Balancing Habitat Delivery for Breeding Marsh Birds and Nonbreeding Waterfowl: An Integrated Waterbird Management and Monitoring Approach at Clarence Cannon National Wildlife Refuge, Missouri

Open-File Report 2017–1051

U.S. Department of the Interior
U.S. Geological Survey

Cover photos: Clockwise from upper right, mixed dabbling duck flock in moist-soil habitat, vocalizing king rail, dabbling duck concentration during migration, and king rail foraging on crayfish in a shallow marsh. Credits: William R. Coatney (mixed flock); Noppadol Paothong, Missouri Department of Conservation (king rails); and Mick Hanan, U.S. Fish and Wildlife Service (dabbling duck concentration).

Balancing Habitat Delivery for Breeding Marsh Birds and Nonbreeding Waterfowl: An Integrated Waterbird Management and Monitoring Approach at Clarence Cannon National Wildlife Refuge, Missouri

By Brian W. Loges, James E. Lyons, and Brian G. Tavernia

Open-File Report 2017–1051

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit https://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit https://store.usgs.gov.

Suggested citation:
Loges, B.W., Lyons, J.E., and Tavernia, B.G., 2017, Balancing habitat delivery for breeding marsh birds and nonbreeding waterfowl: An integrated waterbird management and monitoring approach at Clarence Cannon National Wildlife Refuge, Missouri: U.S. Geological Survey Open-File Report 2017–1051, 28 p., https://doi.org/10.3133/ofr20171051.

ISSN 2328-0328 (online)

Acknowledgments

The authors appreciate the willingness of Jason Wilson, Refuge Manager of the Clarence Cannon Wildlife Refuge, to consider novel approaches to planning efforts and to participate in the elicitation exercise. We gratefully acknowledge Candy Chambers, Jean Favara, Mick Hanan, and Matt McAdams of the U.S. Fish and Wildlife Service for participating in the elicitation exercises and collecting the bulk of the waterbird and marsh bird data used in this report. The support provided by John Coluccy of Ducks Unlimited and Carolyn Gregory and John Stanton of U.S. Fish and Wildlife Service was critical to keeping technicians and volunteers in the field. We are grateful to Kevin Aagaard and Anne Mini for helpful suggestions on the manuscript. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Area	
acre	4,047.0	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
acre-foot (acre-ft)	1,233.0	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)

Abbreviations

CCNWR	Clarence Cannon National Wildlife Refuge
DUDs	Dabbler Use-days
HMP	Habitat Management Plan
IWMM	Integrated Waterbird Management and Monitoring
KIRA	King Rail
Kcals	Kilocalories
MSU	Moist-soil Unit
USGS	U.S. Geological Survey

Balancing Habitat Delivery for Breeding Marsh Birds and Nonbreeding Waterfowl: An Integrated Waterbird Management and Monitoring Approach at Clarence Cannon National Wildlife Refuge, Missouri

By Brian W. Loges[1], James E. Lyons[2], and Brian G. Tavernia[2]

Abstract

The Clarence Cannon National Wildlife Refuge (CCNWR) in the Mississippi River flood plain of eastern Missouri provides high quality emergent marsh and moist-soil habitat benefitting both nesting marsh birds and migrating waterfowl. Staff of CCNWR manipulate water levels and vegetation in the 17 units of the CCNWR to provide conditions favorable to these two important guilds. Although both guilds include focal species at multiple planning levels and complement objectives to provide a diversity of wetland community types and water regimes, additional decision support is needed for choosing how much emergent marsh and moist-soil habitat should be provided through annual management actions.

To develop decision guidance for balanced delivery of high-energy waterfowl habitat and breeding marsh bird habitat, two measureable management objectives were identified: nonbreeding *Anas Linnaeus* (dabbling duck) use-days and *Rallus elegans* (king rail) occupancy of managed units. Three different composite management actions were identified to achieve these objectives. Each composite management action is a unique combination of growing season water regime and soil disturbance. The three composite management actions are intense moist-soil management (moist-soil), intermediate moist-soil (intermediate), and perennial management, which idles soils disturbance (perennial). The two management objectives and three management options were used in a multi-criteria decision analysis to indicate resource allocations and inform annual decision making. Outcomes of the composite management actions were predicted in two ways and multi-criteria decision analysis was used with each set of predictions. First, outcomes were predicted using expert-elicitation techniques and a panel of subject matter experts. Second, empirical data from the Integrated Waterbird Management and Monitoring Initiative collected between 2010 and 2013 were used; where data were lacking, expert judgment was used. Also, a Bayesian decision model was developed that can be updated with monitoring data in an adaptive management framework.

Optimal resource allocations were identified in the form of portfolios of composite management actions for the 17 units in the framework. A constrained optimization (linear programming) was used to maximize an objective function that was based on the sum of dabbling duck and king rail utility. The constraints, which included management costs and a minimum energetic carrying capacity (total moist-soil acres), were applied to balance habitat delivery for dabbling ducks and king rails. Also, the framework was constrained in some cases to apply certain management actions of interest to certain management units; these constraints allowed for a variety of hypothetical Habitat Management Plans, including one based on output from a hydrogeomorphic study of the refuge. The decision analysis thus created numerous refuge-wide scenarios, each representing a unique mix of options (one for each of 17 units) and associated benefits (i.e., outcomes with respect to two management objectives).

Prepared in collaboration with the U.S. Fish and Wildlife Service, the decision framework presented here is designed as a decision-aiding tool for CCNWR managers who ultimately make difficult decisions each year with multiple objectives, multiple management units, and the complexity of natural systems. The framework also provides a way to document hypotheses about how the managed system functions. Furthermore, the framework identifies specific monitoring needs and illustrates precisely how monitoring data will be used for decision-aiding and adaptive management.

Background

Clarence Cannon National Wildlife Refuge (CCNWR; the refuge) in Missouri provides high quality emergent marsh and moist-soil habitat that benefits nesting marsh birds and migrating waterfowl. Once dominated by emergent marsh and wet prairie, locally referred to as "goose pasture," the hydrology and natural communities of the site have been degraded to a highly modified state by drainage district flood

[1] U.S. Fish and Wildlife Service, Brussels, IL.

[2] U.S. Geological Survey.

protection levees, altered hydrology in pool 24 of the Mississippi River, and altered fire regimes (Heitmeyer and Newman, 2014). To compensate for the consequences of a highly altered big river flood plain, the refuge has relied heavily on water level and vegetation manipulations within managed wetland units (fig. 1) Management strategies are used to provide early successional riverine marshes with water regimes and successional stages that mimic historical communities and provide habitats for both nesting marsh birds and migrating waterfowl. The staff of CCNWR manage 17 units of land to fulfill the objectives identified in the Habitat Management Plan (HMP; U.S. Fish and Wildlife Service, 2012).

In the absence of active management, each unit would advance through successional seres to forest or shrub swamp, communities that already dominate much of the natural cover in the lower Mississippi River flood plain (Theiling and others, 2000). Although these communities are primarily dominated by native species, they are relatively common and do not provide habitat for the refuge's focal waterbird species [(*Botaurus lentiginosus* (American bittern), *Anas discors Linnaeus* (blue-winged teal), *Calidris melanotos* (pectoral sandpiper), *Aythya valisineria* (canvasback), *Aythya affinis* (lesser scaup)], which rely on non-forested wetlands. To meet local scale and Joint Venture scale objectives, the refuge is committed to actively managing both plant community succession and water levels to maintain important shallow herbaceous wetland habitats (Kahler and others, 2014). *Rallus elegans* (king rails) are identified in the HMP as a resource of concern and represent marsh-dependent focal species through an umbrella surrogate species approach (Fleishman and others, 2000).

The process of making annual management decisions for the refuge involves selecting areas for prescribed disturbance and water regimes for units with control structures (impoundments). Managing early-successional wetland plant communities for seed production is commonly referred to as "moist-soil management." This approach produces preferred waterfowl foods by exposing early to mid-growing season mudflats that are quickly colonized by annual plant species producing the high energy seeds preferred by waterfowl. Prescribed soil disturbance strategies, such as disking, rolling, and row

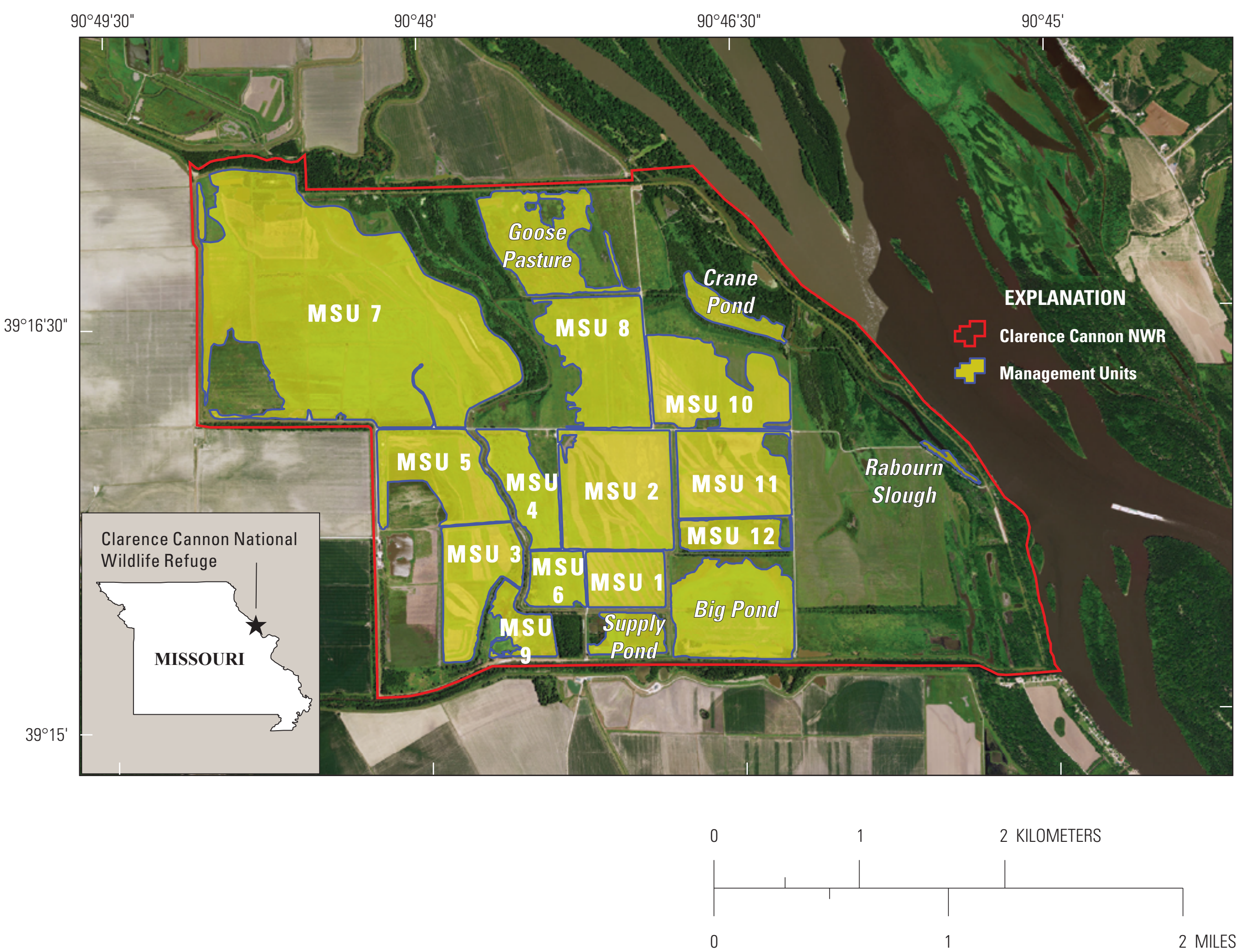

Figure 1. Wetland management units at Clarence Cannon National Wildlife Refuge, Missouri. (MSU, moist-soil unit)

cropping, are required to lower the dominance of perennial herbaceous and woody vegetation, that is to reverse afforestation. Prescribed disturbance inhibits perennial vegetation and is necessary to ensure mudflats for colonizing moist-soil vegetation (Fredrickson and Taylor 1982). Semi-permanent or permanent marsh units are flooded throughout much of the growing season and may include open water, aquatic vegetation, or perennial emergents.

Purpose and Scope

This report discusses an approach to decision support for allocating management actions on a national wildlife refuge that was prepared in collaboration with the U.S. Fish and Wildlife Service. Three composite management actions are presented. The predicted outcomes of the composite management actions for the 17 units in the refuge are described.

Objectives

The objective of the HMP is for all managed impoundments to "provide a three year average (±10%) of 2,470 acres seasonal/temporary, 655 acres semi-permanent, and 55 acres of permanently flooded wetland vegetation types in refuge wetland impoundments for waterfowl, shorebirds and other wetland-dependent wildlife species in areas with water level control capabilities" (U.S. Fish and Wildlife Service, 2012). This objective provides specifics for acres by water regime, but it does not relate targeted waterbird guilds or vegetation states to the measurable acres. The 2012 HMP recognizes "A conflicting habitat need is the tradeoff between an early successional community that benefits waterfowl and a mid-successional community comprised of native species that have less value to waterfowl; however, benefit species that require more well-developed vegetation." The Midwest Marsh Bird Working Group (Larkin and others, 2013) also identified the conflicting habitat need as a research topic, specifically stated as "Does management of impoundments for waterfowl influence marsh bird use relative to un-impounded wetlands, and what conditions maximize use by both bird groups?"

The relative proportions of the refuge being prepped for moist-soil vegetation, producing moist-soil vegetation, or dominated by perennial vegetation are dependent on staff decisions and the completion of a variety of management strategies. Although not explicitly addressed in the HMP, a multiple waterbird guild approach is implied by the focal species selection and the sorting of acre targets by water regime. Having all units in single successional stage in any given year would technically still meet the objective as long as the water regime targets are met but this approach would not be expected to provide greatest use across guilds. As a result, CCNWR wetland management focuses on providing a balance of these successional stages collectively across all the units.

To explore this balance, two supplemental objectives were developed.

- Maximize the number of *Anas Linnaeus* (dabbling duck) use-days (hereafter "dabbler use-days" or DUDs) collectively provided by the impoundments during the non-breeding season (September 1–May 15).
- Maximize the number of units occupied by king rails during the breeding season (April 15–July 15).

The approach to decision support presented here is designed to link waterbird use to recurring management actions and provide an avenue for exploring how applying combinations of management actions in multiple units affects the availability of habitats for nesting king rails and wintering dabbling ducks.

Composite Management Actions

The alternatives for this case study consist of different portfolios, or collections, of annual composite management actions for the 17 intensively managed impoundments at CCNWR, which span 2,177 acres. The composite management actions for each unit are a composite of multiple individual actions related to water regime, soil disturbance, and other characteristics. These composite actions have been explicitly defined to capture the general management decisions outlined in the "Background" section.

Composite management actions represent the steps taken to produce a generalized desired state for the later portions of the growing season.

1. *Moist-soil:* This composite management action incorporates a mid to early growing season drawdown of surface water, exposing mudflats that are quickly colonized by seed producing annual plants. The unit contains little or no perennial marsh vegetation. Drawdowns are completed prior to July 15, and more than 75 percent of the unit's area is in an early successional state (mudflat or annual vegetation). An example scenario incorporates an April drawdown facilitating significant seed production by fall on exposed mudflats.

2. *Intermediate:* This composite management action incorporates a late (after July15) growing season drawdown. Soil disturbance strategies cover less than 75 percent of the unit in any season, and areas of the unit are devoid of perennial vegetation, exposing mudflats that are quickly colonized by seed producing annual plants. At least 50 percent of the unit is flooded through the king rail nesting season.

3. *Perennial:* This composite management action consists of natural drawdown of surface water through evapotranspiration and limited areas of exposed mudflat (<25% of unit area). It is a semi-permanent closed-marsh strategy. The unit is dominated by perennial vegetation by the end of the growing season.

In any given year, one of these composite management actions may be implemented in each of the 17 units in the management decision-making framework (a decision-making framework or "framework" is composed of management objectives, alternative management actions, a model to predict consequences, and an evaluation of tradeoffs). The decision-making challenge is to find the best combination of three actions in 17 units, given the objectives and any constraints placed on the problem.

The decision-support tool in this framework is not designed to prescribe a specific composite management action portfolio in any given year. The purpose is to evaluate a number of portfolios under various constraints and identify multiple scenarios that meet the management objectives. These scenarios become additional information for managers to consider in their planning process.

Consequences of Composite Management Actions

Given the objectives and composite management actions described above, the next step in the framework is to predict the outcomes of each composite management action in terms of the previously described objectives. That is, what sort of benefits can we expect from these actions? The predicted outcomes will be used to identify which combination of composite management actions is best for achieving the objectives.

The dabbling duck (referred to as "dabbler") and king rail objectives serve as criteria to evaluate the benefits of alternative management portfolios for impoundments at CCNWR. The total benefit of a portfolio depends on the total number of DUDs and king rail occupancy rates for all the managed impoundments combined. For this analysis, predictions are needed for the expected number of DUDs and expected probability of king rail occupancy, by impoundment, for each composite management action.

Two approaches were used to predict the number of DUDs and king rail occupancy that would result from each action. First expert-elicitation techniques were used to obtain information from subject matter experts. In this method, experts provide their judgment about DUDs and the number of units occupied by king rails, given their expert knowledge of wetland management and the 17 units considered in the framework. Expert elicitation was used because the amount of data available for the stated objectives was limited.

Second, the limited data that were available for DUDs at the refuge during 2010–13 were compiled; these data were used in place of expert judgment. The DUD data were collected using protocols from the Integrated Waterbird Management and Monitoring (IWMM) Initiative. Because empirical data on king rail occupancy were not available (breeding marsh bird surveys are not currently part of IWMM), predicted outcomes for king rail occupancy from expert elicitation were used in the second approach. Each of these two approaches, one based entirely on expert judgment and the other on a combination of expert judgment and empirical data, are described below.

Predicting Management Outcomes Using Expert Elicitation

A panel of four subject matter experts, including the refuge manager and biologists, was formed in order to elicit expected DUDs and expected rail occupancy for the 17 units in the decision analysis. An influence diagram was used to help obtain the judgments of the experts. Thereafter, a Bayesian decision model was constructed from the influence diagram to quantify relations.

Influence Diagram

To facilitate expert elicitation, a conceptual model of managed wetlands at CCNWR was created using an influence diagram. This graphical model represents a transparent and shared description of wetland management; it was reviewed with subject matter experts before the elicitation was conducted. The model captures composite management actions, habitat conditions, and bird-use metrics monitored by the IWMM Initiative (Loges and others, 2014) and North American Marsh Bird Monitoring program (Conway, 2011). Assuming CCNWR monitors the impoundments using site-specific versions of these two protocol frameworks (Conway, 2011; Loges and others, 2014), the expert-based models and parameter estimates can be updated using future monitoring data.

The influence diagram (fig. 2) focuses on early successional management and water levels for a hypothetical management unit. The influence diagram describes the relations between composite management actions, habitat variables, chance events, and expected bird response.

Bayesian Decision Model

From the influence diagram, a Bayesian decision model (Marcot and others, 2006; Nyberg and others, 2006) was created to quantify the relations among factors affecting DUDs and king rail occupancy. The Bayesian decision model does not capture all aspects of the influence diagram (for example, the uncertainty related to flooding from excessive river flows during the growing season is not incorporated) but provides a requisite predictive model to quantify expected outcomes (fig. 3). The Bayesian model indicates that DUDs are a function of percent emergent vegetation and the energy content of the food plants, whereas probability of occupancy by king rails is a function of percent emergent vegetation and percent woody vegetation. Percent emergent and percent woody vegetation are directly affected by composite management actions. Energy content of the wetland is affected by plant species composition (% annuals) and seed-head quality, which are in turn directly affected by the composite management actions.

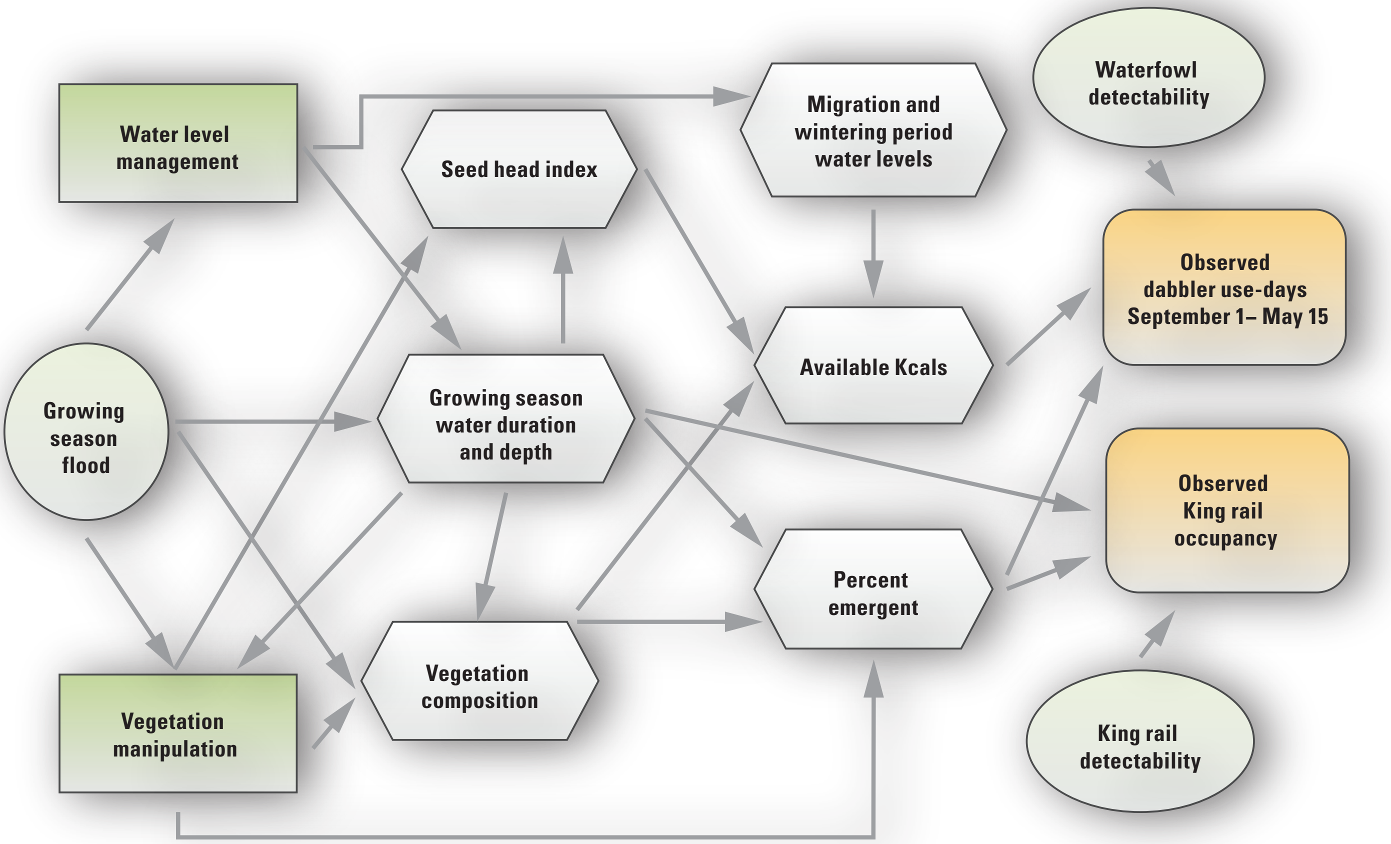

Figure 2. Influence diagram of management decisions affecting nonbreeding waterfowl and breeding king rails in a typical herbaceous wetland unit at Clarence Cannon National Wildlife Refuge, Missouri. An influence diagram is a graphical conceptual model used to identify relations among factors affecting management alternatives and objectives. (Kcals, kilocalories)

We implemented the Bayesian decision model in the software Netica (Norsys Software Corporation, 2014).

Parameters for the Bayesian model were derived from empirical data and available literature. For example, IWMM data collected at the refuge were used to predict change in DUDs as a function of changes in percent emergent vegetation. Specifically, a general linear model was used to predict DUDs as a function of percent emergent vegetation in three cover classes: 0–30 percent, 31–70 percent, and greater than 70 percent (shown as Low, Medium, and High, respectively, in the percent emergent node shown in figure 2). To complete the Bayesian decision model and predict DUDs as a function of percent cover and energy content of emergent vegetation, as indicated in the Bayesian model, expert judgment on the change in DUDs with changes in the energy content of the wetland was used. No data are available on king rail occupancy as a function of composite management actions and other factors, so the literature was relied on to identify factors that affect the probability of occupancy by king rails and the manner in which these factors are affected by composite management actions.

The Bayesian decision model is composed of a combination of empirical observations and expert judgment. The predictions of the Bayesian model are generally consistent with available data and predictions from the panel of experts (table 1). The predictions of the model indicate that DUDs are greatest with the moist-soil composite management action, intermediate with intermediate management, and lowest under perennial management (table 1). King rail occupancy, however, is greatest under intermediate management. When attempting to achieve both objectives, the greatest utility is derived from intermediate management because it provides a substantial number of DUDs (although not as many as with moist-soil management) while also providing the greatest probability of king rail occupancy (table 1).

The predictions of the Bayesian model were not used in the multiple criteria decision analysis; rather, the predicted outcomes from expert judgment and empirical data were used. If the Bayesian model is updated with IWMM monitoring data, it may become the primary predictive model for the decision-making framework. The Bayesian decision model is a powerful way to learn about the factors that link composite management actions to objectives and improve decisions, that is to practice adaptive management (Nyberg and others, 2006; Williams and others, 2007).

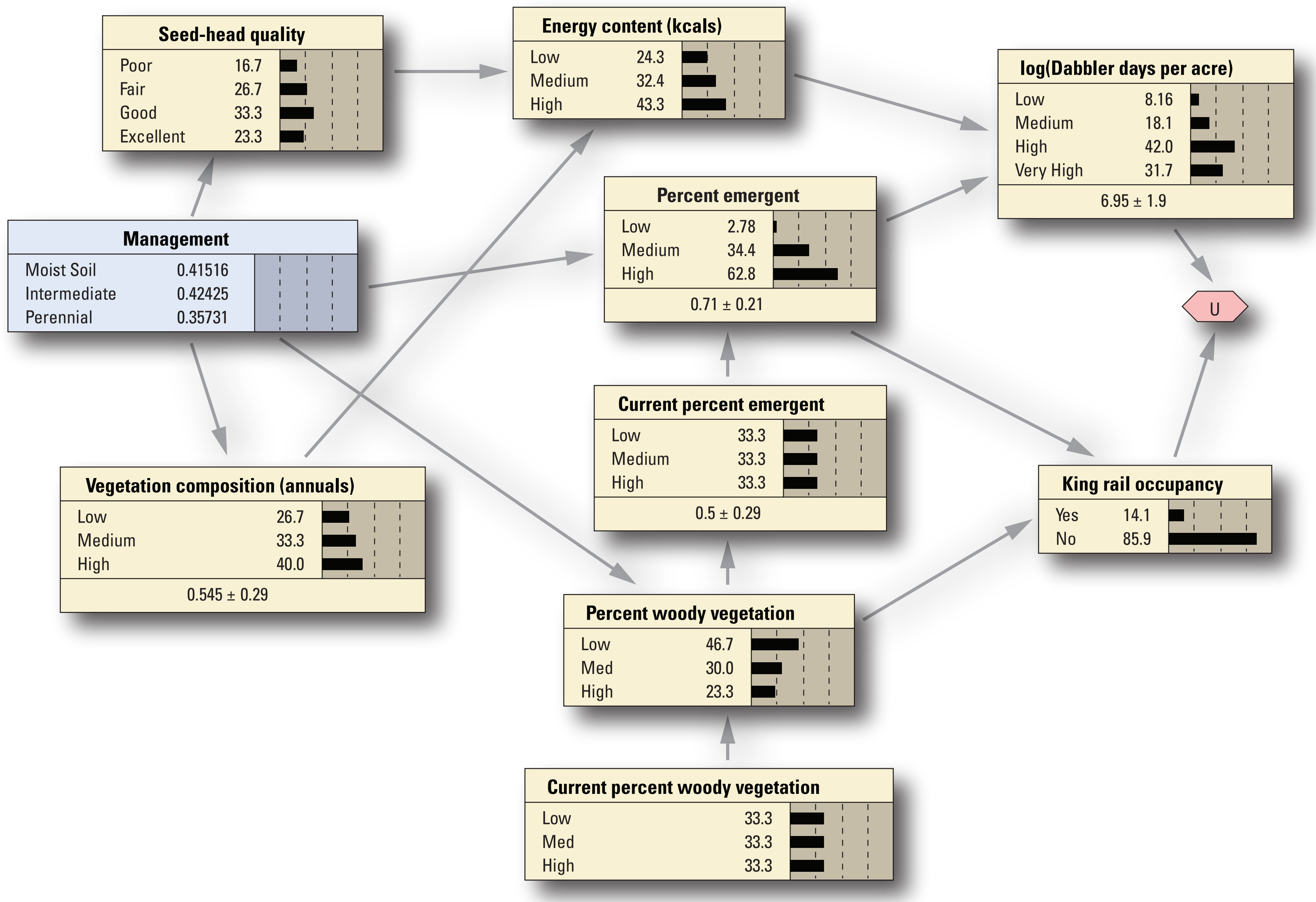

Figure 3. Bayesian decision model of a typical herbaceous wetland unit at Clarence Cannon National Wildlife Refuge, Missouri. The bars and numbers in the yellow nodes indicate the probability of each outcome in the node. The blue node indicates expected utility for each composite management action averaged over uncertainty specified in the model. (Kcals, kilocalories; U, utility)

Table 1. Predicted management outcomes from Bayes network model, utility is the combined benefit from achieving both DUDs and rail occupancy.

Action	Utility	DUDs per acre (log scale number of days)	Probability of king rail occupancy (percent)
Moist-soil	0.415	7.1 ± 1.9	14.2
Intermediate	0.424	6.9 ± 1.9	20.2
Perennial	0.357	6.8 ± 1.9	8.2
Average	0.399	7.0 ± 1.9	14.1

Expert Elicitation Procedures

The first objective of the study was maximize the number of DUDs during the nonbreeding season, September 1 to May 15; our analysis thus requires a prediction for DUDs under each of the three composite management actions. When working with actual monitoring data, DUDs were determined using a plot of the counts over time, the "migration curve." Even with experience and familiarity with the wetlands of CCNWR, however, it is not easy for experts to think in terms of DUDs for the entire non-breeding season. Therefore, rather than attempting to elicit DUDs directly, it was decided to elicit migration curves from the experts and then calculate DUDs from these curves using the same methods used for actual count data (Farmer and Durbian, 2006; Millar and Jordan, 2013). The experts were asked to draw the expected migration curve for each unit under each of the composite management actions, a total of 51 migration curves (17 management units × 3 actions). The experts based their migration curves on their knowledge of when dabblers would arrive and depart the units during the nonbreeding season and typical counts in each unit. We reviewed the procedures for drawing migration curves with our panel before the actual elicitation. Data sheets and written guidance were provided by the authors (Appendix 1) to standardize the methods as much as possible. The experts were asked to draw the expected migration curve without consulting each other.

The second objective was to maximize the number of units occupied by king rails during the breeding season. Although datasets for the CCNWR containing unit-specific information on king rail density or occupancy were not available, there was a limited amount of data from king rail surveys conducted at the CCNWR. This information was compiled and provided to the experts as part of the elicitation. During 2002–09, CCNWR conducted call-back enhanced point counts for the secretive marsh birds (Conway, 2011). Points were located on levees that also function as unit perimeters. Distance estimates for 58 king rail detections were extracted from the national marsh bird monitoring database, but azimuths were not available. Without azimuth data, king rail detections could not be assigned to individual management units. Note that the objective of the 2002–09 marsh bird surveys was to conduct a refuge inventory of marsh birds during spring migration and early breeding season, not to assess occupancy or abundance at the unit scale.

The proportion of surveys with king rail detections at each survey point and a three point ordinary kriging process (ESRI, 2011) were used to interpolate a coverage representing king rail detections. The map (fig. 4; survey points indicated by "CC") was presented to the panel of experts prior to the elicitation of king rail occupancy rates to delineate locations with the greatest number of king rail detections. The map thus informed the elicitation process by providing additional information that the experts could combine with their knowledge of the management units.

The possibility of directly eliciting the probability of occupancy was explored, but the expert panel indicated it would be difficult to provide this measure. Through discussions with the panel, it was decided to elicit, for each unit, the number of years out of 15 that the unit would be occupied by rails given each composite management action. Fifteen years was chosen because it is the time frame used in the CCNWR Comprehensive Conservation Plan (USFWS 2004). To capture the uncertainty present in the expert judgment, the four-point elicitation method of Speirs-Bridge and others (2010) was used. With this method, each expert was asked to provide realistic estimates of (1) the smallest number of years out of 15 that each unit would be occupied, (2) the greatest number of years, (3) the most likely number of years, and (4) a measure of confidence in the interval the experts provided (see Appendix 1 for elicitation guidance provided to experts). Items 1, 2, and 3 were divided by 15 to convert to a probability of occupancy. With these estimates, a quantile-matching procedure was used for a beta distribution to determine the probability that each unit would be occupied by king rails (Conroy and Peterson, 2013). Finally, for each unit the average probability of occupancy was calculated using data from the experts.

Predicting DUDs Using IWMM Data

DUDs were determined from weekly or biweekly IWMM surveys for all management units for fall 2010–spring 2011, fall 2011–spring 2012, and fall 2012–spring 2013, following the methods of Farmer and Durbian (2006). Composite management actions during these three seasons conformed to habitat management plans but did not necessarily coincide with the three composite management actions defined in this framework (actions 1, 2, and 3 above). To match empirical data from these seasons to composite management actions, units were retrospectively assigned to the composite management actions defined in this decision framework. Actions were assigned to the units for each of the three survey seasons on the basis of the dominance of annual vegetation observed in fall vegetation surveys. Units dominated by (>75%) annual vegetation were assigned to the moist-soil composite action. Units with between 25 percent and 75 percent cover of

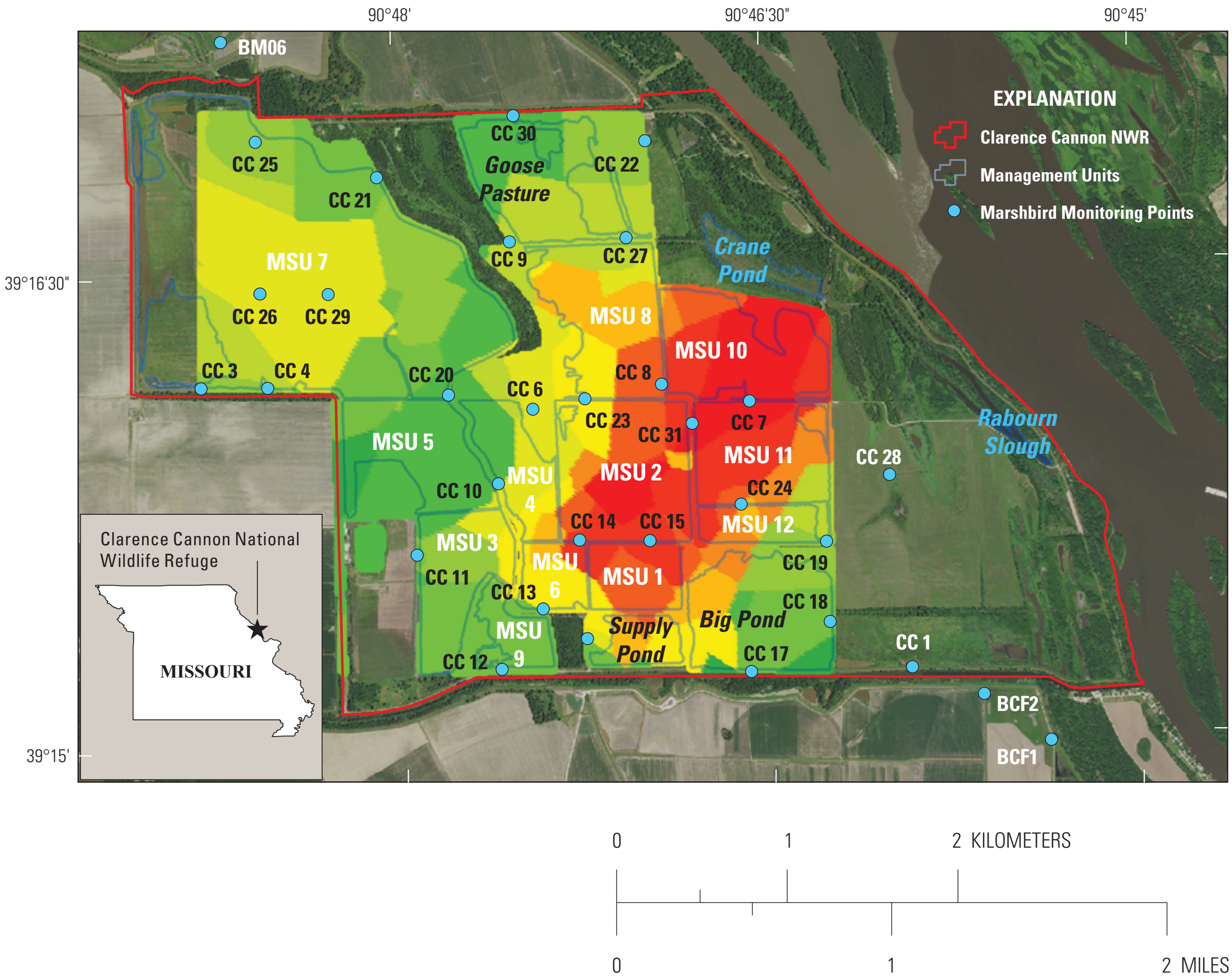

Figure 4. Marsh bird monitoring points in the Clarence Cannon National Wildlife Refuge, Missouri, used during 2002–09 and an interpolation of the proportion of surveys detecting king rails at each point. (Red, high number of detections; dark green, low number of detections)

perennial vegetation were assigned to the intermediate composite action. Units with more than 75 percent perennial cover were assigned to the perennial composite action. Most of the acreage was assigned to the intermediate composite action (table 2).

Open water or other vegetation cover patterns that could not be assigned to a composite action were classified as "other." The amount of available dabbler habitat in these units was checked using fall hydrographs. Only units with hydrographs indicating a fall flood were included in the summary. Appendix 2 outlines the manner in which data collected using the IWMM protocol can be used to assign a unit to a composite management action as part of a retrospective analysis.

Data on all 3 composite management actions in all 17 units were not available because each of the units experienced only 1 or 2 composite management actions during the 3-year period. When dabbler use data were not available for a particular unit under a particular composite management action, mean DUDs from all units were used in place of the

Table 2. Total acres, by composite management action, in the Clarence Cannon National Wildlife Refuge, Missouri, during the three nonbreeding seasons of 2010–13. Units were assigned to a composite management action by the proportion of annual and perennial vegetation recorded in fall Integrated Waterbird Management Monitoring surveys (see Appendix 2).

Migration period	Area by composite management action (acres)		
	Moist-soil	Intermediate	Perennial
2010–11	1,202	744	120
2011–12	0	1,550	571
2012–13	0	1,550	571

missing data. For more accurate imputation of missing data, DUDs were scaled by size of each management unit when calculating the mean. Note that this approach is complicated by small sample size, units as DUD outliers (MO-002-M), and non-normal skewed distributions (Shapiro-Wilk normality test W = 0.2938, p < 0.001).

Preliminary Comparison of Expert Elicitation and Empirical Data on DUDs

DUDs were calculated from two sources: expert judgment and empirical data from the IWMM monitoring. The expected number of use-days, based on expert judgment, was higher than empirical observations for 40 of the 51 unit–action combinations (17 units × 3 actions), especially for moist-soil and intermediate composite management actions (figs. 5 and 6). The two sources were found to be significantly different (Wilcoxon rank sum test with continuity correction, W = 1041, p = 0.0004024).

A relatively small correlation was determined between DUDs (transformed using log base 10) from expert judgment and IWMM data (r = 0.33). Correlation increased, however, and was relatively high (r = 0.85) when the 28 imputed values for cases without any empirical data were removed (Appendix 3, table 3-1; mean values were calculated across units after adjusting DUDs for sizes of units).

Calculating Total Management Benefit from DUDs and King Rail Occupancy

Whether the analysis is based on elicitation data or empirical data, it is necessary to produce a measure of combined benefit in terms of both objectives (DUDs and number of units occupied by king rails). Methods of multi-criteria

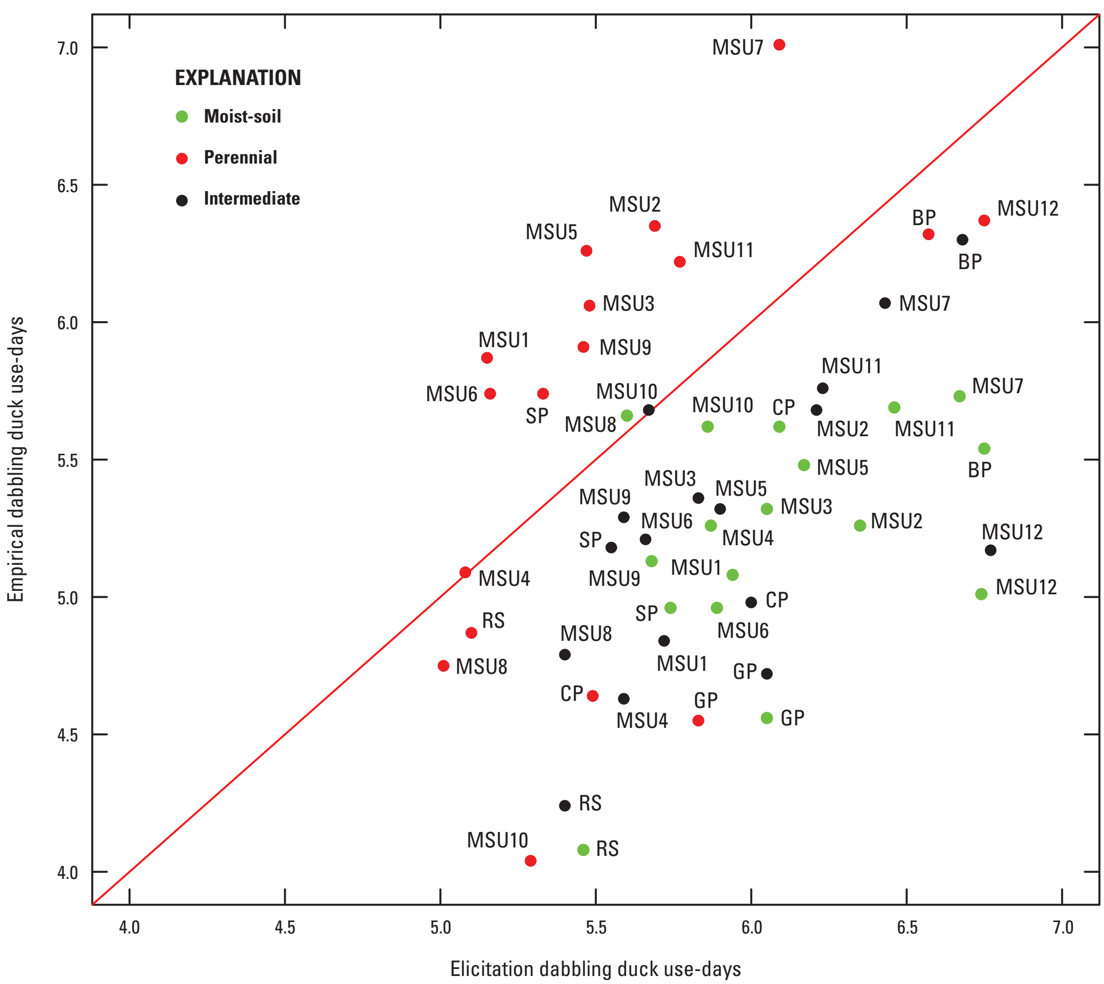

Figure 5. Empirical DUDs in relation to elicitation DUDS, by unit and composite management action (transformed with log base 10), Clarence Cannon National Wildlife Refuge, Missouri. The description code for each point indicates unit name (MSU#, moist-soil unit #, BP, Big Pond; GP, Goose pasture; CP, Crane Pond; RS, Raybourne Slough; and SP, Supply Pond). The red line is the 1:1 line; points below the line show sites where the elicitation data were greater than the empirical data.

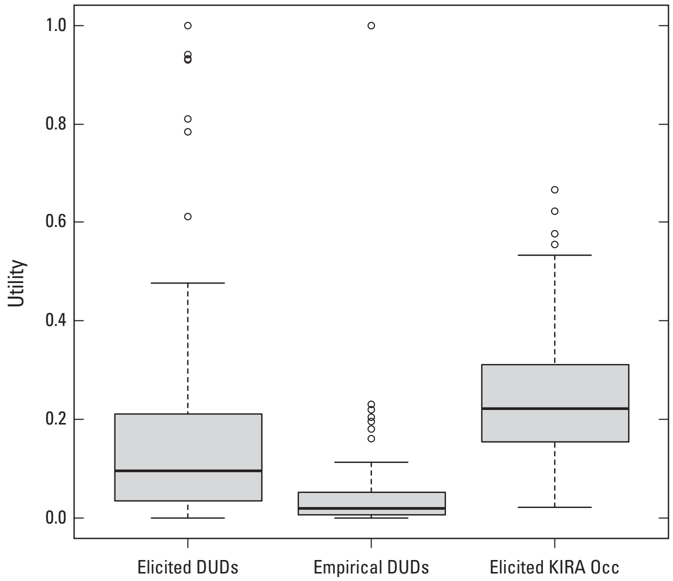

Figure 6. Distribution of utility values derived from expert elicitation for dabbling duck use-days and king rail occupancy, and empirical dabbler use-days, Clarence Cannon National Wildlife Refuge, Missouri. The greater expected utility for dabbling duck use-days (DUDs) from expert elicitation than from empirical DUDs indicates that the experts were optimistic about the potential waterfowl response. Similarly, the experts predicted relatively high king rail (KIRA) occupancy rates in response to composite management actions. The thick horizontal line is the median, the box shows the interquartile range, whiskers show a trimmed range of the data, and open circles show outliers.

decision analysis were relied on to place the two disparate objectives on the same scale, a utility scale that ranges from 0 to 1. Utility of any composite management action is defined as

$$u(a) = \frac{a - min}{max - min} \quad (1)$$

where

- a is the predicted outcome (number of DUDs or king rail occupancy),
- min is the lowest possible outcome with respect to the objective, and
- max is the best possible outcome with respect to the objective.

When calculating utility for DUDs, *min* and *max* are defined by the range of DUDs, *min* being the smallest number of DUDs for any action among all units and *max* being the greatest number of DUDs for any action among all units. For king rail occupancy, *min* and *max* are 0 and 1, respectively, because these are the bounds of the probability range. For each composite management action, total management benefit is the sum of weighted utilities for DUDs and king rail occupancy,

$$Management\ \ Benefit = w_1 u(d) + w_2 u(k) \quad (2)$$

where

- w_1 is the weight associated with the DUDs objective,
- w_2 is weight associated with the king rail occupancy objective,
- $u(d)$ is the utility for DUDs, and
- $u(k)$ is the utility for king rail occupancy.

For this analysis, equal weight was given to these two objectives ($w_1 = w_2$). Of course it is possible for the manager to select alternative weights, if desired.

Comparing Alternative Composite Management Actions and Assessing Tradeoffs

The alternatives in this framework are all the possible portfolios (combinations) of composite management actions. Given 17 units and 3 composite management actions, a very large number of portfolios is possible. A constrained optimization routine (linear programming) was used to find the optimal combination of actions for all units under a variety of constraints. The entire CCNWR (all 17 units in the framework) totals for predicted dabbler use-days and king rail occupancy were used in the objective function, management benefit. The main constraints of interest included costs (dollars) and estimated energetic carrying capacity (acres of moist soil), which is based on the energetic demands for a typical fall/wintering population at CCNWR (see "Building Carrying Capacity and Cost Constraints" section farther on).

Creating Portfolios of Management Actions

Each portfolio represents an allocation of one of the three actions for each management unit for the growing season that precedes the fall and spring waterbird migration cycle. Ideally, managers identify portfolios of interest that they would like to consider in the decision analysis. These portfolios may reflect previous HMPs, new plans of interest, or portfolios recommended by biologists and other local experts in any combination of composite management actions of interest. For this study, a set of portfolios was not created before the analysis, but rather, constrained optimization and a variety of constraints were used to identify optimal portfolios under different scenarios. Twenty-three different sets of constraints were evaluated, and two sets of predictions (one from expert judgment and the other from empirical data) were used as input data for a total of 46 portfolios (table 3).

Building Carrying Capacity and Cost Constraints

Carrying Capacity Constraint

To develop a constraint for carrying capacity (energy available based on amount of moist-soil acres), 337 kilocalories (kcals) per day was used as the daily energy requirement of dabblers at the CCNWR; this figure is a weighted average of the daily energy needs of a dabbling duck community in the Illinois River Valley (Stafford and others, 2011). Seed production estimates specific to the CCNWR are not available. Seed production in moist-soil units can be highly variable and affected by soil fertility, drawdown date, species composition, management intensity, and other factors (Brasher and others, 2007; Kross and others, 2008). Owing to high intensity management and fertile soils, the values at the CCNWR were expected to be near the high end of observed production. Values from six regional estimates were used (Bowyer and others, 2005; Greer and others, 2007; Gray, 2012 and 2013; Low and Bellrose, 1944; Stafford and others, 2011) to derive a seed production constant of 755.7 kilograms per acre. Using a metabolizable value of 2.5 kcals per gram (Kaminski and others, 2003), the per acre contribution of moist-soil units was estimated to be 1.89 million kcals or 5,606 dabbler energy days.

Using empirical use-days from August 12, 2010 to January 15, 2013, and a fall length-of-stay of 68 days (Hagy and others, 2014), the mean fall population of dabblers was estimated to be 85,612. Using a spring length of stay of 28 days (January 16, 2010–April 30, 2013) (O'Neal, 2012), the CCNWR supported an estimated mean population of 27,183 dabblers. Both estimates were made using the approach of Farmer and Durbian (2006). The acres needed to support both populations as full-time residents securing all their energy requirements in CCNWR for spring and fall was 1,174 acres (1,038 fall and 136 spring). Therefore, 1,174 moist soil acres was used as a constraint in the optimization routine to identify portfolios that would produce enough moist-soil acres to sustain this target population.

Cost Constraints

To develop cost constraints, costs were estimated for each composite management action, in each management unit, using the CCNWR fuel costs for pumping water and IWMM management action costs (Loges and others, 2014). With a pump capacity of 20,000 gallons per minute and estimated fuel use equal to 8.23 gallons per hour (Candace Chambers, USFWS, written commum., 2015), the estimated cost is $7.28 per acre-foot ($3.50/gallon diesel fuel). Owing to the small amount of topographic variation in most units, water demand was estimated to be a 1:1 ratio of surface acres to acre-feet to provide shallow water conditions for migrating waterfowl.

A standard budget of $40,000 ($44,856 was the highest possible cost) and reduced budgets ranging from $32,000 to $38,000 ($31,228 lowest possible cost) were applied as constraints in the optimization. In addition, CCNWR annual work plans for fiscal years[3] 2013, 2014, and 2015 were evaluated to select certain management actions for certain units (that is, additional constraints in the optimization) on the basis of annual management goals for these units identified in the plans.

Constrained Optimization

To implement a constrained optimization, a binary decision variable, ai, was defined that is equal to 1 if action i is selected for the portfolio and 0 otherwise; the length of the vector a is 51 (17 units × 3 actions). The optimization problem can be written as

$$Max \sum a_i V_i ,\ where\ V_i = Management\ \ Benefit = \sum w_1 u_i (d) + w_2 u_i (k) \tag{3}$$

subject to the constraint

$$\sum a_i c_i \leq B,\ i = 1, ..., 51 \tag{4}$$

where

c_i is the cost of each action and
B is the available budget.

An additional set of *k* constraints ensures that one and only one composite management action is chosen for each management unit:

$$\sum a_i I_{i(K)} = 1 \tag{5}$$

where

$I_{i(k)}$ is an indicator variable that is equal to 1 if action *i* applies to unit *k* and 0 otherwise.

Constraints for number of moist-soil acres were implemented in a manner similar to cost constraints above; in addition, composite management actions can be predetermined for any unit, if desired, with an additional constraint, $a_i = 1$ for unit *i*. The optimal settings for decision variable a_i were found using linear programming (Conroy and Peterson 2013), as implemented in the Solver tool in Microsoft Excel (Kirkwood, 1997).

Portfolio Comparisons

Twenty-three sets of constraints were evaluated (table 3). Portfolios 1–23 were identified as optimal for each set of

[3] The fiscal year is October 1 to September 30.

Table 3. Optimal management portfolios under a variety of constraints for the Clarence Cannon National Wildlife Refuge, Missouri. Each portfolio is composed of 17 management actions, one for each unit. The optimal portfolio is the one providing greatest total benefit and meeting all budget and non-budget constraints.

[KIRA, king rail; FY, fiscal year, October 1–September 30, identified by the year in which it ends; --, no constraint]

Portfolio	Management benefits and costs					Non-budget constraints	Data source
	Total benefit	Dabbler benefit	KIRA benefit	Moist-soil acres	Cost ($1000×)		
			Budget constraint: $40,000				
1	10	4.4	5.6	1,200	40	Units 3,5,7,9, moist soil (FY15)	Elicitation
2	10.3	4.5	5.8	1,177	40	Units 4 & 7 moist soil (FY14)	Elicitation
3	10.3	4.5	5.8	1,177	40	Unit 7 moist soil (FY13)	Elicitation
4	10.3	4.5	5.8	1,177	40	--	Elicitation
5	10.7	4.3	6.3	902	39	0.75 dabbler carrying capacity	Elicitation
6	10.7	4.1	6.6	710	39	0.50 dabbler carrying capacity	Elicitation
7	10.7	4.1	6.6	710	39	0.25 dabbler carrying capacity	Elicitation
			Budget constraint: $38,000				
8	9.8	4.4	5.4	1,180	38	--	Elicitation
9	10.3	4.3	6.0	905	38	0.75 dabbler carrying capacity	Elicitation
10	10.5	4.0	6.5	710	38	0.50 dabbler carrying capacity	Elicitation
11	10.5	4.0	6.5	710	38	0.25 dabbler carrying capacity	Elicitation
			Budget constraint: $36,000				
12	9.1	4.3	4.8	1,177	36	--	Elicitation
13	9.8	4.2	5.6	902	36	0.75 dabbler carrying capacity	Elicitation
14	10.0	3.9	6.1	710	36	0.50 dabbler carrying capacity	Elicitation
15	10.1	4.0	6.1	301	35	0.25 dabbler carrying capacity	Elicitation
			Budget constraint: $34,000				
16	8.6	4.3	4.3	1,178	34	--	Elicitation
17	9.3	4.2	5.0	938	33	0.75 dabbler carrying capacity	Elicitation
18	9.6	4.1	5.5	596	32	0.50 dabbler carrying capacity	Elicitation
19	9.9	3.9	6.0	311	30	0.25 dabbler carrying capacity	Elicitation
			Budget constraint: $32,000				
20	8.0	4.3	3.8	1,175	32	--	Elicitation
21	9.0	4.2	4.8	884	31	0.75 dabbler carrying capacity	Elicitation
22	9.6	4.1	5.5	591	32	0.50 dabbler carrying capacity	Elicitation
23	9.9	3.9	6.0	311	30	0.25 dabbler carrying capacity	Elicitation

Table 3. Optimal management portfolios under a variety of constraints for the Clarence Cannon National Wildlife Refuge, Missouri. Each portfolio is composed of 17 management actions, one for each unit. The optimal portfolio is the one providing greatest total benefit and meeting all budget and non-budget constraints.—Continued

[KIRA, king rail; FY, fiscal year, October 1–September 30, identified by the year in which it ends; --, no constraint]

Portfolio	Management benefits and costs					Non-budget constraints	Data source
	Total benefit	Dabbler benefit	KIRA benefit	Moist-soil acres	Cost ($1000×)		
				Budget constraint: $40,000			
24	6.3	0.7	5.6	1,180	40	Units 3,5,7,9 moist soil (FY15)	Empirical
25	6.4	0.6	5.8	1,178	40	Units 4 & 7 moist soil (FY14)	Empirical
26	6.4	0.6	5.8	1,178	40	Unit 7 moist soil (FY13)	Empirical
27	6.4	0.6	5.8	1,178	40	--	Empirical
28	6.9	0.6	6.4	905	39	0.75 dabbler carrying capacity	Empirical
29	7.2	0.5	6.6	710	39	0.50 dabbler carrying capacity	Empirical
30	7.6	1.5	6.0	352	31	0.25 dabbler carrying capacity	Empirical
				Budget constraint: $38,000			
31	6.1	0.8	5.3	1,190	38	--	Empirical
32	6.7	0.8	5.9	905	38	0.75 dabbler carrying capacity	Empirical
33	7.1	1.5	5.6	595	32	0.50 dabbler carrying capacity	Empirical
34	7.6	1.5	6.0	352	31	0.25 dabbler carrying capacity	Empirical
				Budget constraint: $36,000			
35	5.8	1.4	4.5	1,217	34	--	Empirical
36	6.5	0.8	5.7	905	36	0.75 dabbler carrying capacity	Empirical
37	7.1	1.5	5.6	595	32	0.50 dabbler carrying capacity	Empirical
38	7.6	1.5	6.0	352	31	0.25 dabbler carrying capacity	Empirical
				Budget constraint: $34,000			
39	5.8	1.4	4.4	1,176	34	--	Empirical
40	6.6	1.5	5.1	893	33	0.75 dabbler carrying capacity	Empirical
41	7.1	1.5	5.6	595	32	0.50 dabbler carrying capacity	Empirical
42	7.6	1.5	6.0	352	31	0.25 dabbler carrying capacity	Empirical
				Budget constraint: $32,000			
43	5.4	1.6	3.8	1,175	32	--	Empirical
44	6.3	1.7	4.6	913	32	0.75 dabbler carrying capacity	Empirical
45	7.1	1.5	5.6	595	32	0.50 dabbler carrying capacity	Empirical
46	7.6	1.5	6.0	352	31	0.25 dabbler carrying capacity	Empirical

constraints when management benefit was determined using the expert judgment data; portfolios 24–46 had the same constraints, but the empirical data on DUDs were used in place of the expert judgment data.

When using elicitation data, the optimal portfolio under a $40,000 budget constraint would include the moist-soil action for 5 units (MSUs 4, 5, 7, 8, and 11, for a total of 1,177 acres), the intermediate action for 11 units (728 acres), and the perennial action for 1 unit (MSU 3, 80 acres). When predicted outcomes are based on the empirical data, the optimal portfolio using the same budget constraint assigns the moist-soil action for 7 units (MSUs 2, 3, 4, 5, 6, 7, and 8; a total of 1,385 acres), the intermediate action for the 10 remaining units, and the perennial action for none.

When based on predictions from our expert panel, expected utility (total management benefit) in each of the units was always greatest for the intermediate action; total benefit from either moist-soil action or perennial action was always lower than total benefit from intermediate action in every unit. Results were similar when the expected utility was based on empirical data: intermediate action was best in all units, except one (MSU 7) where empirical data indicated that perennial action resulted in the greatest utility.

The intermediate action appears optimal because it simultaneously provides waterfowl habitat and potential for king rail occupancy, thus achieving both objectives to a greater degree than the moist-soil action. The moist-soil action provides greater benefit for the waterfowl objective than the intermediate action but little or no benefit for the king rail objective.

When a carrying capacity constraint was added to deliver a minimum of moist-soil acres to meet waterfowl energetic needs, the optimal portfolios assigned just enough moist-soil acres as required to meet the threshold (table 3). For both data sources, units were assigned to moist-soil composite management action only when constrained with acres over the threshold representing balances of the last selected unit's area. The average number of moist-soil acres greater than the carrying capacity constraint in the empirical portfolios is 62.4 acres, whereas the elicitation portfolio average is 27.7 acres.

In addition to the solutions in table 3, which are the result of constrained optimization routines, management benefits and costs can be plotted to provide a graphical solution for the CCNWR decision maker (fig. 7). Total management benefit is plotted as a function of total cost in figure 7 for each of the 46 portfolios in table 3. Portfolio 19 (fig. 7, upper panel, elicitation based) is the least expensive yet provides relatively high management benefit. (Note that portfolio 23 has the same set of actions as 19, identified with a different set of constraints.) If a larger budget is available, the decision maker can consider portfolio 6 and expect greater utility than under portfolio 19. Portfolio 6 (which is the same as 7) and portfolio 5 illustrate an interesting tradeoff. Although costs and total benefit are nearly identical, portfolio 6 derives greater benefit for king rail occupancy, whereas portfolio 5 derives greater benefit for DUDs (table 3). The difference between these two portfolios is that portfolio 6 assigns intermediate action in two units for which portfolio 5 assigns moist-soil action.

The graphical solution, based on elicitation data, indicates that greatest total management benefit results from the least expensive portfolio (fig. 7 bottom panel, identified as portfolio 30, 34, 38, 42, 46 under various constraints). This portfolio, identified as optimal under a variety of constraints, assigns moist-soil action in 5 units and intermediate action in the remaining 12 units. This result is meant to be interpreted with caution for two reasons. First, the expert elicitation data may have resulted in optimistic rates of king rail occupancy in response to intermediate action, increasing expected utility beyond what may be realized in the field. Second, it is important to keep in mind that this portfolio does not meet the moist-soil target, which is a priority for the refuge.

Finally, in addition to using the optimization routine to find optimal portfolios, portfolios can also be produced by direct assignments of 1 of the 3 actions to each unit. This approach could be used to assess annual work plan alternatives factoring in moist-soil acres, king rail benefits, or other constraints. As an example, results from a recent hydrogeomorphic (HGM) study (Heitmeyer and Newman, 2014) were soil type specific and applied to all units (fig. 8); the resulting coverage was used to assign units to 1 of the 3 composite management actions. This HGM-based portfolio assigned moist-soil action for 2 units (120 acres), intermediate action for 8 units, and perennial action for 7 units with a total cost of slightly more than $26,000. The elicitation based total benefit for this portfolio was 8.5, whereas the empirical based total benefit was 7.0.

Updates to Model Predictions and Expected Utility

The predicted outcomes of management and associated utility values are the foundation of this portfolio approach. Additional monitoring, adjustments to survey protocols, and the Bayesian decision network model can all be used improve the accuracy of predicted outcomes which are inputs for the decision analysis. King rail utility was consistently higher (and thus contributed more of the total benefit score) than dabbler-use utility, regardless of whether dabbler-use utility was calculated using expert judgment or empirical data (fig. 6). This outcome may be the result of overly optimistic experts regarding king rail response to management; the predicted outcomes for king rail occupancy need to be evaluated with empirical data from future monitoring efforts.

Data on dabbler abundance collected during daytime surveys will be biased towards units used as loafing areas during daylight hours, and against units with high levels of nocturnal activity. Wetland use by waterfowl is known to vary between diurnal and nocturnal periods (McNeil and others, 1992; Tamisier, 1976; Cox and Afton, 1997; Davis and others, 2009). Nocturnal feeding is assumed to be a response to hunting

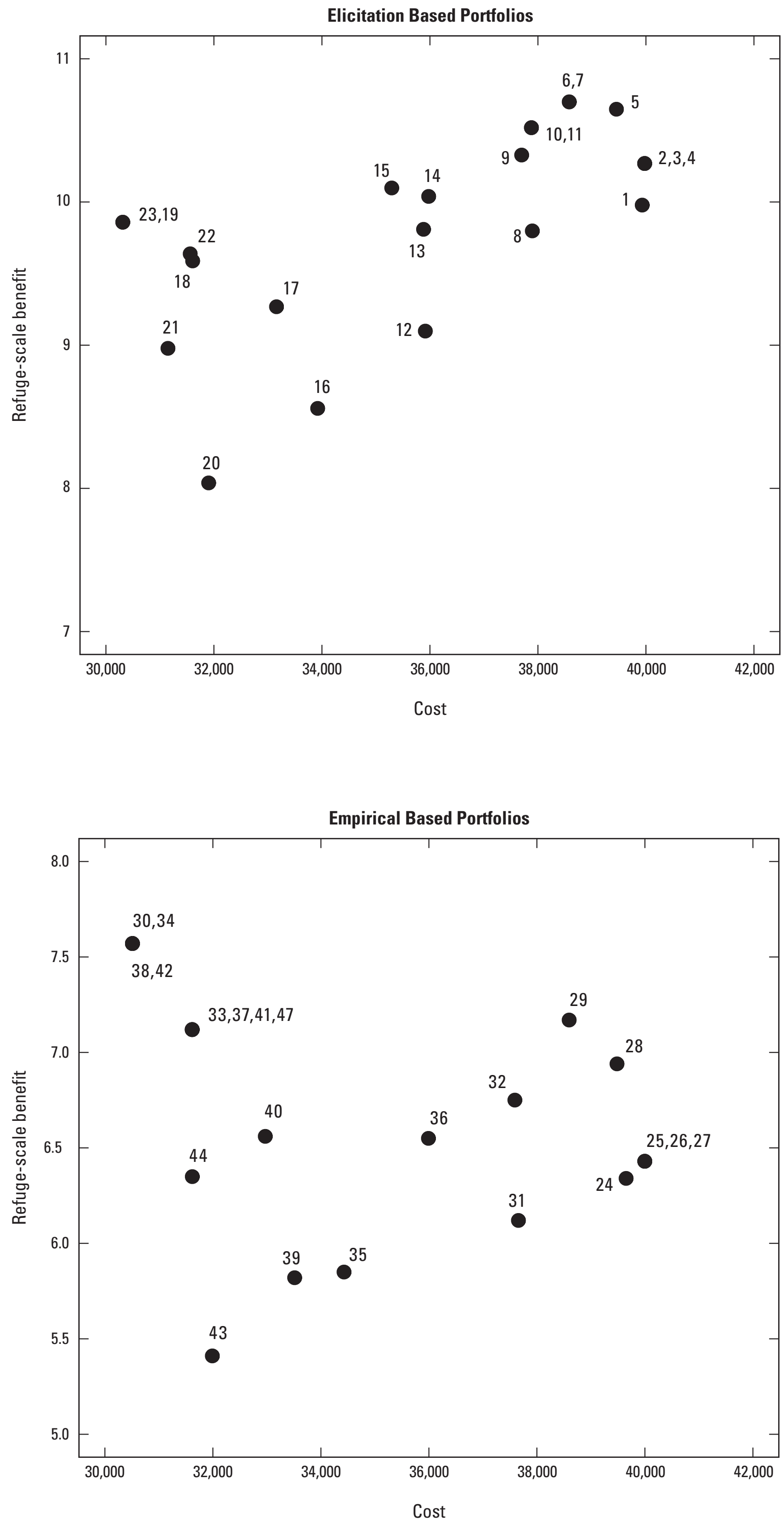

Figure 7. Total management benefit in relation to cost for selected portfolios for Clarence Cannon National Wildlife Refuge, Missouri. Total management benefit is the sum of dabbling duck and king rail utilities. Dabbling duck utility was calculated using elicitation data (upper panel) and empirical Integrated Waterbird Management and Monitoring data (lower panel) for dabbling duck use-days. King rail utility was calculated using elicitation data in both panels. Portfolios are listed in table 3.

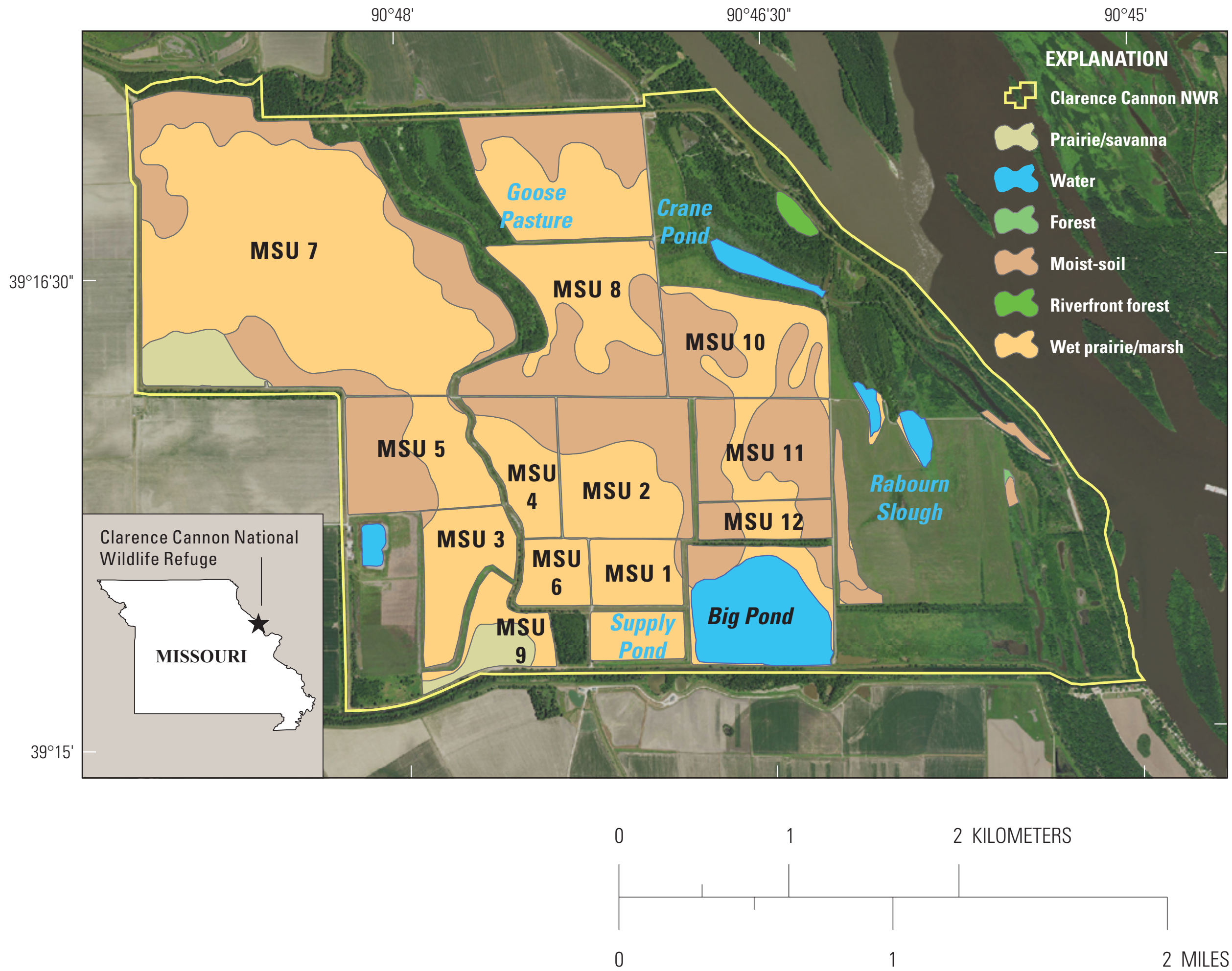

Figure 8. Results of a hydrogeomorphic evaluation of ecosystem restoration and management options at Clarence Cannon National Wildlife Refuge. Modified from Heitmeyer and Newman, 2014.

pressure and more prevalent during the fall migration. Strategies to reduce or compensate for this bias need to focus on estimating nocturnal use by direct observation or patterns of bird movement. Night surveys to assess nocturnal use are not unprecedented (Anderson and Smith, 1999). Thermal imagery and pre-dawn exit counts may also be useful in assessing levels of nocturnal use. Exit counts from known roosting units (MSU 12 and Big Pond) may also be helpful to document nocturnal feeding. A combination of exit counts and nocturnal surveys could be used to explore nocturnal use patterns in moist-soil dominated units. If nocturnal use is prevalent, protocol should be seasonally adjusted to conduct surveys at peak times of bird use.

From a CCNWR carrying capacity perspective, it is not necessary to quantify all nocturnal use in each unit; however, quantifying the proportion of the collective carrying capacity attained off-refuge could be used to adjust the carrying capacity estimate. The influence of high use-day totals from two perennial dominated units, Big Pond and MSU12, and higher king rail utility values for the intermediate composite management action were recognized early and were the impetus for adding the energetics-based carrying capacity as a threshold. Without this constraint, moist soil would not have been selected in optimized sets.

Adaptive Management Using the Bayesian Decision Model

Three components are necessary to practice adaptive management: a predictive model (or models) of the system, field observations, and a method to update the model based on observations (Williams and others, 2007). Bayesian decision models can be used effectively in the application of adaptive management (Nyberg and others, 2006). For this study, a

Bayesian decision model was created that (1) reflects critical aspects of herbaceous wetlands that affect DUDs and probability of occupancy by king rails and (2) assigns composite management actions on the basis of total utility (fig. 2). The nodes of the model that affect DUDs (for example, plant species composition, percent emergent vegetation) are monitored over time using IWMM protocols (Loges and others, 2014). The nodes of the model that affect occupancy by king rails are monitored using the North American Marsh Bird Monitoring protocol (Conway, 2011). Each year as these protocols are implemented, additional observations can be used to update the Bayesian decision model. This decision model currently relies on a combination of expert judgment and empirical data. Dabbler use-days as a function of percent emergent vegetation were estimated using data from IWMM monitoring. The effect of energy available on DUDs and the effect of woody and emergent vegetation on the probability of occupancy of king rails were estimated using expert judgment. As the Bayesian decision network model is updated, predictions from the model will rely more on field observations (empirical data) and less on expert judgment. In Netica software for Bayesian decision models, the monitoring data are passed to the network model as case files reflecting experience in the field. Cases are tallied for each node in the network and the conditional probability tables are updated on the basis of the number of times that states of the node are observed in the field. For example, each year there will be 17 cases (one for each unit) reflecting rail occupancy (yes/no), percent emergent and woody vegetation, and the composite management action implemented in the unit. Understanding of the management and environmental conditions leading to occupancy by rails improves as the number of cases of rail occupancy accrues over time. This learning leads to better understanding of the system and improved decisions that are based on what is learned, that is, adaptive management. Finally, additional models that document alternative hypotheses about how the managed system functions can be added to the framework in the future, and observations can be used to discriminate among hypotheses.

Management Considerations

The portfolio analysis indicates that widespread implementation of the intermediate composite management action would provide the greatest total management benefit for dabbling ducks and king rails. This composite management action results in the “hemi-marsh” state and is consistent with findings for wintering waterfowl (Smith and others, 2004) and the evidence that breeding king rails benefit from periodic disturbances to reduce the dominance of perennial vegetation and enhance interspersion (Bolenbaugh and others, 2012; Darrah and Krementz, 2009).

The proportion of total acres assigned to intermediate management action when the expert elicitation data were used was greater than when empirical data were used (table 4). This outcome needs to be evaluated with caution, however, because the predictions from the expert panel about the king rail response to management may be overly optimistic. Actual king rail occupancy needs to be monitored, along with cover of perennial vegetation, to ultimately build an empirical dataset that can be used to predict outcomes and assign utilities in an approach similar to the one applied to waterfowl.

The moist-soil action was selected only when a carrying capacity constraint was applied. Using empirical data on dabbler days, the moist-soil action has the lowest utility when composite management actions were evaluated without a carrying capacity constraint (table 4) and would be assigned only to meet energy demands of winter/migrating dabblers. Fortunately, the information and procedures to estimate the energetic demands of a migratory and wintering waterfowl at the local scale are well established (Heitmeyer, 2010; Williams and others, 2014) and can be used to quantify the carrying capacity targets in annual work plans. A regionally derived kcal per acre number was used in this approach, but site-specific estimates are highly encouraged (Gray and others, 2009). Seed production may be underrepresented by the current estimate given the refined management approach being implemented at CCNWR. However, seed production estimates can be time consuming, variable, and may exceed the survey capacity of the refuge.

Without an estimate of the proportion of the waterfowl energy obtained off-refuge, the most conservative approach assumes all waterfowl attain 100 percent of their energy on-refuge. Until the carrying capacity approach can be refined, the constraint of 1,174 acres of moist-soil dominated vegetation could serve as a general annual target but is not meant to be misinterpreted as acres in moist-soil composite management action because moist-soil vegetation can also occur within the other two composite management actions.

Previous versions of the IWMM vegetation survey protocol did not capture the proportion of a unit in moist-soil vegetation. However, the revised IWMM fall vegetation survey can be used to monitor the proportion of units dominated by moist-soil vegetation, total moist-soil acres, and a seed production index. Owing to limitations of the pilot vegetation data protocol, moist-soil present in the other two composite management actions could not be captured as part of the total moist-soil acres. Subsequent versions of this prototype could be developed to use data collected under the new protocol. Specifically, the feasibility of pairing composite management actions with unit level proportions of moist-soil vegetation need to be explored.

Changes to the Bayesian Decision Model

The refuge’s Habitat Management Plan explicitly identified the need to address potentially conflicting wetland management objectives. The approach to decision support used in this study focuses on achieving multiple waterbird objectives

Table 4. Predicted relative proportion of total acres by composite management action and data type when using empirical and expert judgment, Clarence Cannon National Wildlife Refuge, Missouri.

[Portfolios with pre-assigned composite management actions are not listed]

Constraint set	Moist-soil acres		Intermediate acres		Perennial acres	
	Empirical	Expert	Empirical	Expert	Empirical	Expert
4	0.55	0.54	0.45	0.42	0	0.04
5	0.55	0.41	0.3	0.59	0.16	0
6	0.51	0.33	0.49	0.67	0	0
7	0.6	0.33	0.4	0.67	0	0
8	0.55	0.54	0.45	0.32	0	0.14
9	0.89	0.42	0.11	0.49	0	0.09
10	0.51	0.33	0.35	0.64	0.14	0.04
11	0.6	0.33	0.4	0.64	0	0.04
12	0.55	0.54	0.45	0.22	0	0.24
13	0.9	0.41	0.1	0.41	0	0.18
14	0.74	0.33	0.26	0.54	0	0.13
15	0.6	0.14	0.4	0.79	0	0.07
16	0.55	0.54	0.45	0.12	0	0.33
17	0.93	0.43	0.03	0.24	0.04	0.33
18	0.75	0.27	0.18	0.4	0.07	0.33
19	0.6	0.14	0.4	0.53	0	0.33
20	0.55	0.54	0.45	0.03	0	0.43
21	0.55	0.41	0.45	0.18	0	0.42
22	0.55	0.27	0.45	0.4	0	0.33
23	0.55	0.14	0.45	0.53	0	0.33
Mean	0.63	0.37	0.35	0.44	0.02	0.19

while exploring alternatives that would result in a variety of successional stages. The predictive model incorporated historical IWMM data and expert judgment. The Bayesian decision model created as part of this study can be updated over time and customized on the basis of the decision maker's needs. Although the process was not intended to provide prescriptions for managing individual impoundments, the variety of outcomes among portfolios can be very informative for habitat allocation decisions across the CCNWR. The framework created for this study can be a decision-aiding tool to inform and advise managers facing difficult management decisions.

This decision framework is being developed through an iterative process to incorporate feedback from the decision makers, update values for variables and constants, and expand the temporal scope. Two informal presentations updated the decision makers on the project's status and gathered suggestions for modifications to the framework. The next iteration of the framework likely will explore the potential for a transition to a 15-year management cycle approach.

Additional monitoring is needed to reduce dependency on expert elicitation. Critical metrics include waterfowl use-days and king rail occupancy for each management unit and for management actions applied each year. A site-specific protocol that incorporates surveys under the IWMM and the North American marsh bird protocols is being developed with standard operating procedures that could be implemented beginning with 2017 marsh bird nesting season. The revised protocol will capture moist-soil proportion for all composite management actions, and the decision support framework can be refined to more accurately document acres contributing to the carrying capacity of the CCNWR.

Summary

The hydrology and natural communities of the Clarence Cannon National Wildlife Refuge (CCNWR) in Missouri have been highly modified. The staff of the CCNWR seeks tools to actively manage the CCNWR to maintain *Anas Linnaeus* (dabbling duck) and *Rallus elegans* (king rail) habitats. The U.S. Geological Survey conducted a study to develop an approach or actions that will assist the CCNWR staff in making management decisions. Eight major points are discussed in the report.

- The approach developed for this study is intended to provide the refuge with rigorous decision support for two objectives: dabbling duck use-days and king rail occupancy.
- The portfolio analysis helps managers identify an effective strategy for multiple units.
- The Bayesian decision model can be updated over time with monitoring data and be used as a predictive tool in an adaptive management framework.
- Of the composite management actions—moist soil, intermediate, and perennial—the intermediate action provided greatest expected utility. Yet, a mix of composite management actions across all units was preferred to maximize total benefit and meet multiple objectives.
- Carrying capacity dictates how many moist-soil acres are needed. This approach could be refined with seed production estimates for the 17 units, decomposition adjustments, and estimates of energetic contributions from invertebrates.
- For units receiving moist-soil and intermediate composite management actions, estimated dabbling duck use-days derived from empirical observations was lower than use-days from expert judgment in all but a single comparison. The empirical data indicated greater use of units managed with the perennial action than was predicted using expert judgment. Fifty-eight percent of the estimates from empirical data for dabbling duck use-days under perennial actions exceeded the estimates elicited from the expert panel.
- King rail response to management and associated utility needs to be updated by monitoring king rail occupancy concurrently with vegetation cover and hydrology of each unit in the CCNWR. Expert judgment on the probability of occupancy by rails may be overly optimistic.
- This approach assumes all units stay in an herbaceous state and reinforces the need to suppress or reverse afforestation within this set of management units for the benefit of king rails and dabbling ducks.

References Cited

Anderson, J.T., and Smith, L.M., 1999, Carrying capacity and diel use of managed Playa Wetlands by nonbreeding waterbirds: Wildlife Society Bulletin, v. 27, no. 2, p. 281–291.

Bolenbaugh, J.R., Cooper, Tom, Brady, R.S., Willard, K.L., and Krementz, D.G., 2012, Population status and habitat associations of the king rail in the midwestern United States: Waterbirds, v. 35, no. 4, p. 535–545.

Bowyer, M.W., Stafford, J.D., Yetter, A.P., Hine, C.S., Horath, M.M., and Havera, S.P., 2005, Moist-soil plant seed production for waterfowl at Chautauqua National Wildlife Refuge: American Midland Naturalist, v. 154, p. 331–341.

Brasher, M.G., Steckel, J.D., and Gates, R.J., 2007, Energetic carrying capacity of actively and passively managed wetlands for migrating ducks in Ohio: The Journal of Wildlife Management, v. 71, no. 8, p. 2532–2541.

Conroy, M.J., and Peterson, J.T., 2013, Decision making in natural resource management: a structured, adaptive approach: West Sussex, UK, John Wiley and Sons, 474 p.

Conway, C.J., 2011, Standardized North American marsh bird monitoring protocol: Waterbirds, v. 34, p. 319–346.

Cox, R.R., and Afton, A.D., 1997, Use of habitats by female northern pintails wintering in southwestern Louisiana: The Journal of Wildlife Management. v. 61, no. 2 p. 435–443.

Darrah, A.J., and Krementz, D.G., 2009, Distribution and habitat use of king rails in the Illinois and upper Mississippi River Valleys: Journal of Wildlife Management, v. 73, no. 8, p. 1380–1386.

Davis, B.E., Afton, A.D., and Cox, R.R., 2009, Habitat Use by Female Mallards in the Lower Mississippi Alluvial Valley: Journal of Wildlife Management, v. 73, no. 5, p. 701–709.

ESRI, 2011, ArcGIS Desktop: Release 10: Redlands, Calif., Environmental Systems Research Institute.

Farmer, A., and Durbian, F., 2006, Estimating shorebird numbers at migration stopover sites: Condor, v. 108, p. 792–807.

Fleishman, E., Murphy, D.D., and Brussard, P.F., 2000, A new method for selection of umbrella species for conservation planning: Ecological Applications, v. 10, p. 569–579.

Fredrickson, L.H., and Taylor, T.S., 1982, Management of seasonally flooded impoundments for wildlife: Washington, D.C., U.S. Fish and Wildlife Service, Resource Publication no. 148.

Gray, M.J., 2012, Lower Swan Lake drawdown seed yield and duck-energy day estimates: Knoxville, Tenn., University of Tennessee, Seed production and DED estimates report, 5 p.

Gray, M.J., 2013, Lower Swan Lake drawdown seed yield and duck-energy day estimates: Knoxville, Tenn., University of Tennessee, Seed production and DED estimates report, 4 p.

Gray, M.J., Foster, M.A., and Peña Peniche, L.A., 2009, New technology for estimating seed production of moist-soil plants: Journal of Wildlife Management, v. 73, p. 1229–1232.

Greer, A.D., Dugger, B.C., Graber, D.A., and Petrie, M.J., 2007, The effects of seasonal flooding on seed availability for spring migrating waterfowl: Journal of Wildlife Management, v. 71, p. 1561–1566.

Hagy, H.M., Yetter, A.P., Stodola, K.W., Horath, M.M., Hine, C.S., Ward, M.P., Benson, T.J., Smith, R.V., and Stafford, J.D., 2014, Stopover duration of mallards during autumn in the Illinois River valley: Journal of Wildlife Management, v. 78, p. 747–752.

Heitmeyer, M.E., 2010, A manual for calculating duck-use-days to determine habitat resource values and waterfowl population energetic requirements in the Mississippi Alluvial Valley: Bloomfield, Mo., Greenbrier Wetland Services Report 10–01.

Heitmeyer, M.E., and Newman, B.M., 2014, Hydrogeomorphic evaluation of ecosystem restoration and management options for Clarence Cannon and Great River National Wildlife Refuges, prepared for U.S. Fish and Wildlife Service, Region 3, Refuges and Wildlife, Minneapolis, Minn.: Bloomfield, Mo., Greenbrier Wetland Services Report 14–03.

Kahler, B.M., Pierce, R.L., and Soulliere, G.J., 2014, State X BCR Assessment: Missouri 22– Eastern Tallgrass Prairie, Upper Mississippi River and Great Lakes Region Joint Venture: Bloomington, Minn., U.S. Fish and Wildlife Service.

Kaminsky, R.M., Davis, B.T., Essig, H.W., Gerard, P.D., and Reinecke, K.J., 2003, True metabolizable energy for wood ducks from acorns compared to other waterfowl foods: Journal of Wildlife Management, v. 67, p. 542–550.

Kirkwood, C.W., 1997, Strategic decision making: Multiobjective decision analysis with spreadsheets: Belmont, Calif., Duxbury Press, 352 p.

Kross, J., and Kaminski, M.K., 2008, Moist-soil seed abundance in managed wetlands in the Mississippi Alluvial Valley: Journal of Wildlife Management, v. 72, p. 707–714.

Larkin, D.J., Brady, R.S., Kahler, B.M., Koch, K.E., Krementz, D.G., Monfils, M.J., Soulliere, G.J., and Webb, E.B., 2013, Collaborative research on secretive marsh birds in the Midwest Region: Linking monitoring and wetland management: Bloomington, Minn., Upper Mississippi River and Great Lakes Region Joint Venture Technical Report No. 2013–1.

Loges, B.W., Tavernia, B.G., Wilson, A.M., Stanton, J.D., Herner-Thogmartin, J.H., Casey, J., Coluccy, J.M., Coppen, J.L., Hanan, M., Heglund, P.J., Jacobi, S.K., Jones, T., Knutson, M.G., Koch, K.E., Lonsdorf, E.V., Laskowski, H.P., Lor, S.K., Lyons, J.E., Seamans, M.E., Stanton, W., Winn, B., and Ziemba, L.C., 2014, National protocol framework for the inventory and monitoring of nonbreeding waterbirds and their habitats, an Integrated Waterbird Management and Monitoring Initiative (IWMM) approach: Fort Collins, Colo., Natural Resources Program Center.

Low, J.P., and Bellrose, F.C., 1944, The seed and vegetative yield of waterfowl food plants in the Illinois River Valley: Journal of Wildlife Management, v. 8, p. 7–22.

Marcot, B.G., Steventon, J.D., Sutherland, G.D., and McCann, R.K., 2006, Guidelines for developing and updating Bayesian belief networks applied to ecological modeling and conservation: Canadian Journal of Forest Research, v. 36, p. 3063–3074.

McNeil, R., Drapeau P., and Goss-Custard, J.D., 1992, The occurrence and adaptive significance of nocturnal habits in waterfowl: Biological Reviews, v. 67, p. 381–419.

Millar, R.B., and Jordan, C.E., 2013, A simple variance estimator for the trapezoidal area-under-the-curve estimator of the spawner abundance of Pacific salmon: Canadian Journal of Fisheries and Aquatic Sciences, v. 70, p. 1231–1239.

Norsys Software Corporation, 2014, Netica, version 5.18, Bayesian network development software, accessed March 16, 2014, at http://www.norsys.com/.

Nyberg, J.B., Marcot, B.G., and Sulyma, R., 2006, Using Bayesian belief networks in adaptive management: Canadian Journal of Forest Research, v. 36, p. 3104–3116.

O'Neal, B.J., Stafford, J.D., and Larkin, R.P., 2012, Stopover duration of fall migrating dabbling ducks: Journal of Wildlife Management, v. 76, p. 285–293.

Smith, L.M., Haukos, D.A., and Prather, R.M., 2004, Avian response to vegetative pattern in playa wetlands during winter: Wildlife Society Bulletin, v. 32, no. 2, p. 474–480.

Speirs-Bridge, A., Fidler, R., McBride, M., Flander, L., Cumming, G., and Burgman, M., 2010, Reducing overconfidence in the interval judgments of experts: Risk Analysis, v. 30, no. 3, p. 512–523.

Stafford, J.D., Yetter, A.P., Hine, C.S., Smith, R.V., and Horath, M.M., 2011, Seed abundance for waterfowl in wetlands managed by the Illinois Department of Natural Resources: Journal of Fish and Wildlife Management, v. 2, no. 1, p. 3–11.

Tamisier, A., 1976, Diurnal activities of green-winged teal and pintail wintering in Louisiana: Wildfowl, v. 27, p. 19–32.

Theiling, C.H., Korschgen, C., De Haan, H., Fox, T., Rohweder, J., and Robinson, L., 2000, Habitat needs assessment for the Upper Mississippi River system: Technical Report. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin: Contract report prepared for U.S. Army Corps of Engineers, St. Louis District, St. Louis, Missouri, 248 p., 27 app.

U.S. Fish and Wildlife Service, 2004, Mark Twain National Wildlife Refuge Complex, Comprehensive Conservation Plan and Environmental Assessment: Bloomington, Minn., 184 p.

U.S. Fish and Wildlife Service, 2012, Great River and Clarence Cannon National Wildlife Refuges Habitat Management Plan: Annada, Mo., U.S. Fish and Wildlife Service, Great River NWR Complex, 165 p.

Williams, B.K., Szaro, R.C., and Shapiro D.C., 2007, Adaptive Management: The U.S. Department of the Interior Technical Guide: Washington, D.C., Adaptive Management Working Group, U.S. Department of the Interior, 72 p.

Williams, C.K., Dugger, B.D., Brasher, M.G., Coluccy, J.M., Cramer, D.M., Eadie, J.M., Gray, M.J., Hagy, H.M., Livolsi, M., McWilliams, S.R., Petrie, M., Soulliere, G.J., Tirpak, J.M., and Webb, E.B., 2014, Estimating habitat carrying capacity for migrating and wintering waterfowl: considerations, pitfalls and improvements: Wildfowl, no. 4, p. 407–435.

Appendixes 1, 2, and 3

Appendix 1

Expert Elicitation Guidance for Clarence Cannon National Wildlife Refuge Prototype Decision Model.

Appendix 2

Assigning Composite Management Actions in a Retrospective Analysis.

Appendix 3

Empirical- and Elicitation-Based Dabbler Use-Days and Utilities.

Appendix 1. Expert Elicitation Guidance for Clarence Cannon National Wildlife Refuge Prototype Decision Model

A communication was sent to several experts on dabbling ducks and king rails. The entire communication in original form is provided below.

Thank you for participating in this expert elicitation. Your knowledge of the Clarence Cannon wetlands and wetland birds will help us build a decision support tool for the refuge. Remember, the exercises below are only starting points for our prototype, so it is not necessary to spend an inordinate amount of time on them. It is not necessary to research the questions or refer to available data. From this starting point, we will improve the decision support over time. Feel free to contact Brian Loges (brian_loges@fws.gov; (618) 883-2524) or Jim Lyons (james_lyons@fws.gov; (301) 497-5682) with any questions (but we ask that you complete the datasheets without consulting the other experts).

Guidance for Drawing Dabbler Migration Curves

Introduction

Our decision framework requires a prediction for the number of dabbler use-days between 1 Sep and 15 May. Therefore, the curve we are drawing is for all dabblers combined for that period. Please print out the pdf document "Mig_Curve_Elicitation_blank.pdf". This document contains 17 pages—one for each managed wetland. Each tick mark on x-axis represents one week of the month. Before you begin, decide on the following aspects of the migration curve (the table below is just a scratch pad—it is not necessary to submit these notes with your migration curves):

1. Week that dabblers first arrive (e.g., "second week of September")?	_________ _____________ _____________ ________
2. Week that dabblers depart the area (when would you expect the counts to drop to zero)?	_________ _____________ _____________ ________
3. What is the peak count during the season (# of birds)? If there is more than one peak count, enter the peaks here separated by slashes (e.g. 1,200/700 for an initial peak of 1,200 followed by a later peak of 700)	_________ _____________ _____________ ________

Steps to Drawing the Migration Curves for Each Managed Wetland

1. Start with the "Moist-soil" action.
2. Label the y-axis tick marks with a range that includes the expected high count in this unit. It is not necessary to label each and every tick mark. See the slides from the webinar for examples.
3. What is the first week that birds arrive? Place a dot on the x-axis at this week.
4. What is the last week that birds are in the area? Place a dot on the x-axis.
5. What week or weeks during the season will have the peak count(s)? There may be multiple peaks during the season. Mark these peak counts with dots at the appropriate week(s) on the diagram.
6. Connect the "arrival" dot with the peak(s) and with the "departure" dot with a solid line (curve) that represents the migration curve you would expect to see in an average year.
7. Repeat for "Limited Soil Disturbance" and "Idle" management actions in this wetland on the same sheet; add a separate curve for each action. There should be three migration curves on each sheet.

Notes

You can make the slope and shape of the curve represent any pattern of change over time within the nonbreeding season that you believe represents an average year. The curve can increase (and decrease) quickly or slowly over time; the curves can be as jagged or smooth as you like.

Estimated time to complete: It should require only a few minutes per wetland to draw 3 migration curves. It is not necessary to refer to actual migration curves using available data. We would like you to rely on your current knowledge of dabbers during the nonbreeding season. The migration curves and estimated dabbler-days are merely starting points for our decision making framework. Moving forward, we will rely on data from our monitoring programs to improve our decision support over time.

Rely on your knowledge to draw the migration curve you would expect in an average year. Blank sheets are in the file "Migr_Curve_Elicitation_blank.pdf".

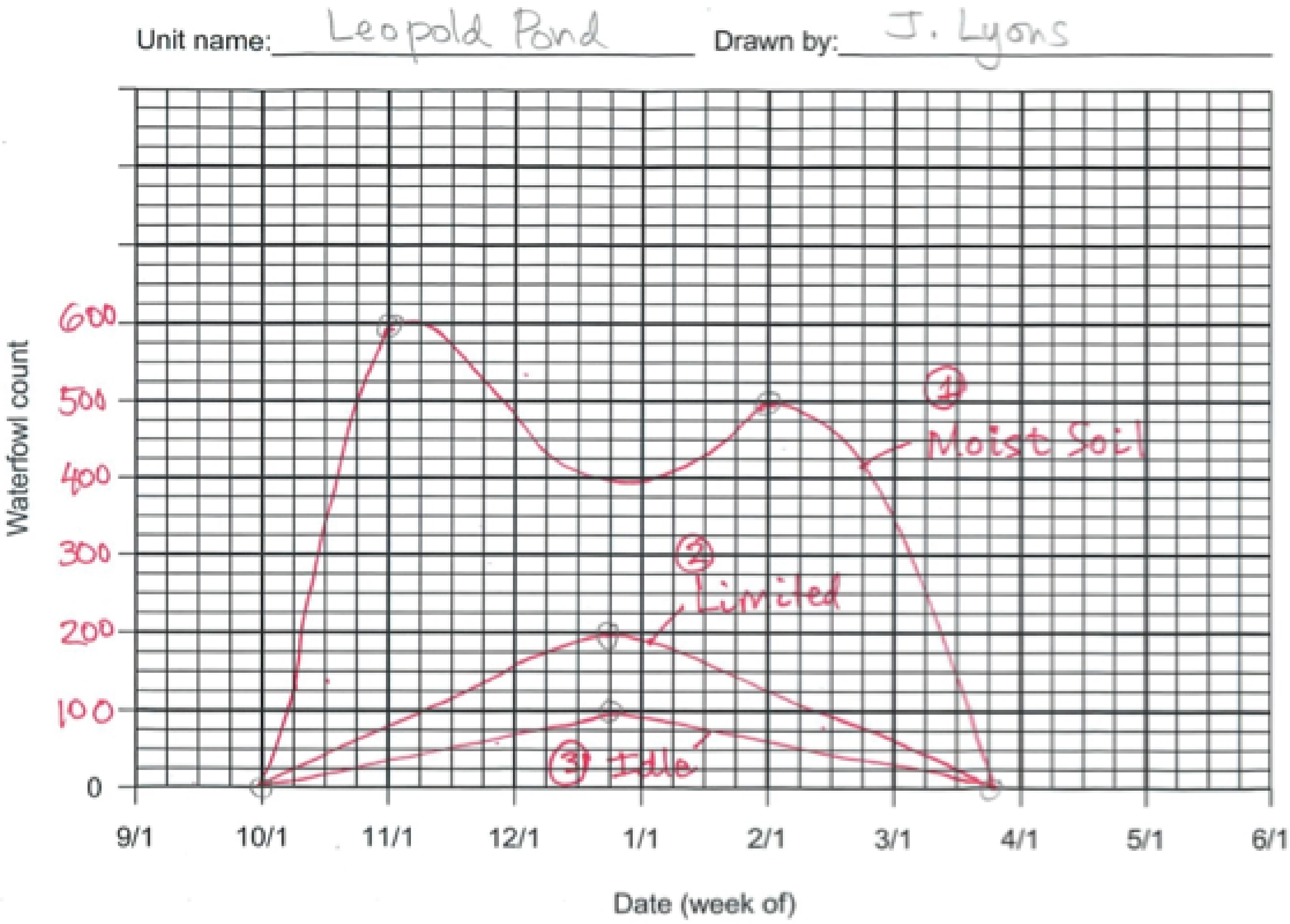

Figure 1-1. Example migration curve. Remember this is just for illustration!

Guidance for Estimating King Rail Occupancy

Introduction

In our webinar, we decided to use King Rail occupancy as our objective in the decision support tool. Rather than attempting to elicit occupancy probability in the range 0.0–1.0, we would like to base the elicitation on the number of years that rails would occupy the wetland during the timeframe of the HMP.

Here we ask you to consider the time frame of the HMP, 15 years, and assess the number of years out of 15 that each wetland—under a given management action—would be occupied by rails.

Steps to Predicting King Rail Occupancy

Please complete the data sheet "King Rail Elicitation v0.2.pdf" which has space for each of these questions. As we discussed on the webinar, we are using the 4-point method, which is a process to capture the uncertainty in the management outcome by asking 4 questions:

- What is the fewest number of years out of 15 that the unit would be occupied under this management action?
- What is the greatest number of years out of 15 that the unit would be occupied under this management action?
- What is the most likely number of years out of 15 that the unit would be occupied under this management action? (The most likely value need not be right in the center of the interval; the most likely value may be closer to one end of the range.)
- How confident (0–100%) are you that the interval you created will capture the true value?

Question 4 may be the most challenging. Your confidence level (0–100%) will be impacted by many factors: the relative width of the interval you created, your understanding of the variability from year to year in King Rail occupancy, your understanding of the impact of the composite management actions on King Rails, and other factors you feel impact King Rail occupancy. There is no right or wrong answer; your confidence level will help us interpret the interval you provided and the most likely value.

Notes

Estimated time to complete: Approximately 30–60 minutes. This is only a suggested time to complete; if you feel you can complete in less than 30 minutes, that is fine. It is not necessary to research prior use of these management units by rails or refer to available data to complete this exercise. We only need you to rely on your experience to date with King Rails. This is only a starting point—we will improve our decision support tools over time. We will provide copies of King Rail articles by Bolenbaugh et al. 2012 and Darrah and Krementz 2009 for your convenience but it is not necessary to consider these articles to complete the data sheet.

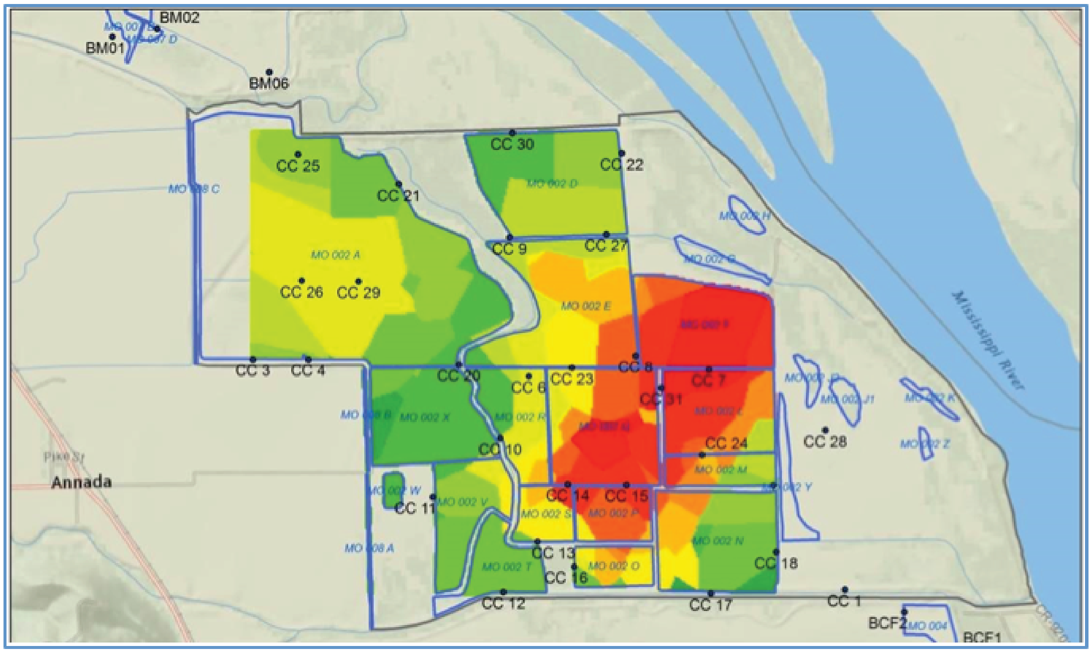

Figure 1-2. King Rail occupancy at Clarence Cannon based on available data. Colors reflect occupancy probability from low (dark green) to high (red). Provided here only for your convenience during expert elicitation; it is not necessary to rely on this map when providing your judgments on the data sheet.

Unit	Action #	Management Action	The number of years, out of 15, with King Rails occupying the wetland (0-15): Realistically, the number of years could be as low as:	Realistically, the number of years could be as high as:	What is your most likely estimate?	How confident (0-100%) are you that the interval you created will capture the true value?	acres
Big Pond	1	Moist-soil	0	5	1	75%	147
Big Pond	2	Ltd. Soil Disturbance	5	10	8	90%	147
Big Pond	3	Idle	3	8	5	50%	147
Crane Pond	1	Moist-soil					15
Crane Pond	2	Ltd. Soil Disturbance					15
Crane Pond	3	Idle					15

Figure 1-3. Screenshot of King Rail elicitation data sheet ("King Rail Elicitation v0.2.pdf"). For illustration purposes only! Do not limit your answers based on this hypothetical example. Number of years can range from 0–15 and confidence level can range from 0–100%.

Appendix 2. Assigning Composite Management Actions in a Retrospective Analysis

To relate future bird responses to implemented composite management actions, bird monitoring and management action data will be summarized at the unit scale. Units are classified into a composite management action based on the proportion of the units receiving various strategies.

Strategies are pooled into two influential groups within the Clarence Cannon National Wildlife Refuge decision context: moist-soil and water-level manipulations. All strategies that decrease perennial vegetation though soil disturbance, cropping, chemical application, mowing, or intense grazing were tagged as a moist-soil strategies. Water-level strategies that decrease pool water levels through active or passive means were tagged as drawdown strategies. The portion of a unit receiving moist-soil strategies for an 18-month period (two growing seasons) prior to the start of the targeted fall waterfowl migration season, drawdown portion, and completion dates for the summer prior to same migration period are used as bounds in the following dichotomous key to the actions.

1. Portion of the unit with a drawdown strategy[1] completed prior to July 15 is greater than 50 percent...go to 2. Portion of the unit with a drawdown strategy completed prior to July 15 is greater than 50 percent...go to 4.

2. Portion of unit with compiled moist-soil strategies[2] is greater than 75 percent... “Moist-soil.” Portion of unit with compiled moist-soil strategies is less than 75 percent... “Other.”

3. Portion of unit with compiled moist-soil strategies is greater than 75 percent... “Other.” Portion of unit with compiled moist-soil strategies is less than 75 percent... go to 4.

4. Portion of unit with compiled moist-soil strategies is greater than 25 percent...”Intermediate.” Portion of unit with compiled moist-soil strategies is less than 25 percent... “Perennial.”

[1]Current season.

[2]Moist-soil strategies are identified as soil disturbance strategies over the past 18 months, including crop production.

Appendix 3. Empirical- and Elicitation-Based Dabbler Use-Days and Utilities

Table 3-1. Empirical- and elicitation-based dabbler use-days and utilities, by unit and composite management action.

[Empirical data: 2010–13 Integrated Waterbird Management and Monitoring surveys. Figures in italics are imputed values using the average use-days from other units (adjusted for unit area) when no empirical data were available for a particular composite management action. $u(d_1)$, utility derived from empirical use-days; $u(d_2)$, utility derived from elicitation use-days]

Unit	Composite management action	Empirical	$u(d_1)$	Elicitation	$u(d_2)$
		Use-days (d_1)		Use-days (d_2)	
Big Pond	Moist-soil	*345,273*	0.03	5,560,937	0.93
Big Pond	Intermediate	2,010,981	0.20	4,841,562	0.81
Big Pond	Perennial	*2,102,124*	0.21	3,679,687	0.61
Crane Pond	Moist-soil	*36,167*	0.00	1,123,125	0.17
Crane Pond	Intermediate	*52,500*	0.00	1,123,125	0.17
Crane Pond	Perennial	*35,201*	0.00	683,267	0.10
Goose Pasture	Moist-soil	*417,003*	0.04	1,225,937	0.19
Goose Pasture	Intermediate	96,097	0.01	995,125	0.15
Goose Pasture	Perennial	43,395	0.00	310,375	0.04
MSU 1	Moist-soil	*121,448*	0.01	875,625	0.13
MSU 1	Intermediate	68,755	0.01	524,125	0.07
MSU 1	Perennial	*739,409*	0.07	142,562	0.01
MSU 2	Moist-soil	183,216	0.02	2,242,250	0.37
MSU 2	Intermediate	475,451	0.05	1,620,000	0.26
MSU 2	Perennial	*2,244,312*	0.22	484,313	0.07
MSU 3	Moist-soil	210,384	0.02	1,122,125	0.17
MSU 3	Intermediate	227,731	0.02	670,688	0.10
MSU 3	Perennial	*1,147,637*	0.11	300,312	0.03
MSU 4	Moist-soil	*181,269*	0.02	742,125	0.11
MSU 4	Intermediate	42,823	0.00	386,375	0.05
MSU 4	Perennial	122,670	0.01	121,375	0.00
MSU 5	Moist-soil	*302,196*	0.03	1,463,125	0.23
MSU 5	Intermediate	208,113	0.02	795,125	0.12
MSU 5	Perennial	*1,839,857*	0.18	297,125	0.03
MSU 6	Moist-soil	*90,960*	0.01	775,375	0.11
MSU 6	Intermediate	161,555	0.01	455,375	0.06
MSU 6	Perennial	*553,794*	0.05	143,313	0.01
MSU 7	Moist-soil	532,950	0.05	4,693,750	0.78
MSU 7	Intermediate	1,165,793	0.11	2,705,625	0.44
MSU 7	Perennial	*10,174,154*	1.00	1,224,375	0.19
MSU 8	Moist-soil	457,853	0.04	394,375	0.05
MSU 8	Intermediate	*61,792*	0.00	253,750	0.03
MSU 8	Perennial	56,433	0.00	103,250	0.00
MSU 9	Moist-soil	134,894	0.01	473,188	0.06
MSU 9	Intermediate	195,810	0.02	392,938	0.05
MSU 9	Perennial	821,272	0.08	288,713	0.03
MSU 10	Moist-soil	412,217	0.04	723,125	0.11
MSU 10	Intermediate	*482,279*	0.05	466,250	0.06

Table 3-1. Empirical- and elicitation-based dabbler use-days and utilities, by unit and composite management action.—Continued

[Empirical data: 2010–13 Integrated Waterbird Management and Monitoring surveys. Figures in italics are imputed values using the average use-days from other units (adjusted for unit area) when no empirical data were available for a particular composite management action. $u(d_1)$, utility derived from empirical use-days; $u(d_2)$, utility derived from elicitation use-days]

Unit	Composite management action	Empirical	u (d_1)	Elicitation	u (d_2)
		Use-days (d_1)		Use-days (d_2)	
MSU 10	Perennial	11,037	0.00	196,875	0.02
MSU 11	Moist-soil	494,347	0.05	2,896,875	0.48
MSU 11	Intermediate	572,781	0.06	1,704,375	0.27
MSU 11	Perennial	1,647,141	0.16	590,000	0.08
MSU 12	Moist-soil	101,397	0.01	5,541,563	0.93
MSU 12	Intermediate	147,187	0.01	5,955,313	1.00
MSU 12	Perennial	2,363,071	0.23	5,605,313	0.94
Rabourn Slough	Moist-soil	12,097	0.00	285,750	0.03
Rabourn Slough	Intermediate	17,559	0.00	251,250	0.03
Rabourn Slough	Perennial	73,649	0.01	125,125	0.00
Supply pond	Moist-soil	91,130	0.01	550,625	0.08
Supply pond	Intermediate	150,113	0.01	358,750	0.04
Supply pond	Perennial	*554,829*	0.05	215,500	0.02

Publishing support provided by the
U.S. Geological Survey Science Publishing Network,
West Trenton Publishing Service Center

For more information concerning the research in this report, contact:
Director, Patuxent Wildlife Research Center
U.S. Geological Survey
12100 Beech Forest Road, Ste 4039
Laurel, MD 20708-4039

http://www.pwrc.usgs.gov/

USGS

Loges and others—**Habitat Delivery for Breeding Marsh Birds and Nonbreeding Waterfowl, Clarence Cannon National Wildlife Refuge, Mo.**—Open-File Report 2017–1051

ISSN 2328-0328 (online)
https://doi.org/10.3133/ofr20171051