# Appendix H
## Part 2

### Shorebird Model Validation

U.S. Army Corps of Engineers
Memphis District

# Validation of Shorebird Habitat Models:
## St. Johns-New Madrid Basins, Missouri.

Daniel J. Twedt, USGS Patuxent Wildlife Research Center, 2524 South Frontage Road, Vicksburg, MS 39180, 601-629-6605, dan_twedt@usgs.gov

***Abstract:*** *In response to proposed completion of levees and installation of pumps as part of the St. Johns-New Madrid Project, a model quantifying potential shorebird habitat within the St. Johns-New Madrid Basins in Missouri was developed. Model outputs were contingent upon several underlying assumptions regarding water distribution, shorebird distribution and behavior, and shorebird response to floodwater conditions. Verification of the validity of the assumptions specified during model development is needed to ensure the model accurately predicts the availability and suitability of potential foraging habitat for shorebirds. I propose laboratory and field validation of 6 underlying assumptions which influence model predictions of the availability of potential foraging habitat for shorebirds.*

**Background:**

Flood control measures implemented along the Mississippi River and its tributaries after the record flooding in 1937 include an extensive network of earthen levees. In southeastern Missouri, a gap within the levee system surrounding the New Madrid Basin permits Mississippi River floodwater entry during periods of increased water (i.e., high river stage) whereas levees around the adjacent St. Johns Bayou drainage isolate this basin from Mississippi River floodwater when gates at the mouth of St. Johns Bayou are closed. However, gate closure denies St. Johns Bayou an outlet, such that during prolonged closure flood water accumulates behind the protective levee. Within both of these basins, most land is in agriculture with an extensive system of canals to drain floodwaters concurrent with Mississippi River stages.

The U.S. Army Corps of Engineers has proposed completion of the earthen levee surrounding the New Madrid Basin, and installation of water pumping stations within both the St. Johns and New Madrid Basins that are capable of transporting accumulating headwaters over the protective levee for deposition in the Mississippi River batture (a.k.a., St. Johns-New Madrid Project). Completion of the St. Johns-New Madrid Project is expected to eliminate backwater flooding from the Mississippi River and afford reduction of headwater flooding within both of these basins.

Reduced flooding with these basins, on areas of sparse vegetation such as those associated with harvested agricultural lands, decreases the area of potential foraging habitat available to shorebirds (Charadriiformes). Because the necessary congruence of water depth and vegetative structure at the appropriate times is the most important issue for shorebird conservation in this region (Brown et al. 2001), reduced flooding likely negatively affects migrating shorebirds. In response to concerns regarding potential reduction in shorebird foraging habitat resulting from completion of the proposed St. Johns-New Madrid Project, a habitat model was developed to assess the historical area of potential shorebird habitat and predict the future area of potential shorebird habitat available under presumed post-project flood conditions upon completion of the St. Johns-New Madrid Project.

A model quantifying potential shorebird habitat within the St. Johns-New Madrid Basins was developed based on several assumptions regarding water distribution and shorebird response to floodwater conditions (Twedt 2011). These assumptions included: 1) a presumed linkage between river stage (i.e., water elevation) and the extent of flooding, 2) presumed dates for planting and harvest of crops, 3) presumed proportions of shorebirds of different body size within these basins, 4) presumed temporal distribution of relative abundance of shorebirds within these basins, 5) presumed shallow-water foraging depths used by shorebirds (Davis 1996, Davis and Smith 1996), and 6) presumed availability and suitability of mudflat habitat within these basins. Verification of the validity of the assumptions specified during model development is needed to ensure the model of shorebird habitat accurately predicts the availability of potential shorebird habitat.

**Study Objectives:**

*Habitat validation* -

1. Validate the presumed geographic extent of floodwater within the SJNM Basins predicted by the shorebird habitat model relative to river elevation derived from hydrological models.
2. Verify dates of crop planting and harvest and determine growth rates for predominant crops within the SJNM Basins to validate temporal changes in habitat suitability value assigned to each of these crops.

*Shorebird validation* -

3. Estimate abundances of shorebirds of different body sizes within the SJNM Basins during spring and fall migrations to validate presumed body size of shorebirds within these basins.
4. Evaluate the temporal change in relative abundances of shorebirds within the SJNM Basins to validate presumed change in shorebird abundance during spring and fall migration periods.

*Habitat-shorebird interaction validation* -

5. Quantify foraging depths used by shorebirds within the SJNM Basins during spring and fall migration to validate presumed depth-dependent suitability value of flooded habitat.
6. Quantify post-exposure duration of mud-flat conditions and relative daily change in shorebird use of mud-flats after floodwaters recede in order to validate the presumed duration and daily change in habitat suitability of mud-flats.

**Methods:**

*Habitat validation – floodwater extent.*

The shorebird habitat model developed for the SJNM Basins relies upon daily water elevations (i.e., river stages) derived from hydrological extrapolations of water elevations reported by river gauging stations after adjustment to reflect previous river conditions (e.g., the duration of flood events) as well as concurrent regional meteorological information (e.g., rainfall, temperature, etc.). The geospatial extent of floodwater presumed to be inundated in concordance with each daily water elevation is the foundation upon which the predictive model estimates the area of shorebird foraging habitat.

Although resultant model outputs of daily area of shorebird foraging habitat within the SJNM basins rely on no explicit assumption regarding the geospatial location of shorebird habitat within these basins, the relative accuracy of model output likely reflects the congruency between the presumed topographic elevations used to predict the extent of floodwater and the actual physical distribution of floodwater within these basins. To identify the actual physical extent of floodwaters, I will use standard band (wavelength image) combinations of Thematic Mapper (TM) imagery (e.g., normalized difference moisture index, tasseled cap wetness index, or other combinations such as [TM4 + TM7; the 0.76 to 0.90 µm, reflective infrared and the 2.08 to 2.35 µm, mid-infrared bands]) to differentiate between water (or saturated soil) and dry land. This classification will be used to delineate the water-land interface present on the date of imagery. Verification of the SJNM Basins shorebird habitat model's predictive ability for each date of satellite imagery will be assessed based on comparison of the area of predicted shorebird habitat with the area associated with the water-land interface identified on classified Landsat TM imagery.

*Verification* – Satellite imagery of the study area with known date of origin, will be obtained from 'in-house' imagery within the archives of U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and Ducks Unlimited. These images will be classified into binary depictions of water versus land (dry) with a linear contour established at all water-land interfaces. Interior (water-side) buffer distances will be generated from these linear contours that represent optimal (shallow) flooding and sub-optimal (moderate) flooding. Similarly, an exterior (land-side) buffer depicting mudflat habitat will be established, if appropriate for the date of the imagery as indicated by a falling river stage, at a distance representative of the maximum 2-day previous floodwater extent. The areas of presumed shorebird habitat (sparsely vegetated landcover classes) within these buffers will be extracted and quantified. Correlation between the area of predicted foraging habitat from shorebird habitat model output and the area adjacent to the water-land interface that is identified on satellite imagery will provide a measure of the reliability of habitat predictions associated with river stage data. Model verification based on ≥10 satellite images from different dates (if available within accessible archives) will be used to provide verification of predictions associated with different water elevations (i.e. river stages).

*Validation* –For each day a TM image of the study area is available, the spatial depictions of predicted shorebird habitat associated with the appropriate, day-specific, river stage will be generated. This spatial representation will be compared with the area of presumed shorebird habitat associated with the water-land interface on TM images. Areas of estimated shorebird habitat that coincide or are in reasonable proximity (distance yet to be determined) between these 2 depictions of shorebird habitat will be assumed to be validated. The proportion of estimated shorebird habitat that is validated versus the proportion that is not validated provides an estimate of overall confidence in the validation. Model validation will use ≥10 satellite images from different dates (if available within accessible archives) for validation.

*Habitat validation – crop condition.*

Within the shorebird foraging habitat model (Twedt 2011), the suitability of flooded cropland is dependent upon the physical condition of each crop which is assumed to be temporally dynamic (Fig. 1). Maximum suitability (SI = 1.0) is attained when cropland is devoid of actively growing crops (i.e., post-harvest until replanted). Minimum suitability for each crop was set at half the maximum suitability (SI = 0.5) from the average date the crop was assumed to attain maximum physical stature until average date that harvest begins. An intermediate suitability (SI = 0.75) was assumed from presumed first date of harvest until last date of harvest, as well as from presumed date of initial planting until the date maximum physical stature is attained. Within the shorebird habitat model, presumed dates used for different crops (Fig. 1) were based on reported state-wide planting and harvest dates (U.S. Department of Agriculture 2010).

*Verification* – Consultations with local agricultural specialists (state extension service, FSA, NRCS, etc.) will be used to verify and refine for each of 7 crop-types (Fig. 1; rice, corn, cotton, soybean, winter wheat, hay [grassland], and other crops) within the SJNM Basins: 1) the average dates of first and last sowing, 2) the average dates of first and last harvest, and 3) the number of days from sowing until maximum physical stature is attained.

*Validation* – Within the presumed spring and fall migration periods identified by the shorebird habitat model, planting, growth, and harvest status of crops will be validated within those portions of the SJNM Basins likely impacted by flooding. Planting and harvest dates will be based on visual evidence of these activities in fields that is visible from randomly selected roadside transects. Growth status of planted crops will be evaluated based on photographic and physical measurements obtained from a sample set of fields for each crop-type. Fields sampled for growth status of crops will be randomly chosen from fields along transects: fields actually sampled will be determined by crop-type present.

*Shorebird validation – timing of migration.*

The shorebird model assumes the timing (i.e., days of year) of shorebird passage through the SJNM Basins is similar to the timing of continental shorebird migration based on latitude (Skagen et al. 1999). As a consequence, the shorebird habitat model allocates greater value to foraging habitat that is available during the periods when more shorebirds are pressumed to be present within the SJNM Basins. However, many factors contribute to the timing and duration of stay at migratory stopover sites (Farmer and Wiens 1998, Skagen 1997, 2006, Skagen et al

2005). Even so, only habitat available during a 93 day (15 March – 15 June) spring migration period and during a 122 day (1 July – 30 October) fall migration period is assumed to be suitable foraging habitat with the SJNM Basins. Shorebirds are assumed to migrate through the SJNM Basins predominately during these migration periods within which their abundance follows a statistically normal distribution, such that populations are assumed to be greatest 24 April – 23 May in spring and 5 August – 16 September during fall, with abundance decreasing temporally both before and after. Quantifying temporal change in abundance of shorebirds during migration within the SJNM Basins is needed to validate changes in temporal suitability related to relative abundance of shorebirds.

*Shorebird validation – species composition.*

Based on regional observations from Missouri, Kentucky, Tennessee, and Arkansas, the shorebird model assumes most shorebirds using the SJNM Basins have small to medium body size (Table 1, http://www.lmvjv.org/shorebird/default.asp, Loesch et al. 2000, Skagen and Knopf 1993). Because small and medium body size shorebirds often forage in water depths <6 cm (Helmers 1992, Plauny 2000), maximum habitat suitability (SI = 1.0) was assigned to lands submerged by ≤6 cm floodwater. Quantification of the relative abundance of shorebirds with small, medium, and large body size within the SJNM Basins during migration is needed to validate restricting maximum habitat suitability to <6 cm.

*Validation* – Because bird surveyors are unlikely to encounter shorebirds unless suitable habitat is present, the most pragmatic approach for validation of both the timing of migration and species composition of migrant shorebirds is to restrict observations to locations with suitable habitat. Furthermore, restricting observations to sites where flood extent and depths can be managed (e.g., moist-soil management units being managed for shorebird habitat), and ideally can be maintained throughout the migration periods, decreases the likelihood that changes in shorebird abundance or composition are in response to change in habitat conditions. I will consult with Federal, State, and private land managers within southeastern Missouri to identify existing conservation lands currently being managed to provide shorebird habitat, or lands that have the capacity to be managed to provide shorebird habitat. All identified conservation lands being managed to provide shorebird habitat within SJNM Basins will be included for selection of sites subject to repeated periodic surveys to assess temporal distribution and species composition of shorebirds. At least 2 different locations, but likely fewer than 6 locations, will be surveyed for shorebirds during spring and during fall. If insufficient area and number of suitable land holdings are present within the SJNM Basins, managed lands within adjacent basins may be included in these shorebird surveys. If lands managed to provide shorebird habitat are unavailable either within or adjacent to the SJNM Basins, naturally flooded sites will be used for observations. The availability of naturally flooded locations however is dependent upon Mississippi River stages being sufficiently elevated such that inundation occurs within the SJNM Basins. Therefore, suitable foraging habitat for shorebirds may not be available at all times within the spring and fall migration periods.

*Habitat interaction with shorebird validation* -

*Foraging depths* – Presumed differential suitability of different water depths used for foraging by shorebirds is a primary determinant of habitat suitability within the shorebird habitat model. Maximum habitat suitability (SI = 1.0) was designated at depths ≤6 cm. Suitability of habitats flooded at greater depths, up to 15.25 cm, was assumed inversely related to water depth: flood depth 6.1 − 9.15 cm (SI = 0.8), 9.15 − 12.2 cm (SI = 0.7), and 12.2 − 15.25 cm (SI = 0.6). However, the proper or relevant assignment of these categorically based suitability scores is somewhat subjective. That is, at what increased depth should the foraging suitability score be lowered and by how much? Thus, quantifying foraging duration of shorebirds at different foraging depths on sites within the SJNM Basins is needed to validate or re-define these categorical model suitability indices.

*Validation* –Using the same conservation lands being managed to provide shorebird habitat within SJNM Basins (or adjacent basins), I will conduct repeated, periodic surveys of shorebirds throughout the spring and fall migration periods. For each observational survey, the water depth associated with foraging shorebirds will be recorded. Behavioral observations on foraging shorebirds will be undertaken to assess differences in behavior relative to depth of flooding and to quantify the duration of association between shorebirds and flooding depth.

*Mudflat exposure* – Similar to foraging depths, the shorebird habitat model assumes that the suitability of mudflat habitat is inversely related to the duration (i.e., number of days) of exposure after previously being flooded: A suitability of 0.6 was assumed for mudflats exposed 1 day (SI = 0.6), and suitability was temporally reduced concurrent with exposure: exposed 2 days

(SI = 0.5) and exposed 3 days (SI = 0.4). Mudflats exposed >3 days were assumed to be unsuitable until re-inundated.

*Validation* – As with foraging depths, the foraging duration of shorebirds using mudflats exposed for different duration (≥1day exposure) will be quantified via observational-behavioral surveys on sites that have receding water resulting in mudflats. Surveyed sites may be the same conservation lands being managed as shorebird habitat that are surveyed to quantify duration of foraging by shorebirds at different foraging depths. However, only sites with receding (falling elevation) water will have mudflats suitable for evaluation. Thus, managed sites may need to be supplemented with additional locations where floodwaters are receding. Concurrent with observations of foraging duration, the potential for shorebirds to probe mudflats that have been exposed for different duration will be quantified using a soil penetrometer (soil probe).

**References and Literature Cited:**

Brown, S.C., C. Hickey, B. Harrington, and R. Gill. 2001. The U.S. Shorebird Conservation Plan, 2nd ed. Manomet Center for Conservation Sciences, Manomet, MA. http://www.manomet.org/USSCP/index.htm

Davis, C.A. 1996. Ecology of Spring and Fall Migrant Shorebirds in the Playa Lakes Region of Texas. PhD Dissertation. Texas Tech University, Lubbock, Texas. 224 pp.

Davis, C. A., and L. M. Smith. 1996. Ecology and management of migrant shorebirds in the playa lakes region of Texas. Wildlife Monographs 140: 1-45.

Farmer, A. and J. A. Wiens. 1998. Optimal migration schedules depend on the landscape and the physical environment: a dynamic modeling view. Journal of Avian Biology 29: 405-415.

Helmers, D. L. 1992. Shorebird Management Manual. Western Hemisphere Shorebird Reserve Network, Manomet, Massachusetts.

Loesch, C. R., D. J. Twedt, K. Tripp, W. C. Hunter, and M. S. Woodrey. 2000. Development of management objectives for waterfowl and shorebirds in the Mississippi Alluvial Valley. Pages 8–11 *in* Bonney, R., D. Pashley, R. Cooper, and L. Niles, eds. Strategies for Bird Conservation: The Partners in Flight Planning Process. Proceedings of the 3rd Partners in Flight workshop; 1995 October 1–5; Cape May, NJ. Proceedings RMRS-P-16, Ogden, UT; United States Department of Agriculture, Forest Service, Rocky Mountain Research Station. <http://www.lmvjv.org/library/research_docs/2000%20RMRS-P-16_8-11%20Loesch%20et%20al.PDF>.

Plauny, H. L. 2000. Shorebirds. U.S. Department of Agriculture, Natural Resource Conservation Service, Wildlife Habitat Management Institute, Fish and Wildlife Habitat Management Leaflet Number 17. 14 pp.

Skagen, S. K. 1997. Stopover ecology of transitory populations: the case of migrant shorebirds. Ecological Studies 125:244-269.

Skagen. S. K. 2006. Migration stopovers and the conservation of Arctic-breeding Calidridine sandpipers. Auk 123:313-322.

Skagen, S. K., S. Brown, and R. Johnson. 2005. Implications of different shorird migration strategies for habitat conservation. Pages 680-683 in Ralph, C. J. and T. D. Rich, eds. Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference. 2002 March 20-24; Asilomar, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-191. Albany, CA.

Skagen, S. K., and F. L. Knopf. 1993. Toward conservation of midcontinental shorebird migrations. Conservation Biology 7:533-541.

Skagen, S. K., P. B. Sharpe, R. G. Waltermire, and M. B. Dillon. 1999. Biogeographical Profiles of Shorebird Migration in Midcontinental North America: U.S. Geological Survey Biological Science Report 2000-0003. 167 p. <http://www.fort.usgs.gov/products/Publications/555/toc.html>

Twedt, D. J. 2011. Habitat for migrating shorebirds in southeast Missouri: Potential impact of St. Johns-New Madrid Project. Unpublished report to Memphis District, U.S. Army Corps of Engineers, Memphis Tennessee. 36 pp.

U.S. Department of Agriculture. 2010. Field Crops Usual Planting and Harvesting Dates. Agricultural Handbook 628. USDA National Agricultural Statistics Service. 51 pp. available online at <http://www.nass.usda.gov>

| Timeline for study (July 2012 – Dec 2014) | |
|---|---|
| July – Oct 2012 | Identification and recruitment of conservation lands under management for shorebirds. Consultation with agricultural experts and preliminary crop validation. |
| Oct 2012 – Feb 2013 | Flooded habitat verification and validation via TM image processing. |
| Feb 2013 | Review and revise methodologies for model validation. |
| Mar – June 2013 | Field evaluations of: 1) timing and species composition of shorebirds, 2) shorebird foraging duration association with floodwater depth, and 3) mudflat condition relative to length of exposure post-flooding during the spring migration period within the St. Johns and New Madrid Basins. Field assessment of crop planting growth and harvest. |
| July – Oct 2013 | Field evaluations of: 1) timing and species composition of shorebirds, 2) shorebird foraging duration association with floodwater depth, and 3) mudflat condition relative to length of exposure post-flooding during the fall migration period within the St. Johns and New Madrid Basins. Field assessment of crop planting growth and harvest. |
| Nov – Dec 2013 | Analysis and interim report. |
| Mar – June 2014 | Field evaluations of: 1) timing and species composition of shorebirds, 2) shorebird foraging duration association with floodwater depth, and 3) mudflat condition relative to length of exposure post-flooding during the spring migration period within the St. Johns and New Madrid Basins. Field assessment of crop planting growth and harvest. |
| July – Oct 2014 | Field evaluations of: 1) timing and species composition of shorebirds, 2) shorebird foraging duration association with floodwater depth, and 3) mudflat condition relative to length of exposure post-flooding during the fall migration period within the St. Johns and New Madrid Basins. Field assessment of crop planting growth and harvest. |
| Nov – Dec 2014 | Analysis and final report. |

**Estimated Cost:**

| USGS PWRC BUDGET | | |
|---|---|---|
| **Personnel** | | |
| Salary (Principal Investigator) | | $24,000 |
| Field Technician 2013 (150 days @ $200/day) | | $30,000 |
| Field Technician 2014 (150 days @ $200/day) | | $30,000 |
| **Other Expenses** | | |
| Field vehicles (Fuel & maintenance) | | $ 5,000 |
| Travel (lodging and per diem) | | $ 5,000 |
| Equipment and supplies | | $ 1,000 |
| | Sub-total | $95,000 |
| **USGS Burdens** | | |
| Overhead | | $ 45,403 |
| | Total | $140,403 |

Table 1. Shorebird species, body size, presumed foraging depth, and numbers of southward (fall) migrating shorebirds in the 4-States (MO, KY, TN, AR) adjacent to the St. Johns- New Madrid study area and in the entire Mississippi Alluvial Valley (MAV), as reported on surveys from the Lower Mississippi Valley Joint Venture Shorebird Monitoring Program[1], as well as an hypothesized abundance, based on International Shorebird Surveys (Manomet Bird Observatory 1993), used to establish management recommendations within the Lower Mississippi Valley/Western Gulf Coastal Plain Shorebird Conservation Plan[2] (Elliott and McKnight 2000).

| | | | Body | Depth | 4-States[1] | | MAV[1] | Plan[2] |
|---|---|---|---|---|---|---|---|---|
| Family | Common Name | Scientific Name | Size[3] | (cm) | Number | Percent | Number | Number |
| Charadriidae | Piping Plover | *Charadrius melodus* | S | <3 | 25 | 0% | 25 | 121 |
| Charadriidae | Semipalmated Plover | *Charadrius semipalmatus* | S | <3 | 1672 | 1% | 3028 | 4,765 |
| Charadriidae | Killdeer | *Charadrius vociferus* | M | <3 | 15292 | 10% | 60248 | 91,838 |
| Charadriidae | American Golden-Plover | *Pluvialis dominica* | M | <9 | 80 | 0% | 301 | 3000 |
| Charadriidae | Black-bellied Plover | *Pluvialis squatarola* | M | <9 | 518 | 0% | 403 | 690 |
| Recurvirostridae | Black-necked Stilt | *Himantopus himantopus* | L | <20 | 4082 | 3% | 21200 | 778 |
| Recurvirostridae | American Avocet | *Recurvirostra americana* | L | <12 | 793 | 0% | 6122 | 232 |
| Scolopacidae | Spotted Sandpiper | *Actitis macularia* | M | <4 | 535 | 0% | 1333 | 4,112 |
| Scolopacidae | Ruddy Turnstone | *Arenaria interpres* | M | <6 | 10 | 0% | 24 | 405 |
| Scolopacidae | Upland Sandpiper | *Bartramia longicauda* | M | <6 | 19 | 0% | 65 | 237 |
| Scolopacidae | Sanderling | *Calidris alba* | M | <3 | 257 | 0% | 267 | 5,052 |
| Scolopacidae | Dunlin | *Calidris alpina* | M | <6 | 152 | 0% | 1529 | 7,866 |
| Scolopacidae | Baird's Sandpiper | *Calidris bairdii* | S | <6 | 925 | 1% | 678 | 0 |
| Scolopacidae | Red Knot | *Calidris canutus* | M | <6 | 2 | 0% | 2 | 162 |
| Scolopacidae | White-rumped Sandpiper | *Calidris fuscicollis* | S | <6 | 540 | 0% | 1639 | 500 |
| Scolopacidae | Stilt Sandpiper | *Calidris himantopus* | M | <9 | 8785 | 5% | 14803 | 3,310 |
| Scolopacidae | Western Sandpiper | *Calidris mauri* | S | <6 | 2521 | 2% | 3232 | 3,382 |
| Scolopacidae | Pectoral Sandpiper | *Calidris melanotos* | M | <6 | 42549 | 27% | 77870 | 121,077 |
| Scolopacidae | Least Sandpiper | *Calidris minutilla* | S | <6 | 46626 | 29% | 132172 | 151,119 |
| Scolopacidae | Semipalmated Sandpiper | *Calidris pusilla* | S | <6 | 11817 | 7% | 26427 | 37,713 |
| Scolopacidae | Calidris spp. (peeps) | *Calidris spp.* | S | <6 | 4674 | 3% | 12897 | 0 |
| Scolopacidae | Willet | *Catoptrophorus semipalmatus* | L | <12 | 19 | 0% | 55 | 92 |
| Scolopacidae | Common Snipe | *Gallinago gallinago* | M | <6 | 92 | 0% | 6039 | 2,374 |
| Scolopacidae | Short-billed Dowitcher | *Limnodromus griseus* | M | <12 | 1097 | 1% | 1427 | 1,121 |
| Scolopacidae | Long-billed Dowitcher | *Limnodromus scolopaceus* | M | <12 | 4622 | 3% | 13939 | 1,121 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scolopacidae | Dowitcher spp. | *Limnodromus spp.* | M | <12 | 1377 | 1% | 9810 | 0 |
| Scolopacidae | Marbled Godwit | *Limosa fedoa* | L | <12 | 18 | 0% | 47 | 39 |
| Scolopacidae | Hudsonian Godwit | *Limosa haemastica* | L | <12 | 0 | 0% | 0 | 0 |
| Scolopacidae | Long-billed Curlew | *Numenius americanus* | L | <9 | 0 | 0% | 0 | 0 |
| Scolopacidae | Whimbrel | *Numenius phaeopus* | L | <12 | 0 | 0% | 2 | 0 |
| Scolopacidae | Red-necked Phalarope | *Phalaropus lobatus* | M | s-d | 18 | 0% | 32 | 0 |
| Scolopacidae | Wilson's Phalarope | *Phalaropus tricolor* | M | s-d | 598 | 0% | 748 | 171 |
| Scolopacidae | Greater Yellowlegs | *Tringa melanoleuca* | M | <12 | 787 | 0% | 5344 | 3,235 |
| Scolopacidae | Solitary Sandpiper | *Tringa solitaria* | M | <6 | 267 | 0% | 1166 | 1000 |
| Scolopacidae | Lesser Yellowlegs | *Tringa. flavipes* | M | <12 | 6533 | 4% | 26753 | 21,120 |
| Scolopacidae | Buff-breasted Sandpiper | *Tryngites subruficollis* | M | <3 | 371 | 0% | 504 | 964 |
| | Large Shorebird | | L | <12 | 54 | 0% | 231 | 0 |
| | Medium Shorebird | | M | <9 | 148 | 0% | 16205 | 0 |
| | Small Shorebird | | S | <6 | 1888 | 1% | 9316 | 0 |

[1] Data from Lower Mississippi Valley Joint Venture Shorebird Monitoring Program <http://www.lmvjv.org/shorebird/default.asp>.

[2] Data from Loesch et al. 2000.

[3] Body size is denoted by "S" (small, total body lengths of <190mm), "M" (medium, body length <350mm) and "L" (large, body lengths exceed 350mm) after Skagen and Knopf (1993).

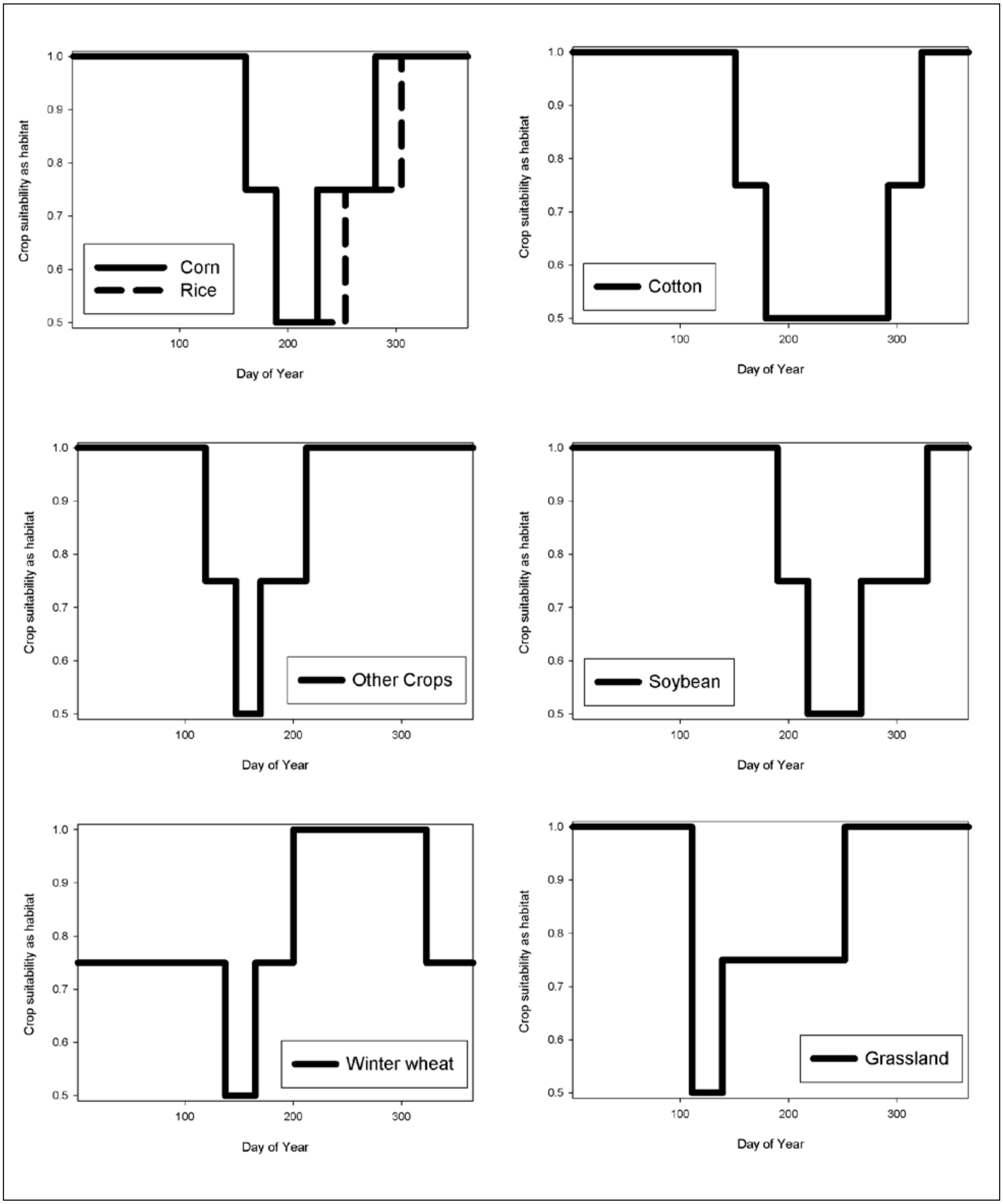


Figure 1. Temporal dynamics of crop suitability within the St. Johns and New Madrid Basins in southeastern Missouri that reflect presumed dates of planting, duration until maturity, and dates of harvest.

**Study Plan Signature Page**

**BASIS Number: 2302-9S2 Task XX**

Title: Validation of Shorebird Habitat Models: St Johns-New Madrid Basins, Missouri.

Submitted by: ________________________________________28 February 2012__

Principal Investigator Date

Peer Review Clearance: ________________________________________

Research Manager assigned Date

Revision Clearance: ________________________________________

Research Manager Date

PWRC Approval: ________________________________________

Center Director Date