578,338 | 128,355 | 263,280 | | | | | 11,797,035 | *13,179,688* | DEDs | |
| 2015 | DUDs | 32,620 | 2,548,983 | 211,680 | - | 1,920,421 | | | | | 12,600 | *4,726,304* | DUDs | 2015 |
| | DEDs | 14,500 | 326,154 | 450,275 | 45,740 | 1,417,879 | | | | | 5,375,000 | *7,629,548* | DEDs | |
| 2016 | DUDs | 12,460 | 7,856,714 | 1,064,242 | - | 1,195,576 | | | | | 1,276,150 | *11,405,142* | DUDs | 2016 |
| | DEDs | 4,800 | 333,307 | 286,085 | 101,459 | 487,490 | | | | | 9,552,300 | *10,765,441* | DEDs | |
| 2017 | DUDs | | 1,938,865 | 348,400 | - | 2,125,752 | | | | | 449,000 | *4,862,017* | DUDs | 2017 |
| | DEDs | | 394,022 | 255,042 | 103,137 | 1,701,301 | | | | | 5,910,354 | *8,363,856* | DEDs | |
| 2018 | DUDs | | 5,360,842 | 4,014,406 | - | 1,103,493 | | | | | 1,207,280 | *11,686,021* | DUDs | 2018 |
| | DEDs | | 571,644 | 291,545 | 330,925 | 814,095 | | | | | 13,510,505 | *15,518,714* | DEDs | |
| 2019 | DUDs | | 3,958,403 | 325,618 | - | 4,114,437 | | | | | 86,963 | *8,485,421* | DUDs | 2019 |
| | DEDs | | 470,217 | 160,410 | 155,249 | 1,869,454 | | | | | 4,146,890 | *6,802,220* | DEDs | |
| | | | | | | | | | | | | 6,963,861 | DUDs | Total across all years |
| | | | | | | | | | | | | 13,008,103 | DEDs | Total across all years |
| Average DUDs | | 34,815 | 3,121,771 | 1,426,544 | 1,609 | 1,382,762 | 364,758 | 802,810 | 261,593 | 737,071 | 603,592 | 8,737,324 | DUDs | Total of all averages |
| Average DEDs | | 9,321 | 362,723 | 486,602 | 96,408 | 889,077 | 226,435 | 1,083,705 | 370,920 | 2,261,690 | 10,439,975 | 16,226,856 | DEDs | Total of all averages |
| | | MUDFLATS | WOODED WETLAND | HARVESTED | MARSH | MOIST-SOIL | GREEN BROWSE | MILLET | BEANS | MILO | RICE | ALL | | |

To assess how ducks were distributed in each cover type in each year, I ranked the total duck counts in each cover type over all fourteen years (Figure 7). To assess how duck were distributed in each cover type during each season (November to March), I ranked each cover type from highest to lowest according to percentage of total duck counts, cumulative DUDs, and percentages of available DEDs for each survey day (1 through 10) over the fourteen years. For duck counts, wooded wetlands ranked first (or tied for first) on Days 1, 2, 3, 4, 7, and 10, moist-soil ranked first on Days 1 and 5, harvested crops on Days 6, 7, 8, and 9. For cumulative duck

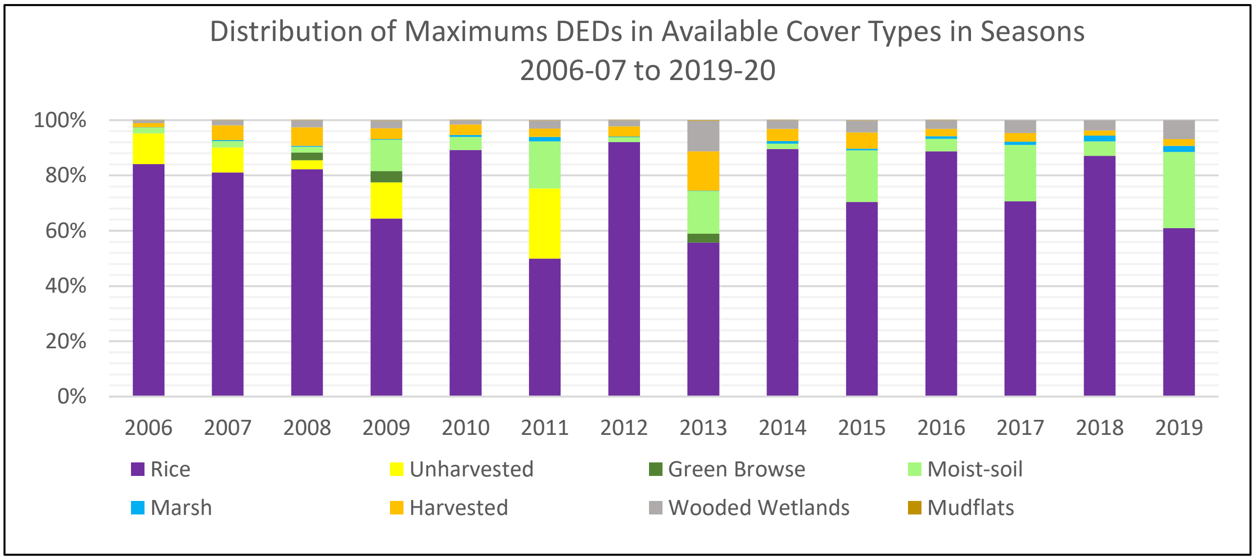


Figure 6. Distribution of maximums DEDs in available cover types at Bald Knob NWR, Arkansas during wintering seasons 2006-07 to 2019-20 (Credit: S. Kreisler).

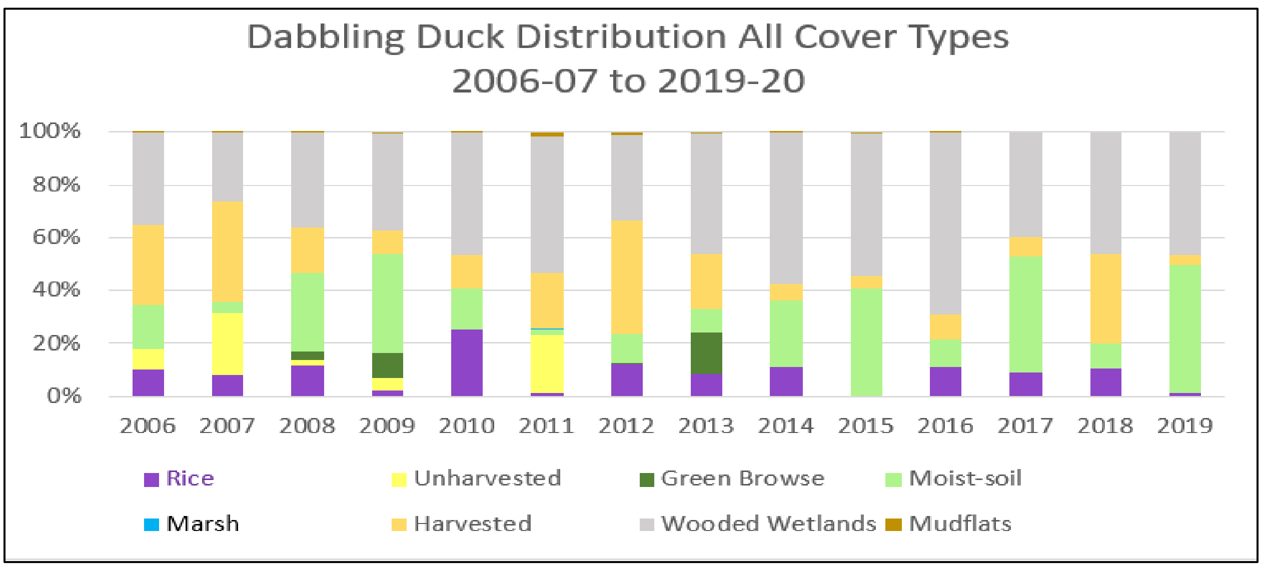


Figure 7. Distribution of dabbling ducks (by total DUDs) in each cover type at Bald Knob NWR, Arkansas during wintering seasons 2006-07 to 2019-20 (Credit: S. Kreisler).

use averages over time, wooded wetlands, moist-soil, and harvested crops tied for Day 1. Harvested crops ranked first on Day 9, while wooded wetlands ranked first in cumulative DUDs on Days 2, 3, 4, 5, 6, 7, 8, and 10. When percentage of available DEDs on each survey day were averaged across all years, unharvested rice ranked the highest on all days (1 through 10) for available DEDs. To review for patterns of duck distribution in each cover type over each season, graphs of DUDs, cumulative DUDs, and available DEDs were compiled and reviewed (Appendix E, Appendix F). Amongst all cover types, DEDs were typically highest in the early-mid season, and ducks continued to be observed using all cover types even after calculated DED values had declined to below zero. General observations are as follows:

- Mudflats (DED = 100/acre): This cover type was available in 11 of 14 years. Duck counts were typically low and no discernable use pattern over years was observed.
- Wooded wetlands (DED = 200/ac): This cover type was available in 14 of 14 years. Duck counts generally peaked in mid-late season (days 3 to 7) in most years and remained stable even when DED values had declined below zero.
- Harvested crops (DED = 500/ac): This cover type was available in 14 of 14 years. Duck counts peaked in early-mid season (days 3 to 5) in most years.
- Marsh (DED = 700/ac): This cover type was available in 14 of 14 years. Duck counts were low to zero throughout each season.
- Moist soil (DED = 1,800/ac): This cover type was available in 14 of 14 years. Duck counts increased in early season (days 2 to 3) and remained stable through mid-season in most years.
- Green browse (layout) (DED = 1,900/ac): This cover type was available in 3 of 14 years. In two of the three years that this cover type was available, duck counts peaked on survey day 5, and duck use stopped once DED values dropped below zero. In the other year (2008-2009), duck counts peaked on survey days 3 to 5, remaining above zero as did DED values. It is unknown if layout was placed multiple times during that year.

- Millet (DED = 5,000/ac): This cover type was available in 3 of 14 years. Duck counts peaked in early season (days 2 to 3), and DED values decreased in mid-winter and increased in late season as did duck counts.
- Soybeans (DED = 9,600/ac): This cover type was only available in one year. Duck counts peaked on survey day 2, declined to zero, then peaked again on days 5 and 6 (mid-late season).
- Milo (DED = 15,000/acre): This cover type was available in 2 of 14 years. Duck counts peaked in early season (days 2 to 5).
- Rice (DED = 25,000/acre): This cover type was available in 14 of 14 years. Duck counts typically peaked in mid-season (days 3 to 6) in most years, and in 8 of 13 years that this cover type was available, a second small rise in duck counts occurred after survey day 6. The survey route at the unharvested rice was inaccessible on several days during 2015-2016 due to flooding (R. Crossett, pers. comm. 2019), and this year was excluded from the graph compilation. In 9 of the 13 years, available DED values remained above zero throughout the season. In 4 years, available DED values remained above zero until the late winter.

To address the common (but not well-tested) assumption of similarity between wintering mallards and other dabbling ducks in cover type selection, I ran regression analyses between mallards and other dabbling ducks. Mallard counts were not strongly related to other dabbling duck species in mudflats and green browse (Table 5). Mallard counts were related to counts of northern pintails and green-winged teal in wooded wetlands, harvested crops, unharvested crops (millet, milo, and soybeans), unharvested rice, and in combined cover types. Mallard counts were

Table 5. Results of regression analysis between mallards (M) and other species (NP = Northern pintail; GWT = Green-winged teal) (Credit: S. Kreisler).

| | Mallards | | | | | Pintails | | | | Green-winged Teal | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All Others | NP | GWT | Others excl. NP & GWT | n | All Others | GWT | Others excl. M & GWT | n | All Others | Others excl. M & NP |
| Cover Type | n | $R^2$ | $R^2$ | $R^2$ | $R^2$ | n | $R^2$ | $R^2$ | $R^2$ | n | $R^2$ | $R^2$ |
| Mudflats | 11 | 0.00 | 0.00 | 0.02 | 0.00 | 11 | 0.39 | 0.35 | 0.39 | 11 | 0.15 | 0.39 |
| Wooded Wetlands | 14 | 0.78*** | 0.57** | 0.50** | 0.16 | 14 | 0.54** | 0.19 | 0.18 | 14 | 0.42* | 0.00 |
| Harvested Crops | 14 | 0.57** | 0.51** | 0.50** | 0.11 | 14 | 0.56** | 0.21 | 0.36* | 14 | 0.45** | 0.13** |
| Marsh | 14 | 0.99*** | N/A | N/A | 0.99*** | 0 | N/A | N/A | N/A | 1 | N/A | N/A |
| Moist-soil | 5 | 0.49** | 0.04 | 0.63*** | 0.33* | 5 | 0.03 | 0.00 | 0.12 | 5 | 0.46** | 0.65*** |
| Green Browse | 4 | 0.00 | 0.03 | 0.17 | 0.00 | 3 | 0.01 | 0.08 | 0.52 | 4 | 0.95* | 0.82 |
| Unharvested Crops | 5 | 0.95** | 0.76*** | 0.94** | 0.73 | 4 | 0.58 | 0.55 | 0.32 | 5 | 0.93** | 0.83* |
| Unharvested Rice | 14 | 0.77*** | 0.77*** | 0.14 | 0.35* | 13 | 0.74*** | 0.10 | 0.25 | 14 | 0.90* | 0.00 |
| All Cover Types | 14 | 0.55** | 0.31* | 0.40* | 0.21 | 14 | 0.14 | 0.00 | 0.31 | 14 | 0.19 | 0.11 |

*P<0.05
**P<0.01
***P<0.001

related to other dabbling species in moist-soil vegetation (excluding northern pintails), unharvested rice (excluding green-winged teal), and marsh. Counts of northern pintails were related to other dabbling species (non-mallards and non-green-winged teal) in harvested crops (P<0.05). Counts of green-winged teal were related to other dabbling species (non-mallards and non-pintails) in moist-soil (P<0.001), harvested crops (P<0.01), and unharvested crops (P<0.05).

To further test the assumption of using mallards as surrogates for other dabbling ducks, I calculated the relative percentages of mallards observed in each available cover type over the fourteen wintering seasons. Mallards dominated the dabbler population in wooded wetlands in all fourteen seasons, in 9 of 14 seasons in unharvested rice, and 3 of 5 years (DUD >0) in marsh (Figure 8). However, non-mallards dominated in most seasons in other cover types (e.g., mudflats, harvested crops, and moist-soil). When all cover types were combined, in five of the fourteen wintering seasons, mallards comprised the majority of dabbling ducks observed

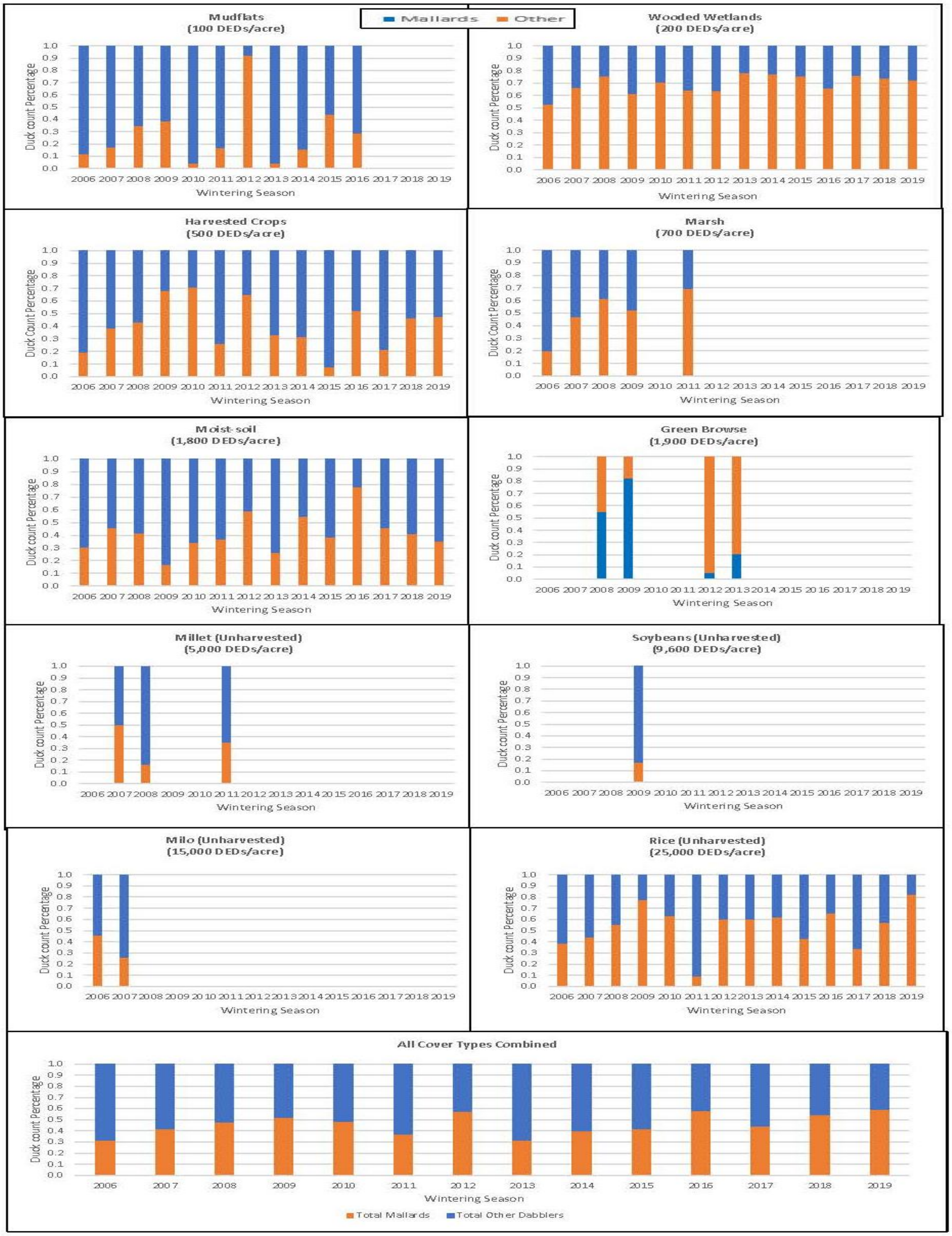


Figure 8. Percentages of mallard ducks compared to all other dabbling ducks in each cover type at Bald Knob NWR over fourteen wintering periods (2006-07 to 2019-20) (Credit: S. Kreisler).


Figure 9: Percentages of dabbling ducks (mallard, northern pintail, green-winged teal, and other species) in each cover type at Bald Knob NWR over fourteen wintering periods (2006-07 to 2019-20) (Credit: S. Kreisler).

Table 6. Most frequently counted species in each of ten cover types at Bald Knob NWR over fourteen wintering seasons (2006-07 to 2019-20) (Credit: S. Kreisler).

| | | | Dominant | | Dominant (mallards excluded) | | |
|---|---|---|---|---|---|---|---|
| Cover Type | DED/acre | No. of Years Available | Mallards | Non-mallards | Northern Pintail | Green-winged Teal | Other |
| Mudflats | 100 | 11 | | x | | | x |
| Wooded Wetlands | 200 | 14 | x | | | x | |
| Harvested Crops | 500 | 14 | | x | x | | |
| Marsh | 700 | 5 | x | | | | x |
| Moist soil | 1,800 | 14 | | x | x | | |
| Green browse | 1,900 | 4 | | | | x | |
| Unharvested Millet | 5,000 | 3 | | x | x | | |
| Unharvested Soybeans | 9,600 | 1 | | x | x | | |
| Unharvested Milo | 15,000 | 2 | | x | x | | |
| Unharvested Rice | 25,000 | 14 | x | | x | | |
| **All cover types combined** | | **14** | | x | | x | |

(>50%), in six seasons, mallards comprised 40-50%% of total dabblers, and in three seasons, mallards comprised 30-40%% of all dabbling ducks observed. Other dabbling ducks dominated mallards in 9 of the 14 seasons.

When the three focal species were compared, mallards dominated both northern pintails and green-winged teal in 13 of the 14 seasons in all cover types combined, and northern pintails dominated mallards in 1 of the 14 seasons (Figure 9). When mallards were excluded (Table 6), northern pintail dominated other dabbling species in 11 of 14 seasons in unharvested rice, 10 of 14 seasons in harvested crops, 7 of 14 seasons in moist soil vegetation, 2 of 3 seasons in unharvested millet, 1 of 4 seasons of green brose, 4 of the 14 seasons in wooded wetlands, 1 in 11 seasons in mudflats, both types were combined, northern pintail dominated other dabbling species (non-mallards) in 5 of the 14 seasons. Green-winged teal dominated other dabbling species (non-mallards) in 6 of 14 seasons in wooded wetlands, 1 of 14 seasons in harvested crops, 5 of 14 seasons in moist soil vegetation, 1 of 3 seasons in unharvested millet, 3 in 11 seasons in mudflats, 2 of 4 seasons of green browse, 2 of 14 seasons of unharvested rice. When all cover types were combined, green-winged teal dominated other dabbling species (non-mallards) in 1 of the 14 seasons.

**DISCUSSION**

The primary purpose of this study is to aid the Refuge managers in meeting the population targets for wintering dabbling ducks, and to assess the usefulness of duck energy days as a tool for decision-making in habitat provision for waterfowl and other water birds. Based on this case study, diurnal duck use of cover types is mostly unrelated to food density and duck use is not a useful measure of energy availability on the Refuge. A secondary finding of this case study is that mallards may be an adequate surrogate (representative) for other dabbling duck species, although the strength of this relationship varies across cover types and species.

The null hypothesis of this case study was: there is not a strong association between duck use and available energy of a cover type. The average maximum DEDs ($DED_{max}$) available per season across all cover types was 13,008,103, a shortfall of 508,659 DEDs from the Refuge's objective of 13,516,762 DEDs (Hagy *et al*. 2020); the relationship between average $DED_{max}$ and average DUDs was not statistically significant ($P>0.05$). From the analysis of individual cover types, only in rice were DEDs significantly associated with DUDs ($P<0.05$). The null hypothesis is rejected for unharvested rice fields, but the study fails to reject the null hypothesis for all other cover types.

The high diurnal duck use in wooded wetlands on the Refuge did not appear to be related to energy available in that cover type. The cover types in descending order of average duck use were: wooded wetlands, harvested crops, moist-soil vegetation, millet, milo, unharvested rice, green browse, soybeans, mudflats, and marsh, while the cover types in descending order of average maximum energy availability were: unharvested rice, milo, millet, moist soil, harvested crops, soybeans, wooded wetlands, green browse, marsh, and mudflats. Although ducks were observed using all cover types throughout the season, duck distribution between cover types changed over the season, with most ducks moving from wooded wetlands and moist-soil vegetation in the early season (November-December) to harvested crops in the mid-to-late season (January-March). Areas open to hunting during surveys were excluded from the analysis, and may have increased total DUDs if included, though the extent of this potential influence on duck use of a cover type was not considered in this case study.

Duck use throughout every season was consistently greatest in wooded wetlands, until the end of the season when ducks moved to harvested crops. Over time, DEDs declined, but ducks continued to use all cover types even after calculated DED values (from maximum availability less duck consumption) had declined to zero. This corroborates the findings of Hagy and Kaminski (2015). Unharvested rice fields consistently provided the highest number of DEDs throughout the season. In most years, calculated DED values remained above zero for all or most of the year in the flooded, unharvested rice fields, and ducks were observed in rice fields on every survey date.

Mallards were observed in every cover type, as was expected of a generalist. However, in this case study, mallards were observed in wooded wetlands in higher numbers and proportions (Appendix G) than any other dabbling duck species, which supports earlier observations that flooded wooded wetlands are important for wintering mallards (Tiner 1984, Kaminski *et al.* 1993, Reinecke and Baxter 1996, Davis *et al.* 2009). Albeit noticeably disproportionate in wooded wetlands, mallards were distributed in lesser or equal proportions to other dabbling species within most other cover types. The relationship between DUDs and DEDs in wooded wetlands was not statistically significant for either mallards separately or all dabbling species combined.

Concentration of mallards in the wooded wetlands on the Refuge is likely either an adaptation to habitat loss (land conversion to agriculture in the area) or is a natural part of the mallard's life history. Heitmeyer and Frederickson (1981) suggested that landscape-scale losses of bottomland forests have resulted in mallards being forced to congregate into smaller areas. I would hypothesize that the observed disproportionate abundance of mallards in wooded wetlands may deter other species, perhaps due to some level of competition for resources (e.g., forage, cover, roosting, pair bonding sites); microhabitat in the bottomlands is important for invertebrate foods and wintering mallards during prealternate and prebasic molt (Allen 1987, Heitmeyer 1987, Combs and Frederickson 1995, 1996), but only in short-term flood regimes (Heitmeyer 1985, Batema *et al*. 1985), and in low-density bottomland forests with open canopy (Kaminski *et al*. 1993). Even though DEDs do not have a strong relationship with DUDs in wooded wetlands, providing this habitat type is likely to support mallards on the Refuge.

I expected to find that the small-bodied green-winged teal would demonstrate use of more dense vegetation types (wooded wetlands), rice stubble, and areas of less exposure (hiding cover from predators and hunters), and this species was observed using (open) marsh in only one year of its availability. Diet studies during the non-breeding period reported that green-winged teal feeds mostly on moist-soil plants and seeds (Anderson *et al*. 2000), agricultural grains, and invertebrates (such as midge larvae as found in bottomland hardwood forests) (Johnson and Lockwood 2013). In terms of relationships between use of certain cover types by green-winged teal and other species, the use of moist-soil vegetation, harvested crops, and unharvested crops by teal was related to other dabblers (non-mallards). Other than mallards, green-winged teal were found in higher numbers than other dabbling species in wooded wetlands (see Table 4 and Figure 7), which supports the Johnson and Lockwood (2013) study. At the Refuge, green-winged teal were also common in green browse (layout) and mudflats, which was surprising upon first considering the open exposure, but supported by the fact that the species prefers to walk while foraging rather than swim (Johnson and Lockwood 2013). Johnson and Rowher (2000) had also observed the green-winged teal using mudflats and rice fields, as did my case study. Additional review of literature suggests that this species is likely to use open areas during the daytime while resting (conserving energy), switching to denser foraging habitat at night (Anderson *et al*. 2000).

Based on literature review, northern pintails were expected to be observed in grain fields and marsh (Chabreck 1979, Suchy and Anderson 1988), feeding primarily on foliage, rhizomes, seeds, amphipods, crustaceans, and agricultural grains (Johnson and Lockwood 2013). However, pintails were absent from marsh in all fourteen survey periods. In my study, this species was more abundant than all other dabbling species in moist-soil vegetation and both harvested and unharvested grain fields. Although not as abundant as mallards, pintails comprised most of the non-mallards in rice fields. Counts of northern pintails were related to other dabbling species (non-mallards) only in harvested crops, and cover type use by pintails was related to mallards in wooded wetlands, harvested crops, and unharvested rice. Northern pintails were statistically unrelated to green-winged teal in cover type use, which was expected given the differences in body size and life history.

Observing the differences in habitat selection between the three focal species, there may be limitations in my approach to the research problem. Although I tested the assumption of using mallards as surrogate for other species, the study grouped mallards with other dabbling ducks in the evaluation of a potential relationship between duck use and energy availability, potentially overlooking differences in morphology, life history and behavior may have been overlooked which may account for species-specific variation in habitat selection. After noting the caution of Hagy and Kaminski (2015) in making too many broad assumptions, I realized that my study had grouped mallards within the guild of dabbling ducks under an assumption that mallard distribution would not differ greatly from that of other dabblers; this assumption is common amongst studies of dabbling ducks, despite some concern in recent years (Herbert *et al.* 2021). Mallards are a generalist forager, unlike some other species, and to test the assumption, I separated the three focal species from the other dabbling ducks in the last segment of the data analysis and ran regression analyses to find possible correlations.

Counts of mallards were related to the other two focal species (*Anas* spp.) in several cover types, including wooded wetlands, harvested and unharvested crops, unharvested rice, and all cover types when combined (see Table 5). Mallards were also related to other dabbling species (besides the other two focal species) in moist-soil, unharvested rice, and marsh. However, mallards were observed in very low numbers using mudflats and green browse compared to other duck species. This suggests that it may be appropriate to use mallards as surrogate for assessing other dabbling ducks only in certain cover types where there appears to be an association. It is noted, however, that the strength of a relationship varies between cover types and by species. For example, mallards were more closely related to pintails in unharvested crops and rice than they were in wooded wetlands and harvested crops. Similarly, mallards were more closely related to green-winged teal in moist-soil vegetation than in other cover types. Further, mallard use of four cover types were related to pintails and teal, but only related to other dabbling species in two cover types (marsh and unharvested rice).

Like mallard and green-winged teal, northern pintail has been observed to mostly forage nocturnally during the winter (Cox and Afton 1997, Fleskes *et al.* 2002, Parejo *et al.* 2019), so diurnal surveys may not adequately represent duck use of the Refuge. Tamisier (1976) suggested that social behaviors unrelated to feeding or roosting drive the daytime gatherings of pintails and other species, which reveals a challenge to the general assumption in this case study: that duck observations in each cover type are related to foraging (and energy consumption). It is apparent from ducks continuing to utilize parcels where calculated duck energy day values have fallen to zero (<0), that ducks may use cover types for reasons other than foraging. Some research indicates that water depth, height of stubble (in grain fields), and smaller particle substrate appear to be main factors influencing pintail habitat selection (Perejo *et al*. 2019). On the Refuge, many of the cover types where ducks were observed are sanctuaries, which exclude not only hunting but other public use. Such factors influencing duck use of a cover type were not considered within this case study, which relied on duck counts and percentage of acres flooded in each cover type. Several other limitations to the accuracy of duck counts (and cumulative duck use) used in my study have been identified, including:

- Percentage of flooding (e.g., 25% of a 100-acre field) was estimated based on visual observation and is therefore imprecise for accuracy in DED availability.
- Despite several studies indicating water depth to be a factor in habitat selection by dabbling ducks (Delnicki and Reinecke 1986, Beatty *et al*. 2015, Perejo *et al.* 2019, Behney *et al.* 2020), water level information at the Refuge was largely unavailable. Water depth could not be ruled out as a variable affecting duck use (DUDs) of any cover type. Refuge managers have also noted this issue (Appendix A).

- Visual obstructions to duck surveying, such as high stubble in agricultural fields, tree/shrub density in the wooded wetlands, and other obstacles to the survey route (road closures due to flooding and ice).
- Unpredictable natural and anthropogenic flooding and backflow from White River may impact the Refuge cover type provision in some years.
- Pesticide and fertilizer use in the agricultural fields on the Refuge is unregulated (R. Crossett, pers. comm. 2020), and any impacts to duck forage, invertebrates, soil quality, water quality, and DEDs values are unknown.
- During certain periods when the Refuge was open to hunting, ducks were likely to seek shelter and may move off the Refuge (and out of the survey area) entirely for unknown durations.
- Diurnal duck surveys may underestimate the full complement of ducks which may be using a cover type, since many species have been observed to forage nocturnally (e.g., Casazza *et al.* 2012).
- Cumulative duck counts were based on the number of ducks observed on the previous survey date, multiplied by the number of days passed. This methodology for calculating cumulative DUDs implies that duck movement is static.
- Ducks may be residing on the Refuge inconsistently during the survey periods, given that areas of suitable duck habitat surrounding the Refuge include agricultural fields, farm ponds, stock ponds, the state wildlife management area, bottomland hardwood forests, wetlands, and areas within the flood plain of the Red River and White River.

- Although eagle presence is to be noted on the survey data sheet, predation by wildlife by eagles (or other predators) which may affect duck movement and distribution on the Refuge is unknown and not tracked (affecting DUDs).

The findings from this case study challenge the research problem and assumption that providing high-energy foods will attract more dabbling ducks to the Refuge. Not only did the regression analyses fail to indicate a strong relationship between duck use and energy availability, but the abundance of ducks using wooded wetlands (which supports only a fraction of the DEDs on the Refuge) supports a conclusion that ducks may be choosing cover types during the daytime for purposes other than forage.

**Management Implications and Recommendations**

One of the challenges faced by the Refuge is how to meet duck hunting pressure by providing hunt-accessible areas while also providing sanctuary to wintering dabbling ducks and meeting Refuge objectives. Refuge management is presently providing a variety of cover types for migrating and wintering waterfowl, maintaining cooperative farming agreements, pumping water into impoundments to create artificial wetlands, and performing seasonal duck counts. The Refuge has been seeking to determine if duck population objectives are being met by current habitat management and survey methods, or if any or all of these methods need to be altered (Appendix A).

The case study results indicated a significant correlation between duck use and energy availability in unharvested rice and moist-soil, but not in other cover types. The private lands surrounding the Refuge are largely agricultural (Service 1998, Hamel *et al.* 2001, Johnson 2018), and rice is a common crop in Arkansas. However, it is a safe assumption that the surrounding farmlands are regularly harvested. This leaves the Refuge with a unique opportunity to provide flooded, unharvested rice fields in a greater concentration than surrounding lands, potentially attracting a proportionate concentration of dabbling ducks. Rice decomposes at a slower rate than soybeans, potentially providing winter forage for longer periods over the winter than other crops (Neely 1956, Shearer *et al*. 1969, Nelms and Twedt 1996). Additionally, Kross (2006) recommended partially burning rice stubble patches to maximize heterogeneity (areas of field/stubble and open water), concluding that this method was superior for reducing waste rice than other typical management practices. The Refuge should consider this alternative to disking and rolling, which create more waste rice (lowering availability for waterfowl) than leaving stubble and burning (Kross 2006).

The case study also demonstrated that mallards are utilizing wooded wetlands disproportionately higher than other dabbling duck species, and annual average dabbling duck use is highest in wooded wetlands relative to other cover types. Since this was not statistically attributed to DED value, mallards and other species are likely utilizing these areas for reasons other than or in addition to foraging. The results suggest that wooded wetlands (bottomland hardwood forest and cypress-tupelo brake) are important areas for wintering ducks. The Refuge has another unique opportunity to provide an ecologically important cover type which the surrounding farmlands do not. Under the NAWMP, the Refuge is obligated to restore and protect wetlands and bottomland hardwood forests, which serve as habitat for migratory birds, wintering waterfowl, wildlife and other biota (Johnson 2018). Only portions of the Refuge currently sustain bottomland hardwoods (Service 2001). By increasing its acreage of restored bottomland forest, the Refuge would not only be meeting its responsibilities under the NAWMP to provide waterfowl habitat, it will be providing additional buffer to surrounding private lands for flood control (one of the ecosystem services of bottomland forests).

While researching the study site, I noted that the soils on the Refuge were almost all indicative of areas periodically inundated with water (such as floodplains and bottomlands) (NRCS 2021). Native vegetation found on these soils usually consists almost entirely of mixed hardwoods, which corroborates survey data dating back to 1837 (Hamel *et al.* 2001). One recommendation to the Refuge is to sustainably exploit these soils by encouraging endemic plant species and cover types which require little to no management (i.e., seasonal marsh, moist-soil vegetation or afforestation of bottomland hardwood forest). Spatial distribution of the agricultural fields does not appear to be systematic. The nature of the cooperative farming agreements is unknown, but it is recommended that management incorporate the use of GIS with hydrogeomorphic analysis (e.g., Heitmeyer *et al.* 2016) in future planning efforts.

Several limitations from the current survey methods were identified (e.g., daytime, inconsistent dates within the season, and estimations), which may have added variability to the data and undermined reliability in the results. Bioenergetic models must consider other factors which likely affect duck abundance and distribution (Miller *et al*. 2014). The results of a study of bioenergetics based on daytime surveys is difficult to interpret with any certainty, especially since it is known that the three focal species forage nocturnally. While nocturnal waterfowl studies are likely impractical for the Refuge, management should consider adjusting the timing of surveys to more closely coincide with when ducks are actively foraging. A related recommendation based on this case study would be to manage habitat for multiple species, because mallards are not equitably related to other species in all cover types on the refuge. Mallards are prolific and generalist foragers, while other species may be of greater conservation need. Providing multiple cover types is likely to be important for other species and taxa which utilize the Refuge.

Variation in cover type use was observed even between the three focal species, such as green-winged teal relating to other dabbling species in moist-soil vegetation. This suggests that providing a variety of different cover types may serve a greater diversity of species. As an example, although the relationship between DUDs and DEDs was weak in moist-soil vegetation, it was second only to rice in the strength of the correlation. Moist-soil was also the second most used (highest average duck counts) cover type (see Figure 6), which suggests that it is an important habitat for dabbling ducks. Complimenting rice fields with moist-soil vegetation may provide a greater diversity of natural plant and animal foods (Reinecke *et al.* 1989), while helping to mitigate the loss of waste rice and other crops on the Refuge which typically decompose over the winter (Penny 2003, Stafford *et al*. 2006, Kaminski *et al.* 2005, Kross 2006).

Water depth is a limiting factor to energy availability (Poysa 1983), and current survey methods estimate percent flooded but may not include sufficient bathymetric and depth data in the flooded parcels to truly gauge its suitability for dabbling ducks. Hagy and Kaminski (2015) suggested an optimal water depth for dabbling ducks is less than 50 cm (19.7 in), but Refuge managers noted in the Structured Decision-Making document (Appendix A) that water depth of 61 cm (2 ft) was the plan. Species' preferences for water depth may vary. For example, green-winged teal may prefer shallower water depths than northern pintails (Euliss and Harris 1987). It is recommended that Refuge management add water depth measurement to its duck survey data collection protocol, and limit water depth to under 50 cm (19.7 in). Any changes implemented should be monitored for effectiveness in achieving Refuge objectives.

Based on the limitations addressed in the discussion section, another recommendation to the Refuge is to adopt the habitat survey protocol of the USFWS' Inventory and Management (I&M) under the IWMM (2020), specifically as it pertains to vegetation surveys. The level of study (plant inventory, seed head density, percent cover) is practiced at numerous other refuges in the region, and implementing this methodology would prepare the Refuge for new waterfowl management strategies if implemented on a regional or nationwide scale.

**CONCLUSION**

In the case study, I addressed the question: Is diurnal cover type use by dabbling ducks at the Refuge related to duck energy days? If such a relationship exists, the management implications would be that strategically increasing or redistributing dabbling ducks would be possible through the provision of certain cover types based on DEDs. I analyzed data to assess whether dabbling ducks on the Refuge are using certain cover types based on the energetic value.

The results of the analyses suggest that a relationship is supported between duck use and energy availability in unharvested rice and moist-soil on the Refuge, but energy is not a strong predictor of duck use in other cover types on the Refuge. Eliminating several of the limitations of this case study may improve the reliability of the results. Based on this case study, as a stand-alone tool, duck use is not a useful measure of energy availability on the Refuge. However, incorporating other variables that affect duck abundance and distribution into a study, and conducting nighttime surveys (or using GPS trackers) may support a different conclusion. Similarly, differences between species should be considered for future studies, as not all dabbling ducks are related in their use of the various cover types.

Habitat modeling for waterfowl continues to develop, evidenced by the multi-national participation in the IWMM program seeks to inform knowledge gaps for the non-breeding period to optimize the entire life cycle of dabbling ducks and other birds. The multi-scale, adaptive framework for data collection and tools of this program will help to guide decision-makers in waterfowl management in the future.

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## Appendix A

(*circa 2010*)
Structured Decision Making Process for Waterfowl and Waterfowl Habitat Management Assessment and Best Management Practices for Waterfowl Habitat Management on Bald Knob National Wildlife Refuge:
*"What is the best thing we can put out there at the refuge to manage wildlife use and manage for their needs?"*

Keywords: MONITOR, ASSESS, PLAN, ADAPT, FEASIBILITY, COST, BENEFITS, ALTERNATIVES, COVARIANTS, WATERFOWL, WATERFOWL HABITAT, STRUCTURED DECISION MAKING, FUNDAMENTAL and MEAN OBJECTIVES

Decision Maker – Bill Alexander (Refuge Manager), with assistance from Richard Crossett (Central AR NWR Complex Wildlife Biologist, with assistance, will conduct SDM protocol, compile data and present info).

Trigger – Waterfowl and waterfowl habitat survey analysis (in progress, "*Waterfowl Habitat Use Database Central AR Complex.mdb"*), benefits and assessment at Complex scale.

Problem Statement – Decision to be made is to determine whether to:

1) Continue the current (status quo) habitat mgmt. and survey methods, whether or not assessments determine if objectives are met, or
2) Adapt current habitat mgmt. and survey methods, as determined by assessment, to meet stated objectives. (seasonal & annual mgmt. activities).

Objectives –
Fundamental Objectives (NAWMP, LMVJV & CCP):

1) *Contribute healthy ducks to the spring breeding population* by providing sufficient winter habitat to ensure adequate winter survival sufficient to meet the habitat and population goals of the NAWMP as stepped-down through the LMVJV to Bald Knob NWR.
2) Increase or maintain the number of healthy breeding ducks.

Mean Objectives (LMVJV & CCP): Habitat and Population Goals

1) Annually provide specific *foraging habitat* (objectives), in the form of DEDs in impounded wetlands
   a) Provide 19 million DEDs.
      Alternatives
      1. Status Quo – Annually plan and grow habitat without knowing whether or not DEDs objectives will be met (No Plan Option).
      2. Consider DEDs objectives when planning and before growing habitat then strive to meet objectives if resources are available (Plan Option).
      3. If current resources limitations make DEDs objectives unattainable strive to obtain resources to reach objectives (Increase DEDs Option).
      4. If DEDs objectives are significantly above goal, reduce habitat (Decrease DEDs Option).
   b) Provide 750 – 1,000 acres of un-harvested crop.
      Alternatives
      1. Status Quo – Annually plan and grow habitat without knowing whether or not DEDs objectives will be met (No Plan Option).
      2. Consider DEDs objectives when planning and before growing habitat then strive to meet objectives if resources are available.

3. If current resources limitations make DEDs objectives unattainable strive to obtain resources to reach objectives.
4. If DEDs objectives are significantly above goal, reduce habitat.

c) Provide 570 acres of harvested crop.
Alternatives
1. Status Quo – Annually plan and grow habitat without knowing whether or not DEDs objectives will be met (No Plan Option).
2. Consider DEDs objectives when planning and before growing habitat then strive to meet objectives if resources are available.
3. If current resources limitations make DEDs objectives unattainable strive to obtain resources to reach objectives.
4. If DEDs objectives are significantly above goal, reduce habitat.

d) Provide $\geq$ 1 million DEDs of moist-soil habitat.
Alternatives
1. Status Quo – Annually plan and grow habitat without knowing whether or not DEDs objectives will be met. (No Plan Option)
2. Consider DEDs objectives when planning and before growing habitat then strive to meet objectives if resources are available.
3. If current resources limitations make DEDs objectives unattainable strive to obtain resources to reach objectives.
4. If current resources limitations make DEDs objectives unattainable reduce the amount convert crop acres to moist-soil acres to obtain objectives.
5. If DED's objectives are significantly above goal, reduce habitat.

e) Provide 500-650 acres of moist-soil habitat that averages $\geq$ 500 lbs./ac. of seed or > 50% coverage of moist-soil plants.
Alternatives
1. Status Quo – Annually plan and grow habitat without knowing whether or not acres, lbs./ac. or coverage objectives are or will be met. (No Plan Option)
2. Consider objectives when planning and before growing habitat then strive to meet objectives if resources are available. Use moist-soil seed sampling and BMP's to make sure lbs./ac. or coverage objectives are met.
3. If current resources limitations make objectives unattainable strive to obtain resources to reach objectives.
4. If current resources limitations make objectives unattainable reduce the amount convert crop acres to moist-soil acres to obtain objectives.
5. If objectives are significantly above goal, reduce habitat.

f) Provide 800 acres of bottomland hardwood forest habitat.
Alternatives
1. Status Quo – Provide (flood) the same amount of bottomland hardwood forest habitat without knowing whether or not objectives is being met. (No Plan Option)
2. Determine if objectives are met then; if not then strive to meet objectives if resources are available. Numerous fields on the Refuge have been reforested and should mature soon enough to provide bottomland hardwood forest habitat.

2) Annually provide managed *thermal, escape and pair bonding habitats* in the form of shrub swamps, afforested fields and bottomland forests.

   Alternatives

   1. Status Quo – Continue to provide managed thermal, escape and pair bonding habitats.
   2. Determine if current habitat types, locations and acreage are sufficient to meet the life cycle needs of the different waterfowl species (uncertainty) then adjust management as needed to meet the needs.

3) Annually provide *water* to flood the previously mentioned habitats so that they are available to waterfowl to meet their life cycle needs.

   a) Annually provide 100-200 acres of early water by September 1 for early migrating waterfowl and shorebirds.

      *Alternatives*

      1. Status Quo – Continue to provide 100-200 acres of early water by September 1 while documenting acres of habitat and bird use.
      2. Stop proving early water
      3. Continue to provide at least 100-200 acres of water and food for shorebirds and early migrating waterfowl, primarily pintails and blue-winged teal, from September 1 to November 1 while quantifying habitat and bird use to assist in determining if the Refuge is providing the amount and quality of habitat to meet the life cycle needs of these early migrants. Adapt habitat management as necessary.

   b) Annually provide 3,125 – 5,050 acres of flooded habitat of all types from November-1 to Feburary-28.

      *Alternatives*

      1. Status Quo – Continue to provide annual flooded habitat using current protocol while monitoring acres of habitat and bird use.
      2. Monitor, Assess & Adapt – Continue to provide flooded habitat from November 1 to February – 28 while charting and assess the amount and type of flooded habitat, as well as bird use, throughout the season to help determine if the Refuge is providing the amount and quality of habitat needed to meet the life cycle needs of waterfowl, with an emphasis on pintails and mallards. Adapt habitat management as necessary.
      3. Stop pumping habitat to reduce costs or opportunity flood habitat as rain fall allows.

   c) Water depth should be predominantly $\leq$ 2 feet for feeding waterfowl.

      *Alternatives*

      1. Status Quo – Continue flooded habitat without quantitative knowledge of habitat that is $\geq$ 2 feet deep.
      2. Examine the feasibility of accurately estimating water depth and the cost/benefits ratio to waterfowl and adapt as necessary.

   d) Annually decrease water depth from mid-January – mid-April to increase invertebrate production.

      Alternatives

      1. Status Quo – Continue dewatering impoundments in March and April to prepare ground for agriculture. Continue to monitor water levels.
      2. Examine the feasible of dewatering impoundments gradually beginning in mid-January through April, if drainage concerns and manpower allows, for the benefits waterfowl and

adapt as necessary. Assess dewatering through monitoring assessment of water coverage data. Plan timing and amount to benefit primary species.

4) Annually provide critical *sanctuary areas* to waterfowl from November 15 to February 28 to help conserve energy to survive the winter period and conduct activities preparatory to perform other life cycle functions.
   a) Provide a minimum of 7,745 acres of sanctuary from November-15 to Feburary-28. Alternatives
      1. Status Quo – Yes? Acres, time and disturbance amount and degree.
      2. No?
      3. Assess functionality and benefit of no entry after 1:00 PM into waterfowl hunt area.
5) Annually provide species specific habitats in the required amount, type, and timing to meet species critical life cycle needs, specifically:
   a) Pintails
   b) Green-winged Teal, and
   c) Mallard
6) Assess the design, detectability, precision and accuracy of current surveys that are used to determine if the stated objectives are met. Adapt if and when necessary.
7) Determine system dynamics and relationships among the different attributes/habitat use vs availability (waterfowl and habitat) through status monitoring and analysis (with hopes of adaptive management, within and among the years thorough biofeedback).
8) Determine waterfowl and waterfowl habitat trends (CCP)
9) Enable adaptive management, as needed, to meet the stated objectives.
   a) Adjust within the year (Seasonal management), look at weekly changes in habitat, water and duck species relationship (determine trigger) and adjust as needed.
   b) Adjust among the years (Yearly management)

Consequences – 1) Time and Money, 2) Data Quality (Accuracy and Precision), etc.

Trade-offs? –

Decision? –

Scale- Impoundment, Hunt or Sanctuary, Refuge, LMV, Flyway

Constraints? -

OTHER:

Estimate *available habitat* (food (grains) + water = available DEDs) for waterfowl at any given time period *or critical life cycle period* (i.e. late summer, early fall, late fall and winter, early spring).

Estimate habitat use and preference by species to determine whether or not:
1) life cycle needs are being met,
2) which habitats are important,
3) adjustments of habitat if needed.

Analyze duck numbers and habitat use on sanctuaries and hunt areas = affectedness of 1:00 pm no entry on hunt area.

Are all crops eaten and how soon? Graph grain availability over time by Refuge & impoundment
Are crops eaten sooner in the sanctuary sooner than hunt area? Compare the two
What is the cost per survey? Create basic stats on survey time.

Amount of flooded area frozen?

What are some general observations on how and when and weather ducks/species use the different habitats? Do they help to inform a decision? and if so, how to analysis?

What is the correlation between habitat DEDs and waterfowl use over time?

Correlation of between water, DEDs and waterfowl use?

Influence of weather on habitat use and estimates?

Graph attributes to check for correlations (e.g. eat outs of certain cover types).

Estimate and calculate habitat production cost for DEDs/DUDs?

Population

a) Trends
b) DEDs/DUDs/ Biological Model TRUEMET = how much food is needed vs waterfowl use?
c) Are population objectives being met?
d) Distribution of the species across the flyway over time?

**Acronyms:**

| | |
|---|---|
| **BMPs** | Best Management Practices |
| **CCP** | Comprehensive Conservation Plan |
| **DED** | Duck Energy Day |
| **DUD** | Duck Use Day |
| **LMVJV** | Lower Mississippi Valley Joint Venture |
| **NAWMP** | North American Waterfowl Management Plan |
| **NWR** | National Wildlife Refuge |
| **SDM** | Structured Decision Making |

# Appendix B

List of all duck survey dates at Bald Knob NWR from 2006-07 to 2019-20

| Year | Survey No. | Date | Month |
|---|---|---|---|
| 2006 | 1 | 11/08/06 | NOV |
| | 2 | 11/29/06 | NOV |
| | 3 | 12/11/06 | DEC |
| | 4 | 01/05/07 | JAN |
| | 5 | 01/23/07 | JAN |
| | 6 | 02/14/07 | FEB |
| | 7 | 03/06/07 | MAR |
| 2007 | 1 | 11/14/07 | NOV |
| | 2 | 11/28/07 | NOV |
| | 3 | 12/12/07 | DEC |
| | 4 | 01/09/08 | JAN |
| | 5 | 01/22/08 | JAN |
| | 6 | 02/07/08 | FEB |
| | 7 | 02/27/08 | FEB |
| | 8 | 03/12/08 | MAR |
| 2008 | 1 | 11/10/08 | NOV |
| | 2 | 11/19/08 | NOV |
| | 3 | 11/25/08 | NOV |
| | 4 | 12/04/08 | DEC |
| | 5 | 12/18/08 | DEC |
| | 6 | 01/07/09 | JAN |
| | 7 | 01/20/09 | JAN |
| | 8 | 01/29/09 | JAN |
| | 9 | 02/12/09 | FEB |
| | 10 | 03/03/09 | MAR |
| 2009 | 1 | 11/17/09 | NOV |
| | 2 | 11/24/09 | NOV |
| | 3 | 12/04/09 | DEC |
| | 4 | 12/09/09 | DEC |
| | 5 | 12/23/09 | DEC |
| | 6 | 01/20/10 | JAN |
| | 7 | 02/11/10 | FEB |
| | 8 | 02/24/10 | FEB |
| 2010 | 1 | 11/14/10 | NOV |
| | 2 | 12/01/10 | DEC |
| | 3 | 12/15/10 | DEC |
| | 4 | 12/29/10 | DEC |
| | 5 | 01/07/11 | JAN |
| | 6 | 01/19/11 | JAN |
| | 7 | 02/02/11 | FEB |
| | 8 | 02/17/11 | FEB |
| 2011 | 1 | 11/16/11 | NOV |
| | 2 | 11/29/11 | NOV |
| | 3 | 12/07/11 | DEC |
| | 4 | 12/14/11 | DEC |
| | 5 | 01/03/12 | JAN |
| | 6 | 01/19/12 | JAN |
| | 7 | 02/10/12 | FEB |
| | 8 | 03/06/12 | MAR |
| 2012 | 1 | 11/14/12 | NOV |
| | 2 | 11/20/12 | NOV |
| | 3 | 12/04/12 | DEC |
| | 4 | 12/18/12 | DEC |
| | 5 | 01/10/13 | JAN |
| | 6 | 01/24/13 | FEB |
| | 7 | 02/14/13 | FEB |
| | 8 | 03/04/13 | MAR |

| Year | Survey No. | Date | Month |
|---|---|---|---|
| 2013 | 1 | 11/14/13 | NOV |
| | 2 | 11/25/13 | NOV |
| | 3 | 12/12/13 | DEC |
| | 4 | 01/10/14 | JAN |
| | 5 | 02/10/14 | FEB |
| | 6 | 02/27/14 | FEB |
| | 7 | 03/12/14 | MAR |
| 2014 | 1 | 11/20/14 | NOV |
| | 2 | 12/10/14 | DEC |
| | 3 | 01/06/15 | JAN |
| | 4 | 01/22/15 | JAN |
| | 5 | 02/10/15 | FEB |
| | 6 | 03/30/15 | MAR |
| 2015 | 1 | 11/13/15 | NOV |
| | 2 | 11/23/15 | NOV |
| | 3 | 12/07/15 | DEC |
| | 4 | 12/29/15 | DEC |
| | 5 | 01/07/16 | JAN |
| | 6 | 01/20/16 | JAN |
| | 7 | 02/09/16 | FEB |
| | 8 | 02/29/16 | FEB |
| 2016 | 1 | 11/09/16 | NOV |
| | 2 | 11/30/16 | NOV |
| | 3 | 12/20/16 | DEC |
| | 4 | 12/29/16 | DEC |
| | 5 | 01/03/17 | JAN |
| | 6 | 01/18/17 | JAN |
| | 7 | 02/16/17 | FEB |
| | 8 | 03/15/17 | MAR |
| 2017 | 1 | 11/13/17 | NOV |
| | 2 | 11/30/17 | NOV |
| | 3 | 12/19/17 | DEC |
| | 4 | 01/05/18 | JAN |
| | 5 | 01/29/18 | JAN |
| | 6 | 02/14/18 | FEB |
| | 7 | 02/26/18 | FEB |
| | 8 | 03/21/18 | MAR |
| 2018 | 1 | 11/06/18 | NOV |
| | 2 | 11/27/18 | NOV |
| | 3 | 12/13/18 | DEC |
| | 4 | 01/28/19 | JAN |
| | 5 | 03/01/19 | MAR |
| 2019 | 1 | 11/07/19 | NOV |
| | 2 | 11/22/19 | NOV |
| | 3 | 12/10/19 | DEC |
| | 4 | 01/09/20 | JAN |
| | 5 | 01/29/20 | JAN |
| | 6 | 02/11/20 | FEB |
| | 7 | 03/12/20 | MAR |

# Appendix C

Energy matrix used for DED values (IWMM 2020)

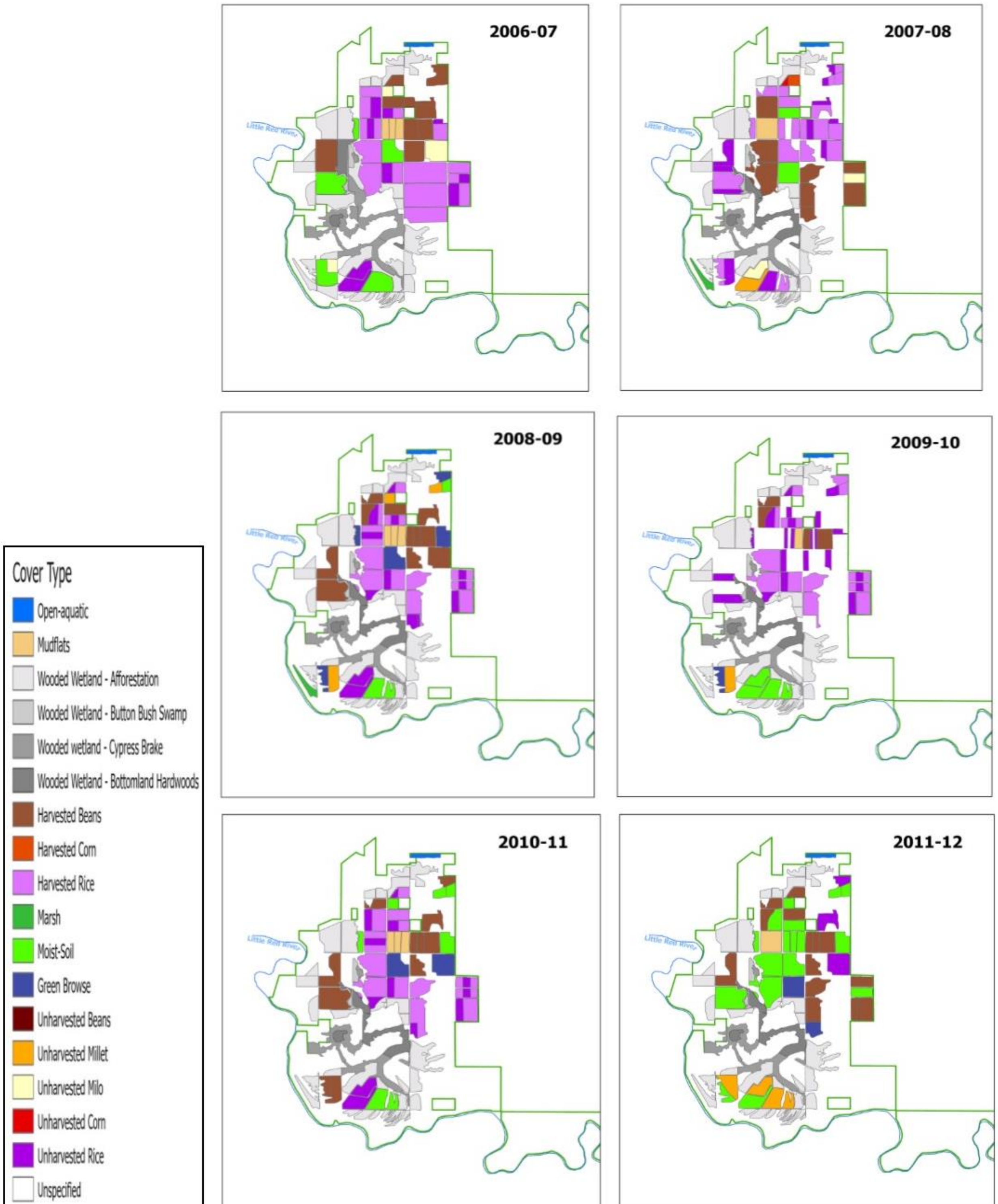
| | | Waterfowl Energetic Quality | | | |
|---|---|---|---|---|---|
| Wetland Habitat Resource Type | Definition | High | Moderate | Low | References |
| Semi-permanent Wooded Wetlands | Wooded (e.g., swamp forest, scrub-shrub) wetlands where water will be present during most of the non-breeding season for waterfowl and for at least 60 days during the growing season, such as cypress-tupelo brakes, narrow bayous, and other swamps with <10% oak component and covered by ≥30% woody vegetation (>2 m in height) | Structurally diverse with high plant diversity and relatively natural hydrology; **300 WED/ac.** | Structurally diverse with moderate plant diversity with altered hydrology; **200 WED/ac.** | Low plant & structural diversity unnatural hydrology; **100 WED/ac** | Energy matrix used to inform ranges and moderate values. |
| Seasonal Wooded Wetlands | Wooded floodplain forests where water will be present at some point during the non-breeding season for waterfowl, but typically not for more than 90 days and typically not for >60 days during the growing season (e.g., bottomland hardwood forest with an oak component >10%); area covered by ≥30% woody vegetation (>2 m in height) | Oak composition >40%, flooding from natural water sources; **300 WED/ac** | Oak composition 20-30%, flooding from natural water sources; **200 WED/ac** | Oak composition <20%, flooding primarily using pumped ground/well water; **100 WED/ac** | Energy matrix used to inform ranges and moderate values. Straub 2012, Foth 2011, Gray et al. 2013 |
| Freshwater Non-persistent Emergent Marsh | Areas of primarily nonpersistent emergent vegetation (e.g., *Cyperus* sp., *Echinochloa* sp., *Panicum* sp.), such as managed moist-soil wetlands, with <30% woody vegetation, bare ground, or open water during the growing season | Excellent seed production (>1,000 lb/ac); primarily seed-producing annual vegetation with >75% grasses (e.g., *Echinocloa* spp., *Leptochloa* spp.) or redroot flatsedge; large seeds heads with dense coverage and SPI >45; **2,500 WED/ac** | Average seed production (500-1000 lb/ac); mix of seed-producing annual vegetation with 25-75% grasses (e.g., *Seteria* sp., *Panicum* sp.) and other annual broadleaf plants (e.g., *Polygonum* sp., *Bidens* sp.); SPI 35-45; **1,800 WED/ac** | Poor seed production (<500 lb/ac); <25% grasses and other annual broadleaf plants (e.g., *Polygonum* sp.); abundant bare ground, sparse vegetation, and coverage of undesirable (e.g., *Sesbania* sp., *Xanthium* sp.), perrenial species (i.e., *P. hydropiperoides*, *Hibiscus* sp.), and/or low energy-producing species (e.g., *Sagitarria* sp., *Echinodorus* sp.); SPI <35; **1,000 WED/ac** | Energy matrix used to inform ranges and moderate values. Hagy & Kaminski 2012, Stafford et al. 2011, Bowyer et al. 2005, Kross et al. 2006, |
| Freshwater Persistent Emergent Marsh | Areas of primarily persistent emergent vegetation (e.g., *Typha* sp., *Zizaniopsis* sp., *Phragmites* sp.), such as semi-permanent emergent marshes, with <30% woody vegetation, bare ground, or open water during the growing season | Areas of perennial emergent vegetation that produces seeds (e.g., Zizania sp.) interspersed with shallow open water and submersed aquatice vegetation; 1,000 WED/ac | Areas of perennial emergent vegetation that produces seeds (e.g., Juncas sp., Scirpus sp., Schoenoplectus sp.) interspersed with shallow open water; 700 WED/ac | Areas of dense, perennial emergent vegetation (e.g., Typha sp., Phragmites sp., ??? sp.) in dense stands or with limited open water or flooding; 400 WED/ac | Energy matrix used to inform ranges and moderate values. |

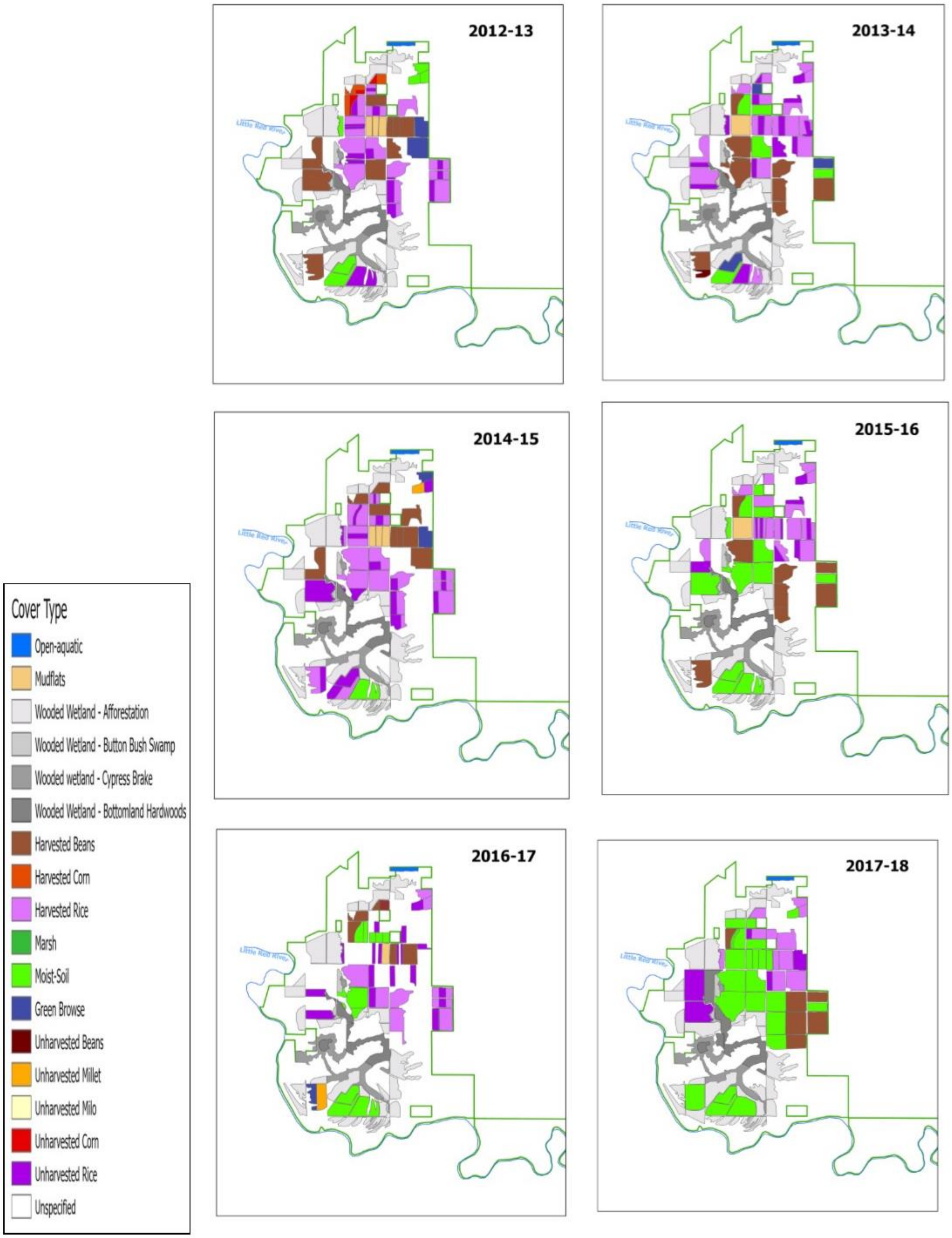
**Appendix C** (continued)

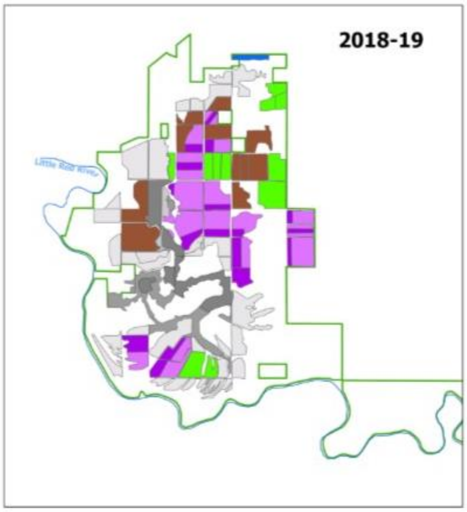
| | | Waterfowl Energetic Quality | | | |
|---|---|---|---|---|---|
| Wetland Habitat Resource Type | Definition | High | Moderate | Low | References |
| Mudflat | Mainly unvegetated areas (<30% vegetation) that can be wet or dry mud, bare ground, or beach. | High levels of organic material; **200 WED/ac** | Moderate levels of organic material; **100 WED/ac** | Low levels of organic material (sand, silt, clay) such as beach; **50 WED/ac** | Energy matrix used to inform ranges and moderate values. |
| Unharvested Rice | Unharvested rice, including ratoon or volunteer rice that may have a reduced yield | Very good yield; ~150 bu/ac; **35,000 WED/ac** | Typical yield on NWRs; ~110 bu/ac; **25,000 WED/ac** | Very poor yield or low planting rates, ratoon and volunteer rice; ~60 bu/ac; **14,000 WED/ac** | Energy matrix used to inform ranges and moderate values. Data from Noxubee, Bald Knob, White River, and Alligator River NWRs recording 50-160 bu/ac; June yield in AR was 120 bu/ac; typical May yield 150-200 bu/ac; |
| Unharvested Grain Sorghum | Unharvested grain sorghum (milo) | ~70 bu/ac; **20,000 WED/ac** | ~50 bu/ac; **15,000 WED/ac** | ~30 bu/ac; **9,000 WED/ac** | Foster et al. 2010. Energy matrix used to inform ranges and moderate values; LA mean is 70 bu/ac; AR is 91 bu/ac; TX is 60 bu/ac |
| Unharvested Corn | Unharvested corn | ~140 bu/ac; **43,000 WED/ac** | Typical yield on public lands from June or July planting; ~105 bu/ac; **33,000 WED/ac** | ~70 bu/ac; **22,000 WED/ac** | Foster et al. 2010. Energy matrix used to inform ranges and moderate values. Data from Tennessee and West TN NWR Complexes recording 60-150 bu/ac |
| Unharvested Soybean | Unharvested soybean or similar bean | ~50 bu/ac; **12,000 WED/ac** | ~40 bu/ac; **9,600 WED/ac** | ~30 bu/ac; **7,000 WED/ac** | Foster et al. 2010. Energy matrix used to inform ranges and moderate values. TN mean is 50 bu/ac, AR mean is 51 bu/ac, US mean is 51 bu/ac |
| Unharvested Millet | Unharvested millet, including Japanese, proso, golden, white, Chiwapa, or other | **8,000 WED/ac** | **5,000 WED/ac** | **2,000 WED/ac** | Energy matrix used to inform ranges and moderate values. |
| Green Browse | Wheat, clover, or other forage planted in uplands where shoots are the primary food available to waterfowl | Lots of growth and consumption to base of plant; **3000 WED/ac** | Moderate growth and consumption primarily above plant base; **1900 WED/ac** | Limit growth or limited consuption of only outermost leaves/blades; **1000 WED/ac** | Limited information; Bradbeer et al. 2012 reported biomass removed by grazing geese |
| Unharvested Other | Unspecified unharvested crop that produces seeds or tubers as the primary food source for waterfowl, such as buckwheat, sunflower, chufa, or other. | **8,000 WED/ac** | **5,000 WED/ac** | **2,000 WED/ac** | Energy matrix used to inform ranges and moderate values. |
| Harvested Crops | Any harvested crop that may be flooded during the non-breeding period and accessible to waterfowl. | Rice or milo or other crops harvested in late fall; **800 WED/ac** | Corn or other grain crops harvested mid-fall; **500 WED/ac** | Soybeans or other crops harvested in early fall; **200 WED/ac** | Energy matrix used to inform ranges and moderate values. |

## Appendix D

Cover types in winter seasons 2006-07 through 2019-20 within managed water impoundments at Bald Knob National Wildlife Refuge, Arkansas, USA.



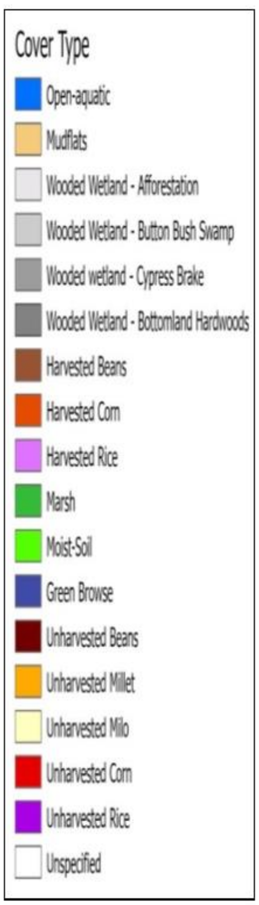

2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
Cover Type
Open-aquatic
Mudflats
Wooded Wetland - Afforestation
Wooded Wetland - Button Bush Swamp
Wooded wetland - Cypress Brake
Wooded Wetland - Bottomland Hardwoods
Harvested Beans
Harvested Corn
Harvested Rice
Marsh
Moist-Soil
Green Browse
Unharvested Beans
Unharvested Millet
Unharvested Milo
Unharvested Corn
Unharvested Rice
Unspecified




**2019-20**

**Map**

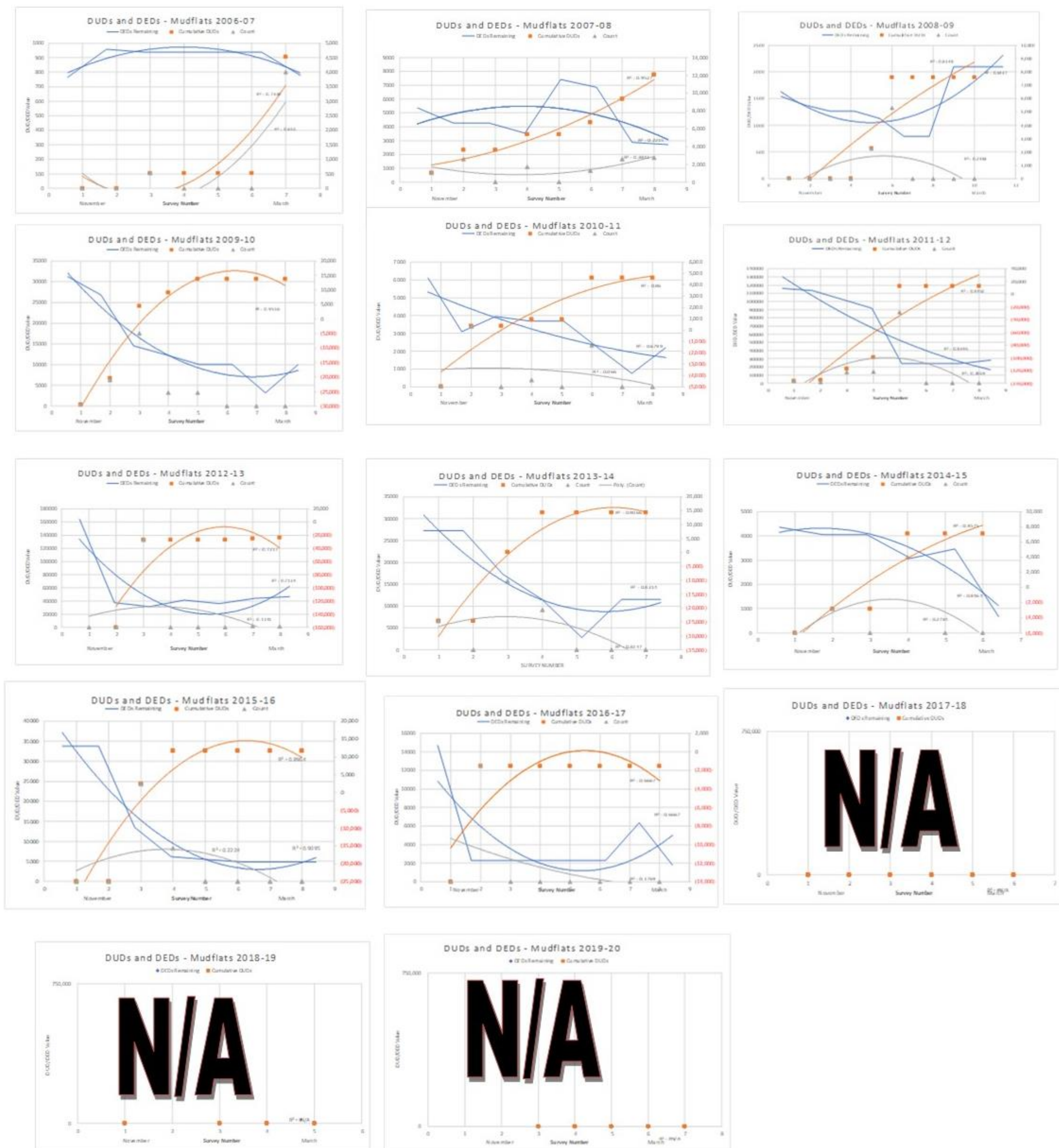
**Not available**



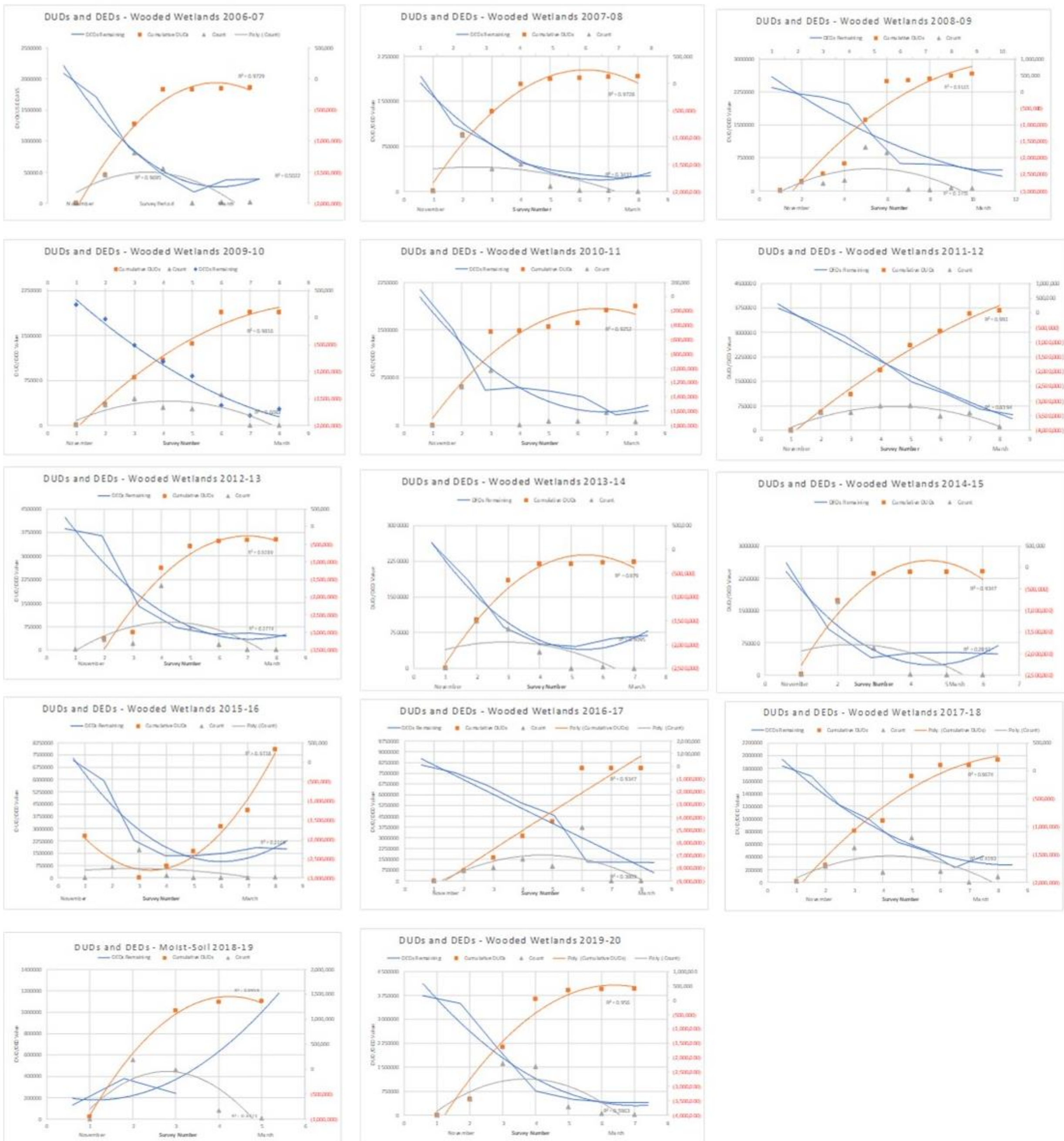
## Appendix E

Charts for DEDs, Cumulative DUDs, and duck counts in each cover type, for all wintering seasons (2006-07 to 2019-20), arranged in ascending order by DED value per acre: Mudflats, Wooded Wetlands, Harvested Crops, Marsh, Moist-soil, Green Browse (Layout), and Harvested Crops (Millet, Soybeans, Milo, and Rice)

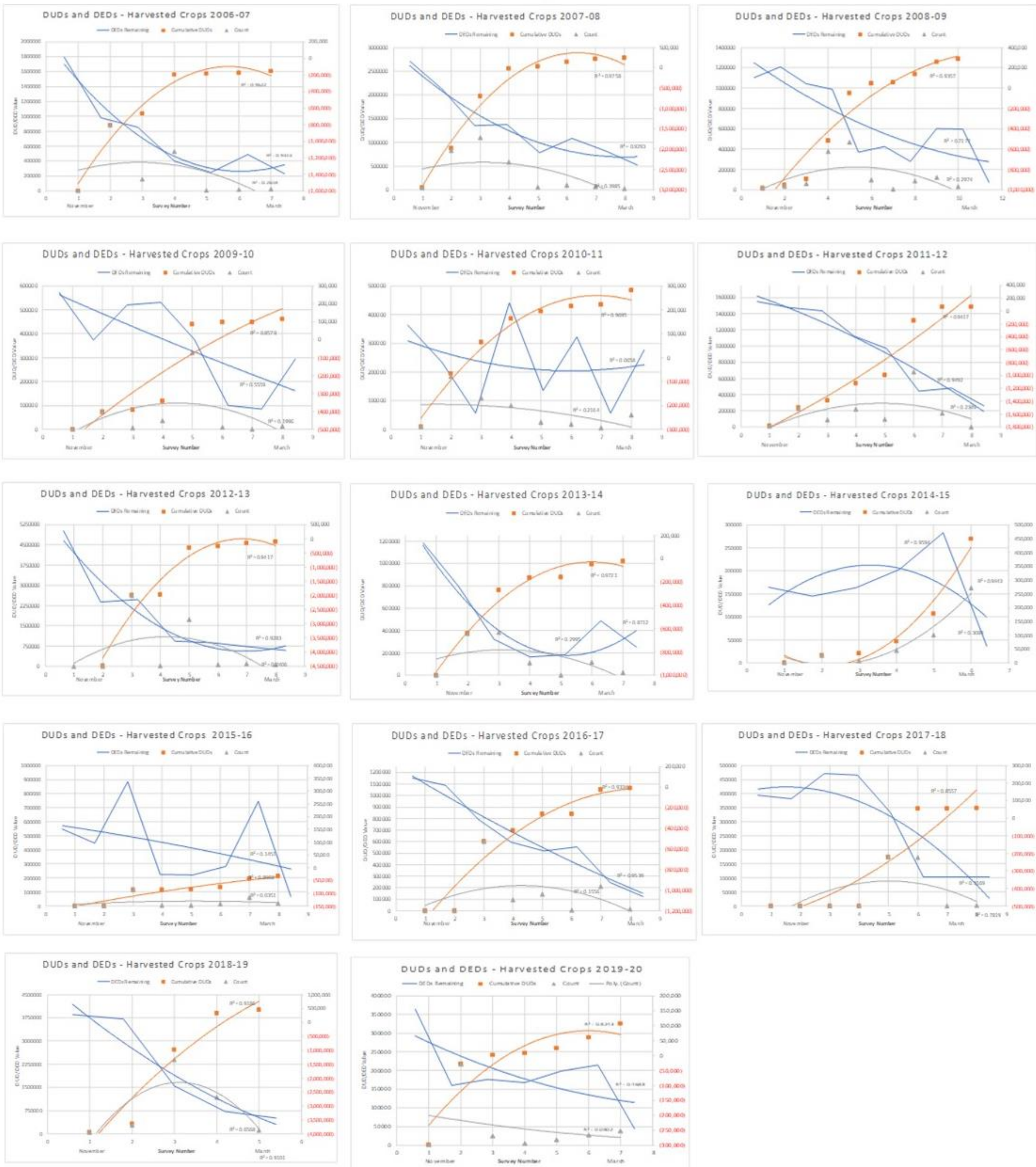
Mudflats—100



Wooded Wetlands—200



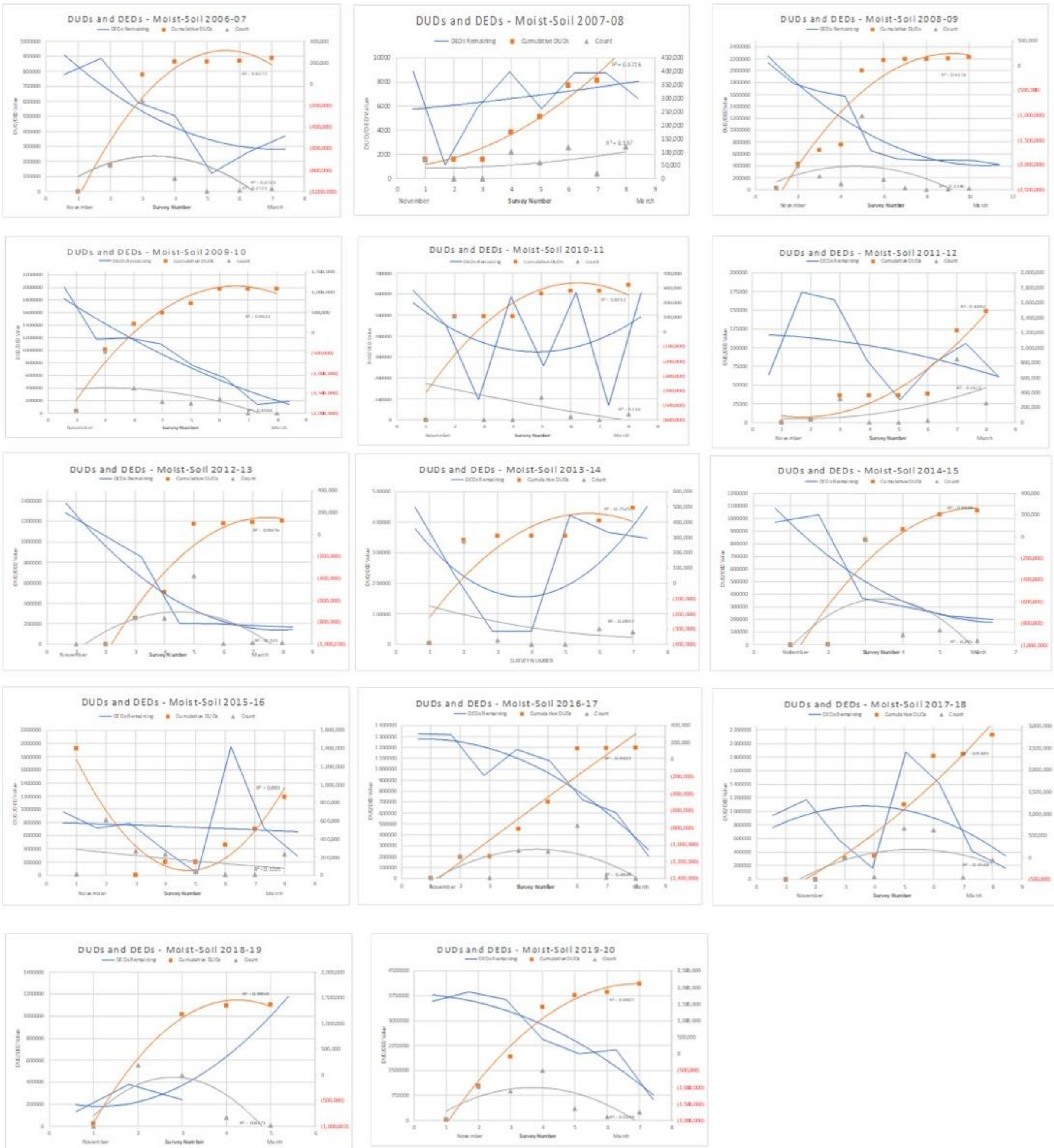
Harvested Crops—500



Marsh—700


DUDs and DEDs - Marsh 2006-07
DUDs and DEDs - Marsh 2007-08
DUDs and DEDs - Marsh 2008-09
DUDs and DEDs - Marsh 2009-10
DUDs and DEDs - Marsh 2010-11
DUDs and DEDs - Marsh 2011-12
DUDs and DEDs - Marsh 2012-13
DUDs and DEDs - Marsh 2013-14
DUDs and DEDs - Marsh 2014-15
DUDs and DEDs - Marsh 2015-16
DUDs and DEDs - Marsh 2016-17
DUDs and DEDs - Marsh 2017-18
DUDs and DEDs - Marsh 2018-19
DUDs and DEDs - Marsh 2019-20

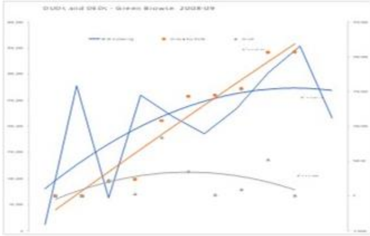
Moist-Soil—1,800

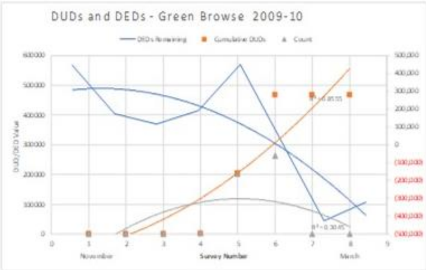


Green Browse—1,900

N/A

N/A

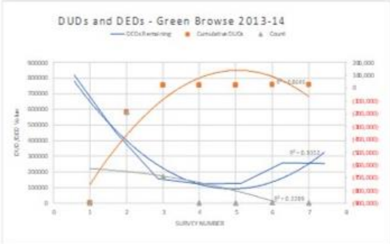





N/A

N/A

N/A




N/A

N/A

N/A

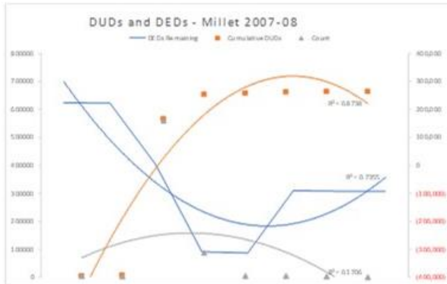
N/A

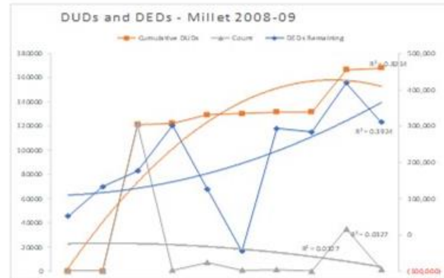
N/A

N/A

Unharvested Millet—5,000

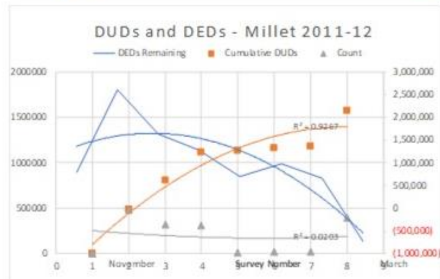
N/A




N/A

N/A




N/A

N/A

N/A

N/A

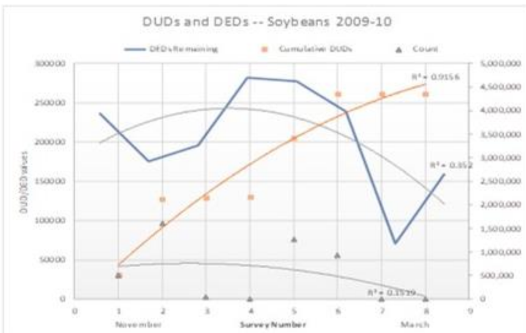
N/A

N/A

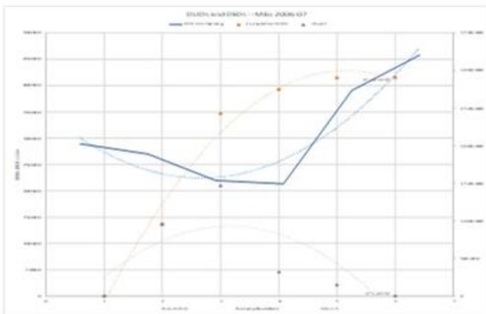
N/A

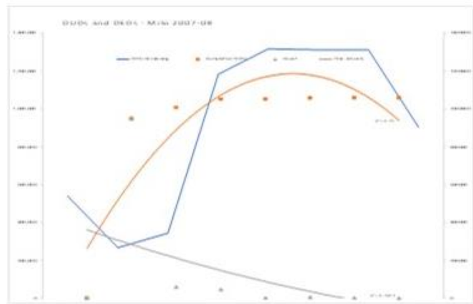
N/A

Unharvested Soybeans - 9,600

| | | |
|---|---|---|
| N/A | N/A | N/A |
|  | N/A | N/A |
| N/A | N/A | N/A |
| N/A | N/A | N/A |
| N/A | N/A | |

Unharvested Milo (Sorghum) - 15,000





N/A

N/A

N/A

N/A

N/A

N/A

N/A

N/A

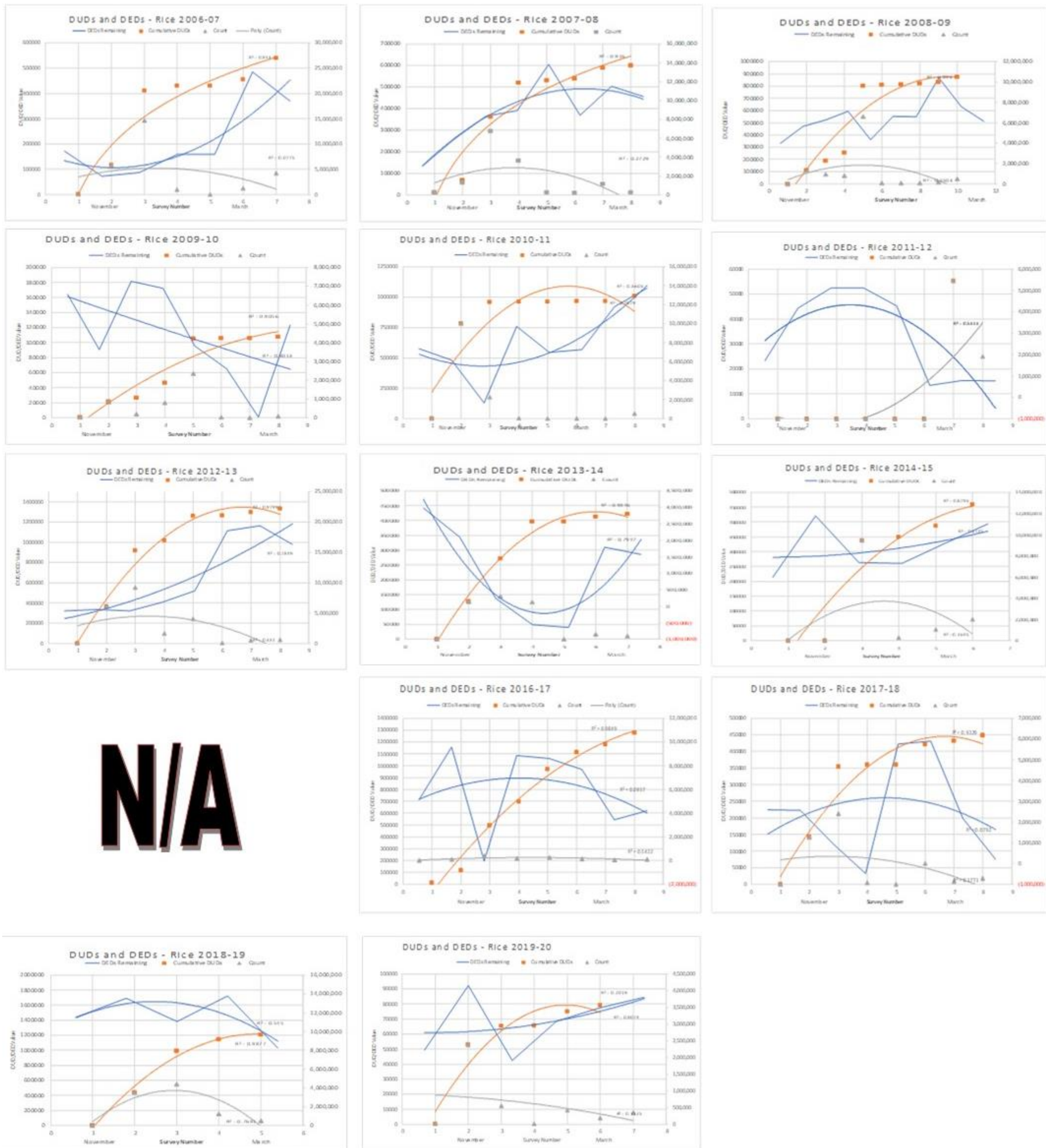
N/A

N/A

N/A

N/A

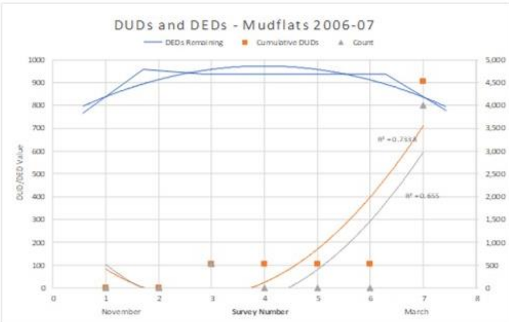
Unharvested Rice—25,000

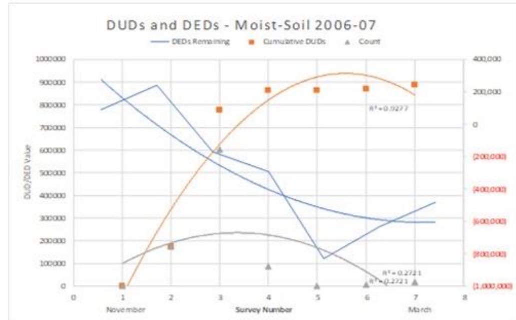


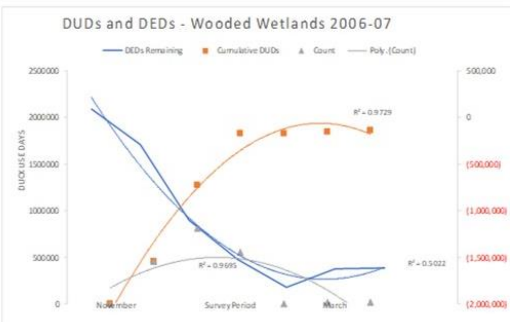
# Appendix F

Charts for DEDs, Cumulative DUDs, and duck counts in each cover type, arranged in ascending order by wintering seasons (2006-07 to 2019-20)

2006-07



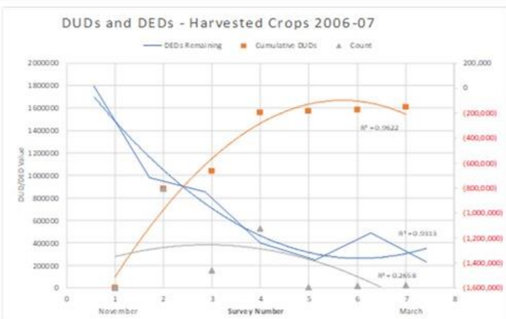



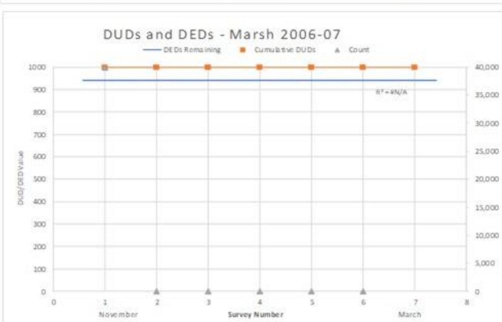



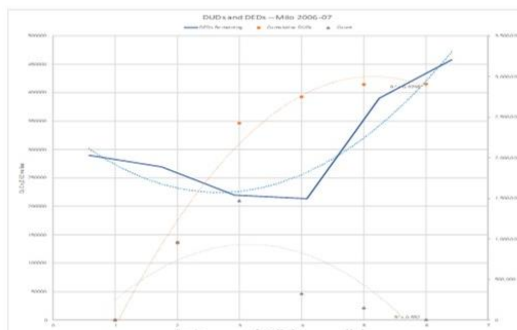

Green Browse—N/A

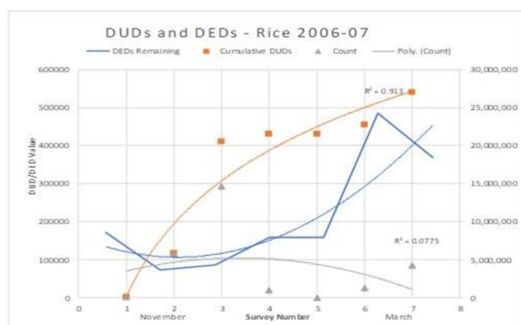
Unharvested Millet—N/A

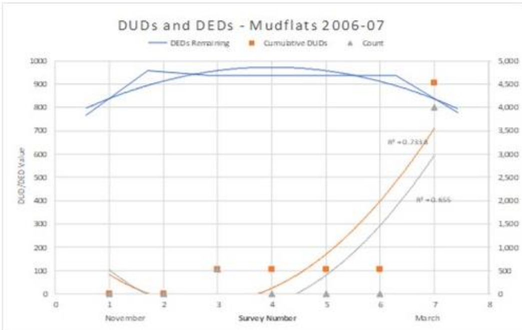
Unharvested Soybean–N/A



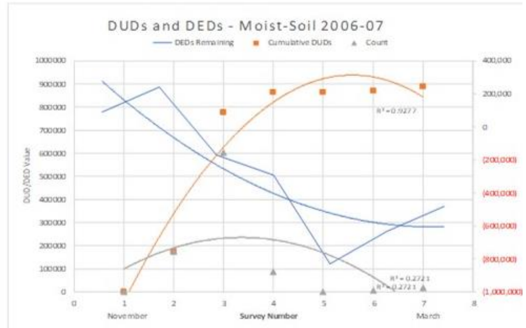



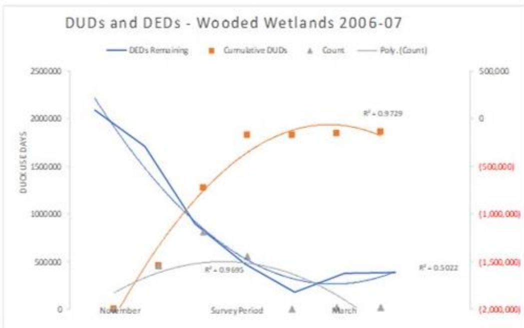








2007-08

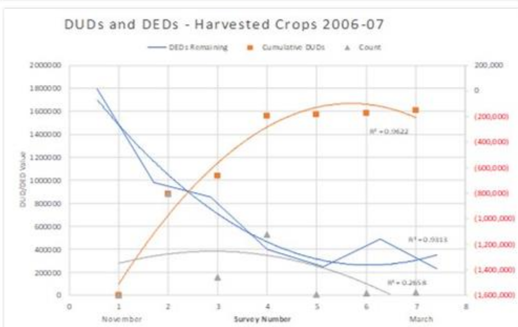


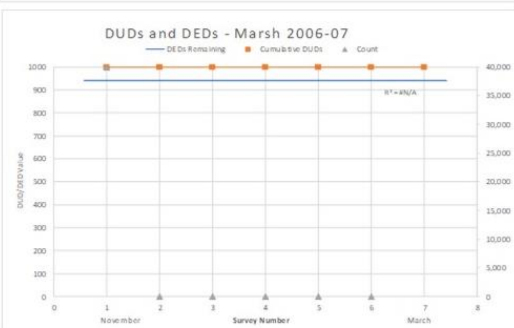



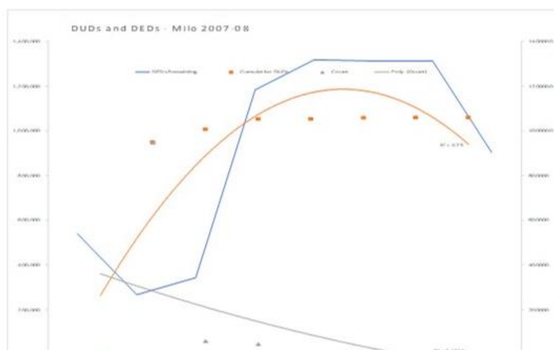

Green Browse—N/A

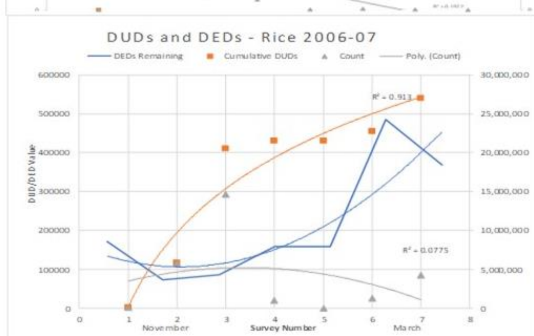
Unharvested Millet—N/A

Unharvested Soybean–N/A

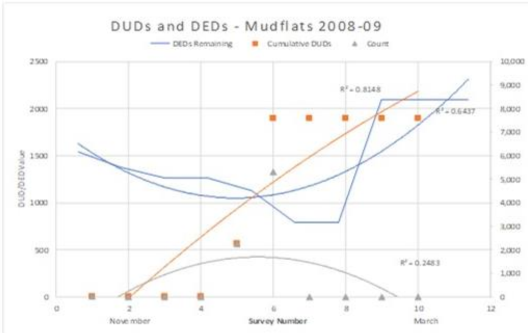


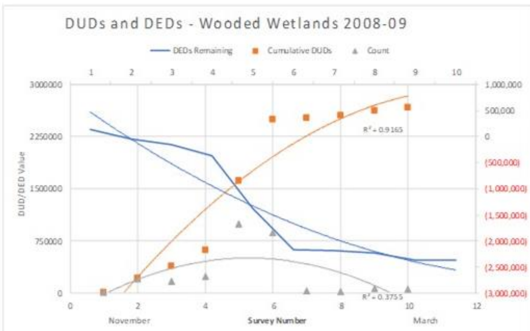



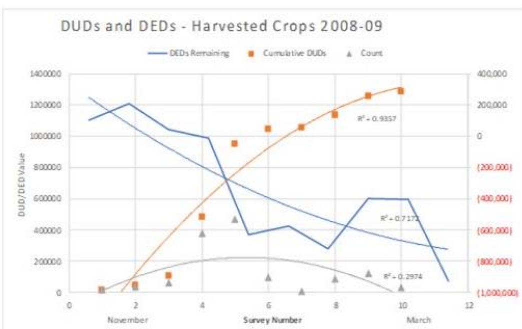





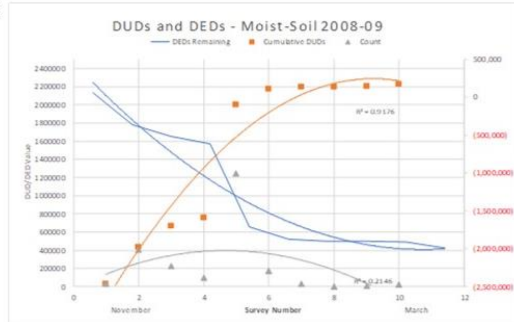
2008-09

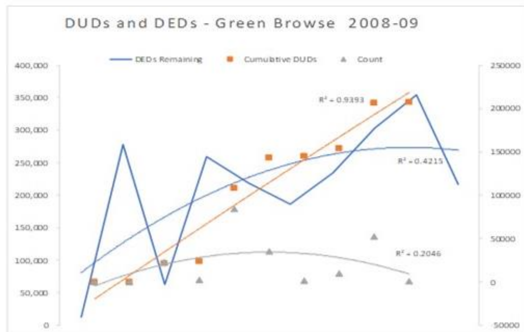


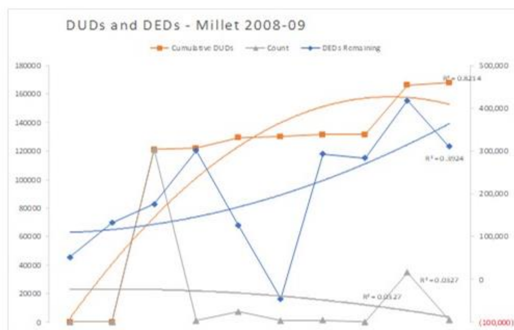



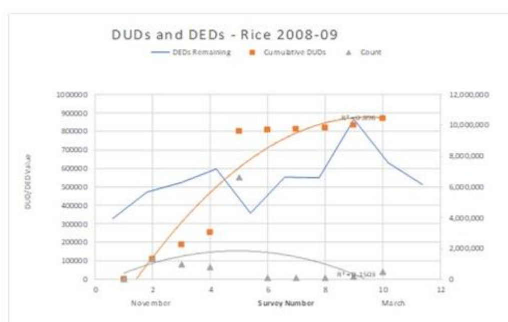




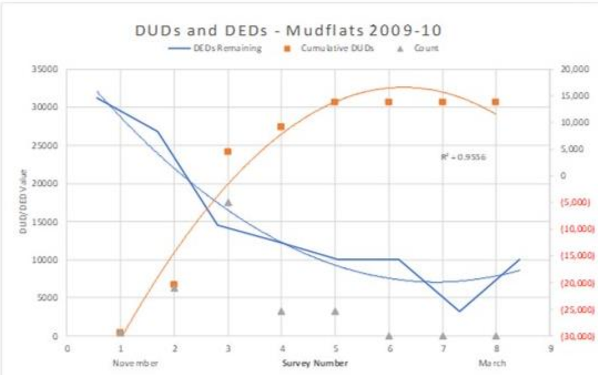



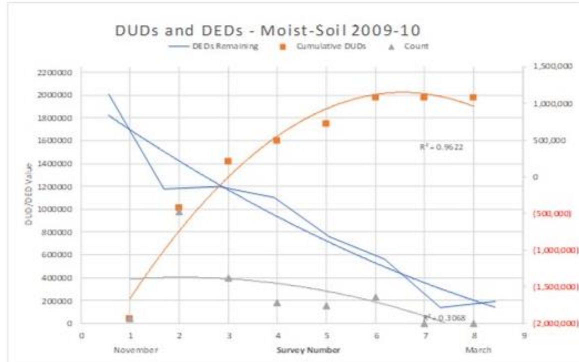



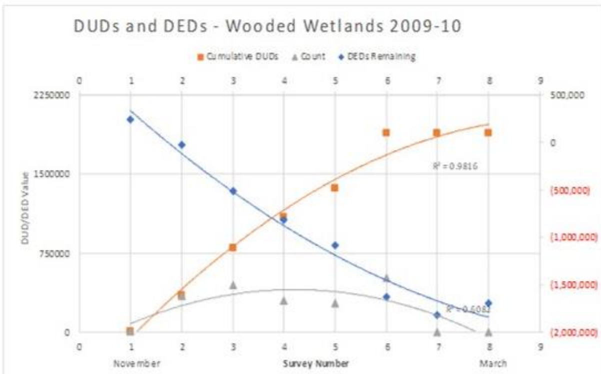

Unharvested Soybean–N/A

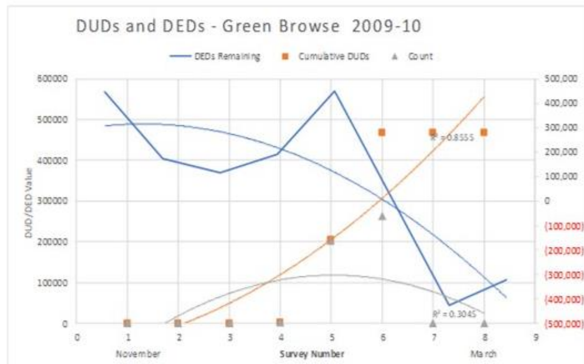


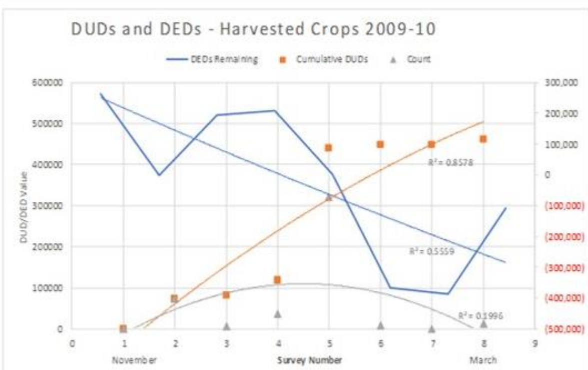
2009-10



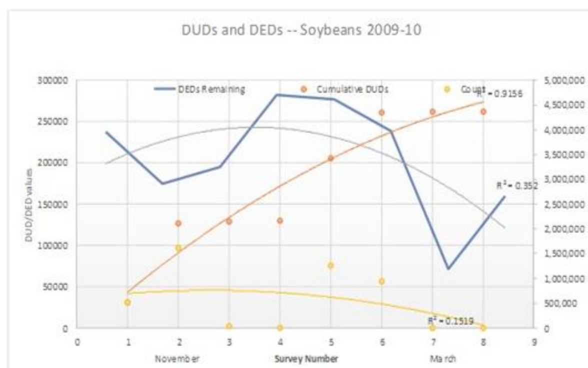



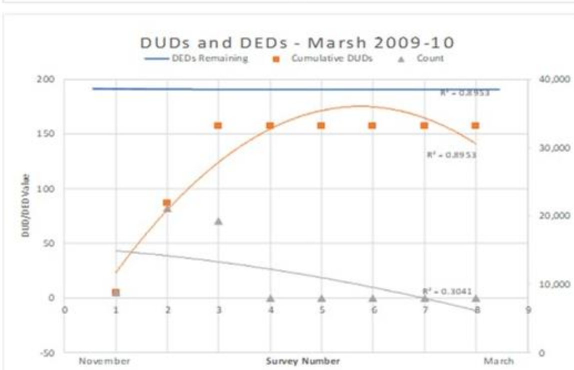



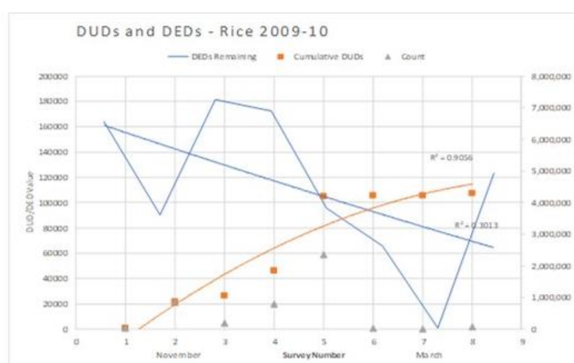



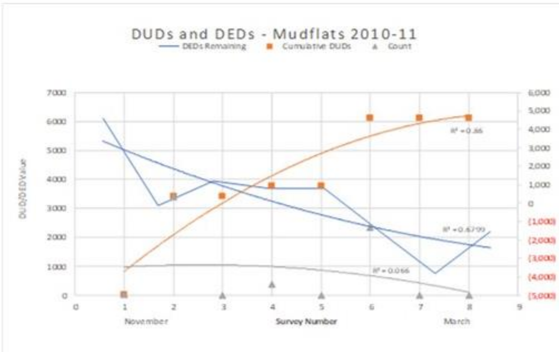

Unharvested Millet–N/A

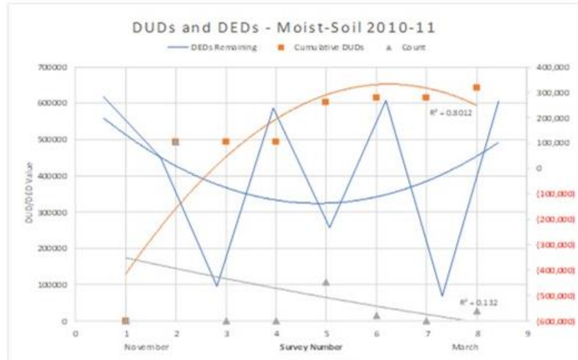


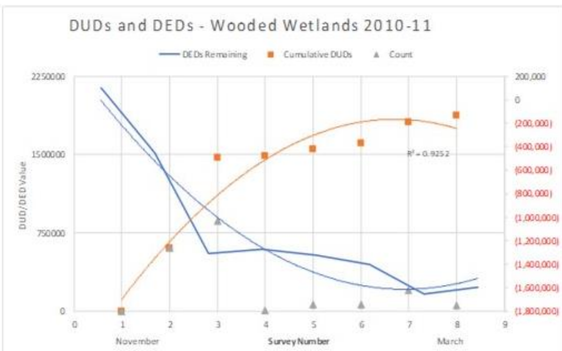



2010-11



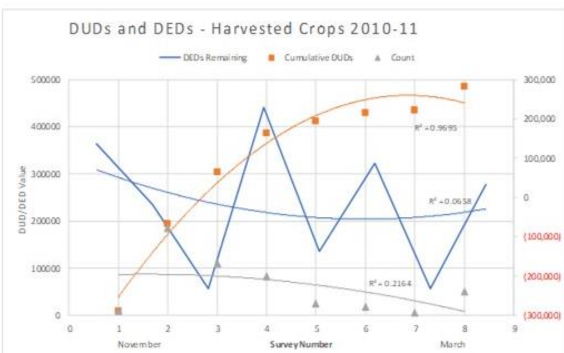



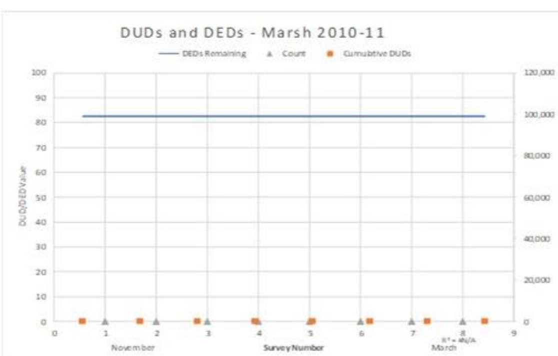

Green Browse—N/A

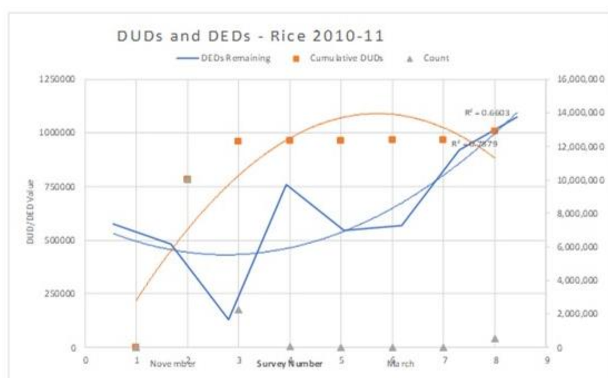
Unharvested Millet—N/A

Unharvested Soybean–N/A

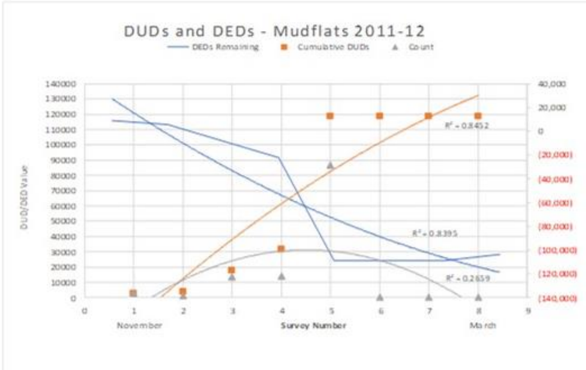
Unharvested Milo–N/A

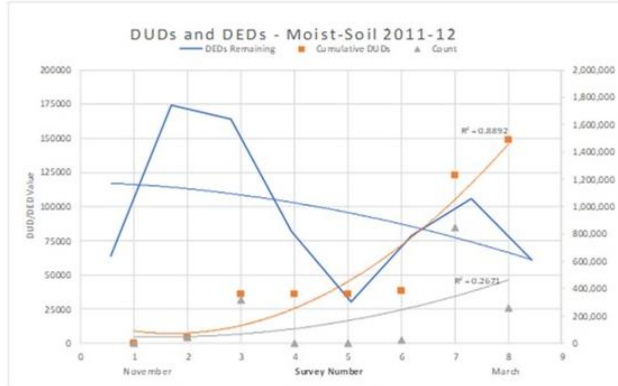


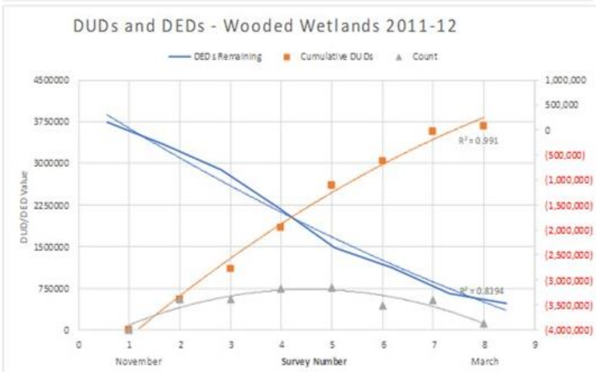



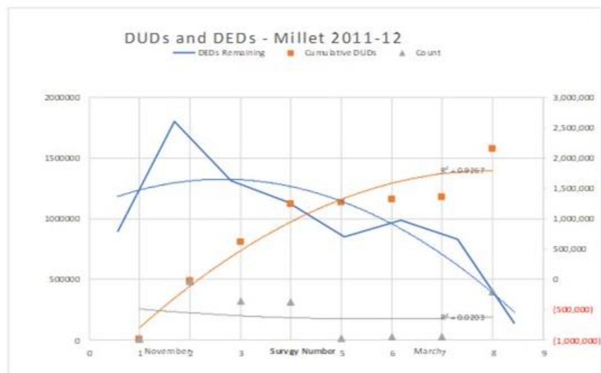
2011-12

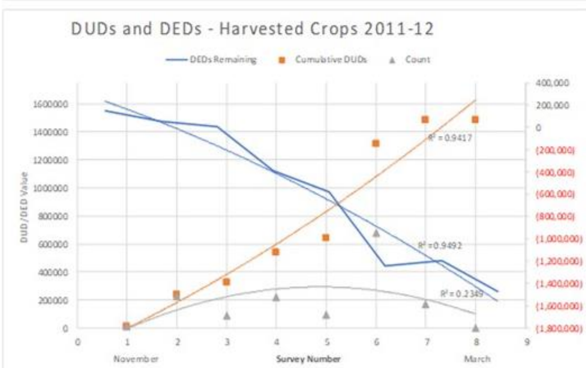


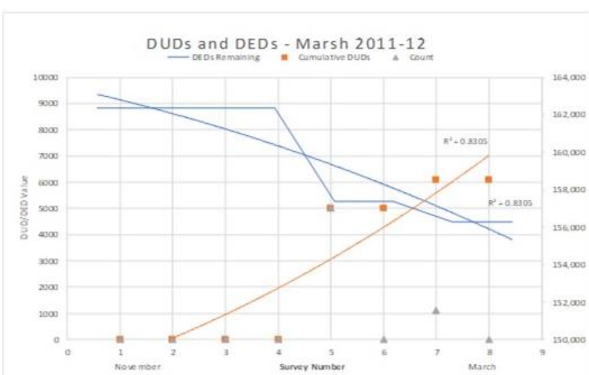

Green Browse—N/A

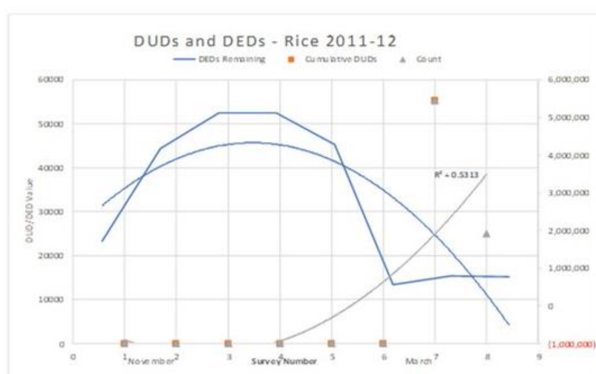


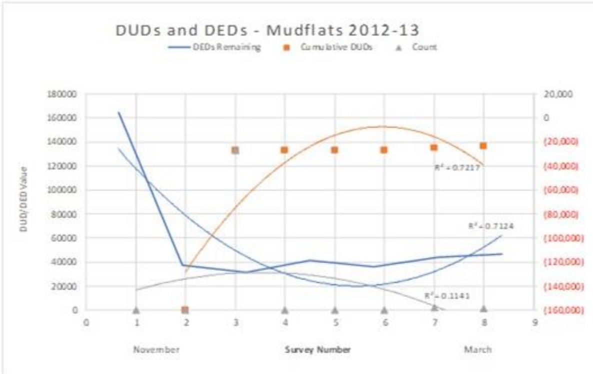

Unharvested Soybean—N/A

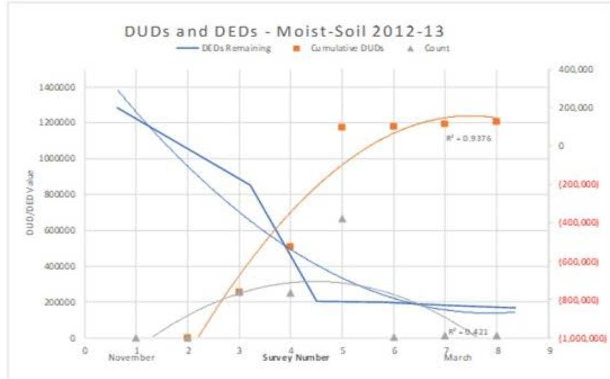
Unharvested Milo-N/A

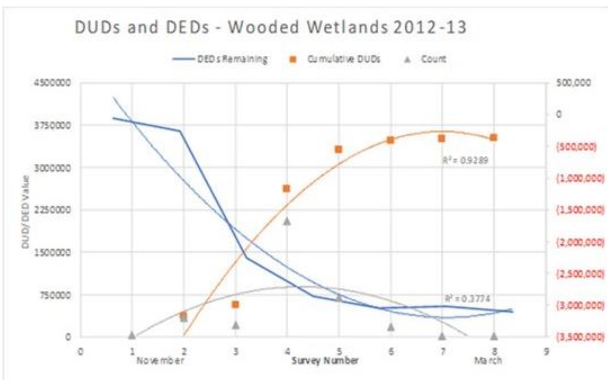


2012-13



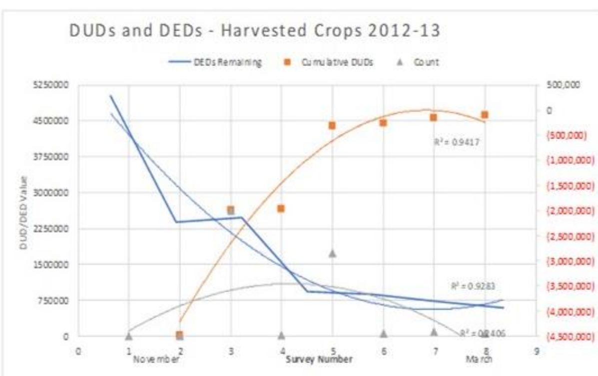



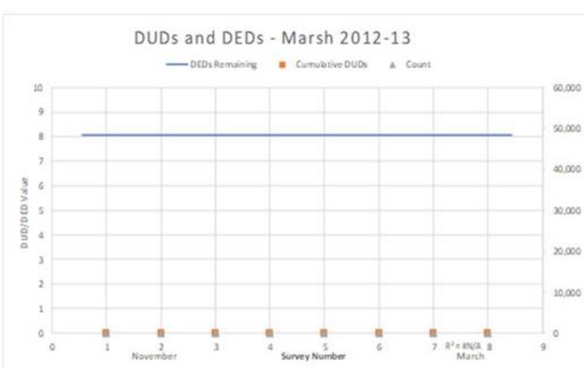

Green Browse—N/A

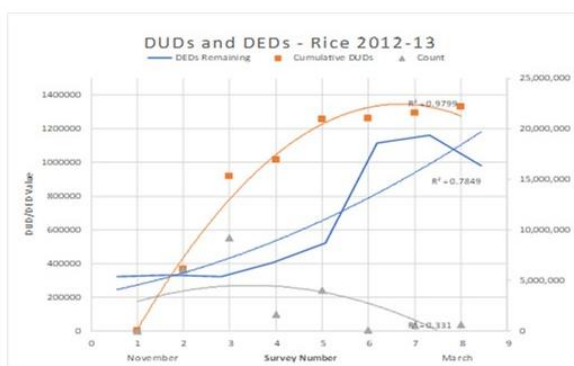
Unharvested Millet—N/A

Unharvested Soybean–N/A

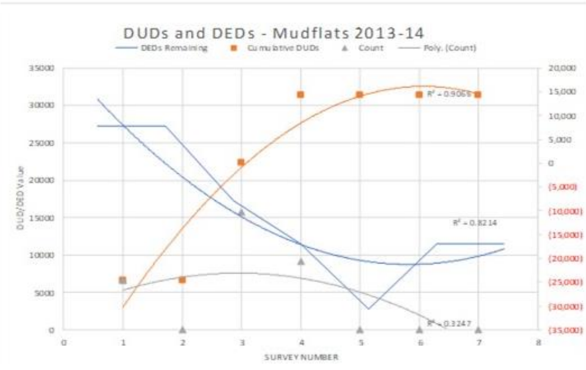
Unharvested Milo–N/A

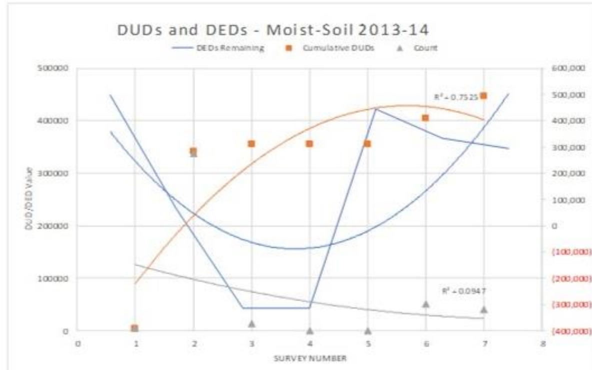


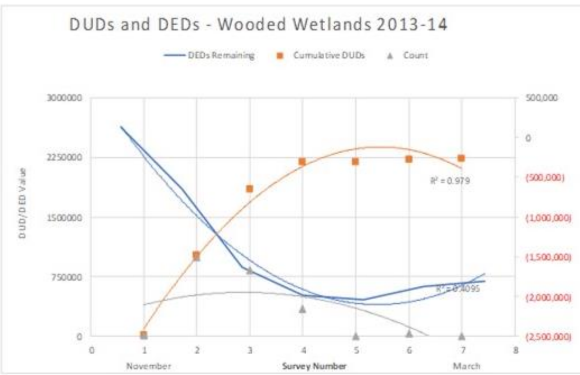



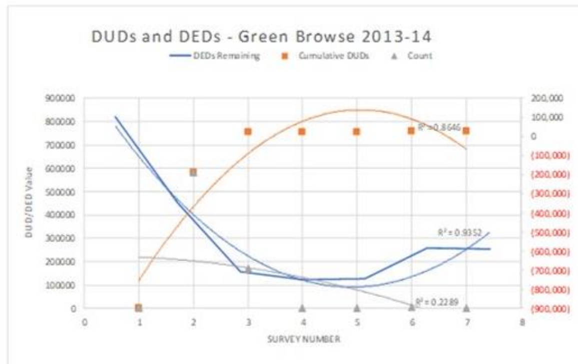



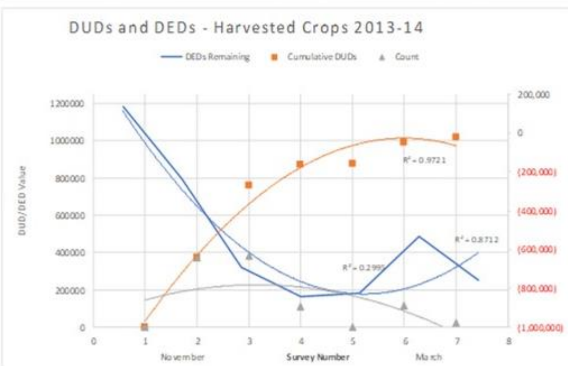
2013-14



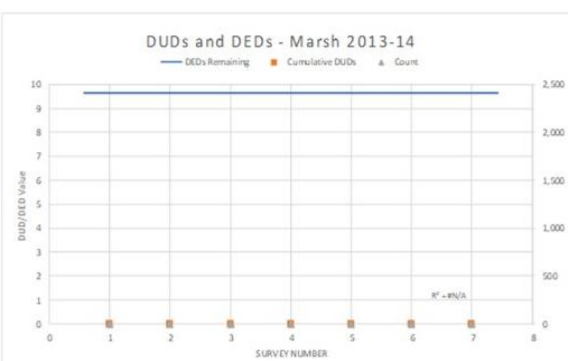



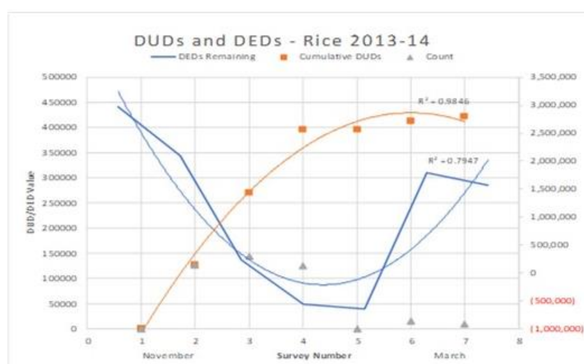




Unharvested Millet—N/A

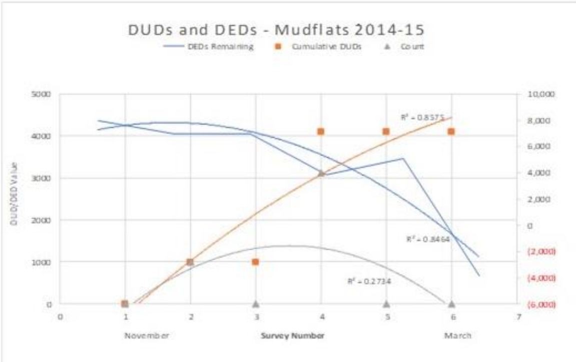
Unharvested Soybean–N/A

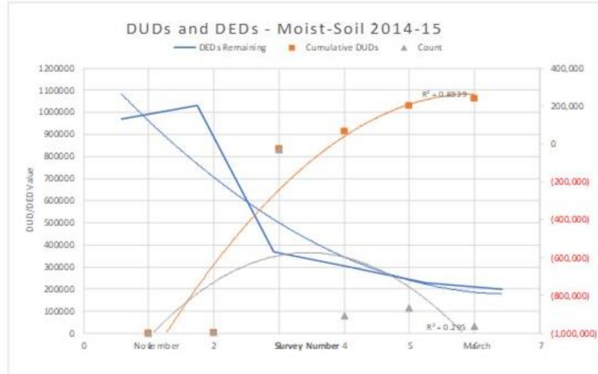
Unharvested Milo–N/A

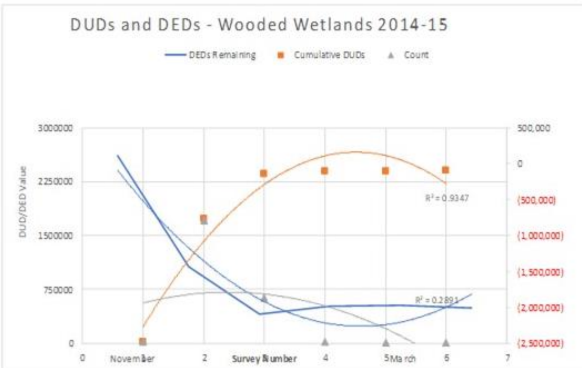


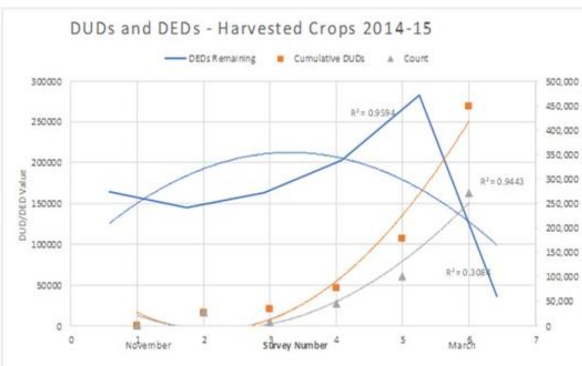



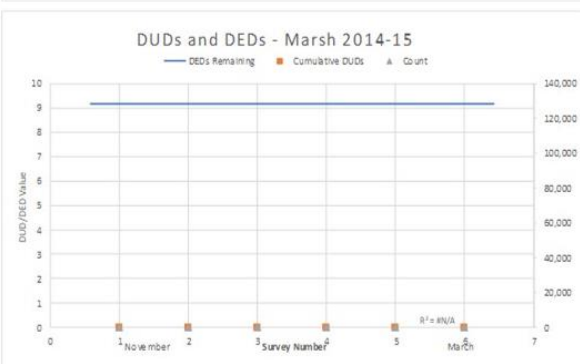
2014-15



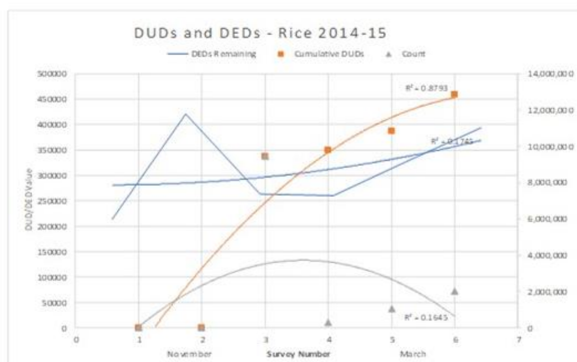




Green Browse—N/A

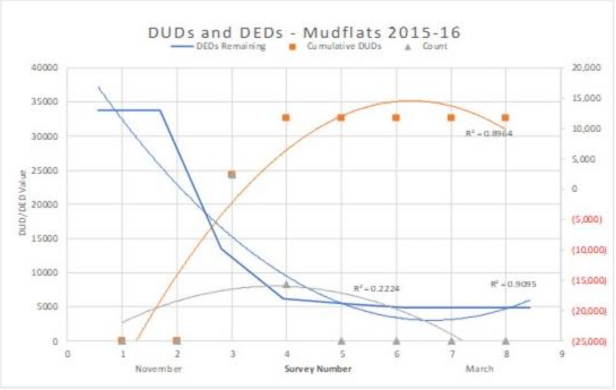
Unharvested Millet—N/A

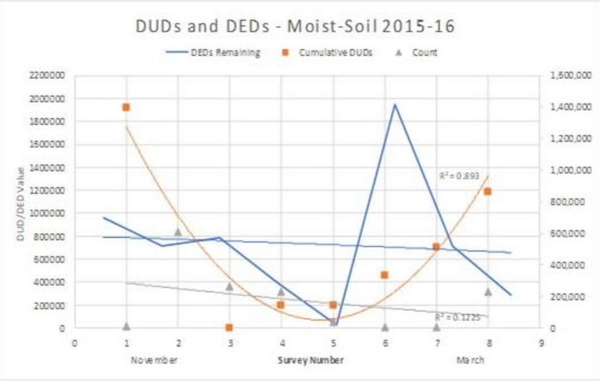
Unharvested Soybean–N/A

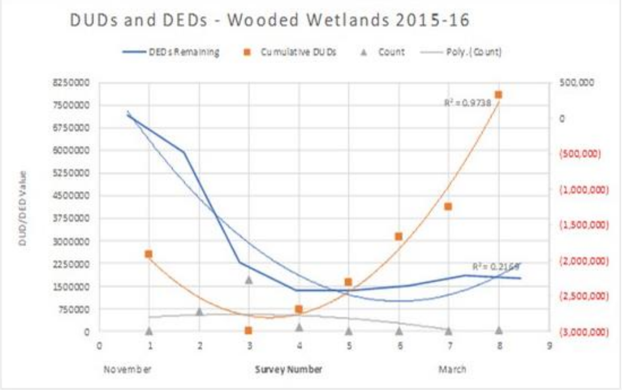
Unharvested Milo–N/A



2015-16



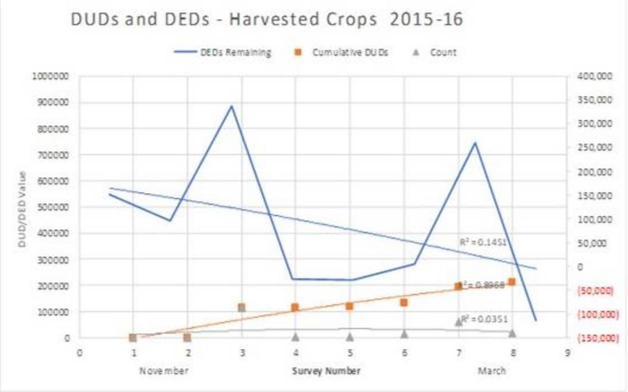

Green Browse—N/A

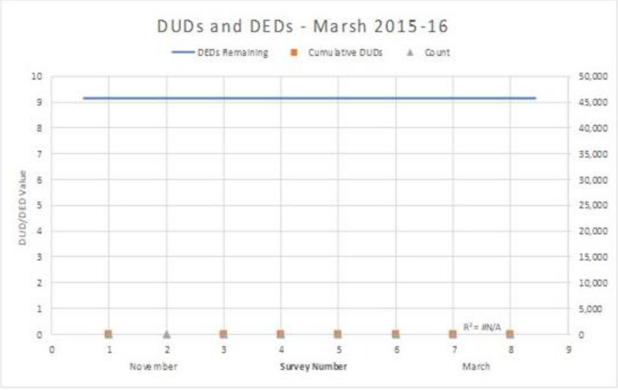
Unharvested Millet—N/A

Unharvested Soybean–N/A

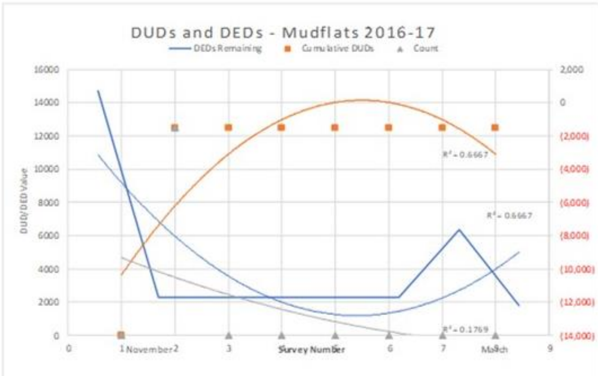
Unharvested Milo–N/A

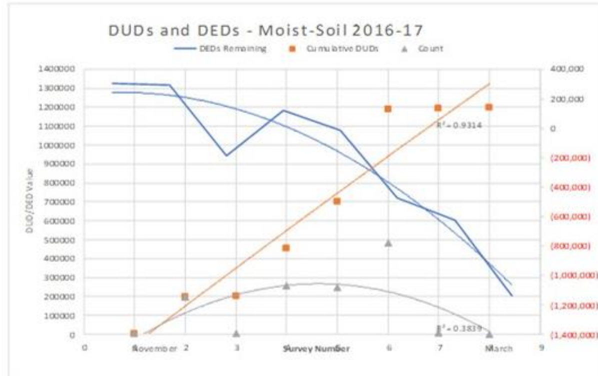
Unharvested Rice—N/A

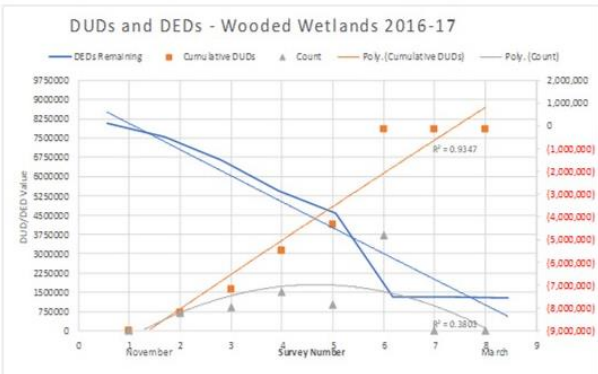


2016-17



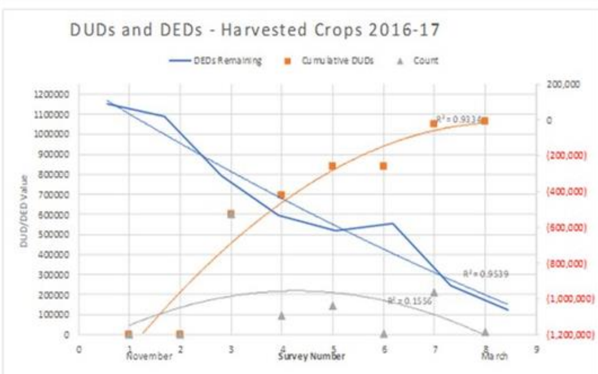



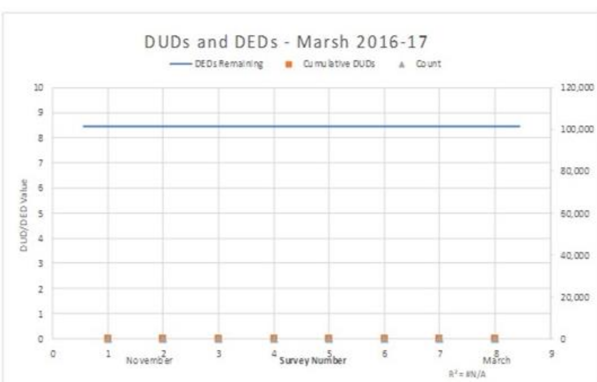

Green Browse—N/A

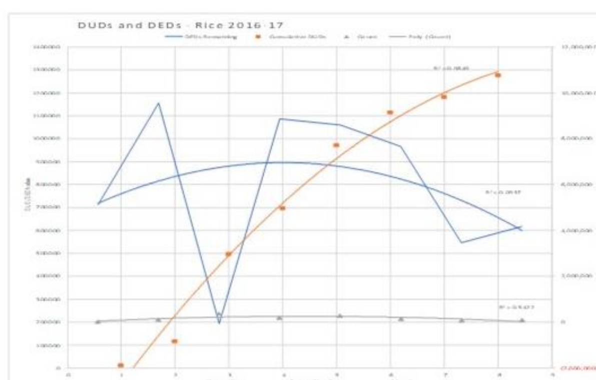
Unharvested Millet—N/A

Unharvested Soybean–N/A

Unharvested Milo–N/A

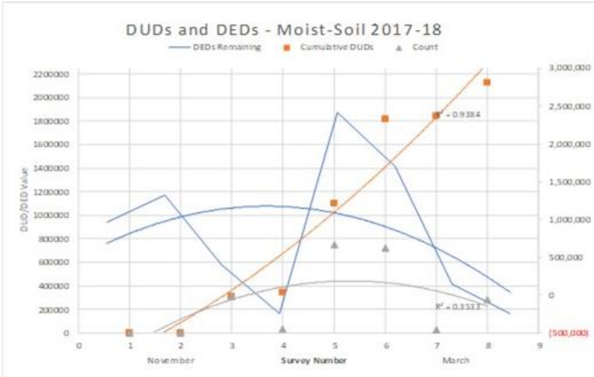


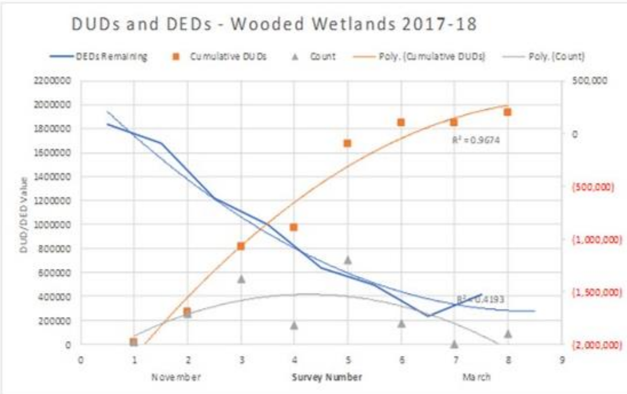



2017-18

Mudflats—N/A



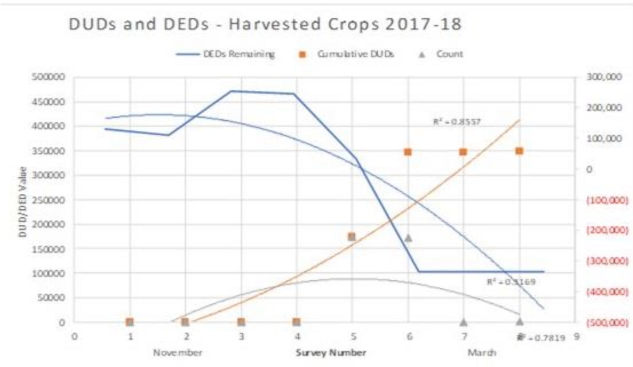



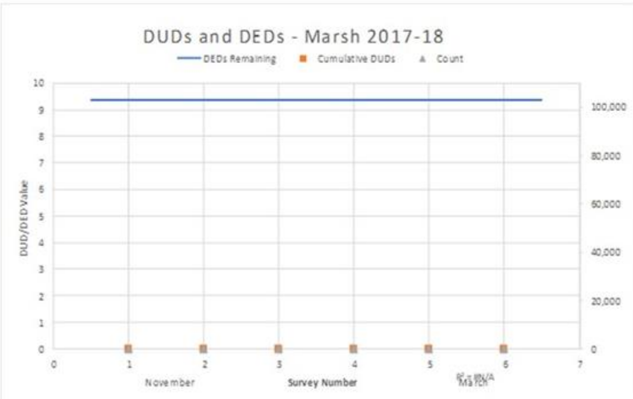

Green Browse—N/A

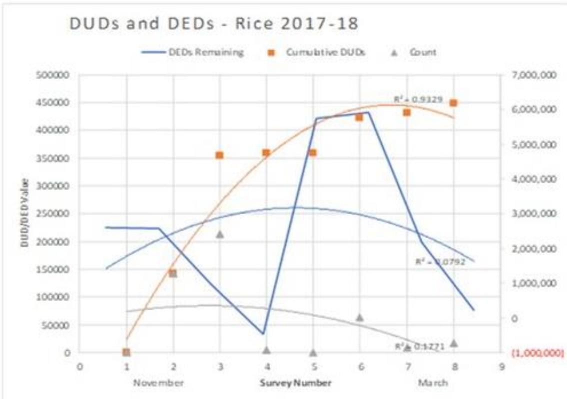
Unharvested Millet—N/A

Unharvested Soybean–N/A

Unharvested Milo–N/A

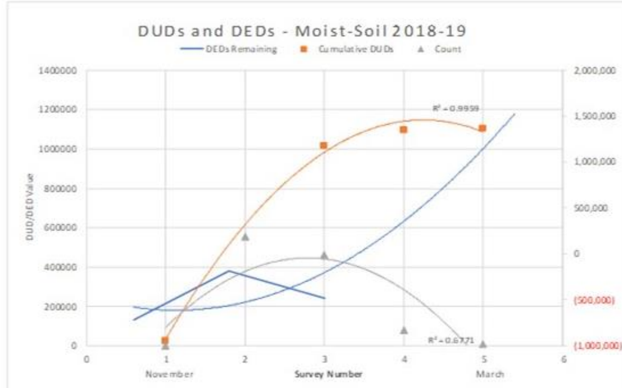


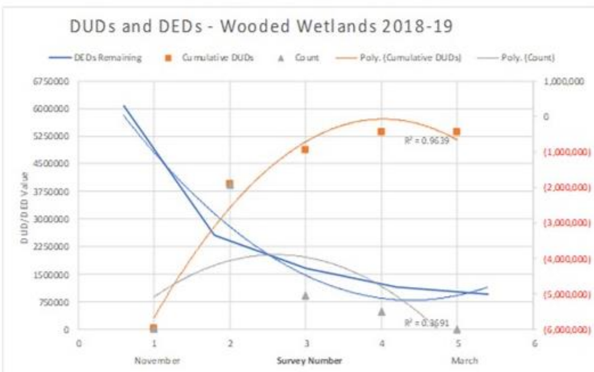



2018-19

Mudflats—N/A



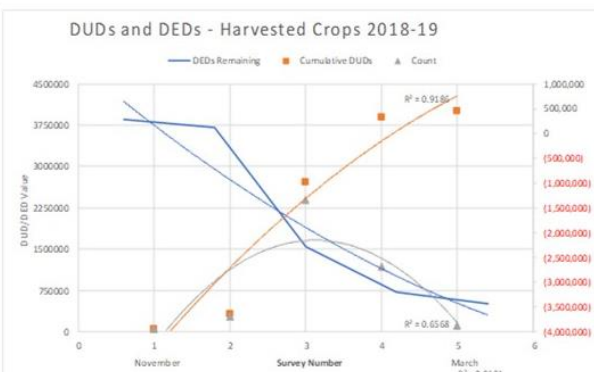



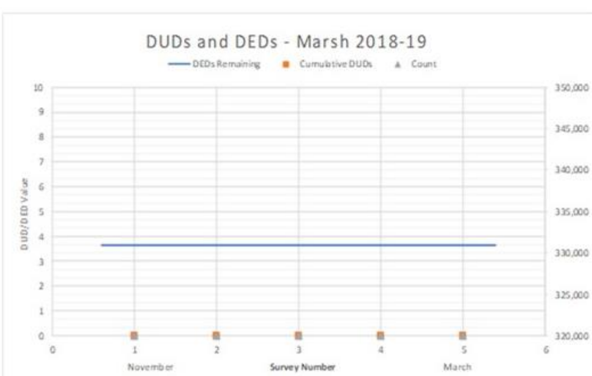

Green Browse—N/A

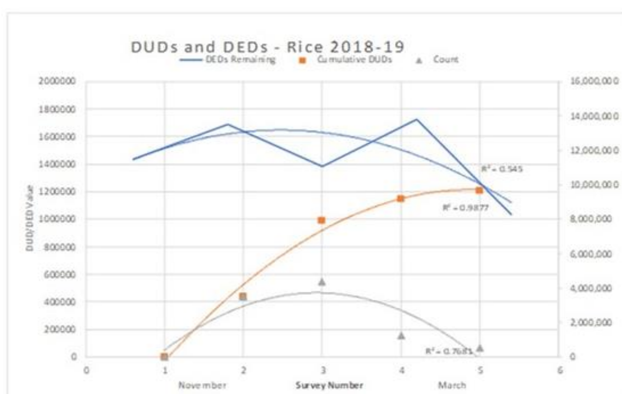
Unharvested Millet—N/A

Unharvested Soybean–N/A

Unharvested Milo–N/A

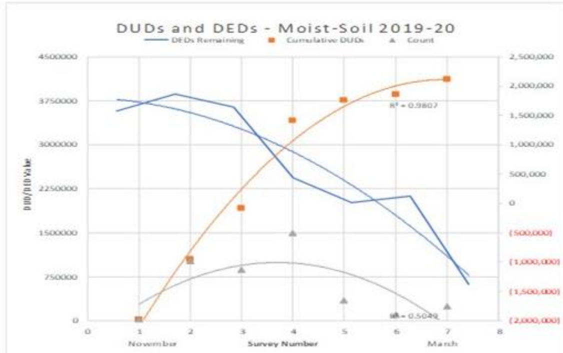


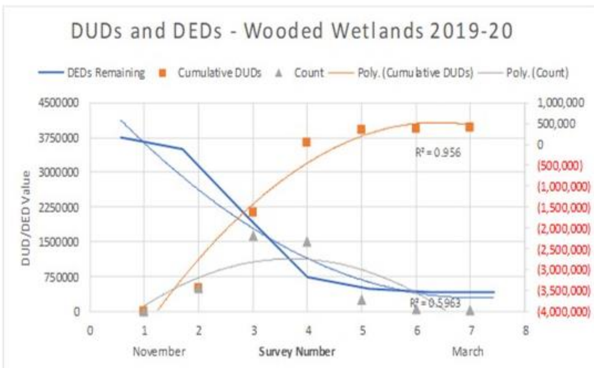



2019-20

Mudflats—N/A



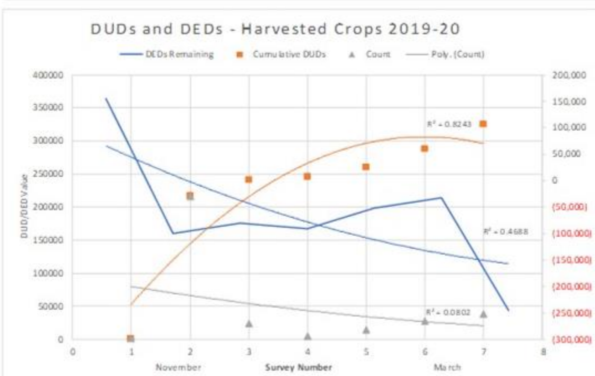



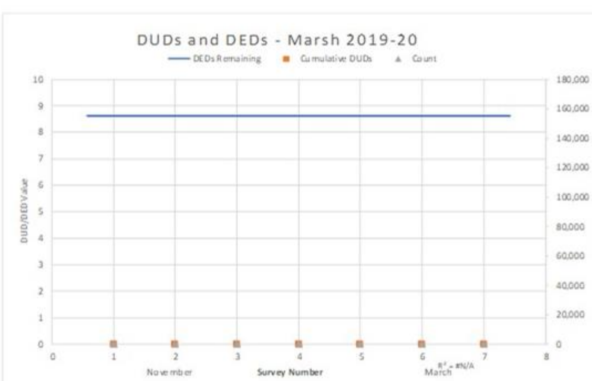

Green Browse—N/A

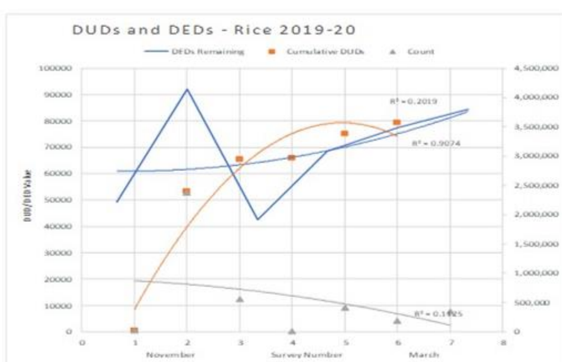
Unharvested Millet—N/A

Unharvested Soybean–N/A

Unharvested Milo–N/A



## Appendix G

Distribution of dabbling ducks by species (mallard, northern pintail, green-winged teal, other species, and all species combined) in cover types across Seasons 2006-07 to 2019-20