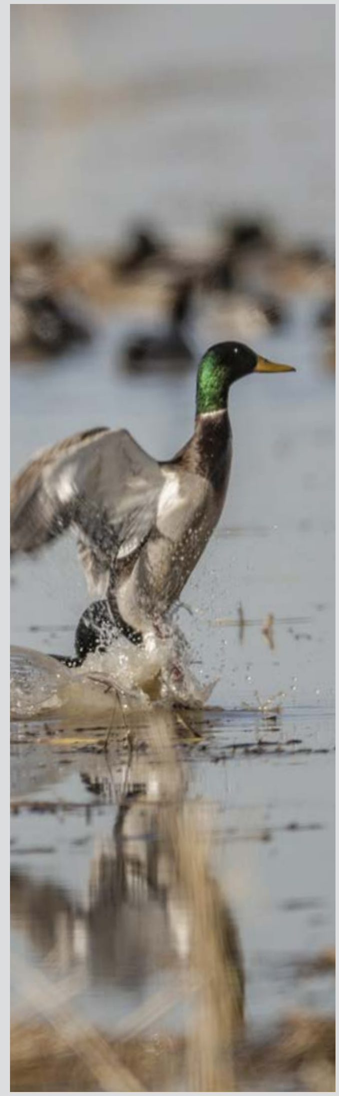
USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

Wetland Easements Support Wintering Waterfowl in the Mississippi Alluvial Valley

Conservation Effects Assessment Project (CEAP)
Conservation Insight

Key Takeaways

- The USDA Natural Resources Conservation Service (NRCS) administers Wetland Reserve Easements through the Agricultural Conservation Easement Program (ACEP), formerly the Wetland Reserve Program, to assist landowners in restoring and improving wetland habitats on private land.
- Conservation Effects Assessment Project (CEAP)-Wildlife cooperators at the University of Missouri (MU) conducted an assessment of how landscape conditions in the Mississippi Alluvial Valley (MAV), including NRCS wetland easements, support and influence wintering mallard populations.
- Focusing on a 29,000-km² study area in east-central Arkansas, an agent-based modeling (ABM) framework was used to model several scenarios to evaluate mallard response to variation in amount and spatial arrangement of food energy provided by wetland habitats in the MAV.
- Modeling revealed that simulated absence of existing wetland easements would result in the reduction of wintering mallard population size by ~70–80% in the study area under normal environmental conditions, emphasizing the important role current wetland easements play in wintering waterfowl conservation.
- Models indicated that increasing easement area through the addition of new easements would be more effective than increasing the size of existing easements and would increase mallard populations by 10–16% over baseline conditions.
- Adding fewer, larger area easements generally increased the simulated mallard population more than adding smaller, more numerous easements. These results can be used to inform waterfowl conservation planning on private lands.



Over 725,000 acres of WRE wetlands throughout the Mississippi Alluvial Valley constitute an important habitat for mid-continent waterfowl populations that migrate to this area to spend the winter months.
Photo by Chris Willis, USDA.

Background

The Wetland Reserve Easements (WRE) program administered by NRCS provides landowners with support and incentives to restore and improve wetland habitats on private land. The over 725,000 acres of WRE wetlands throughout the Mississippi Alluvial Valley (MAV) constitute an important habitat for mid-continent waterfowl populations that migrate to this area to spend the winter months. Easement planning and management for the benefit of waterfowl populations depends on understanding waterfowl responses to habitat conditions, which may be based on complex and emergent interactions between behavioral, environmental and anthropogenic factors.

An assessment of the potential benefits and drawbacks of alternative approaches to restore wetlands in terms of areas, configurations, and conditions could inform conservation planning. Such assessments assist in identifying how and where conservation easements might be best allocated in the future to serve migratory birds. This information can help evaluate the contribution of current NRCS wetland easements to waterfowl conservation as well as inform future conservation planning.

A well-established method to assist planning efforts for waterfowl habitat management in non-breeding areas is the use of bioenergetics models. Such models are used to estimate the energetic carrying capacity of habitats, or the time period that food resources in a landscape could sustain a

given waterfowl population. In its most basic form, this type of model estimates carrying capacity as "duck energy-days" (DEDs) by calculating the ratio of total food energy available in the landscape to daily energy expenditure of the total duck population (Williams et al. 2014). Landscape conditions can then be characterized by their provision of the number of DEDs, and management practices can be evaluated by their capacity to enhance this value. DED models are widely used and readily applied at large scales due to their modest data requirements. However, DED models are subject to a number of limitations in that they treat a waterfowl population as a single unit, ignoring individual behaviors and emergent effects of inter-individual interactions; they do not incorporate spatial heterogeneity; and they describe only the basic metrics of energy supply and demand without representing other factors that determine waterfowl interactions with habitat, such as daily energy and time budgets, body condition, movements, mortality, and variable energy costs for different activities (Williams et al. 2014). These drawbacks limit the use of DED models for generating reliable estimates of carrying capacity in response to management actions.

Agent-based models (ABMs) provide an alternative modeling approach that can represent behavior of landscape-forager systems. The systems' dynamics emerge from the interaction of individual actors (agents) with each other and with their shared habitat, thus providing a bottom-up rather a top-down approach (Grimm and Railsback 2005; Miller et al. 2014). ABMs allow spatially explicit representation of habitat data and agent behavior, enabling explicit inferences about individual-level metrics such as habitat selection and movement patterns in response to changing food availability; thereby extending individual agent effects to the group or population level, allowing the simulation of emergent effects at multiple scales; and, due to their real-time simulation nature, enable tracking of change over time of many parameters with potentially revealing dynamics, such as trends in body condition over the course of the simulation period. ABMs are computationally expensive, but scale well and allow users to employ a much larger range of informative inputs than simpler models (Grimm and Railsback 2005).

Assessment Approach

Through a CEAP cooperative agreement between NRCS and the University of Missouri, an assessment was conducted to model the contribution of various wetland easement scenarios to wintering waterfowl conservation. The assessment used an ABM approach intended to help inform decisions on the acquisition of new easement parcels and the management of existing easements, with the aim of maximizing benefits for wintering waterfowl populations. Specific objectives were to:

- Develop an ABM of waterfowl bioenergetics, foraging behavior, and movement during the wintering season (November through February) when migratory birds are in the MAV
- Model wintering waterfowl population responses to thematic landscape composition and configuration changes that represent alternative future conservation scenarios under a range of environmental variability
- Evaluate the contribution of current NRCS wetland easements to waterfowl populations in the MAV and identify future conservation scenarios that are most likely to benefit wintering waterfowl

Mallards disperse to foraging patches in response to changing food availability and forage efficiency throughout the winter season. Photo by Chris Willis, USDA.

To model waterfowl wintering in the MAV, investigators adapted an existing energetics-based ABM developed by Miller at al. (2014) that allows for tracking the physiological and behavioral response of mallards—the region's most common wintering dabbling duck—to dynamic habitat conditions and emergent behaviors of populations at the landscape scale, focused on a 29,000 km2 study area in east-central Arkansas that is representative of landcover composition across the broader MAV (Fig. 1). The model tracked the fate of a starting population of 212,000 mallards (agents) in the study area during the wintering season. A suite of conservation scenarios was developed focusing on current and potential easement amount and configuration, including eliminating existing easements as well as increasing easement area by 25%, either through adding new easements or rounding out existing easements at opportunistic or selected locations.

Duck physiology, movement and foraging behavior was modeled based on a range of published parameters summarized in Miller et al. (2014), Gray et al. (2013), and Beatty et al. (2014), together with some emergent estimates where no data were available (e.g., target choice when relocating over large distances). The map was parameterized with data from publicly available databases, principally the Cropland Data Layer (USDA 2018) and the National Conservation Easement Database (NCED 2018), and additional data from several proprietary databases. Map inundation probabilities were based on Allen (2016), and food energy and distribution in foraging habitats was largely based on Gray et al. (2013), supplemented by other literature sources. The starting population of mallards represents the long-term median of Arkansas Mid-Winter Count numbers (USFWS 2016), scaled to the simulation area, and ducks were added to the map over the first month of simulation following a distribution derived from observations of radio-tracked individuals (Krementz et al. 2012, Beatty et al. 2014).

Availability of wintering waterfowl food is dependent on sites being inundated with shallow water; dry sites are considered not available for foraging regardless of potential foods present. Therefore, active management of wetland easements as well as regional weather patterns have a profound influence on food availability. Several weather scenarios were modeled (baseline, flood, weak drought, and severe drought.)

MAV Model Location

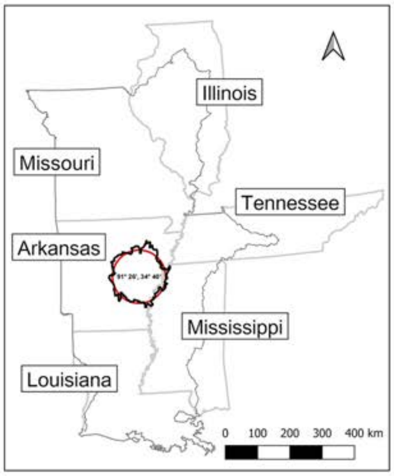
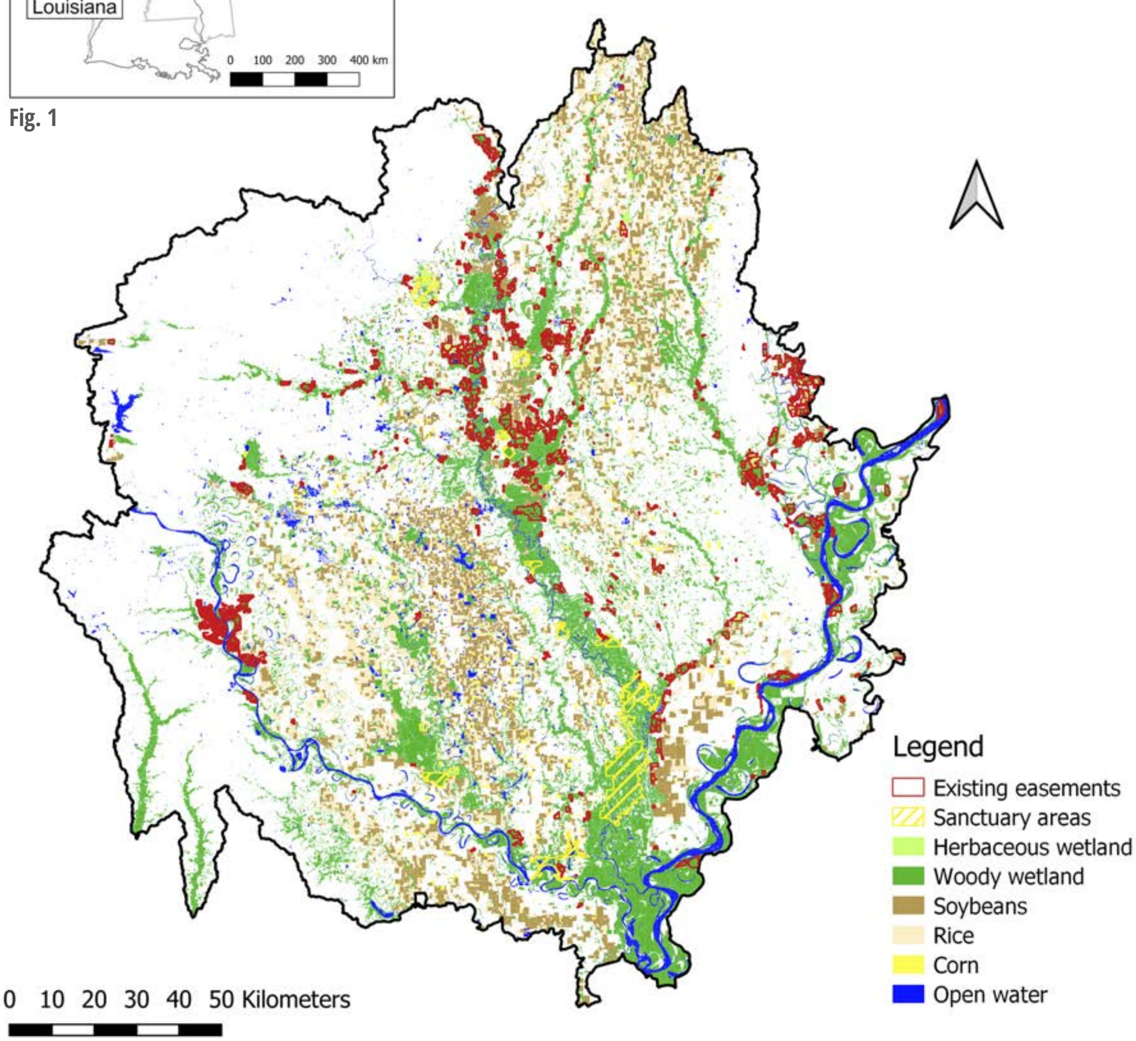


Fig. 1

Fig. 1. Location of selected simulation area for the Mississippi Alluvial Valley (MAV) mallard model, in east-central Arkansas. Circle (red): area used for selection, with midpoint at 91° 26′ N, 34° 40′ E, size 27,000-km^2. Outline (black): area approximated using hydrologic unit (HUC) HUC6 boundaries.

Fig. 2. Habitat type map for the MAV mallard model, with all areas assumed not to be used by foraging mallards removed (non-parameterized; white). Parameterized area: 9,732-km^2 (33.2% of total area). Easement (red) and sanctuary areas (yellow) are distinguished by colored outlines.



Findings

Duck behavior revealed several key findings. This behavior can be tracked through the median proportion of foraging time spent in different habitat types. Fig. 3 illustrates shifts in relative time spent foraging in herbaceous wetland (A), wooded wetlands (B), and rice (C) as foods are depleted over time. This illustrates the expected pattern of seasonal dynamics, corresponding to agent relocation across the study area in response to changes in food energy distribution.

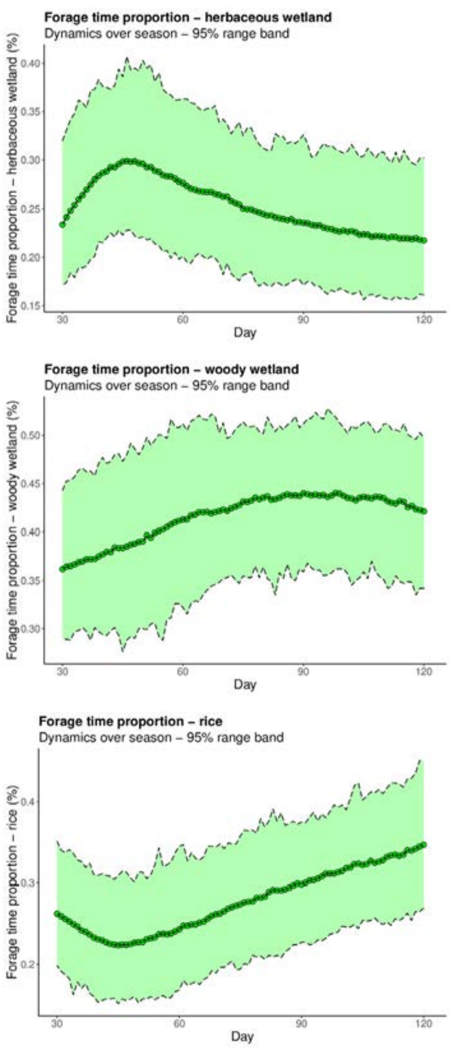


Figure 3. Mallards change time spent foraging in various cover types throughout the winter season in response to food availability and feeding efficiency (Standard base climate conditions).

Table 1. Weather Scenarios Included in Model Simulation to capture contribution of wetland easements to mallard energetic support during different regional hydrologic conditions.

Scenario	Description	Overall Mean Patch Flooding Probability
Baseline	Standard conditions represented average landscape conditions in most years.	37%
Flood	Flood conditions represented natural high inundation conditions where an abundance of flooded habitat is available.	59%
Weak Drought	Weak drought conditions inrepresented moderate food scarcity conditions under lower than normal inundation.	31%
Severe Drought	Strong drought conditions represented severe food scarcity conditions under substantially lowered inundation.	19%

Mallards on a rice field.

Food Resources are Depleted from Patches Througout the Season

Food biomass is assumed to have been produced in the months preceding winter and then depleted by both natural decay and agent foraging over the course of the winter season simulation. The development of summed food energy in the flooded (i.e., available for foraging) part of the landscape shows the expected steady decrease over the season (Fig. 4). As foods are depleted, agents seek alternative foraging patches.

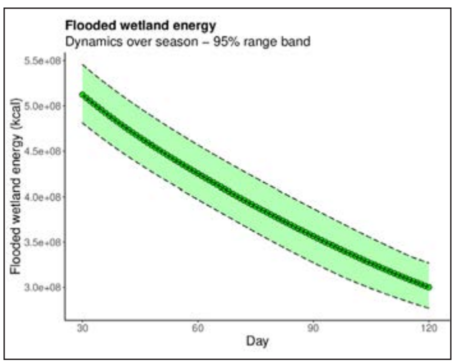


Fig. 4—Waterfowl food energy is depleted in flooded habitats throughout the winter season (Standard base climate conditions).

Energetic Costs Increase Throughout the Season

As winter progresses and food resources are depleted, mallards are expected to incur greater energy costs due to increasing flight distances among diminishing food supplies, and greater frequency of relocation movements due to localized food depletion. As expected, mean foraging flight distances increased throughout the season (after an initial period of settling into optimal early exploitation locations; Fig 5), and mean demand (representing energy expenditure that has to be satisfied by acquiring food energy) subsequently increased (Fig. 6).

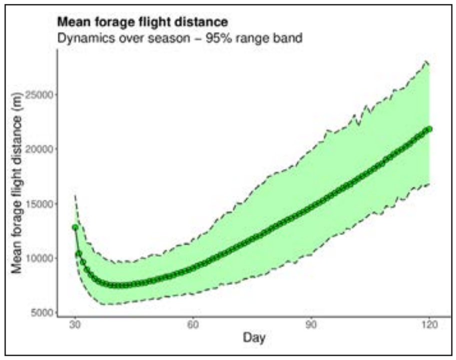


Fig. 5—As food is depleted throughout the season, mallards need to travel greater distances to find suitable food patches (Standard base climate conditions).

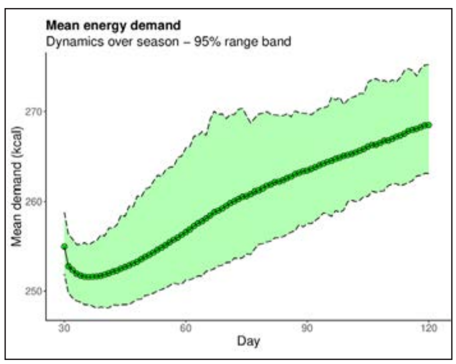


Fig. 6—As food is depleted, mallards expend increasing energy to fly greater distances to find suitable food patches (Standard base climate conditions).

Mallard Populations Declined Under All Climate Conditions Due to Emigration from the Simulation

The population decline was slower under flood conditions than base environmental conditions, generally stronger under weak drought than base, and much more rapid under strong drought, where numbers may reach 0 (entire population emigrated) (Fig. 7). In all scenarios, the population on day 30 following the last daily immigration event was the maximum reached during the scenario, although this was almost always lower than the nominal total number added (because some mallards may already exit the simulation during days 0–30). Outcome variance across replicates increased over the season, except when the population was rapidly dwindling under strong drought (Fig. 7).

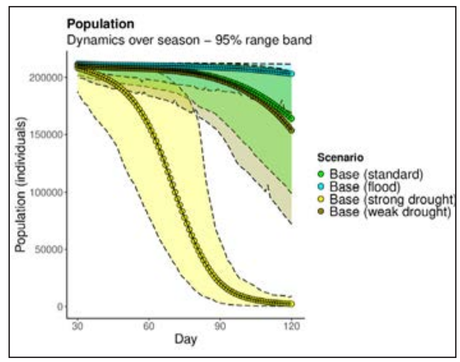


Fig. 7—The number of mallards present on the map during the 120-day model simulation under different environmental scenarios.

Increasing Forage Flight Distances Varies by Environmental Scenario

Flight from roost to first foraging patch, or last foraging patch to roost, made up the majority of mallard movements in the simulation; in conditions when there was little switching between depleted patches during a foraging bout (i.e., except for the late stages of strong drought scenarios), it comprised almost all movement. This metric was a good indicator of ease of food access at any point. It dropped to a minimum in the early season when mallards settled into optimal early exploitation positions, then increased when patches close to roosts became depleted and patches with high food energy became more sparse in the study area (Fig. 8). Under strong drought conditions, flight distance peaked and then declined when

the population dwindled to a few mallards exploiting the best remaining patches.

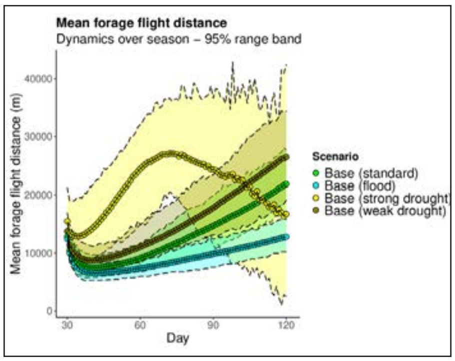


Fig. 8—Mean forage flight distance (m) that a mallard travels from the roosting site to the first foraging patch of the day during the 120-day model simulation under different environmental scenarios.

Easements and Management of Easements Enhance Wintering Mallard Populations

To illustrate how existing wetland easements and active management of those easements contribute to sustaining wintering mallard populations, scenarios were developed to model mallard behavior on the landscape in the absence of management of easements as well as simulated absence of easements (where easements were replaced with pre-restoration non-flooded cropland conditions). These scenarios were run under a range of environmental conditions, illustrated in Figs. 9 through 12.

While all environmental conditions resulted in a reduction of the mallard population in the study area by the end of the season due to emigration in response to food depletion, easement modification scenarios resulted in greater population losses. Population declines s were more extreme for complete absence of easements (i.e., pre-restoration status) than for absence of wetland easement management only (i.e., restored but not managed for food biomass). Specifically, under standard environmental conditions, absence of wetland management resulted in nearly 69% fewer mallards at the end of the season whereas complete absence of easements resulted in nearly 77% fewer mallards at the end of the season (Fig. 9).

Under flood environmental conditions, the effects of easements and easement management were moderated due to the availability of alternative flooded foraging habitats in the study area, although lack of easements and easement management still resulted in 38% and 33% fewer mallards on the landscape at the end of the season, respectively (Fig. 10). Likewise, during strong drought conditions, easements and easement management had little effect on the loss of mallards in the area by the end of the season (Fig. 11) as strong drought conditions made many easements and other wetland habitats unavailable due to lack of surface water.

Weak drought has less of an effect on mallard populations than severe drought, yet modeled lack of easement management and entire absence of easements resulted in 70% and 81% fewer mallards in the area by the end of the season, respectively (Fig. 12).

Except in the case of strong drought, these scenarios illustrate the substantial additional mallards that would otherwise be absent that are sustained in the modeled area under current easement management conditions.

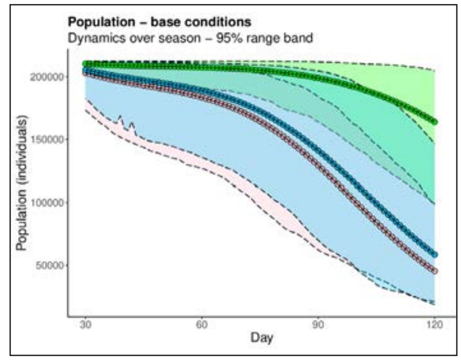


Fig. 9—Modeled mallard population declines in response to food depletion under existing conditions (base), no wetland easement management, and removal of easements under standard environmental conditions.

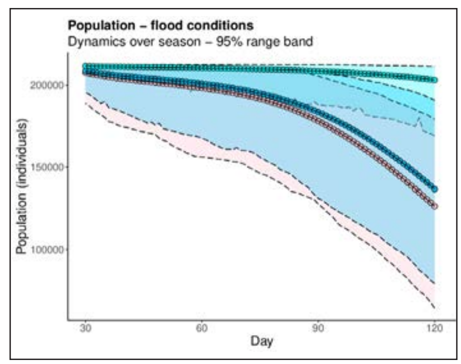


Fig. 10—Modeled mallard population declines in response to food depletion under existing conditions (base), no wetland easement management, and removal of easements under flood environmental conditions.

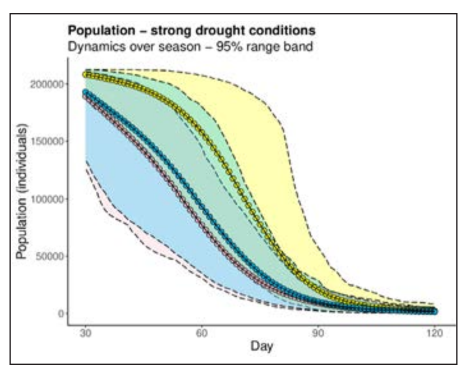


Fig. 11—Modeled mallard population declines in response to food depletion under existing conditions (base), no wetland easement management, and removal of easements under strong drought environmental conditions.

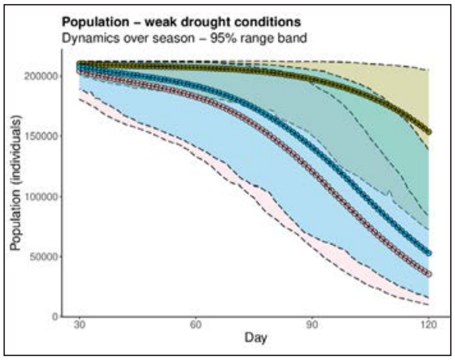


Fig. 12—Modeled mallard population declines in response to food depletion under existing conditions (base), no wetland easement management, and removal of easements under weak drought environmental conditions.

The Addition of New Easements Resulted in Mallard Population Increases by 3.2 to 10.2%

To simulate the addition of easements, the area of foraging habitat contained in easements was increased by a total of ~25% of the existing easement area (+ ~154 km2). This is done by either establishing new, unconnected easements (new easements), or by increasing the contiguous area of existing easements (roundout). In either method, new foraging patches were added until a total increase of ~154 km2 was achieved. All new easement patches received a minimum flooding probability of 25% and affected crop patches were converted to restored wetlands. New easement patches were added either in small units (new easements: created easements were of size ~equal to the median size of existing easements; roundout: all patches directly contiguous to the starting easement were added) or in large units (new easements: created easements were of size ~equal to the 3rd quartile size of existing easements; roundout: a second layer of contiguous patches was added). In all cases, placement on the map was random (new easements: random new locations; roundout: random starting easements).

Under standard environmental conditions, the addition of new easements in the area resulted in an end-of-season mallard population increase of 7.2% for small new easements and 10.2% for large new easements. The population increase associated with rounding out of existing easements was less than that from addition of new easements (3.2% increase for large unit roundout and 5.6% increase for small unit roundout of existing easements).

These findings illustrate the important contribution of existing easements to mallard population support and provide insight into how additional easement area can be added with maximum benefit to wintering waterfowl.

Active flooding of existing easements increased the end of season mallard population by 8.8 to 12.7%

Active flooding of 25% of existing easements at Day 90 yielded the greatest increase in mallard population (12.7 % increase), while active flooding at Day 60 yielded a 11.3% more mallards and active flooding at Day 1 resulted in 8.8% more mallards at the end of the season.

Conclusions

This assessment found that the absence of existing conservation measures would reduce wintering mallard population abundance by ~70-80%, highlighting the importance of current wetland easements for winter waterfowl foraging. Simulated management approaches were only effective under standard (average) or moderately lower inundation conditions (see Weller et al. 2022, 2023), whereas even intensive management approaches made little difference under unusually high-flood or strong drought conditions. However, active flooding (stored water release) considerably increased carrying capacity under strong drought conditions. Under standard conditions, the partial active flooding of easements later in the season and upgrading of unmanaged wetlands to managed status provided the greatest increase in mallard populations.

Scenarios that enhanced the quality or availability of wetlands in existing easements generally yielded greater gains in end-of-season population abundance than scenarios that added new easement area with restored wetlands, but benefits from the latter were still considerable. Establishment of entirely new easements with a high percentage of converted crop patches was preferable over rounding out existing easements using any directly contiguous patches. Selecting added easement patches based on proximity to sanctuaries or former wetland character enhanced the effectiveness of rounding out existing easements, but was largely ineffective when establishing new easements.

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Conservation Effects Assessment Project: Translating Science into Practice

The Conservation Effects Assessment Project (CEAP) is a multiagency effort to build the science base for conservation. Project findings will help to guide USDA conservation policy and program development and help farmers and ranchers make informed conservation choices.

One of CEAP's objectives is to quantify the environmental benefits of conservation practices for reporting at the national and regional levels. Because wildlife is affected by conservation actions taken on a variety of landscapes, the CEAP-Wildlife National Component complements the CEAP National Assessments for cropland, wetlands, and grazing lands. The Wildlife National Assessment works through numerous partnerships to support relevant assessments and focuses on regional scientific priorities.

This project was conducted through a collaborative effort by private landowners, researchers with University of Missouri, and the Conservation Effects Assessment Project. Primary authors of this document were NRCS' Charles Rewa and University of Missouri's Florian Weller and Lisa Webb. Researchers at the University of California-Davis and Louisiana State University developed of the initial ABM model and assisted with adapting it for this assessment.

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This Conservation Insight was edited by Charlie Rewa, CEAP-Wildlife Component Leader. For more information, visit www.nrcs.usda.gov/technical/NRI/ceap or contact Charlie at charles.rewa@usda.gov.