Whooping Crane Migrational Habitat Use in the Central Platte River during the Cooperative Agreement Period, 2001-2006

Shay Howlin, Clayton Derby, and Dale Strickland
Western EcoSystems Technology, Inc.
2003 Central Avenue
Cheyenne, Wyoming 82001

WEST, Inc.

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EXECUTIVE SUMMARY

The whooping crane monitoring protocol was implemented during 11 migration seasons from 2001 to 2006 during the Cooperative Agreement period of the Platte River Endangered Species Partnership. The five objectives stated in the monitoring protocol were addressed through five analyses of the observed data: estimation of aerial survey detection rates, movement pattern summary, trends in the index of use, activity summary, and habitat selection analyses.

Daily aerial surveys sampled for crane group use along eight transects covering the area from Chapman, Nebraska, westward to the junction of US Highway 283 and Interstate 80 near Lexington, Nebraska, and including an area 3.5 miles (5.6 kilometers) on either side of the Platte River centerline. There were 72 observations of crane groups recorded by the surveys, which 52 were in the wetted channel. Through all monitoring activities, there were 353 use locations documented in the study area. Crane groups located by the aerial surveys were continuously monitored by ground-based field crews until the cranes left the study area or their location became unknown. After crane groups departed the study area, habitat characteristics were measured at whooping crane use locations that were within water. Habitat measurements included land use, river profile surveys, estimation of unobstructed view in four directions, and substrate categorization.

Detection trials were experimentally conducted to compare detection rates of the aerial surveys. Single whooping crane decoys were randomly placed on accessible conservation lands in the study area in either the channel or upland stratum and their detection was recorded. A predictive model of detection probability was developed and used to calculate actual sample inclusion probabilities for monitoring flights. Of the possible predictor variables (contractor, year, season, flight direction, flight height, flight orientation, and survey strata), the final predictive model contained parameters for strata, contractor, and altitude. These trials offer evidence of significant variation in the probability of detection for whooping cranes in the study area. The estimated detection probabilities were used to calculate unbiased estimates of the index of use, trends, and unbiased resource selection models with respect to detection.

The average distance a crane group moved was estimated by averaging each successive known movement, where movement was defined as the straight line distance between two consecutive locations. Crane groups were considered to have moved if the crane group flew to a new location or the crane group walked to a different land cover type. The average distance moved was used to define the area for the estimation of "local area" habitat selection. The average distance moved across the 13 crane groups that had consecutive locations documented was 3.22 miles (95% CI: 0.10, 6.34); the minimum distance was 0.49 miles and the maximum distance was 21.64 miles.

The change in the frequency of use of the study area by whooping cranes throughout the Cooperative Agreement period was estimated with an index of crane use: the observed number of cranes adjusted by the estimated probability of detection during the flight per number of flights. The index was calculated for each monitoring season and accounted for seasonal variability in survey effort. A linear regression model was used to estimate the change in the index through time. The estimate of the annual change in the adjusted index of use for whooping cranes in the study area was -0.0057 (95% CI: -0.0507, 0.0393). This estimate was not significantly different from zero (p=0.8042) despite an increase in size of the Aransas-Wood Buffalo population during the Cooperative Agreement period.

The percentage of time a crane group was engaged in each diurnal activity type was calculated based on all observation times of crane groups. Crane groups spent 73% of the observed period feeding in the spring and 69% of the observed period feeding in the fall, on average. Other activities (resting, alert, preening, courtship, and defensive) comprised the remaining time.

Whooping crane habitat selection was modeled with an exponential function to predict the relative probability of use from the landscape characteristics (resource selection functions). Characteristics at the used locations were contrasted to characteristics at randomly selected "available" locations and discrete choice models accounted for spatial and temporal differences in habitat characteristics around each crane group observation. Models were used to investigate the association of habitat use with land cover, characteristics measured on the ground, and flow dependent characteristics.

Habitat selection models involved land cover parameters obtained from the Bureau of Reclamation land use/cover GIS based on 1998 photography and amalgamated into nine land cover categories: agriculture, development, grass, open water, shrub/forest, transportation, wetted channel, wet vegetation, and wet grass. The models suggested that use of the study area by whooping cranes was highly influenced by the amount of open water and adjacent agricultural lands. That is, whooping crane use was higher in areas with high proportions of wetted channel, open water, and agriculture compared to other combinations of land cover types, irrespective of whether the use location was in the channel or out of the channel. Models specific to in-channel use indicated whooping cranes utilize areas of wetted channels, open water, and agriculture that are away from transportation features and trees/shrubs.

The habitat selection model of characteristics measured on the ground documented the use of channels with large unobstructed views. The best model, which predicted the probability of use as a function of obstruction to obstruction width, estimated the maximum probability of selection occurred when obstruction to obstruction width was 343 meters (1,125 feet), and then began to decline beyond this point (Figure 1). Unobstructed width was measured as the distance between obstructions (where obstructions were defined as objects greater than 1.5m above water level through which an observer could not see) along a line perpendicular to the channel and passing through the crane observation. Distances to obstruction frequently extended outside of the channel.

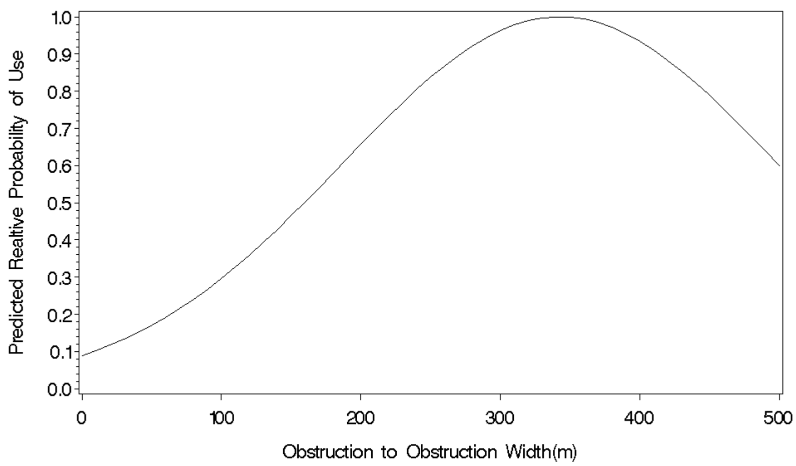

Figure 1. Predicted quadratic relationship between the relative probability of use and obstruction to obstruction width (meters) based on the resource selection function for characteristics measured on the ground.

Habitat selection models of flow dependent characteristics suggested that use of the study area by whooping cranes was influenced by the wetted width and the proportion of the bank to bank width which was depth suitable (where depth suitable was defined as depths less than 8 inches) or sand above the water surface (i.e. sandbars). These parameters were corrected for the change in water surface elevation between the time the river profiles were measured and the time of crane group use with the HECRAS 1D hydraulic model constructed for the Platte River. The daily mean flow during times cranes were observed in the study area represent generally dry conditions within the channel habitat, and predictions that result from models of these data are applicable to habitat use during low flow years.

The study area scale management model suggests Program land acquisition decisions and adaptive management experiments could be guided by the predicted probability of use for values of both wetted width and proportion depth suitable or sand. The maximum probability of selection occurred when wetted width was 319 meters and proportion of depth suitable or sand was 0.48, and estimated proportions of depth suitable or sand which maximize use can be estimated for channels of a given wetted width (Figure 2).

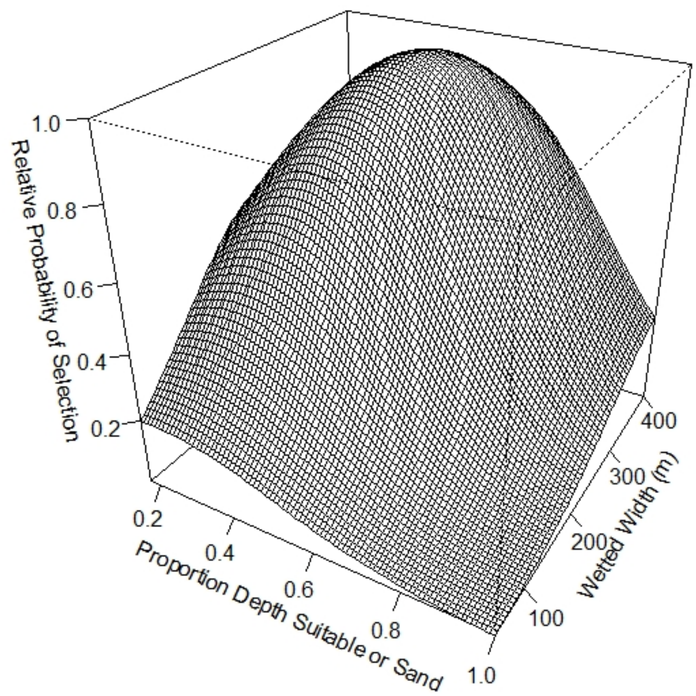

Figure 2. Predicted response surface for relative probability of use across width and proportion depth suitable or sand based on the management model for study area selection.

The study area scale management model provides guidance for Program land acquisition decisions and adaptive management experiments. The existing and potential wetted width and proportion suitable depth or sand could be evaluated and the cost of acquisition and management of a property could then be considered in terms of the change in probability of use of the property from the existing form to the potential form as managed by the Program. The non-flow dependent characteristics of the properties could then be evaluated including: unobstructed width, the proximity to transportation features, the proximity to grain crops, and the proximity to tree and shrub cover. Once properties are acquired, the flow dependent and non-flow dependent models can be used to prepare management plans and to conduct management experiments.

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INTRODUCTION

This analysis summarizes the data obtained through the implementation of the whooping crane monitoring protocol (PRESP 2005) during the Cooperative Agreement (CA) period of the Platte River Endangered Species Partnership. The protocol was developed by the Technical Committee of the CA and implemented during 11 migration seasons; the spring and fall seasons of 2001 to 2006, excluding the spring of 2003. This analysis was completed for the Platte River Recovery Implementation Program (Program).

There were five objectives stated in the monitoring protocol:

1) Detect whooping crane migrational stopovers in the study area: Systematic aerial surveys of the study area will be conducted and the data will be used to comparatively evaluate changes in the frequency and the distribution of stopovers within the study area over time. Opportunistic locates will also be used to evaluate whooping crane stopovers in the study area.

2) Identify the locations of crane group movements and use in the study area: Crane group movements will be documented in order to identify use-sites, and to describe the patterns of movement of each crane group.

3) Qualitatively document crane group activities at use-sites: Observers will qualitatively document activities displayed by the crane groups. Observed activities may help identify factors that influence how cranes use the area and aid in the interpretation of whooping crane behavior.

4) Document the physical and/or biological characteristics of use-sites: Habitat parameters will be described and measured at areas of use for those whooping cranes observed stopping in the central Platte River valley for comparative habitat analyses (e.g., as in determining habitat suitability or preference analyses).

5) Landscape Data Collection: Basic landscape data of whooping crane use-sites in the study area will be collected from aerial photography and Geographic Information System (GIS) information and appropriate landscape data collected using other protocols. This information will be used in landscape scale use/availability analyses.

We addressed these objectives through five analyses of the observed data: estimation of aerial survey detection rates, movement pattern summary, trends in the index of use, activity summary, and habitat selection analyses.

METHODS

The CA study area extends from Chapman, Nebraska, westward to the junction of US Highway 283 and Interstate 80 near Lexington, Nebraska, and includes an area 3.5 miles (5.6 kilometers) on either side of the Platte River centerline (river mile 151 to river mile 258; PRESP 2005; Appendix A). Daily aerial surveys took place from March 21 to April 29 in the spring of 2001-02 and 2004-06, and from October 9 to November 10 in the fall of 2001-06 to locate crane groups in the study area (PRESP 2005). The study area was sampled along eight transects: one following the south bank of the river, one down the centerline of the main river channel, and six transects located in the uplands surrounding and parallel to the river. The study area was further divided into two segments: the east segment between Chapman and the Nebraska Highway 10 (Minden) Bridge, and the west segment from the Minden Bridge to the Lexington Bridge. Two planes, each with two surveyors, surveyed two east-west transects within each segment of the study area each survey day. The first flight surveyed the river from the south bank with both observers looking out of the north side of the plane and focused on the river, and the return flight surveyed one of the seven transects parallel to the river corridor. Flights began a half-hour before sunrise and started with the river transect flown in the westward direction. There were changes to the orientation and start locations of the flights during the first years of protocol implementation (Appendix B). The final method used four start locations with alternating chronological order of the two segments for each plane. This method was implemented to allocate the earlier survey times more evenly throughout the study area.

All locations used by crane groups throughout the study area which were detected by the monitoring were documented. Crane groups located by the aerial surveys were continuously monitored by ground-based field crews until the cranes left the study area or their location became unknown. This set of observations comprised the systematic sample of observations. Crane groups located in the study area by method other than the aerial survey (the field crew, other biologists, or the public) comprised the opportunistic sample of observations. Activities were sampled every 15 minutes while crane groups were being observed, by documenting the observed activity. Activities were categorized as: 1) alert behavior: crane alert and scanning horizon; 2) courtship behavior: crane performing unison call and/or dancing; 3) agonistic/defensive behavior: defensive or offensive display with other birds (whooping cranes, sandhill cranes, etc.); 4) feeding: any behavior suggesting the bird is in the act of feeding, such as a crane flipping over objects and/or probing for food or slow locomotion interrupted by these activities; 5) preening: crane preening feathers; and 6) resting/loafing: crane standing still in one place.

After the crane group departed the study area, habitat characteristics were measured at whooping crane use locations. Habitat measurements included land cover, river profile surveys, estimation of unobstructed view in four directions, and substrate categorization. The river profiles were measured at three transects perpendicular to the flow, with the middle transect traversing through the use area and the endpoints of all transects at obstructions greater than five feet (ft; 1.5 meters [m]) above water level (PRESP 2005).

All analyses were conducted separately for crane groups located through the systematic aerial surveys and for crane groups located systematically and opportunistically. Observations of crane groups located by the aerial surveys were included in the systematic sample of locations. Each observation in this sample had known inclusion probabilities based on the flight coverage of the study area and the probability of detection. All observations of a crane group by ground-based observers on a given day were included in the systematic dataset if the crane group had been observed initially from the systematic aerial survey. Crane groups located opportunistically were combined with the systematic locations and analyzed together. All analyses were conducted using crane groups as the sample unit, because of the inherent dependence among cranes migrating as a group.

Aerial Survey Detection Rates

Experimental trials were conducted to compare detection rates for the many factors relating to the implementation of the aerial survey protocol. Detection trials were conducted using a stratified random survey design. Single whooping crane decoys (sandhill crane decoys painted to resemble whooping crane plumage) were randomly placed on accessible conservation lands in the study area in either the channel stratum (river) or upland (return) stratum and their location was either recorded or not recorded during the aerial survey (PRESP 2005). The resulting strata estimates of detection probability are applicable to the types of aerial transects surveyed. Detection trials were conducted in the study area during each of the 11 survey seasons. All trials were conducted using single decoys randomly placed on accessible conservation lands. A total of 176 decoy trials were deployed during the Cooperative Agreement period for detection by the systematic flights: 111 decoy trials were conducted in the river in the wetted channel and 65 decoy trials were conducted within the entire study area in the return strata (Table 1). Flight orientation covariate information was available for 168 of the decoys.

A predictive model of detection probability was developed and used to calculate actual sample inclusion probabilities for monitoring flights. Models were parameterized assuming the number of decoys detected during the aerial flights followed a binomial distribution with parameters **n** (the number of decoy trials) and **p** (the detection probability). A list of candidate models was generated through listing all possible combinations of the predictor variables: contractor, year, season, flight direction, flight height, flight orientation, and survey strata. Models were fit using logistic regression and the Akaike information criterion (AIC) was calculated to select the most likely model given the data.

Movement Pattern Summary

The average distance a crane group moved was estimated by averaging each successive known movement, where movement was defined as the straight line distance between two consecutive locations. Crane groups were considered to have moved if the crane group flew to a new location or the crane group walked to a different land cover type. Distances were averaged across all movements observed for a crane group. The average distance moved was estimated across the 13 crane groups with multiple observations, using the crane group designation made by the USFWS. Movements were mapped on color infra-red photographs taken during fall 2003, with the length of time a crane group spent in an area indicated by the size of the mapped symbol and arrows to indicate the direction of movement.

The average distance moved was used to define the area within which a crane group will make a "local area" selection of habitat within the study area. While there are other ways to define the local area, WEST chose this definition because it could be calculated with the available data and it adequately represents the average distance a crane group flies when intending to continue use of the study area. It is assumed the distances recorded by the ground crews were a random sample of distances moved by crane groups using the study area.

Trends in the Index of Use

The change in the frequency of use of the study area by whooping cranes throughout the CA period was estimated with the observed trend in an index of use. The index of crane use was defined as the number of crane groups observed per number of flights (PRESP 2005) and was calculated for each monitoring season. Survey detection rates were incorporated into this analysis through adjustment of the observed number of cranes by the estimated probability of detection during the flight, based on the predictive detectability model (Thompson 1992) and the recalculation of the index of use with the adjusted number of crane groups. Simple linear regression with normal errors was used to estimate the change in the index through time. Time was represented by the year and the proportion of year at the midpoint of the survey. The winter peak count of the Aransas-Wood Buffalo population was included as a covariate.

Activity Summary

The percentage of time a crane group was engaged in each activity was calculated for an observation session, where an observation session is defined as all the time a crane group was observed during a day. These percentages were averaged across all observation sessions recorded and the variance of this average was used to calculate confidence intervals. The summaries were made by migration season (spring and fall) and for both migration seasons combined and represent diurnal activities.

Habitat Selection

Characteristics of whooping crane habitat selection in the central Platte River were modeled through the development of resource selection functions (RSF). The basic premise of resource selection modeling (Manly et al. 2002) is that resources (which may be food items, land cover types, or any quantifiable habitat characteristic) that are important to animals will be "used" disproportionately to the availability of those resources in the environment. The RSF model uses an exponential function to model and predict the relative probability of use from the landscape characteristics. In this analysis, the characteristics at the used locations were contrasted to characteristics at randomly selected "available" locations in the same region.

There were two sets of used locations for the RSF analyses: all locations (in and out of channel) for summarizing study area selection, and the subset of in-channel locations for summarizing in-channel selection. A location is defined as a point in space used by a crane group at one point in time. These locations represent multiple re-locations of the same group of birds but since individual cranes were not identifiable in the field and observations of whooping cranes are rare, we have maintained all the observations in the dataset we analyzed.

For the models relating landscape level characteristics to crane group selection in the entire study area, we defined the available set of points with a 500x500m grid randomly placed over the entire study area. The intersection of the gridlines results in 6,420 available points. A subset of 189 points were in the 'wetted channel' or “barren beach/bar” designation of the 1998 land cover/use GIS layer and comprised the available points for the in-channel analysis.

Land cover parameters were obtained from the Bureau of Reclamation (BOR) land use/cover GIS based on 1998 photography (USBOR 2000). Amalgamation of the vegetation classes (VEG_DESC) resulted in nine land cover categories. Agriculture included agriculture alfalfa, agriculture bare ground, agriculture corn, agriculture mown field, agriculture other crops, agriculture soy bean, and agriculture other crop. Development included development commercial, development residential, and development single dwelling. Grass included lowland grasses, mown lowland grasses, and upland grasses. Open water included open water pit, pond or lake, open water, open water slough, and open water canal. Shrub/forest included shrubs inside floodplain, shrubs outside floodplain, wooded river within floodplain, woody outside floodplain. Transportation included bridge, other road, railroad, gravel road, interstate, and paved road. Wetted channel included wetted channel and barren beach/bar. Wet vegetation included herbaceous riparian, emergents, and wet meadow mosaic. Wet grass included all land cover classes in the grass and wet vegetation categories. We extracted the distance from each point to the nearest location of each landscape category (meters) and the proportion of each of the landscape category within a 0.25 mile radius buffer. The distance variables were squared to allow for possible non-linear effects.

For the models relating landscape level characteristics to crane group selection at a local scale, we defined the available set of points as the subset of the study area available sample of points that fell within 3.2 miles of the used location. We defined the available sample of points for the wetted channel models at a local scale as the subset of points that fell within the 'wetted channel' designation of the 1998 land cover/use GIS layer and 3.2 miles of the used location. The distance for the local area definition was obtained through the movement pattern summary of all the data (see above).

For the models relating characteristics measured on the ground to crane group selection in the wetted channel, we defined the available set of points as the set of random locations where decoys were placed during the same survey season. On the ground measurements were obtained by survey crews at the time the profiles were measured. The percentage of fine sand (less than 1mm), coarse sand (1-4.9mm), small gravel (5-14.9mm), and large gravel (greater than 15mm) were occularly estimated as the channel was waded. The distance to visual obstructions (objects (e.g., vegetation, bank, etc.) greater than 1.5m above water line) was estimated as the average of the shortest distance to visual obstructions in four quadrants centered on the crane group location. We also estimated the area around the crane use location which was clear of visual obstructions by the product of the squared average distance and pi. Unobstructed width was measured as the distance between obstructions greater than 1.5m in height through which an observer could not see (e.g., dense vegetation) along a line perpendicular to the channel and passing through the crane observation. This distance variable was squared to allow for possible non-linear effects.

For the models relating flow dependent characteristics of the wetted channel to crane group selection, we employed the HECRAS 1D hydraulic model constructed for the Platte River Unsteady Flow and Bank Storage Model (Randle and Samad 2007) to estimate the water surface differential for the purpose of adjusting flow dependent parameters. The water surface differential corrects for the change in water surface elevation between the time the river profiles were measured and the time of crane group use. Due to the endangered species status of the whooping crane, we were unable to take measurements of the channel while the birds were in the study area. The sediment and river hydraulics group of the USGS in Denver evaluated three methods to incorporate the water surface differential in the flow dependent parameters. The HECRAS model was chosen as the best method based on their evaluation (Fotherby and Russell 2008). The HECRAS model used the mean daily flow values from the gages adjacent to the crane group location, divided the flow between the channels in the full cross section, and computed the water surface differential at each transect. The HECRAS model output included an estimated water surface differential, wetted top width, hydraulic depth, and flow for whooping crane transects on every day with a crane group observation. The HECRAS water surface differential was used to adjust the profile data to estimate sandbar elevation with simple linear interpolation. We included the wetted width, flow, proportion of the wetted width which was depth suitable (where depth suitable was defined as less than 8 inches deep), proportion of the bank to bank width which was depth suitable or sandbars, proportion of the bank to bank width which was sandbars, and the ratio of width to depth in the habitat modeling.

For the models incorporating flow dependent characteristics, we defined the available set of points as the base set of 165 transects spaced every 0.50 mile in the HECRAS model (Fotherby and Russell 2008). This set included transects which were measured in 1989, 1998, or 2002, transects which were interpolated from the measured transects, and transects which were synthetically constructed from the 1998 color infra-red photos. The spatial extent of this set of transects was from river mile 157 to river mile 239, limiting the model to inferences within this section of the river. The HECRAS model output included an estimated water surface differential, wetted top width, hydraulic depth, and flow for base transects on every day with a crane group observation. Sandbar elevation could not be obtained for the base set of transects.

Means of Habitat Parameters

Land cover variables, characteristics measured on the ground, and flow dependent habitat variables were summarized for use sites in the channel and upland strata separately and also combined. For the systematic sample of use locations, strata means and variances were estimated by the Horvitz-Thompson estimator for unequal probability sampling designs (Thompson 1992). Each observation had a predicted probability of inclusion in the sample based on the characteristics of the flight during which it was observed. Strata estimates were combined using standard estimators for stratified random sampling (Scheaffer et al. 1996). Strata weights were based on the number of possible transect days and the number of surveyed transect days.

Characteristics measured on the ground and flow dependent habitat variables which were proportions were summarized for the channel using large sample approximations of estimators for simple random samples. Means and variances were calculated for the systematic sample of use locations, the systematic and opportunistic combined sample of use locations, and available samples for each habitat model.

We also used large sample approximations of estimators for simple random samples to calculate means and variances for the systematic and opportunistic combined sample of use locations. We also estimated these values for the available samples for each habitat model.

Habitat Models

We constructed seven habitat models to describe habitat selection with the three types of habitat parameters.

- Four models were fit to evaluate the association of habitat use with land cover:
    - Habitat selection in the entire study area (in-channel and upland),
    - Habitat selection in-channel in the study area,
    - Habitat selection in the local area (in-channel and upland) and
    - Habitat selection in the local in-channel area.
- One model was fit to evaluate the association of habitat use with characteristics measured on the ground.
- Two models were fit to evaluate the association of habitat use with flow dependent characteristics:
    - Habitat selection in the entire study area and
    - Habitat selection in the local area.

Study area models evaluated selection as compared to availability in the entire study area. Local area models evaluated selection as compared to availability in the local area.

For each type of habitat selection model, we created a model for the systematic sample of observations and a model for the systematic and opportunistic observations combined. For each dataset, we conducted the model selection routine to choose a model. We compared the models for each dataset by assessing the similarity of the variables in the model, and the coefficient value, direction, and interpretation for duplicate variables. Models that resulted in the same interpretation based on similar values for the same parameters were determined to be not biologically different. The final flow dependent model was developed to assist in management decision making using the results of the four flow dependent models.

Models using the systematic sample of observations were weighted by the probability of detection. The final predictive model for detectability was used to estimate the probability of detection for each observation. The overdispersion parameter was divided by the probability of detection for each observation, which has the effect of multiplying the contributions of the log-likelihood function for each observation (SAS Institute).

A forward selection routine was used to develop the models. The AIC was used to determine the entry of a variable at each step of the selection procedure. For example, each variable in the candidate variable list was fit in a model. The model with the lowest AIC score was selected for the first step. The variable added to this model was then removed from the candidate variable list, along with any variables with a high correlation (greater than 0.75 or less than -0.75) with this variable. Next, each variable in the candidate variable list was fit in a model with the variable selected during the previous step. The model with the lowest AIC score from this set of models was selected for the next step. The procedure was continued until there were no variables in the candidate variable list for which their addition into the model produced a model with a lower AIC. Since the latter steps in this model selection procedure generally continue to add variables to the model, though no significant reduction of the AIC is occurring, a graph of AIC through the model selection procedure was used to select a model at the point where additional variables entering the model do not contribute substantially.

For models with quadratic relationships in the explanatory variables in which the parabolic maximum was biologically interesting, we calculated bias-corrected percentile confidence limits on the maximum (Manly 1997). Datasets were resampled 500 times, models were refit, and the maximum of the quadratic curve was calculated for each replication of the bootstrap sample. The percentiles of the bootstrap distribution were used for confidence limits.

Study area selection of land cover

Study area selection of land cover was modeled as a discrete choice in space (Manly et al. 2002). In this model, a used location was considered a choice, and each location was considered to have been chosen from a "choice set" consisting of points in the available sample. For used points in the wetted channel, the choice set consisted of available points in the wetted channel. For used points outside of the wetted channel, the choice set consisted of available points outside of the wetted channel. The discrete choice model accounts for different land cover options within the two strata, wetted channel and upland, while modeling the underlying relationships between selection and land cover predictor variables. The model for all opportunistic locations had sample sizes of 320 used and 6420 available locations. The model for all systematic locations had sample sizes of 72 used and 6420 available locations. The 27 variables considered as candidates for each of these models were the distance to each land cover category, these distances squared, and the proportion of each of the 9 land cover categories within 0.25 miles of the location (Table 2).

Study area in-channel selection of land cover

In-channel selection of land cover was modeled with an exponential function (Manly et al. 2002). The model for in-channel systematic locations had sample sizes of 58 used and 189 available locations. The model including opportunistic locations had sample sizes of 150 used and 189 available locations. The same 27 variables were considered as candidates these two models.

Local area selection of land cover

Local area selection of land cover was modeled as a discrete choice in space (Manly et al. 2002). In this model, a used location was considered a choice, and each location was considered to have been chosen from a "choice set" consisting of points in the available sample within the local area (as described above). A discrete choice model will account for different land cover options within the local area around the crane observation, while modeling the underlying relationships between selection and land cover predictor variables.

The model for all opportunistic locations had sample sizes of 321 used and approximately 300 available locations in each choice set. The model for systematic locations had sample sizes of 72 used and approximately 300 available locations in each choice set. The 27 land cover variables mentioned above and the 9 indicator variables for land cover type were considered as candidates for each of these models. Forward model selection proceeded as described above.

Local in-channel selection of land cover

Local area selection of in-channel land cover was modeled as a discrete choice in space (Manly et al. 2002). In this model, a used location was considered a choice, and each location was considered to have been chosen from a "choice set" consisting of in-channel points in the available sample within the local area (as described above). A discrete choice model will account for different land cover options within the local area around the crane observation, while modeling the underlying relationships between selection and land cover predictor variables.

The model for in-channel opportunistic locations had sample sizes of 151 used and approximately 15 available locations in each choice set. The model for in-channel systematic locations had sample sizes of 58 used and approximately 15 available locations in each choice set. The 27 land cover variables mentioned above and the 9 indicator variables for land cover type were considered as candidates for each of these models. Forward model selection proceeded as described above.

Study area selection of characteristics measured on the ground

Study area selection of land cover was modeled as a discrete choice in time (Manly et al. 2002). In this model, a used location was considered a choice, and each location was considered to have been chosen from a "choice set" consisting of decoy locations on conservation lands and surveyed during the same survey season (the available sample). This analysis only pertains to in-channel use locations because characteristics measured on the ground were only measured at in-channel locations. A discrete choice model will account for seasonal and temporal differences in habitat characteristics, while modeling of the underlying relationships between selection and on the ground predictor variables.

The model for in-channel opportunistic locations had sample sizes of 131 used and between 2 and 14 available locations in each choice set. The model for in-channel systematic locations had sample sizes of 37 used and between 2 and 14 available locations in each choice set. There were 8 variables considered as candidates for each of these models (Table 3, with obstruction to obstruction width squared), and forward model selection proceeded as described above.

Study area selection of flow dependent characteristics

Study area selection of flow dependent habitat characteristics was modeled as a discrete choice in time (Manly et al. 2002). In this model, a used location was considered a choice, and each location was considered to have been chosen from a "choice set" consisting of points in the available sample. A discrete choice model will account for temporal differences in flow characteristics around each crane observation, while modeling the underlying relationships between selection and flow dependent predictor variables.

The model for systematic locations had sample sizes of 55 used and 165 available transects in each choice set. The model for systematic and opportunistic locations combined had sample sizes of 155 used and 165 available locations in each choice set. There were 6 flow dependent variables considered as candidates for each of these models (Table 4, excluding sandbar elevation), and the quadratic term for each. Forward model selection proceeded as described above.

A final model for study area selection for the systematic sample of observations was developed to assist in management decision making. The results of the models parameterized with the model selection procedures were used to guide the choice of variables in the model. Quadratic and interaction terms were considered as a way to assess the limits of modeled linear relationships.

Local area selection of flow dependent characteristics

Local area selection of land cover was modeled as a discrete choice in time and space (Manly et al. 2002). In this model, a used location was considered a choice, and each location was considered to have been chosen from a "choice set" consisting of points in the available sample (the 165 base transects of the HECRAS model). A discrete choice model will account for spatial and temporal differences in habitat characteristics, while modeling of the underlying relationships between selection and flow dependent predictor variables.

The model for systematic locations had sample sizes of 55 used and approximately 13 available locations in each choice set. The model for systematic and opportunistic locations combined had sample sizes of 155 used and from 9 to 19 available locations in each choice set. The same 6 flow dependent variables were considered as candidates for each of these models, and forward model selection proceeded as described above.

Predictive Maps

We used the model coefficients to predict the relative probability of selection for the habitat parameter values at the available sample of points. Land cover maps were based on the land use/cover parameters from the 1998 BOR GIS. Flow dependent models were mapped at three flow levels, based on the quartiles of observed daily flow at the Kearney, NE gage during all crane use days. Flow parameters were output from HECRAS for the 165 base transects during the three flow levels, 250, 350, and 786 cfs.

RESULTS

There were 353 observations of crane groups recorded in the study area during the 11 monitoring seasons of the Cooperative Agreement time period (Figure 1; Table 5). Of the 320 locations within the land use/land cover GIS layer (BOR 2000), 150 were in the wetted channel, 143 in agriculture, 21 in grass, 3 in shrub/forest, and 3 in wet grass (Table 6). There were 72 observations of crane groups detected with the systematic aerial survey flights (Figure 2). There were 58 observations of crane groups in the wetted channel detected with the systematic aerial survey flights, 10 were in agriculture, 2 in grass, 1 in shrub/forest, and 1 in wet grass.

Aerial Survey Detection Rates

A predictive model was developed for use in analyses conducted with the monitoring data. The final predictive model contained parameters for strata, contractor, and altitude. The form of the final model was:

$$P(\text{det}) = \exp[\, -1.10 + (2.74*\text{Strata}) + (1.42*\text{Contractor}_{\text{AIM}}) + (0.97*\text{Contractor}_{\text{GREYSTONE}}) + (3.34*\text{Contractor}_{\text{OTTERTAIL}}) - 1.89*\text{Altitude})]$$

where Strata was 1 for the river and 0 for the upland, Contractor coefficients take on the value of 1 for a given contractor and 0 for WEST, and Altitude was 1 for 750 feet and 0 for 1000 feet. The standard errors of the estimates were 0.56, 0.54, 0.49, 0.59, 0.79, and 0.62 respectively.

The model was used to estimate the probability of detection for each flight. The sum and average predicted values across the flights estimates the overall detectability for a survey (Figure 3; Table 7). The average predicted probability of detection for each survey ranged from 0.34 to 0.78.

Imperfect detection probability of whooping cranes within the study area will bias the frequency of use estimates and any conclusions based on the observed spatial distribution. The aerial survey detection rate study has documented differences in the estimated detection probability, which will be accounted for in the analyses of these data. The estimation of the detection bias with the final predictive model enabled the calculation of an index of use, trend, and resource selection parameters which are unbiased with respect to crane group detection in the study area.

Movement Pattern Summary

The average distance moved across the 13 crane groups was 3.22 miles (95% CI: 0.10, 6.34); the minimum distance was 0.49 miles and the maximum distance was 21.64 miles. Movement patterns of each crane group are shown in figures 4 through 15.

Trends in the Index of Use

The index of crane use was calculated for each monitoring season (Table 8). The systematic surveys resulted in 1168 flights that were completely flown. The 6% of the flights which were incomplete were not used to avoid the bias associated with uneven coverage of the study area in the east-west direction. The estimate of the annual change in the index of use for whooping cranes in the study area was -0.0008 (95% CI: -0.0286, 0.0269). This estimate was not significantly different from zero (p=0.9547). The estimate of the annual change in the adjusted index of use for whooping crane in the study area was -0.0057 (95% CI: -0.0507, 0.0393). This estimate was not significantly different from zero (p=0.8042). The negative trend for each index is shown in figure 16. The winter peak count of the Aransas-Wood Buffalo population increased throughout the Cooperative Agreement period and was not a significant covariate in the model (Figure 17).

Activity Summary

Feeding behaviors were the most common activity observed during crane group monitoring in the spring and fall and for both seasons combined. Crane groups spent an average 73% of the observed period (95% CI: 63, 82) feeding in the spring while they spent 69% of the observed period feeding (95% CI: 62, 76) in the fall (Table 9). The second most commonly observed activity was resting, crane groups spent 15% of the observation period resting in the spring (95% CI: 5, 24) and 9% of the observed period (95% CI: 5, 14) was spent resting in the fall. Alert and preening activities were fairly uncommon, crane groups spent 7% of the observation period (95% CI: 2, 11) alert in the spring and 11% of the observed period (95% CI: 3, 19) was spent alert in the fall. Crane groups spent 3% of the observation period (95% CI: 1, 5) preening in the spring and 10% of the observation period (95% CI: 5, 15) was spent preening in the fall. Courtship and defensive behaviors were very rare, less than 2% of the time, and only observed in the spring. These results are based on observations made by ground crews and observations are limited to diurnal activities.

Habitat Selection

Means were estimated for each land cover habitat parameter for the channel, upland, and for the study area combined with the systematic observations (Table 10). Some variables had significantly different values when the means were calculated including opportunistic observations. We chose to report the means based on the systematic sample because they are an unbiased representation for the population of interest. Opportunistic observations are spatially biased because they were obtained with an unknown detection probability and an unknown level of effort. Means estimated from the combined systematic and opportunistic samples are in Appendix C.

Means were estimated for each habitat parameters measured on the ground with the systematic observations (Table 11). The percentage of fine sand was 61% (95% CI: 51, 71), the percentage of coarse sand was 30% (95% CI: 21, 39), the percentage of small gravel was 8% (95% CI: 4, 12), and the percentage of large gravel was <1% (95% CI: 0, 0.90). The average distance to visual obstruction was 285 meters (95% CI: 219, 351). The average number of acres clear of visual obstruction was 54 (95% CI: 40, 67). The average obstruction to obstruction width was 407 meters (95% CI: 296, 519). The means estimated from the combined systematic and opportunistic samples are in Appendix C.

Means were estimated for each flow dependent habitat parameter with the systematic observations (Table 12). The average wetted width was 246 meters (95% CI: 206, 286), which is equivalent to 807 feet (95% CI: 676, 939). The average flow was 913 cfs (95% CI: 748, 1078). The average sandbar elevation was 0.31 meters (95% CI: 0.22, 0.40), which is equivalent to 1.02 feet (95% CI: 0.73, 1.31). The average proportion depth suitable was 0.57 (95% CI: 0.52, 0.62). The average proportion depth suitable or sandbars was 0.67 (95% CI: 0.62, 0.73). The average proportion of sandbars across bank to bank width was 0.31 (95% CI: 0.25, 0.37). The average ratio of width to depth was 1209 (95% CI: 995, 1422). The means estimated from the combined systematic and opportunistic samples are in Appendix C.

Means were estimated for each land cover habitat parameter, habitat parameter measured on the ground, and flow dependent habitat parameter for the available samples used in the estimation of resource selection models (Appendix D). The models estimated from the combined systematic and opportunistic samples are in Appendix E. Steps for the model selection procedure for the systematic sample of observations are in Appendix F.

Study area selection of land cover

We predicted the relative probability of selection for the study area based on the 1998 CIR photographs (Figure 18). The final resource selection model, w(x), for all observations (wetted channel and upland) contained the linear effects of percent of wetted channel within 0.25 miles (P_WC), percent of open water within 0.25 miles (P_OW), and percent of agriculture within 0.25 miles (P_AG). The form of the final model was:

$$W(x) = \exp[(0.078*P\_WC) + (0.300*P\_OW) + (0.017*P\_AG)]$$

The standard errors for the coefficients were 0.01, 0.05, and <0.01 for percent of wetted channel, percent of open water, and percent of agriculture respectively. This model indicated significant selection for areas with large proportions of wetted channel, open water, and agriculture, regardless of the observation being in the wetted channel or out of the channel.

Study area in-channel selection of land cover

We predicted the relative probability of selection for the in-channel area based on the 1998 CIR photographs (Figure 19). The final resource selection model, w(x), for in-channel observations contained the linear effects of percent of open water within 0.25 miles (P_OW), the percent of wetted channel within 0.25 miles (P_WC), the percent of agriculture within 0.25 miles (P_AG), distance to transportation (trdist), and the linear and quadratic effects of distance to shrub and forest (sfdist). The form of the final model was:

$$W(x) = \exp[-7.319 + (2.028*P\_OW) + (0.067*P\_WC) + (0.055*P\_AG) + (0.003*trdist) + (0.0393*sfdist) - (0.001*sfdist^2)]$$

The standard errors for the coefficients were 1.04, 0.52, 0.02, 0.01,< 0.01, 0.01, and <0.01 for the intercept, percent of open water, the percent of wetted channel, the percent of agriculture, transportation distance, linear effect of shrub and forest distance, and the quadratic effect of shrub and forest distance respectively. This model indicated significant selection for in-channel areas with large proportions of open water, wetted channel, and agriculture. There was an increased relative probability of selection for areas far from transportation features, and the relative probability of selection increased for large distances to shrub and forest with the rate of increase slowing as the distances to shrub and forest reached the largest values in the dataset (Figure 20).

Local area selection of land cover

The final resource selection model, w(x), for all observations (wetted channel and upland) contained the linear effects of percent of wetted channel within 0.25 miles (P_WC), percent of open water within 0.25 miles (P_OW), and indicators for wetted channel and agriculture. The form of the final model for wetted channel was:

$$W(x) = \exp[2.496 + (0.124*P\_WC) + (1.371*P\_OW)]$$

The standard errors for the coefficients were 0.49, 0.02, and 0.14 for wetted channel indicator, percent wetted channel, and percent of open water respectively. The form of the final model for agriculture was:

$$W(x) = \exp[2.449 + (0.124*P\_WC) + (1.371*P\_OW)]$$

The standard errors for the coefficients were 0.60, 0.02, and 0.14 for agriculture indicator, percent wetted channel, and percent of open water respectively. And the form of the final model for all other land cover types was:

$$W(x) = \exp[(0.124*P\_WC) + (1.371*P\_OW)]$$

The standard errors for the coefficients were 0.02, and 0.14 for percent wetted channel, and percent of open water respectively. This model indicated significant selection for local areas with large proportions of wetted channel and open water, as well as for the wetted channel and agriculture cover types.

Local in-channel selection of land cover

The final resource selection model, w(x), for in-channel selection contained the linear effects of percent of open water within 0.25 miles (P_OW), percent of wetted channel within 0.25 miles (P_WC), and the linear and quadratic effects of distance to transportation (trdist). The form of the final model was:

$$W(x) = \exp(3.367*P\_OW) + (0.121*P\_WC) - (0.005*trdist) + (0.001*trdist\_2)$$

The standard errors for the coefficients were 0.77, 0.03, < 0.01, and <0.01. This model indicated significant selection for local in-channel areas with large proportions of open water, and wetted channel. The relative probability of selection was low for small distances to transportation and increased with large distances to transportation (Figure 21).

Study area selection of characteristics measured on the ground

The final resource selection model, w(x), contained the linear and quadratic effects of obstruction to obstruction width (o_to_owidth). The form of the final model was:

$$W(x) = \exp[(0.014*o\_to\_owidth) – (0.001*o\_to\_owidth^2)]$$

The standard errors for the coefficients were <0.01 and <0.01 for the linear and quadratic effects respectively. This model indicated significant selection for large obstruction to obstruction widths up to a point, and then the relative probability of selection decreased with increased obstruction to obstruction width (Figure 22). The quadratic function was maximized at 343 meters (80% CI: 324, 363).

Study area selection of flow dependent characteristics

The final resource selection model, w(x), contained the linear effects of proportion sand and width and the linear and quadratic effects of proportion depth suitable or sand. The form of the final model was:

$$W(x) = \exp[(3.752*P\_sand) + (0.007*width) + (4.196*P\_depth\_sand) – (5.399*P\_depth\_sand^2)]$$

The standard errors for the coefficients were 0.93, < 0.01, 2.81, and 2.49 for the effects of proportion sand, width, the linear effect of proportion depth suitable or sand, and the quadratic effect of proportion depth suitable or sand respectively. This model indicated significant selection for greater proportions of sand and greater widths. This model also indicated significant selection for large proportion depth suitable or sand up to a point, then the relative probability of selection decreased with increased proportion depth suitable or sand (Figure 23). The quadratic function was maximized at 0.39 proportion depth suitable or sand (80% CI: 0.18, 0.51).

Local area selection of flow dependent characteristics

The final resource selection model, w(x), contained the linear and quadratic effects of proportion depth suitable or sand and the linear effect of flow. The form of the final model was:

$$W(x) = \exp[(10.420 * P\_depth\_sand) - (8.020 * P\_depth\_sand^{2}) + (0.002 * Flow))]$$

The standard errors for the coefficients were 3.52, 2.91, and <0.001 for the linear effect of proportion depth suitable or sand, the quadratic effect of proportion depth suitable or sand, and flow respectively. This model indicated significant selection for large proportion depth suitable or sand up to a point, then the relative probability of selection decreased with increased proportion depth suitable or sand (Figure 24). The quadratic function was maximized at 0.65 proportion depth suitable or sand (80% CI: 0.55, 0.80). This model also indicated significant selection for higher flows.

Study area management model of flow dependent characteristics

To assist in management decision making, we expanded on the study area flow dependent model to include the quadratic term for width and the interaction of width and proportion depth suitable or sand. The interaction was included to enable management guidance on both width and proportion depth suitable or sand. The form of the final model was:

$$W(x) = \exp[(5.178 * P\_sand) + (0.012 * width) - (0.001 * width^{2}) + (2.022 * P\_depth\_sand) - (5.929 * P\_depth\_sand^{2}) + (0.012 * width * P\_depth\_sand)]$$

The standard errors for the coefficients were 1.08, < 0.01, < 0.01, 2.87, 2.49, and < 0.01 for the effects of proportion sand, width, the quadratic effect of width, proportion depth suitable or sand, the quadratic effect of proportion depth suitable or sand, and the interaction of width and proportion depth suitable or sand respectively. The predicted relative probability of selection was maximized at 319 meters wetted width and 0.48 proportion of depth suitable or sand (Figure 25). We used the model to predict the relative probability of selection for the in-channel area at low, medium, and high flows (Figures 26-28). In general, the abundance of areas with higher probability of use increased as flows increased throughout the study area, but particularly in areas west of Kearney, Nebraska.

DISCUSSION

Detection Rates

One of the primary objectives of the whooping crane monitoring protocol was to monitor the frequency and spatial distribution of whooping cranes in the study area. The detection trials conducted to date offer evidence of detection probabilities less than 100% and significant variation in the probability of detection for whooping cranes in the study area, indicating our analyses should account for the detection probability. The estimation of this detection bias enabled the calculation of unbiased estimates of the index of use, trends and unbiased resource selection models with respect to detectability.

Detection trials conducted during each survey enabled the calculation of reliable estimates of the probability of detection for each field season. These survey specific estimates reduced the impact of changes made to the survey protocol during the period of study on the results.

Movement Patterns

The main purpose of conducting the movement pattern analysis was to determine a value to use to define a local area for selection. This analysis resulted in the average movement distance of 3.2 miles. However, because the results of the analysis correspond to the study area width established in the monitoring protocol (3.5 miles either side of the main channel centerline), it appears that the Program's defined monitoring corridor will capture the majority of out-of-channel crane use locations. If crane groups moved outside this study area while being monitored, the field crews made a professional judgment on whether or not the cranes were migrating from the Platte River area. If the crane group was judged to be migrating from the area, the ground crew stopped recording observations. If the crane group was judged to be using habitat outside the primary study area temporarily, the ground crew continued to make observations. In this way, the predetermined study area definition was supported by this analysis. Notwithstanding, if cropping/farming or habitat patterns change this movement distance may increase (possibly indicating that cranes are moving further to feed or between roosts) or decrease (possibly indicating increased habitat availability to the cranes).

Index of Use

The index of use was calculated to determine the trend in crane use in the study area. The variability in survey effort was accounted for in estimating the trend in use. Thus, regardless of differences in effort among survey years, an increase in the index of use over time should represent a real increase in crane use of the study area and a decrease in the index over time should indicate a real decrease in use of the study area. There was no statistically significant positive or negative trend in the index of crane use of the study area from 2001 to 2006. That is, while there were annual fluctuations in the number of birds observed, over time there was no change in crane group use, despite an increase in size of the Aransas-Wood Buffalo migrating population during this same time.

It is difficult or impossible to determine what, if anything, a non-significant trend in the index of use means in a biological sense. Although this study did not address the cause of the observed trend, different hypotheses could include: the trend was real but small, the study area is saturated so there can be no increase in use until the available habitat increases, cranes prefer other stopover habitats, or stopover locations are chosen randomly. With continued monitoring of the index of use and with reference data on use at other stopover habitats, these data will be able to provide an understanding of patterns of whooping crane use in the study area in the future.

Activity Monitoring

During the spring and fall migrations, crane groups were observed in the study area spending more time during the day feeding than performing any other activity. Resting, alert, and preening activities were also occasionally observed. Courtship and defensive activities were rare and were observed only in the spring. These observations are consistent with expected diurnal activities during migration; that is, birds need to feed often and tend to conduct courtship activities during the spring season. No unique activities were documented during the 2001-2006 monitoring period.

This summary represents diurnal use during the period of observation by the field crews. Observations were made throughout the day in upland and channel habitats, but the data was combined to calculate the estimates presented here. As more data is collected, it will be possible to estimate activity patterns by habitat and subsets of the diurnal use period.

Habitat Selection – Land use/Land cover

The spatial composition of vegetation types and land use components at whooping crane group use locations influenced habitat selection. Habitat selection models of land cover for both in-channel and uplands suggested that use of the study area by whooping cranes was highly influenced by the amount of open water and agricultural lands. Habitat selection models that described use within the study area contained the variables percent of wetted channel, percent of open water, and percent of agriculture. That is, whooping crane use was higher in areas with high proportions of wetted channel, open water, and agriculture compared to other land cover types, irrespective of whether the use location was in the channel or out of the channel.

Habitat selection models specific to in-channel use contained these same variables, as well as the distance from transportation features (i.e. roads and bridges) and shrub and forest. Models for local selection were consistent with these results. The survey results from 2001-2006 support the assertion that whooping cranes utilize areas of wetted channels, open water, and agriculture that are away from potential disturbances (i.e., roads) and trees/shrubs while on the Platte River. It appears, however, that there is a limit to the influence some of these land cover variables have on habitat selection For example, the influence of the shrub/forest land cover diminishes as distances approach 200 meters (Figure 20).

There was no difference in the biological interpretation between land use/ cover models developed for the systematic observations and the combined systematic and opportunistic observations. Model selection for the combined dataset led to slightly different final models, though there was no biological difference between the model parameterization and the interpretation of the common effects in the models.

Habitat Selection – On the Ground Characteristics

Habitat selection models of characteristics measured on the ground documented the use of channels with large unobstructed views. The model, which predicts the probability of use as a function of obstruction to obstruction width, estimated the maximum probability occurred when obstruction to obstruction width was 343 meters or 1,125 feet, and then declines beyond this point (Figure 22). This is not wetted width or channel width as distances to obstruction frequently extended outside of the channel across agriculture or hay fields, large sand bars, etc. This result supports the assertion that whooping crane groups use, at a disproportionate rate, areas with wide unobstructed views, as measured across the channel. On the other hand, the probability of whooping crane group use actually began to decline once the obstruction to obstruction width exceeded 343 meters.

Interestingly, distance to closest visual obstruction, whether across the channel or upstream/downstream, was not in the best model (with AIC selection criterion) for whooping crane habitat selection. Substrate abundance (e.g., sand) was also not in the best model (with AIC selection criterion) for whooping crane habitat selection.

There was no difference in the biological interpretation between the model developed for the systematic observations and the combined systematic and opportunistic observations. Model selection for the combined dataset led to the same final models, and there was no biological difference in model parameterization. The two models had highly correlated predictions and very similar maximum points in the quadratic relationship (339 meters).

Habitat Selection – Flow Dependent Characteristics

Habitat selection models relating to flow dependent characteristics indicated significant selection by crane groups for large proportions of the bank to bank width which were sandbars, large wetted widths, and greater proportions of the bank to bank width which were less than 8 inches deep or sandbars up to a point, then the relative probability of selection decreased with increased proportions. According to this model, the predicted maximum probability of selection occurred when the proportion of the bank to bank width which was depth suitable or sand was 0.39. Again, the predictive ability of these models is limited, as specific values are estimated with error.

Local area selection of flow dependent characteristics also indicated significant selection by crane groups for high flows and a significant quadratic relationship between selection and proportion depth suitable or sand. According to this model, the predicted maximum probability of selection occurred when the proportion of the bank to bank width which was depth suitable or sand was 0.65.

There were slight differences in the resulting flow dependent models developed for the systematic observations and the combined systematic and opportunistic observations. Model selection for the study area with the combined dataset led to models indicating significant selection for channels with large proportions of the wetted width that were depth suitable and large proportions of the bank to bank width with sandbars. Model selection for the local area led to final models with significant quadratic relationships between selection and wetted width and selection and proportion depth suitable or sand (maximum points were 312 meters (1,024 feet) and 0.43 respectively). The inclusion of the quadratic term for wetted width in the management model was partially based on this model selection result.

The flow dependent habitat model for management of the study area predicts the response (predicted probability of use) for values of both wetted width and proportion depth suitable or sand. This response surface can be used to assist in Program land acquisition decisions and to guide channel characteristic targets in adaptive management experiments. In addition to predicting maximums (319 meters (1,047 feet) wetted width and 0.48 proportion depth suitable or sand), the surface can be used to predict the proportion depth suitable or sand with the highest probability of use, for a given wetted width (Figure 29).

The predictive capabilities of the habitat models are limited and we caution that specific estimated parameter values should be viewed in light of the width of the corresponding confidence intervals. Other models, with different predictor variables, would lead to slightly different conclusions. We do support the use of this model to indicate general direction of increasing or decreasing probability.

MANAGEMENT RECOMMENDATIONS

We recommend using the response surface of the study area scale management model to assist in Program land acquisition decisions and to guide channel characteristic targets in adaptive management experiments. The surface would enable management of a site based on the wetted width and proportion of depth suitable or sand above water surface characteristics, subject to the many other properties of each unique site. The physical limitations of width at each property and the relationships between width and other channel characteristics will need to be considered when acquiring properties and when preparing management plans for Program lands. The results presented here could be used as a tool for predicting the likelihood of use a property might receive by whooping cranes based on the wetted widths, the accompanying proportion of depth suitable or sand, and the non-flow dependent characteristics. These likelihoods can be calculated for existing conditions and conditions potentially available under management of the property being evaluated. Once a property is acquired, the target wetted width can be determined based on physical limitations of the site, then the model can be used to determine the proportion of depth suitable or sand that is predicted to obtain the highest probability of use for that wetted width.

The non-flow dependent characteristics included in the models for land cover and characteristics measured on the ground should also be used to develop management of sites for whooping cranes. When considering all models together, the habitat selection analysis suggested that cranes selected channels and agricultural lands in the absence of transportation corridors and forest and shrub cover. These preferences appear to indicate an interaction of channel characteristics and upland area characteristics. For example, cranes showed a preference for agricultural lands, presumably for feeding, but this preference was limited to those lands in proximity to preferred channels. There was also a clear preference for channels with wide unobstructed widths.

The results of the flow dependent resource selection studies need to be viewed in the context of the flows observed during the study. The daily mean flow during times cranes were observed in the study area (2001 to 2006) was 437 cfs; the minimum flow was 52 cfs and the maximum flow was 1419 cfs. These flows represent generally dry conditions within the channel habitat. Therefore, the predictions that result from these models are applicable to habitat use during low flow years. As more data are collected, it will be possible to predict resource selection outside these bounds. We encourage the reanalysis of data as conditions change so that models can be developed for a range of conditions. Ideally, models could be developed for the three flow conditions that are management targets for the Program, that is, dry, average and wet years.

In summary, if one or more properties are being considered for acquisition, the existing and potential wetted width and proportion suitable depth or sand could be evaluated using figure 25. The non-flow dependent characteristics of the properties could then be evaluated including 1) the existing and potential unobstructed width; 2) the proximity to human disturbance (e.g., roads, dwellings); 3) the proximity to grain crops; and, 4) the proximity to shrub and forest cover. The cost of acquisition and management of a property could then be considered in terms of the change in probability of use of the property from the existing form to the potential form as managed by the Program.

Once properties are acquired, the flow dependent and non-flow dependent models can be used to prepare management plans and to conduct management experiments, such as an evaluation of the effects of two or more management treatments on the probability of use by cranes. Again, figure 25 could be used to develop hypotheses related to treatment effects and to evaluate the treatment in terms of predicted probability of use.

ANALYSIS RECOMMENDATIONS

1) In regards to the detectability trails, Pollock et al (2002) assert that detection probabilities are not constant for wildlife monitoring and detection probabilities should be estimated as part of a scientifically rigorous monitoring design. We agree with this approach and recommend continuing the implementation of the detectability trials each survey season. We also recommend accounting for detection differences in future analyses.

2) Habitat selection analyses should be reanalyzed when updated data become available. Examples of current data that would be useful include GIS coverages of:
    a. vegetation community types (our analysis used land use/land cover from the 1998 photographs),
    b. areas that have received Program management for whooping crane habitat, and

   c. areas that have received other land management practices for whooping crane habitat development/restoration (i.e., management of conservation lands not a part of the Program).

3) HECRAS appears to be a suitable approach to estimate channel characteristics at in-channel use sites and available locations at the time of crane use. We recommend this approach for future analyses, although with the inclusion of the entire study area. We agree with the data collection recommendations made by Fotherby and Russell (2008), future measurements of the channel should be made with survey grade GPS and tied to vertical control.

4) The index of use should be used to evaluate the occurrence of whooping cranes in the study area in response to Program management. The interpretation of these results would be improved if an estimate of crane use could be determined for one or more additional locations along the migration route.

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Table 1. Number of decoys placed in the study area for each survey season and strata. Decoys in the river strata were placed in the wetted channel, and decoys in the return strata were placed within the entire study area.

Year	Season	River	Return	Total
2001	Spring	3	15	18
2001	Fall	20	5	25
2002	Spring	10	5	15
2002	Fall	9	5	14
2003	Fall	9	5	14
2004	Spring	10	5	15
2004	Fall	10	5	15
2005	Spring	10	5	15
2005	Fall	10	5	15
2006	Spring	10	5	15
2006	Fall	10	5	15
Total		**111**	**65**	**176**

Table 2. Land cover variables derived from the 1998 land cover/use BOR GIS layer.

Variable Code	Variable Description
agdist	Distance to agriculture (meters)
dedist	Distance to development (meters)
grdist	Distance to grass (meters)
owdist	Distance to open water (meters)
sfdist	Distance to shrub/forest (meters)
trdist	Distance to transportation (meters)
wcdist	Distance to wetted channel (meters)
wgdist	Distance to wet grass (meters)
wvdist	Distance to wet vegetation (meters)
P_AG_25	Proportion of agriculture within 0.25-mile (400-m) radius circle
P_DE_25	Proportion of development within 0.25-mile (400-m) radius circle
P_GR_25	Proportion of grass within 0.25-mile (400-m) radius circle
P_OW_25	Proportion of open water within 0.25-mile (400-m) radius circle
P_SF_25	Proportion of shrub/forest within 0.25-mile (400-m)radius circle
P_TR_25	Proportion of transportation within 0.25-mile (400-m) radius circle
P_WC_25	Proportion of wetted channel within 0.25-mile (400-m) radius circle
P_WG_25	Proportion of wet grass within 0.25-mile (400-m) radius circle
P_WV_25	Proportion of wet vegetation within 0.25-mile (400-m) radius circle

Table 3. Habitat variables measured on the ground at used and a sample of decoy locations.

Variable Code	Variable Description
Fine_Sand	Percent fine sand (< 1 mm)
Coarse_Sand	Percent coarse sand (1-4.9 mm)
Sm_Gravel	Percent small gravel (5-14.9 mm)
Lg_Gravel	Percent large gravel (> 15 mm)
dist_vo	Distance to visual obstructions (m)
area_clear	Area clear of visual obstructions (km2)
o_to_o_width	Obstruction to obstruction width (m)

Table 4. Flow dependent habitat variables obtained from measured profiles and HECRAS modeling.

Variable Code	Variable Description
Width	Top wetted width of main channel (meters)
Flow	Flow computed in main channel (cfs)
Sandbar elevation	Average elevation of profile above water level (meters)
P_depth	Proportion of wetted width that is depth suitable (less than 8 inches deep)
P_depth_sand	Proportion of bank to bank width that is depth suitable (less than 8 inches deep) or sandbars
P_sand	Proportion of sandbars across bank to bank width
Width to depth ratio	Ratio of width to depth, where depth is hydraulic depth of the main channel calculated as area divided by wetted top width

Table 5. Number of observations of crane groups by stratum and by source during the Cooperative Agreement period, 2001-2006.

Survey	Number of observations	Number of observations in the wetted channel	Number of observations in the probability sample	Number of wetted channel observations in the probability sample	Number of Program Crane Groups*	Number of USFWS Crane Groups*
2001SP	40	9	4	4	2	1
2001FA	1	1	1	1	1	1
2002SP	37	12	11	11	13	1
2002FA	98	46	11	6	7	7
2003FA	2	1	1	1	1	1
2004SP	1	1	1	1	1	1
2004FA	2	0	1	0	2	1
2005SP	21	9	5	5	13	3
2005FA	1	1	1	1	1	1
2006SP	76	28	24	22	49	4
2006FA	74	42	12	6	26	2
Total	**353**	**150**	**72**	**58**	**116**	**23**

* The designation of individual crane groups for the Program monitoring crews was inconsistent across surveys (see Appendix B) while designation of individual crane groups for the USFWS was based on location, size of group, and biological opinion.

Table 6. Number of observations of crane group locations in each land cover category, during the Cooperative Agreement period, 2001-2006. Land cover categories were amalgamated from the vegetation classes in the Bureau of Reclamation (BOR) land use/cover GIS based on 1998 photography (USBOR 2000), see text for exact description of BOR vegetation classes in each land cover category.

Land Cover Category	Count	Percent
Agriculture	143	44.69
Grass	21	6.56
Shrub/forest	3	0.94
Wet grass	3	0.94
Wetted channel	150	46.88

Table 7. Predicted probability of detection totaled and averaged across all flights flown during a survey season.

Survey	Number of flights	Sum of Predicted probability of detection	Mean Predicted probability of detection
2001SP	106	76.0	0.72
2001FA	82	28.2	0.34
2002SP	104	69.9	0.67
2002FA	81	46.2	0.57
2003FA	104	41.0	0.39
2004SP	133	103.2	0.78
2004FA	105	48.7	0.46
2005SP	118	56.3	0.48
2005FA	121	93.2	0.77
2006SP	113	54.3	0.48
2006FA	101	52.8	0.52

Table 8. Observed number and calculated indices of use for whooping crane groups during the Cooperative Agreement period 2001-06.

Survey	Year	Number of crane groups	Number of flights	Index of Use (Number of crane groups / Number of flights)	Adjusted Number of crane groups*	Adjusted Index of Use**
2001SP	2001.27	11	106	0.104	16.98	0.160
2001FA	2001.82	1	82	0.012	2.28	0.028
2002SP	2002.27	14	104	0.135	18.77	0.180
2002FA	2002.82	20	81	0.247	35.05	0.433
2003FA	2003.82	2	104	0.019	2.98	0.029
2004SP	2004.27	1	133	0.008	1.05	0.008
2004FA	2004.82	1	105	0.010	1.31	0.012
2005SP	2005.27	5	118	0.042	6.55	0.056
2005FA	2005.82	1	121	0.008	1.05	0.009
2006SP	2006.27	25	113	0.221	37.30	0.330
2006FA	2006.82	12	101	0.119	15.73	0.156

* The observed number of crane groups was adjusted by the probability of detection during the survey using unequal probability sampling unbiased estimators from Thompson (1992).

** The index of use was recalculated with the adjusted number of crane groups in the numerator.

Table 9. Percentage of time (95% confidence interval) whooping crane groups engaged in diurnal activities by season and for both seasons combined.

Season	n	Defensive	Feeding	Resting	Alert	Courtship	Preening
Spring	34	2 (0, 5)	73 (63, 82)	15 (5, 24)	7 (2, 11)	1 (0, 2)	3 (1, 5)
Fall	14	0 (0, 0)	69 (62, 76)	9 (5, 14)	11 (3, 19)	0 (0, 1)	10 (5, 15)
Total	**48**	**2 (0, 4)**	**72 (65, 79)**	**13 (6, 20)**	**8 (4, 12)**	**1 (0,1)**	**5 (3, 7)**

Table 10. Study area, channel, and upland means and 95% confidence intervals for the land cover variables. Distance variables were measured in meters. There were 58 use sites in the wetted channel and 14 use sites in the upland obtained through the systematic aerial flights.

	Study area			Channel			Upland		
Variable	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
agdist	191.86	188.91	194.82	558.36	464.61	652.11	139.51	47.39	231.63
dedist	1019.91	1007.20	1032.62	1059.20	859.95	1258.45	1014.29	619.71	1408.88
grdist	422.98	417.68	428.27	536.99	417.87	656.11	406.69	242.03	571.35
owdist	610.97	604.32	617.62	557.82	409.58	706.06	618.56	411.92	825.21
sfdist	281.17	276.82	285.51	99.16	73.18	125.15	307.17	172.45	441.88
trdist	644.26	637.76	650.76	979.84	802.50	1157.17	596.32	393.80	798.84
wcdist	447.42	440.44	454.41	0.00	0.00	0.00	511.34	294.84	727.83
wgdist	277.00	272.75	281.25	199.91	163.71	236.11	288.01	156.25	419.77
wvdist	559.07	551.89	566.24	248.21	204.50	291.92	603.47	380.97	825.98
P_AG_25	85.60	84.21	86.98	15.80	8.60	23.00	95.57	52.67	138.47
P_DE_25	0.32	0.31	0.33	0.29	0.18	0.40	0.32	-0.03	0.67
P_GR_25	24.60	24.30	24.90	14.48	10.73	18.24	26.05	16.65	35.44
P_OW_25	0.31	0.31	0.31	1.72	1.24	2.20	0.11	0.04	0.18
P_SF_25	17.34	17.17	17.50	48.41	40.10	56.73	12.90	7.67	18.12
P_TR_25	1.18	1.15	1.20	0.44	0.17	0.71	1.28	0.52	2.04
P_WC_25	23.63	23.42	23.85	58.17	47.70	68.63	18.70	11.92	25.48
P_WG_25	26.39	26.09	26.70	19.55	15.43	23.67	27.37	17.88	36.86
P_WV_25	1.79	1.76	1.82	5.07	3.88	6.25	1.33	0.36	2.29

Table 11. Means and 95% confidence intervals for the habitat parameters measured on the ground at wetted channel use locations, metric and English units.

Variable	n	Mean	95% CI Lower	95% CI Upper	English units	Mean	95% CI Lower	95% CI Upper
Fine_Sand	49	61	51	71				
Coarse_Sand	49	30	21	39				
Sm_Gravel	49	8	4	12				
Lg_Gravel	49	0.41	0	0.90				
dist_vo (m)	52	284.79	218.75	350.83	feet	934.35	717.68	1151.01
area_clear (km^2)	52	0.22	0.16	0.27	acres	53.69	40.02	67.35
oowidth (m)	51	407.27	295.80	518.75	feet	1336.20	970.48	1701.92

Table 12. Means and 95% confidence intervals for flow dependent habitat parameters, metric and English units.

Variable	n	Mean	95% CI Lower	95% CI Upper	English units	Mean	95% CI Lower	95% CI Upper
Wetted width (m)	55	246.20	206.17	286.24	feet	807.76	676.40	939.12
Flow (cms)	55	25.85	21.19	30.52	cfs	912	748	1077
Sandbar elevation (m)	52	0.31	0.22	0.40	feet	1.02	0.73	1.31
Proportion depth suitable	53	0.57	0.52	0.62				
Proportion depth suitable or sand	53	0.67	0.62	0.73				
Proportion sand	53	0.31	0.25	0.37				
Width to depth ratio	56	1209	995	1422				

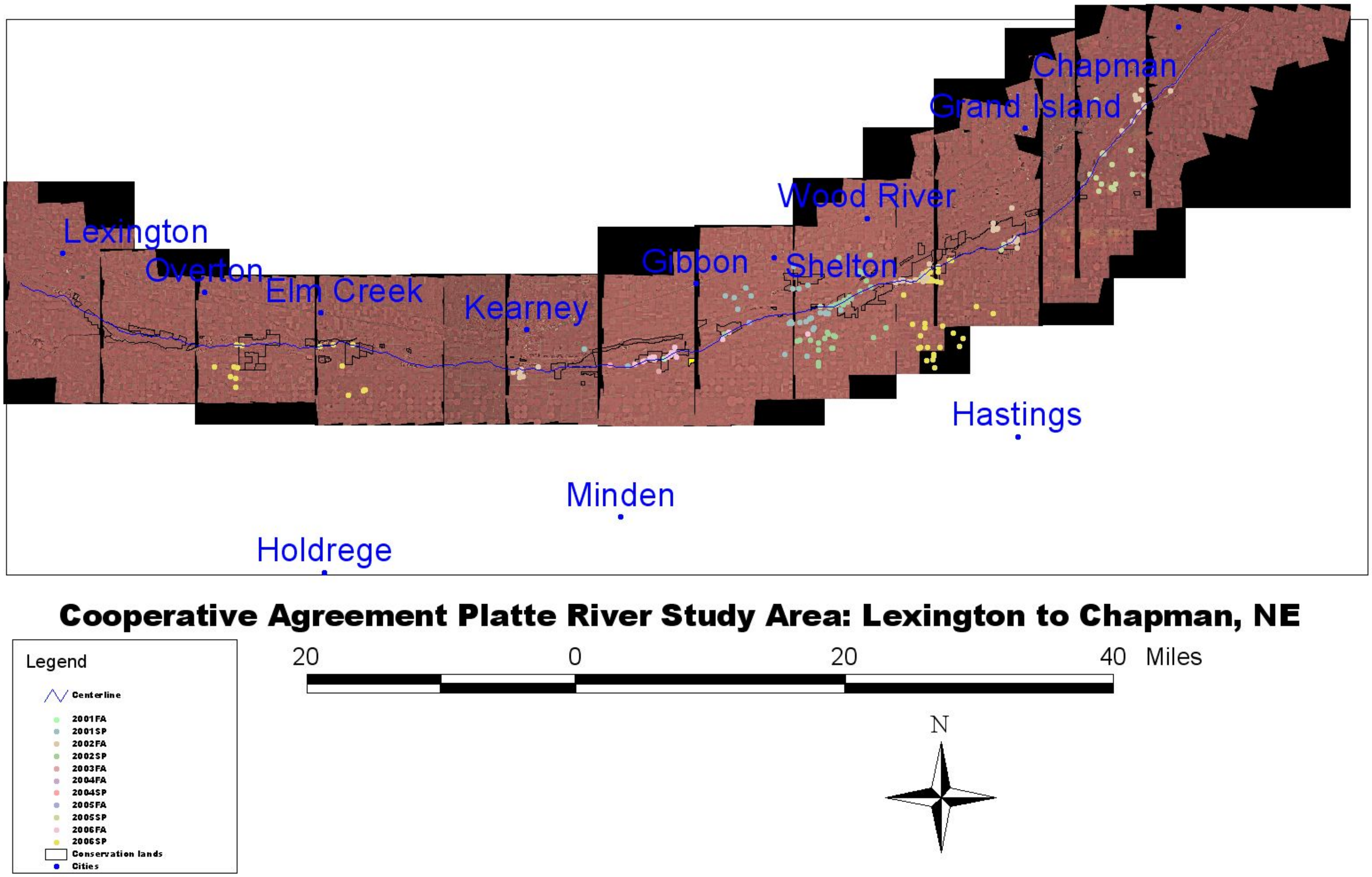

Figure 1. Whooping crane group use locations in the Cooperative Agreement study area from 2001 to 2006.

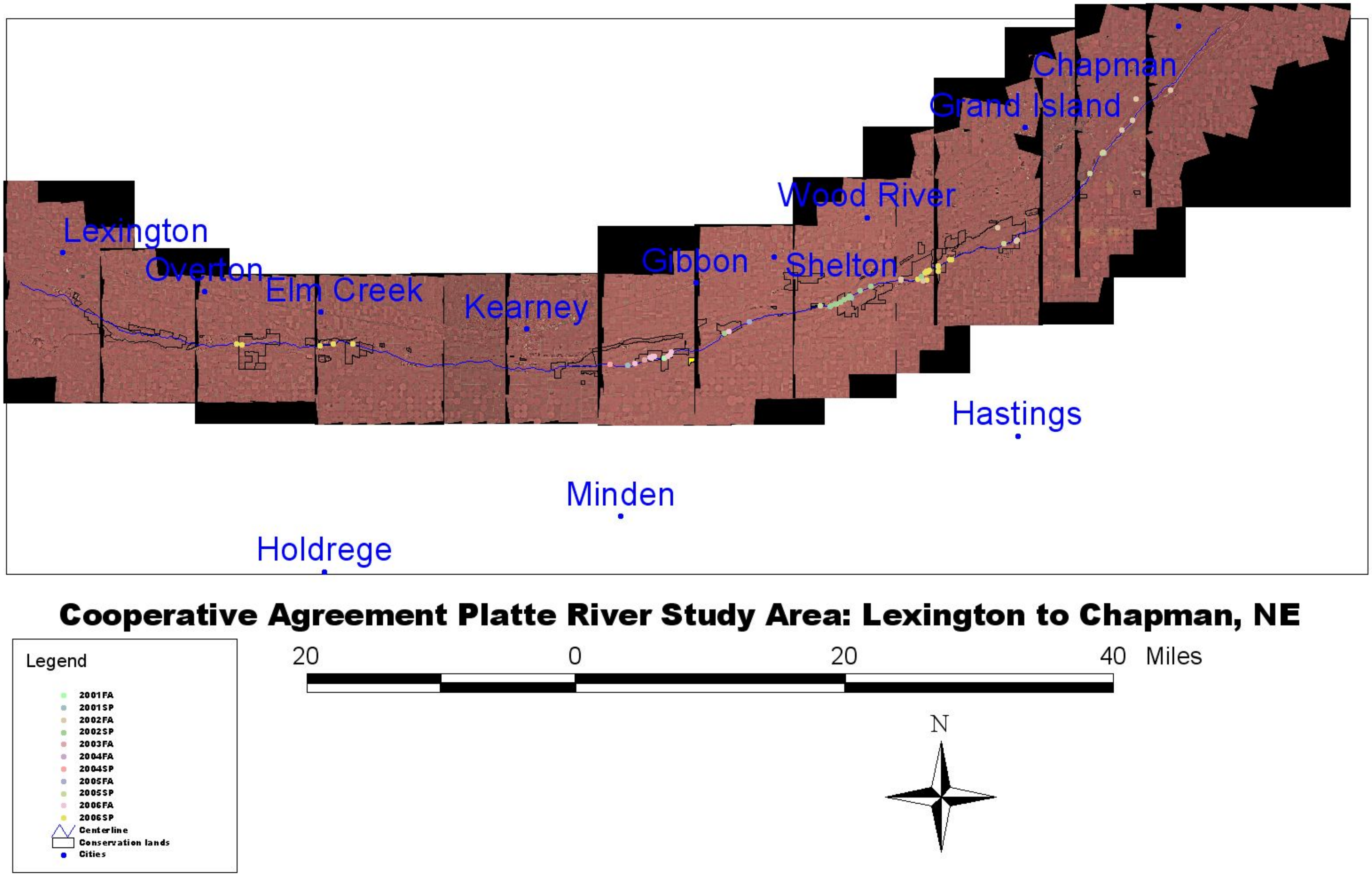

Figure 2. Whooping crane group use locations located through the systematic sampling in the Cooperative Agreement study area from 2001 to 2006.

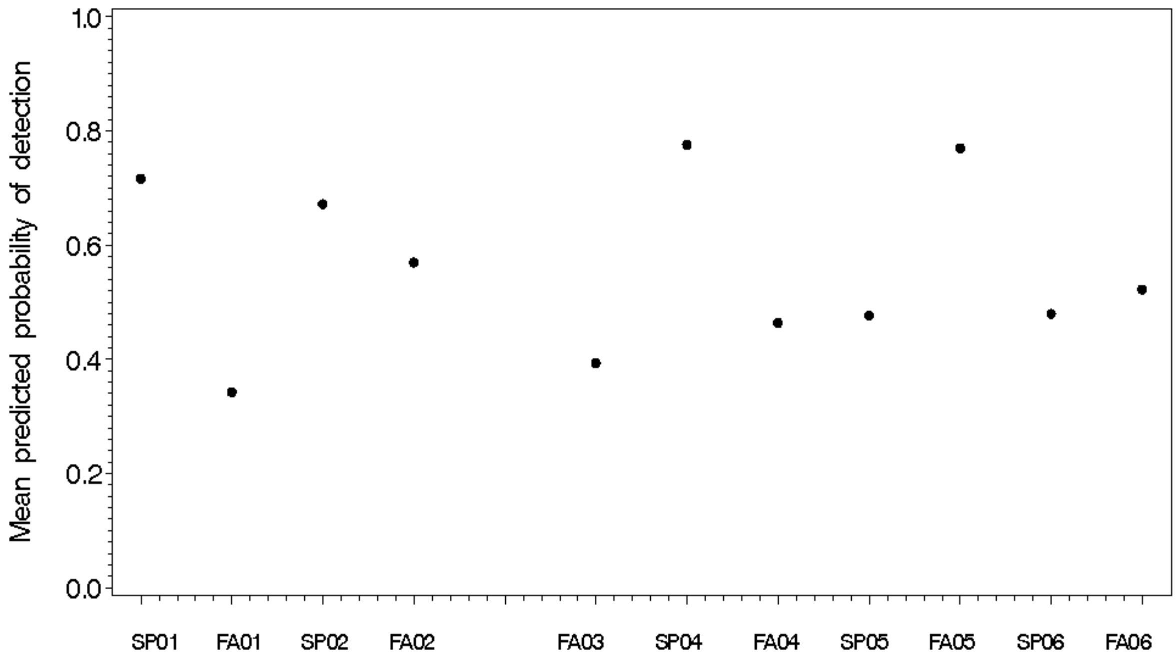

Figure 3. Mean predicted probability of detection averaged across all flights flown during a survey season.

Figure 4. Known movements of crane group 01A-03 across the one day of observation.

Figure 5. Known movements of crane group 02A-01 across the five days of observation.

Figure 6. Known movements of crane group 02B-40 across the six days of observation.

Figure 7. Known movements of crane group 02B-41 across the two days of observation.

Figure 8. Known movements of crane group 02B-42 across the seven days of observation.

Figure 9. Known movements of crane group 02B-43 across the two days of observation.

Figure 10. Known movements of crane group 05A-02 across the four days of observation.

Figure 11. Known movements of crane group 06A-03 across the three days of observation.

Figure 12. Known movements of crane group 06A-05 across the two days of observation.

Figure 13. Known movements of crane group 06A-01 and 02 across the two days of observation.

Figure 14. Known movements of crane group 06B-22 across the thirteen days of observation.

Figure 15. Close up of known movements of crane group 06B-22 across the thirteen days of observation.

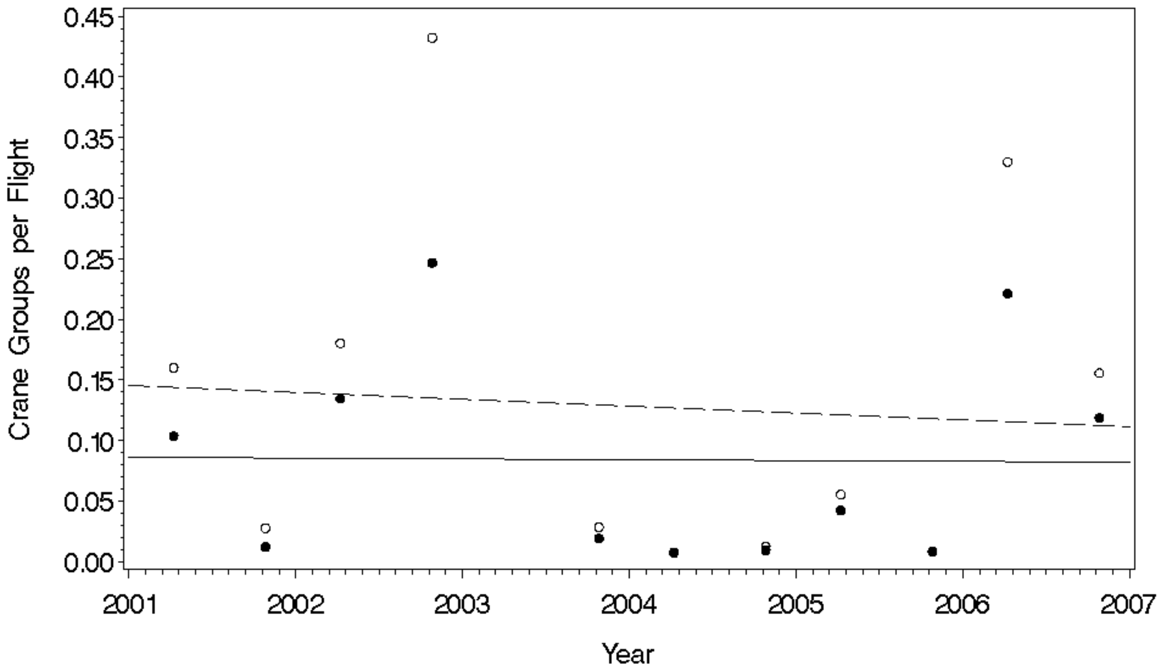

Figure 16. Trend in the index of use (closed circles and solid line) and the adjusted index of use (open circles and dashed line) through the Cooperative Agreement time period.

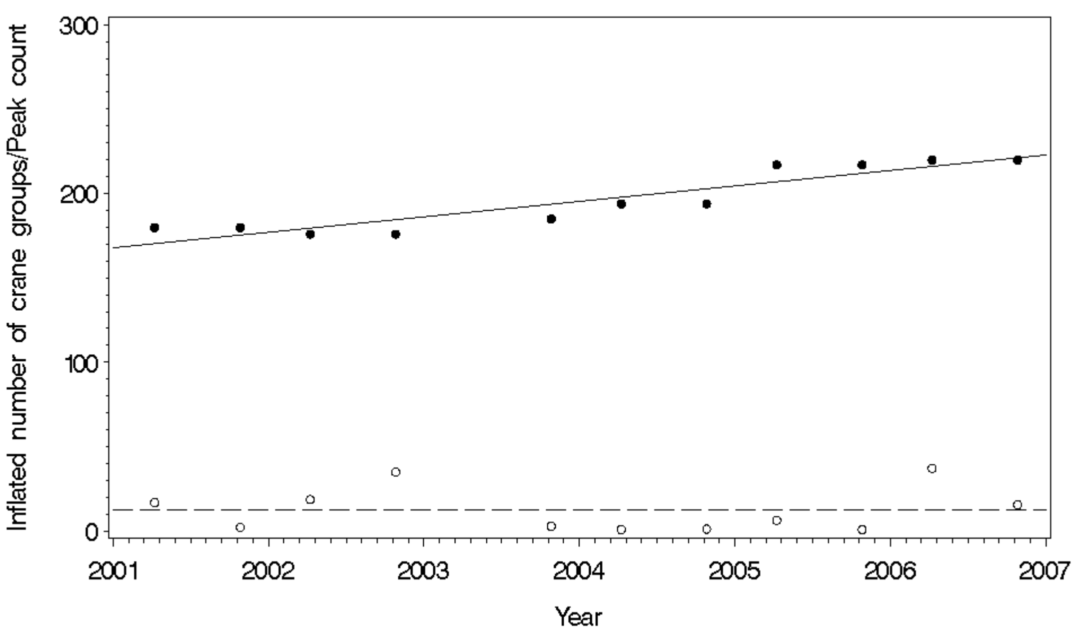

Figure 17. Trend in the peak winter count of the Aransas-Wood Buffalo population (closed circles and solid line) and the adjusted number of crane groups (open circles and dashed line) in the study area through the Cooperative Agreement time period.

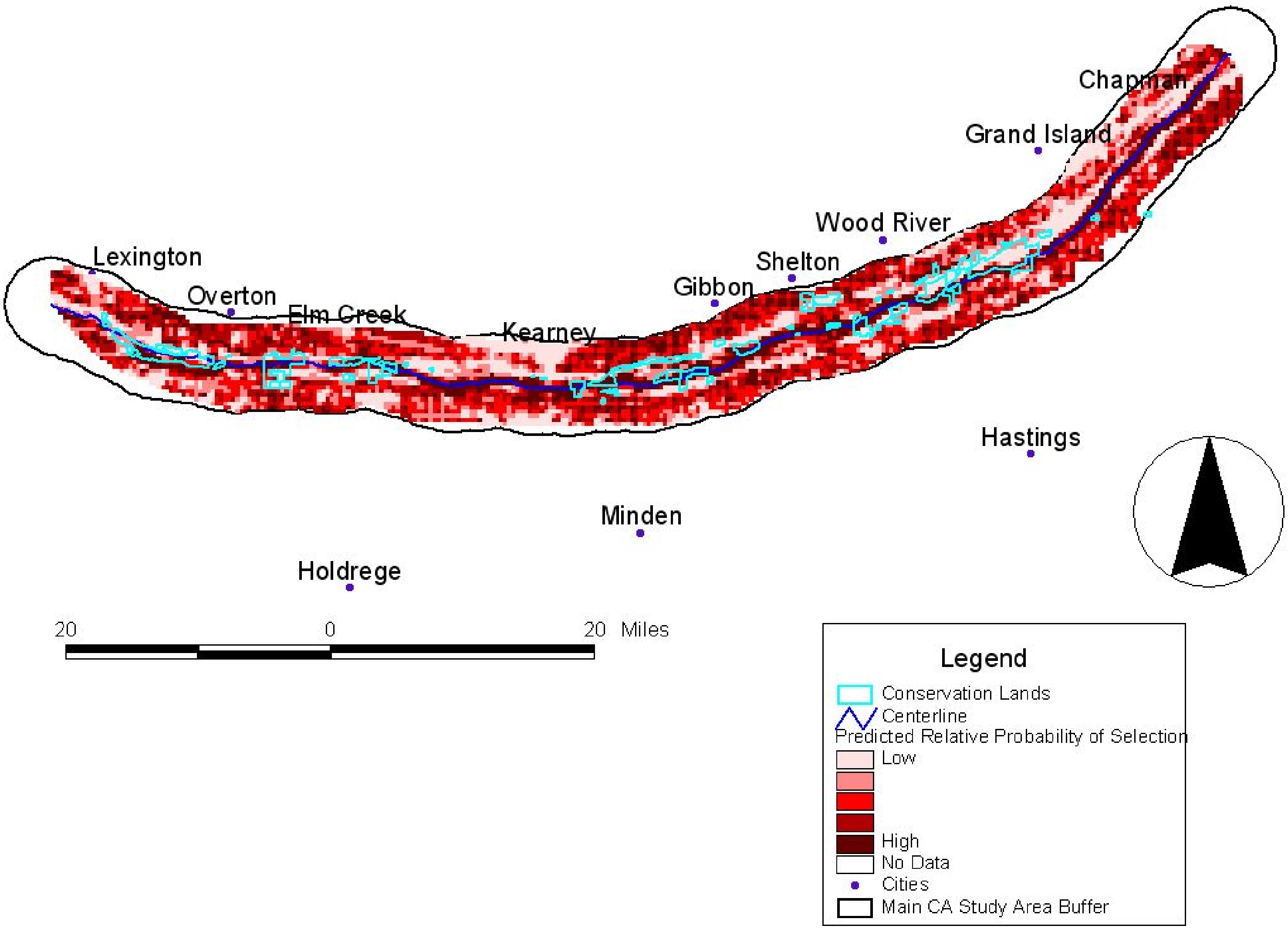

Figure 18. Predicted relative probability of selection of the study area by whooping crane groups based on the model for study area selection of land cover. Dark red areas represent areas with high probability of use while light red areas represent areas with low probability of use.

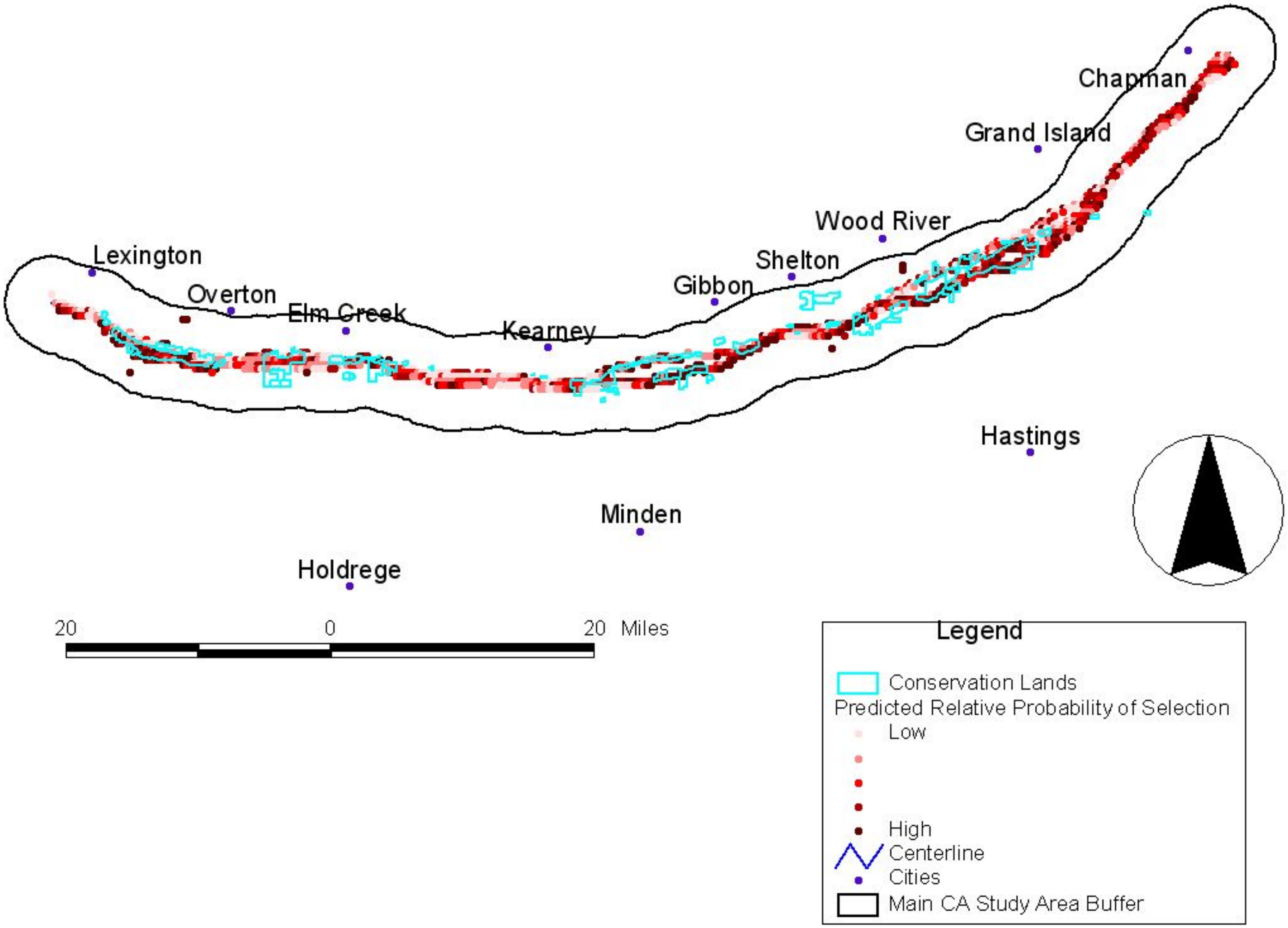

Figure 19. Predicted relative probability of in-channel selection by whooping crane groups based on the model for in-channel selection of land cover. Dark red areas represent areas with high probability of use while light red areas represent areas with low probability of use

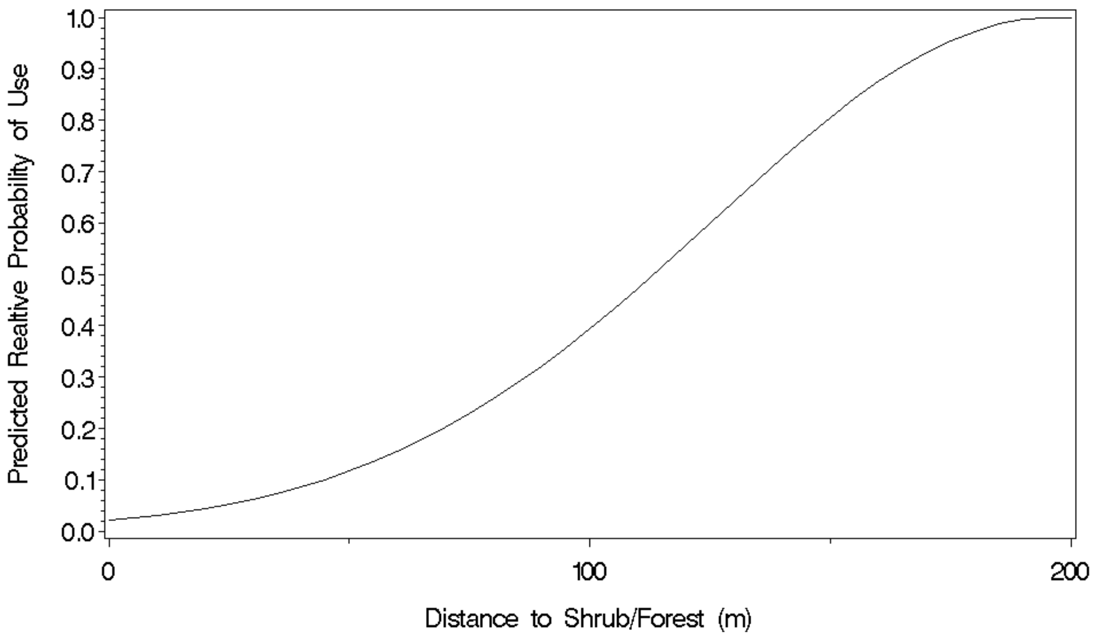

Figure 20. Predicted quadratic relationship between the relative probability of use and distance to shrub/forest (meters) based on the resource selection function for study area selection of land cover for in-channel observations.

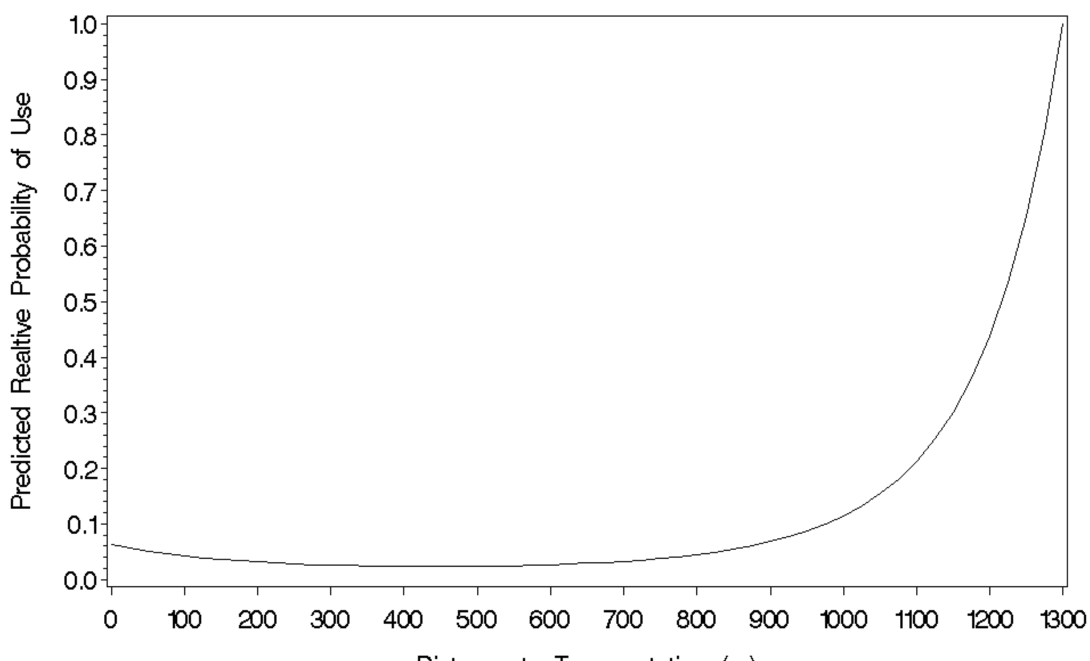

Figure 21. Predicted quadratic relationship between the relative probability of use and distance to transportation (meters) based on the resource selection function for local area selection of land cover for in-channel observations.

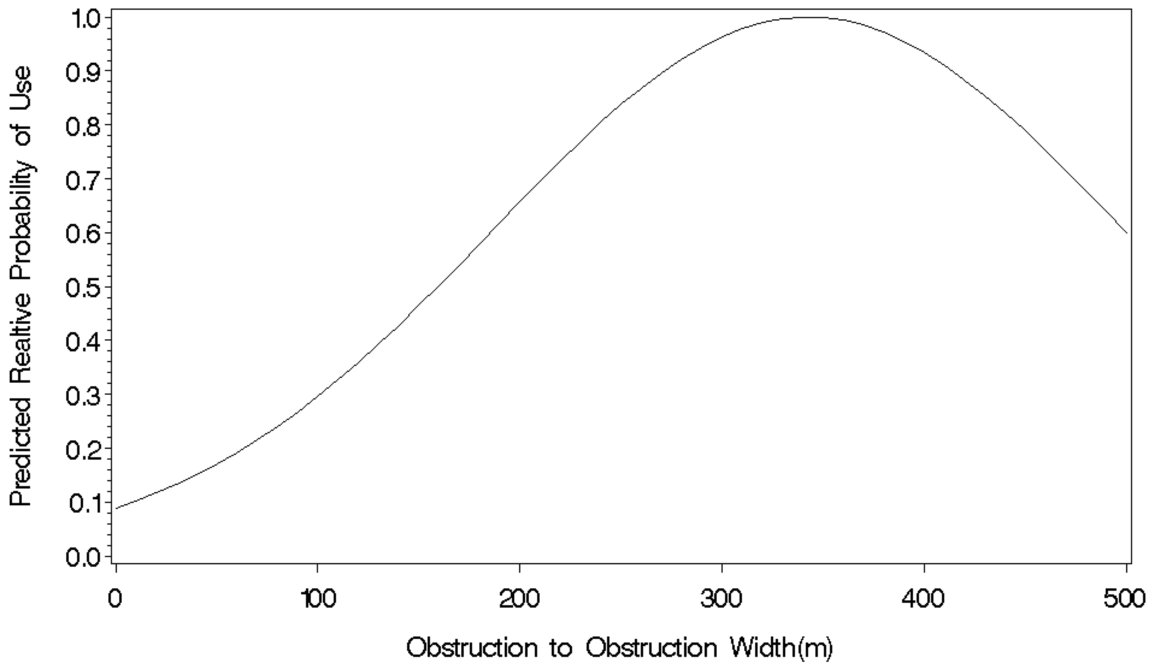

Figure 22. Predicted quadratic relationship between the relative probability of use and obstruction to obstruction width (meters) based on the resource selection function for characteristics measured on the ground.

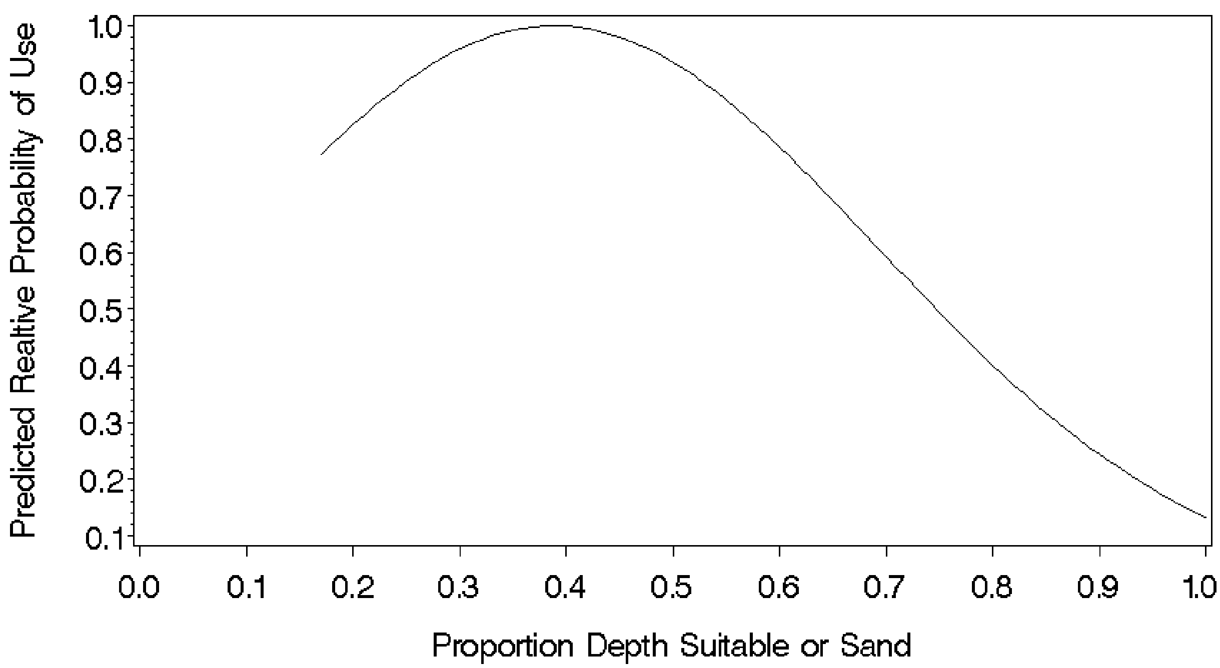

Figure 23. Predicted quadratic relationship between the relative probability of use and proportion depth suitable or sand based on the resource selection function for study area selection of flow dependent characteristics.

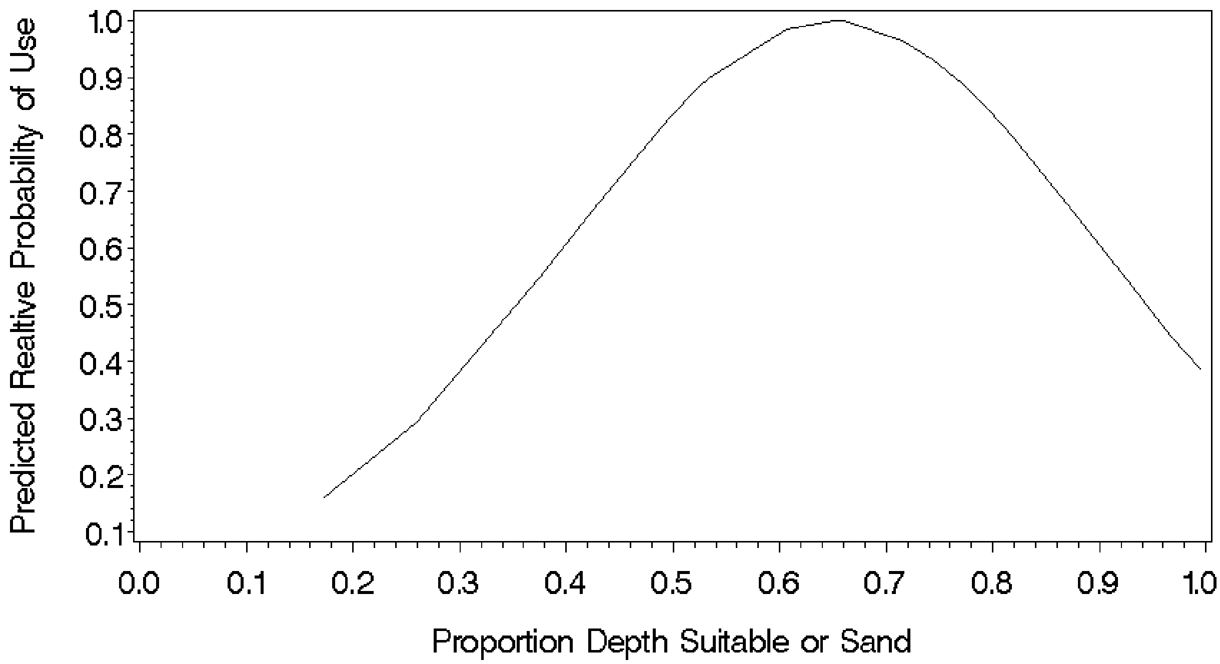

Figure 24. Predicted quadratic relationship between the relative probability of use and proportion depth suitable or sand based on the resource selection function for local area selection of flow dependent characteristics.

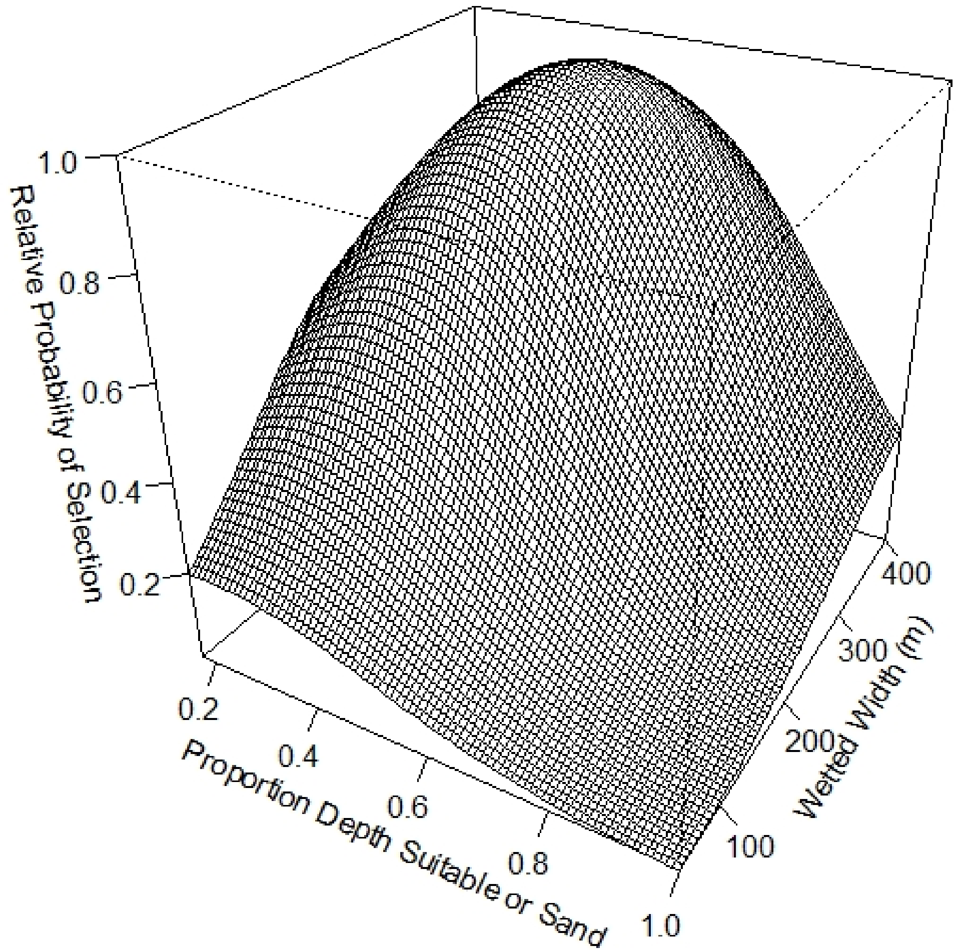

Figure 25a. Predicted response surface for relative probability of use across width and proportion depth suitable or sand based on the management model for study area selection.

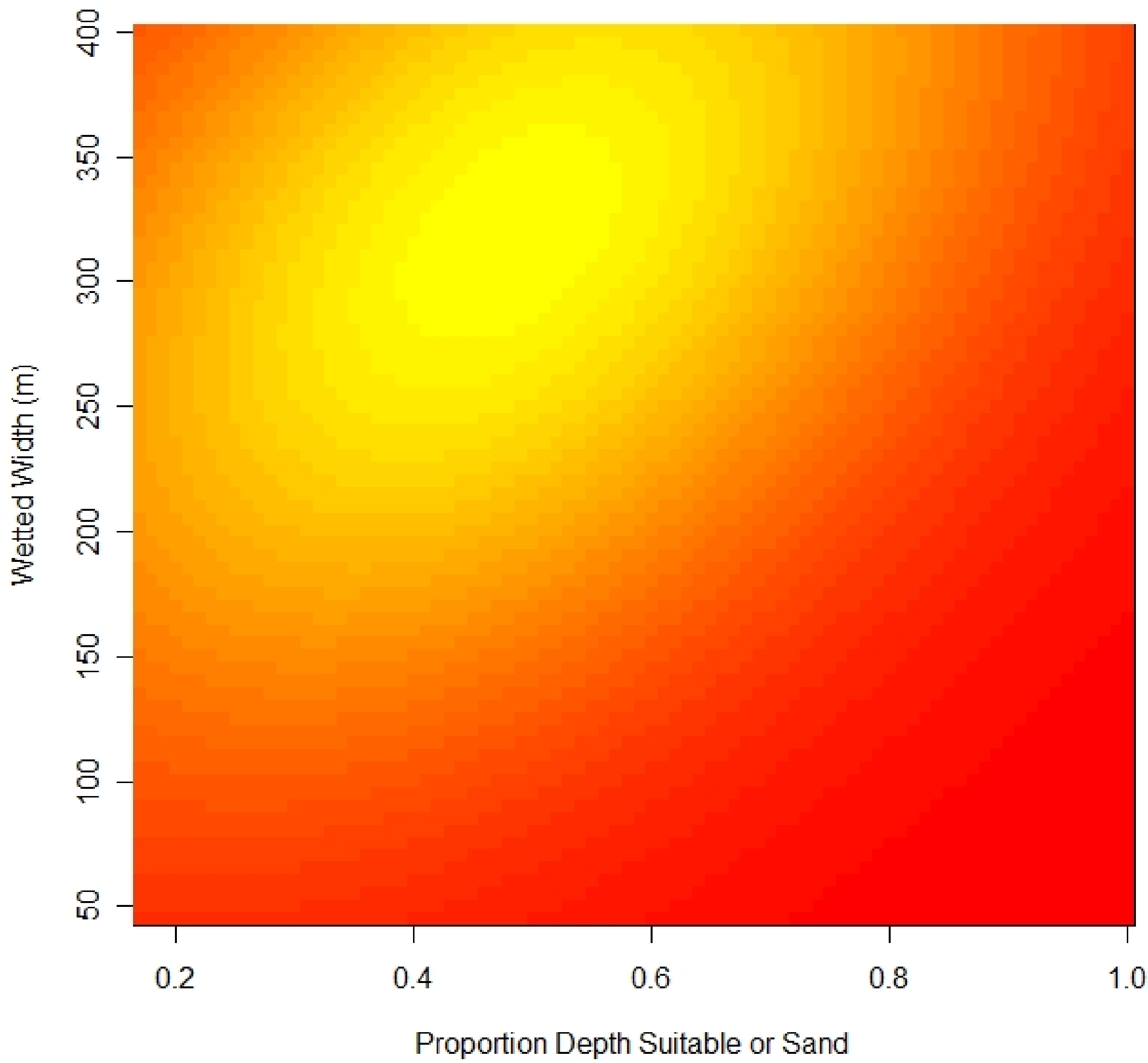

Figure 25b. Predicted response surface for relative probability of use across width and proportion depth suitable or sand based on the management model for study area selection. The third axis (predicted relative probability of use) is in color with red representing areas with low probability of use and yellow representing areas with high probability of use.

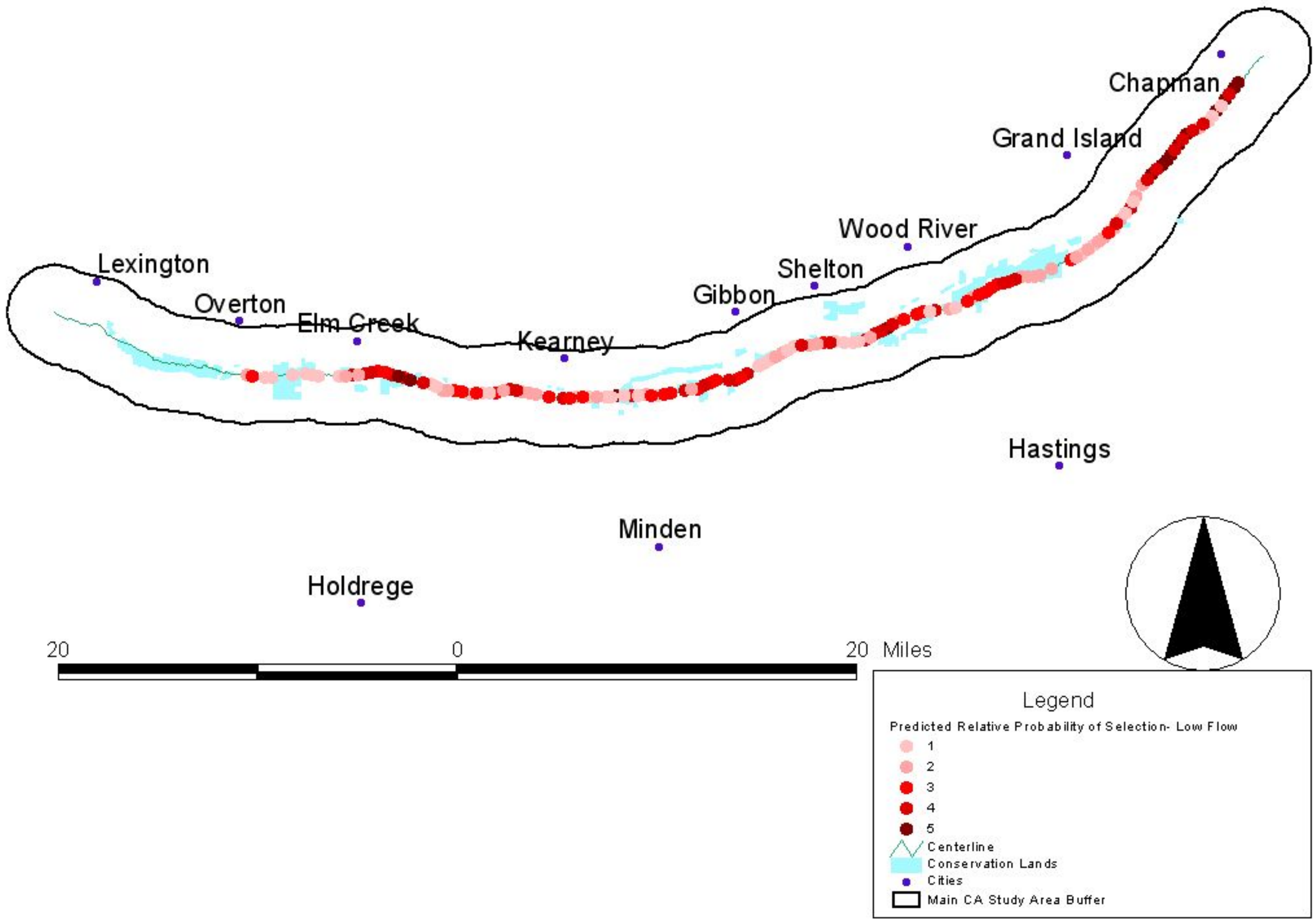

Figure 26. Predicted relative probability of selection of the in-channel area by whooping crane groups at low flow (250cfs at Kearney, NE) based on the management model for study area selection. Dark red areas represent areas with high probability of use while light red areas represent areas with low probability of use. Available data for this analysis only extended from river mile 157 to river mile 239.

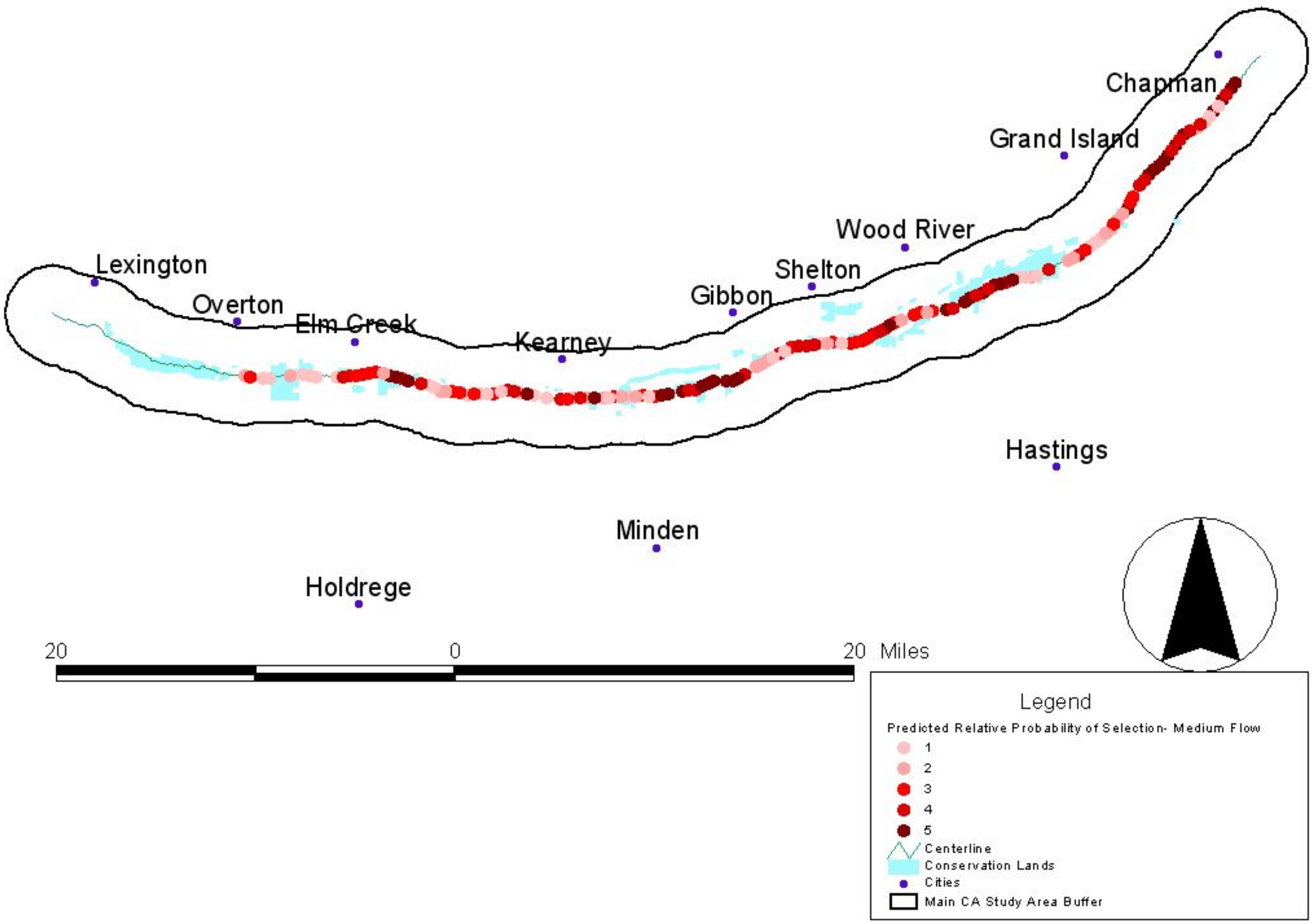

Figure 27. Predicted relative probability of selection of the in-channel area by whooping crane groups at medium flow (350cfs at Kearney, NE) based on the management model for study area selection. Dark red areas represent areas with high probability of use while light red areas represent areas with low probability of use. Available data for this analysis only extended from river mile 157 to river mile 239.

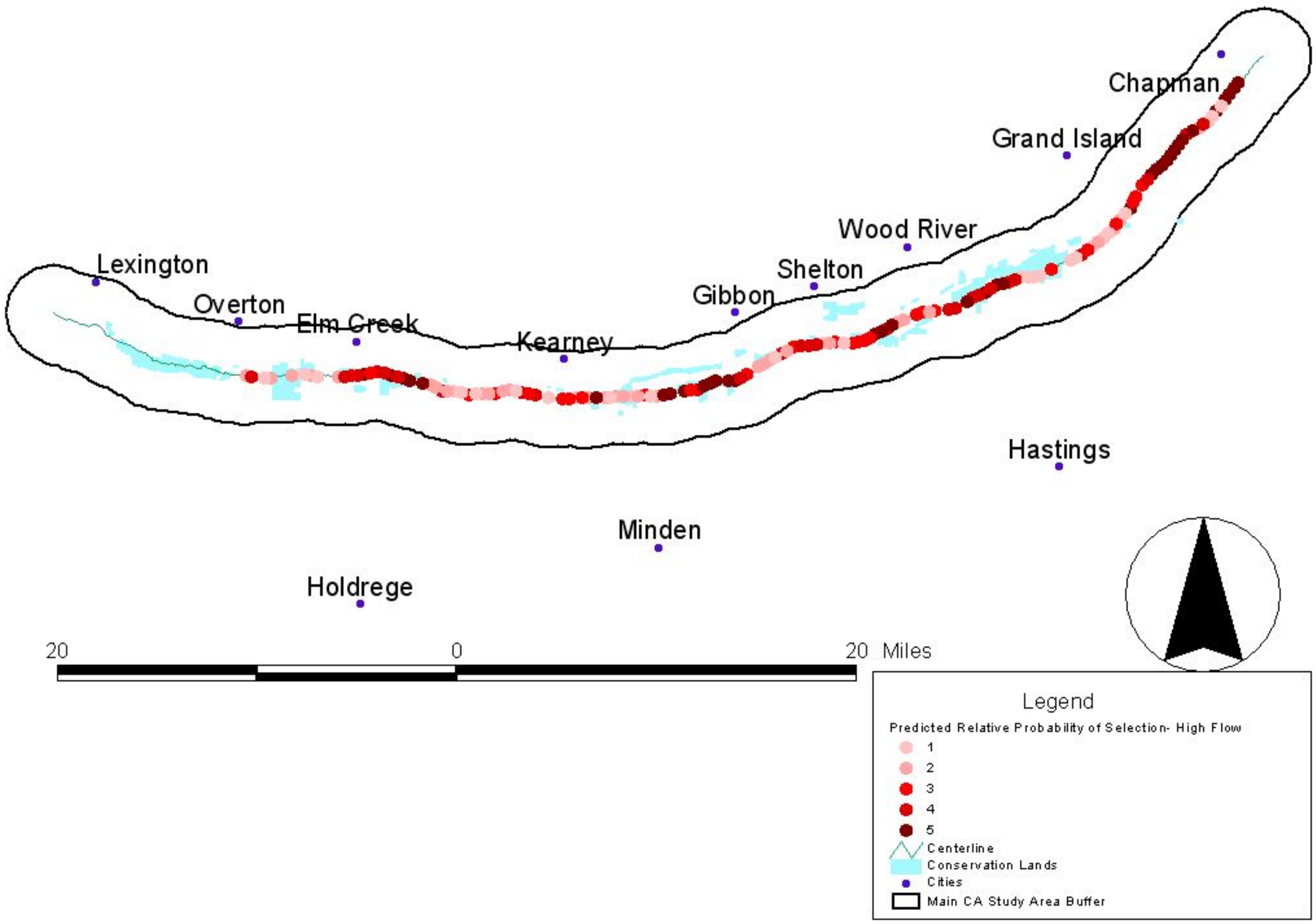

Figure 28. Predicted relative probability of selection of the in-channel area by whooping crane groups at high flow (786cfs at Kearney, NE) based on the management model for study area selection. Dark red areas represent areas with high probability of use while light red areas represent areas with low probability of use. Available data for this analysis only extended from river mile 157 to river mile 239.

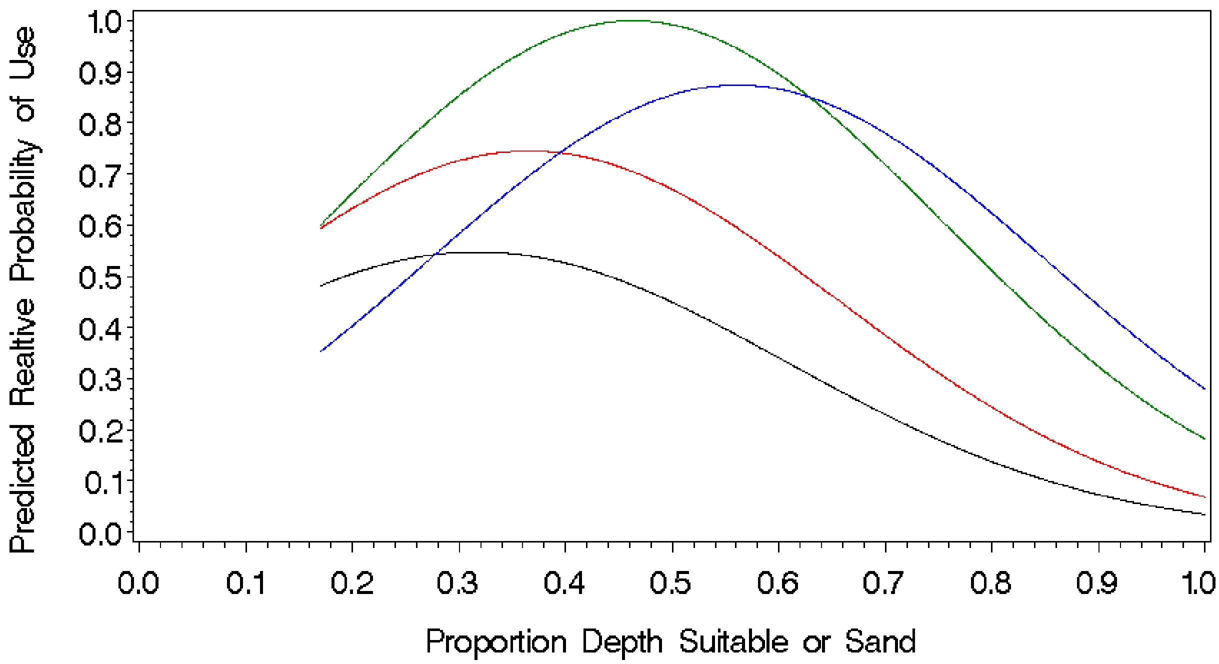

Figure 29. Predicted response surface of relative probability of use by proportion depth suitable or sand for four wetted widths (black=150m, red=200m, green=300m, blue=400m) based on the management model for study area selection.

APPENDIX A. Protocol for Monitoring Whooping Crane Migrational Habitat Use in the Central Platte River Valley; September 16, 2005

I. INTRODUCTION

The States of Colorado, Nebraska and Wyoming and the Department of the Interior (DOI) agreed to participate in a basin-wide cooperative program relating to four target species (interior least tern, piping plover, whooping crane and pallid sturgeon) and their associated habitats in the Cooperative Agreement for Implementing a Platte River Recovery Implementation Program (Program). One of the primary purposes of the Program is to "implement certain aspects of the Fish and Wildlife Service's (FWS') recovery plans for the target species that relate to their associated habitats by providing for the following: 1) securing defined benefits for the target species and their associated habitats to assist in their conservation and recovery through a basin-wide cooperative approach that can be agreed to by the three states and DOI…". The Program builds upon the July 1, 1997 Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitats Along the Central Platte River, Nebraska (July 1997 Cooperative Agreement).

Program implementation will follow a process of adaptive management to address areas of scientific uncertainty. Monitoring is an integral part of the adaptive management process. The adaptive management approach will allow for efficient modification of management actions in response to new and changing environmental conditions. The Program, with assistance from the Technical Advisory Committee will monitor and document, relative to the habitat and species conditions that existed as of the effective date of the Cooperative Agreement, habitat and species responses to habitat improvement activities. With scientific advisory assistance, the Technical Advisory Committee will review monitoring results and make recommendations to the Program's Governance Committee regarding the effects of Program activities on whooping crane habitat use in the study area. The Governance Committee, using the Technical Advisory Committee's input, will evaluate projects and the overall Program to determine what, if any, changes are needed in the management.

This monitoring protocol will be used by the Program to gather information on whooping crane habitat use and to provide an index of abundance in the study area. It is understood that regardless of survey method not all cranes are certain of being detected during migration and therefore full implementation of this or any other protocol will not represent complete use of the central Platte River valley. Information from this protocol will be used to help evaluate the biological response of whooping cranes and habitat to the land and water management activities of the Program.

This monitoring protocol addresses several July 1997 Cooperative Agreement milestones:

- R2-1 A technical committee appointed by the Governance Committee will develop protocols for and initiate habitat and species monitoring and research

- R3-1 the FWS and Technical Committee will identify data needed to ascertain biological response and the time frame required to evaluate those data (R3-1 milestone as revised at the August 2, 2000 Technical Committee/Governance Committee workshop)

R5-1 The Nebraska Districts (Nebraska Public Power District and Central Nebraska Public Power and Irrigation District) will implement any research and monitoring measures required by new Federal Energy Regulatory Commission (FERC) license articles for FERC Projects Nos. 1417 and 1835.

R1-2 and R1-3 A technical committee will continue monitoring to document, relative to the habitat and species conditions that existed as of the effective date of the Cooperative Agreement, habitat and species responses to activities undertaken pursuant to the Cooperative Agreement.

R3-2 and R3-3 The Nebraska Districts will continue to implement any research and monitoring measures required by FERC license articles for FERC Projects Nos. 1417 and 1835.

II. PURPOSE

The purpose of this monitoring protocol is to describe the conceptual design, study methods, and procedures that will be used annually to gather repeatable information on whooping crane stopovers in the central Platte River valley, Nebraska. Detailed Standard Operating Procedures (SOP) will be written for each task when the protocol is finalized. This is a sample survey protocol that will result in an annual index of crane use. This protocol describes the procedures to be used for these specific objectives:

1) Detect whooping crane stopovers in the study area – systematic aerial surveys of the study area will be conducted and the data will be used to comparatively evaluate changes in the frequency and the distribution of stopovers within the study area over time. Opportunistic locates will also be used to detect whooping crane stopovers in the study area.

2) Identify the locations of use and crane group movements in the study area – crane group movements will be documented in order to identify use-sites, and to describe the patterns of movement of each crane group.

3) Qualitatively document crane group activities at use-sites – observers will qualitatively document activities displayed by the crane groups. Observed activities may help identify factors that influence how cranes use the area and aid in the interpretation of crane behavior.

4) Document the physical and/or biological characteristics of use-sites – habitat parameters will be described and measured for those whooping cranes observed stopping in the central Platte River valley for comparative habitat analyses (e.g., as in determining habitat suitability or preference analyses).

5) Landscape Data Collection – Basic landscape source data of whooping crane use-sites in the study area (e.g., central Platte River valley) will be collected through this protocol. This information will be used in future use/availability analyses using aerial

photography and Geographic Information System (GIS) information and appropriate landscape data collected from other protocols. Currently the Program has available a complete land use/land cover GIS analysis of 1998 color infrared photography. Continued regular collection of landscape data sources of the study area through other protocols, such as aerial photographs, geomorphology monitoring protocol and GIS data, will enable future habitat use/availability research.

The protocol also outlines what information Program personnel will collect from the FWS and state agencies throughout the whooping crane's migrational corridor.

The Technical Committee implemented the February 23, 2001 version of this protocol during the spring 2001 season, the September 12, 2001 version during the fall 2001 season, the December 20, 2001 version during the spring and fall 2002 season, and the August 21, 2003 version during the fall 2003 season. The Technical Committee did not implement a survey in spring 2003. This version of the protocol incorporates changes as a result of the previous implementation periods, independent peer review, and other comments.

III. DESIGN CONSIDERATIONS AND SPECIFICATIONS

III.A. Area of Interest

The area of interest for monitoring whooping crane migrational habitat use consists of an area 3.5-miles either side of the Platte River beginning at the junction of U.S. Highway 283 and Interstate 80 near Lexington, Nebraska, and extending eastward to Chapman, Nebraska. When side channels of the Platte River extend beyond the 3.5-mile area, a 2-mile area is included around these channels (see attached map). If crane groups being monitored move outside this study area the field crews will make a professional judgment on whether or not the cranes are migrating from the Platte River area. If the crane group is judged to be migrating from the area, ground crews will stop observations. If the crane group is judged to be just temporarily using habitat outside the primary study area the ground crew will continue to make observations.

III.B. Project Design

This protocol collects information on whooping cranes using the central Platte River, not necessarily on the entire whooping crane population. This may bias the sample for making inference to the entire whooping crane population. In addition, the results from this protocol may not be representative of the population, or subgroup of the population using the central Platte, because of the use of multiple observations per crane group and/or the lack of use by unique crane groups in the analysis (i.e., pseudo-replication). Options for addressing pseudo-replication are discussed in Section IV.D. Analysis Methods.

III.B.1. Detecting/Locating Whooping Crane Stopovers

Whooping crane stopovers will be documented using both systematic surveys and opportunistic sighting reports. Crane groups detected with systematic surveys will have known probabilities of inclusion in the sample, while crane groups detected opportunistically will compromise a non-probability based sample. Since the systematic sample covers the study area from East to West with equal effort, and from North to South with known frequency, biases in sample effort can be accounted for. The opportunistic sample will contain biases associated with the unequal sampling effort that cannot be accounted for, and therefore may not represent actual crane use of the study area.

The relative efficiency of sighting whooping crane groups using systematic aerial surveys is not known, but will become known through protocol implementation over the years (e.g., use of decoys and known birds in the area, etc). Public reports and reports from other survey efforts in the valley (e.g., Nebraska Game and Parks Commission (NGPC), Platte River Trust, FWS surveys) will also be used to identify occurrences of whooping crane stopovers in the study area. These sighting reports may increase the opportunity to gather crane movement and habitat use information. Data on movement and habitat use for birds detected through the systematic aerial survey will be analyzed separated and in conjunction with all other observations of crane movement and habitat use in the analysis of species habitat relationships.

Aerial Survey

Aerial surveys will be used to detect whooping crane stopovers in the study area. Systematic surveys are necessary to develop information on the spatial and temporal distribution of crane stopovers in the Platte River for comparative evaluations. The design of these systematic surveys is intended to provide a known chance for observing crane use throughout the study area. Daily flights will be conducted in early morning during the period when whooping cranes are most likely to be in route between the wintering and breeding grounds. Flights will take place over the main river channel (river transects) and upland regions of the study area (return transects). The “main river channel” is defined as the widest channel when all channels have flowing water. It is recognized that this protocol over-samples the river (river transects are flown daily) compared to return transects that include upland areas and the river (seven return transects are flown in a rotating order). River transects systematically survey the main channel east to west. Return transects systematically sample the entire study area north to south.

Opportunistic Locates

Birdwatchers, outdoor enthusiasts, farmers, and other survey efforts might make initial observations of whooping crane groups in the study area. Sighting reports from these and other groups (labeled “opportunistic locates”) may provide additional information on crane stopover occurrences, but the conclusions are only applicable to the areas searched by the people that would report a sighting. An analysis of habitat use by cranes sighted opportunistically is outlined in this protocol. But locations of whooping cranes obtained through this method are biased and quantifying the bias due to the location and amount of effort expended to obtain these observations is not planned.

Survey Detection Rates

Whooping crane decoys will be used to estimate the accuracy of whooping crane detection from the aerial survey. Crane decoys will be placed randomly throughout the study area and the detection by the aerial survey crew will be recorded. Surveyors will not know the location of decoys while conducting the survey. Searcher efficiency will be calculated as the percentage of cranes observed. Decoys will be placed at randomly selected points in the path of the riverine and return transects. Estimates of searcher efficiency will be made for each transect strata separately (riverine and return). Individuals placing decoys will accurately map or record the UTM of the decoy and the transect on which it was placed. If the vegetation/landscape at the decoy location is different in the field than on the mapped data provided, the individual placing the decoy will move the decoy to the closest point corresponding to the mapped vegetation/ landscape type.

III.B.2 Movement Tracking

After a crane group has been located in the study area, either through aerial surveys or opportunistically, a ground crew will be notified to confirm the sighting and begin immediate monitoring to document habitat use. The ground crew(s) will locate the cranes with directions from the sighting party and will document crane movements, document crane use-site activities, and describe the physical and biological attributes of use-sites. Each crane group will be tracked continuously until they are observed leaving the study site or are lost by the tracking crew. Cranes will be observed at a distance from vehicles to document movements. Monitoring crews will be trained to be aware of crane sensitivity to human presence, to identify behavioral responses to disturbance, and to view cranes using methods that reduce the likelihood of disturbance. Crews will strictly adhere to guidelines regarding minimization or elimination of crane disturbance, to be provided by the FWS, while conducting the monitoring.

Locations of crane groups under observation will be recorded in two categories. Instantaneous points will identify the exact location of the group every 15 minutes. Location points will identify the general location of the group during the observation period. Whenever a crane group moves from the area of one contiguous habitat type to another, a new location ID will be assigned. In the event that a crane group is observed in the same location from 2 observers (e.g., from the ground and from the air), the same location ID will be recorded by each observer.

III.B.3. Activity Monitoring

While monitoring crane movements, ground crews will collect information on crane activities. The field crew will record the activity being conducted by a whooping crane at each of the 15 minute instantaneous point mapped for the movement tracking into one of the following categories: courtship, preening, resting, feeding, alert, agonistic, or other as described. If the crane group is comprised of more than one individual, the observer will select a "focus" crane that will be used to record activity information. The observer will also video tape the crane group using a digital video camera for the entire time it is at a use site.

III.B.4. Use-Site Characteristics

Tracking crews will collect information on the physical and biological characteristics of the riverine and non-riverine whooping crane use-sites. Characteristics of crane use locations will be described and measured as soon as practical after the crane group leaves the study area. Habitat parameters will be described and measured for the purpose of comparative habitat analyses.

Use-site characteristics will also be measured at randomly selected riverine locations each year. These will typically be the same as the decoy locations used for survey detection rates. Measurements will be made using the same methods as outlined for crane use sites. The measurement of these sites will be spaced throughout the aerial survey period. Data from measurements at randomly selected locations (e.g., decoy locations) will be used as an available dataset.

III.C. Timing

Aerial surveys of the study area will be conducted in the spring from March 21 to April 29 and in the fall from October 9 to November 10 (the 5th and 95th percentile of initial observation dates of whooping cranes in Nebraska between 1975-1999). Opportunistic observations will be collected during all times of the year. Measurements of habitat characteristics at whooping crane use sights will occur immediately following each observation regardless of how the birds were found (aerial or opportunistic). Crane movements will be monitored until the crane group leaves the study area or is no longer observable. Measurements of habitat characteristics will be taken after the group departs the study area.

IV. METHODS

IV.A. Definitions

Crane activity- Qualitative definitions

Feeding- any behavior suggesting the bird is in the act of feeding, such as a crane flipping over objects and/or probing for food or slow locomotion interrupted by these activities

Loafing- crane standing still in one place

Preening- crane preening feathers

Agonistic - defensive or offensive display with other birds. Can be with other whooping cranes, sandhill cranes, etc.

Courtship- crane performing unison call and/or dancing

Alert- crane alert and scanning horizon

Crane group – one or more cranes in a migrating unit. The group may consist of an individual crane, a family unit, or small flock.

Sighting – observation of a crane group in the study area.

Confirmed Sighting - Observation made by a State or Federal biologist or officer or by other known qualified observer (trained ornithologist or birder with experience in identification of whooping cranes). A photograph may also be used to confirm sightings. Aerial survey crew with previous aerial whooping crane observations may confirm a crane group during the survey.

Probable Sighting - No confirmation made by State or Federal biologist or officer or by other known qualified observer, yet details of the sighting seem to identify the birds as whooping cranes. To be classified as a probable sighting each of the following factors must be met: (1) location of sighting is within normal migration corridor and is an appropriate site for whooping cranes, (2) date of sighting is within period of migration, (3) accurate physical description, (4) number of birds is reasonable, (5) behavior of the birds does not eliminate whooping cranes, and (6) good probability that the observer would provide a reliable report.

Unconfirmed Sighting - Details of the sighting meet some, but not all of the six factors listed for a probable sighting.

Stopover – Use of the study area during spring or fall migration.

Use-site - A location of a crane group in the study area. A single crane group may have (and likely will have) more than one use-site per day.

Obstruction - objects (e.g., vegetation, bank, etc.) >1.5m above water line

Unobstructed width – The unobstructed width is defined as the area between obstructions less than 1.5m above water line and includes all water and island/sandbars <1.5m. A line will be drawn across the channel, through the use-site and will be oriented perpendicular to the general flow within the channel.

Water/Wetted Width - The water/wetted width is defined as the area covered by water between obstructions less than 1.5m. This measurement does not include sandbars and islands above the water surface but less than 1.5m. A line will be drawn across the channel, through the use-site and will be oriented perpendicular to the general flow within the channel.

IV.B. Field Techniques

IV.B.1. Detecting/Locating Whooping Crane Stopovers

Two methods will be used to locate migrating whooping crane stopovers along the central Platte River during spring and fall migration: aerial surveys and opportunistic locates. The Program's Technical Committee may choose to implement each protocol component as necessary to obtain needed information, for example changing the survey effort based on results of past surveys.

Aerial Survey

Daily aerial surveys, weather permitting, will be conducted along the central Platte River valley between Lexington and Chapman, Nebraska to locate spring and fall migrating whooping crane groups. The aerial surveys will take place from March 21 to April 29 in the spring and October 9 to November 10 in the fall. These dates are based on the 5th and 95th percentile of initial sighting dates for all recorded sightings of whooping crane groups in Nebraska from 1975 to 1999 (Jane Austin, USGS Northern Prairie Wildlife Research Center, pers. comm.). This protocol intends to collect a sample during possible migration time and does not intend to survey the entire time-period it would be possible for a crane group to migrate through the study area. Therefore, the survey dates will not be extended during times of delayed migration. However, if the survey period extends past the migration time in a given season, the surveys will be stopped using the following rules. For the spring survey, flights will be discontinued 5 days after the last normally migrating whooping cranes have departed Aransas, if no whooping cranes have been sighted in the central Platte valley for 5 days, and there are no recent (5 days) reports of whooping cranes in the Central Flyway south of the Platte River. For the fall survey, flights will be discontinued if no whooping cranes have been sighted in the central Platte valley for 5 days, and there are no recent (5 days) reports of whooping cranes in the Central Flyway north of the Platte River. The Program Manager or Biologist responsible for managing these surveys will be in contact with Tom Stehn (or other Aransas official) at (361) 286-3533 to obtain information related to bird departure/arrival from Aransas.

A Cessna 172 or similar aircraft will fly at a speed of 100 mph, as safety allows. One plane will fly the area between Chapman and the Nebraska Highway 10 (Minden) Bridge (the east leg).

The second plane will fly the area between the Minden Bridge and the Lexington Bridge (the west leg). Two observers in addition to the pilot will be in each plane. Surveys will begin between ½ hour before sunrise to sunrise, unless weather during this time period precludes beginning the survey. All attempts should be made to begin the survey at ½-hour before sunrise. If the survey cannot begin during this time period, due to weather/visibility requirements, the survey start time can be extended up to 2 hours after sunrise. Surveys may be canceled due to unsafe weather conditions (e.g., rain, snow, fog, high winds) or if there is significant snow cover on the ground that greatly impedes the surveyors chances of locating a whooping crane group.

All aerial surveys will be flown such that the flight direction when flying the river transect will be away from the rising sun. To help address the concern that one end of the river transect will always be flown early and the other late, there will be two start locations for each leg (east side and west side) of the study area. Using the eastern section as an example: on day one the flight will begin at Chapman, fly the river west to Minden, fly a predetermined return transect (upland) back to Chapman. On day two the flight will begin at the Wood River bridge, fly the river transect west to Minden, fly a predetermined return transect back to Chapman, and then fly the rest of the river transect from Chapman to Wood River. This pattern will continue through the survey period. The start points for the west leg will be the Minden Bridge and Odessa Bridge. During the river transect, observers will be situated such that the main channel(s) can be clearly viewed by both observers looking out the passenger side of the plane. This will necessitate that the plane fly just south of the main channel.

There are seven return transects: one, two or three miles either north or south of the centerline of the river and one directly down the centerline of the river (Figure 1). On the return transect, observers will look out different sides of the plane so that they can survey the half-mile to the north of the transect as well as the half-mile to the south of the transect. The return transect surveyed each day will be set based on a predetermined, systematically rotating schedule. This design will provide a systematic aerial survey to locate whooping crane groups in areas outside of the channel as well as within the channel. Again, it is recognized that this sampling scheme over-samples the river compared to those areas surveyed with the return transects.

All transects will be flown at 750’ altitude unless FAA regulation dictate a higher altitude (e.g., a minimum of 1000’ altitude when flying over towns and cities). The 750’ altitude for transects is selected for safety reasons. Extremely large numbers of migratory waterfowl are present in the central Platte River valley each spring. The 750’ altitude allows pilots to fly over most of the airborne waterfowl and to decrease the chance of flushing additional waterfowl into the air as the plane approaches. If a suspected whooping crane is seen, the plane is encouraged to circle to an altitude of 500’ (when safety allows) to provide a better viewing opportunity of the suspected whooping crane.

Each plane will have aerial photos, maps, and a global position system (GPS) unit to aid in the documentation of crane locations. When a whooping crane group is located, an air to ground radio will be used to immediately contact ground personnel that are geographically closest to the sighting. UTM coordinates taken either from the plane’s GPS system or hand held unit will be recorded on the data sheet and relayed to the ground crew. The aerial survey crew will photograph the whooping crane group and the general location using a 35mm or digital camera.

All observations will be recorded on the aerial observation datasheet. If the ground crew has not located the whooping crane group by the time the aerial survey is complete, the plane will return to the crane group's original coordinates and attempt to relocate the group. If the crane group is relocated from the air, the plane will maintain visual contact with the crane group and direct the ground crew to the location. The procedures to be followed by the ground crew once the crane group is located are in Section IV.B.2.

During the aerial flights, a ground crew will be stationed at four points in the study area. When the aerial survey crew radios a possible crane group sighting to the ground crew, the nearest two ground personnel will immediately attempt to locate the group. The ground crew will search for a minimum of two hours in the suspected area (or until dark) in an attempt to locate the sightings of crane groups made by the aerial flight crew. All effort expended by the ground crew to locate possible whooping crane groups will be documented on the datasheets and in the database.

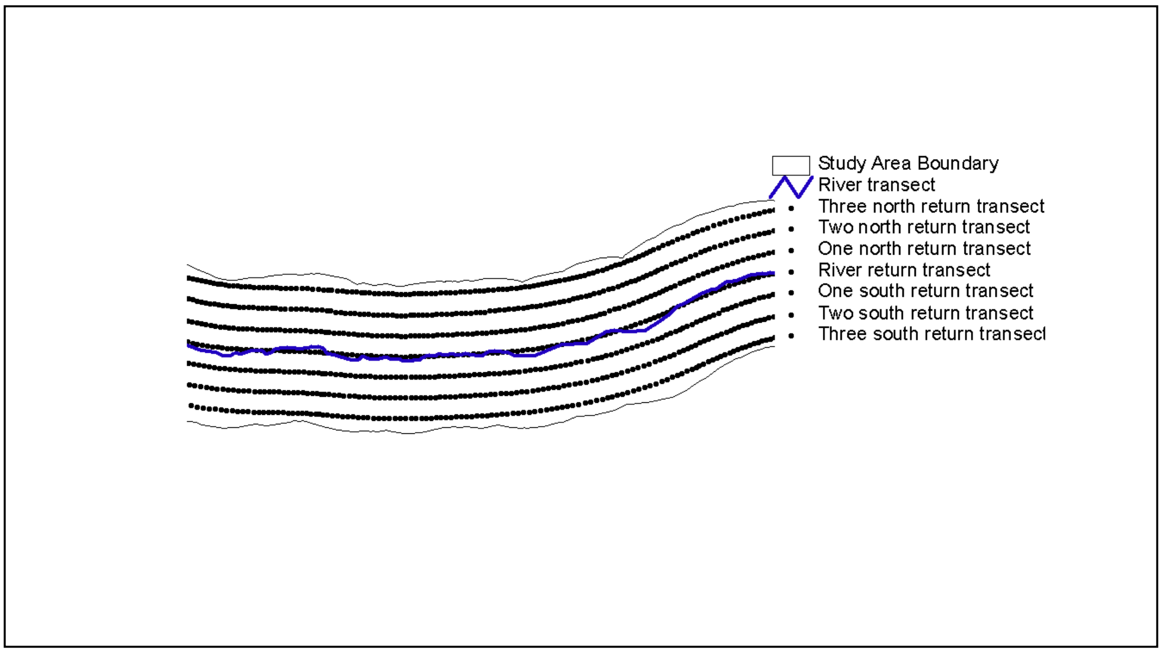

Figure 1. River flight transects and 7 return flight transects flown during the aerial surveys. Only a portion of the study area from East to West is shown.

Opportunistic Locates

The quality and timing of public sighting reports are highly variable. For example, several reports of a single group may be made by different individuals; sightings may be reported after the group has left the area; geese, white sandhill cranes, pelicans, or egrets may be reported as whooping cranes; etc. In an effort to document the validity of a sighting in a timely manner, a toll free number will be used to relay reports of possible whooping crane sightings to the ground crew. This number should be publicized at local areas frequented by birders, FWS offices, NGPC offices, and possibly in newspapers, to mail carries, bus drivers, etc. The ground monitoring crew will attempt to confirm all crane sighting reports that are in the study area and not yet confirmed. As a prioritization after confirmed sightings, the crew will check "probable" sightings, and then check "unconfirmed" sightings. The ground monitoring crew will conduct ground monitoring on all confirmed whooping cranes in the study area as described in Section IV.B.2.

All sightings relayed to the ground crew will be searched for by the ground crew for at least two hours. Incidental observations reported to the ground crew from outside the study area will be immediately forwarded to the FWS Nebraska field office, Whooping Crane Migration Information Coordinator. Information on all confirmed and probable sightings made by the ground crew will be forwarded to the FWS Nebraska field office.

The crew will fill out ground monitoring observation forms for all effort expended to locate confirmed and probable sightings of crane groups in the study area. In addition, the crew will collect use-site characteristics and fill out a use-site characteristics form for all crane sightings classified by the FWS as "confirmed".

Survey Detection Rates

Whooping crane decoys will be placed at randomly selected locations during the aerial survey. Aerial crews will not be aware of the presence of the decoys during the flight. When the aerial crew observes a decoy, the location of the sighting should be relayed to the ground crew for confirmation of the decoy location. Decoy observations will be recorded on the aerial observation datasheet.

IV.B.2 Movement Tracking

Each crane group will be continuously tracked from the roost in early morning until arriving back at roost in the evening, until the crane group leaves the study area, or until the ground crew loses the group. If a crane group is lost, observers will spend a minimum of two hours attempting to relocate the group in the suspected area or until dark. All observations of crane groups by the ground crew will take place at a distance identified in the FWS guidelines and from vehicles.

All observations of cranes will be recorded on the Instantaneous and Continuous Use-site Monitoring data sheet. Both instantaneous and continuous movement data will be collected during the movement tracking monitoring and recorded on this datasheet. Continuous locations will be recorded and documented with a sketch map on the back of the datasheet or aerial photograph. A unique location ID will be assigned to each contiguous habitat type used by the crane group during the movement tracking monitoring.

Instantaneous locations will be recorded at fifteen-minute intervals. The specific location of the crane group will be marked on the map. A unique instant point ID will be assigned during the movement tracking monitoring.

The following information will also be recorded for the observation period: crane group composition (single bird, family group, or flock); group size; age estimation if possible (adult/juvenile); weather conditions; leg band color if present; and the association of the crane group with other avian species (sandhill cranes, waterfowl, etc).

IV.B.3 Crane Group Numbering
Any time a crane group is observed in the study area by the survey crew, a *Crane Group ID* will be assigned to the group. The *Crane Group ID* will consist of the following information: year; "SP" for the spring monitoring period or an "FA" for the fall; sequential number (e.g. 2002FA01, 2002FA02, 2002FA03,… etc). Any time a crane group is observed in the study area by the survey crew, a new *Crane Group ID* will be assigned unless the surveyors note on the data sheets the reasons why they believe this is a previously recorded group (using their professional judgment). In this case, the same crane group ID will be used. FWS crane group numbers for confirmed sightings will be included in the Program database and linked to the Program crane group numbers. This will assist in future cross-referencing between FWS and Program databases.

Each field or location used by a crane group will get a new *Location ID*. *Location ID* will be a sequential alphabetical letter (A, B, etc.). The variables *Crane Group ID* and *Location ID* and *Time* will be used to connect information about sightings in a field through all the datasheets and associated data tables. Specifically, this identifier will document when the crane group used a location on the ground.

For example, if a crane group is observed in the Fall 2002 survey from the air and relayed to the ground crew, the first location observed will be assigned *Location ID* A (Crane Group ID=2002FA01) and the *Time* will be recorded. In the event that a crane group is observed by two people (e.g. from air and from the ground) in the same location and at the same time, the two observations should have the same *Crane Group ID* (Crane Group ID=2002FA01), the same *Location ID* (A), and the same *Time*. If the ground observer observes the crane group moving to another field, the location would be assigned *Location ID* B (Crane Group ID=2002FA01) and the *Time* recorded. If the ground observer observes the crane group returning to a previously used field, say A, the location would be assigned *Location ID* A (Crane Group ID=2002FA01) and the *Time* recorded. If the crane group goes out of sight, the next time a crane group is observed in the area, the crane group ID will be assigned 2 (Crane Group ID=2002FA02) (unless the observers think it is the same group as 01 and the supporting justification is documented); and the first location observed by this group will be assigned *Location ID* A. The project leader will need to continually review the datasheets to ensure the crane group ID and Location ID are correct, since field crew members may not know what the next sequential crane group ID should be.

Instantaneous data will be taken every 15 minutes at each crane group location. Each point will get a new *Instant Point ID*. The variables *Crane Group ID* and *Instant Point ID* will be used to connect information about sightings at instant points through all the datasheets and associated data tables.

IV.B.4. Activity Monitoring
Crane activity will be monitored during the course of movement tracking. As the observer watches the crane group, he/she will record the activity being conducted by the whooping crane at each of the 15 minute instantaneous points documented during the movement tracking as one of the following categories: courtship, preening, resting, feeding, alert, agonistic or other activity

as defined by the observer. If the crane group is comprised of more than one individual, the observer will select a “focus” crane that will be used to record activity information from. This information will be recorded on a datasheet. The observer will also video tape the crane group using a digital video camera for the entire time it is at a use site. Each tape/disk will be numbered and this number will be recorded on the datasheet for later cross-referencing. During the taping the observer will also verbally identify the date, time, location, and whooping crane group number that is being videoed.

IV.B.5. Use-Site Characteristics
The National Vegetation Classification Standard (NVCS) vegetation type will be documented for each continuous and instantaneous use-site using the Instantaneous and Continuous Use-site Monitoring datasheet. The time in, time out, and UTM location will also be recorded at the continuous use-sites. The time, distance to potential disturbance, and the type of disturbance will also be recorded at the instantaneous use-sites.

Additional physical and geomorphological characteristics of crane use locations will be measured for locations with standing or flowing water. These measurements will be made as soon as practical after the cranes leave the study area using the Use Site Characteristics datasheets. In all instances, proper landowner permission will be secured before Program personnel enter private property to conduct the measurements. FWS and/or NGPC personnel that have previously conducted site use evaluations will help train Program staff and contractors for future site evaluations.

Photographs taken of crane use-sites observed from the air will be used to locate the use area on the ground. A general sketch of the area and/or photograph will be taken for each use-site. The following characteristics will be recorded for each site with standing or flowing water.

The *Use Site ID* variable connects each location used by a crane group to the use characteristics measured on the ground. The *Use Site ID* is a sequential number assigned when the measurements are made (beginning with 1). The project manager will record the *Use Site ID* on the datasheets with the corresponding *Crane Group ID*, *Location ID* and *Time*. In cases where a crane group has used the same location multiple times, there will be multiple *Location ID’s* linked to one *Use Site ID* (assuming here the use characteristics were measured only once).

IV.B.5.a. Land cover class
The National Vegetation Classification Standard (NVCS) vegetation type will be documented for each continuous and instantaneous use-site.

IV.B.5.b. Distances to visual obstruction >1.5m
Distances from the crane group location to the nearest obstructions >1.5m in each of four quadrats oriented perpendicular/parallel to the channel for riverine use-sites and in the four cardinal directions for standing water will be made using a laser range finder. An obstruction is defined as objects (e.g., vegetation, bank, etc.) >1.5m above water line and encompassing more than 30 degrees of the horizontal field of view.

IV.B.5.c. Flow

The nearest upstream and downstream gage will be used to document provisional instantaneous flows during the period of crane use, and when the habitat measures are made. These data will be available from USGS gaging stations.

IV.B.5.d. Substrate

The percentage of each substrate type at a crane use-site will be documented for the four classes: less than 1mm, 1-4.9mm, 5-14.9mm, greater than 15mm.

IV.B.5.e. Unobstructed width

Channel width information will be gained by direct measurement and calculated from the water depth profile data. The distance between obstructions >1.5m along a line perpendicular to the channel and passing through the crane observation will be measured.

IV.B.5.f. Water/Wetted Width

Water or wetted width (defined the same for this protocol) will be measured directly in the field and calculated from the water depth profile data. The distance covered by water and between obstructions >1.5m along a line perpendicular to the channel and passing through the crane observation will be measured.

IV.B.5.g. Water depth profiles and sandbar location/elevation

When a crane group utilizes an area containing standing or flowing water, three parallel transects 25m apart will be established such that the middle transect crosses through the most recent crane group location. This procedure will allow the calculation of a mean and variance for each roost characteristic in the area a crane group used while acknowledging the difficulty in determining the exact crane group location when viewed from a distance.

Transects will be situated perpendicular to the general flow for river locations and perpendicular to the long axis of non-flowing water bodies. Elevation measurements will be taken along each transect using a stadia transit and rod. One measurement will be taken at approximately every 3m, when changes in topography are encountered, and at water lines. Each transect will begin and end where the transect line reaches an obstruction greater than 1.5m that a crane could not be seen through. UTMs at the bank of each transect will be documented using a GPS unit. When a sandbar is encountered along the profile transect, the distance at which the sandbar begins and ends (width) and height will be measured and the length estimated.

The channel morphology profile measurements will be interpolated during the analysis stage to produce a continuous profile of relative water surface elevation across the channel. Linear interpolation between each adjacent point along the transect will be used to sample from the profile at equally spaced increments. Water depth will be calculated as the average of equally spaced measurements of the relative water surface elevation profile that are at and below zero (water surface elevation). Sandbar elevation will be calculated as the average of equally spaced measurements of the relative water surface elevation profile that are at and above zero.

IV.B.5.h. Distances to potential disturbance features

Distance to potential disturbance will be documented in the lab using the most recent aerial photographs. Potential disturbance is defined as power lines, houses, etc.

IV.C. Data Collection from State and Federal Agencies

The report will contain a summary of all whooping crane migrational sightings within Nebraska and specifically the central Platte River corridor as obtained from the FWS, Grand Island. FWS crane group identification numbers will be recorded in the database.

IV.D. Analysis Methods

The information collected through this protocol will be used to define the habitat characteristics of whooping crane use-sites in the study area. The protocol is designed to provide information on crane groups with known probability of inclusion in the sample regardless of the crane group location in the study area. Since the aerial survey data provides this information but the opportunistically located cranes have an unknown probability of inclusion in the sample, analyses will be conducted separately for cranes located through the aerial surveys and for cranes located opportunistically.

Habitat Use

Since the whooping crane is a rare species and identifying individual cranes is usually not possible, all analyses with this data will need to balance small sample sizes with pseudo-replication. There are two options for the analysis of habitat use, one analysis will use every observation taken on each crane group, and will contain multiple observations per group. The second analysis will retain the sample size as the number of whooping cranes and average multiple observations of a crane as the first step of the analysis.

There are several analysis methods available for summarizing the habitat characteristics of whooping crane use-sites. The methods range from calculating means and variances, to modeling habitat use, to documenting changes through time, to methods that are not currently developed. With each analysis the probability sample of whooping crane use-sites collected under this protocol will provide data adequate for inferences to all cranes stopping along the Platte River in the study area.

Index of Use

An annual index of crane use will be developed using the information obtained by this protocol. The index of use will document the number of crane groups observed per survey effort (flights). The change in this index through time will estimate a change in the frequency of use throughout the first increment, if the protocol is implemented in a consistent manner.

Activity Monitoring Data

Annual analysis of activity monitoring data will only include the instantaneous data collected every 15 minutes. Videography collected will be archived for later analysis.

V. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

QA/QC measures will be implemented at all stages of the study, including field data collection, data entry, data analysis, and report preparation. Observers will be trained and tested in the methods used and on their ability to identify whooping cranes. Data forms will be completed on a daily basis. At the end of each survey day, each observer will be responsible for inspecting his or her data forms for completeness, accuracy, and legibility. The study team leader will review data forms to insure completeness and legibility, and correct the forms as needed. Any changes made to the data forms will be initialized by the person making the change.

To help train observers that will be conducting the aerial surveys, each individual will be required to fly practice transects, or portion of transect. During this flight there will be whooping crane decoys placed in the river channel to allow observers the opportunity to see a "whooping crane" from the air at the speed and altitude of the surveys.

Data will be entered into the Program's Microsoft Access 2000 database by qualified technicians. These files will be compared to the raw data forms and checked for errors. Any irregular codes detected, or any unclear or ambiguous data will be discussed with the observer and study team leader. All changes made to the raw data will be documented.

After the data have been keyed and verified, the study team leader or QA/QC technician will check a five percent sample of data forms against the final computer file. Any problems identified will be traced back to the raw data forms, and corrections will be documented.

VI. DATA COMPILATION AND STORAGE

The Program's Microsoft Access 2000 database will be used to store, retrieve and organize field observations. The data for each survey will be incorporated within the larger Program database. All field data forms, field notebooks, and electronic data files will be retained for ready reference.

VII. REPORT FORMAT

Data on whooping crane habitat use will be compiled and summarized annually, and incorporated within the larger Program database. A draft and final report will be produced each year describing the methods employed, results, and any conclusions that can be drawn. The report will have both written and graphical components. The report will also contain maps and/or aerial photos showing crane use-sites. Descriptive statistics of whooping crane use will be prepared. Reports will be provided to both the Technical Committee and Governance Committee.

VIII. DATA SHEETS – *To be provided prior to survey implementation*

Aerial Survey
Aerial Observation
Ground Monitoring
Instantaneous and Continuous Use Site Monitoring
Use-site Characteristics Summary
Use-site Characteristics Profile

APPENDIX B. Consistency of Monitoring Methods

The probability sample of crane group observations is affected by the changes in the monitoring methods. Monitoring methods changed as the protocol was tested in the pilot stage (first year of implementation) and in response to peer review comments (PRESP 2001a, PRESP 2001b, PRESP 2001c, PRESP 2002, PRESP 2003, PRESP 2004, PRESP 2005). Changes to the aerial flight protocol were specifically made to increase the chances of detecting a whooping crane (Table 1). Specifically, flight height and flight orientation relative to the sun were changed to increase detection. The analysis of aerial survey detection rates documented the impact of the protocol changes on the probability of detection and based on this analysis we used a detection model to calculate probabilities of inclusion for crane groups in the sample.

The number of transects/start locations in table 1 refers to the number of segments within the entire survey reach (90 miles) for the aerial surveys. When there were only two start locations, and the riverine transect (which has always been flown first) was only flown in the westward direction (as in Spring 2001), then the western part of each transect was consistently surveyed later in time. It was assumed that aerial surveys that occurred later has a smaller chance of detecting a crane group, given a crane group had used the area, because crane groups typically leave the river channel sometime during the morning. The change in the Fall of 2001 to alternate the flight orientation (east to west one morning, then west to east the next morning) was an attempt to rectify this bias against the western end of each transect. The final change, increasing the number of start locations from 2 to 4 with the chronological order of surveying the two segments alternated, was implemented in the Fall of 2003 to allocate the earlier survey time more evenly throughout the study area, again an effort to eliminate systematic bias associated with the time of survey.

Changes to the crane group ID numbering, as described in the protocol, occurred before the Fall 2002 survey. Before this date, all crane groups observed in the study area were assigned a unique number. After the change, the protocol stated that the surveyors could continue to use a crane group ID for a new sighting of a crane group if it was judged to be a previously recorded group. Methods of assignment of crane group numbers varied throughout the Cooperative Agreement time period as a result of differences in contractor implementation. Some contractors used a different crane group ID every day, some contractors reused across days.

Table 1. Monitoring method specifications during the Cooperative Agreement time period.

Survey		Flight Height (feet)		Flight Orientation		Number of Transects/ Start Locations
Year	Season	Riverine Transect	Return Transect	Riverine Transect	Return Transect	
2001	Spring	1000	1000	West	East	2
2001	Fall	750	1000	Alternated East/West	Alternated East/West	2
2002	Spring	750	1000	Alternated East/West	Alternated East/West	2
2002	Fall	750	1000	Alternated East/West	Alternated East/West	2
2003	Spring	NO SURVEY				
2003	Fall	750	750	West	East	4
2004	Spring	750	750	West	East	4
2004	Fall	750	750	West	East	4
2005	Spring	750	750	West	East	4
2005	Fall	750	750	West	East	4
2006	Spring	750	750	West	East	4
2006	Fall	750	750	West	East	4

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APPENDIX C. Means of Habitat Parameters for Systematic and Opportunistic Observations Combined

Table 1. Study area, channel, and upland means and 95% confidence intervals for the land cover variables for the systematic and opportunistic sample of observations combined. There were 151 use sites in the wetted channel and 179 use sites in the upland.

	Study Area			Channel			Upland		
Variable	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
agdist	182.62	154.28	210.97	358.60	314.15	403.05	34.17	18.33	50.01
dedist	640.96	600.59	681.34	723.89	661.76	786.02	571.00	520.31	621.70
grdist	275.06	253.54	296.58	275.65	246.19	305.10	274.57	243.57	305.56
owdist	440.33	414.46	466.20	376.17	344.95	407.39	494.45	456.46	532.44
sfdist	153.59	136.57	170.62	59.49	50.97	68.01	232.98	207.95	258.01
trdist	498.14	463.10	533.18	631.30	583.00	679.61	385.80	342.16	429.45
wcdist	646.37	521.23	771.52	0.00	0.00	0.00	1191.64	994.74	1388.53
wgdist	191.39	175.03	207.76	142.67	127.95	157.39	232.49	206.50	258.48
wvdist	403.57	358.75	448.39	218.43	194.51	242.34	559.75	487.36	632.15
P_AG_25	42.79	38.70	46.88	10.46	8.57	12.36	70.06	65.83	74.30
P_DE_25	0.45	0.33	0.56	0.31	0.17	0.44	0.56	0.38	0.74
P_GR_25	13.93	12.01	15.84	14.39	11.80	16.98	13.54	10.75	16.32
P_OW_25	0.97	0.72	1.22	1.70	1.23	2.16	0.35	0.14	0.57
P_SF_25	17.55	15.78	19.32	30.64	28.48	32.79	6.51	5.35	7.67
P_TR_25	0.98	0.79	1.18	0.27	0.10	0.44	1.58	1.28	1.89
P_WC_25	21.10	19.07	23.12	38.37	37.00	39.75	6.52	5.03	8.01
P_WG_25	15.58	13.65	17.50	17.21	14.59	19.82	14.20	11.42	16.97
P_WV_25	1.65	1.32	1.97	2.82	2.25	3.39	0.66	0.38	0.94

Table 2. Means and 95% confidence intervals for the habitat characteristics measured on the ground at wetted channel for the systematic and opportunistic sample of observations combined, metric and English units.

Variable	n	Mean	95% CI Lower	95% CI Upper	English units		95% CI Lower	95% CI Upper
Fine_Sand	145	59.63	53.82	65.45				
Coarse_Sand	145	30.34	25.06	35.62				
Sm_Gravel	145	7.39	5.16	9.61				
Lg_Gravel	145	2.64	1.26	4.02				
dist_vo (m)	154	175.84	161.61	190.08	feet	576.92	530.23	623.61
area_clear (km^2)	154	0.12	0.10	0.14	acres	30.02	25.08	34.95
oowidth (m)	151	276.29	259.48	293.11	feet	906.48	851.32	961.63

Table 3. Wetted channel means and 95% confidence intervals for flow dependent habitat characteristics for the systematic and opportunistic sample of observations combined, metric and English units.

Variable	n	Mean	95% CI Lower	95% CI Upper	English units	Mean	95% CI Lower	95% CI Upper
Wetted width (m)	155	154.00	141.47	166.53	feet	505.26	464.15	546.37
Flow (cms)	155	12.39	10.83	13.94	cfs	437	382	492
Sandbar elevation (m)	152	0.23	0.21	0.26	feet	0.76	0.68	0.84
Proportion depth suitable	152	0.71	0.67	0.74				
Proportion depth suitable or sand	152	0.80	0.76	0.83				
Proportion sand	152	0.49	0.45	0.54				
Width to depth ratio	155	879	813	945				

APPENDIX D. Means of Habitat Parameters for Available Locations

Table 1. Study area, channel, and upland means and 95% confidence intervals for the land cover variables for the available sample of observations. There were 6420 points in the study area, 189 of these in the wetted channel and 6231 in the upland.

	Study Area			Channel			Upland		
Variable	Mean	Lower	Upper	Mean	Lower	Upper	Mean	Lower	Upper
agdist	115.02	109.17	120.86	430.89	390.22	471.56	105.43	99.71	111.15
dedist	491.22	481.79	500.65	738.59	682.13	795.05	483.71	474.21	493.21
grdist	245.46	238.80	252.13	294.51	261.52	327.51	243.98	237.19	250.76
owdist	553.69	543.20	564.17	391.87	357.40	426.35	558.59	547.87	569.32
sfdist	237.80	232.01	243.58	32.71	27.47	37.95	244.02	238.13	249.91
trdist	338.69	330.82	346.57	584.08	538.08	630.07	331.25	323.33	339.17
wcdist	1911.59	1876.34	1946.84	0.00	0.00	0.00	1969.57	1934.27	2004.87
wgdist	191.94	186.51	197.37	117.04	101.73	132.35	194.21	188.65	199.78
wvdist	581.01	568.13	593.90	167.42	146.10	188.75	593.56	580.43	606.69
P_AG_25	60.37	59.48	61.26	7.99	6.18	9.80	61.96	61.07	62.84
P_DE_25	2.48	2.25	2.71	0.31	0.14	0.48	2.55	2.31	2.78
P_GR_25	17.13	16.53	17.72	12.18	9.75	14.61	17.28	16.67	17.88
P_OW_25	0.08	0.07	0.09	0.03	-0.01	0.08	0.08	0.07	0.09
P_SF_25	9.86	9.42	10.30	40.44	37.85	43.04	8.93	8.51	9.35
P_TR_25	3.41	3.29	3.52	0.76	0.46	1.07	3.49	3.37	3.60
P_WC_25	2.86	2.66	3.06	30.01	28.18	31.84	2.04	1.88	2.19
P_WG_25	18.48	17.88	19.08	16.80	14.29	19.32	18.53	17.92	19.15
P_WV_25	1.36	1.27	1.44	4.62	3.78	5.46	1.26	1.18	1.34

Table 2. Means and 95% confidence intervals for the habitat parameters measured on the ground at the decoy locations, metric and English units.

Variable	n	Mean	95% CI Lower	95% CI Upper	English units	Mean	95% CI Lower	95% CI Upper
Fine_Sand	65	49.48	40.96	57.99				
Coarse_Sand	65	35.88	27.74	44.02				
Sm_Gravel	65	14.15	8.47	19.84				
Lg_Gravel	65	0.49	0.01	0.97				
dist_vo (m)	65	125.18	104.25	146.11	feet	410.70	342.03	479.37
area_clear (km^2)	65	0.07	0.05	0.09	acres	17.61	11.93	23.28
oowidth (m)	71	158.00	136.12	179.87	feet	518.37	446.60	590.13

Table 3. Means and 95% confidence intervals for the flow dependent habitat parameters at available locations throughout the study area, metric and English units.

Variable	flow	Mean	95% CI Lower	95% CI Upper	English units	Mean	95% CI Lower	95% CI Upper
Wetted width (m)	Low	79.38	78.39	80.37	feet	260.43	257.20	263.67
	Med	127.26	125.49	129.03		417.51	411.70	423.32
	High	175.97	173.76	178.17		577.31	570.07	584.55
Flow (cms)	Low	5.13	5.09	5.17	cfs	181	180	183
	Med	12.30	12.23	12.37		434	432	437
	High	26.23	26.08	26.39		926	921	932
Proportion depth suitable	Low	0.69	0.68	0.69				
	Med	0.59	0.58	0.59				
	High	0.42	0.41	0.42				
Proportion depth suitable or sand	Low	0.86	0.86	0.86				
	Med	0.70	0.69	0.71				
	High	0.49	0.49	0.50				
Proportion sand	Low	0.54	0.54	0.55				
	Med	0.30	0.30	0.31				
	High	0.16	0.15	0.16				
Width to depth ratio	Low	605	596	615				
	Med	759	744	774				
	High	779	765	792				

APPENDIX E. Final Models for Systematic and Opportunistic Observations Combined

Study area selection of land cover for all observations

The resource selection model for all observations (wetted channel and upland) including opportunistic observations contained the linear effects of percent of wetted channel (P_WC), percent of agriculture (P_AG), percent of open water (P_OW), and percent of wet grass (P_WG). The form of the final model was:

$$W(x) = \exp[(0.099 * \mathrm{P\_WC}) + (0.038 * \mathrm{P\_AG}) + (0.234 * \mathrm{P\_OW}) + (0.029 * \mathrm{P\_WG})].$$

The standard errors for the coefficients were 0.01, <0.01, 0.03, and <0.01 for percent of wetted channel, percent of agriculture, percent of open water, and percent of wet grass respectively. This model indicated significant selection for areas with large proportions of wetted channel, agriculture, open water, and wet grasses, regardless of the observation being in the wetted channel or out of the channel.

Study area selection of land cover for in- channel observations

The resource selection model for in- channel observations including opportunistic observations contained the linear effects of percent of open water (P_OW) and percent of wetted channel (P_WC). The form of the final model was:

$$W(x) = \exp[-3.802 + (2.360 * \mathrm{P\_OW}) + (0.085 * \mathrm{P\_WC})].$$

The standard errors for the coefficients were 0.53, 0.51, and 0.01 for the intercept, percent of open water, and the percent of wetted channel respectively. This model indicated significant selection for in-channel areas with large proportions of open water and wetted channel.

Local area selection of land cover for all observations

Model selection on the dataset with all observations (wetted channel and upland) including all opportunistic observations resulted in a final model for local selection containing an indicator for wetted channel, percent of open water (P_OW), percent of wetted channel (P_WC), percent of agriculture (P_AG), and percent of grass (P_GR). The form of the final model for wetted channel was:

$$W(x) = \exp[1.571 + (1.417 * \mathrm{P\_OW}) + (0.143 * \mathrm{P\_WC}) + (0.058 * \mathrm{P\_AG}) + (0.044 * \mathrm{P\_GR})]$$

The standard errors for the coefficients were 0.24, 0.08, 0.01, <0.01, and <0.01 for the wetted channel indicator, percent of open water, wetted channel, agriculture and grass respectively. And the form of the final model for all other land cover types was:

$$W(x) = \exp[(1.417 * \mathrm{P\_OW}) + (0.143 * \mathrm{P\_WC}) + (0.058 * \mathrm{P\_AG}) + (0.044 * \mathrm{P\_GR})]$$

The standard errors for the coefficients were 0.08, 0.01, <0.01, and <0.01 for percent of open water, wetted channel, agriculture and grass respectively. This model indicated significant selection for local areas with large proportions of open water, wetted channel, agriculture and grass.

Local area selection of land cover for in- channel observations
The final resource selection model, w(x), for local selection in the wetted channel including all opportunistic observations contained the linear effects of percent of open water (P_OW) and percent of wetted channel (P_WC). The form of the final model was:

$$W(x) = \exp[(3.936*P\_OW)+ (0.126*P\_WC)]$$

The standard errors for the coefficients were 0.58 and 0.02 for percent open water and percent wetted channel respectively. This model indicated significant selection for local in-channel areas with large proportions of open water and wetted channel.

Study area selection of characteristics measured on the ground
The final resource selection model, w(x), including all opportunistic observations contained the linear and quadratic effects of obstruction to obstruction width (o_to_owidth). The form of the final model was:

$$W(x) = \exp[(0.009*o\_to\_owidth) - (0.001* o\_to\_owidth^2)]$$

The standard errors for the coefficients were <0.01 and <0.01 for the linear and quadratic effects respectively. This model indicated significant selection for large obstruction to obstruction widths up to a point, then the relative probability of selection decreased with increased obstruction to obstruction width.

Study area selection of flow dependent characteristics
The final resource selection model, w(x), contained the linear and quadratic effects of proportion depth suitable and the linear and quadratic effects of proportion sand. The form of the final model was:

$$W(x) = \exp[(-1.271* P\_depth) + (4.127* P\_depth^2) - (2.220* P\_sand) + (4.658* P\_sand^2)]$$

The standard errors for the coefficients were 1.71, 1.42, 1.30 and 1.30 for the linear effect of proportion depth suitable, the quadratic effect of proportion depth suitable, the linear effect of proportion sand, and the quadratic effect of proportion sand respectively. This model indicated significant selection for greater proportions of the wetted width which were depth suitable (Figure 1) and sand (Figure 2).

Local area selection of flow dependent characteristics
The final resource selection model, w(x), contained proportion sand, the linear and quadratic effects of width and the linear and quadratic effects of proportion depth suitable or sand. The form of the final model was:

$$W(x) = \exp[(8.378*p\_sand) + (0.046*width) - (0.001*width^2) + (8.062* P\_depth\_sand) - (9.466* P\_depth\_sand^2)]$$

The standard errors for the coefficients were 0.90, <0.01, <0.01, 3.27, and 2.76 for the effects of proportion sand, width, the quadratic effect of width, proportion depth suitable or sand, and the quadratic effect of proportion depth suitable or sand respectively. This model indicated significant selection for greater proportions of sand. This model also indicated significant selection for large widths up to a point, and then the relative probability of selection decreased with increased width (Figure 3). The quadratic function was maximized at 312 meters (80% CI: 276, 351). This model indicated significant selection for large proportion depth suitable or sand up to a point, and then the relative probability of selection decreased with increased proportion depth suitable or sand (Figure 4). The quadratic function was maximized at 0.43 (80% CI: 0.31, 0.50).

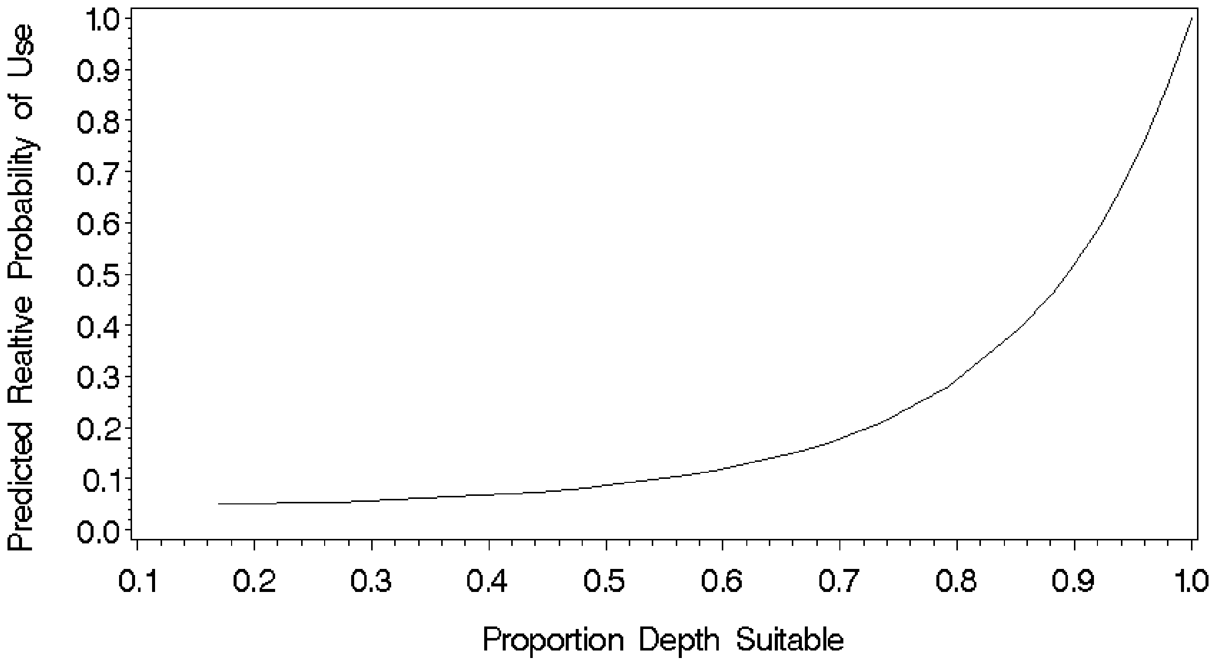

Figure 1. Predicted quadratic relationship between the relative probability of use and proportion depth suitable based on the resource selection function for study area selection.

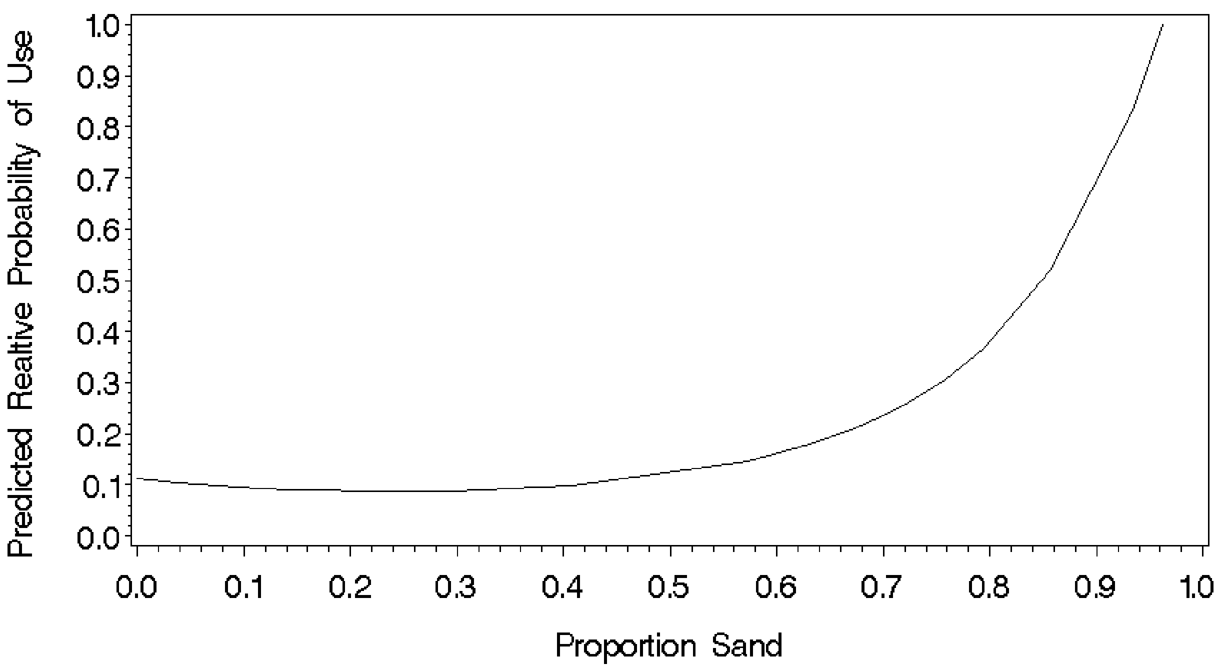

Figure 2. Predicted quadratic relationship between the relative probability of use and proportion sand based on the resource selection function for local area selection.

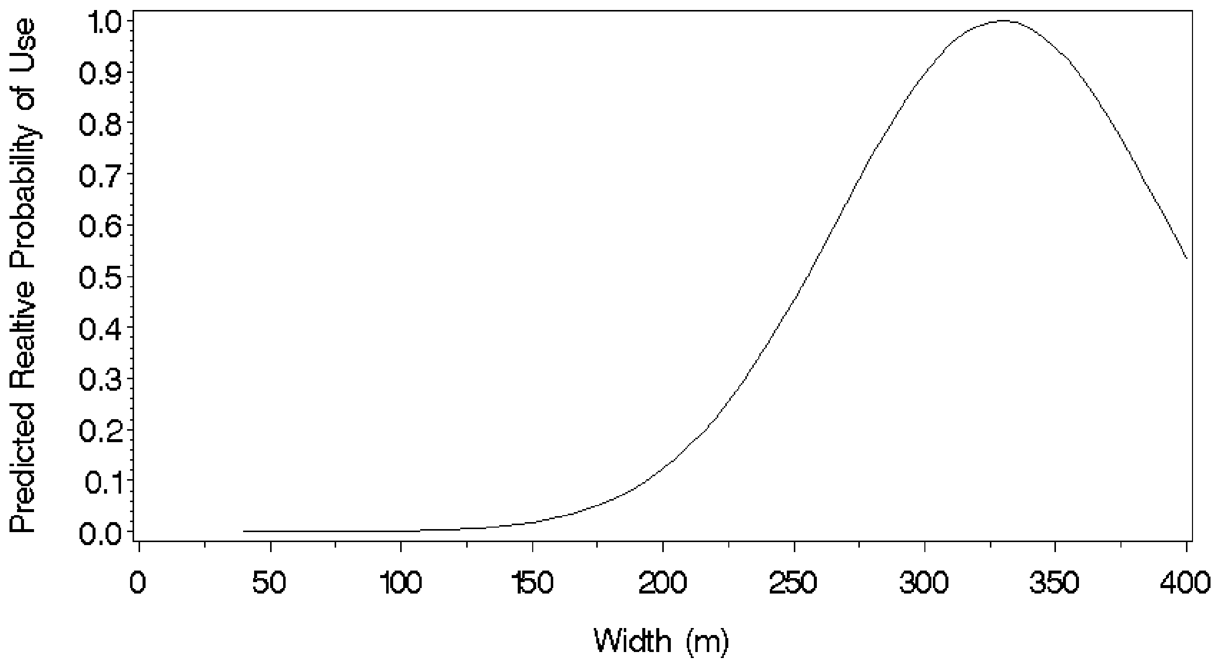

Figure 3. Predicted quadratic relationship between the relative probability of use and width based on the resource selection function for local area selection.

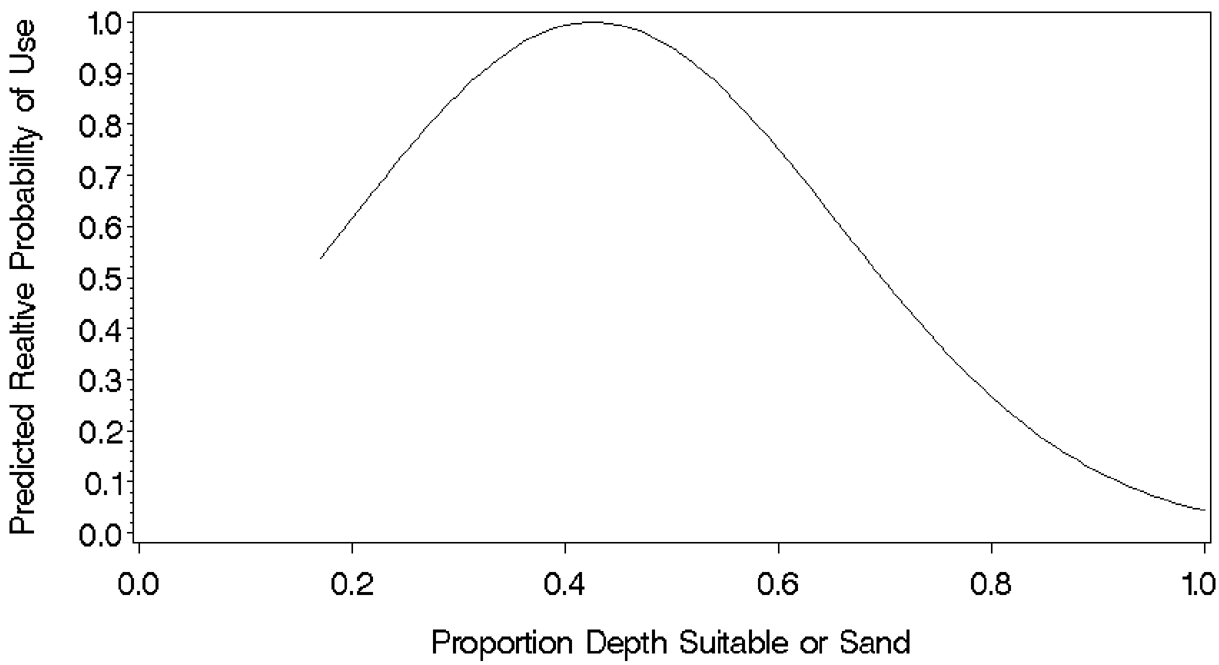

Figure 4. Predicted quadratic relationship between the relative probability of use and proportion depth suitable or sand based on the resource selection function for local area selection.

APPENDIX F. Model Selection Steps

AIC, Akaike's Information Criteria, is defined as

$$AIC = -2LogLikelihood + 2K$$

where K is the number of parameters estimated by the model. AIC can be calculated for any linear statistical model estimated by maximum likelihood. Maximizing the likelihood function results in values for the model parameters that are the most probable given the observed set of data. The actual value of the AIC is meaningless, and highly dependent upon the sample size. Relative values of AIC can be used to rank a set of models when all models are fit with the same set of data, with the minimum AIC being the best. The AIC seeks to rate a model by balancing the perils of overfitting (too many parameters estimated) and parsimony (too few parameters estimated).

The AIC was used to determine the entry of a variable at each step of the selection procedure. The procedure was continued until there were no variables in the candidate variable list for which their addition into the model produced a model with a lower AIC. Since the latter steps in this model selection procedure generally continue to add variables to the model, though no significant reduction of the AIC is occurring, a graph of AIC through the model selection procedure was used to select a model at the point where additional variables entering the model do not contribute substantially (selected model is highlighted in bold in the following tables).

Table 1. Steps of the model selection procedure for study area selection of land cover.

Step	AIC	Model
1	1274.0	P_WC
2	1251.2	P_WC P_OW
3	**1226.8**	**P_WC P_OW P_AG**
4	1190.4	P_WC P_OW P_AG wcdist_2 wcdist
5	1175.9	P_WC P_OW P_AG wcdist_2 wcdist P_TR
6	1166.3	P_WC P_OW P_AG wcdist_2 wcdist P_TR sfdist
7	1159.9	P_WC P_OW P_AG wcdist_2 wcdist P_TR sfdist sfdist_2
8	1151.3	P_WC P_OW P_AG wcdist_2 wcdist P_TR sfdist sfdist_2 owdist_2 owdist

Table 2. Steps of the model selection procedure for study area in-channel selection of land cover.

Step	AIC	Model
1	276.2	P_OW
2	240.3	P_OW P_WC
3	227.8	P_OW P_WC P_AG
4	217.2	P_OW P_WC P_AG trdist
5	207.6	P_OW P_WC P_AG trdist sfdist
6	**205.3**	**P_OW P_WC P_AG trdist sfdist sfdist_2**
7	204.5	P_OW P_WC P_AG trdist sfdist sfdist_2 P_TR
8	204.1	P_OW P_WC P_AG trdist sfdist sfdist_2 P_TR grdist
9	202.2	P_OW P_WC P_AG trdist sfdist sfdist_2 P_TR grdist P_GR
10	197.0	P_OW P_WC P_AG trdist sfdist sfdist_2 P_TR grdist P_GR grdist_2

Table 3. Steps of the model selection procedure for local area selection of land cover.

Step	AIC	Model
1	804.3	P_WC
2	677.5	P_WC P_OW
3	645.4	P_WC P_OW ind_wc
4	**626.7**	**P_WC P_OW ind_wc ind_ag**
5	590.1	P_WC P_OW ind_wc ind_ag wcdist_2 wcdist
6	563.2	P_WC P_OW ind_wc ind_ag wcdist_2 wcdist P_TR
7	548.1	P_WC P_OW ind_wc ind_ag wcdist_2 wcdist P_TR sfdist
8	539.2	P_WC P_OW ind_wc ind_ag wcdist_2 wcdist P_TR sfdist P_AG
9	533.7	P_WC P_OW ind_wc ind_ag wcdist_2 wcdist P_TR sfdist P_AG sfdist_2 sfdist
10	527.1	P_WC P_OW ind_wc ind_ag wcdist_2 wcdist P_TR sfdist P_AG sfdist_2 sfdist P_SF
11	486.9	P_WC P_OW ind_wc ind_ag wcdist_2 wcdist P_TR sfdist P_AG sfdist_2 sfdist P_SF P_WG

Table 4. Steps of the model selection procedure for local in-channel selection of land cover.

Step	AIC	Model
1	332.9	P_OW
2	289.7	P_OW P_WC
3	**269.9**	**P_OW P_WC trdist_2 trdist**
4	260.3	P_OW P_WC trdist_2 trdist sfdist
5	254.2	P_OW P_WC trdist_2 trdist sfdist P_AG
6	253.1	P_OW P_WC trdist_2 trdist sfdist P_AG sfdist_2
7	252.0	P_OW P_WC trdist_2 trdist sfdist P_AG sfdist_2 P_WV
8	249.8	P_OW P_WC trdist_2 trdist sfdist P_AG sfdist_2 P_WV P_TR

Table 5. Steps of the model selection procedure for study area selection of characteristics measured on the ground.

Step	AIC	Model
1	335.0	oowidth
2	**333.5**	**oowidth oowidth_2**

Table 6. Steps of the model selection procedure for study area selection of flow dependent characteristics.

Step	AIC	Model
1	781.2	P_sand
2	764.2	P_sand width
3	**760.4**	**P_sand width P_depth_sand^2 P_depth_sand**
4	748.8	P_sand width P_depth_sand^2 P_depth_sand P_depth
5	742.1	P_sand width P_depth_sand^2 P_depth_sand P_depth flow^2 flow
6	740.2	P_sand width P_depth_sand^2 P_depth_sand P_depth flow^2 flow P_sand^2 P_sand

Table 7. Steps of the model selection procedure for local area selection of flow dependent characteristics.

Step	AIC	Model
1	415.0	P_depth_sand
2	405.8	P_depth_sand P_depth_sand^2
3	**401.7**	**P_depth_sand P_depth_sand^2 flow**
4	401.6	P_depth_sand P_depth_sand^2 flow width
5	395.4	P_depth_sand P_depth_sand^2 flow width P_sand^2 P_sand