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National Wildlife Refuge System

Whooping Crane Winter Abundance Survey Protocol

Aransas National Wildlife Refuge

Survey Identification Number: FF02RTAR00-002

Protocol Signature Page

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Refuge Name:	**Author, Title, and Affiliation:**
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Approvals

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Submitted By:	Matthew J. Butler [signature] Biometrician	3/26/14
Editor[2]:	Grant Harris [signature] Chief Biological Sciences, Region 2	4/22/14
Aransas NWR Approval:	Sonny Perez [signature] Refuge Manager/Project Leader	5/13/14
Refuge Supervisor Approval:	Kelly McDowell [signature] Texas and Oklahoma Refuge Supervisor	5/13/2014
Regional I&M Approval:	Kristine L. Metzger [signature] Inventory & Monitoring Coordinator, Region 2	5/13/2014

Version	Date	Author	Change Made	Reason for Change

[1] Corresponding author, matthew_butler@fws.gov.

[2] Coordinated internal and external peer-review.

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Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.3 to 2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.6 to Version 1.7) when there are minor modifications that do not affect requirements or procedures included in the protocol. Rows will be added in the revision history log for each change or set of changes tied to an updated version number. There is no required timeline for revision of the protocol. However, changes to the objectives, sampling design, field methods, or analysis techniques should prompt protocol revision (U.S. Fish and Wildlife Service 2013).

Revision History Log

Version #	Date	Revised by	Changes
Example	Date of Revision	Name(s)	• List items that were changed or revised and specify if changes were minor or major.
1.0	26 March 2014	Matthew Butler Bradley Strobel Cinthia Eichhorn	• Protocol created.

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Executive Summary

The annual abundance of the Aransas-Wood Buffalo whooping crane (*Grus americana*) flock, which overwinters along the Texas gulf coast, USA, has been enumerated using aerial surveys since 1950. When aerial surveys began the flock consisted of fewer than 30 individuals that wintered on the Blackjack Peninsula and Matagorda Island of the Aransas National Wildlife Refuge (NWR). Since that time the Aransas-Wood Buffalo flock has dramatically increased its population size and the area of its wintering grounds.

Although whooping crane surveys have been conducted for over 60 years, a formal protocol, including survey objectives, survey methods, sampling frame, data analyses, and reporting procedures, was never completed. Stehn and Taylor (2008) briefly described the aerial survey methods employed from 1982–2011 and they identified multiple factors that hampered the defensibility of survey methods including the imperfect detection of whooping cranes. In 2011, the U.S. Fish and Wildlife Service (USFWS) re-evaluated the objectives and methods of the traditional aerial survey technique and determined that as the whooping crane population increases, the traditional methods would become increasingly insufficient at providing the data needed for conservation. Regional and refuge staff then launched a multifaceted effort to improve the survey methods and develop a statistically rigorous technique.

This protocol is primarily designed to provide a mechanism for monitoring trends in whooping crane abundance on their wintering grounds along the Texas gulf coast. Secondarily, the protocol provides mechanisms for monitoring recruitment rates, the number of whooping crane pairs that recruited young into the winter flock, and whooping crane winter range expansion. Finally, this protocol is designed to augment planning and conservation efforts with information about the relationships among local whooping crane abundance and habitat or environmental characteristics.

Imperfect detection of individuals present in the survey area will result in inaccurate estimates of abundance unless the resulting bias is corrected. Distance sampling is a tractable, widespread approach used to correct for the bias that results from imperfect detection and has been used in aerial surveys to estimate density of many bird and mammal species. Recent theoretical advances (i.e., hierarchical distance sampling models) have resulted in models that explicitly consider relationships between local abundance and environmental covariates (known as spatially-explicit models of abundance) while controlling for detectability. Such models are attractive because they can be used to understand ecological relationships among whooping crane abundance and environmental conditions while accounting for imperfect detection. This protocol exploits line transect-based distance sampling and hierarchical models of abundance for monitoring whooping cranes on their wintering grounds.

The survey methods provided in this protocol are a defensible, statistically rigorous means to estimate the annual abundance, and associated degree of confidence, of whooping cranes wintering within the sampling frame. Furthermore, the survey methods provide for defensible estimates of the number of whooping crane pairs and the number of pairs that recruited young into the winter flock, which are downlisting criteria identified by the International Recovery Plan for whooping cranes. Finally, the use of hierarchical distance sampling provides spatially-

explicit maps of whooping crane abundance. The predictive models used to create these maps provide a better understanding of whooping crane resource use, which will guide whooping crane conservation efforts. They also inform management, identify potentially important future whooping crane habitat, and direct land conservation and development initiatives.

Survey Protocol Narrative

Element 1: Background and Objectives

Background

Whooping cranes (*Grus americana*), an endangered species, declined to near extinction by 1941 (Canadian Wildlife Service [CWS] and U.S. Fish and Wildlife Service [USFWS] 2007). Historically, whooping cranes existed at low densities throughout their range, until widespread habitat change coupled with unregulated shooting are thought to have caused the long-term population decline (Allen 1952, Johnsgard 1983). The only remaining wild, migratory population of whooping cranes breed on and around Wood Buffalo National Park, Alberta and Northwest Territories, Canada, and overwinters along the Texas gulf coast centered on Aransas National Wildlife Refuge (NWR), Texas, USA (CWS and USFWS 2007). This population is known as the Aransas-Wood Buffalo flock.

In 1973, with the passage of the Endangered Species Act, the whooping crane was listed as an endangered species. The U.S. Endangered Species Act allows for the development and implementation of species recovery plans including downlisting criteria. The International Recovery Plan has established several downlisting criteria for whooping cranes based on population size and the number of breeding pairs (CWS and USFWS 2007). The plan identified a short-term recovery goal of downlisting from endangered to threatened by 2035 (CWS and USFWS 2007). One alternative downlisting criterion requires ≥1,000 birds in the Aransas-Wood Buffalo flock with ≥250 breeding pairs (Criterion 1B; CWS and USFWS 2007). If an additional self-sustaining flock can be established, the downlisting criterion requires ≥400 birds in the Aransas-Wood Buffalo flock with ≥100 breeding pairs (Criterion 1A; CWS and USFWS 2007). If two additional self-sustaining flocks can be established, the downlisting criterion requires a minimum of 160 birds with ≥40 breeding pairs (Criterion 1; CWS and USFWS 2007).

Monitoring quantitative population metrics is important for determining if the population has achieved downlisting criteria. Monitoring also provides a tool to measure recovery and bolster conservation efforts by providing data that can be used to inform decisions affecting whooping crane conservation and management. Therefore, it is incumbent upon the USFWS to frequently and objectively critique the methods we use to measure the effects of conservation or management actions, especially for endangered species such as whooping cranes. Furthermore, it is USFWS policy to use the most appropriate, best available, high quality scientific and scholarly data and information to support the mission of the Department (Department of the Interior 2011).

Traditional "census" effort

The Aransas-Wood Buffalo whooping crane flock has been monitored on its wintering grounds surrounding Aransas NWR (Figure 1) via aerial surveys since 1950 (Stehn and Taylor 2008). Since establishment of Aransas NWR in 1937, the population has grown at an exponential rate and expanded onto approximately 22,000 ha of coastal marsh and bay (Stehn and Taylor 2008). Early surveys were assumed to be "censuses" that documented all individuals in the population (i.e., complete enumeration). True population censuses for natural, free ranging wildlife populations are exceptionally difficult, if not impossible, to achieve for two primary reasons. First, most study areas are too large to sample completely within a short enough time frame to ensure population closure (e.g., emigration, immigration; Lancia et al. 2005, Morrison et al. 2008, Stehn and Taylor 2008, Conroy and Carroll 2009). Second, the probability of detecting individuals is usually less than 100% and detectability is influenced by various factors including the behavior of individuals, vegetation density, observer fatigue, and field methodology (Krebs 1999, Buckland et al. 2001, Williams et al. 2002, Morrison et al. 2008, Conroy and Carroll 2009). Stehn and Taylor (2008) recognized these sources of bias but they did not address them. They also indicated that as abundance increases and the whooping crane's wintering grounds expand, the accuracy of their "census" attempts would decrease. Therefore, a robust alternative method that does not assume complete enumeration of individuals and quantifies precision is needed. This protocol provides a technique that accounts for incomplete detection and quantifies precision by employing line transect-based distance sampling and hierarchical modeling.

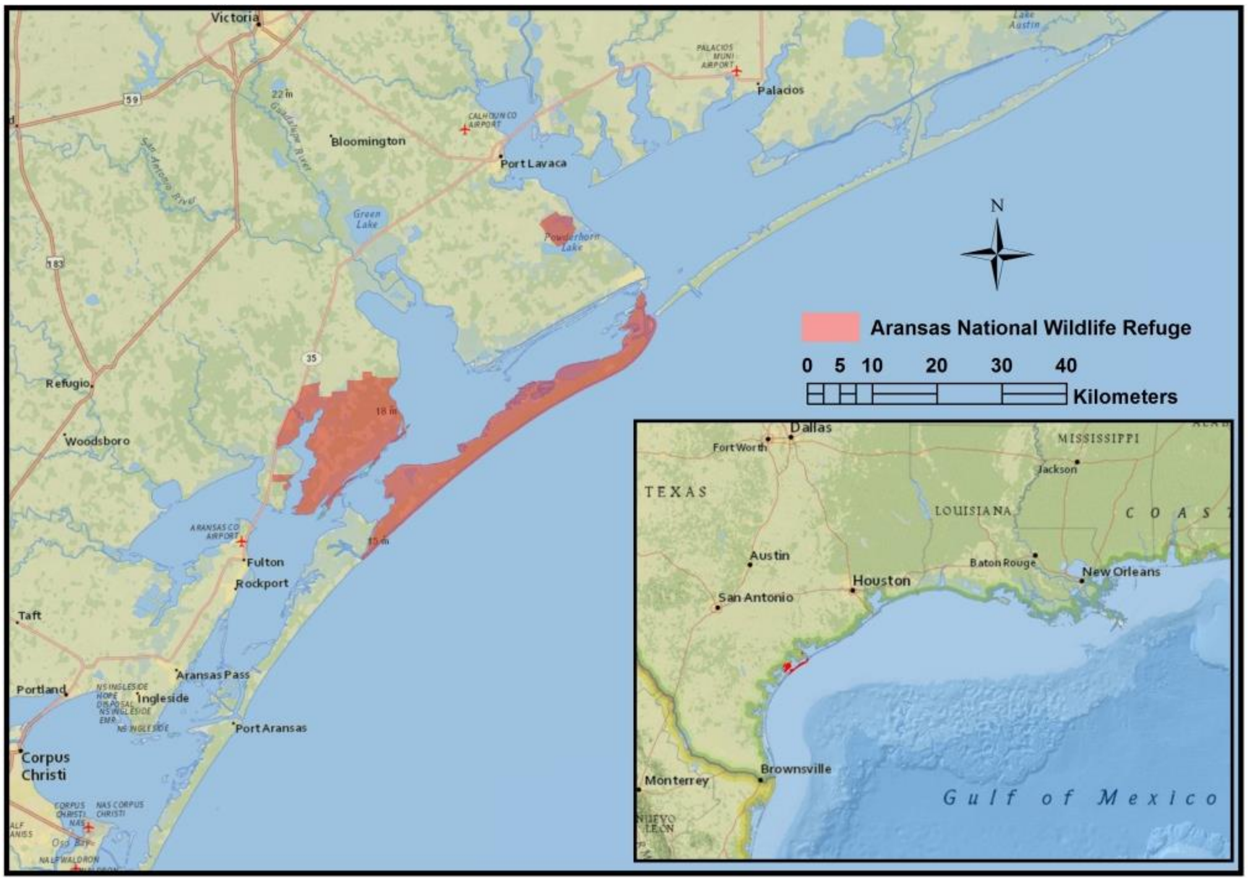

Figure 1. Aransas National Wildlife Refuge and surrounding areas typically inhabited by wintering whooping cranes; area includes portions of Aransas, Calhoun, and Refugio counties, Texas, USA.

A brief description of previously used survey methods was written by Stehn and Taylor (2008). These surveys were conducted with 1 observer and a pilot. The survey typically included San Jose Island, Matagorda Island, Blackjack Peninsula, Welder Flats-Dewberry Island, and the Lamar Peninsula-Tatton Unit (Figure 1). Flight paths of the aircraft were flown parallel to the orientation of the landscape (i.e., parallel to the coast) to increase efficiency. Subsequent flight paths were spaced approximately 250–800 m apart. Transect spacing was not planned prior to flights; it was determined subjectively by the observer in an attempt to detect all whooping cranes along the flight path given individual flight conditions (e.g., cloud cover, sun angle). The flight path of the aircraft was diverted, if necessary, to distinguish between adult versus juvenile whooping cranes. Survey duration was typically between 5–6 hours with a rest break approximately half-way through the survey during which the flight crew returned to the Aransas County Airport.

Stehn and Taylor (2008) assumed that sun angle and visibility influenced the probability of detecting a whooping crane. Therefore, the observer allocated their attention to the side of the aircraft away from the sun (Stehn and Taylor 2008). Upon detecting a whooping crane, the observer would mark the individual's location on a paper copy of a 1:46,080 Digital Orthophoto Quarter Quadrangle (DOQQ). Whooping crane groups would be demarcated on the DOQQs based upon the number of white plumaged birds and juvenile birds (e.g., "2+1" indicated 2 white birds and 1 juvenile). Each survey map was hand tallied after the completion of the survey and the total number of adults and juveniles on each map were summed and reported in publicly released flight reports.

The reported winter abundance was presumably obtained from the survey with the most individuals detected but was rarely replicated in subsequent surveys. However, the survey with the most individuals detected rarely corresponded with the winter abundance reported in the International Recovery Plan (CWS and USFWS 2007) and Aransas NWR annual reports (e.g., Stehn 2009, 2010, 2011; Figure 2). In fact, the reported abundance was ≈3.7 birds ($t = 3.754$, df $= 30$, $P < 0.001$) more than the maximum count observed during the 1980–2010 surveys. This likely occurred because birds observed outside of the survey area by the public or other parties were included in the reported abundances. Interestingly, during 1980–2010, the maximum number of individuals detected during a survey was greater than the reported abundance for 6 of the survey years (Figure 2). This inconsistency may be attributed to the observer's interpretation or perception of double counts. However, we cannot know the sources of these inconsistencies since rules governing how data from separate surveys were combined or how public reports of whooping cranes from outside of the "censused" area were incorporated was largely determined by the observer's opinion. This shows the traditional "census" was not an absolute enumeration of the population but instead a relative index of abundance.

Wintering whooping cranes are thought to demonstrate territoriality and site fidelity within and across winters (based on limited observation data from marked birds; Stehn and Johnson 1987, Stehn 1992, Bonds 2000). The fidelity of whooping cranes to their wintering territory has been used in conjunction with group structure as a surrogate for individually marked birds. Groups of equal size found in similar areas on subsequent surveys were assumed to be the same individuals. These data were used to identify circumstances where distinct groups, or individuals within groups, were not detected and therefore additional search efforts were conducted (Stehn and Taylor 2008).

Group structure and location data was also used to assist in quantifying the mortality of individuals (Stehn and Strobel 2012, Pugesek et al. 2013). For example, subsequent observations of a group of 1 adult and 1 chick where previous surveys located a group of 2 adults and 1 chick resulted in the presumption that 1 adult had died. However, the "unusual movements and behaviors of color-banded whooping cranes" observed by Stehn (1992), such as extra-territorial excursions, rapid pair formation after mate mortality, pair-bonded individuals overwintering apart, and occasional departure from the wintering grounds during the winter period, in addition to incomplete detection of individuals indicates that group structure and location data of unmarked birds from aerial surveys cannot be used to reliably imply mortality.

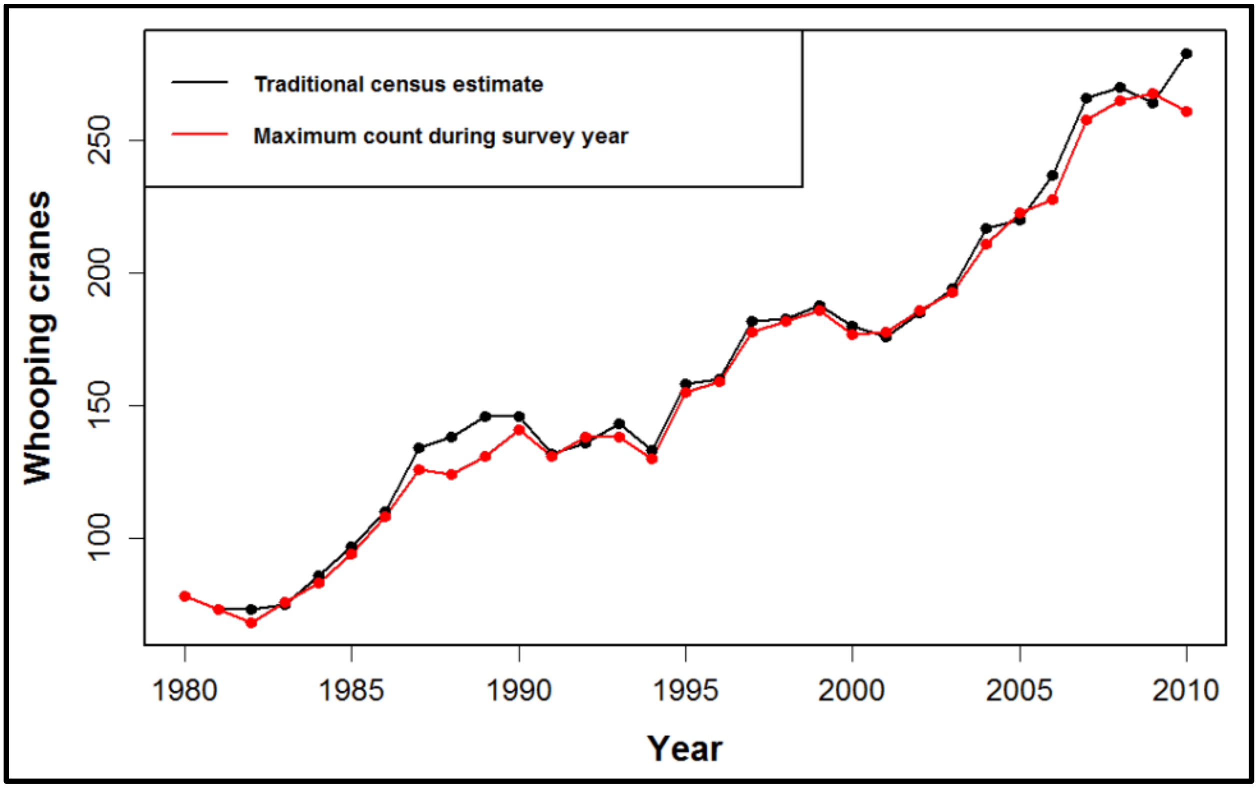

Figure 2. Comparison of the reported population size from the traditional "census" effort and the maximum count of whooping cranes observed during the traditional "census" effort during a survey year. Surveys were conducted during winter 1980–2010 on and around Aransas National Wildlife Refuge, Texas, USA.

The technique for enumerating mortalities assumed that if an individual whooping crane was not observed for 2 or more surveys, that individual was dead (Stehn and Strobel 2012). For this technique to produce consistent results, the number of surveys conducted per winter needed to be relatively constant. However, the number of surveys conducted between December 1st and March 31st of each year ranged from 4 to 21 (mean = 12.52, SD = 4.288; Butler et al. in prep). This deficiency in the technique manifested itself in an inverse relationship between winter mortality estimates and the number of surveys conducted between December 1st and March 31st (binomial regression: odds ratio = 0.932, $\hat{\beta} = -0.071$, SE = 0.028, $W = 6.595$, $P = 0.010$; Butler et al. in prep). Hence, more surveys resulted in less mortality because temporary emigrants had more chances to return and be re-observed on their territories. For example, imagine that 5 consecutive surveys were conducted and a whooping crane was missing from its territory on the third and fourth survey occasions. If the last survey had not been conducted, that whooping crane would have been considered dead.

In general, past methods were adapted to the daily weather conditions, personnel availability, and whooping crane abundance. For example, the type of plane used, area-specific search effort, altitude and flight speed during the survey all varied within and across surveys and years. These "metadata" likely influenced the results of traditional surveys but were infrequently recorded and therefore represent potential sources of bias. Although some sources of variation are uncontrollable (e.g., year effects), many controllable sources were not addressed during previous survey methodology. Identified sources of bias in the traditional "census" effort included:

- Survey logistics lacked standardization (e.g., spacing between transects varied; transect locations vary between surveys; and survey altitude and ground speed were not standardized).
- Allocation of surveying effort was inconsistent and not quantified within or across surveys (e.g., more allocation of effort searching for whooping crane groups with 2 chicks versus those with 1 chick; and more allocation of effort in consistently occupied territories versus sporadically occupied territories).
- The order in which blocks were surveyed was not random, potentially introducing systematic bias.
- Movement of individuals was recognized as occurring but was not accounted for in surveying methodology, data analysis, or reporting. Therefore, reported winter abundance could represent double counted individuals or leave out undetected individuals.
- The observer assumed ability to uniquely identify unmarked individual whooping cranes.
- The suitability of using group structure and territory location as a surrogate for individually marked birds to measure mortality rates has not been tested and is likely untenable. Mortality estimates are better derived from radio- or GPS-telemetry based monitoring of a sample of the population.
- Group size was likely positively related to the probability of detection (Buckland et al. 2001, Butler et al. 2007, Marques et al. 2007, Pearse et al. 2008, Strobel and Butler 2014) but was not accounted for. In fact, more effort was applied to locating larger groups (i.e., groups with 2 chicks) instead of smaller groups which are likely more difficult to detect.
- Transect width was not fixed which allows transect-specific detections rates to vary since detection probability declines with distance.
- Other potential sources of detection bias included: drab coloration of juveniles may reduce the probability of detecting them, and weather and light conditions may influence the probability of detection.

Many technological and statistical advances have resulted in improvements in data collection and analysis techniques that were not readily available when aerial surveys began in the 1950s. However, many of these advances have been available for decades (e.g., Burnham et al. 1980). Further, objectives of the whooping crane monitoring program have not been clearly articulated and the traditional survey protocol lacks detailed documentation and standardization which limits the repeatability of future efforts and weakens inferences drawn from the data. Therefore, a robust alternative method that does not assume complete enumeration of individuals and quantifies precision is needed. This protocol provides a technique that accounts for incomplete detection and quantifies precision by employing line transect-based distance sampling and hierarchical modeling. Below we outline the objectives of this monitoring program and provide rigorous techniques for meeting those objectives.

Objectives

Management Objectives (in priority order):

1. The International Recovery Plan for whooping cranes identified criteria for downlisting based on population abundance and number of breeding pairs (CWS and USFWS 2007). The primary objective of this protocol is to provide a robust means to quantify those metrics for downlisting.

2. Create spatially-explicit resource selection models to facilitate land conservation for whooping cranes including the delineation of important habitat and the prioritization of land protection.

Sampling Objectives (in priority order):

1. Provide an estimate of whooping crane abundance within the surveyed area (see Element 3, Sampling frame) with enough precision to detect a 10–15% annual population decline over a 3- to 4-year period (see justification provided in Butler et al. 2013).

2. Estimate the number of paired whooping cranes (i.e., 2 white-plumaged birds) and recruitive pairs (i.e., a pair with at least 1 hatch-year [HY] bird) in the wintering population within the surveyed area. This information provides an index for the number of paired birds that successfully recruited juvenile birds into the winter population.

3. Estimate annual recruitment rate of hatch-year (HY) whooping cranes into the population wintering within the surveyed area.

4. Create a spatially-explicit resource use model to predict abundance of whooping cranes in relation to local characteristics (e.g., vegetation type, patch configuration, water quality, food availability, etc.) for use in conservation planning efforts.

5. Monitor expansion of the whooping crane population onto "new" areas by identifying and systematically searching areas of known or potential population expansion.

Justification of objectives

Monitoring abundance is important for determining if a population has achieved downlisting criteria and assessing the status of populations (Chadès et al. 2008, Lyons et al. 2008, Reynolds et al. 2011, Nicol and Chadès 2012). Monitoring also provides a tool to measure recovery and bolster conservation efforts by providing data that can be used to inform decisions affecting whooping crane conservation and management. However, no technique can provide abundance metrics without uncertainty in the estimates (Williams et al. 2001). The traditional "census" technique provided estimates without measures of uncertainty. However, the new technique will provide estimates of precision. Precision of abundance estimates dictates our ability to detect changes in population growth through time (Thompson et al. 1998). What magnitude of change is necessary for this survey to detect?

Butler et al. (2013) addressed this issue by simulating this population's trajectory and examining its sensitivity to periods of negative growth. They identified scenarios that would significantly reduce abundance from the current trajectory and delay reaching the downlisting goal of 400 birds by $\geq$5 years. Those scenarios were $\geq$3 consecutive years of 9.5% annual decline or $\geq$2 consecutive years of 14% annual decline (Butler et al. 2013). To estimate one growth rate, 2 years of abundance estimates are needed. Therefore, we need to be able to detecte a 9.5% annual decline over a 4-year period or a 14% annual decline over a 3-year period to discriminate the scenarios outlined in Butler et al. (2013).

However, such scenarios have only occurred once in 73 years of monitoring this population (Butler et al. 2013). This population has grown at an average of 3.9% per year since winter 1938–1939, and has exhibited a 10-year cycle in population growth (Boyce and Miller 1985, Boyce 1986, Butler et al. 2013). Therefore, a meaningful alternative to detecting the scenarios outlined in Butler et al. (2013) might be to detect a 3–5% annual decline over a 10-year period.

The International Recovery Plan for whooping cranes (CWS and USFWS 2007) identified the number of productive pairs as one metric in which downlisting decisions will be based. The International Recovery Plan defines a productive pair as "a pair that nests regularly and has fledged offspring" (USFWS and CWS 2007:xii) and distinguishes productive pairs from breeding pairs that are defined as "a pair that breeds or is intended to breed in the future" (USFWS and CWS 2007:38). Regardless of the subjective nature of such definitions, identification of productive pairs on the wintering grounds is impossible since some juveniles die on the breeding grounds or during migration. However, the number of whooping crane pairs can be estimated based on the proportion of detected groups containing crane pairs. Also, the number of pairs that recruited a juvenile (i.e., recruitive pairs) into the wintering population can be estimated based on the proportion of detected groups containing juveniles. Therefore, this protocol will provide estimates of the number of pairs and recruitive pairs to help decision makers assess whooping crane recovery.

Recruitment of juvenile whooping cranes into the winter flock will be monitored because it is an important component of population growth. In other crane populations, low annual recruitment can be a limiting factor to population growth (Drewien et al. 1995, Littlefield 2003). For whooping cranes, simple linear regression of growth rate (λ) and available vital rates reveals recruitment accounts for 49.9% of the variation in population growth and mortality during the breeding- and migratory-periods accounts for 42.2% (Butler et al. in prep). However, winter mortality only accounts for 14.4% of the variation in population growth (Butler et al. in prep). Monitoring recruitment will provide additional information that can help indicate population trends.

Spatially-explicit models of abundance allow wildlife managers and biologists to relate landscape or habitat features with whooping crane abundance. This advanced modeling technique increases our ecological understanding through descriptions of how abundance and detectability varies spatially resulting in predictive maps of abundance (Royle et al. 2004, Chandler 2011, Chandler et al. 2011, Sillet et al. 2012, Krementz et al. 2014, Timmer et al. 2014). These spatially-explicit maps of abundance are useful for conservation planning efforts such as land protection planning, policy decisions, and decision analyses.

The new technique

Strobel and Butler (2014) found detectability during the traditional survey technique was not 100%. The previous observers relied on experience and knowledge of whooping crane space-use on the wintering grounds to account for missed groups of birds over repeated surveys. However, the traditional technique provided no approach for quantifying the probability of missing whooping cranes nor did it ensure all whooping cranes were accounted for within the survey area. In fact, the survey area was not even formally defined (Strobel and Butler 2014).

Instead of attempting to physically enumerate all whooping cranes in the population, the new technique relies on methods that can estimate the number of whooping cranes missed during the survey. Modern, rigorous approaches to estimating abundance do not attempt complete enumeration because it is nearly impossible due logistical constraints (e.g., survey area too large) and/or imperfect detection (Williams et al. 2001). Techniques with rigor and validity must address partial detectability or resulting estimates will remain clouded in bias (Anderson 2001, 2003). Further, without formal definition of the sampling frame, inferential problems arise due to potential sample selection biases (Thompson et al. 1998). This protocol provides formal definition of the sampling frame and deals with imperfect detection.

Imperfect detection of individuals present in the survey area will result in inaccurate estimates of abundance unless the resulting bias is corrected (Anderson 2001, 2003). Many techniques are available to correct for imperfect detection and include mark-resight methods (e.g., White 1996, McClintock and White 2012), capture-mark-recapture methods (e.g., Williams et al. 2001, Lancia et al. 2005, White 2008), observation probability models (e.g., sightability models; Samuel et al. 1987, Bodie et al. 1995, Lancia et al. 2005), and distance sampling-based surveys (Burnham et al. 1980, Buckland et al. 2001). Techniques that are reliant upon recapture or resighting of previously marked individuals are limited when marked animals are unavailable or marks are inconspicuous. Capture-based techniques are usually reserved for the most difficult to detect and observe species (e.g., carnivores, small mammals; Lancia et al. 2005). Marked whooping cranes have existed in the population for many years (Stehn 1992). However, detecting and identifying color marks on whooping cranes from aerial surveys is a dangerous proposition requiring low level flights at low airspeeds (i.e., a landing-type approach; Stehn 2001).

Distance sampling, however, is a tractable, widespread approach used to correct for the bias that results from imperfect detection (Burnham et al. 1980, Buckland et al. 2001). Distance sampling does not rely on the capture and marking of animals and subsequent identification of those animals in successive surveys (Burnham et al. 1980, Buckland et al. 2001). The conventional distance sampling (CDS) methodology that models a detection function using the key function + series expansion or key function + multiple covariate approach (Buckland et al. 2001, Buckland et al. 2004) provides a robust framework for estimating abundance for many wildlife species. In fact, distance sampling has been used in the application of aerial survey techniques to estimate the density of many bird (e.g., Shupe et al. 1987, Johnson et al. 1989, Smith et al. 1995, Rusk et al. 2007, Ridgway 2010, McRoberts et al. 2011) and mammal species (e.g., White et al. 1989, Johnson et al. 1991, Jackmann 2002, Fewster and Pople 2008, Schmidt et al. 2012).

Recent theoretical advances (i.e., hierarchical distance sampling [HDS] models) have resulted in models that explicitly consider relationships between population density and environmental covariates while controlling for detectability resulting in spatially-explicit models of abundance (Royle et al. 2004, Chandler et al. 2011, Sillet et al. 2012). Such models are attractive because they can be used to understand ecological relationships among animal abundance and environmental conditions while accounting for imperfect detection. The conventional distance sampling models are easily implemented in Program Distance (Thomas et al. 2010) and the hierarchical distance sampling models are easily implemented in R package `unmarked` (Fiske and Chandler 2011). Below we develop and outline a protocol that exploits line transect-based distance sampling and hierarchical models of abundance for monitoring whooping cranes on their wintering grounds.

Element 2: Pilot Studies

Though distance sampling is a tractable, widespread approach used to monitor many wildlife species, efforts to test and pilot the technique were employed (see Strobel and Butler 2014). These efforts provided useful insights for developing this protocol.

Winter 2010–2011 surveys

We conducted aerial surveys of whooping cranes along the Texas gulf coast during winter 2010–2011 (Strobel and Butler 2014). Surveys were conducted with 2 observers (T. Stehn and B. Strobel; typically only 1 observer was used in the past) in a Cessna Centurion 210-RG (Cessna Aircraft Company, Wichita, KS). We followed survey protocols established by Stehn and Taylor (2008) except we recorded the aircraft's track with a global positioning system (GPS) unit and digitized the mapped whooping crane locations in a geographic information system (GIS). We measured distance from detected groups to the transect in the GIS. We used those detections and distances in a conventional distance sampling analysis to estimate encounter rates and model detection probabilities (Buckland et al. 2001, Thomas et al. 2010).

We found ≈95% of detected whooping crane groups were within 500 m of transects (Figure 3). We observed a whooping crane group encounter rate of 0.211/km (SE = 0.0199). We found the detection function was best fit with a half-normal key function which indicated detection probability of a whooping crane group within 500 m of the survey line was 0.558 (SE = 0.031). Many have believed the traditional survey techniques of Stehn and Taylor (2008) resulted in a complete census of whooping cranes overwintering on and around Aransas NWR but these results clearly show detectability was <1 (note, these analyses were based on data obtained during the traditional census conducted during winter 2010–2011).

Decoy experiment

Several methods exist for determining how results from aerial surveys for wildlife are affected by their detectability (Pollock and Kendall 1987, Green et al. 2006, Conroy et al. 2008). These methods include double sampling, comparison to ground based counts, use of a marked subpopulation, and comparison to locations of known individuals. Alternatively, Smith et al. (1995) used waterfowl decoys as a surrogate to better understand how survey platform, habitat type, and group size influenced detection of waterfowl during aerial surveys. Similarly, Pearse et al. (2007) used decoys to quantify the detection biases associated with group size and habitat type for wintering waterfowl in Mississippi, USA. Howlin et al. (2008) used decoys to develop a predictive model of detection probability for whooping cranes in the central Platte River valley, Nebraska, USA. Decoys have been used to quantify the detection biases for wild turkeys (*Meleagris gallopavo*) as well (Butler et al. 2007). We used sandhill crane (*Grus canidensis*) decoys painted to resemble whooping cranes as surrogates (Figure 4; Howlin et al. 2008) to examine the impact of observer experience, sun position, distance from transect, and group size on the detection of whooping cranes. The experiment was conducted during September 2011 prior to the arrival of whooping cranes to eliminate potential confusion with live birds (Strobel and Butler 2014). This experimental test provided valuable information for survey design and implementation; we reference this material throughout the protocol and summarize results here.

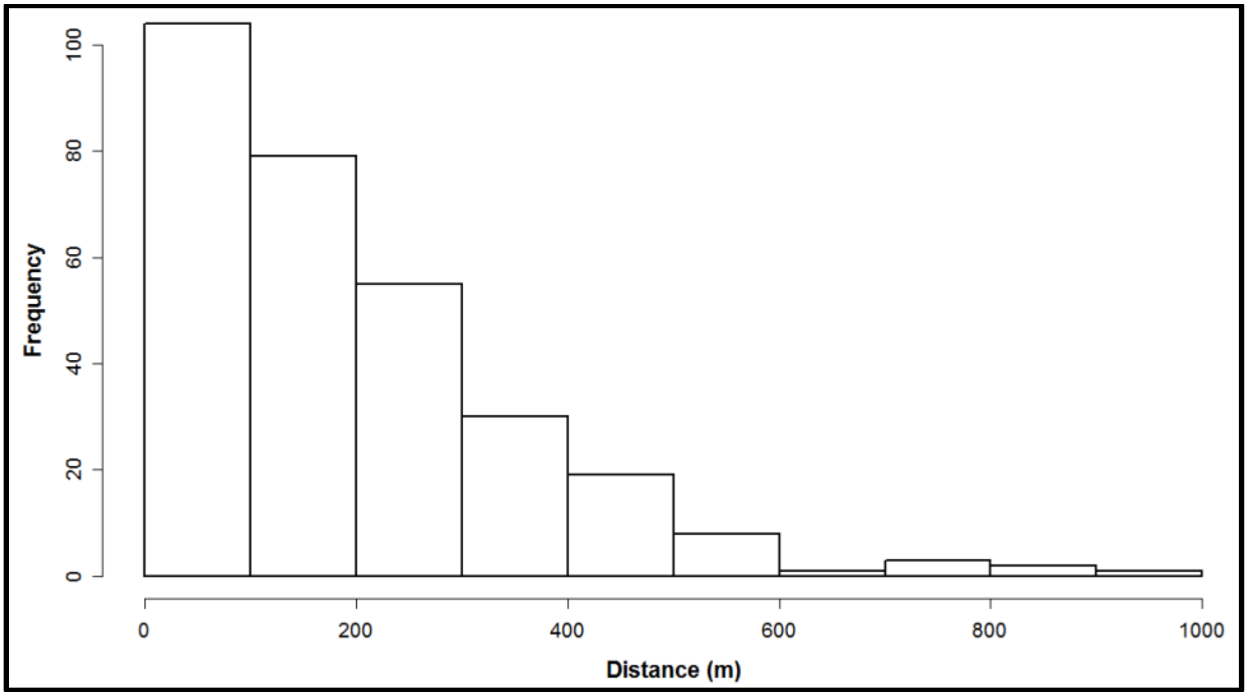

Figure 3. Histogram of distances from transect to whooping crane groups observed during aerial surveys along the Texas gulf coast, USA, during the traditional census flights, winter 2010–2011.

The experimental decoy surveys were conducted from an amphibious Kodiak (Quest Aircraft Company, Sandpoint, ID) fixed-wing airplane with 2 observers. We conducted 4 surveys of decoys with an average of 104 decoy groups within 500 m of transects. Results from the experimental decoy survey indicated decoy detectability increased with group size and exhibited a quadratic relationship with distance likely due to the pontoons on the aircraft. We found detectability was 2.704 times greater (Wald statistic [*W*] = 6.812, df = 1, $P = 0.009$) when the sun was overhead and 3.912 times greater ($W = 7.696$, df = 1, $P = 0.006$) when the sun was at the observer's back than when it was in the observer's eyes. Though observer experience did not seem to influence detection probability, we found the inexperienced observer misclassified non-target objects more often than the experienced observer ($\chi^2 = 8.543$, df = 1, $P = 0.004$). During the decoy surveys we used marks on the struts (e.g., Caughley et al. 1976, Guenzel 1997, Butler et al. 2007) to categorize distances into intervals but we found observers misclassified distances 46.7% of the time (95% CI = 37.0–56.6%). We accurately estimated decoy group size 86.9% of the time ($n = 107$; 95% CI = 79.0–92.7%). In 14 instances, decoy group size was underestimated and during 8 of those instances, group size was only underestimated by 1 individual. Also, we found detectability of individuals within detected groups was effected by group size (odds ratio = 0.200; $W = 11.573$, df = 1, $P < 0.001$) and distance from transect (odds ratio = 0.996; $W = 7.726$, df = 1, $P = 0.005$). Specifically, the number of decoys within a detected group was underestimated as group size increased and distance increased.

Figure 4. Sandhill crane decoys (Carry-Lite Decoys, Alabaster, Alabama, USA) were painted to resemble whooping cranes. Some decoys were painted white to resemble adults and some were painted tawny to represent hatch-year birds. Though sandhill cranes are smaller than whooping cranes, their body form is similar resulting in good surrogates for examining factors that influence the detection process.

Lessons learned from pilot studies

Though results from the pilot studies were not particularly surprising, they provided useful insights for improving whooping crane monitoring efforts.

1. The angle of the sun significantly affected detection of whooping crane decoys in our pilot study. Though Stehn and Taylor (2008) also noted that sun angle affected detection of whooping cranes, the traditional census was conducted during the morning and afternoon with a break for lunch. Therefore, much of the survey effort was accomplished when the sun was at lower angles resulting in high detectability on one side of the aircraft but low detectability on the other. We recommend using two observers (instead of just 1) and conducting flights during midday to take advantage of the consistent and relatively high detectability on both sides of the aircraft which would allow for more efficient search effort and transect spacing.
2. Our results emphasized that observer training was important in reducing misidentification of non-targets; some experience could be gained as a non-observer in the fourth seat of the aircraft.
3. Although apparently useful in other aerial surveys (potentially with larger distance intervals, higher altitude, and less turbulence), sighting marks placed upon the aircraft's struts did not provide accurate measurements of distances (e.g., Caughley et al. 1976,

Guenzel 1997, Butler et al. 2007). Other techniques such as marking the location of detected groups with a GPS, the use of an inclinometer, or marking locations on a heads-up display GIS would improve distance measurements (Buckland et al. 2001, Marques et al. 2006).

4. We recommend avoiding the use of aircraft with pontoons or high instrument panels to maintain complete detection on the transect line. If such aircraft cannot be avoided, other distance sampling-based techniques such as a double-observer approach could be employed to estimate detection probability at the line (Laake and Borchers 2004).
5. Buckland et al. (2001) showed the use of regression of detection probability against group size to adjust expected group size will correct for both size-biased detection and underestimation of group size assuming that group sizes are estimated accurately on or near the transect. The group size of all detections within 100 m of the transect were correctly counted during the decoy experiment. However, observers should attempt to count group size as accurately as possible.
6. The traditional technique provided no measure of precision which facilitated the presumption that it resulted in an absolute enumeration without error (i.e., a perception that there was little or no uncertainty in the estimates). New techniques such as line transect-based distance sampling, however, will account for imperfect detectability and allow for a statistically rigorous estimate of whooping crane abundance. Our pilot studies show that distance sampling would be an appropriate technique for estimating whooping crane abundance.

Element 3: Sampling Design

Sampling design

This protocol is primarily designed to provide a mechanism for monitoring trends in whooping crane abundance on their wintering grounds along the Texas gulf coast, USA. Secondarily, the protocol provides mechanisms for monitoring recruitment rates, the number of whooping crane pairs that recruited young into the winter flock, and whooping crane winter range expansion. Finally, this protocol is designed to augment planning and conservation efforts with information about the relationships among local abundance and habitat characteristics.

Target universe

The biological population in which inference is intended is the entire Aransas-Wood Buffalo whooping crane flock that overwinters in the central flyway. However, the extent of the winter range (i.e., much of the Texas gulf coast, north into Kansas and even Nebraska; Wright et al. 2014) and the extremely low density throughout much of the range, places extraordinary logistic constraints on monitoring the entire Aransas-Wood Buffalo flock. Therefore, we focus monitoring efforts on the areas occupied consistently on and around Aransas NWR. Additional effort will be conducted in other nearby areas where primary winter range expansion is expected.

Sampling frame

Whooping cranes are thought to exhibit high fidelity toward territories on their wintering grounds (Stehn and Johnson 1987, Stehn 1992, Bonds 2000). In 1950, when the traditional aerial "census" efforts for whooping cranes began, most known territories were located on the Blackjack Peninsula with a few on Matagorda Island (Stehn and Johnson 1987). During the traditional "census" effort, a sampling frame was not strictly defined and the spatial extent of the search effort used for each "census" was not recorded. However, the effort of "census" flights was allocated to areas where whooping cranes were either observed previously or where they were fortuitously observed by refuge staff or the public (Figure 5).

Since 1950, whooping cranes have recolonized several adjacent areas (Stehn and Johnson 1987, Stehn and Prieto 2010). Although no formal mechanism existed for expanding the "censused" area in recent years, flights were typically conducted over portions of the Blackjack Peninsula, Lamar Peninsula, Matagorda Island, San Jose Island, and Welder Flats-Dewberry Island (Figure 5). The boundaries of these areas are the basis for formally defining the sampling frame for this protocol.

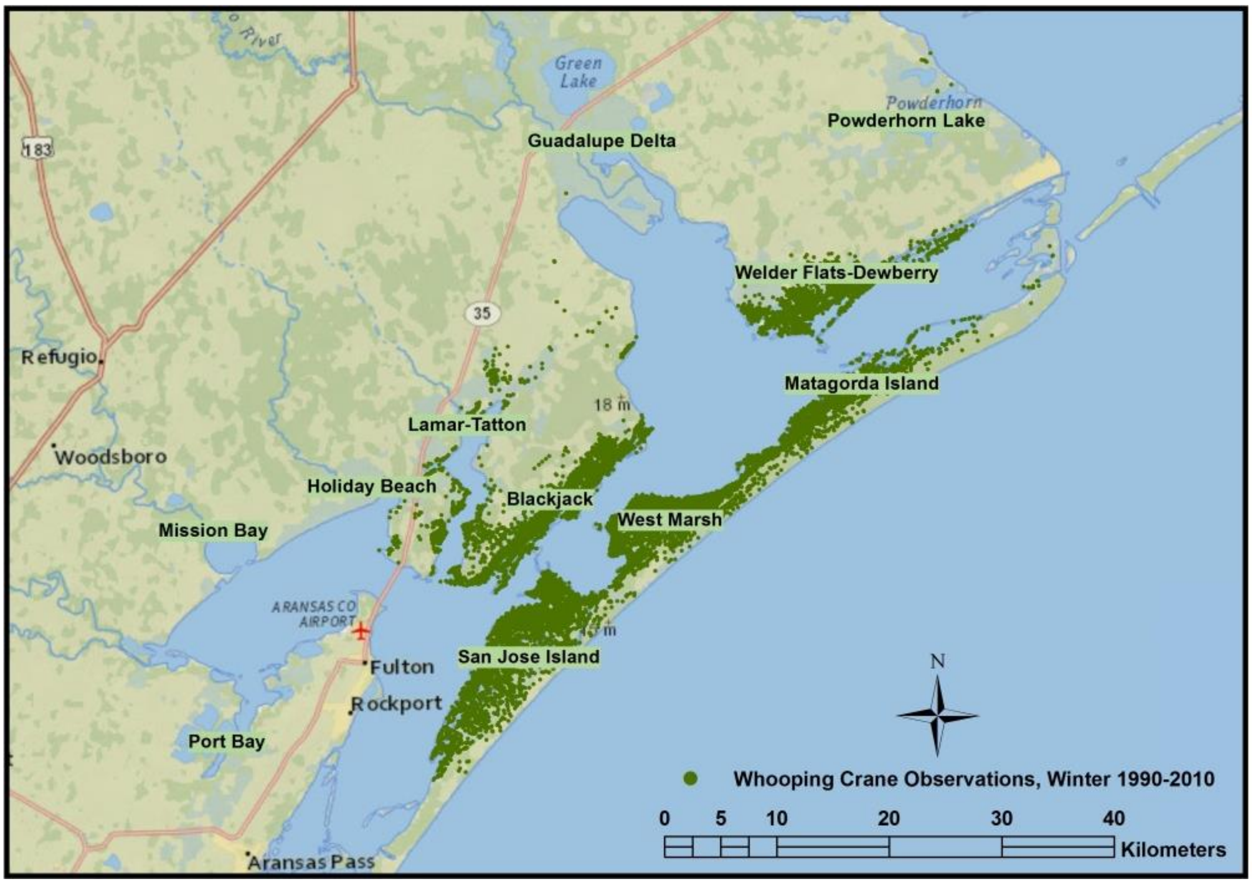

Figure 5. Locations where whooping cranes have been observed during the traditional surveys on and around Aransas National Wildlife Refuge, Texas, USA, winter 1990–2010.

The sampling frame is divided into two strata: Primary Sampling Frame (PSF) and Secondary Sampling Frame (SSF; Figure 6). Each strata includes several "regions." Regions within the PSF were designated as such because recent data indicate they are occupied consistently by multiple groups of whooping cranes each winter (Figure 5). Regions within the SSF are not currently used consistently by whooping cranes but have either been occupied recently or have apparently suitable whooping crane habitat and may become occupied consistently as whooping crane populations increase (Figure 5). Our estimates of annual abundance will only apply to the primary sampling frame, not the entire Aransas-Wood Buffalo whooping crane flock. Absence of information in areas not surveyed should not be construed to imply the absence of whooping cranes.

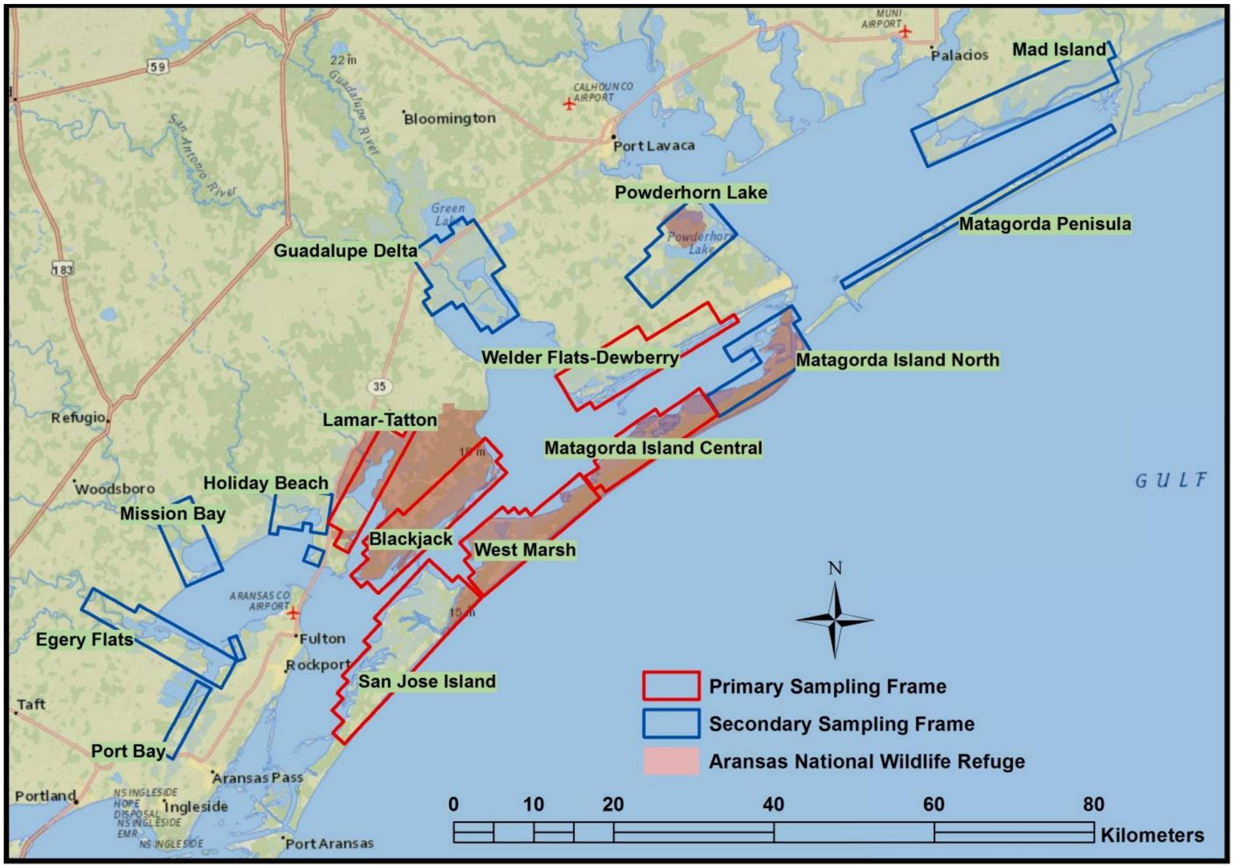

Figure 6. The sampling frame for monitoring whooping crane on their wintering grounds along the Texas gulf coast, USA. These were not formally defined during the traditional "census" effort.

The Primary Sampling Frame contains 6 regions totaling 62,300 ha (Table 1; Figure 6). The Secondary Sampling Frame contains 9 regions totaling 62,000 ha (Table 1; Figure 6). Below we describe how SSF regions will eventually be included in the PSF (see Element 3–Sampling frame, Sampling Objective 5).

The sampling objectives of this protocol (see Element 1–Objectives) are to 1) provide an estimate of winter whooping abundance; 2) index the number of whooping crane pairs that successfully recruited juveniles into the winter population; 3) estimate the age-ratio of wintering whooping cranes; 4) create spatially-explicit models of wintering whooping crane abundance; and 5) monitor whooping crane winter range expansion.

Sampling Objective 1:
Estimates of winter abundance for whooping cranes will only be based on surveys conducted in the PSF where the historic data indicated abundance of the population is consistently highest and

the traditional "census" effort was conducted. We provide criteria below for adding regions from the SSF to the PSF as the population grows and the wintering grounds expand (see Element 3–Sampling frame, Sampling Objective 5).

Table 1. The number of transects and survey effort (i.e., total transect length) for the regions within the Primary and Secondary Sampling Frames.

Region	Acronym	Area (ha)	No. transects	Total length (km)
Primary Sampling Frame				
Blackjack Peninsula	BJ	11,900	6	119
Lamar Peninsula-Tatton Unit	LT	6,400	4	64
Matagorda Island, Central	MIC	7,500	5	75
Matagorda Island, West Marsh	WM	10,000	7	100
San Jose Island	SJ	15,700	8	157
Welder Flats-Dewberry Island	WF	10,800	6	108
Total		62,300	36	623
Secondary Sampling Frame				
Egery Flats	EF	7,700	5	77
Guadalupe Delta	GD	10,400	11	104
Holiday Beach	HB	3,900	7	39
Mad Island	MAD	13,200	5	132
Matagorda Island, North	MIN	7,300	7	73
Matagorda Peninsula	MP	3,900	1	39
Mission Bay	MB	5,000	5	50
Port Bay	PB	2,000	2	20
Powderhorn Lake	PL	8,600	7	86
Total		62,000	50	620

Sampling Objectives 2–4:
The data required to meet these sampling objectives will be obtained using the PSF.

Sampling Objective 5:
Previously collected data indicated that whooping cranes have sporadically used several areas outside of the PSF. The SSF will be used to monitor expansion of the whooping crane wintering grounds. We determined a minimum number of whooping cranes groups that must be detected in a SSF region, before that SSF region will be included in the PSF for future surveys. The minimum number of groups (G) for SSF region i was determined based on the following formula:

$$G_i = \text{floor}(D \cdot A_i \cdot p)$$

where D was the minimum PSF region-specific density of whooping crane groups estimated during the winter 2013–2014 surveys (≈0.1 groups/km^2), A_i was the area of SSF region i, and p was the average detection probability during the 2013 surveys (0.7 detection probability within 500 m of transect). We rounded each G_i down to the nearest integer. The estimated threshold

(G_i) of groups for a SSF region must be detected $\geq$2 times within a survey year before that SSF region will be promoted into the PSF for future surveys (beginning the next year). The minimum number of whooping crane groups needed to promote a SSF region into a PSF region varied from 1 to 9 (Table 2).

Table 2. The minimum number of whooping cranes groups that must be detected in a secondary region before that secondary region will be included in the primary sampling frame for future surveys.

Secondary Sampling Frame	No. Needed	Secondary Sampling Frame	No. Needed
Egery Flats	5	Matagorda Peninsula	2
Guadalupe Delta	7	Mission Bay	3
Holiday Beach	2	Port Bay	1
Mad Island	9	Powderhorn Lake	6
Matagorda Island, North	5		

As SSF regions are promoted into the PSF as the population expands, additional areas will need to be added to the SSF. Because the Aransas-Wood Buffalo population is growing at ≈4% per year, we will address how to add more SSF regions when this monitoring plan is due for revision. For example, the spatially-explicit models of habitat use could be used to predict areas composed of the best potential habitat. Ancillary information gained from internal and external sources (e.g., fortuitous public or staff observations; Texas Whooper Watch) could potentially be used to identify new SSF regions as well.

Sampling units

The sampling units for this design can be considered in a hierarchical or nested sense (Figure 7). The regions in the PSF are the primary sampling units. Within each region, transects provide complete coverage of the region and are systematically spaced 1,000 m apart (e.g., fixed-width transects). We established 623 km of transects in the PSF and 620 km in the SSF (Table 1, Figure 8). Each transect is split into 1-km^2 segments where landscape conditions are characterized (Element 4–Environmental covariates). Within the transect segments, whooping crane groups are detected and each group is composed of 1 or more whooping cranes. Groups of whooping cranes are primarily 1, 2, 3, or 4 individuals (usually a family group) and the occasional larger group of subadults.

During a survey, the observers record attributes about whooping crane groups (i.e., group size, composition, and location coordinates). After a survey, vegetative or environmental characteristics of each 1-km^2 segments are characterized from remotely sensed data or other sampling efforts. The 1-km^2 transect segments are the sampling units for modeling relationships between local abundance and environmental characteristics, whooping crane groups are the sampling unit for the detection function (i.e., clusters; Buckland et al. 2001), and individual whooping cranes are the sampling unit for estimation of age-ratios.

Sample selection

Currently, all regions within the PSF and all transects within a PSF region will be sampled. However, as more regions are added to the PSF as the whooping crane wintering grounds expand, complete sampling will likely become infeasible. Eventually logistic constrains will dictate random sampling of regions, transects within regions, or a combination of both. This issue will be addressed when this monitoring plan is due for revision.

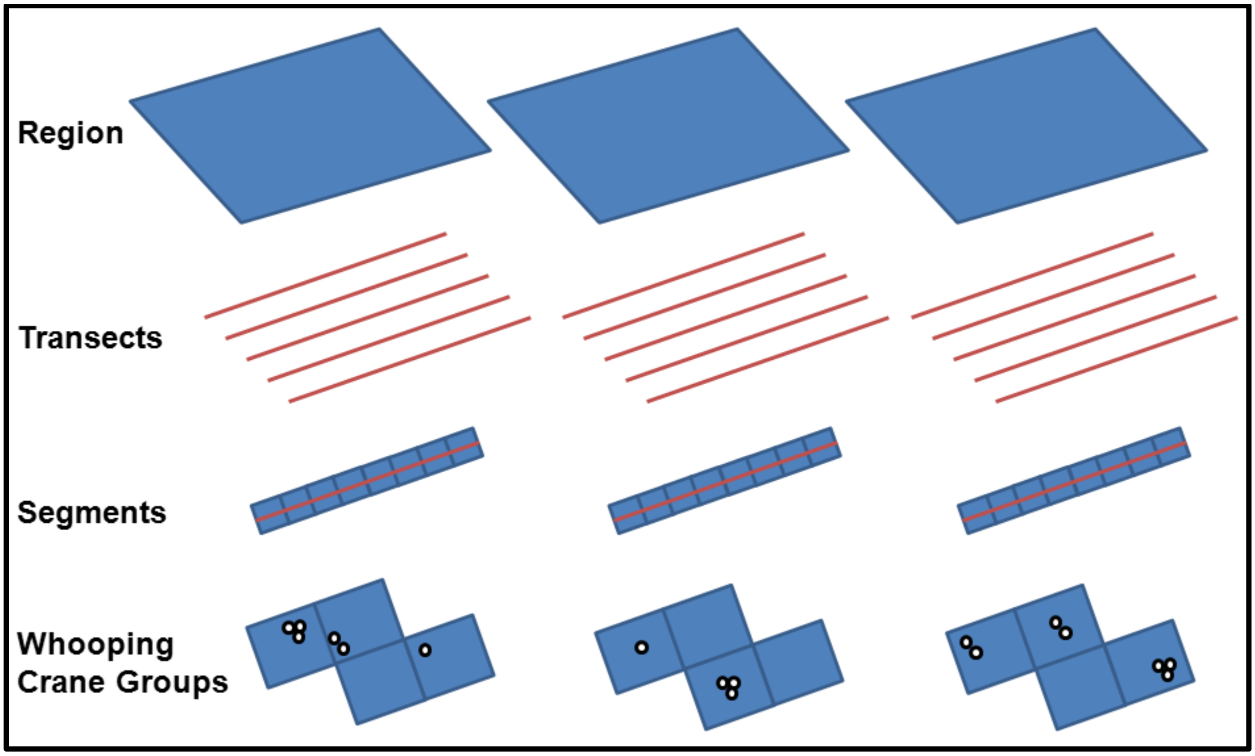

Figure 7. The sampling design for whooping crane surveys on their wintering grounds has nested sampling units.

Transect spacing

The precision of abundance estimates obtained from conventional distance sampling (CDS) or hierarchical distance sampling (HDS) analyses is related to the number of whooping crane groups detected and how those groups are distributed across the sampling frame. Analyses of data collected during winter 2010–2011 indicate ≈95% of whooping cranes were detected within 500 m of transects (Figure 2). Therefore, transects were established using 1-km spacing (Figure 8). Although the current method is not intended to provide a "census" of the population within the sampling frame, transects have been established at a density to provide a uniformly high search effort within each region while balancing the logistic constraints that can result from closer spacing. Transects are identified with region-specific acronyms (i.e., BJ, SJ, WM, etc.; Table 1) and sequentially numbered from the mainland toward the Gulf of Mexico.

Survey timing

Presumably the Aransas-Wood Buffalo Population of whooping cranes reaches its annual maximum at the conclusion of the year's nesting season. However, due to the isolation of Wood Buffalo National Park and the low density at which whooping cranes nest, large-scale survey efforts at Wood Buffalo are not feasible at this time. The high density of whooping cranes on and around Aransas NWR during winter facilitates large-scale survey efforts. Therefore, it is likely the most efficient opportunity to index the population size of the flock is shortly after their arrival on the wintering grounds but prior to winter mortalities. Historical data indicated that this typically occurs at the end of November through the end of December (Figure 9). Therefore, the annual winter whooping crane abundance estimate will be based on data collected during the time period between 28 November and 26 December. We chose a month-long period to facilitate survey logistics (i.e., inclement weather and aircraft availability). Multiple surveys will be conducted during this period (see Element 3–Survey repetition and sample size); we will attempt to conduct those surveys within a 2-week window to minimize changes in whooping crane resource use, dispersal from the PSF, and losses from winter mortality.

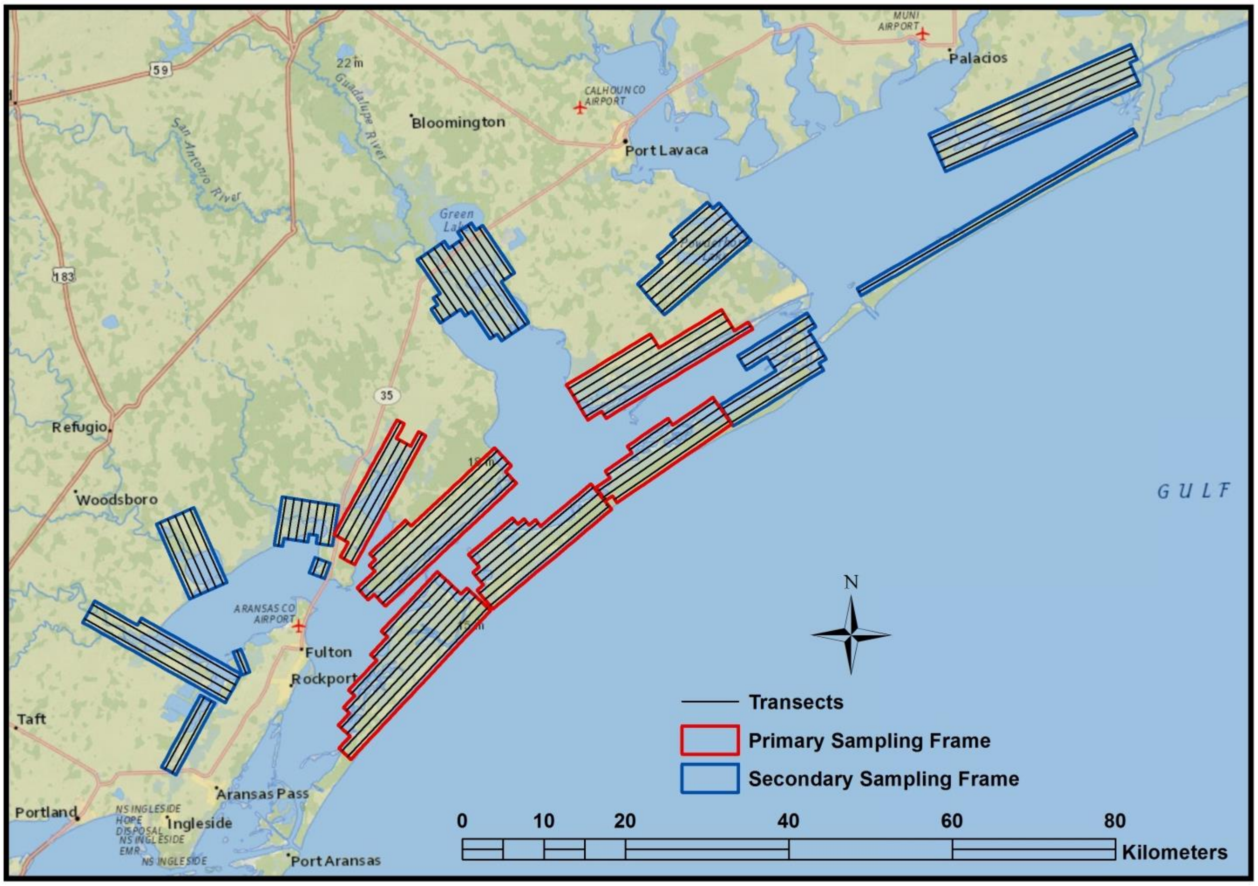

Figure 8. The sampling frame and survey transects for monitoring whooping cranes on their wintering grounds along the Texas gulf coast, USA. Transects are spaced at 1-km intervals.

Additional surveys can be conducted during the months of January, February, and March to document temporal changes in resource use. Surveys conducted during these other periods will be conducted within a 2-week window during each period. Surveys conducted during these other periods are optional and should only be conducted if clear, resource management objectives are identified.

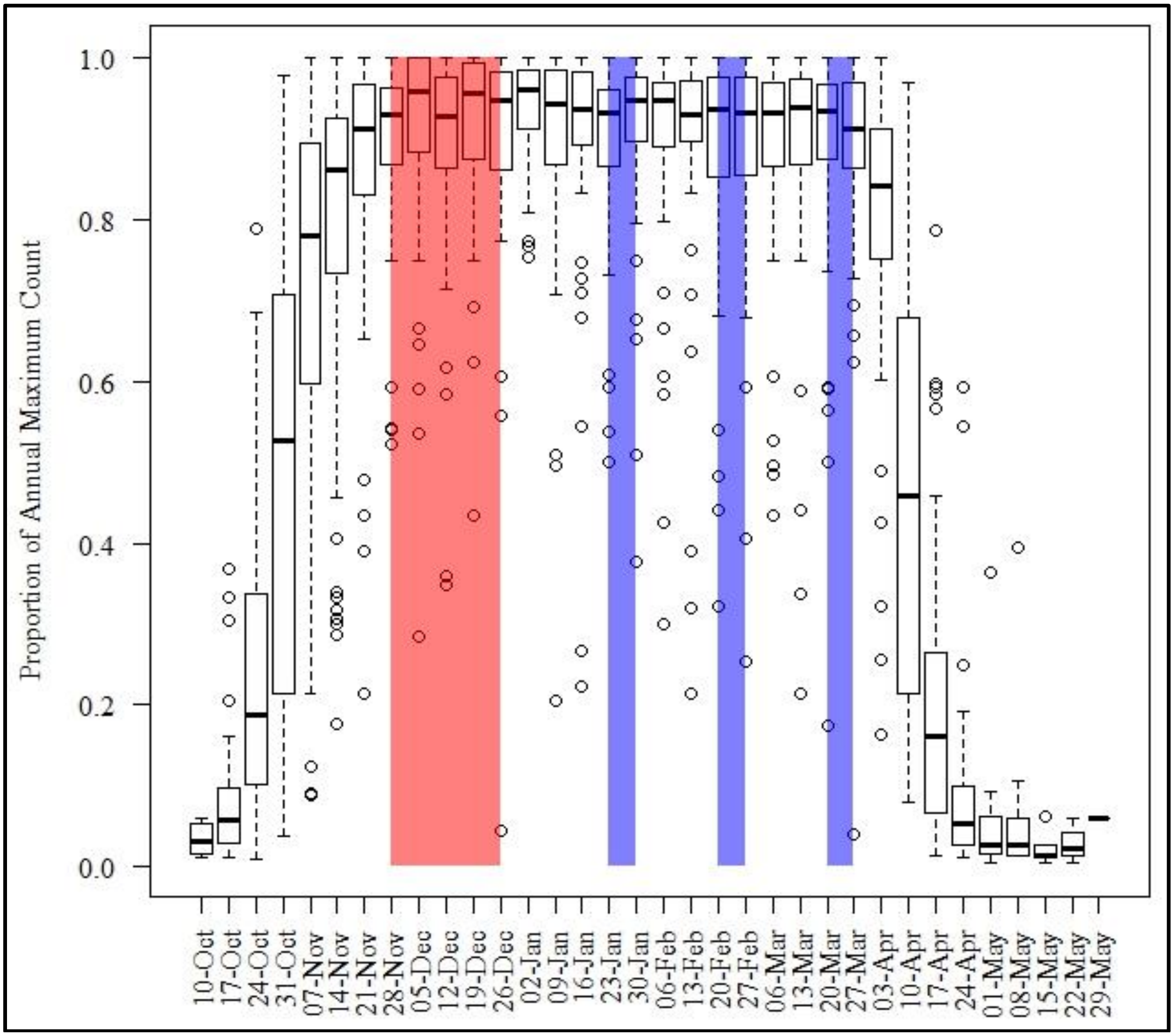

Figure 9. Box plots describing chronology of whooping crane arrival and departure on the Texas gulf coast, USA. Data from periodic aerial surveys, centered on Aransas National Wildlife Refuge, conducted during the winters of 1950–2011. Solid black lines represent the median proportion of the annual maximum count by date. Boxes contain the 0.25 and 0.75 quantiles of data, while the lines span the entire dataset except outliers (black circles). The red box represents the time of year during which effort will be exerted to estimate the whooping crane abundance, age-ratios, and number of recruitive pairs in the primary sampling frame (Sampling Objectives 1–3). Blue boxes represent times in which additional survey effort could be exerted for other monitoring objectives.

Sampling Objective 1:

To estimate whooping crane abundance within the sampling frame, surveys will be conducted between 28 November and 26 December annually (Figure 9). Surveys will be limited to a 2-week window to maximize population closure.

Sampling Objectives 2–3:
Winter mortality or dispersal from the wintering grounds will occur as the winter months progress and could bias estimates of the number of recruitive pairs and recruitment rates. Therefore, those estimates will be based on the surveys conducted during the same time period as sampling objective 1 (i.e., 28 November–26 December).

Sampling Objective 4:
Spatially-explicit models of abundance will be developed for the 28 November–26 December survey period. Optionally, spatially-explicit models of abundance may be developed from data collected during other time periods (e.g., January, February, and March) if additional resource management objectives are identified and justified.

Sampling Objective 5:
All 6 regions of the SSF will be surveyed at least twice during the 28 November–26 December survey period. This can be accomplished by sampling 3 of the SSF regions each time the PSF is surveyed (see Element 3–Survey repetition and sample size) or by devoting 2 days to conducting surveys of the SSF. Optionally, SSF regions can be surveyed during the other survey periods if additional resource management objectives warrant such effort.

Survey repetition and sample size
Sampling Objectives 1, 2, and 4:
Multiple conditions influence the precision obtained from a given survey using CDS or HDS analysis techniques, therefore a precise definition of the sample size required to meet this sampling objective is not possible. However, a power analysis suggested that detection of an average annual decline of 10% over a 4-year period will require a coefficient of variation ($\mathrm{CV}(N)$) of 0.09 and a 15% decline over a 3-year period will require a $\mathrm{CV}(N)$ of 0.06 (Appendix A). Analyses based on data collected during winter 2011–2012 indicated that 5–6 surveys will be required to obtain a $\mathrm{CV}(N) \leq$ 10% (Appendix A). Therefore, at least 6 complete surveys of the PSF (all transects within the PSF) will be conducted each year between 28 November–26 December. These surveys will be limited to a 2-week window during this period to minimize changes in whooping crane resource use, dispersal from the PSF, or mortality (i.e., maximize population closure).

As an alternative, a $\mathrm{CV}(N) \leq$ 20% (Appendix A) would be required to detect a 3–5% annual decline over a 10-year period. This precision would require only 1–3 surveys per year (Appendix A).

Sampling Objective 3:
Recruitment of hatch-year (HY) whooping cranes into the wintering population will be indexed as the observed ratio of HY to after-hatch-year (AHY) birds obtained from survey flights conducted during 28 November–26 December. Since multiple surveys will be conducted for estimating abundance on the wintering grounds, the most appropriate estimator of HY:AHY ratio is the multiple samples with replacement ratio estimator where each survey represents a sample (Skalski et al. 2005; Appendix B). Analyses of previously collected data suggested variance of estimated HY:AHY age-ratios is low in most cases (Figure 10). In most years, $\geq$3 surveys were conducted between 28 November–26 December resulting in tight confidence intervals (Figure

10). This will allow adequate power to meet sampling objective 3 prior to having adequate power to meet sampling objective 1. Therefore, specific sample size required to meet sampling objective 3 was not determined.

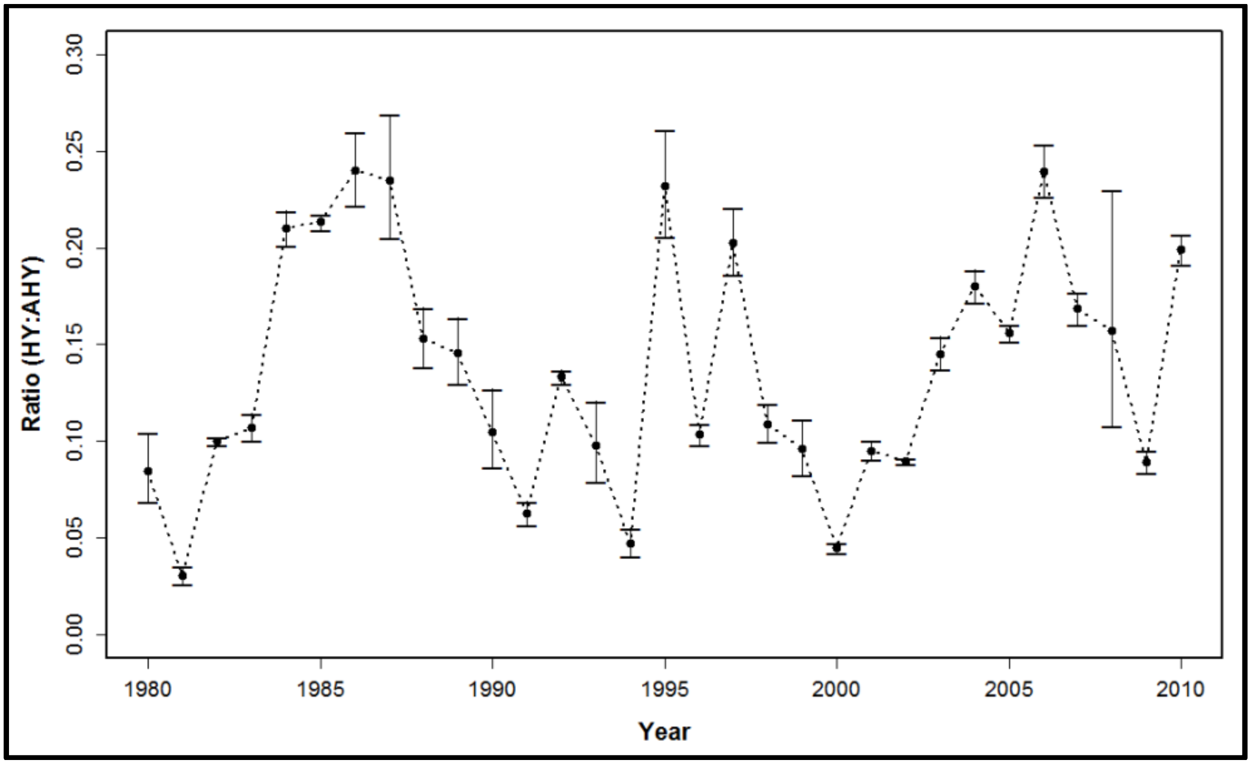

Figure 10. Ratio and 95% confidence intervals of hatch-year (HY) to after-hatch-year (AHY) whooping cranes observed during the traditional "census" effort from 1980–2010 on and around Aransas National Wildlife Refuge, Texas, USA. We only used data from surveys conducted between 28 November–26 December. The estimates were based on multiple samples with replacement ratio estimator where each survey represented a sample (Skalski et al. 2005). During winter 2008–2009, only one survey was conducted between 28 November–26 December, so we used an estimator based on a single sample survey (Skalski et al. 2005).

Sampling Objective 5:
The regions within the SSF will be surveyed $\geq$2 times (2 complete surveys of all transects in the SSF) between 28 November–26 December, to monitor expansion of the whooping crane wintering grounds. Once the predetermined number (see Element 3–Sampling frame–Sampling Objective 5; Table 2) of whooping crane groups are detected $\geq$2 times in a SSF region, that SSF region will be included in the PSF for future surveys (beginning the next year).

Monitoring frequency
The USFWS has monitored whooping crane abundance for over 7 decades, providing data to model and predict population trajectories and evaluate management triggers. Maintaining continuity in this dataset remains important for understanding how this population changes over time. However, this whooping crane population is ≈12 years (>0.8 probability by 2025) from reaching 400 individuals (downlisting criterion 1A; CWS and USFWS 2007) and abundance

estimates do not trigger most, if any management decisions (Butler et al. 2013). For example, many management activities on Aransas NWR such as prescribed burning will continue to occur regardless of whether an abundance estimate is available. This begs the question, why continue to monitor whooping crane abundance annually? Annual monitoring may be more informative when the policy decisions regarding downlisting are imminent (Chadès et al. 2008, Lyons et al. 2008, Reynolds et al. 2011, Nicol and Chadès 2012). Perhaps a biennial-interval would still provide enough information for policy or management decisions (Butler et al. 2013). However, meeting the public expectation of annual abundance estimates remains important. Therefore, monitoring frequency for the Aransas-Wood Buffalo flock should be discussed to ensure survey costs and effort is commensurate with data utility.

Environmental covariates

Hierarchical distance sampling results in spatially-explicit models of abundance that explicitly consider relationships between population density and environmental covariates while controlling for detectability (Royle et al. 2004, Chandler et al. 2011, Sillet et al. 2012). Currently, environmental covariates are derived from the Texas Ecological Systems Classification Project (http://www.tpwd.state.tx.us/gis/gallery/), Phase 3 (Ludeke et al. 2012; Appendix E). The percent of each 1-km^2 transect segment is determined for 6 general vegetation types: saltmarsh, open water, wetland, saltmarsh-shrubland, upland, and urban (Appendix E). Though these covariates are only rudimentary, strong relationships with whooping crane abundance has been demonstrated with some of them (Strobel et al. 2012). As managers, biologists, and policy makers begin to recognize the value and potential of spatially-explicit models of resource use and develop more detailed hypotheses about whooping resource use, specific resource maps can be tailored to answer more specific management or policy questions. Maps from which environmental covariates are derived will need to be periodically updated with the most current data.

Sources of biases

Sampling Objective 1:

Imperfect detection of whooping crane groups occupying the survey area will result in inaccurate estimates of abundance unless the resulting bias is corrected (Anderson 2001). To account for imperfect detection, perpendicular distances to detected groups will be measured during surveys. These distances will be used to model detection probabilities and adjust estimates of abundance (Buckland et al. 2001). Distances need to be measured accurately and to the center of the group. Tests of marks on struts indicated that technique performed poorly during pilot studies. Therefore, we provide a new technique of marking locations on a heads-up display GIS (see Element 4–Field Methods).

Movement of whooping crane groups in response to the aircraft prior to detection could bias estimates of abundance. Movement that is independent of the aircraft causes no problems and movement after detection is not a problem as long as the initial location can be accurately determined (Buckland et al. 2001). Movement towards the aircraft by whooping cranes would result in positive bias but evasive movements would result in abundance being biased low (Buckland et al. 2001). However, attraction to or avoidance of the aircraft by whooping cranes is not an issue. During previous surveys, we observed the immediate response of hundreds of whooping cranes groups to the aircraft. We did not observe any whooping cranes being flushed into flight or make movements of >100 meters in response to the passage of the aircraft. Further, initial locations of whooping crane were easily established. When visibility allowed the detection of groups from the next transect, groups were often detected in the same location, suggesting movement away from the aircraft was not substantial.

Size-biased detection (i.e., larger groups have greater detection probability than smaller groups) and underestimation of group size will result in inaccurate estimates of abundance unless the resulting bias is corrected. Buckland et al. (2001) shows the use of regression of detection probability against group size to adjust expected group size will correct for both sources of bias as along as group sizes are estimated accurately on or near the transect. The group size of all decoy detections within 100 m of the transect were correctly counted (see Elemet 2–Lessons learned from pilot studies).

Distance sampling assumes detection probability is 1.0 on the transect line (Buckland et al. 2001). This can be a problem for fixed-winged aircraft because it is often difficult to see directly below the aircraft (e.g., Buckland et al. 2001, Butler et al. 2007, McRoberts et al. 2011). However, despite the pontoons on the aircraft we used during the experimental decoy survey, the shortest distance to an undetected decoy group was 37 m; 5 other decoy groups had shorter distances and they were detected. When we used the Cessna Centurion 210-RG during winter 2010–2011, data indicated 100% detection on the transect line was likely (Figure 1). A low instrument panel in the survey platform allows forward observation of the transect, reducing the probability of missing groups on or near the transect. A description of the allocation of observer search effort is described below (see Element 4–Field data collection methods).

Misidentification of other white birds as whooping cranes could bias estimates of abundance (Figure 11). To minimize potential bias from misidentification, observers must have superior bird identification skills for Texas coastal waterfowl. In addition to basic bird identification training, we recommend new observers participate as a non-observer in the fourth seat of the aircraft during at least 3 surveys with experienced observers before participating as an observer. If an observer has any doubt as to the species, that detection should not be recorded.

Buckland et al. (2001) recommends orienting transects perpendicular to linear environmental features (i.e., the coastline) because they can result in density gradients. Sampling parallel to the density gradient will result in inflation of the variance of the encounter rate when using CDS. However, incorporation of environmental covariates that cause the density gradient into hierarchical models of abundance will account for the density gradient when using spatial distance sampling (Johnson et al. 2010, Hedley and Buckland 2004, Hedley et al. 2004). As Stehn and Taylor (2008) did, we chose to orient transects parallel to the coastline which greatly reduces the number of turns required which increases survey safety.

Sampling Objective 2:
The number of paired whooping cranes (i.e., 2 white-plumaged birds) must be estimated in order to estimate the number of recruitive pairs. The number of whooping crane pairs can be estimated based on the proportion of detected groups containing AHY whooping crane pairs. The number of pairs that recruited a juvenile into the wintering population can be estimated based on the proportion of detected groups containing HY birds. These proportions are easily estimated from the observed data. However, both estimates will likely be biased low due to group size-biased

detection and inability to identify some individuals to age-class resulting in biased estimates of the number of recruitive pairs in the flock. Therefore, we consider this an index of the number of recruitive pairs.

Figure 11. Multiple whooping cranes observed with species of other white birds during traditional winter surveys along the Texas gulf coast, USA. Photograph taken by T. Stehn.

Sampling Objective 3:
Skalski et al. (2005) noted several assumptions of the HY:AHY ratio estimator. Assumptions of primary concern are equal probability of detection of each age group and the survey period is short enough that both age groups have equal probability of survival during the survey period. The survey period will be limited to 2 weeks. We currently have no evidence suggesting HY and AHY birds have differential detection probabilities. Though HY birds are tawny-colored, they are rarely unassociated with AHY birds. However, group size-biased detection could skew age-ratios high but assuming any differential detection remained constant among years, the HY:AHY estimator remains a relative index of the age-ratio and juvenile recruitment into the winter flock.

Sampling Objective 4:
Spatially-explicit modeling of resource use will be based on available maps of vegetation, other whooping crane resources (i.e., salinity, blue crab abundance, etc.), or management actions (i.e., time since prescribed burn, fresh water provisioning, etc.). Currently, only rudimentary vegetation characteristics are available limiting the scope of inference possible. However, as managers, biologists, and policy makers begin to recognize the value and potential of spatially-explicit models of resource use and develop more detailed hypotheses about whooping crane resource use, specific resource maps can be tailored to answer more specific management or policy questions.

Predictions beyond the sampling frame to other areas of interest can be made. However, caution must be used in interpreting such predictions. Such predictions cannot be used to infer abundance or resource use beyond the sampling frame but they can be useful for identifying areas likely to be inhabited by whooping cranes in the future (assuming those areas do not change). For example, conservation planning efforts could use these predictions for land protection planning purposes or researchers could use them for evaluation of the potential impacts of sea level rise.

Sampling Objective 5:
Sporadic or occasional use of SSF regions by whooping cranes has little consequence on abundance estimates. However, as these SSF regions become consistently occupied, their inclusion into the PSF becomes more important. The SSF will be used to monitor expansion of the whooping crane wintering grounds. Once the predetermined number (see Element 3–Sampling frame–Sampling Objective 5; Table 2) of whooping crane groups are detected $\geq$2 times in a SSF region, that SSF region will be included in the PSF for future surveys. We chose the predetermined thresholds to reduce early inclusion of SSF regions into the PSF due to sporadic or occasional use by whooping cranes. This sampling scheme is not designed to detect occupation of "new" areas beyond the counties surrounding Aransas NWR (i.e., Aransas, Calhoun, Matagorda, Refugio, and San Patricio counties, Texas, USA) due to logistic constraints. Ancillary information gained from internal and external sources (e.g., fortuitous public or staff observations; Texas Whooper Watch) will be used to augment winter range expansion data.

Element 4: Field Methods

Logistics required before implementing each season's field survey

Data collection requires 2 observers, a Department of the Interior-Aviation Management Directorate certified plane and pilot, aviation safety plan, as well as all personal protective equipment (PPE) necessary for low-level flight. Before each survey, the aviation safety plan will be reviewed by the Lead Biologist. The Lead Biologist is responsible for initiating the flight planning and flight following procedures outlined in the aviation safety plan (Strobel 2011).

Each observer will collect data on independent laptop computers (Table 3). At a minimum, data collected will include the size of detected whooping crane groups, the spatial location of whooping cranes, the age-class of detected birds within the group (i.e., hatch-year, after-hatch-year, or unknown age-class), and the track the aircraft flew. Multiple techniques can be used to collect these data but any deviations from the equipment (Table 3) and techniques described below will be thoroughly vetted prior to its application to ensure ease of use, data integrity, and security. The use of trade, firm, or product names is for reference only and does not constitute endorsement of any nature.

Personal Protective Equipment:
The personal protective equipment needed during low-level flight is aircraft dependent but generally includes (Department of the Interior 2008):

1. Nomex flight suit or other fire-resistant clothing,
2. Nomex or leather gloves,

3. aviation helmet,
4. communication plug adapter, and
5. close-toed leather footwear.

Aviation Policy and Guidance:
Consult the following policy and guidance when planning aerial survey activities:
1. Office of Aviation Services, oas.doi.gov
2. Federal Aviation Regulations, 14 CFR Part 91, www.ecfr.gov
3. FWS Service Manual, Part 330, www.fws.gov/policy/manuals/
4. Aviation Life Support Equipment Handbook, www.iat.gov/docs/ALSE_2008.pdf
5. DOI Department Manual, Part 352, oas.doi.gov/library/dm/index.htm

Table 3. Hardware needed to conduct aerial surveys for whooping cranes on their wintering grounds along the Texas gulf coast, USA.

Equipment	Purpose
Phillips SpeechMike Pro – USB	allows mouse-type interface with CPU and records audio files.
Bluetooth GPS Receiver	allows real-time position tracking through GIS.
Panasonic Toughbook 19	displays and records spatial data via GIS.
Spare Toughbook Battery	ensures CPU runtime >5 hours.
Garmin GPS 76	provides redundant data of aircraft's flight path.
Olympus Digital Voice Recorder	records and stores audio files of observations.

Aircraft type

A Department of the Interior-Aviation Management Directorate certified plane and pilot are required. The aircraft used during whooping crane monitoring should provide observers with as much visibility as possible. A low instrument panel in the survey platform will allow forward observation of the transect, reducing the probability of missing groups on or near the transect. Further, use of aircraft with pontoons will likely reduce visibility along the line and their use will be avoided. The aircraft selected should be comfortable for the observers. We recommend using an aircraft similar to a Cessna 206.

Establish and select sampling units

Sampling Objectives 1–4:
All PSF regions will be surveyed at least 6 times between 28 November–26 December. As mentioned previously, CDS and HDS methods use the transects established within the PSF as the sampling units. These sampling units are intended to remain static across surveys and years. Therefore, sampling units are predetermined and do not require selection on an annual or survey-specific basis. To ensure each region is sampled at various times of day (i.e., to avoid systematic bias), a randomly ordered list of the regions within the PSF will be used to determine the region in which each surveys will begin with (i.e., the first survey will begin with the first region on the list, the second survey will begin with the second region on the list, etc.). Simple R code (R Development Core Team 2012) can be used to create this list (e.g., `sample(c("BJ","LT","MIC","WM","SJ","WF"))`). After the randomly selected starting region, all regions will be surveyed in a clockwise fashion. On a given survey flight, all transects within each region will be surveyed; however, safety and logistics may result in some transects or regions not being completed.

Transects within regions will be surveyed chronologically in ascending or descending order whichever is most efficient, safe, and logistically beneficial.

Sampling Objective 5:
<u>All SSF regions will be surveyed at least twice between 28 November–26 December.</u> Use the transects established within the SSF as the sampling units. These sampling units are intended to remain static across surveys and years. Therefore, sampling units are predetermined and do not require selection on an annual or survey specific basis. All transects within each SSF region will be surveyed at least twice between 28 November–26 December.

Field data collection methods
Stehn and Taylor (2008) postulated sun angle influenced the ability of observers to detect whooping cranes. This was substantiated using experimental surveys of whooping crane decoys (Figure 12). Data collected under high sun angles yielded more consistent detection curves which improved model performance and subsequent population estimates. To avoid inconsistent detection rates, <u>surveys will be conducted between 10:00 and 15:00 hours</u>, or under high overcast conditions.

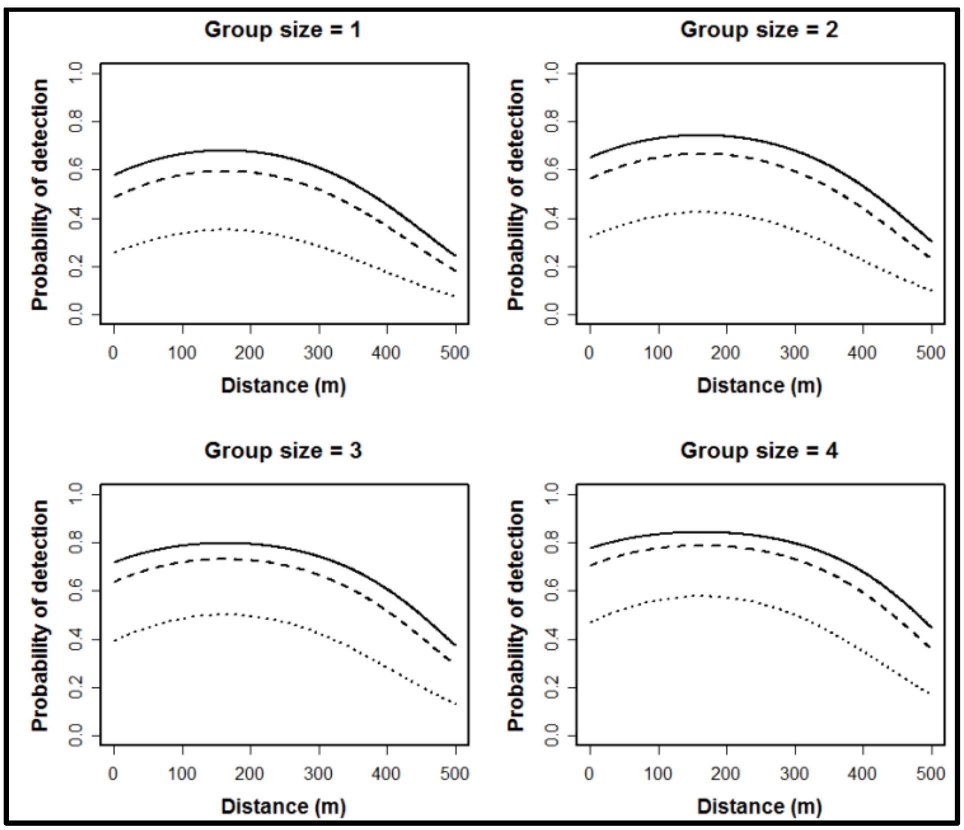

Figure 12. Predicted probability of detection for whooping crane decoy groups on Aransas National Wildlife Refuge, Texas, USA. Predictions based on logistic regression of detection with covariates of group size, distance from transect (quadratic effect), and sun position. Solid line is sun at observer's back, dashed line is sun overhead, and dotted line is sun in observer's face. The decoy experiment was conducted from a fixed-wing aircraft with pontoons resulting in reduced detection probability near the line. Such aircraft will not be used in future surveys.

To ensure safe and consistent navigation along transects while in-flight, the location of transect endpoints will be entered into the aircraft navigation system. Survey altitude and flight speed will be standardized to 60 m and 90 knots, respectively, as suggested by Stehn and Taylor (2008). While in flight, the pilot's primary responsibility is to safely navigate the aircraft along the transects. Although the pilot is not an observer during the survey, the pilot is encouraged to communicate any incidental observations of whooping cranes they happen to detect. Under most seating configurations the observer in the front seat is responsible for surveying forward of the aircraft and the starboard side. The observer in the rear seat is responsible for surveying the port side of the aircraft. While transects are being surveyed, each observer will allocate 90% of their attention ahead of a line perpendicular to the transect (i.e., 90°, Figure 13). Since the aircraft is moving at 90 knots, cranes will only be visible for a few seconds. Therefore, it is imperative that observers are constantly searching and scanning. Observers must avoid staring themselves into a hypnotic state (Buckland et al. 2001). Refer to section 7.6.2 in Buckland et al. (2001) for a good discussion on search protocol from aircraft.

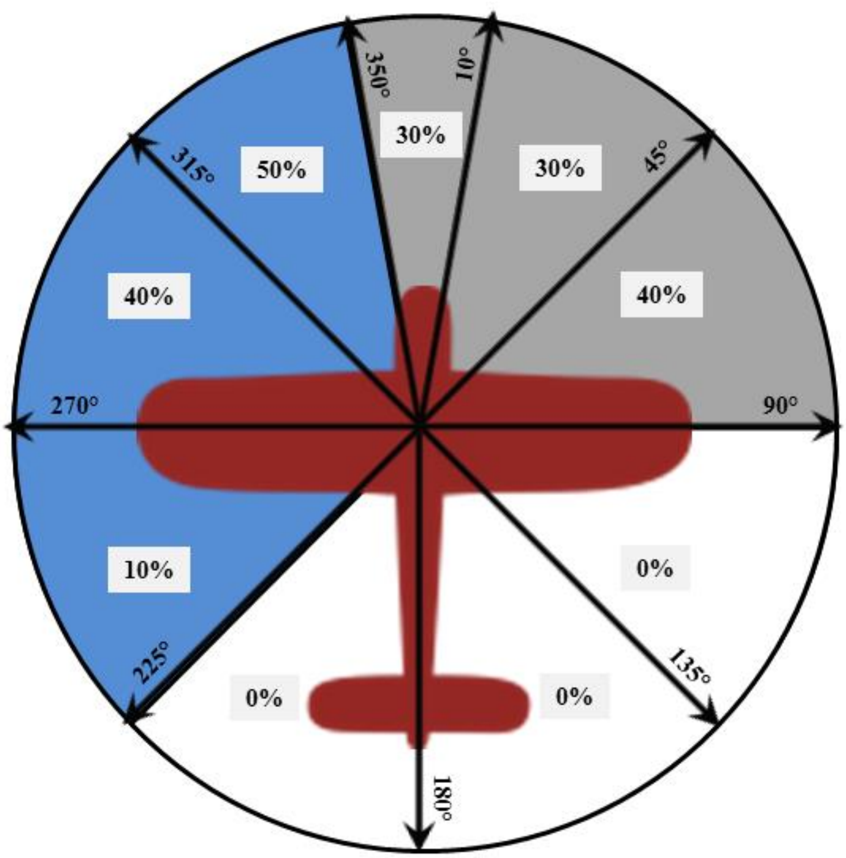

Figure 13. Allocation of observer search effort for distance sampling-based survey methods for wintering whooping cranes along the Texas gulf coast, USA. The gray area represents search effort by the front seat observer and the blue area represent search effort by the back seat observer.

Complete detection of whooping crane along the line is imperative. "Seeing everything close to the line is more important" than seeing as many whooping cranes as possible across the transect width (Buckland et al. 2001:285). To facilitate 100% detection on the line, the front seat observer should scan ahead of the aircraft for whooping cranes. If the front seat observer is short and has difficulty seeing over the instrument panel, that observer will need to elevate their seating position (i.e., use a boat-seat cushion). Also, the pilot often detects whooping cranes along the line; it is important that the pilot communicate those detections to the front seat observer.

Observers will scan this area systematically, allocating less effort as distance from the aircraft increases. Special attention must be made to ensure high, ideally perfect, detection on and near the transect. To increase the detection rate of individuals on or near the transect, the observer in the front seat will be responsible for allocating effort ahead of the aircraft to detect cranes on or near the line. Each observer will collect data independently in their own laptop computer. However, if the front seat observer detects whooping cranes on the port side of the aircraft, the front seat observer will immediately communicate that observation to the back seat observer and decide who is responsible for recording that detection.

Each observer will mark the starting and ending location of each transect with a point in the feature class and use the digital voice recorder to record transect id (e.g., record point number, start or end of the transect, and transect id). Upon detecting a whooping crane, the observer will determine whether the individual is a hatch-year (HY) or after-hatch-year (AHY) bird based upon its plumage coloration (Johnsgard 1983, Link et al. 2003). If an observer has any doubt as to the species, that detection should not be recorded. When the observer detects more than one whooping crane within 100 m of each other, the centroid of the group will be visually estimated and marked on the aerial image. The observer then uses physical characteristics of the landscape (e.g., ponds, roads, shoreline, etc.) and the real-time GPS location of the aircraft to mark the location of the bird(s) in relation to a high resolution aerial image displayed on the laptop. Occasionally, flying whooping cranes will be observed. If the location from which the group flushed is observed, that location will be marked. If the location from which the group flushed is unknown, then observers will mark the location the group was first observed. The label of the location will be displayed immediately upon the point being marked. Using the digital voice recorder (make sure the microphone is turned on), the observer will then record the point number displayed on the GIS, and the number of whooping cranes of each age-class observed. Additionally, observers can record specific comments regarding the cranes (e.g., band information, feathers appear dirty, etc.) or the area they are using (e.g., salt marsh, hog rooting, pond with windmill, etc.). After completing all transects within a region, each observer will "save edits" of the point feature class attribute table and verify the battery life remaining on the laptop. If edits can be saved at other times, observers will do so. It is important that data are saved as often as possible to ensure inadvertent data loss is avoided in the event of battery failure. Check battery life often to avoid inadvertent data loss. At the conclusion of a survey each observer should again "save edits" of the point feature class. Any GPS unit collecting track data should be selected to save the track file and shut down. As soon as observers return to the office, all data should be downloaded from the GPS units and laptops. Data must be backed-up to an external hard drive or server drive before observers leave the office.

Communication during survey

Communication among the observers and the pilot during the survey is imperative. Though the pilot is not an observer during the survey, the pilot should communicate any incidental observations of whooping cranes. The front seat observer, with assistance from the pilot, is responsible for detecting whooping cranes on and near the transect line including those under the aircraft on the port side. The front seat and back seat observers can freely communicating their observations to one another while retaining their attention to the respective search areas (Figure 13). If the front seat observer detects whooping cranes under the port side of the aircraft, they need to immediately communicate that observation to the back seat observer in order to determine which observer will record that detection.

Equipment failure

Occasionally equipment failure during a survey will occur (e.g., laptop battery dies, recording device operated incorrectly, software glitch, etc.). First, observers must do everything possible to avoid equipment failure (i.e., practice using all survey equipment prior to conducting surveys). If equipment failure occurs, observers will do the following:

1. Observers will immediately stop the survey once problem is realized and begin flying outside the survey area.
2. If the problem can be remedied in flight, observers will correct it.
3. Once the problem is corrected, observers will determine where the data loss began and resume the survey at the beginning of the first transect in which data were lost.
    a. For example, if a laptop battery fails halfway through a PSF region and all data for that region are lost, observers will need to resurvey that entire PSF region once the battery is replaced.
    b. If microphone operation was an issue, the observer should examine the digital audio files and determine where the last detection was recorded. Observers will need to restart the survey in that location.
4. If the problem cannot be remedied in flight, observers should return to the airport.
5. If enough time remains (i.e., surveys will be conducted between 10:00 and 15:00 hours) to complete the survey once the problem is corrected, observers should resume and complete the survey; otherwise, finish as much of the PSF as possible before 15:00 hours.
    a. Just as above, once the problem is corrected, observers will resume the survey at the beginning of the first transect in which data were lost.

Environmental covariates

Currently, environmental covariates are derived from the Texas Ecological Systems Classification Project (http://www.tpwd.state.tx.us/gis/gallery/), Phase 3 (Ludeke et al. 2012). The percent of each 1-km^2 transect segment is determined for 6 general vegetation types: saltmarsh, open water, wetland, saltmarsh-shrubland, upland, and urban (Appendix E). Though these covariates are only rudimentary, strong relationships with whooping crane abundance has been demonstrated with some of them (Strobel et al. 2012). As additional maps of vegetation layers, other whooping crane resources (i.e., salinity, blue crab abundance, etc.), or management actions (i.e., time since prescribed burn, fresh water provisioning, etc.) become available and more detailed hypotheses of whooping crane abundance relationships are developed, additional environmental covariates will be derived and incorporated into the hierarchical models of abundance.

End-of-season procedures

At the conclusion of each field season all digital data collection or storage devices will be checked to ensure all data have been removed and archived and their memories are cleared. In addition, all electronic equipment will be stored in a cool and dry place with the batteries removed. Verify the geodatabase (WHCR_SOP_yyyy-yyyy_ServCat) used to store that year's data contains all required feature classes and tables properly labeled. Complete the metadata (see Element 5–Metadata). Archive the geodatabase on the Aransas NWR server, and contact the regional data management team for archiving in the Service Catalog (ServCat; see Element 5–Data security and archiving; SOP 6). Download the template geodatabases from the WHCR SharePoint to store the data collected for the next season.

Element 5: Data Management

Data entry, verification, and editing

Step-by-step details for data collection, entry, verification, editing, and archiving can be found in the standard operating procedures (SOPs 1–6). Some basic knowledge of ArcGIS and Program R are required. Steps for pre-flight preparation and in-flight data collection are detailed in SOP1. SOP 1, along with Element 4, will be reviewed by each observer before each survey flight. General methods for data post-processing are described below (SOPs 2–5).

At the completion of a given survey each observer should have a feature class (i.e., survey_mmddyy_obs1) with plotted locations of whooping crane observations as well as digital audio files containing the details of each observation. Each observer will transcribe their own data (SOP 2) from their voice recordings into the corresponding fields in the feature class attribute table (i.e., WHITE, JUVEN, UNK) and archive the original audio files (SOP 6). Each observer will also record the line transect from which each observation was made in the appropriate field in the feature class. Once both observers have completed the data entry both feature classes shall be combined in the WHCR_SOP_mmddyy geodatabase.

The design of the whooping crane survey is such that transects have been specified prior to the survey (i.e., ideal transects). However, rarely can a pilot follow transects exactly. Therefore, the track of the aircraft will be recorded during each survey with a GPS unit. At the completion of a given survey, track data from the GPS should be imported into ArcMap as a line feature class. The "ideal transect" feature class and the track file will be used to create the survey-specific transect feature class (i.e., transects_mmddyy). Each transect will be labeled in accordance with the labels of the "ideal transects" feature class (SOP 3).

The terms fishnet and sampling frame are used interchangeably throughout this protocol as fishnet is a geospatial term and tool used to create a sampling frame. In ArcMap, we will use the fishnet dissolved on region to clip the track file into transects and remove portions of the track file where surveys were not occurring (i.e., turns between transects, off transect forays, etc.). Once the track file is converted into a clean transect file, distance between observed whooping crane groups and transects will be calculated using SOP 3. Once distances between detected whooping crane groups and transects are calculated, data will be summarized into text files (SOP 4) and R objects (SOP 5) needed for data analyses.

During post-processing intermediate feature classes and tables will be saved in the indicated geodatabases per the SOPs. For daily back-up, the 2 observer geodatabases (i.e., WHCR_SOP_mmddyy_obs1 and WHCR_SOP_mmddyy_obs2) and the primary geodatabase (i.e., WHCR_SOP_mmddyy) will be copied, renamed with an _bu suffix, zipped, and uploaded to the back-up folder on the WHCR SharePoint. After post-processing the data (SOPs 2–4), the following objects should exist within the WHCR_SOP_mmddyy geodatabase, spreadsheets, and audio folders:

- survey_mmddyy (point feature class)
- cranes_mmddyy (point feature class)
- transects_mmddyy (line feature class)
- gen_near_tbl_mmddyy (database table)
- track_mmddyy (line feature class)
- CDS_mmddyy (database table)
- CDS_mmddyy.txt (spreadsheets)
- HDS_mmddyy (database table)
- HDS_mmddyy.txt (spreadsheets)
- SurveyAudio_mmddyy_obs1 (audio)
- SurveyAudio_mmddyy_obs2 (audio)
- track_mmddyy.txt (spreadsheets)

The fishnets and ideal transects will remain in the WHCR_SOP_mmddyy geodatabase. If new fishnets are need, see Appendix D. If SSF regions become consistently occupied by whooping cranes and need to be promoted to PSF regions, see Appendix J.

Survey-specific conditions data

Information regarding survey conditions and logistics may be valuable for future analysis and interpretation of a survey's results. For example, weather conditions may influence the detectability of whooping cranes on a given survey or within a given sampling frame. If these characteristics are recognized and recorded they can potentially be incorporated into multi-survey analyses. Therefore, immediately prior to departure from the airport one observer (responsibility of the Lead Biologist) should record the automated weather observation station's (AWOS) report. The AWOS broadcasts a loop of up-to-the-minute weather conditions at the airport and is commonly used by pilots. Consult the pilot or airport personnel to obtain the frequency of the local AWOS (the Aransas County Airport AWOS can be found at http://w1.weather.gov/obhistory/KRKP.html). Prior to taxiing, record the following information from the AWOS:

1. wind speed,
2. wind direction,
3. sky conditions,
4. visibility, and
5. temperature.

In addition to the information from the AWOS, record the following information:

1. aircraft type (e.g., Cessna 182) and configuration (e.g., retractable gear, STOL kit),
2. pilot's name,
3. name and seating location (Observer 1),
4. name and seating location (Observer 2), and
5. recent weather events (e.g., precipitation, drought, red tides, cold fronts, etc.).

Metadata
Appendix G lists and describes which files must be archived and provides a description of each data field in each dataset (i.e., data dictionary). Metadata should be provided as part of the whooping crane geodatabase. This geodatabase in final, end of season form is the WHCR_SOP_yyyy-yyyy_ServCat.gdb. Metadata for the survey_mmddyy feature class should include information about equipment issues, search effort, and type of GPS unit used. A database table will include information about each survey flight including aircraft type, AWOS data, and observers' names and positions. Metadata for the cranes_mmddyy and transects_mmddyy feature classes should indicate issues encountered in the post-flight data processing. Each of the feature classes' metadata shall reference this survey protocol's ServCat ID number.

Data security and archiving
Prior to 2013, the aerial survey data was stored on the Aransas NWR server. Per this protocol for future surveys, the aerial survey data will be stored both on the Aransas NWR Server and duplicated on the WHCR Aerial Surveys (TX Coast) SharePoint site (Figure 14).

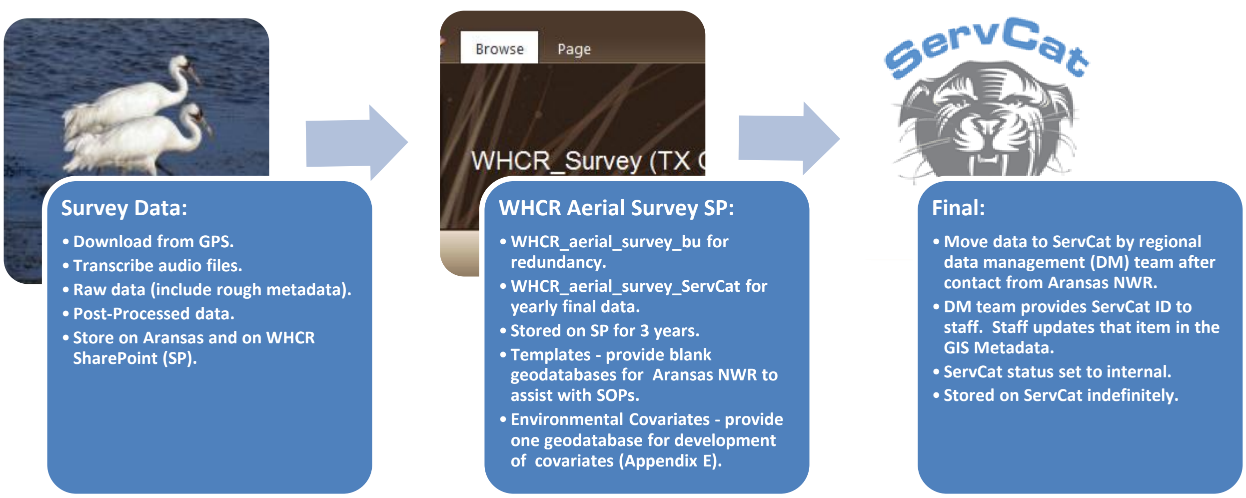

Figure 14. Overview of data management and data archiving for winter aerial surveys of whooping cranes on the Texas gulf coast, USA.

After completing SOPs 1–4 for each survey date, the data shall be uploaded to the SharePoint site for duplication. The WHCR Aerial Surveys (TX Coast) SharePoint contains a folder called WHCR_aerial_surveys_bu explicitly for redundancy to prevent data loss. This SharePoint site has restricted permissions. The Supervisory Biologist at Aransas NWR will ask the regional data management team to assign specific personnel access to this site (Appendix H). After each flight year, Aransas NWR will upload the final data to SharePoint, inform the regional data management team that the data upload has occurred, and that the data is ready for ServCat. The WHCR Aerial Surveys (TX Coast) SharePoint site is located at: https://fishnet.fws.doi.net/regions/2/nwrs/IM/WHCR/SitePages/Home.aspx.

The regional data management team is responsible for uploading the data to ServCat, and providing the ServCat ID both to the refuge contact and in the metadata for the geodatabase.

ServCat is the USFWS's document and geospatial repository. Permission levels in ServCat will be set to Restricted. ServCat can be accessed at: https://ecos.fws.gov/ServCat.

Element 6: Data Analysis

Analysis methods

Prior to analyses, data should be prepared following the data preparation guidelines in the standard operating procedures (SOPs 4–5). Most of the analysis will be conducted in RStudio (2012), an interface for Program R (Crawley 2007, R Development Core Team 2012). Example R Scripts for the various analyses have been provided in Appendix C. These scripts are intended to provide guidance in data analyses but should be modified according to the needs of a particular analysis (i.e., new landscape covariates become available allowing development of new models of abundance). Once data analyses are complete, R Scripts will be saved and stored for future reference. Further, the R Workspace, which is the working environment of Program R that includes all user-defined objects such as data frames and functions, will be saved and stored for future reference. Also, the function `sessionInfo()` will be used to store information about the versions of packages and libraries used in the analysis. For example, the version of R and all the attached packages used in the analysis will be stored with `versions=sessionInfo()`. All versions of packages and libraries used in the analysis will be stored in the saved R Workspace.

Other analyses such as conventional distance sampling in Program Distance (Thomas et al. 2010) may be warranted. Save and store Distance projects as "zip archive files" using the export project option in Program Distance. Also, Program TRENDS (Gerrodette 1987, 1991, 1993) stores the results of power analyses in a file named "TRENDS.OUT."

Sampling Objectives 1–4:
Data will be pooled for the surveys conducted during the 28 November–26 December survey period, resulting in one estimate of abundance, HY:AHY ratio, number of adult pairs, and number of recruitive pairs, and one spatially-explicit model of abundance (perhaps a model average). The whooping crane survey data will be analyzed using the **`distsamp`** or **`gdistsamp`** function of package **`unmarked`** in program R (Fiske and Chandler 2011, R Development Core Team 2012). The **`distsamp`** function can only fit the multinomial-Poisson mixture model of Royle et al. (2004). However, the generalized HDS model of Chandler et al. (2011), which allows abundance to be modeled using a negative binomial, can be fit using the **`gdistsamp`** function (e.g., Sillet et al. 2012). Chandler (2011) provided an easy to follow description (vignette) to guide analyses of distance sampling data using package **`unmarked`**. Following the vignette-style, Appendix C provides some guidelines for data analysis and R code development based on the **`distsamp`** function.

If repeated surveys are conducted, the generalized HDS model is designed to estimate the availability survey objects. This can be used to account for individuals in the sampling frame that are not available for detection (i.e., marine mammals that are underwater such as whales, fossorial animals that are underground such as prairie dogs), account for incomplete detection on the line (i.e., situations where detection is obscured by aircraft type), or estimate temporary emigration among sampling units. However, if temporary emigration and incomplete detection (or availability) are both occurring, generalized HDS models cannot account for both and will result in positive bias in estimates. Thus, it is imperative to maintain complete detection on the transect line. Currently, we plan to pool all the surveys from the 28 November–26 December survey period and use the model configuration that ignores temporary emigration (see Appendix C–A note about generalized HDS).

Archiving data analysis files

Once a final comprehensive report is completed, files resulting from data analyses will be uploaded to ServCat by the regional data management team. Files will include any R Workspaces and R Scripts generated by the final data analysis.

Software

Multiple software programs facilitate the collection, processing, storage, and analyses of the data collected during this monitoring effort. Recommended software and their sources are:

- ESRI® ArcMap™ 10.0, www.esri.com
- ESRI® ArcCatalog™ 10.0, www.esri.com
- ESRI® ArcGIS Desktop Service Pack 2, www.esri.com
- Microsoft® Excel 2010, www.microsoft.com
- Program DISTANCE, www.ruwpa.st-and.ac.uk/distance/
- DNR Garmin, www.dnr.state.mn.us/mis/gis/DNRGPS/DNRGPS.html
- Geospatial Modeling Environment (GME), www.spatialecology.com
- Program R, cran.r-project.org
- RStudio, rstudio.org
- R Package **unmarked**, cran.r-project.org/web/packages/unmarked/
- TRENDS, swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=228&id=4740

More information regarding R Package **unmarked** can be obtained from:

- Unmarked webpage, sites.google.com/site/unmarkedinfo/home
- Unmarked Google Group, groups.google.com/forum/?fromgroups#!forum/unmarked

Other potentially useful R Packages include:

- R Package **dsm**, cran.r-project.org/web/packages/dsm/
- R Package **mrds**, cran.r-project.org/web/packages/mrds/
- R Package **Distance**, cran.r-project.org/web/packages/Distance/
- R Package **Rdistance**, cran.r-project.org/web/packages/Rdistance/

Element 7: Reporting

A survey is not completed until the results have been documented in one or more reports, archived for future reference in the Service Catalog (https://ecos.fws.gov/ServCat/), and disseminated to interested parties. The regional data management team will assist or provide the ServCat data entry and the ServCat ID.

Reports

Reports will be divided into three types: update, interim, and comprehensive reports. Update reports will be prepared a few days after each survey and summarize survey activities but will not provide comprehensive results. Interim reports will be issued at least once yearly during the overwinter period in which whooping cranes inhabit areas on and around Aransas NWR. Comprehensive reports will be issued every 3 to 5 years and provide comprehensive documentation of monitoring efforts for wintering whooping cranes. Compilation of interim and comprehensive reports will be a collaborative effort among the Lead Biologist, Regional Biometrician, Regional Data Manager, and Whooping Crane Recovery Coordinator (see Element 8–Roles and responsibilities). Update reports are the responsibility of the Lead Biologist with assistance from other observers. Also, we recommend periodic (i.e., every 3 to 5 years) publication of survey results in the peer-reviewed scientific literature.

Update Reports:
Update reports will provide brief summaries of survey activities. These reports will describe the flight mission, survey conditions, aircraft used, search effort, who were the observers, and the number of detections. The reports will not provide comprehensive results but are intended as a simple permanent record of short-term monitoring activities and survey-specific conditions. Appendix F is a template for update reports. Since update reports only contain information about raw data and no results, we recommend not distributing update reports widely unless absolutely necessary. This is because raw data from a survey where detection of whooping cranes is not 100% can be misleading, misinterpreted, and misused.

Interim Reports:
Interim reports will be brief summaries of survey activities and results designed to update stakeholders and USFWS personnel. These reports are not intended to be comprehensive but should provide enough information to explain number of surveys completed, search effort, weather conditions during surveys, and summary statistics of interest (i.e., annual winter abundance estimate, HY:AHY ratio, number of adult pairs, number of recruitive pairs, number of HY birds; see Element 7–Summary statistics of interest). One interim report will be issued after the 26 November–26 December survey period (i.e., March); any additional interim reports are optional.

Comprehensive Reports:
Comprehensive reports will be a complete account of monitoring efforts for wintering whooping cranes. These reports will only be issued every 3 to 5 years. They will describe background information and survey objectives, briefly describe survey methodology, provide details of data analyses, report results, provide comparison with previous years and report trends, discuss important findings, and provide context for management and planning decisions. Deviations from protocol will be described though deviations are to be avoided if possible.

Summary statistics of interest

In interim and comprehensive reports, we will report 5 summary statistics and their associated coefficients of variation (CV), and 95% confidence intervals (95% CI). Those summary statistics are:

1. annual winter abundance estimate within the primary sampling frame,
2. HY:AHY ratio (index of juvenile recruitment) between 28 November–26 December within the primary sampling frame,
3. estimated number of adult pairs between 28 November–26 December within the primary sampling frame,

4. estimated number of recruitive pairs (i.e., number of adult pairs with HY birds) between 28 November–26 December within the primary sampling frame, and
5. estimated number of HY birds between 28 November–26 December within the primary sampling frame.

In addition to these 5 statistics, comprehensive reports will contain:

6. summaries of the number of detections in SSF regions will be provided to document monitoring of range expansion (see Element 7– Comparison with estimates from the traditional technique).
7. summaries of whooping cranes observed outside of the primary sampling frame will be reported separately and identified according to the source of the observation.

Wildlife managers and decision makers are often interested in understanding the relationships between whooping crane abundance and environmental covariates. The covariates included in a priori models will be listed and the a priori models described in the comprehensive reports. The coefficients (i.e., slopes) and their standard errors of covariates included in the best or "averaged" model(s) will be summarized in the comprehensive reports.

Documentation of analysis

In comprehensive reports, data analyses will be described in a manner similar to typical scientific journal articles and provide adequate detail for a reader to duplicate it (e.g., Block et al. 2011). The comprehensive report will document the assumptions that were made to complete analyses and rationale for the analyses. The rationale for the development of a priori model set(s) will be described as well. As additional environmental covariate become available or land-classification systems available for use change, a priori model set(s) may need to be modified according to the available environmental data.

Once data analyses are complete, R Scripts will be saved and stored for future reference. Further, the R Workspace, which is the working environment of Program R that includes all user-defined objects such as data frames and functions, will be saved and stored for future reference. Also, the function `sessionInfo()` will be used to store information about the versions of packages and libraries used in the analysis. Analyses conducted in other software will be saved as well. These files will be archived with reports on ServCat.

Implications and application

The primary management objectives driving this monitoring effort are providing metrics for assessing progress towards downlisting criteria (CWS and USFWS 2007) and development of spatially-explicit resource use models that can facilitate land conservation through the delineation of important habitat and the prioritization of land protection. These management objectives will be pursued through coordination with partners in Ecological Services and the National Wildlife Refuge Planning Division.

Long-term trends are important for conservation planning and population management (Thomas et al. 2004). Therefore, power analyses (like those demonstrated in Appendix A) will be used to assess the capacity of the monitoring efforts to detect trends prescribed in objective 1 and help elucidate limitations or improvement for future monitoring efforts. This will be used to provide recommendation for continuing, discontinuing, or modifying efforts in the future. All reports should include a brief discussion of implications and recommendations that stem from these monitoring activities.

Comparison with estimates from the traditional technique

We recommend caution when comparing estimates from the new technique with estimates from the traditional technique. The traditional technique attempted to incorporate whooping crane observations from outside of the sampling frame into the reported estimated. However, estimates obtained with the new technique are only applicable to the primary sampling frame.

Whooping cranes observed outside of the primary sampling frame will be reported separately and identified according to the source of the observation (e.g., Texas Whooper Watch, satellite transmitter, or secondary sampling frame during aerial survey efforts). However, adding these reported birds to the estimate presents potential problems. For example, we cannot ever be completely certain that whooping cranes observed outside the primary sampling frame on one day did not move to or from the primary sampling frame before the surveys were completed.

Reporting schedule

Update reports will typically be made a few days after each survey but delays due to survey schedules may occur. One interim report (optionally two) will be issued each year and comprehensive reports will only be issued every 3 to 5 years (Figure 15).

Figure 15. Reporting schedule for whooping crane monitoring activities on and around Aransas National Wildlife Refuge, Texas, USA.

Interim Reports:
Interim reports will be issued in late-winter and optionally in late-spring of each year. The first interim report will provide an update and interim analysis of the surveys conducted between 28 November–26 December. The optional second interim report will provide an update and interim analysis of the surveys conducted during the optional survey periods (i.e., January, February, and March). The second interim report is relevant only if surveys are conducted during other periods.

Comprehensive Reports:
Comprehensive reports will be a complete account of monitoring efforts for wintering whooping cranes. Therefore, those reports will only be issued on a semiannual basis (i.e., every 3 to 5 years). These reports will document all monitoring activities, detail methods and analyses, summarize annual results, and the implications and application of those results. Also, comparison with previous years and trend analysis will be reported.

Interim reports are considered optional given time constrains of USFWS personnel. However, comprehensive reports are not optional and must be completed in a timely manner (i.e., every 3 to 5 years).

Report distribution

Each interim and comprehensive report will be distributed to interested USFWS personnel and other partners via the Aransas NWR website (www.fws.gov/refuge/aransas/). All reports must contain the following disclaimer (USFWS 2010). *"The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service."* U.S. Fish and Wildlife Service policy requires that authors add a disclaimer because reports are not specifically reviewed for policy implications, and they may or may not represent the official views of the Service (USFWS 2010). Also, the authors of reports should follow the guidelines outlined in "Information Quality Guidelines and Peer Review" (USFWS 2012*a*).

Archiving

Data and reports will be archived in ServCat (USFWS 2012*b*). Many data files are produced during data manipulation stages. Appendix G lists and describes which files must be archived and provides a description of each field in each dataset (i.e., data dictionary). The WHCR Aerial Surveys (TX Coast) SharePoint site will serve as a duplicate data site for the survey data. When the final, end of season survey data is ready, Aransas NWR staff will upload this data to the SharePoint into the WHCR_aerial_surveys_ServCat location, and notify the regional data management team by email. The regional data management team will upload the data into ServCat.

Element 8: Personnel Requirements and Training

Roles and responsibilities

Two observers and one pilot are needed to conduct the survey. The pilot must be Department of the Interior-Aviation Management Directorate certified. One observer will serve as Lead Biologist for the monitoring effort and will be responsible for coordinating pilots, equipment, and personnel and initiating the flight planning and flight following procedures outlined in the aviation safety plan (Strobel 2011). The Second Observer will be responsible for assisting the Lead Biologist with coordinating logistics. Data analysis will be conducted by the Regional Biometrician or trained and qualified biologist. Compilation of interim and comprehensive reports will be a collaborative effort among the Lead Biologist, Regional Biometrician, Regional Data Manager, and Whooping Crane Recovery Coordinator (see Element 7–Reports). Update reports are the responsibility of the Lead Biologist with assistance from other observers.

Qualifications

Observers will be trained to conduct surveys. New observers must participate as a non-observer in the fourth seat of the aircraft during <u>at least 3 surveys</u> (i.e., 3 full survey days) with experienced observers. Observers must have a strong stomach; otherwise, motion sickness medication may be needed. Good eyesight is required for observers. Observers must have the ability to endure 5 hours or more of sitting in a cramped aircraft. Superior knowledge of birds of the Texas coast is needed for observers. At minimum, observers must be able to distinguish the species of white-colored birds from great distances; practice is recommended (Figure 11). High confidence and ability to identify whooping cranes, sandhill cranes, American white pelicans (*Pelecanus erythrorhynchos*), great egrets (*Ardea alba*), snowy egrets (*Egretta thula*), cattle egret (*Bubulcus ibis*), and snow geese (*Chen caerulescens*) at great distances are required. All staff involved in conducting, coordinating, and analyzing data from these surveys must conduct monitoring activities with scholarly and scientific integrity (USFWS 2011).

Training

Pilots and observers must have the required aviation training outlined in USFWS Service Manual, 330 FW 3 (www.fws.gov/policy/330fw3.html). The training courses needed are B3-Combination Helicopter/Airplane Safety and M3-DOI Aviation Management Training for Supervisors. We also recommend observers have A312-Water Ditching and Survival. More information regarding these and other aviation training courses are available at the Interagency Aviation Training website (https://www.iat.gov/Training/course_list.asp). Observers need to be CPR/First Aid certified in case of emergencies. At least one alternate observer should be trained in case one of the primary observers is not able to conduct a survey.

It is important observers are familiar with all the equipment and how to operate it. Observers must practice using all survey equipment prior to conducting whooping crane surveys. We recommend that observers practice using the equipment from an automobile prior to conducting surveys each year. Without practice, costly mistakes during monitoring activities could result in data loss. Losing data because of simple, avoidable mistakes is unacceptable.

Element 9: Operational Requirements

Budget

Annual and extended costs required for the complete implementation of this protocol (i.e., not objective specific) are divided into several categories (i.e., Pilot Travel, Survey Costs, Equipment, Staff Costs, Office Supplies; Table 4). Costs associated with pilot travel and flight costs were forecast to include an annual increase of ≈10%. Staff costs were forecast to increase annually by ≈3%. The largest line item cost of the survey was staff costs, yet see Element 9–Staff time below (Table 4). Equipment cost were estimated to be incurred every third year to ensure reliable collection of data (Table 4).

Staff time

The total staff time required to complete all portions of this protocol (i.e., training, survey preparation, data collection, data processing, data analysis, and reporting and distribution) have been estimated based upon the approximate time required for completion in 2011–2012 (Table 5). As familiarity with methods increases total staff time required to complete the protocol may decrease. Staff time is contributed by two observers (e.g., Refuge Biologists) and the Regional Biometrician. The estimated Full Time Employee (FTE) equivalence to complete this survey is 0.47.

Schedule

Field data collection will occur annually between 28 November and 31 March. To meet sampling objectives 1–4, data collection will occur annually between 28 November and 26

December. To ensure adequate power has been obtained to meet sampling objective 1 it is expected that data processing, data analysis, and reporting will be conducted as soon after the completion of the 28 November–26 December surveys as practical. Similarly, data processing, analysis, and reporting should be conducted as soon after subsequent survey periods (e.g., January, February, and March survey periods) as practical (Figure 15). However, interim reports will only be issued once annual (optionally twice) and comprehensive reports will only be issued every 3 to 5 years (Figure 15). The interim reports are of lowest priority and are, thus, considered optional given time constrains of USFWS personnel. However, comprehensive reports are not optional and must be completed in a timely manner (i.e., every 3 to 5 years).

Table 4. Estimated budget for monitoring whooping cranes on their wintering grounds along the Texas gulf coast, USA.

Budget item	FY2013	FY2014	FY2015	FY2016	FY2017	Total
28 November–26 December Survey Period						
Pilot Travel	$2,000	$2,250	$2,500	$2,750	$3,000	$12,500
Survey Flight	$7,000	$8,000	$9,000	$10,000	$11,000	$45,000
Staff Costs	$15,000	$15,500	$16,000	$17,000	$18,000	$81,500
Survey Equipment	$8,000	$0	$0	$8,000	$0	$16,000
Office Supplies	$2,500	$2,500	$2,500	$2,500	$2,500	$12,500
Subtotal	$34,500	$28,250	$30,000	$40,250	$34,500	$167,500
Optional Survey Periods (January, February, and/or March)						
Pilot Travel	$2,000	$2,250	$2,500	$2,750	$3,000	$12,500
Survey Flight	$7,000	$8,000	$9,000	$10,000	$11,000	$45,000
Staff Costs	$15,000	$15,500	$16,000	$17,000	$18,000	$81,500
Subtotal	$24,000	$25,750	$27,500	$29,750	$32,000	$139,000
Total	$58,500	$54,000	$57,500	$70,000	$66,500	$306,500

Table 5. Estimated staff time to complete annual monitoring of whooping cranes on their wintering grounds along the Texas gulf coast, USA. Estimates based on number of times and duration of each activity during winter 2011–2012.

	Number	Duration (hr)	Staff	Total (hr)
Training	3	16	2	32
Survey Preparation	12	4	2	96
Data Collection	12	8	2	192
Data Processing	12	8	2	192
Data Analysis	3	40	1	240
Reporting and Distribution	3+	40	2	240
Total				992

Coordination

Monitoring of whooping cranes on their wintering grounds will be coordinated by the Lead Biologist. The Lead Biologist will need to coordinate funding through the Region 2 Chief of Biological Sciences, data analyses through the Regional Biometrician or other qualified personnel, and communication with the Whooping Crane Recovery Team through the Whooping Crane Recovery Coordinator. The Lead Biologist will typically be the Supervisory Biologist at

Aransas NWR. Optionally, the Lead Biologist may be the Whooping Crane Recovery Coordinator in the absence of a Supervisory Biologist at Aransas NWR.

Element 10: References

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Overview of the Whooping Crane Abundance Protocol

Below we provide a table that summarizes the details of the wintering whooping crane abundance survey and where to find information regarding each survey activity. The SOP or Appendix is noted under the item column and the action column details each activity.

Item	Action
SOP 1, Appendix I	Download I&M Survey folder structure from SharePoint and unzip it to a data storage space like a server or c:\ (completed by NWR).
SOP 1, Appendix I	Download WHCR geodatabase templates and unzip into the *im_surveys\at_risk_biota\birds\survey_name_folder\data\yyyy-yyyy\RO_templates* to the Aransas server and to the c:\temp.
SOP 1	Once downloaded into *RO_templates*, in *Windows Explorer*, extract all.
SOP 1	Create a new folder called *pre-flight* in the *im_surveys\at_risk_biota\birds\survey_name_folder\data\yyyy-yyyy\geodata* folder.
SOP 1	Copy and rename the two observer geodatabases into *im_surveys\at_risk_biota\birds\survey_name_folder\data\yyyy-yyyy\geodata\pre-flight*.
SOP 1	Copy and rename the *WHCR_SOP_mmddyy_template* and the ServCat geodatabases into *im_surveys\at_risk_biota\birds\survey_name_folder\data\yyyy-yyyy\geodata*.
SOP 1	Before Flights, practice SOP 1 using an automobile to check that GPS and files are working correctly and ensure users are comfortable with SOP 1. Observers will read Element 4–Field Methods prior to conducting surveys each year.
SOP 1	Conduct the aerial survey. The Primary Sampling Frame (PSF) surveyed ≥6 times (6 complete surveys of all transects within the PSF) between 28 November–26 December. The Secondary Sampling Frame (SSF) surveyed ≥2 times (2 complete surveys of all transects within the SSF) between 28 November–26 December.
SOP 2	Download survey flight data: **Observer geodatabases**: *im_surveys\at_risk_biota\birds\WHCR_aerial_surveys\data\yyyy-yyyy\geodata*. These geodatabases have the observers initials and were originally the _obs1 and _obs2 geodatabases. **Audio recording files**: *im_surveys\at_risk_biota\birds\WHCR_aerial_surveys\data\yyyy-yyyy\audio.* Name as *SurveyAudio_mmddyy_obs1*.

Item	Action
SOP 2	Download survey flight data: **GPS track:** Save in the respective observer geodatabases at *im_surveys\at_risk_biota\birds\WHCR_aerial_surveys\data\yyyy-yyyy\geodata*
Appendix F	Prepare update reports within a few days after each survey (completed by NWR).
SOP 2	Transcribe and attribute the survey flight data (completed by the observers) as soon as possible after each survey.
SOP 3	Combine 1st and 2nd observers' *survey_mmddyy* feature classes in the *WHCR_SOP_mmddyy* geodatabase located in *im_surveys\at_risk_biota\birds\WHCR_aerial_surveys\data\yyyy-yyyy\geodata.*
SOP 3	Clip the flight lines to the fishnet and remove turn areas from the flown transects.
SOP 3	Measure distance to whooping crane detections from transects for PSF regions.
SOP 3	Identify the whooping crane detections that have Near Distance problems (Appendix G).
SOP 3	Correctly attribute the detections with Near Distance problems.
SOP 4	Create the HDS file and export as both a text file and a geodatabase table named as *HDS_mmddyy*.
SOP 4	Create the CDS file and export as both a text file and a geodatabase table named as *CDS_mmddyy*.
SOP 5	Format data for analyses in Program R. Save these files in the *im_surveys\at_risk_biota\birds\WHCR_aerial_surveys\data\yyyy-yyyy\analysis* folder (contact Regional Biometrician to determine if RO or NWR will complete SOP 5).
SOP 6	Daily archiving and backup of survey data including any SSF regions crane detections to the WHCR SharePoint (access restricted) in the *WHCR_aerial_surveys_bu* folder under Data. The *WHCR_SOP_mmddyy* geodatabase will contain 7–9 feature classes. There will be an audio file and text files.
Appendix C	Conduct data analyses.
SOP 6	Combine all survey data for the flight year into the *WHCR_SOP_yyyy-yyyy_ServCat* geodatabase and upload to the WHCR SharePoint (access restricted) into the WHCR_aerial_surveys_ServCat folder under Data. Also, upload data analysis files and reports.

Item	Action
SOP 6	Email regional data management team that the data is ready for ServCat.
Appendix D	If new areas are identified for inclusion in the SSF, generate a fishnet in ArcMap (data management team can do this for the NWR).
Appendix E	Creating the Enviornmental Covariates based on TESC data (data management team or Biometrician can do this for the NWR).
Appendix I	Downloading template geodatabases and I&M Survey folder structure from SharePoint (completed by NWR).
Appendix J	Once enough whooping crane groups are consistently detected within a SSF area, that SSF area will be promoted to a PSF area (data management team can do this for the NWR).

Standard Operating Procedures

Standard Operating Procedure 1: Conducting Surveys

UNDERSTANDING THIS DOCUMENT

- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin).
- *Italicized* text indicates background information, a filename, or a field name.
- When filenames have an *_mmddyy_* or an *_obs1* this would be updated to reflect the date the survey was conducted for *_mmddyy_*, and *_obs1* or *_obs2* is the observer's initials.
- SOP written for a Windows 7 environment.

DATA COLLECTION

This SOP will be reviewed by the observers prior to each survey.

- PRE-FLIGHT PREPARATION FOR DATA COLLECTION

  *Ensure the I&M Surveys folder structure is on the server or data storage location (Appendix I). Template file geodatabases for observer1 and observer 2 are available on the WHCR Aerial Surveys (TX Coast) SharePoint site in Data>SOP_templates, and in the near future, on ServCat. These geodatabases are located in WHCR_SOP_yyyy-yyyy_template.zip. Users will download this zip file into the im_surveys\at_risk_biota\birds\survey_name_folder\data\yyyy-yyyy\RO_templates to the Aransas server and to the c:\temp. Once downloaded into RO_templates, in Windows Explorer, **Extract All**. Then, use ArcCatalog to review the five geodatabases that should be present:*

  a. *WHCR_SOP_mmddyy_template.gdb*
  b. *WHCR_SOP_mmddyy_template_obs1.gdb*
  c. *WHCR_SOP_mmddyy_template_obs2.gdb*
  d. *WHCR_SOP_yyyy-yyyy_template_ServCat.gdb*
  e. *Environmental_Covariates.gdb*

  Users will copy and rename the observer geodatabases into \....\data\yyyy-yyyy\geodata\pre-flight. Users will also copy and rename the WHCR_SOP_mmddyy_template and the ServCat geodatabases into \....\data\yyyy-yyyy\geodata.

  Note: *The term "OBJECTID" is used when discussing geodatabases; whereas, "FID" is used when discussing shapefiles. Also, a .gdb is a file geodatabase.*

Before going to the Airport

1. Read and familiarize yourself with Element 4.
2. Plan surveys in advance.
3. To ensure each region is sampled at various times of day (i.e., to avoid systematic bias), a randomly ordered list of the regions within the PSF will be used to determine the region in which each survey will begin with (i.e., the first survey will begin with the first region on the list, the second survey will begin with the second region on the list, etc.). To create this list, simple R code can be used:

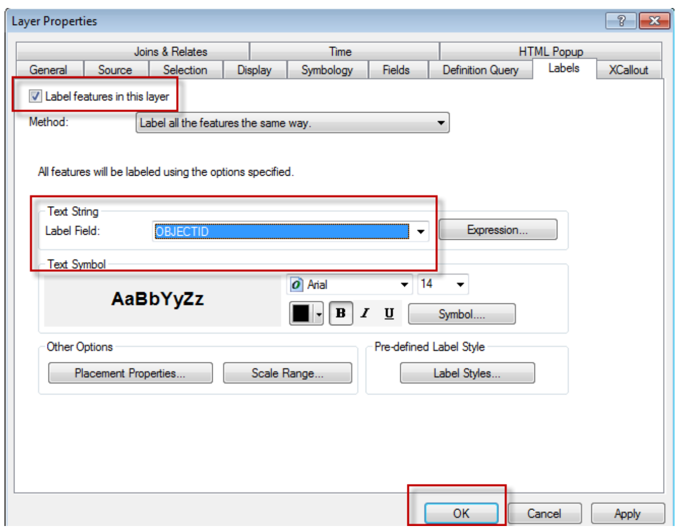
```
sample(c("BJ","LT","MIC","WM","SJ","WF"))
```

4. It is important observers are familiar with all the equipment and how to operate it. Observers must practice using all survey equipment prior to conducting whooping crane surveys. <u>For example, observers could practice using the equipment from an automobile prior to conducting surveys each year.</u> Without practice, costly mistakes during monitoring activities could result in data loss. Losing data because of simple, avoidable mistakes is unacceptable.
5. Ensure all electronic equipment is fully charged, has new batteries installed, or an auxiliary power supply (e.g., power inverter). Charge batteries the night before a survey flight.
6. Ensure all electronic devices have the correct time and date settings (e.g., digital voice recorder).
7. In ArcCatalog, **open** the *im_surveys>at_risk_biota>birds>WHCR_aerial surveys>data>2013-2014>geodata.*
   Note: *2013-2014 is the current survey year. Appendix I describes file directory structure for I&M Surveys.*
8. In the *geodata* folder **create** a new folder named *pre-flight.*
9. In *im_surveys>at_risk_biota>birds>WHCR_aerial surveys>data>2013-2014>RO_templates*, **Right-click** on the geodatabase (i.e., *WHCR_SOP_mmddyy_template_obs1.gdb*) and select **Copy.**
10. **Paste** to the *im_surveys>at_risk_biota>birds>WHCR_aerial surveys>data>2013-2014>geodata>pre-flight* folder.
11. Observers should **rename** the geodatabases by changing the date, removing "template", and changing obs1 or obs2 to the observer's initials similar to the following:
    Template Name: *WHCR_SOP_mmddyy_template_obs1.gdb*
    Renamed: *WHCR_SOP_032813_dpi.gdb*
12. In the geodatabase from step 9, **Rename** the *survey_mmddyy* feature class using the survey date and the observer's initials (i.e., *survey_014112_dpi*).
13. **Right-click** on the geodatabase from step 9 and **Copy.**
14. Navigate to the proper location on a portable memory device used for the aerial survey, and **paste** the renamed geodatabase.

15. If not already available on the portable memory device, **copy** imagery (e.g., 1-m NAIP) to the device.
    Note: *Imagery can be downloaded from the USDA Data Gateway (http://datagateway.nrcs.usda.gov/) if it is not already available on the Aransas NWR server.*

Before take-off

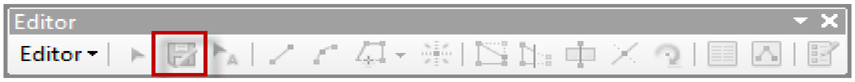
1. **Open** ArcMap on the laptop, and **add** the *survey_mmddyy_obs1* (i.e., *survey_011112_dpi*) feature class to the dataframe.
2. **Save** this ArcMap project as *whcr_mmddyy_obs1.mxd* using the date and observer initials.
3. **Right-click** on the *survey_mmddyy_obs1* feature class and **click** on **Properties>Labels** tab. **Set** the **Label Field** to *OBJECTID*. Confirm **Label features in this layer** is checked. **Click OK.**
   Note: *This will automatically label each point in chronological order as they are created.*



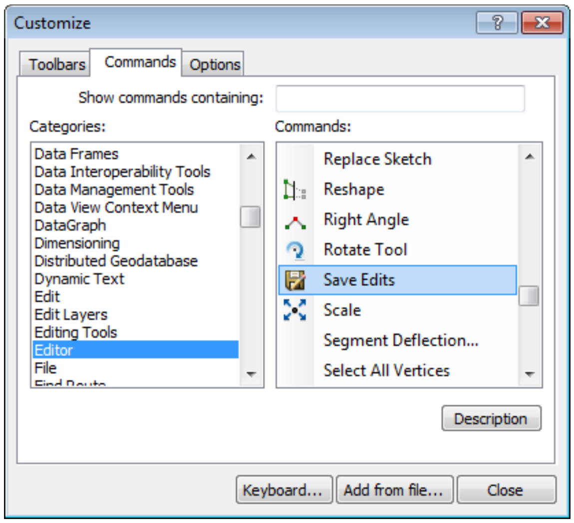
4. **Add** the *fishnet_dissolved* feature class to the dataframe (Optional step).
5. **Add** the *transects_ideal* to the dataframe. Following step 3 above, label the TRANSECT_ID, but choose a different font color.
6. **Add** imagery (e.g., 1-m NAIP) to dataframe covering the sampling frame's extent.
   Note: *Imagery can be downloaded from the USDA Data Gateway (http://datagateway.nrcs.usda.gov/) if it is not already available on the Aransas NWR server. Observers will use the most current imagery available.*
7. In ArcMap, **set** the dataframe display scale to **1:8000**.

8.
9. In ArcMap, **open** the **Editor toolbar** by clicking on the **Editor** icon.

10. On the **Editor toolbar** confirm the **Save Edits** icon is shown.



11. If the **Save Edits** icon is not on the **Editor toolbar**, then **click Customize>Customize mode>Commands** tab. Under **Categories**, scroll down and **click** on **Editor**. Under **Commands**, **click** and drag **Save Edits** to the **Editor toolbar** in ArcMap.



12. Turn on the handheld GPS unit and any redundant handheld GPS units and allow them to search for satellites.
13. Check that the coordinate system is set to UTM NAD83 in the handheld GPS units (**Setup>Position Format**, change **Position Format** to **UTM UPS** and **Map Datum** to **NAD83**).
14. Check that the track data collection rate is set to a 1-second interval in the handheld GPS units (**Setup>Tracks**, change **Record Method** to **Time** and **Recording Interval** to **00:00:01**).
15. Ensure redundant handheld GPS is set to record its track as well. Repeat steps 12–14 for the redundant handheld GPS; it should have a recording interval of 1 second.
16. Establish communications between a GPS and the laptop computer and display current location in ArcMap (Appendix L).
    Note: *Steps to do this will depend upon the GPS and CPU used and their connection type (i.e., wired, wireless). Appendix L contains the most recent steps, and is updated by the Refuge Biologist. Use Appendix L with steps 12-16.* <u>*These steps should be practiced and well understood prior to any survey flight.*</u>

In-flight data collection

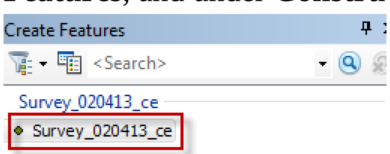
1. While taxiing repeat the automated weather observation station (AWOS) data into the digital voice recorder. Be sure to indicate units of measurements (i.e., if

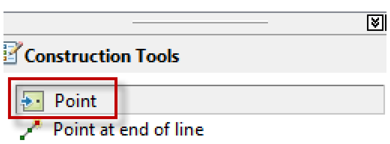
temperature is Fahrenheit or Celsius). Also make any additional and pertinent observations of weather conditions.
Note: *Aransas County Airport AWOS can be found at:* *http://w1.weather.gov/obhistory/KRKP.html*.

2. Both observers will record the date, each observers name and seating position, the pilot's name, and the aircraft type and configuration. For example, record "December 17th 2012" pause "Wade Harrell, front-seat observer" pause "Diana Iriarte, backseat observer" pause "Terry Liddick, Pilot" pause "Cessna 206" pause "This is Wade Harrell's recording."
3. In ArcMap, be sure the dataframe display scale to is **set** to **1:8000**.
4. **Click** on **Editor**>**Start Editing** the *survey_mmddyy_obs1* feature class during taxiing.

At the appropriate times you will plot a point at the start and end of each transect. Steps 5–7 describe collecting both the point and audio file data for the start and end of transects being flown. Steps 8–15 describe the point and audio file data collection for the crane observations.

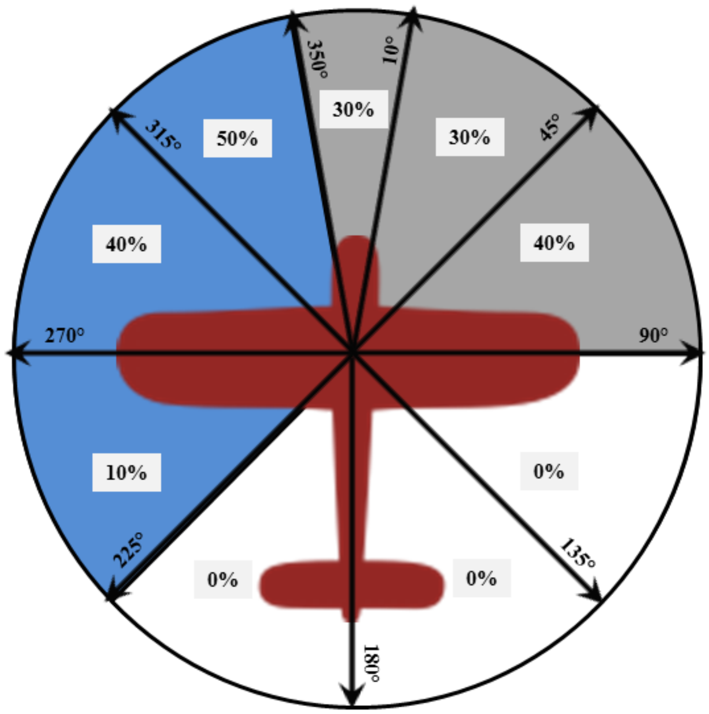
5. To plot a point in ArcMap, click on the *survey_mmddyy_obs1* in **Create Features**, and under **Construction Tools**, click on **Point**.





6. **Click** the appropriate place on the map for either the start or end of the transect.
7. **Click Save Edits** and in the **Construction Tools**, click on **Point** again to ready for the next point location. If the **Save Edits** icon is not on the toolbar, see SOP 1, before take-off, step 9 for instructions.
8. Use the digital voice recorder, start an audio file to record the transect id for each start and end point. Holding the microphone near your mouth record the transect id and whether the point is starting or ending a transect. Speak loudly, clearly, and methodically following the example: pause "Point 1" pause "Start" pause "Transect Blackjack 1."
9. Complete detection of whooping crane along the line is imperative. <u>Seeing everything close to the line is more important than seeing as many whooping cranes as possible across the transect width.</u> To facilitate 100% detection on the

line, the front seat observer should scan ahead of the aircraft for whooping cranes. If the front seat observer is short and has difficulty seeing over the instrument panel, that observer will need to elevate their seating position (i.e., use a boat-seat cushion). Also, the pilot often detects cranes along the line; it is important that the pilot communicate those detections to the front seat observer. The figure below depicts allocation of observer search effort. The gray area represents search effort by the front seat observer and the blue area represent search effort by the back seat observer.



10. <u>Communication</u> among each of the observers and the pilot during the survey is imperative.
11. Using the **Create Features** from step 5, **click** the appropriate place on the map to capture the point location of observed cranes in the *survey_mmddyy_obs1* feature class as accurately as possible. Pay attention to the *OBJECTID* of the point which should label on the map. This *OBJECTID* is used in step 13 with the audio recording. <u>If multiple cranes are detected within 100 m of each other, plot the geometric center of the group.</u>
12. If whooping cranes are observed flying, mark the locations from which the group flushed. If the spot from which the group flushed is unknown, then mark the location the group was first observed at and note in the comments that the group was observed flying.
13. <u>If an observer has any doubt as to the species, that detection should not be recorded.</u>

14. **Click Save Edits** on the **Editor toolbar**, and in the **Construction Tools**, **click** on **Point** again to ready for the next point location.
15. Use the digital recorder to start an audio file for each observation. Holding the microphone near your mouth record the *OBJECTID* of the point as well as the age-class of all cranes observed. Speak loudly clearly and methodically following the example: pause "Point 23" pause "Transect Blackjack1" pause "2 White" pause "1 Juvenile" pause "1 Unknown" pause "4 total cranes" pause "Comments."
16. Record what you see for each detected group; do not make assumptions about group structure. For example, if a group of 2 white birds and 1 unknown age-class birds is observed do not assume the unknown bird is a juvenile record it as "1 Unknown."
17. **End** and **Save** each observation's recording separately.
18. After completing each survey region select **Save Edits** on the **Editor toolbar** in ArcMap. Then, click **Start Editing** the *survey_mmddyy_obs1* feature class again. ***Note:*** *If saving can be accomplished more often, do so!*

Standard Operating Procedure 2: Data Download and Transcription

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UNDERSTANDING THIS DOCUMENT

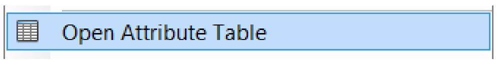
- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin).
- *Italicized* text indicates background information, a filename, or a field name.
- When filenames have an *_mmddyy_* or an *_obs1* this would be updated to reflect the date the survey was conducted for *_mmddyy_*, and *_obs1* or *_obs2* is the observer's initials.
- SOP written for a Windows 7 environment.

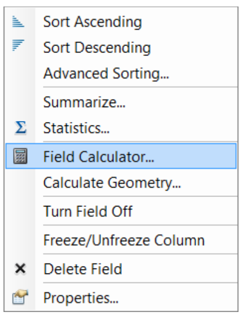
Both observers should complete the SOP 2 steps for their survey data. Then, only 1 of the 2 observers should complete the remaining steps for post-flight data processing and synthesis in SOPs 3, 4, and 6. This SOP will be completed for both the Primary and Secondary Sampling Frames (see Element 3).

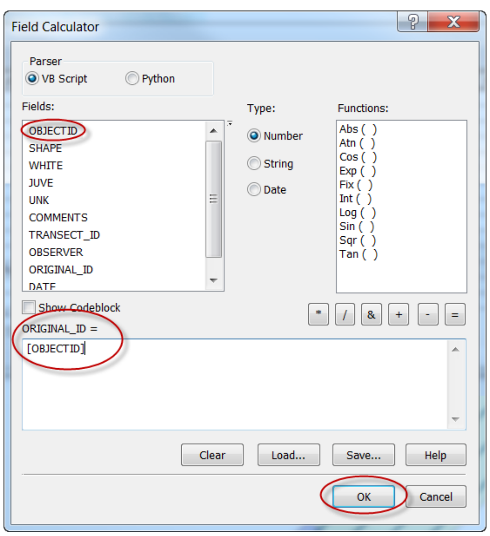
Data download

1. **Copy** observer geodatabase from the portable media used during the survey to the Aransas NWR server. Store the observer geodatabases in *\\im_surveys\at_risk_biota\birds\WHCR_aerial_surveys\data\yyyy-yyyy\geodata*.
2. **Copy** audio recording files to *\\im_surveys\at_risk_biota\birds\WHCR_aerial_surveys\data\yyyy-yyyy\audio.* Name as *SurveyAudio_mmddyy_obs1*.
   Note: *Previous location used was V:\WHCR\ Survey Audio Files\2011\SurveyAudio_DDMMYY_OBS.*
   Note: *If primary handheld GPS failed during the survey; use the redundant handheld GPS for steps 3-5.*
3. **Open** DNR Garmin program. Depending upon the type of GPS and the settings in the DNR Garmin software, a user may need use the **Download** command or the **Load** command to obtain the data from the GPS. To use the **load** command, once the program is connected to the GPS select **File>Load From>File.**
4. Locate the correct device and select the correct file. Before downloading, in **DNR Garmin Properties** leave the **Fields to Use** set to **type-symbol, altitude,** and **model.**
5. Use **save as** to create two copies of these data, one as a line feature class in the observers geodatabase (*WHCR_SOP_mmddyy_obs1.gdb*) and the other as a point text file. Each observer should have a track log saved geospatially, and a redundant text file.
   a. *track_mmddyy_dp1_obs1 (feature class)*
   b. *track_mmddyy_dpi_obs1.txt*

Data transcription and attribution

1. Steps 2–14 describe data transcription and attribution of whooping crane detections (i.e., the points feature).
2. **Open** ArcMap and using the **Add Data** icon , add the *survey_mmddyy_obs1* feature class.
   Note: *The second observer should add survey_mmddyy_obs2.*
3. **Right-click** on *survey_mmddyy_obs1* and choose **Open Attribute Table**.
   

4. To protect data integrity, **copy** the *OBJECTID* field into the *ORIGINAL_ID* field by right-clicking on the *ORIGINAL_ID* column heading, and choosing the **Field Calculator**.
   

5. In the **Field Calculato**r under **Fields**, **double-click** on *OBJECTID* so it appears in the text box. **Click OK**.
   

6. After confirming the *OBJECTID* was copied to the *ORIGINAL_ID* field, **label by** the *OBJECTID* field.
7. **Open** the **Editor toolbar** by clicking on the **Editor toolbar** icon . On the **Editor toolbar**, **click** the black arrow beside **Editor>Start Editing**. Choose the *survey_mmddyy_obs1* feature.
   Note: *Observer 2 will choose the survey_mmddyy_obs2 feature.*

8. Each observer will transcribe the data from their voice recordings into the corresponding fields in the feature class attribute table (i.e., *WHITE, JUVEN, UNK*). The observer will update the *WHITE, JUVEN, UNK, OBSERVER, TRANSECT_ID, Type, and COMMENTS* fields. After entering this information per point, save the edits by clicking **Editor>Save Edits**.
9. While listening to the survey audio files, listen for the point number (the *OBJECTID*), whether it was the start or end of a transect, or if the point is a crane observation like "*2 White" "1 Juvenile", "1 Unknown*." Enter the data into the appropriate fields.
   <u>***Note:*** *If there are zero (0) whooping cranes for a particular age-class, enter "0" do not leave blank.*</u>
10. Listen for and enter the transect from which each observation was made from into the *TRANSECT_ID* field of the feature class.
    Note: *If the observer knows the observation was closer to an adjacent transect, the observer should indicate that in the NEAR_PROBLEM field.*
11. Complete the *DATE_* and *OBSERVER* fields in the feature class using field calculator. For date type enter *MM/DD/YYYY*. For observer, use three letter initials (e.g., *dpi* or *bns*).
12. Complete the *Type* field by choosing if the point was the start or end of a transect, cranes, cranes off-transect, or an error like an accidental click.
    Note: *If cranes were detected while the aircraft was turning and not while flying the transect line, those detections should have the* ***Type field*** *as* ***off-transect****.*
13. In the *COMMENTS* enter additional information if necessary (e.g., SSF).
14. When finished transcribing all of the data, perform a final **Save Edits** and **Stop Editing**.

Note: *Steps 15–18 describe data transcription and attribution of the survey conditions table. This table contains information about the survey-specific conditions for each flight.*

15. **Open** the *flight_mmddyy.dbf* in ArcMap.
16. Under the **Editor tool**, select **Start Editing**.
17. Enter the information described in the "Survey-specific conditions data" section in Element 5.
18. When completed, under the **Editor tool**, select **Save Edits**, then **Stop Editing**.

Standard Operating Procedure 3: Post-flight Data Processing and Formatting

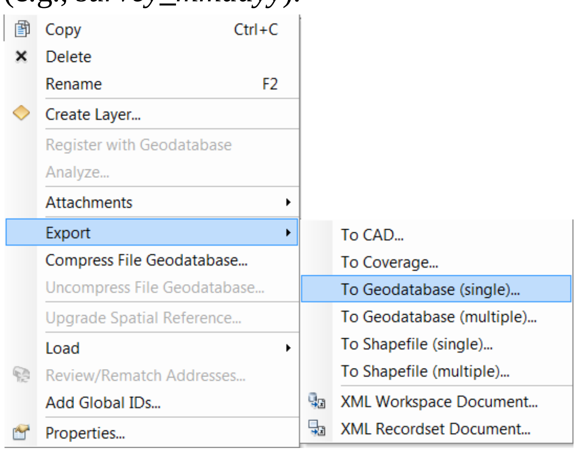
UNDERSTANDING THIS DOCUMENT

- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin)
- *Italicized* text indicates background information, a filename, or a field name.
- When filenames have an *_mmddyy_* or an *_obs1* this would be updated to reflect the date the survey was conducted for *_mmddyy_*, and *_obs1* or *_obs2* is the observer's initials.
- SOP written for a Windows 7 environment.

After each observer has completed SOP 2 Data Transcription and Attribution, only 1 of the 2 observers should completed the remaining steps. Ensure that the WHCR_SOP_mmddyy_template.gdb has been copied from \im_surveys\...\WHCR_aerial_surveys\data\yyyy-yyyy\RO_templates into WHCR_aerial_surveys\data\yyyy-yyyy\geodata and renamed WHCR_SOP_mmddyy.

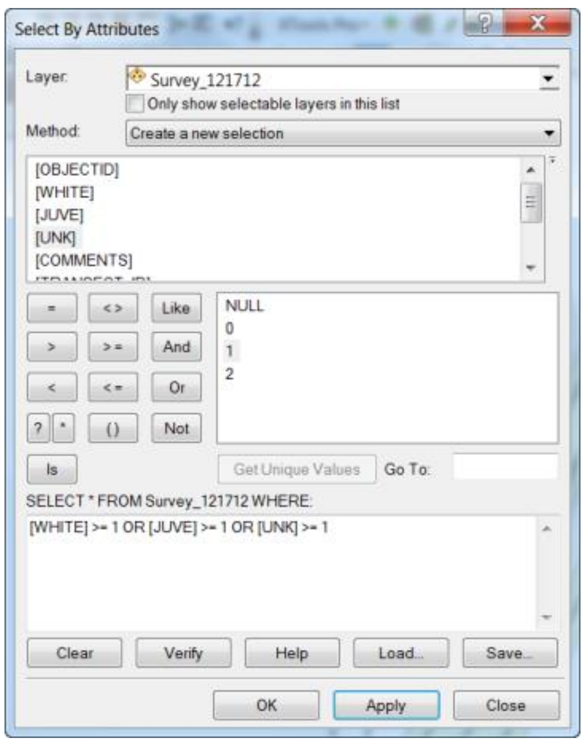
Exporting the whooping crane observation dataset

1. In ArcCatalog, from the 1st observer's geodatabase (e.g., *WHCR_SOP_mmddyy_dpi)* export the obs1 point feature classes (e.g., *survey_mmddyy_dpi*) to the *WHCR_SOP_mmddyy.gdb* geodatabase by **right clicking** on the feature class and selecting **Export>To Geodatabase (single)**. Name the exported feature class to represent the finalized survey feature class (e.g., *survey_mmddyy*).



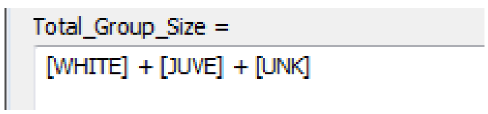
2. In ArcCatalog, go to *WHCR_SOP_mmddyy.gdb*, **right-click** on the newly imported feature class *survey_mmddyy* and select **Load>Load Data**.
3. The **Simple Data Loader** will appear. **Click Next** on the introduction screen. In the Input data screen, click on the folder icon, and browse to the 2nd observer's geodatabase (e.g.,*WHCR_SOP_mmddyy_bns*), and the survey feature class (e.g., *survey_mmddyy_bns*). A user may have to click on **Folder Connections** in order to browse to the proper location.

4. In the **Simple Data Loader's** Input data screen, click **Add** to have the source data path appear in the text box under **List of source data to load**, and **click Next**.
5. Confirm **I do not want to load the features into a sub-type** is chosen. **Click Next**.
6. Confirm the **Target and Matching Source** fields are correct and **Load all of the source data**.
7. Repeat steps 2–6 for the primary GPS unit track log. Use only the primary GPS unit track lines unless the primary GPS unit failed during the survey. Do **not** use both primary and redundant GPS track logs.
8. In ArcMap, **Add** the finalized survey feature class from step 6. This should be *WHCR_SOP_mmddyy.gdb>survey_mmddyy*.
9. **Right-click** on *survey_mmddyy* and **Open Attribute Table**.
10. Sort the attribute table by the *WHITE*, *JUVEN*, and *UNK* fields.
    Click on **Selection>Select by Attributes** and enter the following
    WHITE >= 1 OR JUVE >=1 OR UNK >=1.



11. **Export** all of the selected records for which cranes were detected by **right-clicking** on *survey_mmddyy* and choosing **Data>Export Data**. The exported data shall be saved into *WHCR_SOP_mmddyy.gdb* as a feature class named *cranes_mmddyy*.
    Note: *Cranes for SSF will be exported separately and named cranes_mmddyy_ssf. Complete remaining steps for cranes_mmddyy_ssf until the section on Measuring distance to whooping crane detections on page 69.*

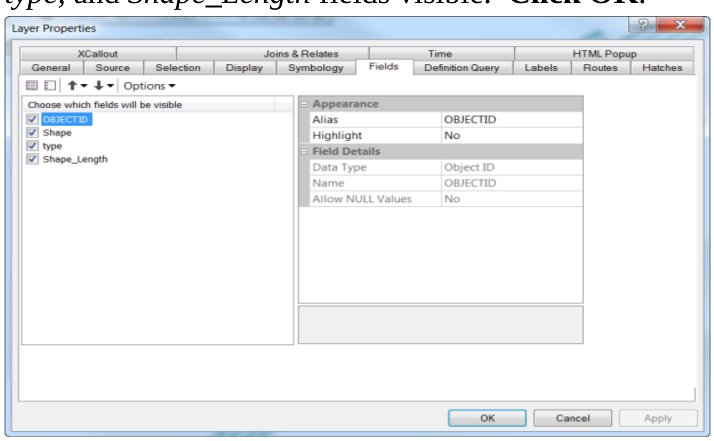
12. Examine the *Comments*, *Type*, and *Near_Problems* fields for detections that occurred “off transect.” **Delete** “off transect” detections from the *cranes_mmddyy* feature class.
    Note: *These are the detections usually made while the aircraft is turning to start a new transect. These detections were not made during the actual transect flight. Users may need to complete step 12 after clipping the flight lines.*
    Note: *These whooping crane observations are not lost during this step since they are still available in the survey_mmddyy feature.*
13. **Open** the attribute table, and **right-click** on the *Total_Group_Size*, and choose the **Field Calculator.**
14. In the **Field Calculator** enter [WHITE] + [JUVE] + [UNK].



15. **Click OK**. The *Total_Group_Size* is calculated. If there are null values, change the <Null> values in the *WHITE*, *JUVENILE*, or *UNKNOWN* fields to zero, 0.

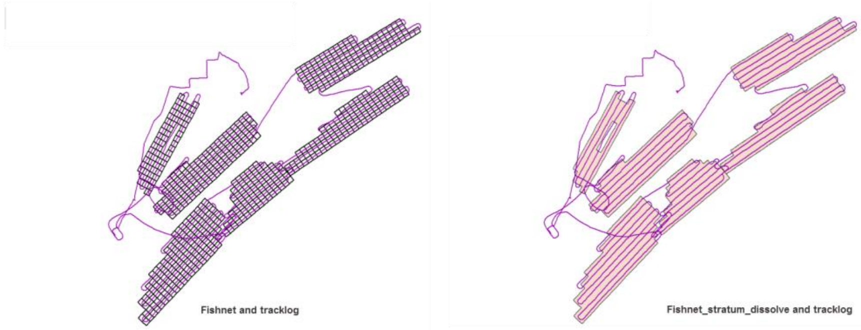
Clipping the flight lines

1. **Open** ArcMap, add the *track_mmddyy* feature class, **right-click** on it and **open** the attribute table.
   Note: *These steps will be completed for both PSF and SSF transects.*
2. If the DNR Garmin fields are part of the attribute table, **right-click** on *track_mmddyy*>**Properties>Fields**.
3. In the **Choose which fields will be visible**, leave only the *OBJECTID*, *Shape*, *type*, and *Shape_Length* fields visible. **Click OK**.

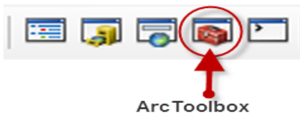


4. **Add** the *fishnet_primary_dissolve* feature class. If working with the SSF add *fishnet_secondary_dissolve.*
   Note*: fishnet_dissolve is the term used in the SOP, but can represent either primary or secondary.*
5. The fishnet **clip** method allows for clipping the tracklog line shapefile using the *fishnet_dissolve*. The graphic below shows the fishnet in black with the tracklog

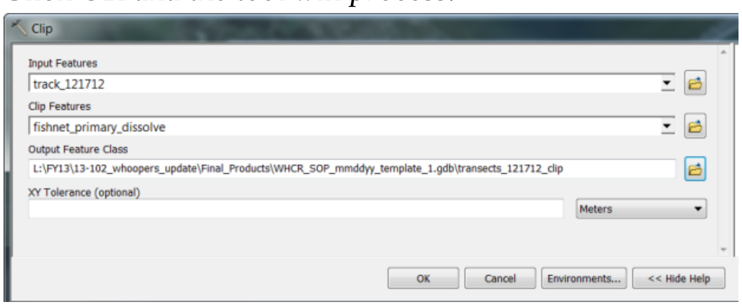
in purple. The *fishnet_dissolve* is the fishnet dissolved on the stratum field. It is this file which will be used to **clip** the tracklog line shapefile.



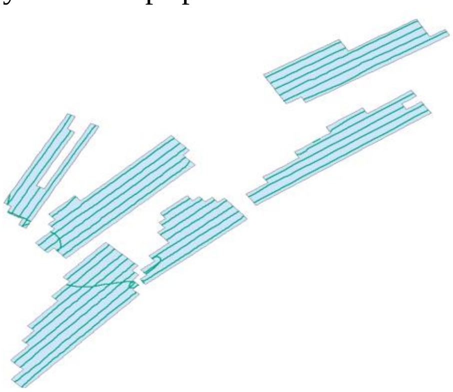
6. In ArcMap, to clip the tracklog by the fishnet, **open ArcToolbox**.



7. In **ArcToolbox**, **click** on **Analysis Tools>Extract>Clip**.
8. In the **Clip** tool enter:
    a. *Input Features = track_mmddyy*
    b. *Clip Features = fishnet_dissolve*
    c. *Output Feature Class = transects_mmddyy_clip (in the same geodatabase).*
    d. *XY tolerance = blank*
    e. ***Click OK** and the tool will process.*

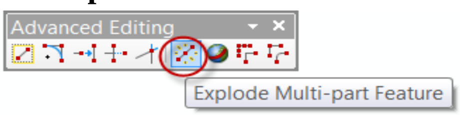


9. The new feature class should be added to the ArcMap Table of Contents, and will display in the map space with a similar view to the graphic.

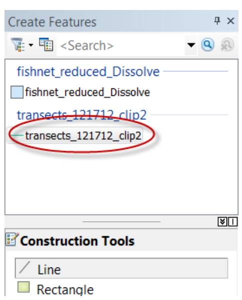


10. **Right-click** on the *transects_mmddyy_clip*, and **open the attribute table**. There should be one record as the clipped feature is a multipart feature.
11. **Right-click** on *transects_mmddyy_clip* layer again. **Choose Selection>Select All**.
12. On the **Editor toolbar>Start Editing**. **Choose** the *transects_mmddyy_clip*.
13. In the **Create Features** box that may appear on the right side of the screen, **click** on the *transects_mmddyy_clip* (if it is not listed under **Create Features**, build a template for it using the **Organize Templates** icon).

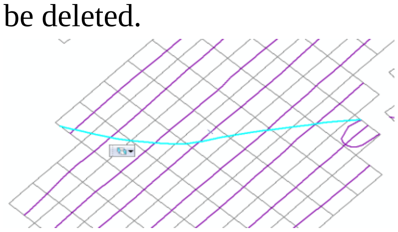
14. **Click Editor>More Editing Tools>Advanced Editing**.
15. Confirm the clipped transects are selected. With transects selected, **click Explode Multi-part Feature** from the **Advanced Editing** toolbar.



16. Review the clipped transects attribute table. It should have increased from one record to many records.
17. **Right-click** on the *transects_mmddyy_clip*. **Choose Selection>Make the only selectable layer**.
18. In the **Create Features** box, confirm that the clipped transects are highlighted.

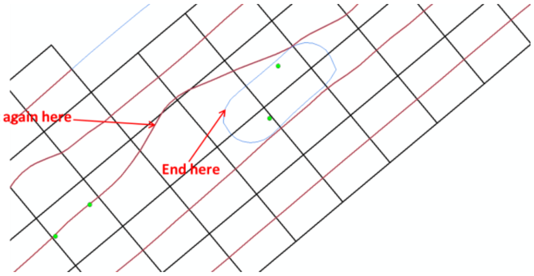


19. Review the clipped transects looking for turn areas. **Select** those lines and **press** the ***Delete*** key on the keyboard to delete each of these lines that are not the surveyed transects. Be sure to remove all of the non-transects as leaving a line that is not a transect will affect the Spatial Join in step 22. If there are more records than the number of transects flown, then non-transects remain that need to be deleted.



Note: *In some rare cases, the split tool on the Editor toolbar may have to be used if the flown transects started or stopped within the fishnet due to in-flight issues. Indicate these instances in the metadata of this feature class.*

__Note:__ In some rare cases, the aircraft may have veered extremely far from transect. Consult the RO staff on editing the transect in such cases.



20. On the **Editor Toolbar>Save Edits>Stop Editing**.
21. **Add** *transects_ideal.*

    ***Note:** If this is a SSF area, these will be secondary transects.*
22. **Label** each transect according to the "ideal" transect labels (those found in the *transects_ideal* feature class) using the **Spatial Join** in **ArcToolbox**. **Open ArcToolbox>Analysis Tools>Overlay>Spatial Join.** Set the following parameters:
    a. *Target Features = transects_mmddyy_clip*
    b. *Join Features = transects_ideal*
    c. *Output Feature Class = set to the working geodatabase (WHCR_SOP_mmddyy) and name transects_mmddyy*
    d. *Join Operation = Join One to One*
    e. *Check "Keep All Target Features"*
    f. *Match Option = Intersect*
    g. *Search Radius = 50 m*
23. **Open** the *transects_mmddyy* attribute table, confirm that the transects received the proper *transect_id*. Does it compare to the transcribed transect?
24. If there any null *transect_ids* in the attribute table, highlight each of those records, and determine if a non-transect line was not deleted back in Step 19. If that is the case, **delete** them.

    ***Note:** For all SSF files, proceed to SOP 6.*

Measuring distance to whooping crane detections

For PSF areas, the perpendicular distance between observer and the observed whooping crane(s) is necessary for distance sampling analysis. Usually cranes are detected from the transect they are nearest to (i.e., <500 m from the transect). However, occasionally survey conditions allow for increased visibility and whooping cranes are detected when they are nearer to an adjacent transect (i.e., >500 m from the transect). Comparing the OBJECTID of each observation to the plotted locations at the end of each transect will correctly identify which transect each observation was made from.

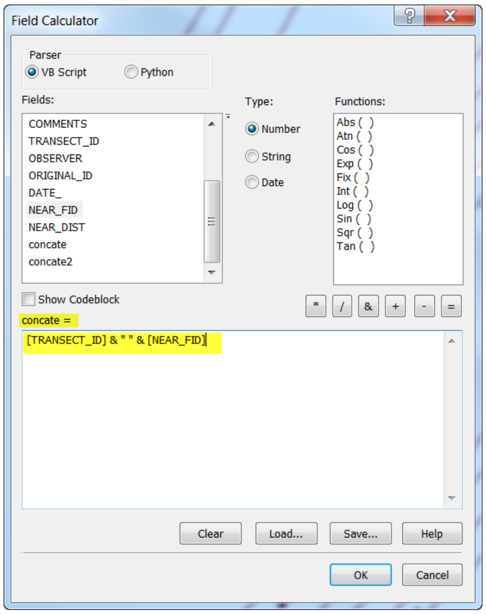
1. In **ArcToolbox, click Analysis Tools>Proximity>Near**
    i. *Input features = cranes_mmddyy*

ii. *Near features = transects_mmddyy* ***(confirm it is that survey date's transects, not the ideal_transects).***

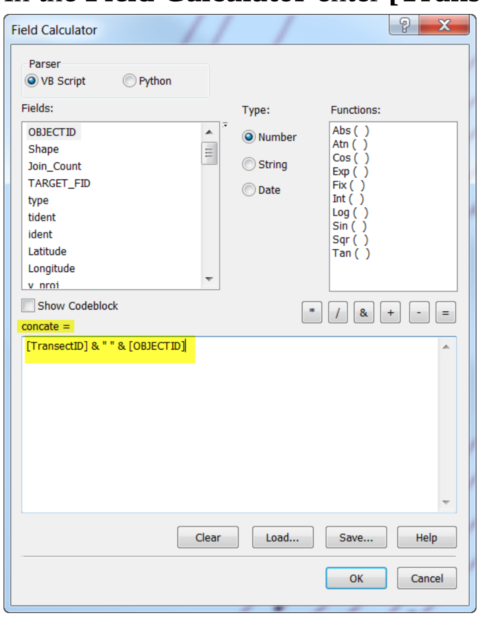
iii. *Search Radius = 1000 meters*

iv. *Leave Location and Angle unchecked.*

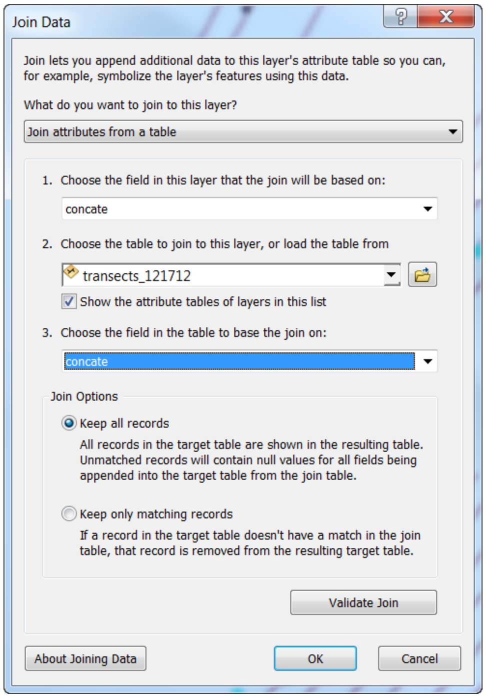
2. **Open** the attribute table of *cranes_mmddyy*.
3. **Add** a **text** field called *concate*. Set the **field length** to 25.
4. **Right-click** on the *concate* field and **click** the **Field Calculator**.
5. In the **Field Calculator** enter **[TRANSECT_ID] & " " & [NEAR_FID]**.



6. **Open** the *transect_mmddyy* attribute table.
7. **Add** a **text** field called *concate*. Set the **field length** to 25.
8. **Right-click** on the *concate* field, and **click** the **Field Calculator**.
9. In the **Field Calculator** enter **[TransectID] & " " & [OBJECTID]**.



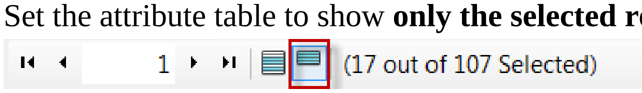
10. **Right-click** on *cranes_mmddyy*>**Joins and Relates**>**Join**.
11. In the join attributes from a table screen, **join** the *cranes_mmddyy* to the *transects_mmddyy* based on the *concate* field. **Keep all records**, and choose **No** when asked to **Create Index**.



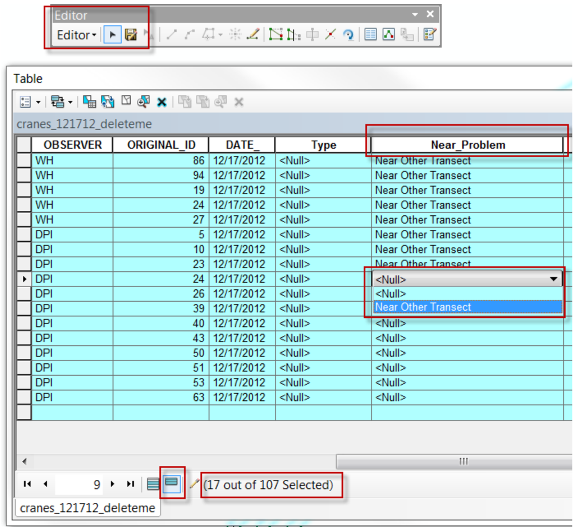
12. In the *cranes_mmddyy* attribute table, **scroll over** to the joined *concate* field (most likely the last column).
13. **Sort Ascending** the joined *concate* field. Do any NULLs appear? The NULLs will be where the closest, but incorrect transect was used by the **Near** tool in step 1 to assign the *TRANSECT_ID* to the crane locations.
    Note: *These are the NEAR_PROBLEM observations. If there are not any NULLs SOP3 is complete, go to SOP4.*

Attributing the near distance problems

1. **Select** the NULLs in the joined *concate* field.
2. Set the attribute table to show **only the selected records** for the *cranes_mmddyy*.



   a. Start editing the *cranes_mmddyy*, and use the drop-down choice for the *Near_Problem* field. This standardizes the text in the *Near_Problem* field.



b. **Save** Edits.

c. **Stop** Editing.

d. Open the *cranes_mmddyy* attribute table, and **select** "Near Other Transects" records in the *Near_Problem* field.

e. **Set** the attribute table to **Show selected records** again before proceeding.

f. Confirm that it is only the *cranes_mmddyy* that has selected records.

3. **Open ArcToolbox>Analysis>Proximity>Generate Near Table**.

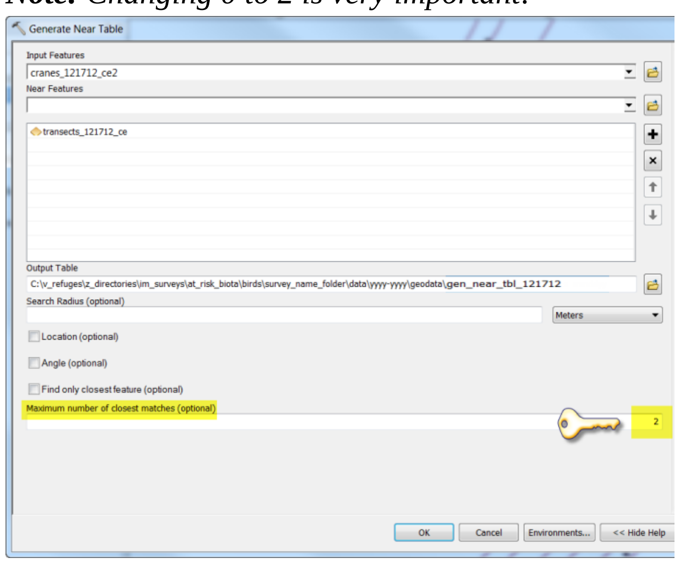
a. *Input Features = cranes_mmddyy (selected records only)*

b. *Near Features = transects_mmddyy (no records should be selected)*

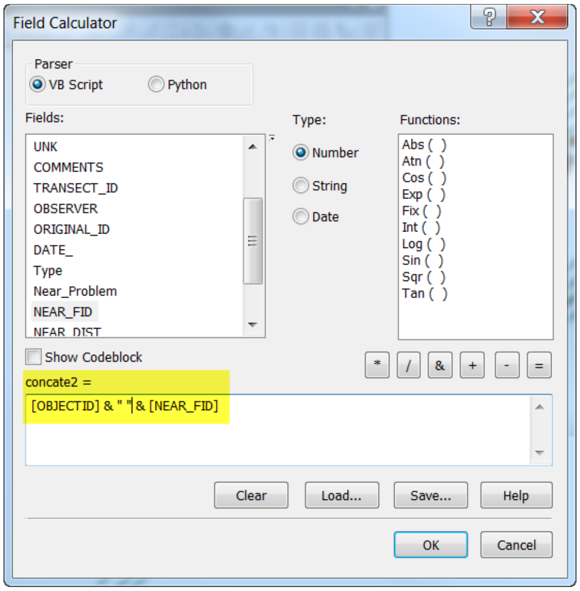
c. *Name the output table gen_near_tbl_mmddyy.*

d. *Uncheck "Find only closest feature (optional)"*

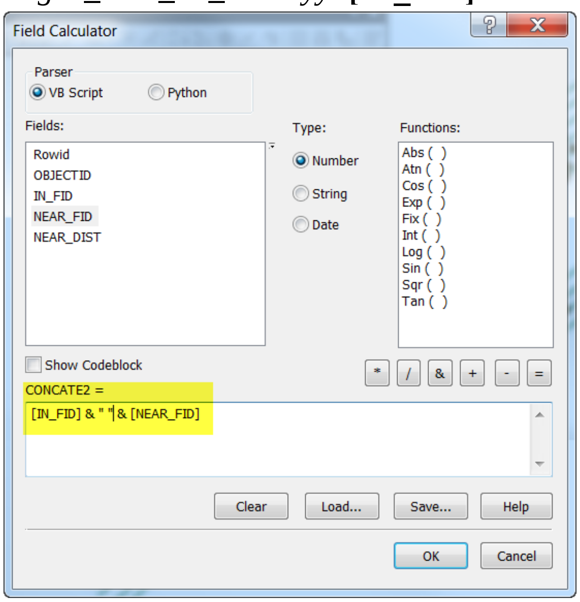
e. *Change 0 to 2 for the "Maximum number of closest matches (optional)"* ***Note:*** *Changing 0 to 2 is very important!*



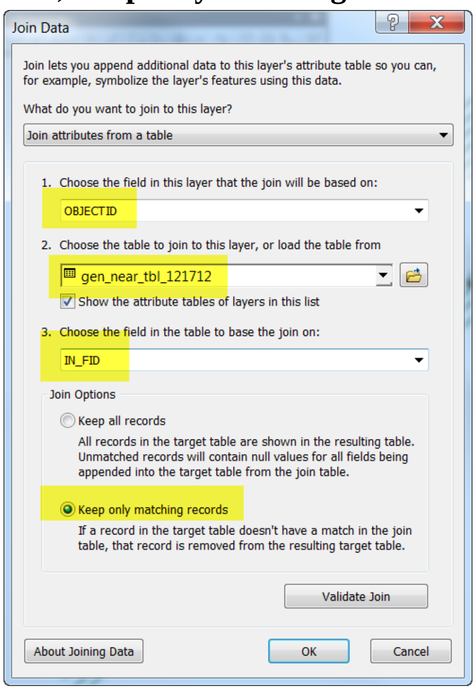
4. The *gen_near_tbl_mmddyy* table is showing the closest two transects to a crane point. After the table is created it will appear in the ArcMap table of contents. **Open** the *gen_near_tbl_mmddyy* table and **hide** the *Object_ID* field. In this table, the *IN_FID* is the *OBJECTID* from *cranes_mmddyy*. The *Near_FID* is the *OBJECTID* from *transects_mmddyy*, and the *NEAR_DIST* is the distance to the crane point from the transect in the *NEAR_FID*.
5. **Remove** the **join**.
6. Build a *concate2* field in both the *cranes_mmddyy* and *gen_near_tbl_mmddyy* as **text**, and **field length** 25.
7. Calculate the *concate2* field as:
   a. In *cranes_mmddyy*: **[OBJECTID] & " "& [NEAR_FID]**



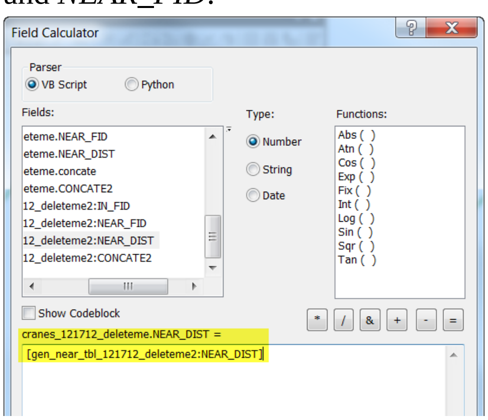
   b. In *gen_near_tbl_mmddyy*: **[IN_FID] & " " & [NEAR_FID]**

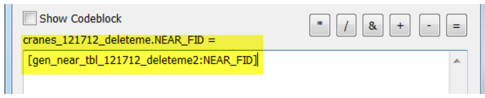


8. **Click** on the *gen_near_tbl_mmddyy*, and **join** the *cranes_mmddyy* to it based on the concate2. **Keep only matching records**.
__Note:__ The resulting table contains only matching records. These matching records are the ones that need to be deleted (see step 9) because the non-matching records contain the correct distance measurements.
9. **Start Editing, Select all** the records in the *gen_near_tbl_mmddyy*, and **delete** the records that match from *gen_near_tbl_mmddyy*. **Save Edits**, and **Stop Editing**.
__Note:__ This step does not remove all the records from the gen_near_tbl_mmddyy as it appears because the join in step 9 is based only on matching records.
10. **Remove** the **join**, and show all the records remaining in *gen_near_tbl_mmddyy*.
11. **Right-click** on the *cranes_mmddy*, and **Join** the *gen_near_tbl_mmddyy* to the *cranes_mmddyy* based on the crane *OBJECTID* and *gen_near_tbl_mmddyy's IN-FID*, **Keep only matching records.**

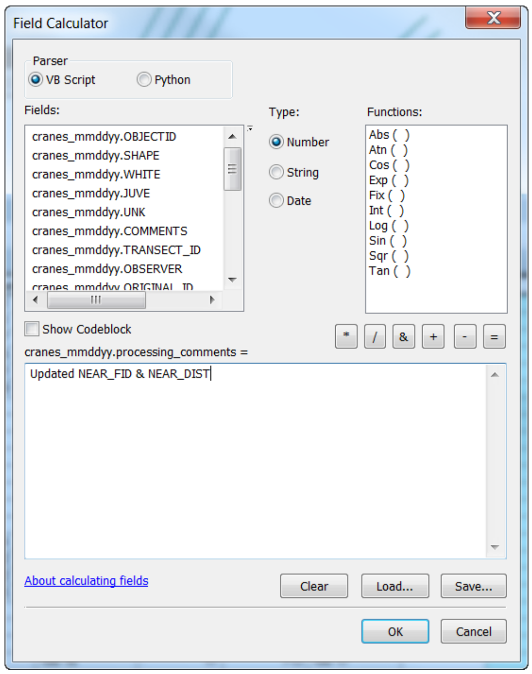


12. Use the **field calculator** in the *cranes_mmddyy* to add in the correct *NEAR_DIST* and *NEAR_FID*.





12. **Remove** the join.
13. **Add** a **text** field called *processing_comments* to *cranes_mmddyy*. Set the **field length** to 50.
14. **Select** for the *Near Problems*.
15. Update the *processing_comments* field using the **field calculator** to reflect the corrections to distance measurements made above (i.e., “Updated NEAR_FID & NEAR_DIST”).



Standard Operating Procedure 4: Creating Text Files for Analyses

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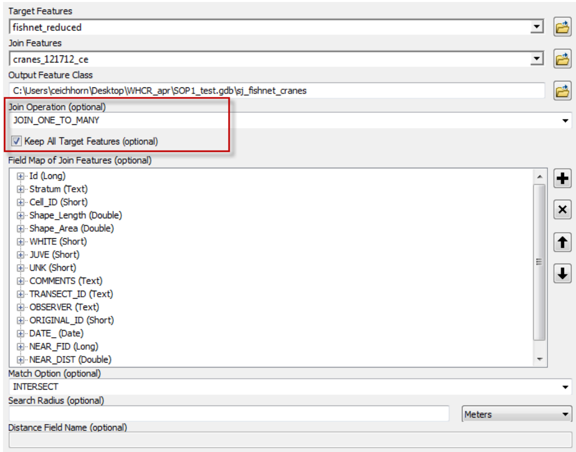
UNDERSTANDING THIS DOCUMENT

- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin).
- *Italicized* text indicates background information, a filename, or a field name.
- When filenames have an *_mmddyy_* or an *_obs1* this would be updated to reflect the date the survey was conducted for *_mmddyy_*, and *_obs1* or *_obs2* is the observer's initials.
- SOP written for a Windows 7 environment.

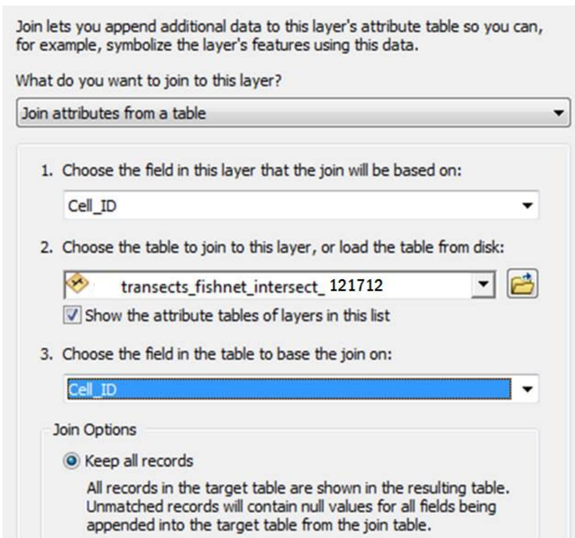
Once the corrections to the near distance have been made, create two files for export. These files will be for hierarchical distance sampling (HDS_mmddyy) in Program R and conventional distance sampling analysis (CDS_mmddyy) in Program Distance.

Creating the HDS file

1. **Open ArcToolbox>Analysis Tools>Overlay>Intersect**.
    a. *Input Features = transects_mmddyy and fishnet*
    b. *Output Feature Class = transects_fishnet_intersect_mmddyy*
    c. *JoinAttributes = All*
    d. *XY Tolerance = (Blank)*
    e. *Output Type = Input*
2. **Right-click** on *transects_fishnet_intersect_mmddyy* once it is added to ArcMap, **click** on **Properties>Fields** tab. Make only the following fields visible: *OBJECTID*, *Shape*, *TransectID*, *Stratum*, and *cell_id*.
3. **Add** a **new field** to *transects_fishnet_intersect_mmddyy* named *Length_HDS* as **Double**.
4. **Right-click** on *Length_HDS*, and **Calculate Geometry** set to meters and property set to length. Steps 1–4 results in a linear feature class with cell ids and length of transect in each cell.
5. To create a file with all of the fishnet cells attributed with whooping crane detections, **Open ArcToolbox>Analysis>Overlay>Spatial Join**.
6. In the **Spatial Join Tool**:
    a. *Target Features = fishnet*
    b. *Join Features = cranes_mmddyy*
    c. *Output Feature Class = sj_fishnet_cranes_HDS1_mmddyy*
    d. *Join Operation = JOIN_ONE_TO_MANY*
    e. *Keep All Target Features*
    f. *Match Option = Intersect*



7. **Open** the attribute table of the *sj_fishnet_cranes_HDS1_mmddyy*.
8. **Join** the *transects_fishnet_intersect_mmddyy* to the *sj_fishnet_cranes_HDS1_mmddyy* based on the *Cell_ID* field.

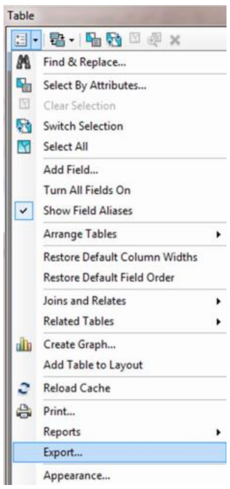


9. The resulting table should still have the same number of records. Use the *Join_Count* field to determine which records should have crane values (1) or no crane values (0). Check the *cell_ids* that should have two or more records; this will help you confirm the join was done correctly.

OBJECTID *	Shape *	Join_Count	DATE_	TransectID	Cell_ID	length_m	OBSERVER	WHITE	JUVENILE	UNKNOW	NEAR_DIST	Stratum	TRANSECT_ID	Cell_ID
525	Polygon	1	12/17/201	SJ3	579	1000.000801	WH	2	0	<Null>	41.403486	SanJoseIsla	SJ3	579
534	Polygon	1	12/17/201	SJ2	588	1000.000833	WH	2	0	<Null>	445.735884	SanJoseIsla	SJ2	588
542	Polygon	1	12/17/201	SJ2	596	1000.000869	DPI	2	1	0	442.567061	SanJoseIsla	SJ1	596
543	Polygon	1	12/17/201	SJ2	596	1000.000869	DPI	2	1	0	475.660113	SanJoseIsla	SJ2	596
544	Polygon	1	12/17/201	SJ2	596	1000.000869	DPI	2	1	0	442.567061	SanJoseIsla	SJ2	596
546	Polygon	1	12/17/201	SJ8	598	1000.000832	DPI	2	1	0	261.050861	SanJoseIsla	SJ8	598
548	Polygon	1	12/17/201	SJ6	600	1000.000801	DPI	2	1	0	43.766731	SanJoseIsla	SJ6	600
1	Polygon	0	<Null>	BJ6	2	999.999991	<Null>	<Null>	<Null>	<Null>	<Null>	Blackjack	<Null>	2
2	Polygon	0	<Null>	BJ6	3	999.999994	<Null>	<Null>	<Null>	<Null>	<Null>	Blackjack	<Null>	3
3	Polygon	0	<Null>	BJ6	4	1000.000026	<Null>	<Null>	<Null>	<Null>	<Null>	Blackjack	<Null>	4
4	Polygon	0	<Null>	BJ6	5	999.999994	<Null>	<Null>	<Null>	<Null>	<Null>	Blackjack	<Null>	5
5	Polygon	0	<Null>	BJ6	6	999.999957	<Null>	<Null>	<Null>	<Null>	<Null>	Blackjack	<Null>	6
6	Polygon	0	<Null>	BJ6	7	1000.000062	<Null>	<Null>	<Null>	<Null>	<Null>	Blackjack	<Null>	7
7	Polygon	0	<Null>	BJ6	8	999.999957	<Null>	<Null>	<Null>	<Null>	<Null>	Blackjack	<Null>	8

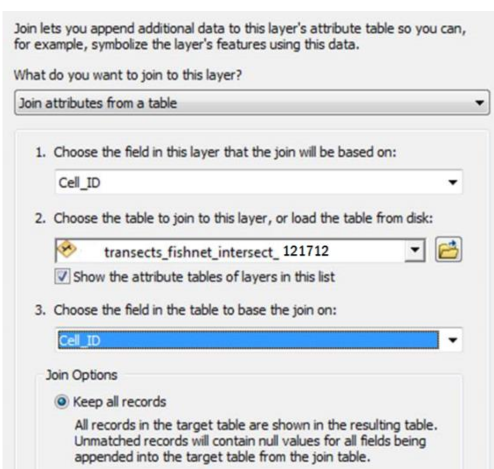
10. **Right-click** on *sj_fishnet_cranes_HDS_mmddyy*>**Properties>Fields**.

11. In the **Choose which fields will be visible**, leave only the *Cell_ID*, *WHITE*, *JUVENILE*, *UNKNOWN*, *COMMENTS*, *Transect_ID*, *OBSERVER*, *DATE_*, *Total_Group_Size*, *NEAR_FID*, *NEAR_DIST*, and *Length_HDS* fields visible. **Click OK**.
    Note: *There will be 2 Cell_ID fields; they contain duplicate data so choose the first one.*
12. **Export** the attribute table created by the spatial join in steps 6–9 as both a geodatabase table and a text file. Both of these will be named *HDS_mmddyy*. The text file will be stored in the *Data>Spreadsheets* folder, and the geodatabase table in the *WHCR_SOP_mmddyy.gdb*. Be sure to include *.txt* in file name when saving the text file.



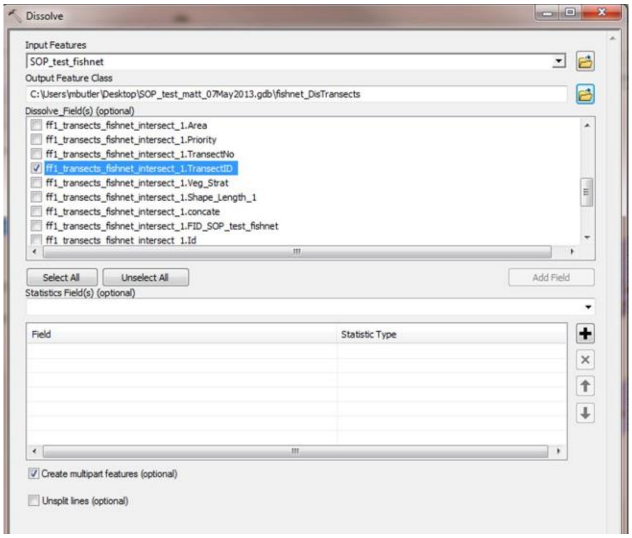
Creating the CDS file

1. **Open** the attribute table for *transects_mmddyy*.
2. **Add** a **new field** named *Length_CDS* as **Double**.
3. **Right-click** on *Length_CDS*, and **Calculate Geometry** set to meters.
4. **Join** the *transects_fishnet_intersect_mmddyy* to *fishnet* based on the *Cell_ID* field.

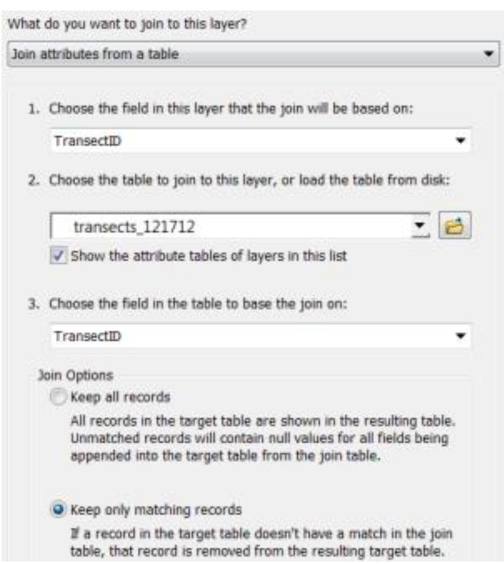


5. **Open ArcToolbox>Data Management Tools>Generalization>Dissolve**:

a. *Input Features = fishnet*
b. *Output Feature Class = fishnet_DisTransects_mmddyy*
c. *Dissolve_field(s) = TransectID*



6. To create a file with all of the transects attributed with whooping crane detections, **Open ArcToolbox>Analysis>Overlay>Spatial Join**.
7. In the **Spatial Join Tool**:
   a. *Target Features = fishnet_DisTransects_mmddyy*
   b. *Join Features = cranes_mmddyy*
   c. *Output Feature Class = sj_fishnet_cranes_CDS1_mmddyy*
   d. *Join Operation = JOIN_ONE_TO_MANY*
   e. *Keep All Target Features*
   f. *Match Option = Intersect*
8. **Open** the attribute table of the *sj_fishnet_cranes_CDS1_mmddyy*.
9. **Join** the *transects_mmddyy* to the *sj_fishnet_cranes_CDS1_mmddyy* based on the *TransectID* field.



10. **Right-click** on *sj_fishnet_cranes_CDS1_mmddyy* **>Properties>Fields**.
11. In the **Choose which fields will be visible**, leave only the *WHITE*, *JUVE*, *UNK*, *COMMENTS*, *OBSERVER*, *DATE_*, *TransectID*, *Total_Group_Size, NEAR_FID, NEAR_DIST,* and *Length_CDS* fields visible. **Click OK**.
    Note: Be sure that the TransectID not the Transect_ID field is selected.
12. **Export** the attribute table created in step 11 as both a geodatabase table and a text file. Both of these will be named *CDS_mmddyy*. The text file will be stored in the *Data>Spreadsheets* folder. Be sure to include *.txt* in file name when saving the text file.

Standard Operating Procedure 5: Data Preparation for Hierarchical Distance Sampling Analyses using `Unmarked`

UNDERSTANDING THIS DOCUMENT

- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin).
- *Italicized* text indicates background information, a filename, a field name, or a R dataframe.
- Text in `Lucidia Console` font indicates it is a function, package, library, or a directly executable command line (i.e., can be copied and paste into the command prompt in the software) in Program R.
- SOP written for a Windows 7 environment.

Consult Regional Biometrician to determine if the Refuge staff will complete this SOP, or if the Regional Office I&M staff will complete this SOP. Regardless, NWR staff will complete SOP6 for data archiving.

Formatting data for hierarchical analysis in Program R

- SEVEN DATAFRAMES ARE NEEDED TO CONDUCT HIERARCHICAL DISTANCE SAMPLING (HDS) ANALYSES USING PACKAGE `unmarked`
    1. Distance dataframe (*DIST*): describes the distances to each detected group of whooping cranes each fishnet cell surveyed in the primary sampling frame.
    2. Transect lengths dataframe (*LENGTHS*): contains the total length of transects surveyed for each fishnet cell in the primary sampling frame.
    3. Covariate dataframe (*COVS*): contains descriptive covariates for each fishnet cell surveyed in the primary sampling frame.
    4. Planning dataframe (*PLANNING*): contains descriptive covariates for each fishnet cell of a large-scale prediction grid for planning activities.
    5. Group Size by Distance dataframe (*DISTGROUP*): links the size of each detected whooping crane group in the primary sampling frame with the distance at which it was detected.
    6. Recruitment dataframe (*JUVS*): describes whether a group in the primary sampling frame contained an adult pair or juvenile(s).
    7. Group Size dataframe (*GROUP*): contains data about group structure (i.e., number of juveniles and adults) for each detected group in the primary sampling frame.
- IMPORTING THE *HDS_MMDDYY.TXT* FILES INTO PROGRAM R
    1. **Copy** each *HDS_mmddyy.txt* file for a survey winter (i.e., winter 2012–2013) into a working directory (i.e., *c:\...\ 2012-2013\analysis*).
    2. **Open** Program R using the RStudio interface.

3. **Set** the working directory (**optional**):

```
setwd("C:/folder/folder/winter_2012_2013")
```

4. **Load** each survey's data file (i.e., *HDS_mmddyy.txt*) and **name** them sequentially (e.g., *HDS1* through *HDS6*).

```
HDS1=read.delim("HDS_121412.txt",header=T,sep=",",na.strings="")
HDS2=read.delim("HDS_121512.txt",header=T,sep=",",na.strings="")
HDS3=read.delim("HDS_121712.txt",header=T,sep=",",na.strings="")
HDS4=read.delim("HDS_121812.txt",header=T,sep=",",na.strings="")
HDS5=read.delim("HDS_121912.txt",header=T,sep=",",na.strings="")
HDS6=read.delim("HDS_122212.txt",header=T,sep=",",na.strings="")
```

5. The date is not populated for each data row in ArcMap. Use the following code to populate each row with the survey date. Do this for each survey's dataframe.

```
HDS1$DATE_=(na.omit(HDS1$DATE_))[1]
HDS2$DATE_=(na.omit(HDS2$DATE_))[1]
HDS3$DATE_=(na.omit(HDS3$DATE_))[1]
HDS4$DATE_=(na.omit(HDS4$DATE_))[1]
HDS5$DATE_=(na.omit(HDS5$DATE_))[1]
HDS6$DATE_=(na.omit(HDS6$DATE_))[1]
```

6. **Combine** all surveys into one dataframe in Program R.

```
HDS=rbind(HDS1,HDS2,HDS3,HDS4,HDS5,HDS6)
```

7. Null-values in numeric fields (i.e., *JUVE*) are inadvertently converted to zeros by ArcMap during the table export (SOP 4). To correct these values, use the following code.

```
HDS$WHITE[is.na(HDS$TRANSECT_ID)]=NA
HDS$JUVE[is.na(HDS$TRANSECT_ID)]=NA
HDS$UNK[is.na(HDS$TRANSECT_ID)]=NA
HDS$Total_Group_Size[is.na(HDS$TRANSECT_ID)]=NA
HDS$NEAR_FID[is.na(HDS$TRANSECT_ID)]=NA
HDS$NEAR_DIST[is.na(HDS$TRANSECT_ID)]=NA
```

Note: *We are currently using the* `distsamp` *function for analyses (see Appendix C–A note about generalized HDS). Therefore, all surveys conducted between 28 November–26 December will be pooled for analysis.*

- BUILDING THE DATAFRAMES NEEDED FOR DATA ANALYSIS IN PROGRAM R

  1. **Create** the distance (*DIST*) dataframe using the following code:

```
DIST=cbind(HDS$Cell_ID,HDS$NEAR_DIST)
colnames(DIST)=c("FNID","Dist")
```

```
DIST=as.data.frame(DIST)
# Sort DIST dataframe by fishnet id.
DIST=DIST[with(DIST,order(FNID)),]
```

Note: *Fishnet ID needs to be sorted ascending correctly. If cell_ids are formated as "numeric" sorting will be correct but if cell_ids are formatted as a "factor" when they are called into Program R they will not sort correctly (see column E).*

Column A	Column B	Column C	Column D	Column E
YES	YES	YES	YES	NO
1	001	a	a01	1
2	002	b	a02	10
3	003	c	b01	100
4	004	d	b02	101

2. **Create** the transect lengths (*LENGTHS*) dataframe using the following code:

```
# Get the needed columns from the combined HDS dataframe.
LENGTHS=cbind(HDS$DATE_,HDS$Cell_ID,HDS$Length_HDS)
colnames(LENGTHS)=c("occ","FNID","Length")
LENGTHS=as.data.frame(LENGTHS)
# Remove duplicate cells for a given survey occasion.
LENGTHS=unique(LENGTHS)
# Remove the occasion field.
LENGTHS=as.data.frame(cbind(LENGTHS$FNID,LENGTHS$Length))
colnames(LENGTHS)=c("FNID","Length")
# Aggregate (sum) transect lengths for each fishnet cell.
LENGTHS=aggregate(LENGTHS,by=list(LENGTHS$FNID),sum)
LENGTHS=as.data.frame(cbind(LENGTHS$Group.1,LENGTHS$Length))
colnames(LENGTHS)=c("FNID","Length")
# Sort the LENGTHS dataframe by fishnet id.
LENGTHS=LENGTHS[with(LENGTHS,order(FNID)),]
```

3. **Import** the covariates (*COVS*) dataframe using the following code (see Appendix E for creation of *COVS.txt*):

```
COVS=read.delim("COVS.txt",header=T,sep=",",
  colClasses=c(rep("numeric",3),"factor",rep("numeric",6)))
COVS=COVS[,c(2,4:10)]
# Rename the columns of the dataframe.
names(COVS)=c("FNID","BLOCK","OPENWATER","SALTMARSH",
  "SALTMARSHSHRUB","UPLAND","URBAN","WETLAND")
# Sort the COVS dataframe by fishnet id.
COVS=COVS[with(COVS,order(FNID)),]
# Make openwater quadratic.
COVS$OPENWATER2=COVS$OPENWATER^2
```

4. **Import** the planning covariates (*PLANNING*) dataframe using the following code (see Appendix E for creation of *planning.txt*):

```
PLANNING=read.delim("planning.txt",header=T,sep=",",
  colClasses=c(rep("numeric",7)))
PLANNING=PLANNING[,c(2,4:9)]
# Rename the columns of the dataframe.
names(PLANNING)=c("FNID","OPENWATER","SALTMARSH",
  "SALTMARSHSHRUB","UPLAND","URBAN","WETLAND")
# Sort the PLANNING dataframe by fishnet id.
PLANNING=PLANNING[with(PLANNING,order(FNID)),]
# Make openwater quadratic.
PLANNING$OPENWATER2=PLANNING$OPENWATER^2
```

5. **Create** the group size by distance (*DISTGROUP*) dataframe using the following code:

```
DISTGROUP=cbind(HDS$Total_Group_Size,HDS$NEAR_DIST)
colnames(DISTGROUP)=c("Size","Dist")
DISTGROUP=as.data.frame(DISTGROUP)
# Remove NAs from the dataframe.
DISTGROUP=na.omit(DISTGROUP)
# Remove observation beyond 500 m from transects.
DISTGROUP=DISTGROUP[DISTGROUP$Dist<500,]
```

Note: *Only observations made within 500 m of transects will be used to draw inference about the whooping crane population. Therefore, all detections made beyond 500 m will be removed from the DISTGROUP dataframe.*

6. **Create** the recruitment (*JUVS*) dataframe using the following code:

```
JUVS=cbind(HDS$WHITE,HDS$JUVE,HDS$NEAR_DIST)
# Remove NAs from the dataframe.
JUVS=na.omit(JUVS)
colnames(JUVS)=c("WHITE","JUVE","Dist")
JUVS=as.data.frame(JUVS)
# Remove observation beyond 500 m from transects.
JUVS=JUVS[JUVS$Dist<500,]
Juv=JUVS$JUVE>0
Pair=JUVS$WHITE>1
Pair=(Juv+Pair)>0
JUVS=as.data.frame(cbind(Juv,Pair)*1)
colnames(JUVS)=c("Juv","Pair")
```

Note: *This creates an object where the "Juv" column indicates if the group contained a juvenile whooping crane and the "Pair" column indicates if the group contained a pair of adult whooping cranes.*

7. **Create** the group size (*GROUP*) dataframe using the following code:

```
GROUP=cbind(HDS$DATE_,HDS$WHITE,HDS$JUVE,HDS$NEAR_DIST)
colnames(GROUP)=c("occ","AHY","HY","Dist")
```

```
# Remove NAs from the dataframe.
GROUP=as.data.frame(na.omit(GROUP))
# Remove observation beyond 500 m from transects.
GROUP=GROUP[GROUP$Dist<500,]
GROUP=GROUP[,1:3]
```

8. **Load** package `unmarked`.

```
library("unmarked")
```

9. Use the function `sessionInfo()` to store information about the versions of packages and libraries used in the analysis.

```
versions=sessionInfo()
```

10. Using the function `formatDistData`, organize the distance data into the multinomial format used by hierarchical distance sampling models and package `unmarked`. At this point the analyst must decide on appropriate distance interval cut-points for binning the distance data. A close examination of a histogram of the distance data (`hist(DIST$Dist)`) will help suggest appropriate cut-points; Buckland et al. (2001) also provides recommendations (i.e., binning to help reduce spiking around the centerline and to reduce heaping). All detections beyond 500 m will be truncated from the analysis since they are either outside of the sampling frame or the plot.

```
yDat=formatDistData(DIST,distCol="Dist",transectNameCol="FNID",
  dist.breaks=c(0,100,225,350,500))
```

Note: *The desired cut-points for the distance bins are specified with* `dist.breaks`.

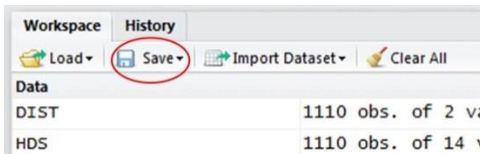
11. Once the data is **formatted** into the multinomial format using the `formatDistData` function, the distance data, covariate data, and transect lengths must be combined into one dataframe compatible with package `unmarked` using the `unmarkedFrameDS` or `unmarkedFrameGDS` function. Since we are currently limiting analysis to the `distsamp` function, only the `unmarkedFrameDS` function will be needed.

```
umf=unmarkedFrameDS(y=as.matrix(yDat),siteCovs=COVS,survey="line",
  dist.breaks=c(0,100,225,350,500),tlength=LENGTHS$Length,
  unitsIn="m")
# Take a quick look at the umf.
summary(umf)
# Check to see if number of detections is correct.
sum(na.omit(DIST$Dist<=500))==sum(yDat)
# View first few rows of data.
umf[1:20]
# Plot the distance data.
hist(umf,xlab="distance (m)",main="",cex.lab=0.8,cex.axis=0.8)
```

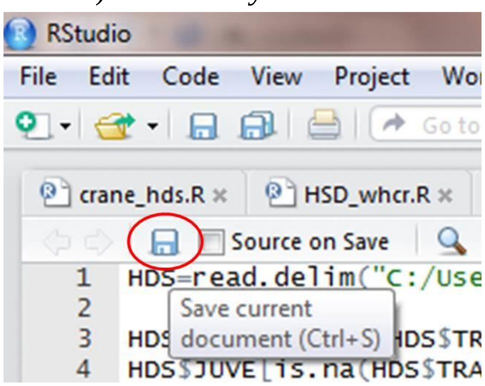
Note: *Sometimes the data may be overdispersed requiring abundance to be modeling using the negative binomial distribution. In order to fit the negative binomial, the* `gdistsamp` *function must be used and data complied using the* `unmarkedFrameGDS` *function.*

```
# Make the unmarked dataframe for gdistsamp.
umfg=unmarkedFrameGDS(y=as.matrix(yDat),siteCovs=COVS,
  survey="line",dist.breaks=c(0,100,225,350,500),
  tlength=LENGTHS$Length,numPrimary=1,unitsIn="m")
```

12. **Save** the R workspace as *HDS_dataframes_yyyy-yyyy.Rdata* (e.g., *HDS_dataframes_2012-2013.Rdata*) to the *analysis* folder.



13. **Save** the R script as *HDS_datascript_yyyy-yyyy.R* (e.g., *HDS_ datascript_2012-2013.R*) to the *analysis* folder.



14. More details concerning modeling strategies and data analyses are provided in Appendix C.

Standard Operating Procedure 6: Data Archiving

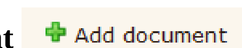
UNDERSTANDING THIS DOCUMENT

- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin, SharePoint).
- *Italicized* text indicates background information, a filename, or a field name.
- When filenames have an *_mmddyy_* or an *_obs1* this would be updated to reflect the date the survey was conducted for *_mmddyy_*, and *_obs1* or *_obs2* is the observer's initials.
- SOP written for a Windows 7 environment.

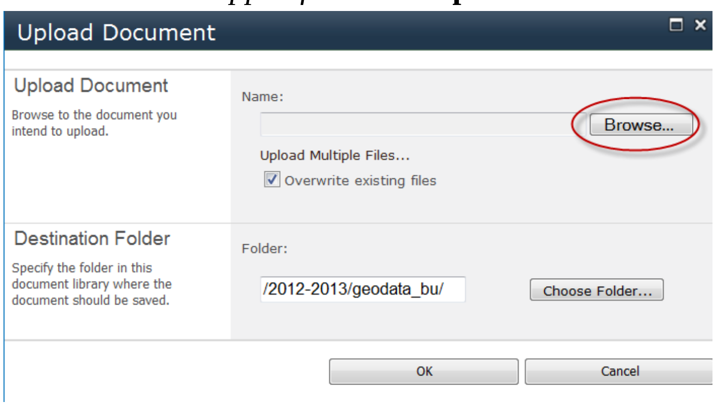
Daily archiving and backup of survey data

Once SOPs 1–4 are completed for the daily surveys, the data will be copied over to the WHCR Aerial Surveys (TX Coast) SharePoint site to provide an off-site data storage location in case a catastrophic event occurs such as server failure or hard-drive failure (see Apppendix G for full file structure). For surveys that included SSF areas those files shall be included as well.

1. For each flight the following files will be saved by date to the primary geodatabase, *WHCR_SOP_mmddyy.gdb*, the *spreadsheets or audio* folders. Observer geodatabases shall be included in the daily back-up. If SSF areas were surveyed those files should be included in the daily back-up. Intermediate feature classes and tables will be included in the *WHCR_SOP_mmddyy.gdb* for back-up as well.
    a. *gen_near_tbl_mmddyy (gdb).*
    b. *survey_mmddyy (gdb).*
    c. *cranes_mmddyy (gdb).*
    d. *transects_mmddyy (gdb).*
    e. *track_mmddyy (gdb).*
    f. *track_mmddyy.txt (spreadsheets).*
    g. *CDS_mmddyy (gdb).*
    h. *HDS_mmddyy (gdb).*
    i. *CDS_mmddyy.txt (spreadsheets).*
    j. *HDS_mmddyy.txt (spreadsheets).*
    k. *SurveyAudio_mmddyy_obs1 (audio).*
    l. *SurveyAudio_mmddyy_obs2 (audio).*
    m. *Flight_mmddyy (gdb).*
2. In **ArcCatalog**, **right-click** on the *WHCR_SOP_mmddyy.gdb*>**Copy**.
3. **Paste** the copy, and **rename** to *WHCR_SOP_mmddyy_bu.gdb*.

4. Repeat steps 2 and 3 for both of the observer geodatabases, renaming these geodatabases as *WHCR_SOP_mmddyy_obs1_bu.gdb* and *WHCR_SOP_mmddyy_obs2_bu.gdb*. Close ArcCatalog.
5. In Windows Explorer, browse to *WHCR_SOP_mmddyy_bu.gdb*, select it and the two observer geodatabase back-ups.
6. **Right-click** on it and select **Send to>Compressed (zipped)** file.
7. All three geodatabases should s**ave** into one zip file with the *WHCR_SOP_mmddyy_bu.gdb.zip* name and in the same location.
8. **Browse** to the WHCR Aerial Surveys (TX Coast) SharePoint site: https://fishnet.fws.doi.net/regions/2/nwrs/IM/WHCR/SitePages/Home.aspx
9. Under *Libraries>Data>WHCR_aerial_surveys_bu*, choose the survey year folder.
10. Click on the *geodata_bu* folder, click the **Add document** 

.
11. Browse to the *zipped file* in the **Upload Document** screen.



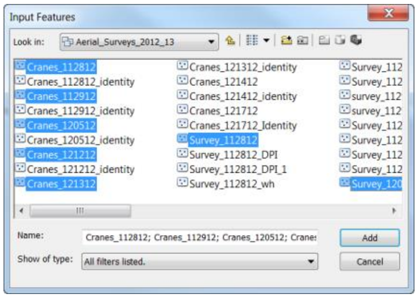
12. Click **OK** on the **Upload Document** screen.
13. Complete steps 8–10 for the audio files, and spreadsheets as well.

End of season data archiving

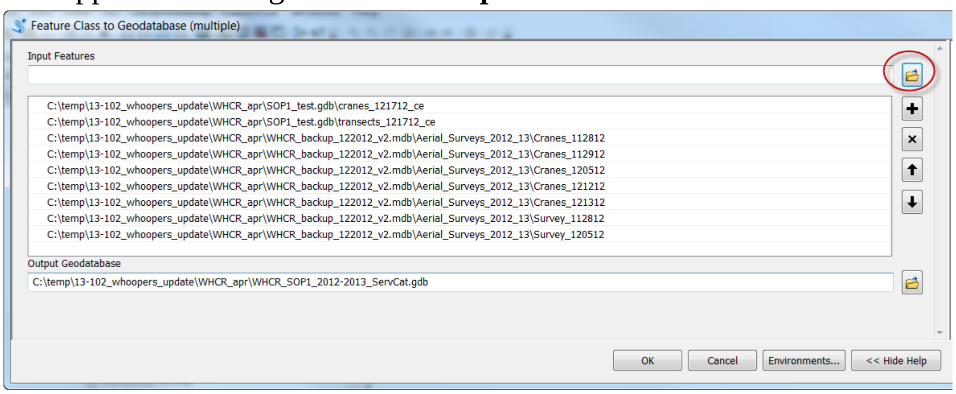
The end of season archiving will pull all of the features classes and tables into 1 final geodatabase, WHCR_SOP_yyyy-yyyy_ServCat.gdb, for upload to SharePoint and ServCat.

1. In **ArcCatalog**, **right-click** on *WHCR_SOP_yyyy-yyyy_template_ServCat.gdb*.
2. Click **Rename.**
3. Rename the geodatabase to the survey year and delete the word “template.” The final name should look similar to *WHCR_SOP_2013-2014_ServCat.gdb*.
4. **Right-click** on the renamed geodatabase from step 3, and choose **Import>Feature Class (multiple)**.
5. In the **Feature Class to Geodatabase (multiple)** screen for the input features. Browse to the multiple *WHCR_SOP_mmddyy* geodatabases, and choose the feature classes (*cranes_mmddyy, survey_mmddyy, transects_mmddyy, and track_mmddyy*). ***When choosing multiple feature classes in a geodatabase, click***

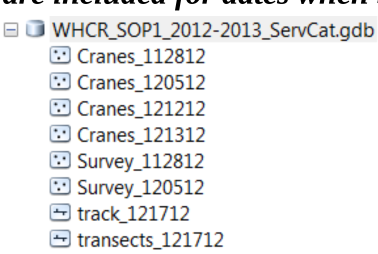
on the first feature class to import, then press the Control key while clicking on the remaining feature classes.



6. With the feature classes selected, click **Add** in the **Input Features** screen.
7. To add the other *WHCR_SOP_mmddyy* geodatabases and their feature classes, click on the folder icon beside the Input Features text box in the Feature Class to Geodatabase (multiple) screen. Each of the feature classes and their geodatabase will appear in the large box below **Input Features**.



8. After adding all of the features classes for each survey date, **click OK**. The tool will take several minutes to process.
9. Once the tool has completed, review the *WHCR_SOP_yyyy-yyyy_ServCat* geodatabase. Are all of the feature classes from step 8 included? The illustration provides an idea of how the end product should appear. ***Ensure SSF cranes files are included for dates when SSF areas were surveyed.***



10. Right-click on the *WHCR_SOP_yyyy-yyyy_ServCat.gdb*>**Import>Table (multiple).**
11. In the Table to Geodatabase (multiple) screen, **add** in all of the *gen_near_tbl_mmddyytables* for each survey date.
12. Once all of the tables have been **added**, click **OK** to run the tool.

13. **Merge** *flight_mmddyy.dbf* tables from each survey into one flight.dbf table in the *WHCR_SOP_yyyy-yyyy_ServCat.gdb*.
14. Confirm all the tables where imported into the *WHCR_SOP_yyyy-yyyy_ServCat* geodatabase.
    Note: *If the Refuge created new fishnets/sampling frame this should also be included in the ServCat geodatabase. The Refuge would have contacted the Biometrician to confirm a change in the survey design was warranted.*
15. In Windows Explorer, **browse** to the *WHCR_SOP_yyyy-yyyy_ServCat.gdb* folder.
16. **Right-click** on *WHCR_SOP_yyyy-yyyy_ServCat***>Send to>Compressed (zipped) folder**.
    Note: *If an error message about permission is received, close ArcCatalog and ArcMap, and try step 15 again.*
17. It will appear in the same directory and named similar to *WHCR_SOP_yyyy-yyyy_ServCat.gdb.zip*.
18. On the WHCR Aerial Surveys (TX Coast) SharePoint site under Libraries, **click** on *Data>WHCR_aerial_surveys_ServCat.*
19. **Click** on the *survey year* folder (e.g., 2013–2014).
20. **Click** on the *geodata* folder.
21. **Click** on **Add document**.
22. **Browse** to the zipped geodatabase from step 16, and upload it to the SharePoint.
23. **Click** on the *audio* folder and upload the audio files.
24. **Click** on the *spreadsheets* folder and upload the text files created in SOP 4.
25. **Click** on the *analysis* folder and upload the R Workspace and R Script files *(upload responsibility depends on who generates these associated files).*
26. **Click** on the *reports* folder and upload the update, interim, and comprehensive reports *(upload responsibility depends on who generates the reports).*
27. After all files have been uploaded to SharePoint, send an email to the I&M Regional Data Manager and the I&M Zone Data Manager. The subject line of "WHCR E-O-S SharePoint Upload Complete." Include a courtesy copy "cc" to the I&M Coordinator, I&M Biometrician, Aransas NWR Supervisory Biologist, and the Aransas NWR Refuge Manager.

Appendix A: Power Analysis of Aerial Whooping Crane Abundance Surveys

Effort and precision

The following equation was used to determine the number of surveys (S) needed to achieve a target precision for the annual winter abundance estimate (Buckland et al. 2001)

$$S = \left(\frac{L_o \{ \mathrm{CV}(\hat{N}) \}^2}{\{ \mathrm{CV}_t(\hat{N}) \}^2} \right) / L$$

where L_o is the total line length flown during the pilot survey, L is the total line length in the sample frame, $\mathrm{CV}(\hat{N})$ is the coefficient of variation of the abundance estimate from the pilot survey, and $\mathrm{CV}_t(\hat{N})$ is the target coefficient of variation desired from future survey efforts (Buckland et al. 2001).

We used the surveys conducted during January 2012 as our pilot survey effort and estimated the number of surveys need to obtain a target CV (Table A1).

Table A1. The number of surveys that need to be conducted in the Primary Sampling Frame to obtain a target coefficient of variation for the abundance estimate ($\mathrm{CV}_t(\hat{N})$). Based on data collected during winter 2011–2012.

Number of Surveys (S)[a]	$cv_t(\hat{N})$
1–2	0.200
2	0.150
3	0.125
4–5	0.100
5–6	0.090
6–7	0.080
8–10	0.070
10–13	0.060
15–18	0.050

[a] The number surveys is shown as a range because analysis of the data using hierarchical distance sampling models will results in greater precision than analysis with conventional distance sampling. Therefore, more surveys are required with conventional distance sampling to achieve similar precision as hierarchical distance sampling.

Power: 2-sample z-test

To compare 2 estimates of abundance obtained from distance sampling-based surveys, a simple *z*-test can be performed (Buckland et al. 2001)

$$Z = \frac{(\hat{N}_1 - \hat{N}_2) - (N_1 - N_2)}{\sqrt{\widehat{\mathrm{var}}(\hat{N}_1 - \hat{N}_2)}} \sim \mathrm{N}(0,1)$$

where $\hat{N}_1$ and $\hat{N}_2$ are abundance estimates and $\widehat{\mathrm{var}}(\hat{N}_1 - \hat{N}_2)$ is the variance of the difference. The variance of the difference is easily computed as

$$\widehat{\text{var}}(\widehat{N}_1 - \widehat{N}_2) = \widehat{\text{var}}(\widehat{N}_1) + \widehat{\text{var}}(\widehat{N}_2)$$

provided abundances were independently estimated. Typical output from distance sampling software provide coefficients of variation which are

$$\text{CV}(\widehat{N}) = \frac{SE(\widehat{N})}{\widehat{N}}$$

and variance of the abundance estimate is simply estimated as

$$\widehat{\text{var}}(\widehat{N}) = SE(\widehat{N})^2.$$

We developed an R function to estimate the statistical power $(1-\beta)$ of this *z*-test (see example R Code below; Crawley 2007, R Development Core Team 2012). We developed 3 power analyses to demonstrate the relationships among $\text{CV}(\widehat{N})$, percent change in abundance, power, and alpha (α; Figures A1–A3).

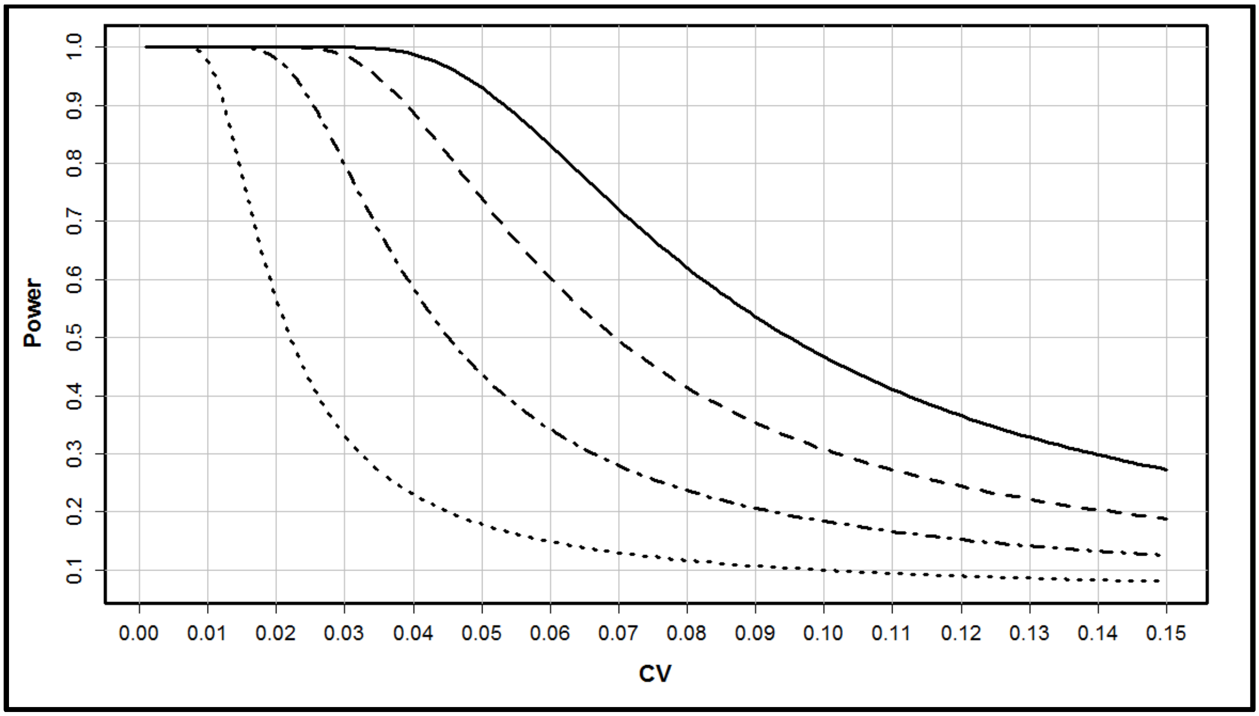


Figure A1. Power curves for determining the coefficient of variation of abundance estimates required to detect a given decline in abundance; based on 1-tailed *z*-test ($\alpha = 0.05$). The solid line represents a 20% decline, the dashed line is a 15% decline, the dot-dashed line is a 10% decline, and the dotted line is a 5% decline.

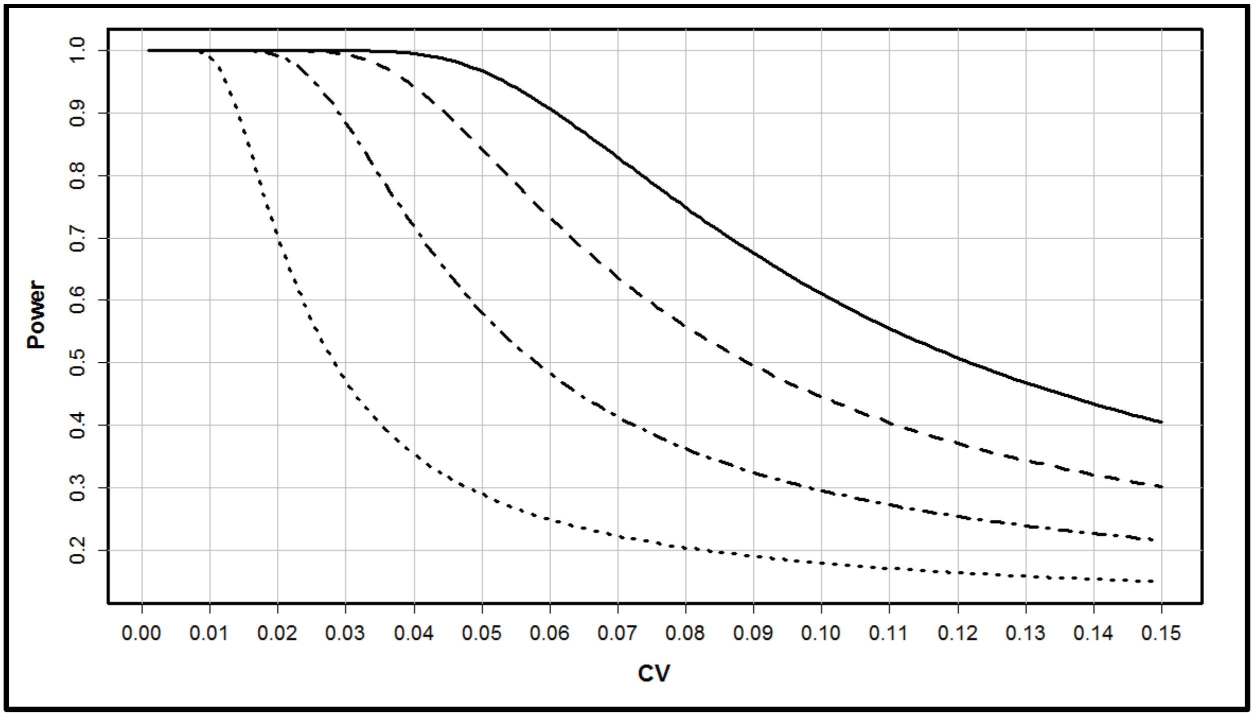


Figure A2. Power curves for determining the coefficient of variation of abundance estimates required to detect a given decline in abundance; based on 1-tailed *z*-test ($\alpha = 0.1$). The solid line represents a 20% decline, the dashed line is a 15% decline, the dot-dashed line is a 10% decline, and the dotted line is a 5% decline.

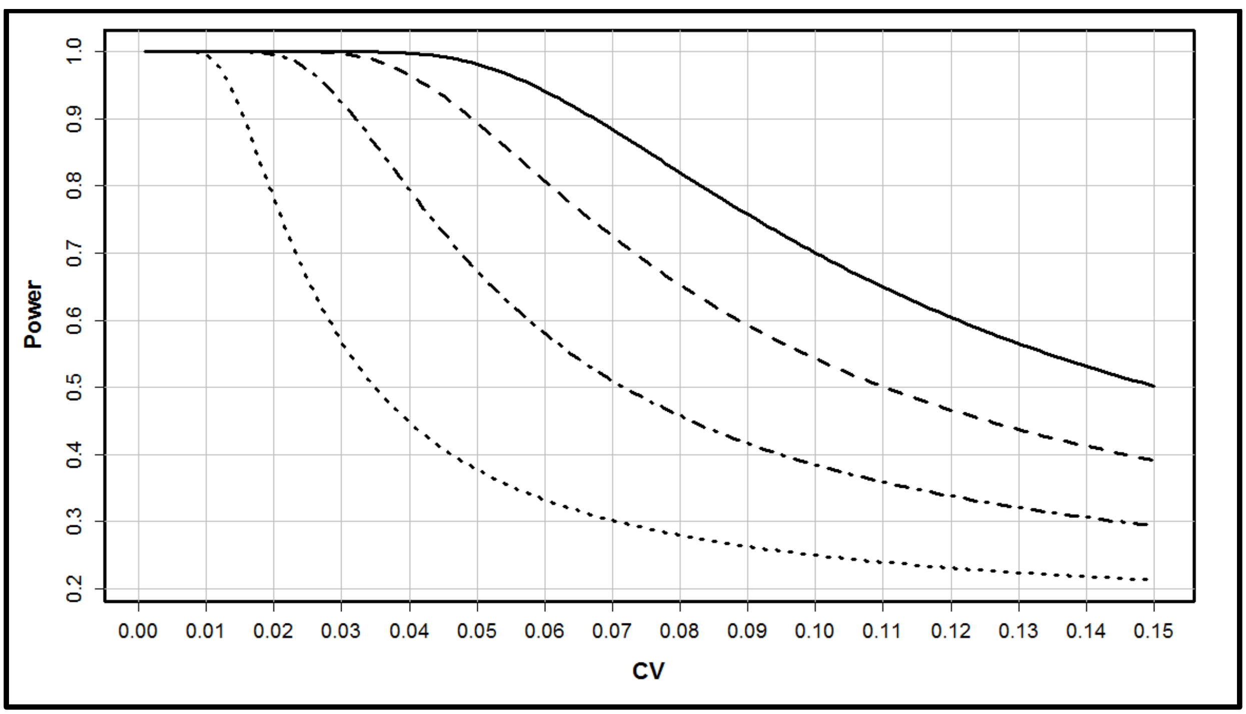


Figure A3. Power curves for determining the coefficient of variation of abundance estimates required to detect a given decline in abundance; based on 1-tailed *z*-test ($\alpha = 0.15$). The solid line represents a 20% decline, the dashed line is a 15% decline, the dot-dashed line is a 10% decline, and the dotted line is a 5% decline.

Power: trends

Though changes in abundance over 2-year periods do occur, wildlife managers are typically more interested in determining population trends. A simple change from one year to the next is part of normal population dynamics, but longer-term trends are more important for conservation planning and population management (Thomas et al. 2004). We used program TRENDS (Gerrodette 1987, 1991, 1993; Link and Hatfield 1990) to estimate the $\mathrm{CV}(\hat{N})$ needed to detect a population change given $1-\beta=0.8$ and $\alpha=0.1$ (based on a 1-tailed *t*-test; Table A2).

Table A2. Estimated precision of abundance estimates ($\mathrm{CV}(\hat{N})$) required to detect a population trend from distance sampling-based aerial surveys for whooping cranes along the Texas gulf coast, USA.

Decline per year	Annual $\mathrm{CV}(\hat{N})$ required during the period							
	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
3%	0.01	0.03	0.04	0.06	0.07	0.09	0.12	0.14
5%	0.02	0.04	0.07	0.10	0.13	0.17	0.21	0.26
10%	0.04	0.09	0.16	0.23	0.31	0.41	0.52	0.65
15%	0.06	0.15	0.26	0.39	0.54	0.70		
20%	0.08	0.22	0.38	0.58	0.72			

Example R code for power analysis of z-test of differences in abundances estimated using distance sampling:

```
# A function to estimate power to detect a change between two abundance estimates
# using a 1-tailed z-test (Buckland et al. 2001). Where N1 and N2 are the two
# abundance estimates, change is the desired percent change, CV is the coefficient of
# variation of the abundance estimates, and alpha is the desired alpha-level.

ZPOWER.1tailed = function(change,N1,CV,alpha){
	N2=N1+(N1*change)
	SD1=N1*CV
	SD2=N2*CV
	VAR=(SD1^2)+(SD2^2)
	if(change>0) q=qnorm(alpha)
	if(change<0) q=qnorm(1-alpha)
	z=(N1-N2)/sqrt(VAR)
	if(change>0) power=pnorm(q-z)
	if(change<0) power=1-pnorm(q-z)
	cbind(N1,N2,change,CV,SD1,SD2,VAR,q,z,alpha,power)}

changes=seq(-0.2,-0.05,by=0.05)
N=300
CVs=seq(0.001,0.15,by=0.001)
a=0.1
length1=length(changes)
length2=length(CVs)
power.z.1tailed=matrix(,(length1*length2),11)
colnames(power.z.1tailed)=c("N1","N2","change","CV","SD1","SD2","VAR","q","z","alpha",
	"power")
for (i in 1:length1) {
	for (j in 1:length2) {
	power.z.1tailed[j+((i-1)*length2),]=ZPOWER.1tailed(changes[i],N,CVs[j],a)
	}
}

power.z.1tailed=as.data.frame(power.z.1tailed)

# Plot the power curves.

par(cex.lab=1.4)
par(font.lab=2)
par(cex.main=1.6)
par(font.main=2)
par(cex.axis=1.2)
par(lwd=3)

plot(power.z.1tailed$CV[power.z.1tailed$change==-0.05],
	power.z.1tailed$power[power.z.1tailed$change==-0.05],
	type="l",lty=3,xlab="CV",ylab="Power",yaxp=c(0,1,10),xaxp=c(0,0.15,15))
abline(h=c(seq(0,1,0.1)),lwd=0.1,col="gray")
abline(v=c(seq(0,0.15,0.01)),lwd=0.1,col="gray")
lines(power.z.1tailed$CV[power.z.1tailed$change==-0.05],
	power.z.1tailed$power[power.z.1tailed$change==-0.05],lty=3)
lines(power.z.1tailed$CV[power.z.1tailed$change==power.z.1tailed$change[171]],
	power.z.1tailed$power[power.z.1tailed$change==power.z.1tailed$change[171]],
	lty=2)
lines(power.z.1tailed$CV[power.z.1tailed$change==-0.1],
	power.z.1tailed$power[power.z.1tailed$change==-0.1],lty=4)
lines(power.z.1tailed$CV[power.z.1tailed$change==-0.2],
	power.z.1tailed$power[power.z.1tailed$change==-0.2],lty=1)
```

Appendix B: Indexing Annual Recruitment of Whooping Cranes

Multiple samples with replacement ratio estimator

Recruitment of hatch-year (HY) whooping cranes into the wintering population will be indexed as the observed ratio of HY to after-hatch-year (AHY) birds from survey flights conducted between 28 November–26 December. Since multiple surveys will be conducted for estimating annual abundance on the wintering grounds, the most appropriate estimator of HY:AHY ratio is the multiple samples with replacement ratio estimator where each survey represents a sample (Skalski et al. 2005).

$$\hat{R}_{J/A} = \frac{\sum_{i=1}^{k} j_i}{\sum_{i=1}^{k} a_i} = \frac{\bar{j}}{\bar{a}}$$

where

$\hat{R}_{J/A}$ is juvenile:adult ratio (HY:AHY ratio),
j_i is the number of juveniles observed during the *i*th survey ($i = 1,\ldots,k$), and
a_i is the number of adults observed during the *i*th survey ($i = 1,\ldots,k$).

The variance of $\hat{R}_{J/A}$ is estimated as (Skalski et al. 2005:61)

$$\widehat{\text{var}}\left(\hat{R}_{J/A}\right) = \frac{\sum_{i=1}^{k}\left(j_i - \hat{R}_{J/A} \cdot a_i\right)^2}{k\bar{a}^2(k-1)}$$

where

$\bar{a}$ is the average number of adults observed across surveys and
k is the number of surveys.

The standard error and confidence intervals are estimated as

$$\widehat{\text{SE}}\left(\hat{R}_{J/A}\right) = \sqrt{\widehat{\text{var}}\left(\hat{R}_{J/A}\right)}$$

$$\text{CI}\left[\hat{R}_{J/A} e^{-z_{1-\alpha/2}\sqrt{\frac{\widehat{\text{var}}\left(\hat{R}_{J/A}\right)}{\hat{R}_{J/A}^2}}} \le \hat{R}_{J/A} \le \hat{R}_{J/A} e^{+z_{1-\alpha/2}\sqrt{\frac{\widehat{\text{var}}\left(\hat{R}_{J/A}\right)}{\hat{R}_{J/A}^2}}}\right].$$

Skalski et al. (2005) noted several assumptions of this estimator. Assumptions of primary concern are equal probability of detection of each age group and the survey period is short enough that both age groups have equal probability of survival during the survey period.

We currently have no evidence suggesting juvenile and adults have differential detection probabilities. Though juveniles are tawny-colored, they are rarely unassociated with adults. However, group size-biased detection could skew age-ratios but assuming any differential detection remains constant among years, the above estimator is a relative index of the HY:AHY ratio and juvenile recruitment into the winter flock.

Single sample ratio estimator

Only one survey may be completed during optional survey periods during January, February, and March. If only one survey is conducted on the wintering grounds during one of the periods, the most appropriate estimator of HY:AHY ratio is the single sample ratio estimator (Skalski et al. 2005).

$$\hat{R}_{J/A} = \frac{j}{a}$$

where

j is the number of juveniles observed during the survey and
a is the number of adults observed during the survey.

The variance of $\hat{R}_{J/A}$ is estimated as (Skalski et al. 2005:56)

$$\widehat{\text{var}}(\hat{R}_{J/A}) = \frac{\hat{R}_{J/A}\left(1 + \hat{R}_{J/A}\right)^2}{n} = \frac{nj}{a^3}$$

where

n is the number of whooping cranes observed during the survey.

The standard error and confidence intervals are estimated as above.

Appendix C: Data Analysis Using Hierarchical Distance Sampling

Rationale

Whooping crane monitoring data from the wintering grounds will be analyzed using spatially-explicit models of abundance which allow wildlife managers and biologists to relate landscape or habitat features with whooping crane abundance (Royle et al. 2004, Chandler et al. 2011, Sillet et al. 2012). Though many spatially-explicit models exist (e.g., MacKenzie et al. 2002, Hedley and Buckland 2004, Royle et al. 2004, Phillips et al. 2006, Chandler and King 2011, Jarnevich and Laubhan 2011), the hierarchical distance sampling (HDS) model of Royle et al. (2004) or the generalized HDS model of Chandler et al. (2011) is most appropriate for these survey data.

During the historic survey effort (1950–2010), flight-lines were not recorded nor were information regarding which areas were surveyed (Stehn and Taylor 2008). This oversight by previous observers has limited the potential use of spatially-explicit modeling of whooping crane occurrence on the landscape. Though techniques such as maximum entropy modeling (MaxEnt) can be used with the historic data to provide spatially-explicit models of historic whooping crane occurrence, the convenience-based sampling design (Stehn and Taylor 2008) employed during the historic surveys can produce misleading results due to sampling bias (Elith et al. 2011, Yackulic et al. 2013).

Further, the use of a convenience-based sampling design and the untenable assumption of complete detection mislead stakeholders to believe the historic survey effort was a complete census. A complete census of a wildlife population is rarely, if ever possible (Lancia et al. 2005). However, implementation of a repeatable, randomized sampling design that incorporates detection probabilities into the estimation of abundance can provide a solid foundation for population monitoring and reduce the potential for spurious results (Anderson 2001). Further, the use of advanced techniques such as hierarchical distance sampling will provide simple estimates of abundance while advancing our ecological understanding through descriptions of how abundance and detectability varies spatially (Royle et al. 2004, Chandler 2011, Chandler et al. 2011, Sillet et al. 2012).

Distance sampling is a tractable, widespread approach used to correct for the bias that results from imperfect detection (Buckland et al. 2001, Buckland et al. 2004, Thomas et al. 2010). The conventional distance sampling (CDS) paradigm has been limited to a focus on modeling the detection function (Buckland et al. 2001, Thomas et al. 2010) and has provided techniques for incorporating covariate effects on detection probability (Marques and Buckland 2003, Marques and Buckland 2004). However, wildlife managers and biologists are most interested in understanding relationships between abundance and environmental covariates not variation in the detection process though accounting for variation in the detection process can improve precision of abundance estimates (Thomas et al. 2010). Recent and concurrent advances in modeling techniques have provided new, robust methods for modeling spatial-abundance relationships (i.e., spatial distance sampling [SDS], Hedley and Buckland 2004; HDS, Royle et al. 2004). The SDS technique is based on an inhomogeneous Poisson point process where parameters estimation is often based in a generalized additive modeling (GAM) framework where the likelihood is conditioned on detections (Hedley et al. 1999, Hedley and Buckland 2004, Hedley et al. 2004, Katsanevakis 2007). The SDS techniques are often less tractable when complex abundance models are used (Hedley and Buckland 2004, Hedley et al. 2004, Royle et al. 2004). In contract, HDS techniques are based on the unconditional likelihood which provides a framework for modeling both the detection process and the intensity of abundance where site-level abundance is the latent variable (Royle et al. 2004, Chandler et al. 2011, Sillet et al. 2012). For complex functions, this likelihood appears to be better-behaved (Royle et al. 2004). Further, one of the greatest advantages of the hierarchical modeling framework is the ability to simultaneously model the abundance and detection processes. This allows the effects of a given covariate, on either process, to be disentangled (Kéry 2008).

Just as in CDS and SDS, HDS allows modeling of the detection process using a half-normal, hazard-rate, negative exponential, or uniform detection function (Chandler 2011). However, the detection process is treated as a multinomial where distances are binned into intervals (Royle et al. 2004, Chandler 2011). Currently, HDS models have been developed that can model abundance using a Poisson or negative binomial distribution (Chandler et al. 2011, Fisk and Chandler 2011).

The whooping crane survey data will be analyzed using the `distsamp` or `gdistsamp` function of package `unmarked` in program R (Fiske and Chandler 2011, R Development Core Team 2012). The `distsamp` function can only fit the multinomial-Poisson mixture model of Royle et al. (2004). However, the generalized HDS model of Chandler et al. (2011), which allows abundance to be modeled using a negative binomial, can be fit using the `gdistsamp` function (Sillet et al. 2012). Chandler (2011) provided an easy to follow description (vignette) to guide analyses of distance sampling data using package `unmarked`. Provided below are some guidelines for data analysis and R code development similar to the style used in the R vignettes. Step-by-step directions are not provided because input data requires close examination to ensure it meets model assumptions.

Importing and formatting data

Locate the R workspace and R script (HDS_dataframes_yyyy-yyyy.Rdata and HDS_data_yyyy-yyyy.R) that were created using SOP 5. Open them into Rstudio (2012). There will be 6 dataframes in the R workspace that are used in data analyses. The DIST dataframe contains 2 columns: distance to detection (Dist) and fishnet id (FNID). The LENGTHS dataframe contains 2 columns: transect length (Lengths) and FNID. The COVS file contains a column for each covariate and FNID. Make sure the DIST, LENGTHS, and COVS files are sorted by FNID. The FNID is the identity of the 1-km^2 sampling units (i.e., fishnet cells). The DISTGROUP dataframe contains 2 columns: distance to detection (Dist) and group size (Size). The JUVS file contains 2 indicator variables: group contained at least one juvenile bird (Juv) and group was composed on a pair of white birds or contained at least one juvenile (Pair). The GROUP contains 3 columns: survey occasion (occ), number of AHY birds observed (AHY), and number of HY birds observed (HY).

To organize the distance data into the multinomial format used by HDS, use the function `formatDistData`. At this point the analyst must decide on appropriate distance interval cutpoints for binning the distance data. A close examination of a histogram of the distance data (`hist(DIST$Dist)`) will help suggest appropriate cutpoints; Buckland et al. (2001) also provides recommendations (i.e., binning to help reduce spiking around the centerline and to reduce heaping). All detections beyond 500 m will be truncated from the analysis since they are either outside of the sampling frame or the plot (SOP 5).

```
yDat=formatDistData(DIST,distCol="Dist",transectNameCol="FNID",
  dist.breaks=c(0,100,225,350,500))
```

Once the data is formatted into the multinomial format, the distance data, covariate data, and transect lengths must be combined into a data frame compatible with package `unmarked` using the `unmarkedFrameDS` or `unmarkedFrameGDS` function (SOP 5).

```
umf=unmarkedFrameDS(y=as.matrix(yDat),siteCovs=COVS,survey="line",
  dist.breaks=c(0,100,225,350,500),tlength=LENGTHS$Length,unitsIn="m")
# Take a quick look at the umf.
summary(umf)
# Check to see if number of detections is correct.
sum(na.omit(DIST$Dist<=500))==sum(yDat)
# View first few rows of data.
umf[1:20]
# Plot the distance data.
hist(umf,xlab="distance (m)",main="",cex.lab=0.8,cex.axis=0.8)
```

Modeling strategy

Model and covariate selection must not be an unthinking process; think about ecologically meaningful relationships. Much "hard thinking" must be conducted a priori to the analysis stage (Anderson and Burnham 2002, Burnham and Anderson 2002, Anderson 2008). Though 4 key functions (i.e., half-normal, hazard-rate, negative exponential, or uniform) for modeling the detection function are available in package `unmarked`, Buckland et al. (2001:48) recommended not using the negative exponential key function unless distance data are from poorly collected data where the distance data are truly spiked at the centerline. A myriad of factors could influence detectability at the observation level (e.g., sun angle, observer, size of the group, age of the animal, etc.) or site level (e.g., woody cover or other vegetative conditions). However, the HDS models are only capable of including site level covariates such as habitat conditions (Chandler 2011). A myriad of factors could also influence abundance (e.g., survey region, percent saltmarsh, time since prescribed fire, distance to anthropogenic structures, percent open water, interactions, etc.). Once ecologically meaningful covariates are decided upon, correlations among those covariates must be examined and highly correlated covariates should not be included in the same model to avoid potential multicollinearity problems (Zar 1999, Graham 2003). The analyst could use `cor(COVS)` to examine correlations; Pearson or Spearman-rank correlations can be computed with this function. The analyst ought to examine plots of the covariates as well (e.g., `boxplot`, `hist`).

To select the best model(s), a two-stage approach is recommended. First, the analyst should focus on modeling the detection function. Do the "hard thinking" to develop a meaningful a priori model set for the detection process. Fit each model in the a priori model set and select the best model(s) based on Akaike's Information Criterion (AIC; Anderson and Burnham 2002, Burnham and Anderson 2002, Anderson 2008). Models with $\Delta AIC \leq 2$ are typically considered as competitive models (Anderson 2008), though models with uninformative parameters should be excluded (Anderson et al. 2001, Arnold 2010).

```
# Fit the base detection functions and pick one to use.
hn=distsamp(~1~1,umf,keyfun="halfnorm",output="density",unitsOut="kmsq")
haz=distsamp(~1~1,umf,keyfun="hazard",output="density",unitsOut="kmsq")
unif=distsamp(~1~1,umf,keyfun="uniform",output="density",unitsOut="kmsq")
expon=distsamp(~1~1,umf,keyfun="exp",output="density",unitsOut="kmsq")
hn.woody=distsamp(~WOODY~1,umf,keyfun="halfnorm",output="density",
  unitsOut="kmsq")
haz.woody=distsamp(~WOODY~1,umf,keyfun="hazard",output="density",
  unitsOut="kmsq")
unif.woody=distsamp(~WOODY~1,umf,keyfun="uniform",output="density",
  unitsOut="kmsq")
expon.woody=distsamp(~WOODY~1,umf,keyfun="exp",output="density",
  unitsOut="kmsq")
# Create a fitList.
CDS_fitlist=fitList(hn,haz,unif,expon,hn.woody,haz.woody,unif.woody,
  expon.woody)
# Rank the models by AIC.
ms1=modSel(CDS_fitlist)
# Create a dataframe of the model set's statistics.
MS1.modelstats=as(ms1,"data.frame")
```

At this stage, it is good practice to examine detection curves and estimate detection probabilities. For example:

```
# Plot the detection curve with histogram.
hist(hn)
# To estimate and plot detection probabilities for a model.
plot(function(x) gxhn(x,sigma=exp(coef(hn,type="det"))),0,500,
  xlab="distance",ylab="Detection probability",ylim=c(0,1))
# To estimate detection probability between 0 and 500 m.
det.hn=integrate(gxhn,0,500,sigma=exp(coef(hn,type="det")))$value/500
```

Once the best detection function or competitive detection functions (including key function and covariates) are identified, the analyst should model the abundance process. Do the "hard thinking" to develop a meaningful a priori model set for abundance (include both main effects and appropriate interactions). Fit each model in the a priori model set and select the best model based on AIC. For example:

```
# Fit the abundance models using the best detection model.
hn.woody=distsamp(~WOODY~1,umf,keyfun="halfnorm",output="density",
  unitsOut="kmsq")
hn.woody_marsh=distsamp(~WOODY~SALTMARSH,umf,keyfun="halfnorm",
  output="density",unitsOut="kmsq")
hn.woody_open=distsamp(~WOODY~OPENWATER+OPENWATER2,umf,keyfun="halfnorm",
  output="density",unitsOut="kmsq")
```

```
hn.woody_marsh.open=distsamp(~WOODY~SALTMARSH+OPENWATER+OPENWATER2,umf,
  keyfun="halfnorm",output="density",unitsOut="kmsq")
# Create a fitList.
AICfitlist=fitList(hn.woody,hn.woody_marsh,hn.woody_open,hn.woody_marsh.open)
# Rank the models by AIC.
ms2=modSel(AICfitlist)
# Create a dataframe of the model set's statistics.
MS2.modelstats=as(ms2,"data.frame")
```

Testing goodness of fit

Once the best models are identified, goodness of fit for those models should be evaluated using a conventional parametric bootstrap procedure (`paraboot`; Fiske and Chandler 2011). For example, the following code shows a parametric bootstrap for Freeman-Tukey fit statistic (Sillet et al. 2012) and Pearson's χ^2 (Fiske and Chandler 2011). Allow ample time to run the goodness of fit bootstrap function since it can require >5 hours to complete for some datasets and models. If the observed fit statistic lies between the 0.05 and 0.95 percentiles of the bootstrap distribution, then the model adequately fits (Krementz et al. 2014).

```
# Goodness of Fit Analysis function.
fitstats=function(fm){
  observed=getY(fm@data)
  expected=fitted(fm)
  resids=residuals(fm)
  sse=sum(resids^2)
  chisq=sum(((observed-expected)^2)/expected)
  freeTuke=sum((sqrt(observed)-sqrt(expected))^2)
  out=c(SSE=sse,Chisq=chisq,freemanTukey=freeTuke)}
GOF=parboot(hn.woody_marsh.open,fitstats,nsim=1000,report=2)
```

If the best models do not fit adequately, consider using the `gdistsamp` function to refit the best models using the negative binomial distribution. Check the goodness of fit for the best negative binomial model.

```
# Make the unmarked dataframe for gdistsamp.
umfg=unmarkedFrameGDS(y=as.matrix(yDat),siteCovs=COVS,survey="line",
  dist.breaks=c(0,100,225,350,500),tlength=LENGTHS$Length,
  numPrimary=1,unitsIn="m")
# Refit the best model using gdistsamp with negative binomial specified. Note
# that detection and abundance formulas appear in different locations in the
# gdistsamp function than in the distsamp function.
nb_hn.woody_marsh=gdistsamp(~SALTMARSH,~1,~WOODY,umfg,keyfun="halfnorm",
  output="density",unitsOut="kmsq",mixture="NB")
```

Testing for size-biased detection

Size-biased detection occurs when larger groups have greater detection probability than smaller groups (Buckland et al. 2001). Testing for size-biased detection can be accomplished by regressing ln(group size) against detection probability, group size against detection probability, ln(group size) against distance, or group size against distance (Buckland et al. 2001). Buckland et al. (2001) recommends regressing ln(group size) against detection probability.

```
# Get the detection probabilities by distance.
gx_hn=gxhn(DISTGROUP$Dist,exp(coef(hn,type="det")))
# Regress ln(group size) against detection probability.
size.bias_hn=lm(log(DISTGROUP$Size)~gx_hn)
summary(size.bias_hn)
plot(log(DISTGROUP$Size)~gx_hn)
```

If a significant (typically $\alpha = 0.15$ is used) negative slope is found, this suggests larger groups tend to be detected at greater distance than smaller ones. Hence, larger groups are overrepresented in the sample resulting in a positive bias in average group size. If a significant positive slope is found, this suggests that observers are underestimating the size of detected groups. Hence, average group size will be biased low if group size is underestimated. These biases, if not corrected, could cause biased abundance estimates. However, this regression technique can provide an unbiased estimate of average group size (Buckland et al. 2001:74).

```
# If significant at alpha=0.15, use adjusted mean group size.
adj.group.size_hn=exp(sum(size.bias_hn$coefficients)+
  ((1+(1/n)+((1-mean(DISTGROUP$Size))^2)/sum((gx_hn-
  mean(DISTGROUP$Size))^2))*mean(size.bias_hn$residuals^2))/2)
```

Abundance estimation

Estimating abundance using package `unmarked` is accomplished with the function `predict` which estimates the state variable (i.e., the state variable is abundance or density depending on model specification; note, use the lambda variable for the `gdistsamp` function) for each site. Remember, to maintain independence of detections, detections are recorded as groups of whooping cranes not individuals (Buckland et al. 2001). Therefore, HDS models under this scenario are predicting the abundance of groups. The number of individuals is easily estimated as the estimated number of groups multiplied by mean group size. For example:

```
# Estimate the number of groups.
G.hat=sum(predict(hn.woody_marsh.open,type="state")$Predicted)
# Since each plot is 1 km² and the state variable was density/km² no conversion
# was needed.  However, if the state variable was density/ha, the predicted
# values would need to be multiplied by 100 to give group abundance for each
# site.  Estimate the number of individuals.
N.hat=G.hat*mean(DISTGROUP$size)
# If size-biased detection occurred; be sure to use the adjusted group size.
N.hat=G.hat*adj.group.size_hn
```

To estimate the uncertainty in abundance estimates, a conventional parametric bootstrap approach is used (Chandler 2011). Allow ample time for the bootstrap function to run.

```
# Covariate values needed for bootstrap.
GRID=cbind(rep(1,nrow(COVS)),COVS$SALTMARSH,COVS$OPENWATER,COVS$OPENWATER2)
```

```
# A function to do parametric bootstrap of total number of groups. Note, if
# model was fit with gdistsamp then replace "state" with "lambda".
G.hat.fun=function(fm){
  sum(predict(fm,type="state")$Predicted)}
# Do the bootstrap for the number of groups; it takes a while.
G.pnb=parboot(hn.woody_marsh.open,G.hat.fun,nsim=1000,report=2)
plot(G.pnb)
G.boots=attr(G.pnb,"t.star")
G.boot.SD=apply(G.boots,2,sd)
G.boot.CV=G.boot.SD/G.hat
# Get the 95% CIs for the G.hat.
CI.G.boot=quantile(G.boots,probs=c(0.025,0.975))
```

Below we provide code for a parametric bootstrap of abundance.

```
# A function to do parametric bootstrap of abundance.
N.hat.fun=function(fm){
  sum(predict(fm,type="state")$Predicted)*
  mean(sample(DISTGROUP$size,replace=T))}
# Do the bootstrap for abundance; it takes a while.
N.pnb=parboot(hn.woody_marsh.open,N.hat.fun,nsim=1000,report=2)
plot(N.pnb)
N.boots=attr(N.pnb,"t.star")
N.boot.SD=apply(N.boots,2,sd)
N.boot.CV=N.boot.SD/N.hat
# Get the 95% CIs for the model.
CI.N.boot=quantile(N.boots,probs=c(0.025,0.975))
```

If size-biased detection is found, the parametric bootstrap must be modified.

```
# A function to do parametric bootstrap of abundance if size-biased detection
# occurred.
N.hat.fun=function(fm) {
  n=length(data$Size)
  gx=gxexp(data$Dist,exp(coef(fm,type="det")))
  model=lm(log(data$Size)~gx)
  group_size=exp(sum(model$coefficients)+((1+(1/n)+
    ((1-mean(data$Size))^2)/sum((gx-mean(data$Size))^2))*
    mean(model$residuals^2))/2)
  group_size*sum(predict(fm,type="state")$Predicted)}
```

Predictions within the sampling frame can be accomplished using the `predict` function in `unmarked` by providing covariate values.

```
# Get predicted values for best model.
Predicted=predict(hn.woody_marsh.open,type="state")
Predicted$Block=COVS$BLOCK
Predicted$FNID=COVS$FNID
```

```
write.table(Predicted,file="predict_PSF.csv",sep=",",qmethod="double")
```

Model averaging

Several HDS models could be competitive (i.e., <2 ΔAIC). Therefore, multimodel inference is recommended (Burnham and Anderson 2002). To model average estimates of abundance, simply create a `fitList` and use it as the object in the `predict` function:

```
# Get the competitive models and put them in a fit list.
bestfitlist=fitList(hn.woody,hn.woody_marsh.open)
ms.best=modSel(bestfitlist) # Rank them by AIC.
ms.best.modelstats=as(ms.best,"data.frame")
# Estimate the number of groups.
G.hat.Mod.Avg=sum(predict(bestfitlist,type="state"")$Predicted)
# Estimate the number of individuals.
N.hat.Mod.Avg=G.hat.Mod.Avg*mean(DISTGROUP$size)
# Estimate number of individuals for each of the competitive models.
N.hat.hn.woody=sum(predict(hn.woody,
  type="state"")$Predicted)*mean(DISTGROUP$size)
N.hat.hn.woody_marsh.open=sum(predict(hn.woody_marsh.open,
  type="state"")$Predicted)*mean(DISTGROUP$size)
```

However, providing an estimate of the variance of model averaged abundance estimates is a little more complex because the `parboot` function only accepts a fitted model, not fit lists. Just as above, the parametric bootstrap approach is used for each of the competitive models. Once parametric bootstrap standard deviations are obtained for model-specific estimates, the simple unconditional variance estimator from Burnham and Anderson (2002:162) is used:

$$\widehat{\text{var}}(\bar{N}) = \left[\sum_{i=1}^{R} w_i \sqrt{\widehat{\text{var}}(\hat{N}_i) + (\hat{N}_i - \bar{N})}\right]^2$$

where $i = 1, \ldots, R$ models, $\bar{N}$ is the model averaged abundance, $\hat{N}_i$ is the estimated abundance for model i, $\sqrt{\widehat{\text{var}}(\hat{N}_i)}$ is the bootstrap standard deviation of $\hat{N}_i$, and $w_i$is the AIC weight for model i.

```
# Get the model weights for the competitive models.
AICwt.hn.woody=ms.best.modelstats$AICwt[2]
AICwt.hn.woody_marsh.open=ms.best.modelstats$AICwt[1]
# Do parametric bootstraps for the competitive models.
```

Parametric bootstrap code is not shown here (see examples above).

```
N.SD.Mod.Ave=(AICwt.hn.woody*(sqrt((N.boot.SD.hn.woody^2)+(N.hat.hn.woody-
  N.hat.Mod.Avg))))+(AICwt.hn.woody_marsh.open*
  (sqrt((N.boot.SD.hn.woody_marsh.open^2)+(N.hat.hn.woody_marsh.open-
  N.hat.Mod.Avg))))
N.CV.Mod.Ave=N.SD.Mod.Ave/N.hat.Mod.Ave
```

More on prediction

Predictions within and beyond the sampling frame can be accomplished using the `predict` function in `unmarked` by providing covariate values for other areas of interest. However, caution must be used in interpreting such predictions. Such predictions cannot be used to infer abundance or resource use beyond the sampling frame but they could be useful for identifying areas likely to be inhabited by whooping cranes in the future (assuming those areas do not change). For example, conservation planning efforts could use these predictions for land protection planning purposes or researchers could use them for evaluation of the potential impacts of sea level rise. Prediction is also useful for facilitating plotting of covariate relationships (Chandler 2011). See Appendix E for information about creating a prediction grid (i.e., planning.txt) for planning activities.

```
# Make large-scale predictions.
Y=cbind(PLANNING$SALTMARSH,PLANNING$OPENWATER,PLANNING$OPENWATER2,
  PLANNING$WETLAND)
colnames(Y)=c("SALTMARSH","OPENWATER","OPENWATER2","WETLAND")
Y=as.data.frame(Y)
PREDICTED.PLANNING=predict(haz.nb_marsh_wetland_open_km,type="lambda",
  newdata=Y,appendData=T)
PREDICTED.PLANNING$FNID=PLANNING$FNID
# Save the predictions to a table.
write.table(PREDICTED.PLANNING,file="predict_planning.csv",sep=",",
  qmethod="double")
```

Estimating HY:AHY ratio

Below we provide some example code for estimating the HY:AHY ratio and its variance, standard error, and 95% confidence intervals. More information about formulas are available in Appendix B.

```
# Code for HY:AHY ratio using the multiple samples with replacement ratio
# estimator (Skalski et al. 2005:61).
ratio=sum(GROUP$HY)/sum(GROUP$AHY)
# Compute sums by survey occasion.
group=aggregate(GROUP[,2:3],by=list(GROUP$occ),sum)
ratio.var=(sum((group$HY-(ratio*group$AHY))^2))/((length(group$Group.1))*
  (mean(group$AHY)^2)*(length(group$Group.1)-1))
ratio.se=sqrt(ratio.var)
ratio.cv=ratio.se/ratio
alpha=0.05
ratio.LCL=ratio*(exp((qnorm(alpha/2))*(sqrt(ratio.var/(ratio^2)))))
ratio.UCL=ratio*(exp((qnorm(1-(alpha/2)))*(sqrt(ratio.var/(ratio^2)))))

# Code for HY:AHY ratio using the single sample ratio
# estimator (Skalski et al. 2005:56).
ratio=sum(GROUP$HY)/sum(GROUP$AHY)
ratio.var=(ratio*((1+ratio)^2))/(sum(GROUP$AHY)+sum(GROUP$HY))
ratio.se=sqrt(ratio.var)
```

```
ratio.cv=ratio.se/ratio
alpha=0.05
ratio.LCL=ratio*(exp((qnorm(alpha/2))*(sqrt(ratio.var/(ratio^2)))))
ratio.UCL=ratio*(exp((qnorm(1-(alpha/2)))*(sqrt(ratio.var/(ratio^2)))))
```

Other estimates

The International Recovery Plan for whooping cranes (CWS and USFWS 2007) identified the number of productive pairs as one metric in which downlisting decisions will be based. The International Recovery Plan defines a productive pair as "a pair that nests regularly and has fledged offspring" (USFWS and CWS 2007:xii) and distinguishes productive pairs from breeding pairs that are defined as "a pair that breeds or is intended to breed in the future" (USFWS and CWS 2007:38). Regardless of the subjective nature of such definitions, identification of productive pairs on the wintering grounds is impossible since some juveniles die on the breeding grounds or during migration. However, the number of whooping crane pairs can be estimated based on the proportion of detected groups containing crane pairs. Also, the number of pairs that recruited a juvenile (i.e., recruitive pairs) into the wintering population can be estimated based on the proportion of detected groups containing juveniles. These proportions are easily estimated from the data imported from the"JUVS.txt" file.

```
# Proportion of groups with pairs or juveniles.
prop.pairs=sum(JUVS$Pair)/length(JUVS$Pair)
# Number of potential pairs.
Pairs.hat=G.hat*prop.pairs
# Proportion of groups with juveniles.
prop.juv=sum(JUVS$Juv)/length(JUVS$Juv)
# Number of recruitive pairs.
Recruit.hat=G.hat*prop.juv
# Estimate number of HY birds.  This
N.HY.hat=N.hat*(sum(group[,3])/(sum(group[,2])+sum(group[,3])))
```

The uncertainty of these estimates can be estimated using conventional parametric bootstraps similar to the ones above.

```
# A function to do parametric bootstrap of number of pairs.
Pairs.hat.fun=function(fm){
  sum(predict(fm,type="state")$Predicted*
  (sum(sample(JUVS$Pair,replace=T))/length(JUVS$Pair))}
# Do the bootstrap for the number of pairs; it takes a while.
Pairs.pnb=parboot(hn.woody_marsh.open,Pairs.hat.fun,nsim=1000,report=2)
plot(Pairs.pnb)
Pairs.boots=attr(Pairs.pnb,"t.star")
Pairs.boot.SD=apply(Pairs.boots,2,sd)
Pairs.boot.CV=Pairs.boot.SD/Pairs.hat
# Get the 95% CIs for the Pairs.hat.
CI.Pairs.boot=quantile(Pairs.boots,probs=c(0.025,0.975))

# A function to do parametric bootstrap of number of recruitive pairs.
```

```
Recruit.hat.fun=function(fm){
  sum(predict(fm,type="state")$Predicted*
  (sum(sample(JUVS$Juv,replace=T))/length(JUVS$Juv))}
# Do the bootstrap for the number of recruitive pairs; it takes a while.
Recruit.pnb=parboot(hn.woody_marsh.open,Recruit.hat.fun,nsim=1000,report=2)
plot(Recruit.pnb)
Recruit.boots=attr(Recruit.pnb,"t.star")
Recruit.boot.SD=apply(Recruit.boots,2,sd)
Recruit.boot.CV=Recruit.boot.SD/Recruit.hat
# Get the 95% CIs for the Recruit.hat.
CI.Recruit.Pairs.boot=quantile(Recruit.boots,probs=c(0.025,0.975))

# Bootstrap the proportion of the population that are HY birds.
prop.hy=NA
for (i in 1:1000){
  rows=sample(seq(1:length(group$Group.1)),replace=T)
  prop.hy[i]=sum(group[rows,3])/(sum(group[rows,2])+sum(group[rows,3]))}
# Bootstrap the number of HY birds.
N.HY.boots=N.boots*prop.hy
N.HY.boot.SD=apply(N.HY.boots,2,sd)
N.HY.boot.CV=N.HY.boot.SD/N.HY.hat
CI.N.HY.boot=quantile(N.HY.boots,probs=c(0.025,0.975))
```

Because some individuals cannot be identified to age-class during the surveys, estimates of the number of pairs or the number of recruitive pairs will likely be biased low. Unfortunately, there is currently no way to determine the magnitude of this bias.

A note about generalized HDS

If repeated surveys are conducted, the generalized HDS model is designed to estimate the availability survey objects (Chandler et al. 2011). This can be used to account for individuals in the sampling frame that are not available for detection (i.e., marine mammals that are underwater such as whales, fossorial animals that are underground such as prairie dogs), account for incomplete detection on the line (i.e., situations where detection is obscured by aircraft type), or estimate temporary emigration among sampling units. However, if temporary emigration and incomplete detection (or availability) are both occurring, generalized HDS models cannot account for both and will result in estimates with positive bias. Temporary emigration among the 1-km^2 sampling units (i.e., fishnet cells) seems evident in this whooping crane population. If detection on the line is near 100%, estimates of the number of groups from generalized HDS models must be adjusted to account for temporary emigration (Chandler et al. 2011)

$$\hat{G}_i = \hat{\lambda}_i \hat{\phi}_i$$

where $\hat{G}_i$ is the estimated number of groups for cell *i*, $\hat{\lambda}_i$ is the predicted superpopulation that uses cell *i*, and $1 - \hat{\phi}_i$ is the temporary emigration probability at cell *i*.

If there is little interest in estimating the probability of temporary emigration, we recommend pooling data from repeated surveys and using a model configuration that ignores $\hat{\phi}_i$. However, changes in temporary emigration across years could indicate interesting changes in environmental conditions on the wintering grounds or behavioral changes in the population which could be of interest to management and conservation of this whooping crane population.

Archiving the analysis

Once data analyses are complete, the R Script will be saved and stored for future reference (e.g., HDS_analysis_script_yyyy-yyyy.R). Further, the R Workspace, which is the working environment of Program R that includes all user-defined objects such as data frames and functions, will be saved and stored for future reference (HDS_analysis_dataframes_yyyy-yyyy.Rdata). Also, the function `sessionInfo()` will be used to store information about the versions of packages and libraries used in the analysis. For example, the version of R and all the attached packages used in the analysis will be stored with `versions=sessionInfo()`. All versions of packages and libraries used in the analysis will be stored in the saved R Workspace.

Appendix D: Generate a Fishnet using Transects in ArcMap

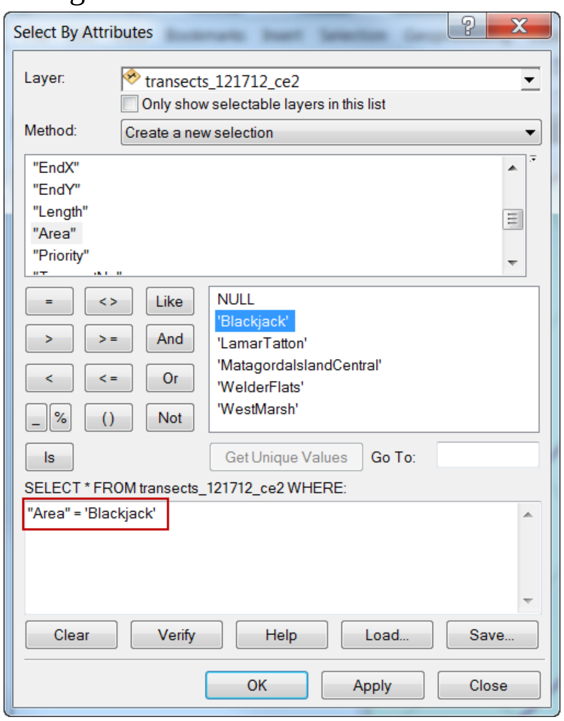
UNDERSTANDING THIS DOCUMENT

- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin, SharePoint).
- *Italicized* text indicates background information, a filename, or a field name.
- Appendix written for a Windows 7 environment

When a fishnet needs to be created, and transects are available the following process will generate the fishnet. These instructions were developed using ArcMap 10 in a Windows 7 environment. Data is in meters.

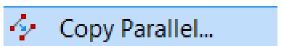
Create fishnet tool

1. In **ArcMap**, **add** the *ideal_transects* and imagery.
2. Use the **Selection>Select by Attributes** to select a transect area like Blackjack or Matagorda Island North.

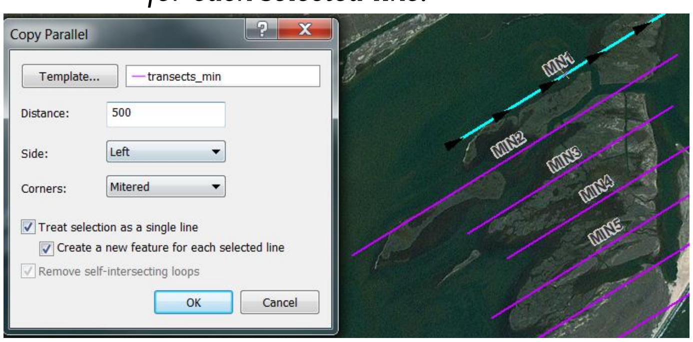


3. **Click OK**.
4. **Right-click** on *transects_ideal*>**Data>Export Data**.
5. Name the output file as *transects_area* (e.g., *transects_blackjack*).
6. Once the data has exported, **add** it to ArcMap.
7. **Select** one of the outer transects from the *transects_area*.

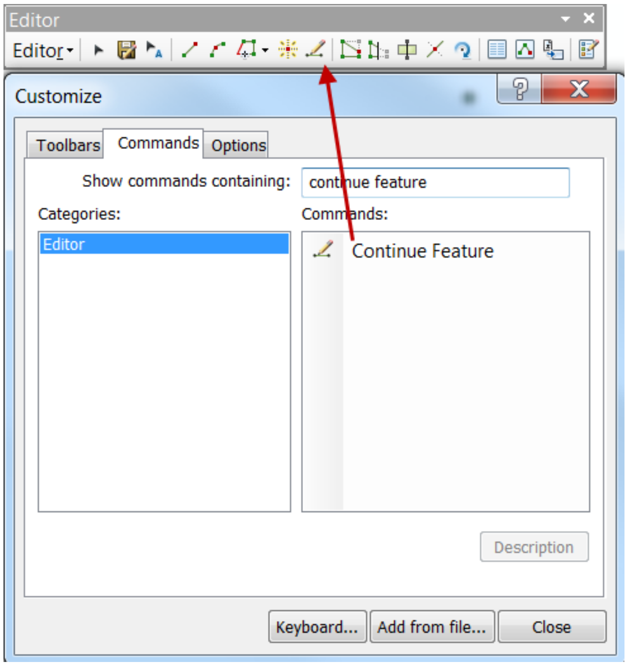
8. On the **Editor toolbar**, **click Editor>Start Editing.**
9. **Click Editor>Copy Parallel**.



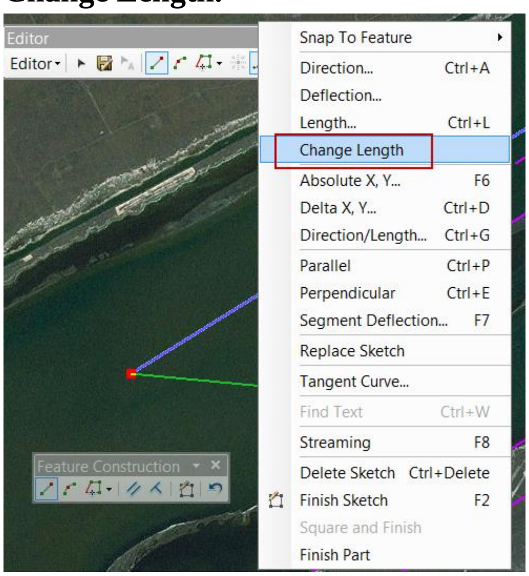
10. In the **Copy Parallel** screen confirm the following:
    a. *Template = transects*
    b. *Distance = 500*
    c. *Side = Right or Left depending on the line direction displayed in ArcMap*
    d. *Corners = Mitered*
    e. *Place a check in "Treat selection as a single line" and "Create a new feature for each selected line."*



11. A new line is created with the same attributes. **Open** the attribute table and indicate this line is the fishnet in the *TRANSECT_ID* field, and not one of the transects.
12. **Click** on the **Editor** icon  to open the **Editor toolbar**.
13. **Click Customize>Customize Mode**.
14. In the **Customize** screen, **click** on the **Commands** tab.
15. In the **Show commands containing**: type "*continue feature.*"
16. Under **Commands**, **click** on the **Continue Feature** and drag it to the **Editor toolbar**.



17. **Editor toolbar>Editor>Start Editing**.
18. **Select** the fishnet line, and **click** the **Continue Features** icon added to the **Editor toolbar** in the previous step.
19. The End vertex is red and is the direction the line can be extended. If this is the correct direction to extend the line, **right-click** away from the highlighted line, and choose **Change Length.**

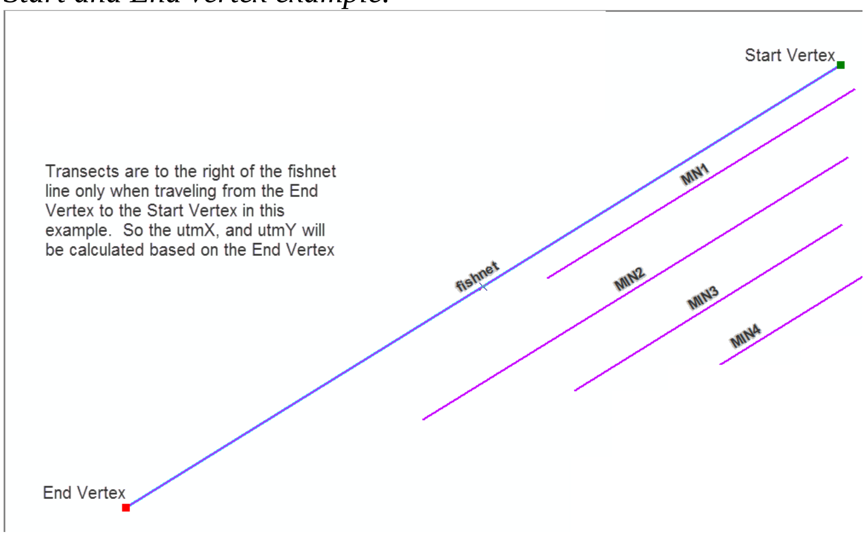


Note:** If the line needs to extend using the Start (green) vertex, right-click on the End (red) vertex and choose **Flip.

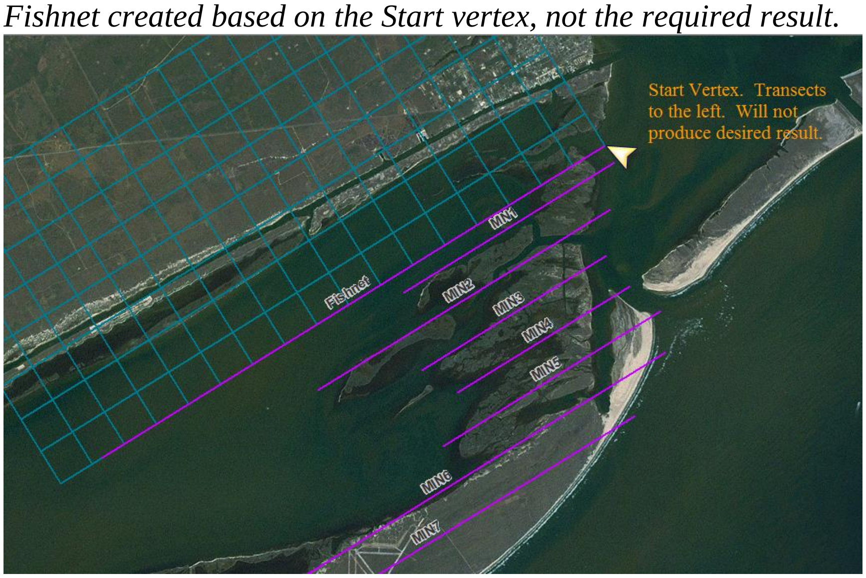
20. The **Change Length** will only allow a straight line extension. Extend the line to a distance that will match the longest transect.
21. **Right-click** and **Finish Sketch**.
22. **Editor toolbar>Editor>Save Edits** and **Stop Editing**.

23. **Open** the attribute table of the transects, and **add** four fields: *utmX*, *utmY*, *midX*, and *midY*. These should be set to field type **Double**.
24. On the fishnet line, determine the Start vertex (green) and End vertex (red) of the line. If traveling on the line from the Start vertex to the End vertex which side of the fishnet line are the transects located? Are the transects to the Right of the fishnet line moving from the Start vertex to the End vertex? If the answer is Yes, then use the Start of the line for the *utmX* and *utmY* in step 26. If the answer is No, use the End of the line for the *utmX* and *utmY* in step 26. Realize the fishnet will be created to the right of the start or end vertex of the line, then rotated based on the point calculated for the *midX* and *midY*. Examples are shown below.

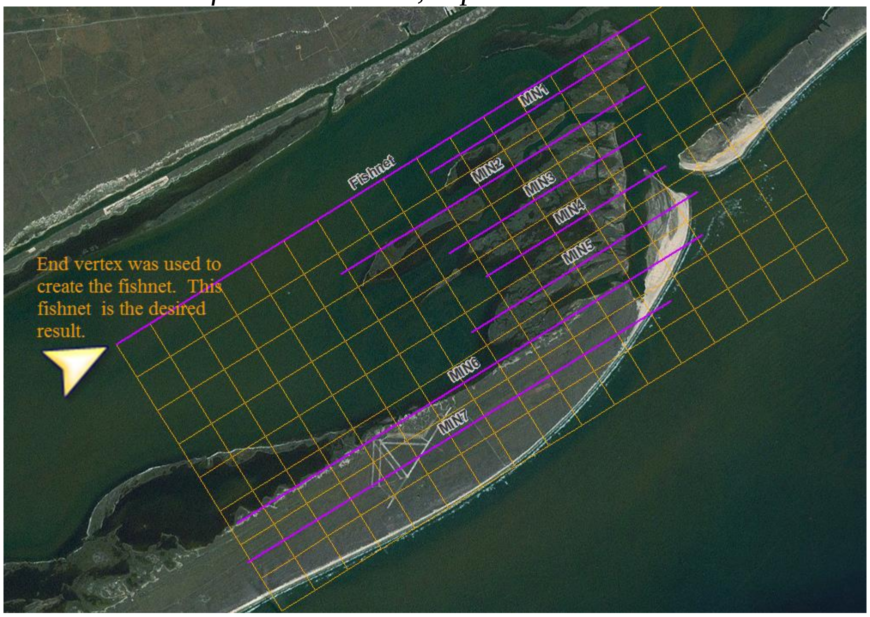
Start and End vertex example.



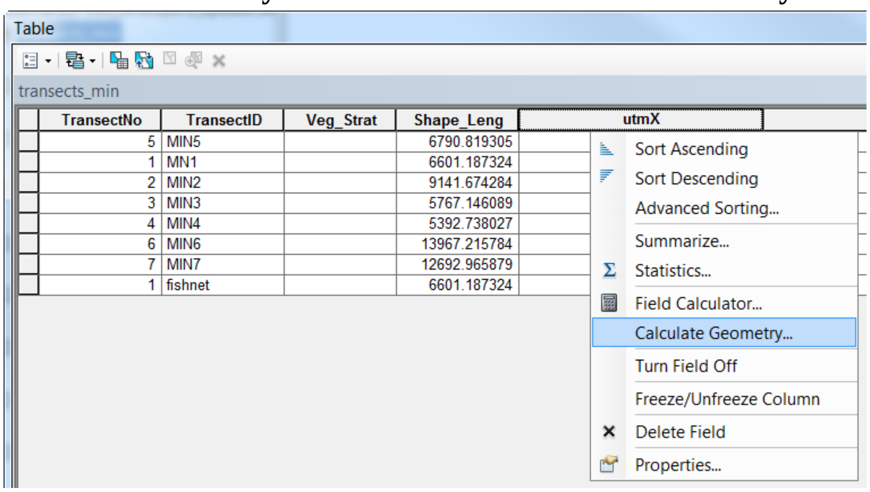
Fishnet created based on the Start vertex, not the required result.



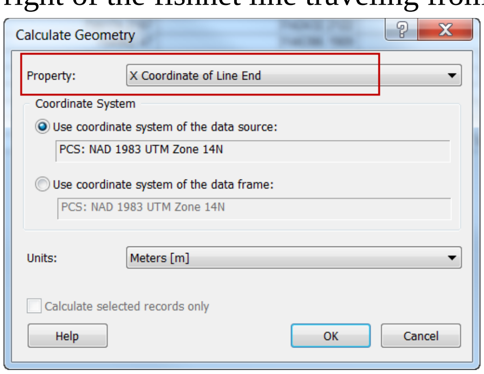
Fishnet created from End vertex, expected result.



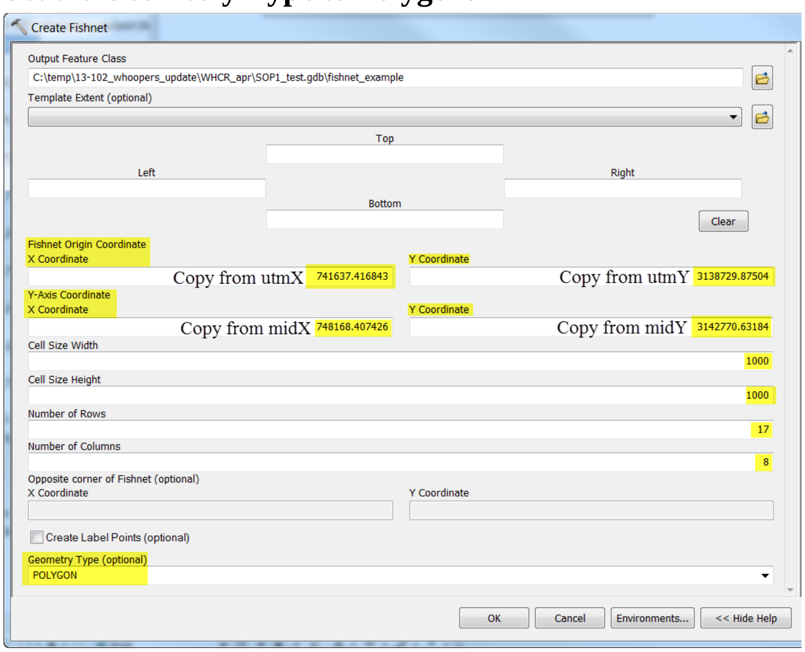
25. **Open** the *transect_area* attribute table and **right-click** on the *utmX* field and choose **Calculate Geometry**. **Click OK** to the **Calculate Geometry** warning if it appears.



26. In the **Calculate Geometry** screen for **Property**, **click** the drop-down arrow and choose the X Coordinate of Line End if the transects were to the right of the fishnet line traveling from the End vertex. Choose the X Coordinate of Line Start if the transects were to the right of the fishnet line traveling from the Start vertex.



27. Repeat steps 25 and 26 for *utmY*, choosing the Y Coordinate.
28. For the *midX* and *midY* repeat steps 25 and 26, choosing the X Coordinate of Midpoint, and Y Coordinate of Midpoint respectively.
29. After calculating the geometry for the additional four fields (*utmX*, *utmY*, *midX*, and *midY*), go to **ArcToolbox>Data Management Tools>Feature Class>Create Fishnet**.
30. The **Fishnet Origin Coordinate** should have the X Coordinate copied from the *utmX* field, and the Y Coordinate copied from the *utmY* field. See illustration of steps 30–36 below step 36.
31. The **Y-Axis Coordinate** should have the X Coordinate copied from the *midX* field, and the Y Coordinate copied from the *midY* field.
32. In this protocol the **Cell Size Width** and **Height** are set to 1,000 m.
33. The **Number of Rows** is determined by rounding the length of the longest transect up to the nearest 1,000 m (13,967 m to 14,000 m), adding an extra 3,000 m (17,000 m) then setting the **Number of Rows** to 17.
34. The **Number of Columns** is determined by the number of features in the transects feature class including the fishnet line created from the copy parallel step. In this example, 8 is used for the **Number of Columns**.
35. **Uncheck** the **Create Label Points**.
36. **Set** the **Geometry Type** to **Polygon**.



37. Once the proper fishnet is created, it can be edited to remove cells that may be in areas that will not be surveyed such as areas of open water 5 km from the shoreline.
38. Once the fishnet has been edited per the Supervisory Biologist’s specifications, append it to the larger fishnet dataset.

Appendix E: Environmental Covariates Used in Modeling

UNDERSTANDING THIS DOCUMENT

- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin).
- *Italicized* text indicates background information, a filename, or a field name.
- Appendix written for a Windows 7 environment.

*Environmental covariates are currently derived from the Texas Ecological Systems Classification Project (*http://www.tpwd.state.tx.us/gis/gallery/*), Phase 3 (Ludeke et al. 2012). Spatially-explicit relationships between abundance and vegetative covariates in the hierarchical models are based on 6 generalized vegetation types: saltmarsh, open water, wetland, saltmarsh-shrubland, upland, and urban (Table E1). Though these covariates are only rudimentary, strong relationships with whooping crane abundance has been demonstrated with some of them (Strobel et al. 2012). As additional maps of vegetation layers, other whooping crane resources (i.e., salinity, blue crab abundance, etc.), or management actions (i.e., time since prescribed burn, fresh water provisioning, etc.) become available and more detailed hypotheses of whooping crane abundance relationships are developed, additional environmental covariates will be derived and incorporated into the hierarchical models of abundance.*

Below we describe how to create the environmental covariates based on the Texas Ecological Systems Classification needed for analysis. ***Note:*** *Appendix D describes how to create prediction grid (i.e., fishnet).*

Downloading Texas Ecological Systems Classification (TESC) data

1. **Browse** to http://www.tpwd.state.tx.us/gis/gallery/.
2. **Download** TESC data (e.g., Phase 3, *Phase3_EMST_Vector_20130201.gdb*), and save to *im_surveys\....\WHCR_aerial_surveys\data\yyyy-yyyy\geodata*. Use the *yyyy-yyyy* folder for the year that the environmental covariates are being created.
3. **Unzip** TESC data into the *covariates* folder.
4. In ArcMap, **add** the following data from the *Phase3_EMST_Vector* geodatabase *Phase3_Central_Objects* and *Phase3_South_Objects;* from the *Environmental_Covariates* geodatabase **add** *big_fishnet_dissolve.*
5. Click on **Geoprocessing>Clip**, and clipthe Phase3_Central_Objects and the Phase3_South_Objects by the *big_fishnet_dissolve.* Name the clips *Phase3_Central_clip* and *Phase3_South_clip*.
6. Click on **Geoprocessing>Merge** *Phase3_Central_clip* and *Phase3_South_clip* and name it *Environmental_Covariates.gdb>TESC_Vegetation*.

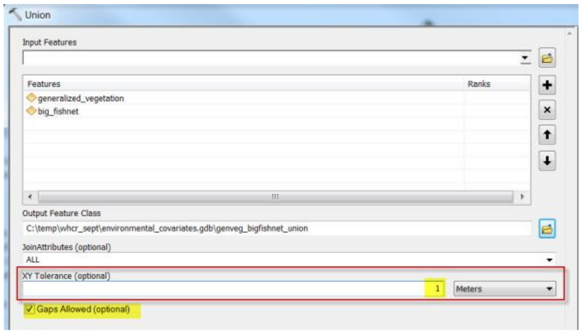
Generalizing TESC vegetation classes

1. TESC vegetation classes are generalized into 6 vegetation types: saltmarsh, open water, wetland, saltmarsh-shrubland, upland, and urban.
2. Table F1 depicts the relationship between the 6 generalized vegetation classes and the TESC vegetation types.
3. **Open** ArcMap, load *Environmental_Covariates.gdb>TESC_Vegetation* and open its attribute table.
4. **Add** a **new field** named *GenVeg* as **text**. Field length of 50.
5. **Select by Attribute** and enter the following: **Veg_ID = 9600**.
6. **Right-click** on *GenVeg* and select the **Field Calculator** and enter **"open water"**, **click OK.**
7. **Select by Attribute** and enter the following: **Veg_ID = 5600 OR Veg_ID = 5605 OR Veg_ID = 5607 OR Veg_ID = 5617 OR Veg_ID = 6600 OR Veg_ID = 6610**.
8. **Right-click** on *GenVeg* and select the **Field Calculator** and enter **"saltmarsh"**, **click OK.**
9. **Select by Attribute** and enter the following: **Veg_ID = 9410 OR Veg_ID = 9411**.
10. **Right-click** on *GenVeg* and select the **Field Calculator** and enter **"urban"**, **click OK.**
11. **Select by Attribute** and enter the following: **Veg_ID = 4517 OR Veg_ID = 4617 OR Veg_ID = 5307 OR Veg_ID = 6407 OR Veg_ID = 6507 OR Veg_ID = 9007**.
12. **Right-click** on *GenVeg* and select the **Field Calculator** and enter **"wetland"**, **click OK.**
13. **Select by Attribute** and enter the following: **Veg_ID=5606 OR Veg_ID=5616**.
14. **Right-click** on *GenVeg* and select the **Field Calculator** and enter **"saltmarsh-shrubland"**, **click OK.**
15. **Select by Attribute** and enter the following: **GenVeg IS NULL**.
16. **Right-click** on *GenVeg* and select the **Field Calculator** and enter **"upland"**, **click OK.**
17. **ArcToolbox>Data Management Tools>Generalization>Dissolve**
    a. *Input feature = TESC_Vegetation*
    b. *Output feature = Environmental_Covariates.gdb>generalized_vegetation*
    c. *Dissolve field = GenVeg (allowing multipart features).*
    d. ***Click OK*.**

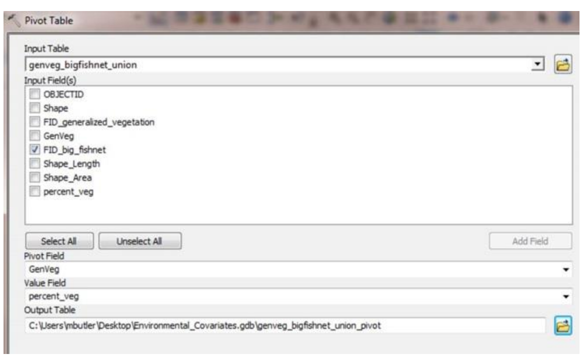
Creating a large-scale prediction grid for planning activities

1. **ArcToolbox>Analysis Tools>Overlay>Union** to union *generalized_vegetation* with *big_fishnet* and name output *genveg_bigfishnet_union*. Set the **XY**

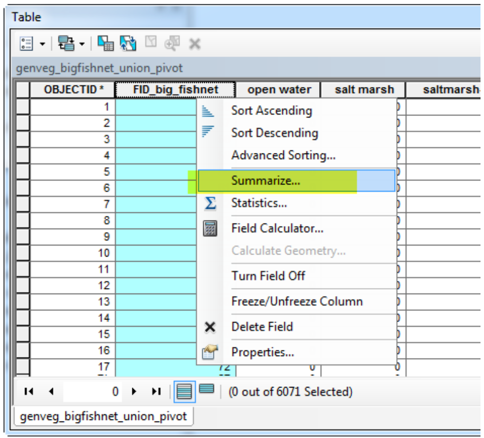
Tolerance to **1 meter** as the TESC data has multiple small slivers. Confirm there is a check in the **Gaps Allowed**.



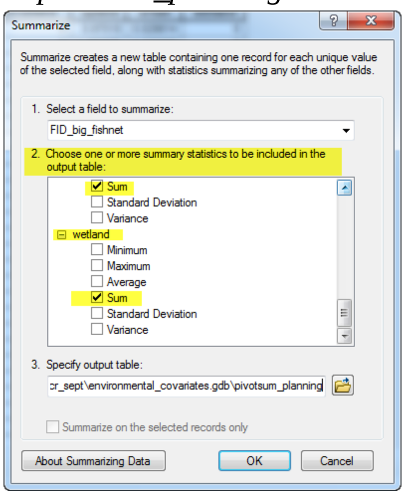
2. **Open** attribute table of *genveg_bigfishnet_union*.
3. **Select By Attribute** and enter the following: **FID_generalized_vegetation = -1**.
4. **Click** on **Show Selected Records** in the attribute table.
5. **Right-click** on *GenVeg* and select the **Field Calculator** and enter **"open water"**, **click OK.** This categorizes the areas beyond the boundaries of the vegetation layer (i.e., areas in the Gulf of Mexico beyond Matagorda beach) as open water.
6. **Clear Selection. Click** on **Show All Records** in the attribute table.
7. **Add** a **new field** named *percent_veg* as **double**.
8. **Right-click** on *percent_veg* and select the **Field Calculator** and enter **[Shape_Area]/1000000**, **click OK.**
9. **ArcToolbox>Data Management Tools>Table>Pivot Table**
    a. *Input Table = genveg_bigfishnet_union*
    b. *Input Field = FID_big_fishnet*
    c. *Pivot Field = GenVeg*
    d. *Value Field = percent_veg*
    e. *Output Table = Environmental_Covariates.gdb> genveg_bigfishnet_union_pivot*
    f. ***Click OK.***



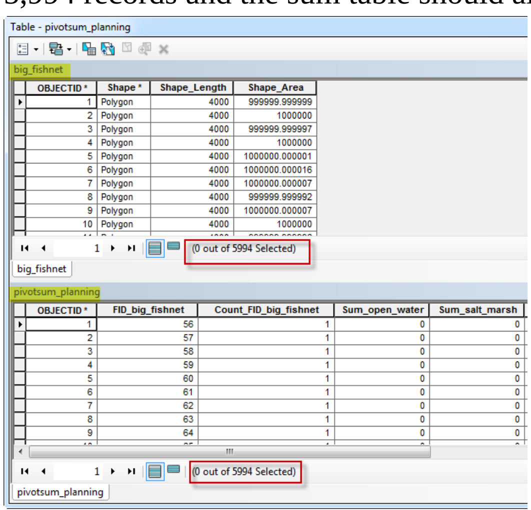
10. After creating the pivot table create a table that summarized on the *FID_big_fishnet*; summing each of the *genveg* classes. **Right-click** on the *FID_big_fishnet* column, and choose **Summarize.**



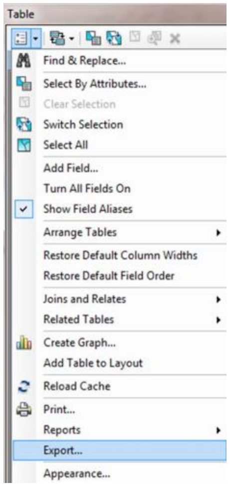
11. In **Summarize,** under the summary statistics **choose *Sum*** for each of the six genveg classes (i.e., *open_water*, *salt_marsh*, *urban*, etc.). Name the output table as *pivotsum_planning*.



12. **Compare** the number of records in the summary table to the number of records in big_fishnet. These should be the exact same number (i.e., the *big_fishnet* has 5,994 records and the sum table should also have 5,994).

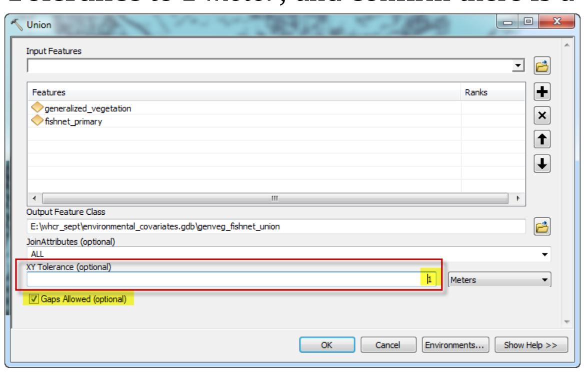


13. **Export** the attribute table created by the summarize table in step 11 as a text file named *planning.txt* and save it to the *spreadsheets* folder.



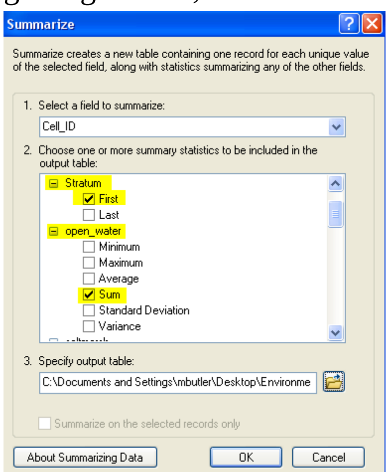
Creating COVS file for data analysis

1. **ArcToolbox>Analysis Tools>Overlay>Union** to union *generalized_vegetation* with *fishnet_primary* and name output *genveg_fishnet_union*. Set the **XY Tolerance** to *1 meter*, and confirm there is a check in **Gaps Allowed**.

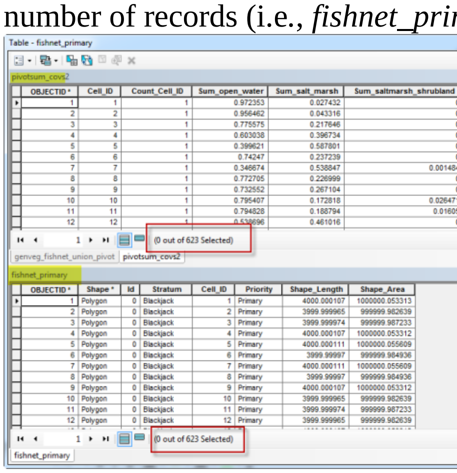


2. **Open** Attribute Table of *genveg_fishnet_union*.
3. **Select By Attribute** and enter the following: **FID_fishnet_primary = -1**.
4. Click on **Editor>Start Editing>***genveg_fishnet_union* and **delete** selected records. This removes all the vegetation polygons that did not overlay the fishnet.
5. Click on **Save Edits** and then click on **Stop Editing**.
6. **Open** Attribute Table of *genveg_fishnet_union*.
7. **Select By Attribute** and enter the following: **FID_generalized_vegetation = -1**.
8. **Click** on **Show Selected Records** in the attribute table.
9. **Right-click** on *GenVeg* and select the **Field Calculator** and enter **"open water"**, **click OK**. This categorizes the areas beyond the boundaries of the vegetation layer (i.e., areas in the Gulf of Mexico beyond Matagorda beach) as open water.
10. **Clear Selection**. **Click** on **Show All Records** in the attribute table.
11. **Add** a **new field** named *percent_veg* as **double**.

12. **Right-click** on *percent_veg* and select the **Field Calculator** and enter **[Shape_Area]/1000000**, **click OK.**
13. **ArcToolbox>Data Management Tools>Table>Pivot Table**
    a. *Input Table = genveg_fishnet_union*
    b. *Input Field = Cell_ID* and *Stratum*
    c. *Pivot Field = GenVeg*
    d. *Value Field = percent_veg*
    e. *Output Table = Environmental_Covariates.gdb> genveg_fishnet_union_pivot*
    f. **Click OK**.
14. Create a summarize table by summing each of the *genveg* classes with the following steps.
15. **Right-click** on the *Cell_ID* column, and choose **Summarize. Expand** each of the genveg classes, and **check** *Sum*. Name this table *pivotsum_covs*.



16. **Open** both the *pivotsum_covs* attribute table and the *fishnet_primary* attribute table. Compare the number of records each attribute table should have the same number of records (i.e., *fishnet_primary* has 623 records, *pivotsum_covs* has 623).



17. **Export** the attribute table created by the summarize table in step 15 as a text file named *COVS.txt* and save it to the *spreadsheets* folder.

Table E1. Generalization of the Texas Ecological Systems Classification scheme into 6 general vegetation classes for use in hierarchical distance sampling models.

Veg_ID	Texas Ecological Systems Classification	Generalized Class
9600	Open Water	open water
5600	Coastal: Tidal Flat	saltmarsh
5605	Coastal: Sea Ox-eye Daisy Flats	saltmarsh
5607	Coastal: Salt and Brackish Low Tidal Marsh	saltmarsh
5617	Coastal: Salt and Brackish High Tidal Marsh	saltmarsh
6600	South Texas: Wind Tidal Flats	saltmarsh
6610	South Texas: Algal Flats	saltmarsh
5606	Coastal: Mangrove Shrubland	saltmarsh-shrubland
5616	Coastal: Salt and Brackish High Tidal Shrub Wetland	saltmarsh-shrubland
602	Post Oak Savanna: Live Oak Motte and Woodland	upland
604	Post Oak Savanna: Post Oak Motte and Woodland	upland
605	Post Oak Savanna: Live Oak Shrubland	upland
613	Post Oak Savanna: Post Oak - Yaupon Motte and Woodland	upland
633	Post Oak Savanna: Post Oak - Live Oak Motte and Woodland	upland
2206	Gulf Coast: Salty Prairie Shrubland	upland
2207	Gulf Coast: Salty Prairie	upland
4502	Coastal Bend: Floodplain Live Oak Forest	upland
4503	Coastal Bend: Floodplain Live Oak - Hardwood Forest	upland
4504	Coastal Bend: Floodplain Hardwood Forest	upland
4505	Coastal Bend: Floodplain Evergreen Shrubland	upland
4506	Coastal Bend: Floodplain Deciduous Shrubland	upland
4507	Coastal Bend: Floodplain Grassland	upland
4602	Coastal Bend: Riparian Live Oak Forest	upland
4603	Coastal Bend: Riparian Live Oak - Hardwood Forest	upland
4604	Coastal Bend: Riparian Hardwood Forest	upland
4605	Coastal Bend: Riparian Evergreen Shrubland	upland
4606	Coastal Bend: Riparian Deciduous Shrubland	upland
4607	Coastal Bend: Riparian Grassland	upland
5207	Gulf Coast: Coastal Prairie	upland
6100	Central and Lower Coastal: Beach	upland
6200	Active Sand Dune	upland
6306	Coastal and Sandsheet: Deep Sand Shrubland	upland
6307	Coastal and Sandsheet: Deep Sand Grassland	upland
6402	Coastal and Sandsheet: Deep Sand Live Oak Forest and Woodland	upland
6403	Coastal and Sandsheet: Deep Sand Live Oak - Mesquite Woodland	upland
6405	Coastal and Sandsheet: Deep Sand Live Oak Shrubland	upland
7002	South Texas: Clayey Live Oak Motte and Woodland	upland
7004	South Texas: Clayey Mesquite Mixed Shrubland	upland
7005	South Texas: Clayey Blackbrush Mixed Shrubland	upland
7102	South Texas: Sandy Live Oak Motte and Woodland	upland
7103	South Texas: Sandy Mesquite - Evergreen Woodland	upland

Table E1. Continued.

Veg_ID	Texas Ecological Systems Classification	Generalized Class
7104	South Texas: Sandy Mesquite Woodland and Shrubland	upland
7105	South Texas: Sandy Mesquite Dense Shrubland	upland
7107	South Texas: Sandy Mesquite Savanna Grassland	upland
7907	Coastal Plain: Terrace Sandyland Grassland	upland
9000	Barren	upland
9104	Native Invasive: Deciduous Woodland	upland
9106	Native Invasive: Mesquite Shrubland	upland
9107	Native Invasive: Common Reed	upland
9116	Native Invasive: Baccharis Shrubland	upland
9124	Native Invasive: Huisache Woodland or Shrubland	upland
9204	Non-native Invasive: Saltcedar Shrubland	upland
9214	Non-Native Invasive: Chinese Tallow Forest, Woodland, or Shrubland	upland
9307	Row Crops	upland
9505	Invasive: Evergreen Shrubland	upland
9410	Urban High Intensity	urban
9411	Urban Low Intensity	urban
4517	Coastal Bend: Floodplain Herbaceous Wetland	wetland
4617	Coastal Bend: Riparian Herbaceous Wetland	wetland
5307	Gulf Coast: Coastal Prairie Pondshore	wetland
6407	Coastal and Sandsheet: Deep Sand Live Oak Swale Marsh	wetland
6507	Coastal and Sandsheet: Deep Sand Grassland Swale Marsh	wetland
9007	Marsh	wetland

Appendix F: Template for Update Reports

Update reports will be prepared within a few days after each survey and are the responsibility of the Lead Biologist with assistance from other observers. They will provide brief summaries of survey activities but will not provide comprehensive results. These reports will describe the flight mission, survey conditions, aircraft used, search effort, who were the observers, and the number of detections. The reports will not provide comprehensive results but are intended as a simple permanent record of short-term monitoring activities and survey-specific conditions. Since update reports only contain information about raw data and no results, we recommend not distributing update reports widely unless absolutely necessary. This is because raw data from a survey where detection of whooping cranes is not 100% can be misleading, misinterpreted, and misused. Below is a template for update reports. <u>CAPTIALIZED text will be replaced with survey-specific details.</u>

All update reports <u>**must**</u> contain the following disclaimer:

"Data presented in this report are preliminary and results only reflect a summary description of the number of whooping cranes and their group structure observed during this survey. These statistics are <u>not</u> to be construed as the annual winter abundance estimate since they have not been corrected for incomplete detection. The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service."

Whooping Crane Survey Summary

Aransas National Wildlife Refuge
U.S. Fish and Wildlife Service

Report Prepared By:

NAME, TITLE
AFFILIATION

NAME, TITLE
AFFILIATION

Survey Date: DD MONTH YYYY

Pilot: NAME, AFFILIATION

Aircraft: MAKE, MODEL

Observers: NAME, AFFILIAITON
NAME, AFFILIAITON

Data presented in this report are preliminary and results only reflect a summary description of the number of whooping cranes and their group structure observed during this survey. These statistics are <u>not</u> to be construed as the annual winter abundance estimate since they have not been corrected for incomplete detection. The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

Flight Mission: EXAMPLES: "SURVEY ALL TRANSECTS WITHIN PRIMARY SAMPLING FRAMES TO ESTIMATE THE NUMBER OF CRANES USING THE SAMPLED AREA", "SURVEY SECONDARY SAMPLING FRAMES TO DETECT AND DOCUMENT ADDITIONAL WHOOPING CRANE LOCATIONS", ETC.

Conditions: WIND: SPEED, DIRECTION, GUSTY/STEADY
SKY: CONDITIONS, VISIBILITY
TEMPERATURE

Results: NOTE DIFFERENCES BETWEEN FLIGHT MISSION AND REALIZED SURVEY (E.G., MISSION ABORTED DUE TO WEATHER, INCLUSION OF ADDITIONAL SAMPLING FRAMES, ETC), DURATION OF SURVEY, NUMBER OF CRANES DETECTED, NUMBER OF GROUPS DETECTED, ETC.

Comments: UNIQUE OBSERVATIONS, LONG-TERM WEATHER CONDITIONS, EXPECTED COMPLETION DATE FOR ANALYSES, EXPECTED DATE OF NEXT FLIGHT, ETC.

Table 1. Number of whooping crane groups detected by group structure.

Group structure		Number of whooping crane groups detected	
AHY[a]	HY[b]	Primary sampling frame	Secondary sampling frame
1	0	#	#
2	0	#	#
2	1	#	#
2	2	#	#
Other		#	#
Total		#	#

[a] After Hatch Year whooping crane, full white plumage.
[b] Hatch Year whooping crane, tawny plumage.

Table 2. Number of whooping crane groups detected by age-class.

	Number whooping cranes detected	
Age-class	Primary sampling frame	Secondary sampling frame
AHY[a]	#	#
HY[b]	#	#
Unknown	#	#
Total	#	#

[a] After Hatch Year whooping crane, full white plumage.
[b] Hatch Year whooping crane, tawny plumage.

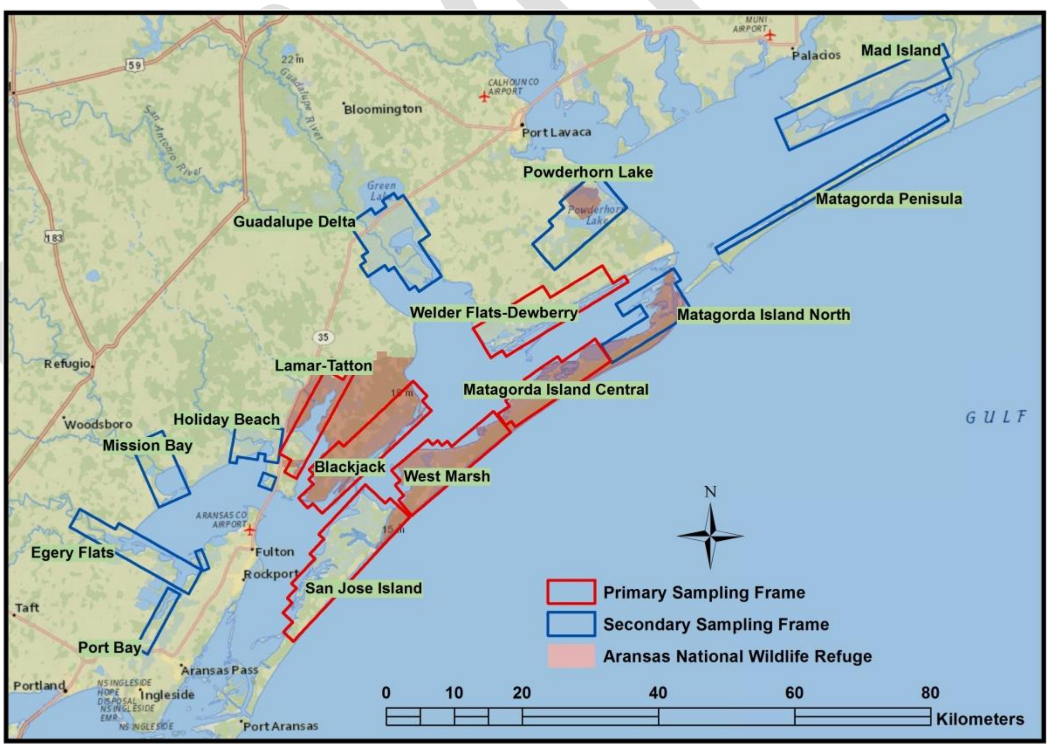


Figure 1. Sampling frames within the whooping crane aerial survey area. Primary sampling frames are denoted with red boundaries while secondary sampling frames are denoted with blue boundaries.

Appendix G: Description of Archived Data Files (Data Dictionary)

Initially, users will download the template geodatabases from the WHCR Aerial Surveys (TX Coast) SharePoint site. These will contain template data for the survey. They will also contain the fishnet (as cells), the dissolved fishnet, and the ideal transects and their endpoints.

The geodatabases have two domains (i.e., drop-down lists) to allow for user selection data attributes:

Domain Name: Near_Problem
Domain Definition: Indicates that the point is closer to an adjacent transect other than the one being flown.
Domain Values: Near Other Transect

Domain Name: Type
Domain Definition: Observer indicates if a point is an end, start, crane, or error.
Domain Values: Crane(s), End Transect, ERROR, Start Transect, Off Transect

The two domains above are used in the *survey_mmddyy* feature classes.

Table G1. The *survey_mmddyy* feature class has the following attributes.

Attribute	Definition
OBJECTID	Sequential unique whole numbers that are automatically generated.
SHAPE	Coordinates defining the features.
WHITE	Number of white (adult) whooping cranes.
JUVE	Number of juvenile (hatch-year) whooping cranes.
UNK	Number of unknown age whooping cranes.
COMMENTS	Observer's comments.
TRANSECT_ID	The transect id abbreviation (see Table 1).
OBSERVER	The observer's initials (use 3 initials).
ORIGINAL_ID	The original OBJECTID from the survey_mmddyy feature class created during the flight.
DATE_	The date of the aerial survey (i.e., MM/DD/YY).
Type	The type of point identifying if the point is the start or end of a transect, an accidental click, a whooping crane observation, or an off-transect observation.
Near_Problem	Indicates that the point is closer to an adjacent transect other than the one observed from. This is important for correcting the near tool results.
Total_Group_Size	Calculated from WHITE, JUVE, and UNK in protocol SOP 3.

Table G2. The *transects_ideal_primary* and *transects_ideal_secondary* feature classes have the following attributes.

Attribute	Definition
OBJECTID	Internal feature number.
Shape	Feature geometry.
Area	Name of the sampling frame.
Priority	Primary or secondary sampling frame.
TransectNo	The number assigned to the transect.
TransectID	Identifies transect by abbreviating the survey area and adding the transect number. An example is WF8 for Welder Flats, number 8 transect (see Table 1).
Shape_Length	Length of feature in internal units.

Table G3. The *cranes_mmddyy* feature class has the following attributes.

Attribute	Definition
OBJECTID	Sequential unique whole numbers that are automatically generated.
SHAPE	Coordinates defining the features.
WHITE	Number of white (adult) whooping cranes.
JUVE	Number of juvenile (hatch-year) whooping cranes.
UNK	Number of unknown age whooping cranes.
COMMENTS	Observer's comments.
TRANSECT_ID	The transect id abbreviation (see Table 1).
OBSERVER	The observer initials (use 3 initials).
ORIGINAL_ID	The original OBJECTID from the survey_mmddyy feature class created during the flight.
DATE_	The date of the aerial survey (i.e., MM/DD/YY).
Type	The type of point identifying if the point is the start or end of a transect, an accidental click, a whooping crane observation, or an off-transect observation.
Near_Problem	Indicates that the point is closer to an adjacent transect other than the one observed from. This is important for correcting the near tool results.
Total_Group_Size	Calculated from WHITE, JUVE, and UNK in protocol SOP.
NEAR_FID	FID of the NEAR Feature Class used with the NEAR tool.
NEAR_DIST	Distance to the cranes from the transect or NEAR feature.
Concate2	Field created to help determine correct near feature for updating the near distance issues when crane detections are closer to an adjacent transect (SOP3).

Table G4. The *CDS_mmddyy* file has the following attributes.

Attribute	Definition
WHITE	Number of white (adult) whooping cranes.
JUVE	Number of juvenile (hatch-year) whooping cranes.
UNK	Number of unknown age whooping cranes.
COMMENTS	Observer's comments.
TRANSECT_ID	Name as initials and number of transect.
OBSERVER	The observer's initials (use 3 initials).
DATE_	The date of the aerial survey (i.e., MM/DD/YY).
Total_Group_Size	Calculated from WHITE, JUVE, and UNK in protocol SOP.
NEAR_FID	FID of the NEAR Feature Class used with the NEAR tool.
NEAR_DIST	Distance to the transect from which the detection was observed.
Length_CDS	Length of the CDS transect in meters (total length of each transect).

Table G5. The *HDS_mmddyy* has the following attributes.

Attribute	Definition
Cell_ID	Fishnet cell number.
WHITE	Number of white (adult) whooping cranes.
JUVE	Number of juvenile (hatch-year) whooping cranes.
UNK	Number of unknown age whooping cranes.
COMMENTS	Observer's comments.
TRANSECT_ID	Name as initials and number of transect.
OBSERVER	The observer's initials (use 3 initials).
DATE_	The date of the aerial survey (i.e., MM/DD/YY).
Total_Group_Size	Calculated from WHITE, JUVE, and UNK in protocol SOP.
NEAR_FID	FID of the NEAR Feature Class used with the NEAR tool.
NEAR_DIST	Distance to the transect from which the detection was observed.
Length_HDS	Length of the HDS transects in meters (length of transect within each fishnet cell).

Table G6. The *gen_near_tbl_mmddyy* has the following attributes.

Attribute	Definition
OBJECTID	Sequential unique whole numbers that are automatically generated.
IN_FID	The IN features *OBJECTID.* In SOP3, this is from the *cranes_mmddyy.*
NEAR_FID	The NEAR features *OBJECTID*. In SOP3, this is from the *transects_mmddyy.*
NEAR_DIST	Distance calculated from a near feature.
Concate2	Field created to help determine correct near feature for updating the near distance issues when crane detections are closer to an adjacent transect (SOP3).

Table G7. The *transects_mmddyy* has the following attributes.

Attribute	Definition
OBJECTID	Sequential unique whole numbers that are automatically generated.
SHAPE	Coordinates defining the features.
TYPE	From DNR Garmin.
IDENT	From DNR Garmin.
Transect_id	The transect name as initials and number (SOP3).
Area	NWR name for stratum.
Shape_Length	Length of feature in internal units

Table G8. The *flight_mmddyy* file has the following attributes.

Attribute	Definition
OBJECTID	Sequential unique whole numbers that are automatically generated.
Date	The date of the aerial survey (i.e., MM/DD/YY).
WindSpd	Wind speed.
WindDir	Wind direction.
SkyCond	Sky condition.
VisibMi	Visibility in miles.
TempF	Air temperature in Fahrenheit.
Aircraft	The type of aircraft used in the survey.
NamePilot	Name of the pilot.
NameObs1	Name of 1st observer.
NameObs2	Name of 2nd observer.
SeatObs1	Observer in seat 1.
SeatObs2	Observer in seat 2.
Comments	User generated comments.

Table G9. The *fishnet_primary* and *fishnet_secondary* feature classes have the following attributes.

Attribute	Definition
OBJECTID	Sequential unique whole numbers that are automatically generated.
SHAPE	Coordinates defining the features.
Stratum	NWR name for the area.
Cell_ID	Fishnet cell number.
Priority	Primary or secondary flight area.
Shape_Length	Length of feature in internal units.
Shape_Area	Area of feature in internal units.

After post-processing the data, the following objects should exist within the *WHCR_SOP_mmddyy* geodatabase, spreadsheets, and audio folders:

- survey_mmddyy (point feature class)
- cranes_mmddyy (point feature class)
- transects_mmddyy (line feature class)
- gen_near_tbl_mmddyy (database table)
- track_mmddyy (line feature class)
- CDS_mmddyy (database table)
- CDS_mmddyy.txt (spreadsheets)
- HDS_mmddyy (database table)
- HDS_mmddyy.txt (spreadsheets)
- SurveyAudio_mmddyy_obs1 (audio)
- track_mmddyy.txt (spreadsheets)

The fishnets and ideal transects will remain in the *WHCR_SOP_mmddyy* geodatabase. If the Refuge made changes to the fishnets or transects, the Biometrician and Regional Data Manager should have been consulted to account for survey design issues and archiving those datasets, respectively.

Observer geodatabases will be backed-up to the SharePoint, but will not be included in the final upload to ServCat.

Appendix H: Permission Levels and Requests

There are 3 digital locations discussed in this document: the Aransas NWR server, WHCR Aerial Surveys (TX Coast) SharePoint site, and Service Catalog (ServCat). Aransas NWR is an Active Directory site, and one of the few Region 2 refuges with a server for data storage. Given that most refuges in Region 2 do not have a server for data storage, past survey data is stored on individual computers at refuges. In 2012, the USFWS's Service Catalog or ServCat became available, and was built to "increase accessibility of natural resource inventory and monitoring information to managers and biologists engaged in planning, management, and decision-making" (USFWS 2012*b*).

Given the decentralized IT environment, when I&M protocols are developed, Region 2 is creating survey specific SharePoint sites with unique permissions for the following reasons:

1. Provide a duplicate site for survey data.
2. Restrict survey data access until deemed ServCat ready by the PI or Supervisory Biologist of the I&M survey per the I&M protocol.
3. Facilitate a survey data staging area where the regional data management team can upload the survey data to ServCat reducing the data management workload for the NWRs.
4. Ensuring standardization of ServCat metadata to facilitate better search results for USFWS staff using ServCat.

SharePoint permission levels

For this Whooping Crane Winter Abundance Survey, a SharePoint site named "WHCR Aerial Surveys (TX Coast)" has been created. The permission levels to this site are set to unique as it does not inherit permissions from the Region 2 I&M SharePoint site.

Table H1. List of groups and users with access to the WHCR Aerial Surveys SharePoint site.

SharePoint Group/User	Permission Level	Who is included
Inventory and Monitoring Owners	Limited Access	R2 I&M Coordinator & R2 I&M Regional Data Manager
R2 Inventory and Monitoring Owners	Full Control	R2 I&M Coordinator & R2 I&M Regional Data Manager
R2_IM_WHCR	Contribute	Authorized USFWS Users
R2 Regional Data Manager	Limited Access	R2 I&M Regional Data Manger
System Account (SHAREPOINT\system)	Limited Access	SharePoint System Administrators

Requesting access to the WHCR Aerial Surveys SharePoint

For the initial population of the R2_IM_WHCR group, which has Contribute permission to this site, the Aransas NWR Supervisory Biologist, Refuge Manager, or the I&M Coordinator will email the I&M Regional Data Manager the names of the USFWS employees who should access the site. The subject line shall be "WHCR SP Access." The email shall be courtesy copied "cc" to the Aransas NWR Supervisory Biologist, Aransas NWR Refuge Manager, I&M Coordinator, and the I&M Regional Data Manager regardless of who sends it.

The WHCR Aerial Surveys SharePoint site is set-up to allow requests to join or leave the R2_IM_WHCR group. SharePoint 2010 allows only one email address to be entered for sending the join/leave requests. The I&M Regional Data Manager's email address will receive the email. The I&M Regional Data Manager will forward the email to the Aransas NWR Supervisory Biologist and the I&M Coordinator for approval. The Aransas NWR Refuge Manager will be in the "cc" line of the email. For these approvals, when replying to the I&M Regional Data Manager the reply to all should be used. Once the I&M Regional Data Manager receives confirmation of approval, the user request will be approved.

SharePoint information for the Regional I&M Data Management Team

Use the *Site Settings>Site Permissions>R2_IM_WHCR>Settings>Group Settings* to change the email address able to receive these permission requests from the SharePoint site.

When an email is received from the Supervisory Biologist or the I&M Coordinator to add or remove users from the R2_IM_WHCR group, the *Site Actions>Site Permissions* should be used. Click on the R2_IM_WHCR group, and choose to add a new user or remove users from the group.

When there is an I&M Zone Data Manager for the Texas Gulf Coast, that position will receive these email requests and shall follow this process and include the I&M Regional Data Manager on all correspondence.

ServCat permission levels

ServCat allows for a Sensitivity Evaluation, Proprietary Evaluation, Quality Evaluation, and Use Constraints. The ServCat record for this data will be set as:

Sensitivity Evaluation: Sensitive with the Endangered Option
Proprietary Evaluation: Non-Proprietary
Quality Evaluation: High
Use Constraints: Restricted open to I&M Coordinator, Biometrician, Aransas NWR Biologist, WHCR Coordinator

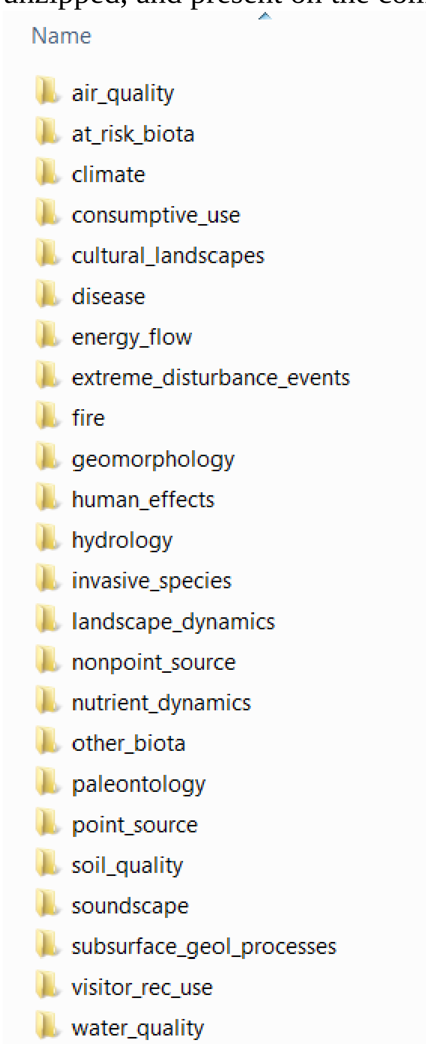
Appendix I: Downloading Template Data from SharePoint

UNDERSTANDING THIS DOCUMENT

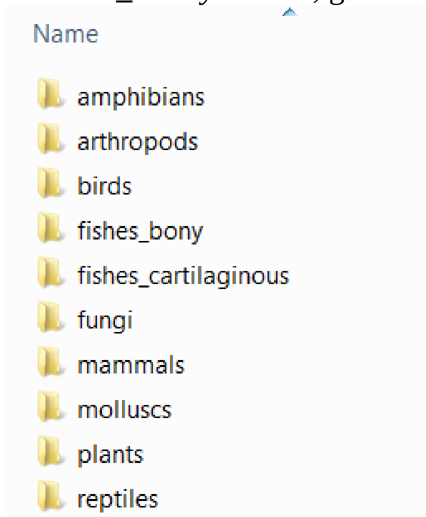
- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin, SharePoint).
- *Italicized* text indicates background information, a filename, or a field name.
- Appendix written for a Windows 7 environment

End users should already have the im_surveys directory structure on their server, computer, and/or external drive. If this directory structure is not present, go to the I&M SharePoint site and download the im_surveys zip file:
https://fishnet.fws.doi.net/regions/2/nwrs/IM/DMGISIT/Data Management/Forms/AllItems.aspx

1. Ensure the file directory structure for I&M Surveys called *im_surveys.zip* is unzipped, and present on the computer or server as *im_surveys* folder.



2. In the *im_surveys* folder, go to *at_risk_biota>birds*.



3. **Right-click** on and copy the *survey_name* folder.
4. **Paste** it in the same directory of birds.
5. **Right-click** on the copy and **rename** it *WHCR_aerial_surveys*.
6. **Click** on the *WHCR_aerial_surveys folder>data*.
7. **Right-click** on the *yyyy-yyyy*, **copy and paste** it in the same *WHCR_aerial_surveys* folder.
8. **Rename** it to the current survey year (e.g., *2012-2013* or *2013-2014*).
9. **Browse** to the SharePoint site at: https://fishnet.fws.doi.net/regions/2/nwrs/IM/WHCR/SitePages/Home.aspx
10. **Click** on *Data>SOP_templates*.
11. **Download** the zip file and save to *im_surveys>at_risk_biota>birds>WHCR_aerial_surveys>data>yyyy-yyyy>RO_templates*.
    Note: *yyyy-yyyy is the current survey year.*
12. In *RO_templates*, extract all from the zip files. There will be 5 geodatabase templates.
13. In ArcCatalog, **copy** the 5 geodatabases from the *RO_templates* into the *im_surveys>at_risk_biota>birds>WHCR_aerial_surveys>data>yyyy-yyyy>geodata* folder.
14. These are now the working databases.

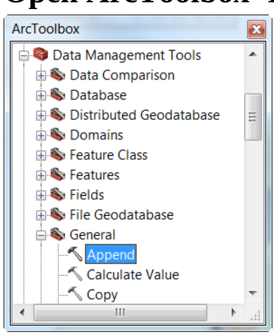
Appendix J: Promoting a Secondary Sample Frame (SSF) to a Primary Sample Frame (PSF)

UNDERSTANDING THIS DOCUMENT

- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 3.0.1, DNR Garmin, SharePoint).
- *Italicized* text indicates background information, a filename, or a field name.
- Appendix written for a Windows 7 environment

The terms "fishnet" and "sampling frame" are used interchangeably throughout this protocol as "fishnet" is a geospatial term and tool used to create a "sampling frame." When enough whooping crane groups are detected (see Element 3–Sampling frame–Sampling Objective 5; Table 2) at least twice in a SSF region between 28 November–26 December, it may be time to promote the SSF region to the PSF fishnet feature class, fishnet_primary. Ideally, a protocol user should contact the regional data management team to complete these steps and update the WHCR Aerial Surveys (TX Coast) SharePoint site with the revised files, and update ServCat. Send an email to the Regional Data Manager and the Zone Data Manager with a subject of: WHCR_PROTOCOL_request. If an end user must promote these files follow the steps below, and contact the regional data management team with the updated files so both the SharePoint site and ServCat can be updated as well.

1. Make a copy of the *WHCR_SOP_mmddyy_template* geodatabase.
2. From the copied geodatabase, add *fishnet_primary* and *fishnet_secondary* fishnets to ArcMap.
3. Using the selection tools, **select** the SSF that will be promoted.
4. **Right-click** on *fishnet_secondary* and **click** on **Data>Export Data**, name the file *ssf_promote_mmddyy*.
5. **Add** *ssf_promote_mmddyy* to ArcMap.
6. **Open ArcToolbox>Data Management Tools>General>Append.**



7. The Input Dataset is *ssf_promote_mmddyy*.
8. The Target Dataset is *fishnet_primary*.
9. Set the *Schema Type* to *TEST.*
10. Repeat steps 1–9 for promoting the transects as well.

Appendix K: Pre-flight GPS Unit Set-up

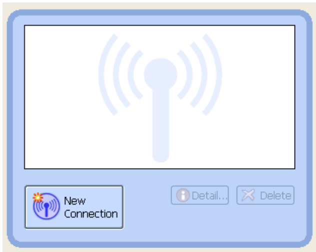
UNDERSTANDING THIS DOCUMENT

- This appendix is for use with SOP1.
- Emboldened terms are commands, tools, or tasks within the referenced software programs (i.e., ArcMap 10, ArcCatalog 10, Microsoft Excel 2010, Program R 2.15.0, DNR Garmin, SharePoint, GPSinfo).
- *Italicized* text indicates background information, a filename, or a field name.
- Appendix written for a Windows 7 environment

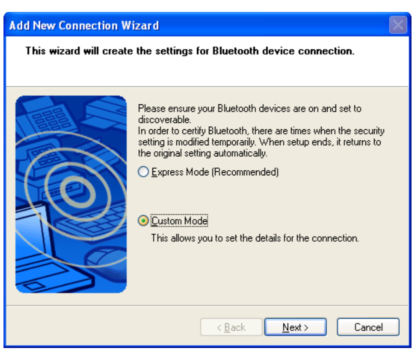
GPS technology rapidly changes. The Refuge may find a lighter weight GPS solution for the in-flight survey. Therefore, the pre-flight GPS set-up is included as an Appendix to facilitate easier changes to this protocol. This appendix shall be used with ***SOP1 at steps 12-16****. The screenshots and text for this Appendix were provided by Refuge Biologist, Diana Iriarte. When the Refuge changes GPS solutions the Refuge Biologist will provide an update to this Appendix. In winter 2012–2013, the Refuge used two GSAT GPS units attached to the laptops for on-screen GPS in ArcMap, and two Garmin GPS units are the redundant, handheld GPS units.*

Bluetooth Pairing of the GSAT GPS Unit

1. The GPS device used with the inflight laptop is a Bluetooth GPS Receiver (BT-359) made by GlobalSat. This GPS device allows each observer to display their current location within ArcMap.
2. To pair the GPS device with the computer for the first time, go to bluetooth settings and **click** on **New Connection**.

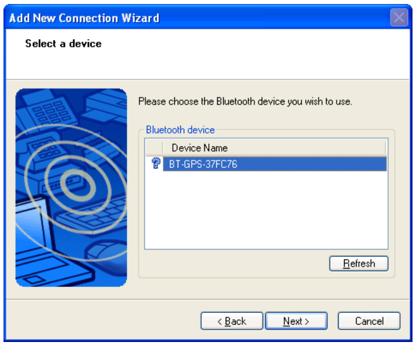


3. Be sure to select **Custom Mode** so that you can select the COM port you want to use. Select **Next**.



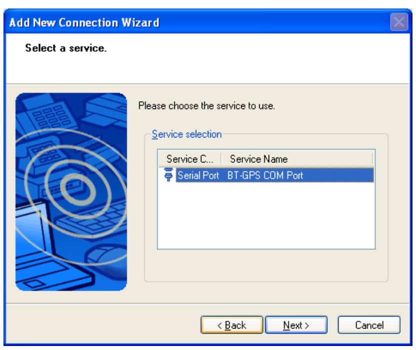
4. The computer will search for Bluetooth devices.

5. **Click next** after the GPS device has been detected.

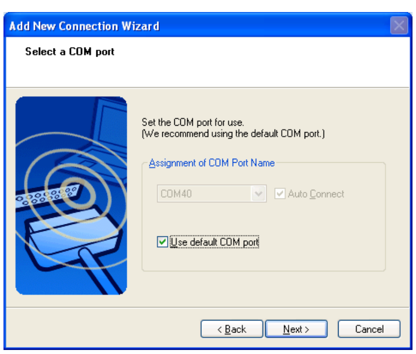


6. The computer will connect to the GSAT GPS unit.

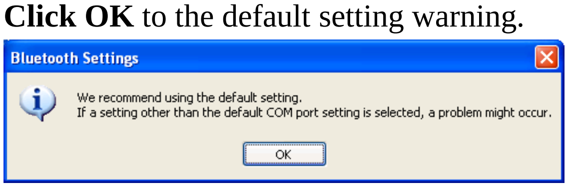
7. Choose a service.



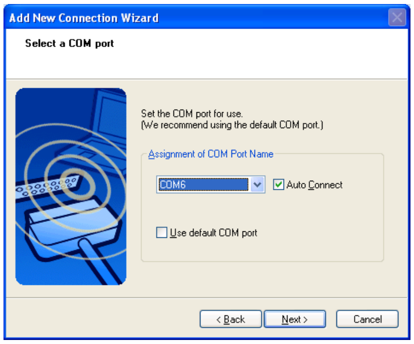
8. **Uncheck** the **Use default COM port**.



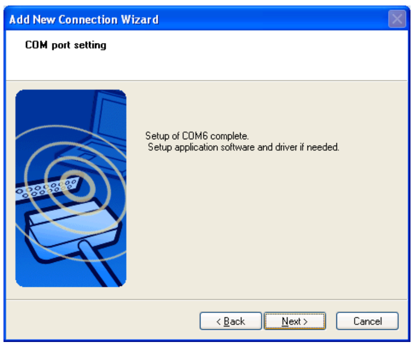
9. **Click OK** to the default setting warning.



10. Select a COM port between 1 and 10. Some software may not allow COM ports greater than 10.

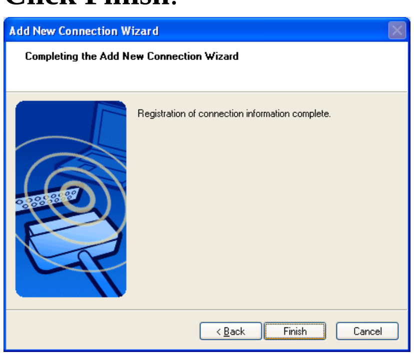


11. The setting of the COM port will display.



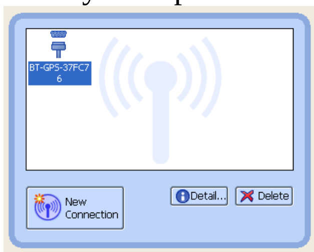
12. Choose a connection name or accept the default name.

13. **Click Finish**.



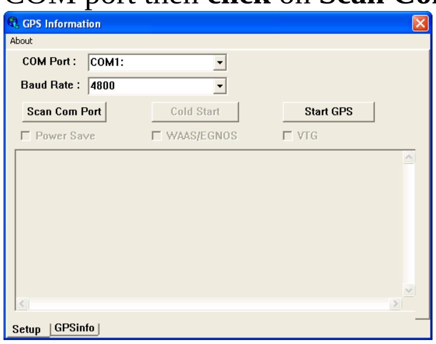
Connecting the GSAT GPS to the Computer for Use in ArcMap

1. Go to computer's bluetooth manager and open bluetooth settings. If device has already been paired with computer then just double **click** on icon for device.

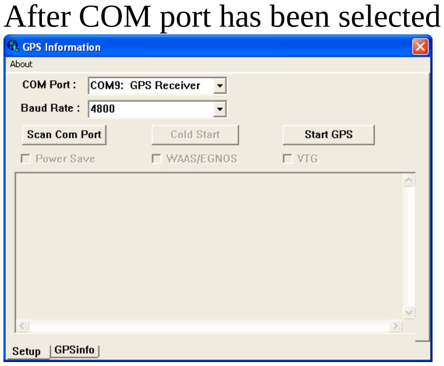


2. Icon changes when successful detection of bluetooth GPS device.

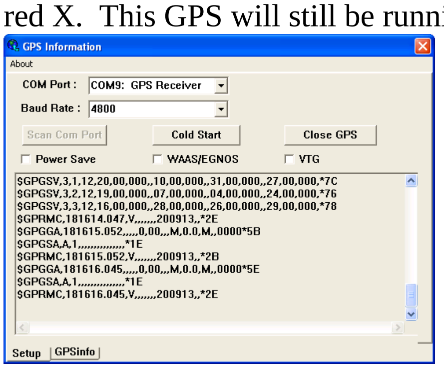
3. **Open** GPSinfo software. This software came with GPS device which is a Bluetooth GPS Receiver (BT-359) made by GlobalSat. The COM port will be determined during initial Bluetooth Device Pairing. If you do not remember the COM port then **click** on **Scan Com Port**.



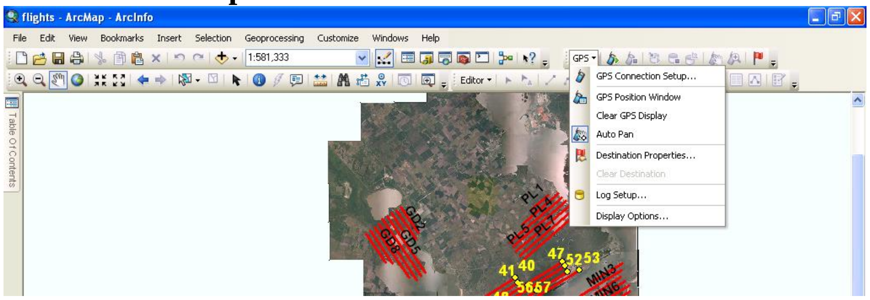
4. After COM port has been selected click on **Start GPS**.



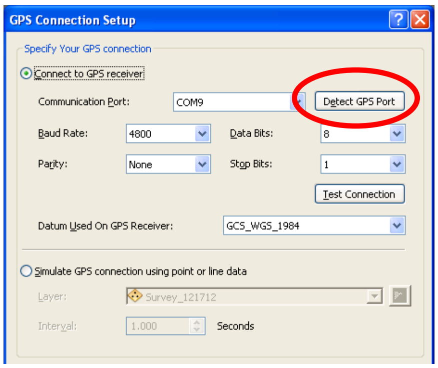
5. After GPS has been started, close out of the GPSinfo window by **clicking** on the red X. This GPS will still be running.



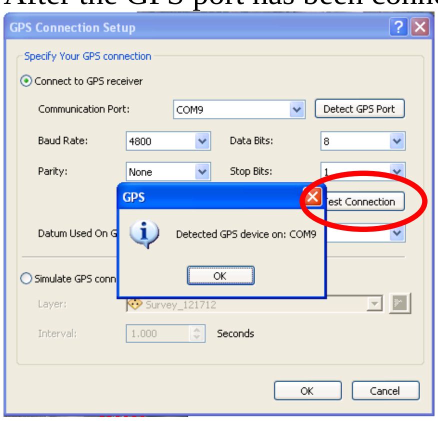
6. In the *whcr_mmddyy_obs1.mxd* map go the GPS toolbar and **click** on **GPS Connection Setup**.



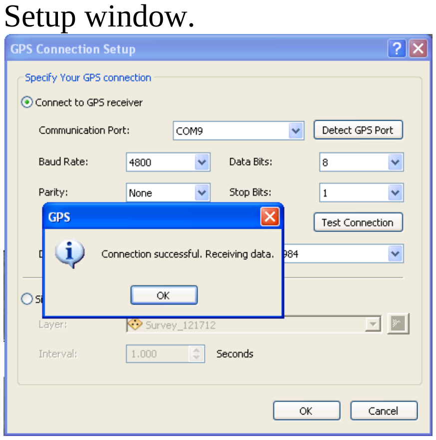
7. **Select** the same COM port used for bluetooth device pairing in GPSinfo. Then **click** on **Detect GPS Port**.



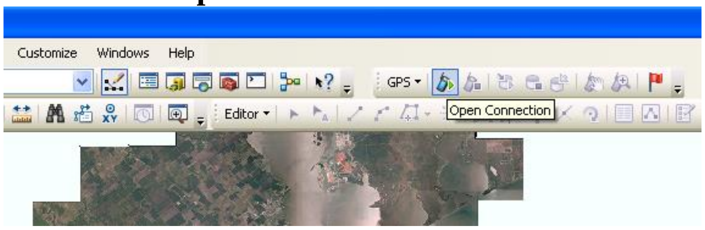
8. After the GPS port has been connected, **click** on **Test Connection**.



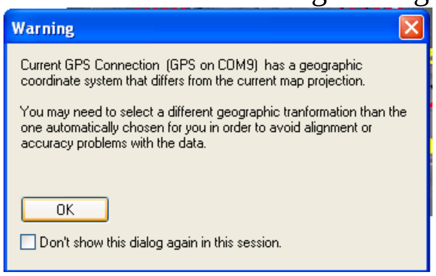
9. After successful test connection, **click OK** and then **click OK** on GPS Connection Setup window.



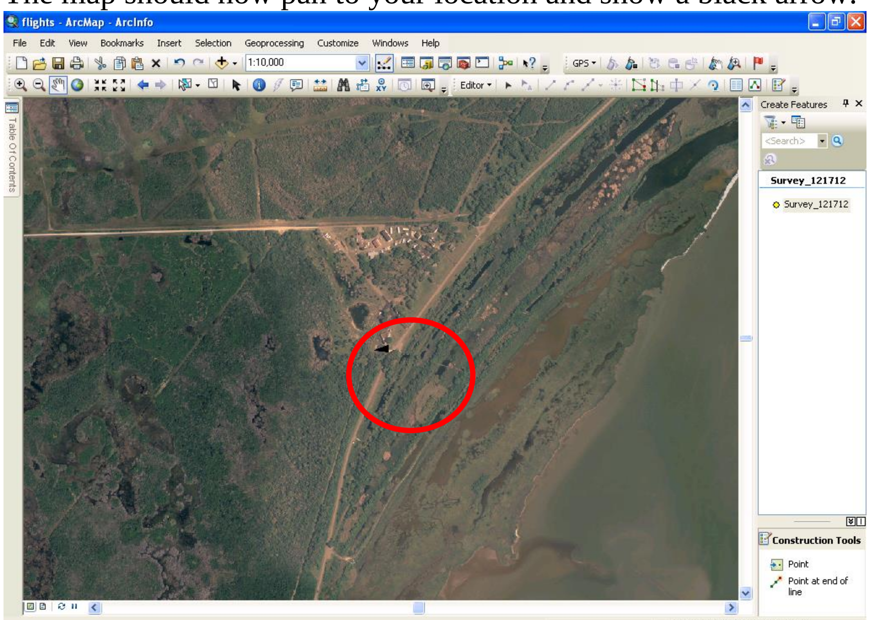
10. **Click** on the **Open Connection** icon on the **GPS toolbar** in ArcMap.



11. **Click OK** to the warning message.



12. The map should now pan to your location and show a black arrow.



U.S. Fish and Wildlife Service
U.S. Department of the Interior

National Wildlife Refuge System

I&M Protocol Peer-Review

Protocol Title: Whooping Crane Winter Abundance Survey Protocol **Version:** 1.0
Survey Identification Number: FF02RTAR00-002
Refuge: Aransas National Wildlife Refuge
Authors: Matthew J. Butler, Biometrician, U.S. Fish and Wildlife Service
Bradley N. Strobel, Wildlife Biologist, U.S. Fish and Wildlife Service
Cinthia Eichhorn, Regional Data Manager, U.S. Fish and Wildlife Service

Protocol Review Timeline:

6/15/13 – Protocol submitted for peer review.

9/23/13 – Peer reviews received and returned to authors.

Note: Authors notified of unanimity, and reviews not in order (3 external to USFWS (Joshua Schmidt, Charles Anderson, John French); 2 internal to USFWS (Beau Hardegree, Wade Harrell)

3/26/14 – Protocol revision received from authors.

4/22/2014 – Final decision (accepted).

Letter From Dr. Harris:

22 April 2014

Dear Dr. Butler:

I have carefully reviewed the "Whooping Crane Winter Abundance Survey Protocol" and the response to reviewers. Clearly, the reviewer comments were addressed thoroughly. By doing so, this protocol revision has improved in content and clarity.

The work done by you and the co-authors is much appreciated by the United States Fish and Wildlife Service, and will advance the understanding and conservation of this whooping crane population.

Please consider this protocol accepted and finalized.

Regards,

Grant Harris

Letter to Dr. Harris:

26 March 2014

Dear Dr. Harris,

We have completed revision of the Inventory and Monitory protocol entitled "Whooping Crane Winter Abundance Survey Protocol". Below we have attached the reviews and our response to questions, edits, or suggestions raised by each of the Reviewers. All comments from the reviewer have been addressed in this document (see blue text) or within the protocol.

We have included some R code in appropriate places to help demonstrate analyses (see Reviewer 1, comment 2) or support simulation efforts to better demonstrate the behavior of Generalized HDS models (see Reviewer 2, comment 14). The R code throughout this rebuttal is in `Lucida Console` font.

We believe this critique has helped us craft a better protocol. We appreciate and thank each Reviewer for their time and effort.

Sincerely,

Matthew J. Butler

Letter From Dr. Harris:

23 September 2013

Dear Dr. Butler:

I have received 3 external reviews and 2 internal reviews of your protocol titled “Wintering Whooping Crane Abundance Survey”. All Reviewers identified points worth addressing in a revision. Notably, I think more effort could be placed on the following:

1) Further justification and description regarding implementation of the distance sampling technique.

   We have provided a new section in Element 1 entitled “Justification of objectives.” We have also provided additional discussion of the distance sampling technique throughout the protocol in appropriate places.

2) Reducing some discussion of the former method, keeping only the salient deficiencies; namely those necessary to describe why a revision and new approach was required.

   Some description and critique of the traditional survey technique is all we provided (i.e., less than 4 pages of a document containing over 150 pages). As we began addressing the Reviewers’ comments, we have begun to wonder if we spent enough time critiquing the traditional technique since many of the Reviewers’ comments have highlighted their misunderstanding of the traditional technique which further emphasizes the need for critiquing it (we point out each of those comments below). Many of the Reviewers revealed several misconceptions about the traditional technique. Therefore, we have chosen to include the description and critique of the traditional survey technique. In a few cases we had to expand the critique to address some of the Reviewers’ questions (e.g., misconceptions about the enumeration of mortalities during the traditional surveys).

3) Please increase size of text in Figure 1.

   We have made all map-based figures larger (e.g., Figs. 1, 5, 6, and 8). Originally these figures were only 4.5 inches wide but now they are 6.5 inches wide. We are unable to increase the font size associated with the background layers within these figures because those fonts are embedded as part of a basemap in ArcGIS. However, by increasing the size of the figures, the text is much larger. After increasing the size of the map-based figures, we decided to increase the size of all figures.

Reviewers provided general and specific comments. Please respond to each line by line, and identify where you modified the protocol as/if necessary.

Below we address all comments from the Reviewers in blue and note the section in the protocol in which changes (if necessary) were made.

Once this document and revised protocol are returned, I will evaluate your responses and revision. At that point, the protocol may be declined, accepted or further reviews sought.

Sincerely,

Grant Harris
Chief Biological Sciences
United States Fish and Wildlife Service, Region 2
Albuquerque, NM 87103

<u>REVIEWER #1</u>:

Overall, this is a much-needed, thorough and excellent upgrade to the survey methods for whoopers at Aransas. I am impressed with the amount of effort and thoughtfulness evident in this review draft.

Thank you for your thoughtful review; we value your comments and appreciate your efforts. We want to note upfront that this survey extends well beyond the borders of Aransas National Wildlife Refuge and covers over 1,200 km^2 of the winter grounds. There seems to be a misunderstanding that whooping crane ostensibly overwinter only on Aransas National Wildlife Refuge. However, 55.3% of new primary sampling frame covers areas beyond the boundaries of Aransas National Wildlife Refuge. We have included the boundaries of Aransas NWR in Figure 6 to help illustrate this point.

General comments:

1. Too much time spent critiquing the former survey method; this is evident in the description <u>multiple</u> times of the new methods as “defensible”, “scientific”, etc.

   We felt it important to make clear that the new technique is “defensible” and “scientific.” The previous methods were not, hence the need for this protocol. We have removed some of this language as it was repetitive.

   Some description of the deficiencies is needed, as a platform for describing this method which will improve upon it, but the important point is the demonstrating the features, validity and benefits of the proposed method.

   Some description and critique of the traditional survey technique is all we provided (i.e., less than 4 pages of a document containing over 150 pages). As we began addressing the Reviewers' comments, we have begun to wonder if we spent enough time critiquing the traditional technique since many of this Reviewers' comments have supported the need for critiquing the traditional survey technique (there seems to be much misunderstanding about it). We point out each of those comments below. Other Reviewers had similar misconceptions about the traditional survey technique. Therefore, we have chosen to include the description and critique of the traditional survey technique as was originally included in the protocol. In addition, we have had to include some more information to dispel misconceptions about the enumeration of mortalities during the traditional surveys.

2. Related to (1), is the need to use the numbers derived from the former methods as we go forward with the conservation of whooping cranes. So those numbers cannot be described as useless, and

indeed they are useful (just not useful enough). A section is needed somewhere on how the data from the new methods can be compared properly to the numbers from the former methods.

We have never described the estimates derived from the traditional survey technique as useless and in fact we have used them to help better understand the dynamics of this population (see Butler et al. 2013). We undertook revision of the survey because the traditional technique needed improvements because 1) it was not repeatable and lacked standardization, 2) it provided no description of the uncertainty of abundance estimates, and 3) it was contingent upon an assumed ability to uniquely identify unmarked individual whooping cranes. Since the traditional estimates were not provided with SEs nor can those SEs be calculated, all one can do to compare new estimates with the old estimates is to continue to assume the old technique produced a complete census. We understand this is unsatisfactory, but there was no way to replicate the traditional technique with new observers to create some sort of correction factor.

Since the abundance estimates from the traditional technique have always be treated as if they are exact counts and unfortunately will likely continue to be treated that way, comparison between estimates from the two techniques is conceptually simple. For example, in 2010, the traditional estimate was 283 whooping cranes. In 2011, the new technique resulted in an estimate of 254 whooping cranes (0.126 CV). A simple z-test can be used to test if the 2011 estimate is different from the 2010 estimate ($z = -0.906$, $p = 0.182$; `pnorm((254-283)/(254*0.126))`). However, since we do not know how whooping cranes outside of the sampling frame were incorporated into the traditional survey technique, comparison with the new technique may be problematic since the new technique only applies to the primary sampling frame.

Finally, if we continue to assume the traditional technique produced exact abundances, then for trend analysis, weighted regression would be appropriate (Gerrodette 1991). The weights used would be the inverse of variance estimate for each abundance estimate; for the estimates from the traditional technique, 1 would be used as the weight (assuming no uncertainty in traditional estimates). Of course this makes many uncomfortable, but how else can uncertainty about the past estimate be incorporated when uncertainty was not quantified. Perhaps, assuming no uncertainty in the traditional estimates is a poor assumption but we have no other estimate of the uncertainty. We could be more conservative, and give them less weight by assuming a CV of 15% or some other value, but that would be an arbitrary decision.

3. Figures are excellent; very helpful (although Fig 1 would be better larger…).

   Thank you, we strove to provide useful figures that described the issues. We have made all map-based figures larger (e.g., Figs. 1, 5, 6, and 8). Originally these figures were only 4.5 inches wide but now they are 6.5 inches wide. We are unable to increase the font size associated with the background layers within these figures because those fonts are embedded as part of a basemap in ArcGIS. After increasing the size of the map-based figures, we decided to increase the size of all the figures in the protocol.

4. A couple of references were made to later revisions of the protocol; did I miss a calendar for revision?

   We considered including a calendar for protocol revision but decided protocol revision should occur on an "as needed basis" as recommended in the Survey Protocol Handbook (U.S. Fish and Wildlife

Service 2013). We added some additional description of the revision process to the "Revision History" section.

Related to that there are likely to be practical limitations on carrying out some of the specifics; those kind of could/should be changed before the date of a more complete revision.

We are unsure what "practical limitation" is being referred to. The protocol, as it is currently designed, can be carried out as planned. It would be poor design on our part if the protocol could not be implemented in the field.

5. Definition of transect; it seems to be used as both the flight path of the aircraft and the width of territory sampled by the flights: choose one, define it and stick to it (I suggest the width of territory sampled…).

   Just as with any other line-transect based survey, the transects are the lines from which the survey is conducted. The transects are fixed-width strip transects. Therefore, the transect refers both to the line and the 500-m strip on either side of the line. It is very much appropriate to use the word transect for the flight path or the strip around the flight path. We defined the transect in "Element 3, Sampling units" section and "Element 3, Transect spacing". The transect is the flight-path and the survey area is a fixed-width around each transect. The transect configuration is independent of whooping crane territories.

Specific comments:

1. P2, L19 – I was under the impression that the flight paths were a more consistent distance apart…

   Though erroneously so, apparently many were under the impression that flight paths were closer together and more consistent during the traditional survey. Perhaps this was because Stehn and Taylor (2008) reported that transects were spaced 400 to 500 m apart. However, GPS track data from the 2010 surveys indicated transect spacing varied between 250 to 800 m. Unfortunately, no GPS track data were saved by observers during the previous years. The traditional surveys were much less systematic than portrayed in Stehn and Taylor (2008) and were more targeted to areas known to be occupied by whooping cranes. We believe this is a good example of why we needed to critique the traditional survey technique.

2. P2, L24 – define briefly 'survey blocks' in this sentence.

   We have changed the sentence to read: "Survey duration was typically between 5–6 hours with a rest break approximately half-way through the survey during which the flight crew returned to the Aransas County Airport." We see no reason to define the concept of a survey block at this point since the traditional technique did not have survey blocks delineated and defined as the new technique does.

3. P4, L35 – consider deleting this; I suspect that Tom could identify many of the cranes.

   The statement in question is "The observer assumed ability to uniquely identify unmarked individual whooping cranes." It is true the observer assumed he had this ability though he provided no evidence that he could. We consider an assumed ability to identify unmarked birds without any uniquely identifying characteristics untenable. In our professional experience, defensible identification of free-ranging individuals requires the use of unique markers. While some believe that Tom Stehn could consistently identify unmarked whooping cranes there are no data available to support this belief. As such, we feel our comment is accurate. This forms another good example of why we needed to critique the traditional survey technique.

4. P4, L39 – is there a citation for this detection function, in another birds or situation?

   On this line we stated that "group size was likely positively related to the probability of detection." Size-biased detection is very common in these types of surveys and has been noted in many species, both birds and mammals. We have provided some citations where detection probability was related to group size.

5. P4, L42 and L43 – are you sure this is true, at the transect width that was used formerly? I was under the impression that the transect width was narrow enough that detection did not vary across it… maybe not.

   Yes, we are sure this is true. See Strobel and Butler (2014) for detailed analysis of detection probabilities from the traditional survey technique. They show that detection probability of a whooping crane group within 500 m of the survey line was 0.558 (SE = 0.031). We summarized these results in "Element 2, Winter 2010–2011 surveys" section. Even if the traditional survey technique used 400 m wide transects (200-m half-width), detection probability was still less than 1.0. The detection function in Strobel and Butler (2014) shows that the detection probability within 200 m of the survey line was 0.69. Narrowing the transect does not ensure complete detection. Again, this emphasizes the need for critiquing the traditional survey technique.

6. P5, L21 – define 'surveyed area', or refer to the later section where it is defined, and precision is a VERY important aspect of this or any survey; a review of the justification of "...enough precision to detect a 10-15% decline over 3 years" is needed, and probably warrants a separate section; I am not sure that is adequate (although it may be all that is practical), but I could be convinced; I am sure that some on the WCRT will object to that criterion as too lax, and I am also sure that there is a decidedly false and overblown sense of precision in the numbers form the current methods. This issue needs to be met head on, and can be discussed usefully with reference to the costs outlined later in the document.

   We added a reference to the later section for the "survey area."

   We added a new section to summarize the justifications provided in Butler et al. (2013) for developing a survey with enough precision to detect a 10–15% annual population decline over 3- to 4-year period. See new section, "Justification of objectives" in Element 1.

   We agree that "there is a decidedly false and overblown sense of precision in the numbers form the" traditional technique. That is why we believe the critique of the traditional technique is so important. We do not think there is an overblown sense of precision with the new technique. Early on precision has been lower than we wanted (12% to 19% CV) but now that all the kinks have been worked out of the protocol, we expect better precision from future surveys (see discussion of Internal Reviewer #2's general comment #2).

7. P5, L24 – I realize you don't want to imply breeding pair, or any other biological interpretation to these associations, so create operational definitions of <u>paired</u> birds, and <u>recruitive pairs</u> (an awkward term), and leave out the quotes.

   An operational definition was already provided parenthetically after each term. We removed the quotes from these two terms.

8. P9, L6 – good section: what about the type of aircraft (airspeed, nose, comfort, etc.)

   We have added some additional information about the type of aircraft required for this protocol to "Element 4, Aircraft type" section. Aircraft speed is specified in "Element 4, Field data collection methods" section and was based on the traditional survey technique.

9. P11 – very nice table and figure.

   Thank you. We have made all the map-based figures larger.

10. P12, L8 – here might be a place to indicate how the data collected with this new method will or should be compared to past numbers…

    See response to Reviewer's general comment #2. We have added a note about comparison of estimates from the two techniques to "Element 3, Comparison with estimates from the traditional technique."

11. P12, L22 – do you mean PSF…?

    The sentence in question is "Eventually, additional areas will need to be added to the SSF as the population expands." We do not mean PSF, we mean SSF. The SSF regions will be promoted into the PSF when criteria outlined in "Element 3, Sampling frame" section are met. Then new regions will be added to the SSF once SSF regions are promoted to PSF regions. We reworded this sentence to clarify: "As SSF regions are promoted into the PSF as the population expands, additional areas will need to be added to the SSF."

12. P12, L21 and L22 – also should use anecdotal information to add areas for formal survey (secondary); one does not want the methods designed to survey birds where they are now, to constrain the places one looks for cranes as they expand: the birds may get to very different areas (this applies to the habitat modeling efforts too, probably more so).

    We speak to this in the "Element 3, Sampling frame" section. "Because the Aransas-Wood Buffalo population is growing at ≈4% per year, we will address how to add more SSF regions when this monitoring plan is due for revision. For example, the spatially-explicit models of habitat use could be used to predict areas composed of the best potential habitat." We did not suggest other anecdotal information could potentially be used as well so we have added this sentence. "Ancillary information gained from internal and external sources (e.g., fortuitous public or staff observations; Texas Whooper Watch) could potentially be used to identify new SSF regions as well."

13. P13, L18 – I suggest the numbering/lettering system go from the shore north: it is easier to add survey regions/blocks which will probably be inland.

Survey blocks are lettered with the survey blocks initials (i.e., Blackjack Peninsula is labeled with BJ). Since there is no plan to add additional transects to specific survey blocks but instead add new survey blocks as the population expands then we see no reason to change the way in which transect are numbered within a survey block. Besides, since all survey information is now spatially explicit unlike before, we can simply add new transects as needed and renumber them appropriately. Since all the transects are displayed on the computer during the survey, renumbering them if additional transects were added would not cause confusion.

14. P13, L30 – the term <u>peak abundance</u> is a very poor one, and should be discarded in favor one without interpretation imbedded in it; I am very interested in what the greatest number of birds at Aransas may be, but there may be/are many opinions on how to get that number; it is interesting that numbers from past survey methods are the highest in Dec, but that might not be the case with the new method; better might be to define the period intense survey with reference to the dates of migration (it might be some function of departure date, arrival dates, etc.); this would allow the dates of intensive surveys to vary with the birds; I can imagine that seasonal differences may alter the date of 'peak abundance' and indeed climate change may well alter the phenology of crane migrations over the years; call it the "early resident period"??

    We agree that the peak abundance term may be imbedded with too much interpretation and have removed it from the protocol. There is no reason to expect this method to result in higher abundance later in the winter. To ensure comparability from one year to the next, surveys need to be conducted during the same time period. To facilitate comparison with the traditional technique, which aimed to provide estimates of "peak" abundance (i.e., abundance post fall-migration prior to any winter mortality), then December is the most appropriate time period.

    We know of no way to rigorously tie survey timing to anecdotal observations of migration phenology. Based on the historic data, we felt that surveys probably could begin either the second or third week of November. However, we delayed starting surveys until December just in case migration was delayed some years. We agree that if we see that migration is delayed in a particular year, then we as program managers need to delay surveys a little while for that year. In fact, that is part of the reason we allowed surveys to be conducted anytime during a 1-month period (as long as they are blocked together into a 2-week window). If a trend of later migration dates becomes apparent, then of course we would need to re-evaluate the survey dates for future surveys.

15. P14, L28 – I can well imagine (but do not know firsthand) that habitat use will vary thought the season, and especially for the birds of the year; hence spatially explicit models relevant to Feb-Mar might be very revealing.

    We agree that the spatially-explicit models of abundance might provide interesting insights into whooping crane habitat use during different periods of the winter. That is why we have provided a mechanism for developing such models during the secondary survey periods if the Refuge or stakeholders chooses to pursue surveys during January, February, or March. However, as outlined in "Element 3, Survey timing," surveys conducted during the secondary periods are optional and will only occur if clear objectives are identified by the stakeholders. We do not consider a passing curiosity about changes in habitat use through time a clear enough objective. Frankly, there are much better ways to understand temporal trends in habitat use such as satellite-telemetry.

16. P16, L3 – see general comment (4) above.

    See our response above concerning revisions of the protocol.

17. P17, L15 – very interesting…. And relevant to the discussion about precision, etc.; the numbers at Aransas can help us learn about life history during migration south, as well as help inform management needs at Aransas proper.

    Actually, the numbers at Aransas cannot inform us about life history during the southern migration because little information is available from the flock during the breeding season. Assuming the precision of estimates is tight enough, the work in Butler et al. (2013) shows that biennial monitoring would likely provide the information necessary to detect the kind of declines that would cause significant delays in time to recovery. But moreover, the discussion in Nicol and Chadès (2012) really reveals intensive monitoring when the policy decisions regarding downlisting are imminent is most important but other times are much less relevant.

18. P17, L31 – Unclear: is the TESC too coarse grained?

    It depends on the question one wants to ask of the data. If we wished to determine how whooping crane abundance responds to varying densities of blue crab across the landscape, then of course the TESC vegetation map is inappropriate. However, if all we wish to characterize is how whooping cranes distribute themselves among saltmarsh and upland habitats, then the TESC vegetation map is appropriate. So all we were trying to convey is that the spatial layer used in the analysis must be compatible with the question being asked. We find this idea is outlined clearly in the following paragraph from "Element 3, Environmental covariates" section of the protocol:

    "Hierarchical distance sampling results in spatially-explicit models of abundance that explicitly consider relationships between population density and environmental covariates while controlling for detectability (Royle et al. 2004, Chandler et al. 2011, Sillet et al. 2012). Currently, environmental covariates are derived from the Texas Ecological Systems Classification Project (http://www.tpwd.state.tx.us/gis/gallery/), Phase 3 (Ludeke et al. 2012; Appendix E). The percent of each 1-km2 transect segment is determined for 6 general vegetation types: saltmarsh, open water, wetland, saltmarsh-shrubland, upland, and urban (Appendix E). Though these covariates are only rudimentary, strong relationships with whooping crane abundance has been demonstrated with some of them (Strobel et al. 2012). As managers, biologists, and policy makers begin to recognize the value and potential of spatially-explicit models of resource use and develop more detailed hypotheses about whooping resource use, specific resource maps can be tailored to answer more specific management or policy questions. Maps from which environmental covariates are derived will need to be periodically updated with the most current data."

    We also note in "Element 4, Environmental covariates" section of the protocol:

    "As additional maps of vegetation layers, other whooping crane resources (i.e., salinity, blue crab abundance, etc.), or management actions (i.e., time since prescribed burn, fresh water provisioning, etc.) become available and more detailed hypotheses of whooping crane abundance relationships are developed, additional environmental covariates will be derived and incorporated into the hierarchical models of abundance."

19. P18, L19 – good; can an ID test be developed like is done for BBS observers? This would be useful. BTW, the emphasis on training and practice (later section) is excellent, but should be strengthened: you might consider requiring practice using the computer recording method, coordinating with the other observer (I like the idea of practice in a car..), and with identification; the BBS has shown very clearly how much difference experience, and hence training means to the quality of the data.

    We like the idea of an ID test but currently have no plans to implement such a test. We believe the training requirement that new observers must participate as a non-observer in the fourth seat of the aircraft during a minimum of 3 surveys is adequate training.

    We strengthened the language about practicing using the equipment from an automobile. Staff have implemented this practice session prior to beginning the surveys each year.

20. P19, L17 – is there detection variability by habitat of HY birds? (white birds are a bit easier..)

    There is likely some detection variability by habitat for all whooping cranes not just juveniles. However, as indicated in the section in question, groups with juvenile birds will have slightly higher detection probability than groups without juveniles simply because those groups with juveniles are larger groups.

21. P19, L36 – yes, good; and keep in mind that we have been consistently surprised by the habitat selection of the re-introduced whooping cranes, so as they expand in S. Texas, I now expect cranes in unexpected locations.

    Agreed, we already have seen unusual habitat selection as this population has grown (e.g., Granger Lake). By the way, we included a section in Appendix C entitled "More on prediction" that discusses prediction beyond the bounds of inference and possible uses of those predictions.

REVIWER #2:

General comments:

1. While I agree there is a potential for bias in the past estimates, the intensity and frequency of the surveys, combined with the small population size (with a large number marked during many years), suggests that the max estimates are probably pretty close to the true number of individuals, or at least a very good index. The relatively low annual variability in the estimates (Fig 2, page 3) suggests that this is the case. A poor index would result in a more 'jagged' graph due to sampling error.

    Unfortunately this Reviewer has little knowledge of the past intensity and frequency of the traditional surveys. No one but the previous observers even knew the intensity (i.e., what areas were surveyed) of their surveys since only information about detections were recorded (i.e., past observers did not record where they surveyed and did not detect birds). Further, the frequency of the traditional survey varied widely. The number of surveys conducted between December 1st and March 31st per year varied from 4 to 21 (mean = 12.7, SD = 4.2) indicating little consistency in survey effort from year to year (Butler et al. in prep).

Wild whooping cranes were not individually marked until 1975. In fact, only 132 marked birds have been in the population spanning the period of 1977 through 2004 (Gil-Weir et al. 2012). There were not "a large number of marked birds during many years." Sure, nearly 60% of birds were marked during winter 1988–1989 (Stehn 2004) but the proportion of marked cranes was typically much lower. Over 40% of the years in which the traditional survey was conducted (1950–2011), no color marked birds were in the population. By the winter of 2010–2011, only 7.8% of the flock was marked (Stehn 2011). It is also important to note that many of the banded cranes were not marked with uniquely identifiable color marks but with aluminum bands (Stehn 2011).

It seems that this Reviewer misunderstood the point of figure 2. Figure 2 shows how the traditional technique somehow resulted in an estimate that was often greater than the maximum number of birds observed but sometimes resulted in an estimate that was smaller than the maximum number of birds observed. This is disconcerting. If the observer observed 100 birds on a survey but only reported an estimate of 97 birds, we wonder what happened to those 3 birds. As we noted in the protocol, "this inconsistency may be attributed to the observer's interpretation or perception of double counts. However, we cannot know…since rules governing how data from separate surveys were combined or how public reports of whooping cranes from outside of the 'censused' area were incorporated was largely determined by the observer's opinion." We have developed this protocol to get away from a technique largely based on expert opinion and experience to something that can be replicated by staff that do not have many years of experience working on the species. As current staff move on to new jobs, we now have a technique that can be replicated by anyone.

Fundamental problems with the traditional technique can be illustrated easily. For example during the winter of 2008–2009, the traditional technique reported 270 birds on the wintering grounds with 23 of them dying during the winter. During the winter of 2009–2010, the population was reported to be 264 birds with 22 juveniles which would mean there were 242 adults in the population. However, the maximum count during the winter 2009–2010 was 270 birds which would presumably mean there were 248 adults in the population. If 23 mortalities occurred during the winter of 2008–2009, there could only be 247 adults in the population during the winter of 2009–2010 (270–23=247; assuming no mortality during other parts of the year). Where did that extra adult come from? Did the maximum count of 270 during the winter of 2009–2010 include 6 birds that were counted twice? Was mortality during the breeding- and migration-periods only 2% ((247–242)/247)? This is an illustration of the fundamental danger of a technique that portends to deal in absolute truth when there is really much uncertainty in the estimates.

2. I wonder if the approaches described in these 2 papers would be more appropriate for the existing and future whooping crane data since the cranes appear to be territorial on the wintering grounds?

   Chandler, R.B. and J.A. Royle. Spatially explicit models for inference about density in unmarked or partially marked populations. Annals of Applied Statistics 7:936-954.

   Sollman et al. 2013. Using multiple data sources provides density estimates for endangered Florida panther. Journal of Applied Ecology DOI: 10.1111/1365-2664.12098

   Particularly with a partially marked population, you could employ these methods across all the historic data to produce corrected density estimates (assuming the field maps/data are still available?). You could also then quantify the level of bias in past estimates and determine the amount of effort needed going forward. A spatially explicit approach to density estimation may also be useful for jointly addressing your habitat use objectives (e.g., Royle et al. 2013. Spatial capture-recapture models for jointly estimating population density and landscape connectivity. Ecology 94:287-294.) These are just suggestions. If there are reasons that distance sampling would be more appropriate or efficient than these newer methods, please provide additional explanation.

Detecting and identifying color marks on whooping cranes from aerial surveys is a dangerous proposition requiring low level flights at low airspeeds (i.e., a landing-type approach; Stehn 2001). Mark-resight based techniques are not feasible from the fixed-wing aircraft platform. Ground or boat based approaches might be possible. However, undue disturbance from a close ground-level approach might bring undue stress on this highly endangered species.

Finally, the presumption of territoriality does not induce some special ability to identify unmarked individuals. We will not assume we have the ability to identify unmarked birds as was done by the previous observers. Also, unfortunately, little of the raw data from the traditional technique is still available (hence the need to standardize the technique and provide for data archiving as this protocol does).

3. Although a distance sampling approach would theoretically work, I am unsure that it would be much of a logistical improvement given the level of precision required to meet your stated objectives, the small population size, and the level of survey effort that would be required.

We are unsure why this Reviewer suggests that distance sampling would not be much of an improvement over the traditional technique. We have provided many reasons why the traditional technique was deficient including it was unstandardized, likely could not be repeated by new observers, and lacked formal measures of uncertainty. The new technique provides a repeatable, standardized method that allows for rigorous statistical analysis. Distance sampling is very appropriate for a transect-based aerial survey and frankly, we do not understand why such techniques were not implemented earlier. As we note in the protocol, many robust techniques "have been available for decades."

If I understand your power analyses correctly, it appears that you would need to conduct 15-20 surveys per year to meet your objective of detecting a 10-15% decline over 3 years? Is that level of effort reasonable?

As for the power analysis and justification of the objectives, we did not provide enough detail. Thank you for catching that. Butler et al. (2013) identified scenarios that would significantly reduce abundance from the current trajectory and delay reaching the downlisting goal of 400 birds by $\geq$5 years. Those scenarios were $\geq$3 consecutive years of –9.5% annual decline or $\geq$2 consecutive years of –14% annual decline. To estimate one growth rate, 2 years of abundance estimates are needed. Therefore, we need to be able to detected a –9.5% annual decline over a 4-year period or a –14% annual decline over a 3-year period. We have now provided this information in the new section, "Justification of objectives" in Element 1. We have also reworded the objective to better reflect this. "Provide an estimate of whooping crane abundance within the surveyed area (see Element 3, Sampling frame) with enough precision to detect a 10–15% annual population decline over a 3- to 4-year period (see justification provided in Butler et al. 2013)."

To detect a –15% annual decline over a 3-year period, a CV of 6% is needed and to detect a –10% annual decline over a 4-year period, a CV of 9% is needed. Based on the winter 2010–2011 pilot work, we estimated 6 surveys would result in a CV of 7%. Based on the surveys conducted during January 2012, we estimated 5 to 6 surveys would result in a CV of 9% and 10 to 13 would result in a CV of 6%. We show a range in Table A1 because the number of surveys needed to reach a given CV depends on whether data are analyzed using HDS or CDS (see new note in Table A1). We have also updated Table A1 with additional effort estimates. We are recommending that at least 6 surveys be conducted (see "Element 3, Survey repetition and sample size" section); this does not mean more surveys cannot be conducted. However, our experience suggests that 7 or 8 surveys per year is about the logistical limit that can be accomplished in the 2-week window.

Note, that Butler et al. (2013) recommended being able to detect a –15% annual decline over a 2-year period or a –10% annual decline over a 3-year period to allow enough time to respond to the scenarios. This would require 4% to 6% CV which can be easily obtained by pooling data from multiple years as this Reviewer recommended in comment #20.

However, realize that the scenarios outlined in Butler et al. (2013) have only occurred once in 73 years of monitoring this population. This population has grown at an average of 3.9% per year since winter 1938–1939, and has exhibited a 10-year cycle in population growth (Boyce and Miller 1985, Boyce 1986, Butler et al. 2013). Therefore, a meaningful alternative to detecting the scenarios outlined in Butler et al. (2013) might be to detect a 3–5% annual decline over a 10-year period.

It also seems that because you are covering the entire area, you would not be able to address temporary emigration, correct? If I misunderstood these issues, please clarify.

The Reviewer does misunderstand the appropriate use of the gdistsamp function in unmarked. As long as complete detection on the line occurs, temporary emigration can be estimated. If temporary emigration is not occurring, then incomplete detection on the line can be accounted for. However, if both temporary emigration and incomplete detection are occurring then the parameter ϕ is confounded and uninterpretable. We discuss this issue in "Appendix C, A note about generalized HDS" and we address additional components of this Reviewer's concerns about temporary emigration below.

4. Overall, it seems like it would be worthwhile exploring the potential for utilizing both the mark-resight information and the spatial location/territory information to adjust past estimates. Going forward, I would expect that any method should utilize spatial location, knowledge of territories, and mark-resight of banded individuals to improve estimates. Distance sampling could be used as one component of this process if the probability of detecting a bird given it was present and available was of particular interest, but it seems the gains in precision may be much greater if the rest of the available information were incorporated as well.

   We will not assume we have the ability to identify unmarked birds as was done by previous observers. Some of the birds are marked in the population but we will not attempt risky flight procedures in an attempt to identify those marks from the air. We like the idea of using mark-resight data from the traditional survey in an attempt to improve historic estimates. However, much of that information is not available anymore.

5. In general the protocol reads well, although some key information is only available in the appendices. More detail on the relationship between the stated objectives and the ability of the proposed methods to meet them is needed. In my reading the stated objectives required much

more intensive sampling than the recommended ~6 surveys in order to detect a 10-15% change over 3 years. Based on the power analyses, sampling would need to be much more intensive. Please clarify how the sampling effort will meet the objectives as stated.

It would have been helpful if this Reviewer identified what key information is only available in the appendices. Without specifics, addressing this is difficult. We have provided a new section justifying the objectives and have inserted additional details throughout the protocol where needed based on the other Reviewers' recommendations. We have provided clarification of the power issue in response to this Reviewer's comment #3.

Specific comments:

Element 1: Background and Objectives

1. Fig. 1: font map is too small.

   We have made all map-based figures larger (e.g., Figs. 1, 5, 6, and 8). Originally these figures were only 4.5 inches wide but now they are 6.5 inches wide. We are unable to increase the font size associated with the background layers within these figures because those fonts are embedded as part of a basemap in ArcGIS. The font sizes displayed in the larger figures will have to suffice. After increasing the size of the map-based figures, we decided to increase the size of all the figures in the protocol.

2. Sampling Objective 1: Is this reasonable? Based on Appendix A it looks like you would need to conduct >20 surveys per year to meet your objective. It seems this is as many or more flights than have been conducted in the past.

   We have provided clarification of the power issue in response to this Reviewer's comment #3. During the traditional technique, the number of surveys conducted between December 1st and March 31st ranged from 4 to 21 (mean = 12.52, SD = 4.288; Butler et al. in prep). Again, another reason why the critique of the traditional technique is needed.

Element 2: Pilot Studies

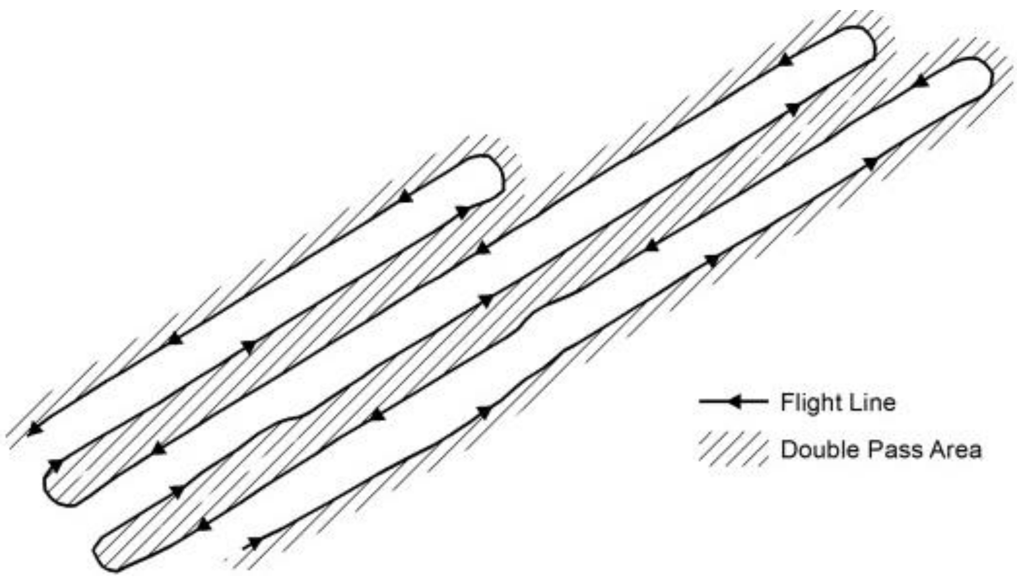
3. It may be important to require a specific type and configuration of aircraft for these surveys. As alluded to, the Kodiak has poor visibility in some areas and travels at a much higher rate of speed than planes used in the past. Tandem aircraft generally have better visibility for the observer and fly at slower speeds. Have you considered tandems (e.g., SuperCub, Husky) or are they not available?

   We have considered other aircraft but none of them are available. We have added the following sentence to "Element 4, Aircraft type." "We recommend using an aircraft similar to a Cessna 206." However, we recognize that logistics and aircraft availability may limit which aircraft is used during the survey. This is unfortunate, but often out of our control.

4. In the past surveys it appears that the pilot and observer surveyed out opposite sides of the plane correct? If so, if transect spacing was 400-500m (Stehn and Taylor 2008), then each 'strip' was covered twice, once by the pilot (partially) on the first transect and then again by the observer on the next pass. Under this scenario, detection would be much higher than that of your pilot work.

Our pilot work replicated the traditional technique (last year of surveys conducted using the traditional technique provided the data to estimate detection probabilities from the traditional technique).

The pilot did not participate as an observer but did occasionally detect whooping cranes. The observer attempted to survey both sides of the aircraft but primarily observed only one side (left-side). Stehn and Taylor (2008) reported that transects were spaced 400 to 500 m apart. However, GPS track data from the 2010 surveys indicated transect spacing varied between 250 to 800 m. Unfortunately, no GPS track data were saved by observers during the previous years. The traditional surveys were much less systematic than portrayed in Stehn and Taylor (2008) and were more targeted to areas known to be occupied by whooping cranes. We believe this is a good example of why we needed to critique the traditional survey technique. Further, as we show in the pilot work (Strobel and Butler 2014), detectability within 500 m of the survey line was only 0.558 (SE = 0.031). One might think detection was higher during the traditional survey because of the so called "double pass" by the observer. However, some areas would get a "double pass" while other areas would not get observed at all (see diagram below, assumes one observer on left-side of aircraft).



5. The high error rate for distance categories suggests that GPS locations may be required for each group. You mention this as an option, but I think the language should be stronger in 'lessons learned #4'.

This is not in "Lessons learned #4" but #3; we strengthened the language. In "Element 4," we specified a technique to avoid having to categorize distances into bins.

6. Is there a reason that the plane does not leave the transect line to mark and count each group? It seems like this would reduce or eliminate both measurement and counting errors. I see later this will be corrected by the heads-up display?

Deviating from the transect line to mark and count each group would reduce potential measurement and counting errors but it would also increase the duration of the survey substantially. If it requires 1 deviation from the transect for each group and the deviation is a circle with a diameter similar to transect width (1,000 m) each deviation would add >3 kilometers. If 100 groups were detected it would increase the survey duration by approximately 2.25 hours to the survey. The value of reducing measurement and counting errors would need to be weighed against the cost of observer fatigue and safety. Further, whooping crane group density is high enough in many parts of the primary sampling frame that diversion from the transect to flyover each detected groups might cause other groups to be missed. However, occasionally observer do divert the plane from the transect to confirm a detection if necessary.

7. I disagree somewhat with lesson 6. Your pilot work demonstrated that detection is likely <1 in a single pass survey, not that it is an appropriate technique in this situation.

   Our pilot work specifically demonstrated that the traditional technique had a detection rate within 500 m of the survey line of 0.558 (SE = 0.031). It seems that this Reviewer misunderstands the traditional technique and is misrepresenting it as a double-pass survey. As shown above (see comment #4), it is not.

   Yes, our pilot work does show distance sampling is an appropriate technique in this situation. We do not, however, exclude the possibility of other techniques with our pilot work. Please take a look at Strobel and Butler (2014).

   The way I read the results of your power analyses, you'd need quite a few surveys to reach your objectives. Is that level of effort reasonable and sustainable as the population expands?

   See response to this Reviewer's general comment #2 for discussion of the power issue. We can meet precision objectives with 6 surveys per winter.

   Would spatial approaches provide more information and increases in precision?

   Yes, spatial approaches do provide more information and increases in precision, that is why we are using the spatially-explicit hierarchical distance sampling methods.

   Could you combine distance sampling with the spatial and mark-resight information to increase precision?

   Focusing on mark-resight techniques will not be productive since so little of the population was marked in most years. Further, detecting and identifying color marks on whooping cranes from aerial surveys is a dangerous proposition requiring low level flights at low airspeeds (e.g., a landing-type approach; Stehn 2001).

<u>Element 3: Sampling Design</u>

8. The plan for expanding the sampling frame seems appropriate.

   We agree that a plan for adding new areas to the secondary sampling frame is needed. However, it is not needed immediately. This population is only growing at about 3.9% per year. It will likely be many years before many of the secondary sampling frames are promoted into primary sampling frames. Only then will we need to determine additional areas for secondary sampling frames. As we allude to in the protocol, the spatially-explicit maps of abundance can be used in the future to identify new secondary sampling frames.

9. Page 16, lines 1-7: Your objectives state that you need to be able to detect a 10-15% decline over 3 years, but that is not what is implied here. The number of required repeat surveys increases dramatically at CVs below 0.10, and it appears that 20 surveys may be required to meet your stated objectives. Please clarify you recommended sample size here or modify the objectives above.

   We have provided clarification of the power issue in response to this Reviewer's general comment #3.

10. Group size estimator: I am not certain how *unmarked* models group size, but it might be worth assessing the fit of the group size model to the observed data. In some cases the Poisson model does not represent the observed data well and can cause fairly substantial bias in estimates. It may be worth exploring simpler models for group size (e.g., individuals vs. groups).

    We are not modeling group size. As outlined in Appendix C, we use hierarchical distance sampling to estimate the number of groups in the population. We then test for size-biased detection. If size-biased detection is apparent, we adjust mean group size accordingly. We then multiply group abundance by mean group size (or adjusted group size if needed) to estimate total abundance. This is standard practice for conventional distance sampling.

11. Page 18, lines 6-15: Another alternative would be to left truncate the data to account for the partially observable strip under the aircraft if there is continued evidence of <100% detection on the line. This effectively moves the 'line' to the tire of the aircraft and as long as all groups are seen close to the plane, no bias should occur. This would help deal with individuals missed that were under the plane. It would also allow the front seat observer to search more intensively over the rest of the transect.

    Generally the idea of left truncation does not solve this problem because detectability is usually not 100% at 20 or so meters out from the line (the half-width of the band blocked by the aircraft). We have found with forward observation, detection on the line is possible in most Cessna aircraft. Further, distance sampling does not require intensive searching over the rest of the area, it just requires 100% detection on the line. Therefore, changing the technique to increase detection at greater distances from the aircraft does little to improve estimates.

<u>Element 4: Field Methods</u>

12. Have you considered wiring a cigarette plug into the aircraft? We have had good luck using small inverters to power laptops in small planes, eliminating the concerns about battery life. All our DOI planes have them, as well as our contractors, so I don't think permitting would be an issue.

    We do use a small inverter in the aircraft. Battery issues still sometimes occur because of mistakes by observers or other reasons. We likely have corrected this issue by changing to ipad-like tablets for data collection.

Element 5: Data Management

13. The data management and backup procedures seem appropriate.

    Thank you.

Element 6: Data Analysis

14. Pages 28-29: I'm not sure you can use the repeated surveys to estimate temporary emigration in the way that Chandler et al. (2011) did because groups are likely move among adjacent sample units between surveys. Chandler et al. (2011) spaced their points so that individuals wouldn't be detected on 2 different points during repeated surveys allowing separate estimation of the two detection components. In your situation, I think this potential for movement between units between surveys would cause positive bias even if detection on the line was 1.0 because you essentially have a full coverage survey. Under that scenario, I think you'd be estimating something like the superpopulation or the amount of 'use' each sample unit gets. If I am mistaken, please clarify/discuss.

    We find nowhere in Chandler et al. (2011) that they spaced survey points so that individuals would not be detected on different points during different survey reps. Movement to different cells between surveys does not cause any problems with the generalized HDS model. In fact, the point of the generalized HDS model is to characterize that movement through the estimation of a temporary emigration parameter (ϕ). Regardless of the scenario (i.e., spacing of the survey locations), abundance from this model will be biased high, as demonstrated by Chandler et al.'s (2011) equation 4, unless it is adjusted by ϕ. Following the ideas outlined in the simulation study of Chandler et al. (2011), we show that a so called "full-coverage survey" such as ours can be used to generate unbiased estimates of abundance using the generalized HDS model of Chandler et al. (2011).

    We simulated a landscape of 100 cells that were 100 x 100 m. We divided the landscape into to 2 habitat types with each habitat type being assigned to 50 cells. The first habitat type was assigned an average abundance of 2 (based on Poisson distribution, $\lambda = 2.0$) and the second habitat type was assigned an average abundance of 0.5 (based on Poisson distribution, $\lambda = 0.5$). For each iteration of the simulation, we selected the abundance for each cell based on these Poisson distributions. We also randomized the arrangement of the habitat types across the landscape for each iteration. During each iteration, the home range center of each animal in a cell was randomly selected. Then each animal was allowed to move between surveys (movement was dictated by a multivariate normal distribution allowing animals to move in and out of their cells of origin; variance-covariance matrix = [500, 0; 0, 500]). We placed a "full coverage survey design" over our simulated landscape which resulted in 10, 100-m wide transects that were 1,000 m long. For each iteration of the simulation, we conducted 6 replicate surveys between which animals were allowed to move. For each animal location, we measured its distance to the transect line and estimated its detection probability assuming a half-normal detection curve ($\sigma = 30$). We simulated the detection process with a binomial distribution (where p was the detection probability). We conducted 1,000 iteration of the simulation and estimated 95% CIs as the 2.5 and 97.5 percentiles of the simulated distribution. We have proved the R code we used below (see attached Appendix).

The landscape we simulated had a true population size of 125 animals. The generalized HDS model estimated abundance as 200.1 animals (95% CI = 159.0–247.8) but once it was adjusted for temporary emigration (ϕ), then estimated abundance was 130.9 (95% CI = 104.5–161.0). The adjusted abundance estimate was unbiased (mean =–3.9%; 95% CI = –25.6% to 19.5%). Therefore, to correctly use the generalized HDS model, abundance must be multiplied by probability of temporary emigration (ϕ). In the protocol, we already discussed this issue in "Appendix C, A note about generalized HDS."

As mentioned above, I think you could deal with the partially observed strip beneath the plane through left truncation.

Generally the idea of left truncation does not solve the problem of incomplete detection on the line because detectability is usually not 100% at 20 or so meters out from the line (the half-width of the band blocked by the aircraft). We have found with forward observation, detection on the line is possible in most Cessna aircraft. This was only an issue in the Kodiak with pontoons.

In general, I think the density estimates from each survey will be interpretable on their own and could be thought of as analogous to the historic counts adjusted for incomplete detection. It is somewhat unclear to me how you will be using the multiple surveys/estimates other than maybe considering the highest one as the max population size estimate?

The data will be pooled across the surveys from the 28 November–26 December. This will result in one estimate of abundance, HY:AHY ratio, number of adult pairs, and number of recruitive pairs, and one spatially-explicit model of abundance. Though we believe this is clearly articulated in the methods outlined in Appendix A and C, we add a note to "Element 6, Analysis methods" section. Realize, the Elements are really just summaries and the details abound in the SOPs and Appendices. We are a little disappointed this reviewer did not examine Appendix C closer.

(I see that many of these issues are addressed in Appendix C, page 97, but I think it should be made more clear in the main text that the temporary emigration piece will probably not be usable under the proposed design.)

We have added the following statement to "Element 6, Data analysis" section. "Currently, we plan to pool all the surveys from the 28 November and 26 December survey period and use the model configuration that ignores temporary emigration (see Appendix C–A note about generalized HDS)."

15. For clarity, abundance estimates for each survey will represent the portion of the population using the survey area the day of the survey (i.e., birds temporarily located in areas outside the primary sampling units are not accounted for).

    For clarity, all surveys are pooled for analysis. We emphasize that our estimates will only pertain to the primary sampling frame in multiple places throughout the protocol (e.g., "Element 1, Objectives" and "Element 7, Summary statistics of interest"). We limit the survey to a 2-week window in order to provide as much population closure as possible.

16. How are you accounting for the spatial autocorrelation induced by your small (1 km) subunits? When all are sampled sequentially, there will be a fair bit of autocorrelation present. Will this information only be used for the habitat component?

Spatial autocorrelation or lack thereof has nothing to do with the size of the subunits. Spatial correlation could occur regardless of the size of the subunits. Spatial correlation could affect the standard errors of the parameter estimates but the magnitude of effect would be minimal. Thus, the inferences gained from our models about the effects of habitat on whooping crane abundance would not change if potential spatial correlation was accounted for. Further, there is not currently a tractable way to deal with spatial correlation in these already complex models.

Element 7: Reporting

17. The reporting requirements seem appropriate. Requiring at least an annual report that is placed in a government series is a good idea in my opinion. One suggestion would be to include periodic publication of results in the peer-reviewed literature (e.g., every 5 years). Over time this would establish your methods and results as scientifically defensible and would help support future delisting decisions.

    Thank you, we agree annual reporting is important and have provided for it in "Element 7: Reporting." We agree that periodic publication is important and we will be pursuing publication of our results. We added the following sentence to "Element 7, Reports" section. "Also, we recommend periodic publication of survey results in the peer-reviewed scientific literature."

Element 8: Personnel Requirements and Training

18. These seem appropriate.

    Thank you.

Element 9: Operational Requirements

19. These seem appropriate.

    Thank you.

Appendix A: Power Analysis

20. These analyses seem appropriate given the limitations of TRENDS and the basic assumptions made. Multiple sources of heterogeneity could reduce the power to detect trends, but the approach used is reasonable. Have you considered the increase in power that might be possible either through analyzing multiple years' data together or using a Bayesian approach with informed priors on the detection function? That should increase your precision over time assuming the detection process is similar through time.

    Yes we have considered this and will likely implement some sort of data pooling in the future to bolster our power. Thank you for the suggestions.

Appendix B: Indexing Recruitment

21. As long as this is treated as an index rather than abundance the methods seem appropriate.

    Agreed, thank you. However, we are not talking about abundance but a ratio.

Appendix C: Data Analysis

22. Page 97: As described above, I don't think temporary emigration is estimable under your current full-coverage design. If you disagree, please explain.

    See our responses to other comments regarding this issue (see Reviewer #2, comment 14). Temporary emigration is estimable under a so called "full-coverage design."

REVIEWER #3:

It is clear that a considerable amount of work went into this protocol. The techniques and analyses used within this protocol seem appropriate and logical.

Thank you. Indeed much work has gone into developing this protocol.

This is a sound protocol but needs, in my opinion, more details with explicit statements and discussion. You make many implied statements or cover specific topics but they need to be brought together in a clear and concise manner. I make specific comments below.

We thank you and the other Reviewers for their comments. Those comments have allowed us to fill in details in import places throughout the protocol.

Specific comments:

1. There are several grammatical edits needed throughout the document. I will provide two examples:

    A) Element 1, Page 1, Lines 5-6: The focus is the crane and not the "endangered species." I suggest the following change.

       Whooping cranes (*Grus americana*), an endangered species, declined to near extinction by 1941 (Canadian Wildlife Service [CWS] and U.S. Fish and Wildlife Service [USFWS] 2007).

       Agreed, changed as recommended.

    B) Element 1, Page 1, Line 10: Delete the "s" in ".....breed~~s~~ on and around Wood Buffalo National Park ….. ."

       Agreed, changed as recommended.

2. The authors make implied statements in the document on how their study design and pilot studies demonstrate how the surveys will meet the assumptions of Distance Sampling. It is my opinion that you need a section dedicated to that information. You must explicitly state how your study design and pilot studies have shown or how you will meet those assumptions. A good place may be in Element 3.

   We agree that assumptions must be addressed and we did address them. "Element 3, Sources of biases" section explicitly addressed the assumptions of our techniques.

3. You need to make a statement as to why the plane does not alter the movement or behavior of the cranes. It may be obvious to you but not to others.

   We added the following paragraph to "Element 3, Sources of biases" section:
   "Movement of whooping crane groups in response to the aircraft prior to detection could bias estimates of abundance. Movement that is independent of the aircraft causes no problems and movement after detection is not a problem as long as the initial location can be accurately determined (Buckland et al. 2001). Movement towards the aircraft by whooping cranes would result in positive bias but evasive movements would result in abundance being biased low (Buckland et al. 2001). However, attraction to or avoidance of the aircraft by whooping cranes is not an issue. During previous surveys, we observed the immediate response of hundreds of whooping cranes groups to the aircraft. We did not observe any whooping cranes being flushed into flight or make movements of >100 meters in response to the passage of the aircraft. Further, initial locations of whooping crane were easily established. When visibility allowed the detection of groups from the next transect, groups were often detected in the same location, suggesting movement away from the aircraft was not substantial."

4. You need to discuss randomness of line transect placement. Having a random start point or time is great to account for temporal bias but does nothing for spatial bias. Random transects provide unbiased coverage of landscape heterogeneity and distribution of focal wildlife species. I understand that you may survey the entire area but you need to explicitly state how that justifies the nonrandom placement of transects. It is even more important to explain given your statement on Page 12…."However, as more regions are added to the PSF as the whooping crane wintering grounds 46 expand, complete sampling will likely become infeasible." You then must justify, with less than full coverage of the study area, why you did not use randomly placed transects.

   We agree that sampling strategy is a very important consideration influencing the rigor of any survey. Hedley and Buckland (2004) indicate that spatial distance analyses such as those we use are not as dependent upon random sampling because environmental covariates are incorporated directly into the model and thus do not need to be controlled through randomization. This allowed us to place transects anywhere we wanted across the survey blocks because the environmental covariates are used to control any potential bias. We chose to place transects so that coverage of each survey block was maximized. Transects were systematically placed 1,000 meters apart.

   "Spatial modelling does not require that the lines or points are located according to a formal survey sampling scheme" (Hedley et al. 2004:48).

5. I assume that "groups" are "clusters?" Per the Distance Sampling lingo. You might want to make a reference early in the document that groups are your clusters.

In our experience most readers are more confused by the term cluster than they are by group. Usually when cluster is used it is followed by parenthetic phrase like "i.e., a group of birds." We added a note in "Element 3, Sampling units" that groups is referring to the cluster lingo used in Buckland et al. (2001).

6. I would make a quick statement somewhere as to why it is important to measure perpendicular distance to the center of the cluster or group. The statement on page 52 is not enough.

   We are glad you pointed this out since the protocol does not specify that distances need to be measured to the center of the group (except in SOP1). We have now added information regarding measuring distance to the group center to "Element 3, Sources of biases" and "Element 4, Field data collection methods." As for explaining why, SOP 1 is not the appropriate place to explain why since it is a step-by-step explanation of what the observers are to do.

7. It is important to explicitly state and discuss what will be considered a group or cluster and what are the criteria (e.g., behavior, separation distance, etc.) used to separate those groups. I know you make implied statements, "a group is greater than 1 crane" and "any crane within 100 m is counted within the group," but that is not enough. You must justify that criterion with data or citations. This will strengthen the value of your abundance estimate.

   Groups of whooping cranes are primarily 1, 2, 3, or 4 individuals (usually a family group) and the occasional larger group of subadults. We added this statement to "Element 3, Sampling units" section.

8. Determining size bias is not the only important item when it comes to group size. A consistent size from group to group will improve or strengthen your CV. A consistent size from group to group can be controlled sometimes with a good, a priori, definition of what a group is and a procedure to separate groups.

   Groups of whooping cranes are primarily 1, 2, 3, or 4 individuals (usually a family group) and the occasional larger group of subadults. It is not possible to control group size; it is what it is. However, group size is a minor part of the total variance of abundance estimates from these surveys and, therefore, has a minor impact on the CV.

9. Being a little facetious, but is a survey the act of traversing a transect or is it the amalgamation of all transects being flown. The author needs to explicitly state what a survey is. The use of the term survey is loosely used throughout the document. The description/definition of a survey, segment, and transect need to be tightened up. Segments make up transects and transects make up a survey. A completed survey is when all segments of all transects are flown. You mentioned at least two surveys will be flown during peak times. The explicit definition of what you are calling a survey is vital here.

   A survey is all transects within the sampling frame under discussion. We provided clarification throughout the protocol that 6 surveys of the PSF means that all transects will be surveyed 6 times and that 2 surveys of the SSF means that all transects will be surveyed 2 times.

10. Suggestion: I would fly each transect at least twice (on separate days, preferably back to back) and define that as 1 survey. If you fly each transect 4 times (4 separate days) then you would have 2

complete surveys. By flying each transect (alternate directions) twice per survey, you strengthen the abundance estimate and CIs by attempting to capture the inherent variation (e.g., crane behavior, environmental factors, etc.) that is present.

Thank you for the suggestion. We are flying the survey (all transects in the primary sampling frame) at least 6 times. We never start a survey with the same survey block. Transects are usually flown in different directions than the last time.

11. Please don't combine objectives when providing information, such as on Page 14/Line 20. Discuss objectives individually.

    When discussing the reasons for selection of survey timing or other protocol constraints, we combined objectives when the reason was similar. This is simply more efficient and reduces the overall length of the protocol. Thank you for your suggestion but we opted for efficiency here.

12. Regardless of plotting locations on a map within a GIS, I imagine you will still need to bin your perpendicular distances. Perpendicular distances must be precise and human error will still be very much present with hand plotting. I would discuss that binning will still be part of the data analysis as exact distances can't be made.

    Beyond binning because of potential errors associated with distance measurements, we must bin our data for analyses because the hierarchical distance sampling model we are using is the multinomial-Poisson mixture model of Royle et al. (2004). This multinomial part of this model requires data to be binned. Binning does not necessarily fix problems with measurement error.

13. Will binning be used to create the all imperative shoulder on the detection probability histogram. You should probably discuss how the data will be handled if an apparent shoulder is not found in the data.

    Our data have exhibited a shoulder in the past for this survey and there is no reason to expect it not to in the future. Therefore, we chose not to discuss this issue in the protocol. If users are interested in this issue, we suggest they consult Buckland et al. (2001).

14. Element 1, Page 1, Lines 26-27: This sentence is confusing. Are you monitoring the metrics or are you stating the quantitative population metrics from monitoring are important for achieving criteria? I suggest rewording this sentence to be clearer.

    The sentence in question states, "Monitoring quantitative population metrics is important for determining if the population has achieved downlisting criteria." We do not see how this is confusing. The population must be monitored in order to know if the downlisting criteria have been achieved. We choose not to change the sentence since the Reviewer provided no suggestions on how to improve or clarify the sentence.

15. Element 1, Page 2, Line 1: I suggest the following addition "…..ensure population closure (e.g., emigration, immigration; Lancia et al. 2005, Morrison et al. 2008, Stehn and Taylor 2008, Conroy and Carroll 2009)."

    Agreed, changed as recommended.

Element 1, Page 2, Lines 2-5: I suggest the following additions "…..individuals is usually less than 100% (i.e., <1) and 2 detectability is influenced…."

Agreed, changed as recommended.

Element 1, Page 2, Lines 9-10: I suggest the following modification "Therefore, a~~n~~ robust alternative method that does not…."

Agreed, changed as recommended.

16. Element 1, Page 3, Lines 3-4: I suggest the following addition, "….location on a paper copy of a 1:46,080 Digital Orthophoto Quarter Quadrangle (DOQQ)."

    We added "Digital Orthophoto Quarter Quadrangle" as suggested.

17. Element 3, Page 9, Line 27: I would suggest deleting this secondary heading, "Sampling Design."

    Element 3, Page 9, Line 35: This is a very odd heading. I would suggest changing the heading from "Target universe" to "Target inference" or something a little more descriptive.

    Thank you for your recommendation. However, we choose not to change these headings since they are part of the I&M Protocol Template.

***INTERNAL REVIEWER #1*:**

First of all, many thanks to you and your staff for undertaking the monumental task of getting a protocol in place. I know first-hand how time consuming and difficult this was, particularly with ongoing staffing changes, etc. I think the protocol puts us in an excellent position moving forward as we evaluate metrics needed for species recovery, Refuge acquisition decisions, etc. I am excited about the upcoming season and the opportunity that the well-thought out protocol and additional staffing capacity provides us, ensuring that we get things "right". Attached are some of my initial thoughts and comments, I wanted to get you something as quickly as possible so we can continue the upcoming season's planning efforts. Let me know if you have questions about any of my comments.

Thank you for your thoughtful review; we value your comments.

Specific comments:

1. Pg. 1, line 37: remove "the"

    Agreed, changed as recommended.

2. Pg. 2, line 3: change "influence" to "influenced"

    Agreed, changed as recommended.

3. Pg. 4, line 15: consider adding "reliably" to "aerial surveys cannot be used to reliably imply mortality."

   Agreed, changed as recommended.

   It may be worth pointing out that there were marked individuals during a portion of the 1950-2010 surveys and the marked individual's presence and location was used to establish observer knowledge of territoriality, etc. For the most part, this is no longer the case and detection of marked individuals from an aerial survey is nearly impossible given the protocol for flight speed and altitude.

   We added additional discussion of the potential problems associated with the traditional estimates of winter mortality. We also added a note about territoriality and site fidelity were derived from limited observation data from marked birds.

   Wild whooping cranes were not individually marked until 1975. In fact, only 132 marked birds have been in the population spanning the period of 1977 through 2004 (Gil-Weir et al. 2012). Over 40% of the years in which the traditional survey was conducted (1950–2011), no color marked birds were in the population. By the winter of 2010–2011, only 7.8% of the flock was marked (Stehn 2011). It is also important to note that many of the banded cranes were not marked with uniquely identifiable color marks but with aluminum bands (Stehn 2011).

4. Pg. 4, line 36: Consider stating that "mark-recapture models using information from marked whooping cranes to estimate mortality may be explored in future."

   We are unsure mark-recapture based estimates of mortality are possible given the difficulty of detecting marks during the aerial survey. However, we did add the statement, "mortality estimates are better derived from radio- or GPS-telemetry based monitoring of a sample of the population."

5. Pg. 5, line 20: Suggest conducting surveys annually until this precision goal is achieved over 3 yrs.

   We recommended annual monitoring in "Element 3, Monitoring frequency" section. But we discuss the potential of biennial monitoring which could meet the survey's objectives if the precision of surveys is adequate.

6. Pg. 7, line 17: Might want to emphasize that the decoy study was conducted when WHCRs were not present at Aransas, eliminating confusion with live birds.

   Agreed. We added the sentence, "the experiment was conducted during September prior to the arrival of whooping cranes to eliminate potential confusion with live birds" for clarification.

7. Pg. 10, line 20: add "primary" to "apply to the primary sampling frame"

   Good catch; changed as recommended.

8. Pg. 12, line 20: Should consider some type of density estimate to serve as a threshold for including SSF into PSF. The way it is structured now, relatively small SSFs (i.e., Holiday Beach) have the same threshold applied for inclusion into PSF as those that are much larger (i.e., Guadalupe Delta). Given

this fact, some small SSFs may never be included into the PSF even after several years of consistent WHCR use. Consider analyzing what the average WHCR density is in the PSF and using that to determine an inclusion threshold.

Great idea! We have now estimated a threshold of number of detections for promotion of each SSF to PSF based on minimum density estimated in the PSF regions. New text in protocol is:

"Previously collected data indicated that whooping cranes have sporadically used several areas outside of the PSF. The SSF will be used to monitor expansion of the whooping crane wintering grounds. We determined a minimum number of whooping cranes groups that must be detected in a SSF region, before that SSF region will be included in the PSF for future surveys. The minimum number of groups (G) for SSF region i was determined based on the following formula:

$$G_i = \text{floor}(D \cdot A_i \cdot p)$$

where D was the minimum PSF region-specific density of whooping crane groups estimated during the winter 2013–2014 surveys (≈0.1 groups/km^2), A_i was the area of SSF region i, and p was the average detection probability during the 2013 surveys (0.7 detection probability within 500 m of transect). We rounded each G_i down to the nearest integer. The estimated threshold (G_i) of groups for a SSF region must be detected $\geq$2 times within a survey year before that SSF region will be promoted into the PSF for future surveys (beginning the next year). The minimum number of whooping crane groups needed to promote a SSF region into a PSF region varied from 1 to 9 (Table 2)."

We also add a new table to summarize the new thresholds.

9. Pg. 13, line 25: May want to note that surveys in WBNP are primarily used to estimate WHCR nests and fledged chicks, not abundance. I can see what protocols CWS has if you would like.

   Please check on those protocols, if any exist, and let us know how CWS's surveys are currently conducted and for what purposes. We believe integration of information from the abundance surveys on the wintering grounds with information about reproductive output on the breeding grounds could provide valuable insight into the limiting factors for this population.

10. Pg. 14, line 2: The 2-wk window may be too narrow once weather and logistical issues (plane maintenance) are considered. Consider changing to 3-wk window.

    We have decided to keep the 2-week window for now and see how things work out for winter 2013. We do not necessarily consider the 2-week window an absolute. It emphasizes the importance of getting the surveys done in as short of a window as possible. And a 2-week window is realistic. However, if it takes 16 days to complete the 6 surveys instead of 14 days, that is alright.

11. Pg. 14, line 13: Seems as though a clear objective for surveys done in secondary periods has already been established ("to document temporal changes in resource use"). May want to clarify this and note that surveys during secondary periods are optional and will be conducted only if primary objectives have been met and resources allow.

We do not consider "to document temporal changes in resource use" as a sufficient objective. During the first year of the new survey, we conducted surveys in a few different time periods during winter. Though there were slight changes in habitat use through time, the primary driver of all the models remained percent saltmarsh. We agree that surveys during secondary periods are optional and did note this in "Element 3, Survey timing" section. The primary reason for conducting the surveys is to estimate abundance, not quantify temporal changes in resource use. Models of resource use are a useful byproduct of the statistical analyses but resource use is best studied using other means, such as GPS-telemetry.

12. Pg. 15, Figure 9: Given the historical nature of this graph, I am concerned that we could be starting primary surveys too early in the year, potentially not capturing peak abundance in the early surveys. Should later migration events be accounted for?

    Based on the historic data we felt that surveys probably could begin either the second or third week of November. However, we delayed starting surveys until December just in case migration was delayed some years. We agree that if we see that migration is delayed in a particular year, then we should delay surveys as appropriate for that year. In fact, that is part of the reason we allowed surveys to be conducted anytime during the 1-month period (as long as they are blocked together into a 2-week window). If a trend of later migration dates becomes apparent, then we should re-evaluate the survey dates for future surveys.

13. Pg. 17, line 4-5: As stated previously, this threshold seems somewhat arbitrary considering the SSFs vary greatly in size and habitat quality.

    Agreed and we have addressed this issue in this Reviewer's comment #11.

14. Pg. 17, monitoring frequency: Need to explain how sampling objective 1 ("enough precision to detect a 10-15% population decline over 3 yrs") can be met without annual sampling.

    The paragraph in question is a discussion beyond objective 1. It broaches the issue current monitoring may be unnecessary until the population is closer to reaching the downlisting goal. We feel it is appropriate to discuss this point of view since it is an alternative to the objective outlined in the protocol. At current levels of precision, biennial monitoring probably could not meet current objectives. However, as the kinks are worked out in the new protocol, precision may improve.

15. Pg. 18, line 17: Is it worth saying that if an observer has any doubts as to the species ID during a survey, the bird should not be recorded? Or come up with a similar rule?

    Yes, this is worth saying. We had assumed that observers would only record detections they were certain to be whooping cranes. We have made this explicit in the protocol in the section in question and we added "if an observer has any doubt as to the species, that detection should not be recorded" to SOP1.

16. Pg. 20, line 29: Note that full Nomex fire clothing (shirt and pants) can be substituted for a flight suit per regs.

    The Reviewer is correct. See ALSE Handbook. We added a reference to the ALSE Handbook to the protocol and changed from "Nomex flight suit" to "Nomex flight suit or other fire-resistant clothing."

17. Pg. 20, line 30: I have not seen Nomex gloves identified as a PPE requirement, need to check on this. It would make data recording much more difficult.

    The Reviewer is correct; leather gloves maybe used instead of Nomex gloves. See ALSE Handbook. We changed "Nomex gloves" to "Nomex or leather gloves."

18. Pg. 20, Table 2: We should check to see if voice-activated voice recorders are available. This would reduce data loss associated with on/pause toggle issue.
    The Refuge Biologist was looking into this as a possibility; also, one observer has switched to simply writing down their observations. We encourage observers to use whatever technique works for them without compromising the survey's integrity.

19. Pg. 21, line 19: This list should be created prior to survey season and used accordingly by pilot and observers.

    Yes it should. Thanks for emphasizing the importance of making this list prior to the start of surveys. We have added this to SOP1.

20. Pg. 21, line 38: Per our experience last year, it takes about 4.5 hrs to conduct the survey (PSF). The stated time allotment doesn't leave any time to conduct SSF as suggested earlier in the document. Is it okay to conduct SSF flights outside of 10:00 to 15:00 hrs?

    We should attempt to keep all surveys inside the 10:00 to 15:00 timeframe. However, some deviance is probably acceptable.

21. Pg. 23, line 22-24: I still think we should explore a drop-down menu available via DNR Garmin or other software that would allow instantaneous data recording of group size/type. This would eliminate the need to voice record location and #/type of crane group detected and lowers potential data loss associated with this step. Each observer would still use a voice recorder for notes.

    We agree alternative data recording options need to be explored in the future. As mentioned before, we encourage observers use whatever technique works for them without compromising the survey's integrity.

22. Pg. 32, line 19-20: Need to state who is responsible for the annual report. Refuge biologist in conjunction with I&M, WHCR coordinator?

    Thank you for catching that oversight. We have added the following sentence to the "Element 7, Reports" section and the "Element 8, Roles and responsibilities" section. "Compilation of interim and annual reports will be a collaborative effort among the Lead Biologist, Regional Biometrician, Regional Data Manager, and Whooping Crane Recovery Coordinator (see Element 8–Roles and responsibilities). Update reports are the responsibility of the Lead Biologist with assistance from other observers."

23. Pg. 33, line 4-9: Is it worth stating that at least one alternate observer should be trained if possible in case one of the primary observers is not able to conduct the survey. This is particularly important given the survey's time constraints.

Good idea. We added the following to "Element 8, Training" section. "At least one alternate observer should be trained in case one of the primary observers is not able to conduct a survey."

INTERNAL REVIEWER #2:

I would like to thank the authors for giving me the opportunity to review the whooping crane abundance survey protocol. Below are my line by line comments followed by general overall comments.

Thank you for taking the time to evaluate and critique our protocol. We appreciate your efforts.

Specific Comments:

1. Cover Page: Insert "(Protocol)" after the word "Survey"

   Agreed, changed as recommended.

2. Page x, Line 11-13. Rewrite to: Stehn and Taylor (2008) briefly described the aerial survey methods employed from 1982-2011 and identified multiple factors that affect detection of whooping cranes.

   We disagree. Stehn and Taylor (2008) identified more than just factors that affect detectability. For example, they discussed problems associated with not predefining flight paths, whooping crane movements during surveys, upland use by whooping cranes, etc…

3. Page x, Line 17-18. Rewrite to: Regional and refuge staff then launched a multifaceted effort to develop a statistically rigorous survey method.

   Thank you for the suggestion, we reworded the sentence as "Regional and refuge staff then launched a multifaceted effort to improve the survey methods and develop a statistically rigorous technique."

4. Page x, Line 40. Rewrite to: The survey methods in this protocol provide a statistically rigorous means to estimate the annual peak abundance, and associated degree of confidence, of whooping cranes wintering within the sampling frame. Furthermore, the survey methods provide estimates of….

   Thank you for the suggestion, we reworded the sentence as "The survey methods provided in this protocol are a defensible, statistically rigorous means to estimate the annual abundance, and associated degree of confidence, of whooping cranes wintering within the sampling frame."

5. Page 1, Line 11. "Gulf" should be capitalized.

   We disagree. Texas gulf coast is not a proper noun. The Gulf of Mexico is a proper noun. The grammar is similar to "south Texas." The words "south Texas" does not indicate a state like West Virginia and therefore, should not be capitalized. The same applies to the Texas gulf coast.

6. Page 1, Line 28. Replace "defensible and creditable" with "statistically rigorous"

The sentence in question reads, “monitoring also provides a tool to measure recovery and bolster conservation efforts by providing defensible and creditable data that can be used to inform decisions affecting whooping crane conservation and management.” This sentence is discussing monitoring in general terms, not a specific monitoring technique. We believe it would be better to exclude either phrases from this general sentence and reserve such phrases for discussing a specific monitoring technique. Therefore, we have reworded the sentence as “Monitoring also provides a tool to measure recovery and bolster conservation efforts by providing data that can be used to inform decisions affecting whooping crane conservation and management.”

7. Page 2, Line 5-8. Rewrite to: Stehn and Taylor (2008) recognized these sources of potential bias and also indicated that population increases and range expansions would decrease the accuracy of the census.

   Thank you for the suggestion, we reworded the sentence as “Stehn and Taylor (2008) recognized these sources of bias but they did not address them. They also indicated that as abundance increases and the whooping crane’s wintering grounds expand, the accuracy of their “census” attempts would decrease.”

8. Page 2, Line 9-12. These two sentences should be moved to just above “Objectives” on Page 5.

   Thank you for your suggestion but these two sentences are appropriate in their current location.

9. Page 3. Delete blank line 7 and move Line 8 (sentence beginning “Each”) up to line 6.

   We agree that this sentence should be part of the previous paragraph.

10. Page 3. Delete line 10-31 (sentence beginning The “peak population size” and ending with the graph and Figure 2 caption). This paragraph has nothing to contribute to the understanding of why the Service is changing methods. The “Traditional census estimate and Maximum count during the survey year” are clearly correlated. The use of a T-test to statistically show the minor difference between the two does not seem appropriate and to report a 3 bird difference as significant seems absurd.

    The section in question reads, “The reported winter abundance was presumably obtained from the survey with the most individuals detected but was rarely replicated in subsequent surveys. However, the survey with the most individuals detected rarely corresponded with the winter abundance reported in the International Recovery Plan (CWS and USFWS 2007) and Aransas NWR annual reports (Stehn 2009, 2010, 2011; Figure 2). In fact, the reported abundance was ≈3.7 birds ($t = 3.754$, df = 30, $P < 0.001$) more than the maximum count observed during the 1980–2010 surveys. This likely occurred because birds observed outside of the survey area by the public or other parties were included in the reported abundances. Interestingly, during 1980–2010, the maximum number of individuals detected during a survey was greater than the reported abundance for 6 of the survey years (Figure 2). This inconsistency may be attributed to the observer’s interpretation or perception of double counts. However, we cannot know the sources of these inconsistencies since rules governing how data from separate surveys were combined or how public reports of whooping cranes from outside of the “censused” area were incorporated was largely determined by the observer’s opinion. This shows the traditional “census” was not an absolute enumeration of the population but instead a relative index of abundance.”

Understanding the limitations of the historic data only strengths our ability to use those data; this section is important to help readers understand those limitations. We believe the inability to discern exactly how numbers were derived is a fundamental issue associated with the traditional technique. Instead of assuming those data are absolute, we think it is better to couch our inferences within the data's limitations and avoid risking drawing conclusions that are beyond the scope of the historic data.

Discussing a 3 bird difference is not absurd. Three birds can fundamentally change the interpretation of these data since they have been treated as absolute truth. For example during the winter of 2008–2009, the traditional technique reported 270 birds on the wintering grounds with 23 of them dying during the winter. During the winter of 2009–2010, the population was reported to be 264 birds with 22 juveniles which would mean there were 242 adults in the population. However, the maximum count during the winter of 2009–2010 was 270 birds which would presumably mean there were 248 adults in the population. If 23 mortalities occurred during the winter of 2008–2009, there could only be 247 adults in the population during the winter of 2009–2010 (270–23=247; assuming no mortality during other parts of the year). Where did that extra adult come from? Did the maximum count of 270 during the winter of 2009–2010 include 6 birds that were counted twice? Was mortality during the breeding- and migration-periods only 2% ((247–242)/247)? This is an illustration of the fundamental danger of a technique that portends to deal in absolute truth when there is really much uncertainty in the estimates.

11. Page 4, line 1-7. Move up to page 3 line 6 just ahead of current line 8 on page 3.

    Since we chose not to delete the previous paragraph, these lines should remain where they are.

12. Page 4, line 7-15. Sentence beginning "Group structure" start as a new paragraph. Rewrite to: In the past, group structure and location data was also used to assist in quantifying mortality of individuals. For example, subsequent observations of a group of 1 adult and 1 chick where previous surveys located a group of 2 adults and 1 chick could result in the presumption that 1 adult had died. However, the "unusual movements and behaviors of color-banded whooping cranes" observed by Stehn (1992), such as extra-territorial excursions, rapid pair formation after mate mortality, pair-bonded individuals overwintering apart, and occasional departure from the wintering grounds during the winter period, in addition to incomplete detection of individuals makes using group structure and location data of unmarked birds from aerial surveys problematic.

    We added more information to this paragraph in order to help readers better understand the problems associated with the mortality estimates derived from the traditional technique. The section is now split into 3 paragraphs:

    "Wintering whooping cranes are thought to demonstrate territoriality and site fidelity within and across winters (based on limited observation data from marked birds; Stehn and Johnson 1987, Stehn 1992, Bonds 2000). The fidelity of whooping cranes to their wintering territory has been used in conjunction with group structure as a surrogate for individually marked birds. Groups of equal size found in similar areas on subsequent surveys were assumed to be the same individuals. These data were used to identify circumstances where distinct groups, or individuals within groups, were not detected and therefore additional search efforts were conducted (Stehn and Taylor 2008)."

"Group structure and location data was also used to assist in quantifying the mortality of individuals (Stehn and Strobel 2012, Pugesek et al. 2013). For example, subsequent observations of a group of 1 adult and 1 chick where previous surveys located a group of 2 adults and 1 chick resulted in the presumption that 1 adult had died. However, the "unusual movements and behaviors of color-banded whooping cranes" observed by Stehn (1992), such as extra-territorial excursions, rapid pair formation after mate mortality, pair-bonded individuals overwintering apart, and occasional departure from the wintering grounds during the winter period, in addition to incomplete detection of individuals indicates that group structure and location data of unmarked birds from aerial surveys cannot be used to reliably imply mortality."

"The technique for enumerating mortalities assumed that if an individual whooping crane was not observed for 2 or more surveys, that individual was dead (Stehn and Strobel 2012). For this technique to produce consistent results, the number of surveys conducted per winter needed to be relatively constant. However, the number of surveys conducted between December 1st and March 31st of each year ranged from 4 to 21 (mean = 12.52, SD = 4.288; Butler et al. in prep). This deficiency in the technique manifested itself in an inverse relationship between winter mortality estimates and the number of surveys conducted between December 1st and March 31st (binomial regression: odds ratio = 0.932, $\hat{\beta} = -0.071$, SE = 0.028, $W = 6.595$, $P = 0.010$; Butler et al. in prep). Hence, more surveys resulted in less mortality because temporary emigrants had more chances to return and be re-observed on their territories. For example, imagine that 5 consecutive surveys were conducted and a whooping crane was missing from its territory on the third and fourth survey occasions. If the last survey had not been conducted, that whooping crane would have been considered dead."

13. Page 4, line 35. Delete entire bullet.

    The bullet in question is "The observer assumed ability to uniquely identify unmarked individual whooping cranes." This is a true statement, and relevant, so we are unsure of the request for deletion. While some believe that previous observers could consistently identify unmarked whooping cranes, there are no data available to support this belief. In our professional experience, defensible identification of free-ranging individuals requires the use of unique markers. As such, we feel our comment is accurate. This point forms an added example of why we needed to critique the traditional survey technique.

14. Page 4, Line 37. Stop the sentence after the word "tested." Delete "and is likely untenable."

    The statement in question is "The suitability of using group structure and territory location as a surrogate for individually marked birds to measure mortality rates has not been quantified or tested and is likely untenable." We have changed this sentence to "The suitability of using group structure and territory location as a surrogate for individually marked birds to measure mortality rates has not been tested and is likely untenable." We have provided additional information in a previous paragraph to explain the problems associated with estimating winter mortality from the traditional survey technique.

15. Page 5, line 1-3. Delete entire first two sentences

    The sentences in question are "Many technological and statistical advances have resulted in improvements in data collection and analysis techniques that were not readily available when aerial surveys began in the 1950s. However, many of these advances have been available for decades (e.g., Burnham et al. 1980)." These statements are valid and they make us wonder why previous biologists did nothing to address problems with the traditional technique when much better techniques have been available for decades. We are updating the survey, and the methods we use are tested and established.

16. Page 5, line 6. After the sentence ending "data." Add the two sentences from Page 2 Line 9-12

    We edited as suggested.

17. Page 5, line 7. Replace "rigorous, defensible" with "statistically rigorous"

    We removed the word defensible.

18. Page 5, Line 9. Add another paragraph with this text: Quantifying winter mortality will not be a stated objective of this monitoring protocol due to the multiple factors previously identified regarding group structure and location data of unmarked birds. Estimates of mortality will require an additional protocol.

    We refrained from adding this sentence because we will not be developing an additional protocol to estimate winter mortality. Winter mortality has little influence on population change but recruitment and mortality during migration have large influence on population change (Butler et al. in prep.). This protocol indexes recruitment but radio- or GPS-telemetry based monitoring are probably the only ways to better understand the causes of mortality (this is an ongoing research project).

    We did add the statement, "mortality estimates are better derived from radio- or GPS-telemetry based monitoring of a sample of the population," to the "Element 1, Traditional "census" effort" section.

19. Page 5, line 14. Replace "defensible" with "robust"

    Ok, thank you.

20. Page 5, line 17. Delete "including the delineation of critical habitat" Critical habitat has already been established and until such time that the Service formally decides to modify the critical habitat units I would refrain from stating that this will be one of the uses of the data.

    Good catch; we did not intend for this to mean "critical habitat" in the legal sense of the term. We have changed term to "important habitat."

21. Page 5, line 20-22. I think being able to statistically show a 10 to 15% decline over a three year period is exactly what we should be striving for. This would be a 3-5% decline annually. This does not seem to match the text in Butler et al. 2013 which is used as a reference here.

    We did not provide enough detail for the power analysis and justification of the objectives. Thank you for catching that. Butler et al. (2013) identified scenarios that would significantly reduce abundance from the current trajectory and delay reaching the downlisting goal of 400 birds by $\geq$5 years. Those scenarios were ≥3 consecutive years of –9.5% annual decline or ≥2 consecutive years of –14% annual decline. To estimate one growth rate, 2 years of abundance estimates are needed. Therefore, we need to be able to detected a –9.5% annual decline over a 4-year period or a –14% annual decline over a 3-year period. We have now provided this information in the new section, "Justification of objectives" in Element 1. We have also reworded the objective to better reflect this. "Provide an estimate of whooping crane abundance within the surveyed area (see Element 3, Sampling frame) with enough precision to detect a 10–15% annual population decline over a 3- to 4-year period (see justification provided in Butler et al. 2013)."

To detect a –15% annual decline over a 3-year period, a CV of 6% is needed and to detect a –10% annual decline over a 4-year period, a CV of 9% is needed. Based on the winter 2010–2011 pilot work, we estimated 6 surveys would result in a CV of 7%. Based on the surveys conducted during January 2012, we estimated 5 to 6 surveys would result in a CV of 9% and 10 to 13 would result in a CV of 6%. We show a range in Table A1 because the number of surveys needed to reach a given CV depends on whether data are analyzed using HDS or CDS (see new note in Table A1). We have also updated Table A1 with additional effort estimates. We are recommending that at least 6 surveys be conducted (see Element 3, section Survey repetition and sample size); this does not mean more surveys cannot be conducted. However, our experience suggests that 7 or 8 surveys per year is about the logistical limit that can be accomplished in the 2-week window.

Note, that Butler et al. (2013) recommended being able to detect a –15% annual decline over a 2-year period or a –10% annual decline over a 3-year period to allow enough time to respond to the scenarios. This would require 4% to 6% CV which can be easily obtained by pooling data from multiple years as Reviewer #2 recommended in comment #20.

We think it is worth noting that detection of a 5% annual decline over the course of 2 years would require a CV of approximately 1.5%. Such precision is rather impossible; thus, suggesting that the revised survey detect a 3 to 5% decline annually is also unreasonable. However, detection of a 3–5% annual decline over a 10-year period, instead of a 2-year period, would require a CV of 14–26%. This might be a meaningful alternative to detecting the scenarios outlined in Butler et al. (2013) since this population has grown at an average of 3.9% per year since winter 1938–1939, and has exhibited a 10-year cycle in population growth (Boyce and Miller 1985, Boyce 1986, Butler et al. 2013).

22. Page 6, Line 36-42. Including figure 3. It might be better to show the plot of the raw data as opposed to the selected cut-intervals of 100 m. I assume this was done to improve the model fit but maybe there needs to be some explanation here.

    Frequency data are never shown as raw data but histograms. This Reviewer implies that the model we used to determine detection probability during the winter 2010-2011 surveys was based on binned data but it was not (see Strobel and Butler 2014). Since the draft protocol was reviewed, a Wildlife Society Bulletin paper (Strobel and Butler 2014) has been published that describes the pilot work in great detail. We have added the citation to appropriate places throughout the protocol.

23. Page 6, line 40-42. I think I know what the authors are trying to say here but this seems a case of mixing "apples and oranges". This would be true if the traditional survey technique had fixed transects but because the traditional technique varied transect width and intentionally made excursions off transect to verify bird identification the observer could have counted all the birds and then sum. Because there is no way of quantifying the error associated with the traditional survey

technique it is not correct to say that the detectability was < 1. I think I would recommend deleting lines 40-42 and replace it with a statement like “Because distance from the transect line clearly affects detection then a distance modeling approach is necessary to statistically estimate the number of whooping crane groups that were not detected along the transect.”

This comment is incorrect. We show that detectability was less than one (see Strobel and Butler 2014). The assumption that the observers made during the traditional technique was that they could, after multiple surveys, figure out all the individuals in the population (even though most were unmarked). Clearly detectability was less than 100% during an individual survey. Figure 2 shows that for many years the maximum number of whooping cranes counted was often less than the reported abundance; hence, detection less than 100%. For example, the population was reported to have been comprised of 264 birds in 2009, but surveys from that year reported from 201 to 268 birds. Again, there are a lot of misconceptions about the traditional technique and that is why the critique is so important.

24. Page 8, line 1-2. Why would the authors try and gauge distance based on marks on the struts? Even in the traditional census groups were marked on paper DOQQ’s.

    The use of marks on struts to measure distance from transect during aerial surveys is a common technique (e.g., Caughley et al. 1976, Guenzel 1997, Butler et al. 2007). That is why we considered it.

25. Page 8, line 21-24. Rewrite to: “Angle of the sun significantly affected detection of whooping crane decoys in our pilot study. Stehn and Taylor (2008) also noted that sun angle affected detection of whooping cranes during the traditions census. To minimize the effect of sun angle we recommend…..”

    The sentences in question are “The traditional census was conducted during the morning and afternoon with a break for lunch (Stehn and Taylor 2008). Therefore, much of the survey effort was accomplished when the sun was at lower angles resulting in high detectability on one side of the aircraft but low detectability on the other. We recommend…” We edited those sentences as follows, “The angle of the sun significantly affected detection of whooping crane decoys in our pilot study. Though Stehn and Taylor (2008) also noted that sun angle affected detection of whooping cranes, the traditional census was conducted during the morning and afternoon with a break for lunch. Therefore, much of the survey effort was accomplished when the sun was at lower angles resulting in high detectability on one side of the aircraft but low detectability on the other. We recommend…”

26. Page 9, line 20. Replace “defensible” with “rigorous”

    Change made.

27. Page 11, line 6. Delete the last sentence in the Figure 6 caption. This sentence is not germane to the methods.

    The caption of Figure 6 was “Figure 6. The sampling frame for monitoring whooping crane on their wintering grounds along the Texas gulf coast, USA. These were not formally defined during the traditional “census” effort.” We retained this sentence because we want to be clear that a formally defined sampling frame is new to the revised technique. We believe this sentence is important for the reader to understand how the revised technique compares with the traditional technique. Further, our critique of the traditional technique must be open and transparent in order to increase understanding for why we established the new technique.

28. Page 12, line 2. Delete "scientifically defensible" and replace with "statistically rigorous"

    We deleted "scientifically defensible."

29. Page 12, line 8-12. I understand what the authors are saying here; however, I think reports should include not only those estimates made from the PSF but also legitimate counts from areas well outside of the sampling frame. In addition if qualified observers can verify that they were watching a group of cranes that are outside the sampling frame the entire time a survey was taking place the reports should also add these birds to the peak count.

    We added the following to the new section, "Element 7, comparison with estimates from the traditional technique."

    "Whooping cranes observed outside of the primary sampling frame will be reported separately and identified according to the source of the observation (e.g., Texas Whooper Watch, satellite transmitter, or secondary sampling frame during aerial survey efforts). However, adding these reported birds to the estimate presents potential problems. For example, we cannot ever be completely certain that whooping cranes observed outside the primary sampling frame on one day did not move to or from the primary sampling frame before the surveys were completed."

30. Page 12, line 28. I am not sure what relevance this sentence has to the analyses. In fact, I cannot tell from Appendix C how regions are treated.

    The sentence in question reads, "The sampling units for this design can be considered in a hierarchical or nested sense (Figure 7)." This sentence is simply an introductory sentence to a paragraph that explains how the sampling design was constructed in a hierarchical manner. The regions, primary and secondary sampling frames, are treated differently in that data from the secondary sampling frame are not included in the analysis since so few whooping cranes currently inhabit it. Please refer to the "Element 3, Sampling frame" section among other places throughout the protocol.

    It looks to me like each 1km^2 along the transects are treated as independent samples and all used in the quantification of groups within the PSF.

    Yes, the 1-km^2 grid cells are used as the sampling unit for abundance of groups. However, the groups themselves are the sampling unit for detection probability. Thus, the hierarchical nature of this sampling design.

31. Page 12, lines 32, 38 and 39. The 1-km^2 segments, how will they be characterized? I assume that the entire segment will be given one vegetation class. If this is correct then the 1-km^2 may be too large. I think the TPWD classification effort had a 10-m resolution. (I found later that each 1-km^2 will have 6 classes). This language should be inserted here.

No, each 1-km^2 grid cell will not be given one vegetation class. This is not the appropriate place to discuss the environmental covariates used since this section is about the sampling design not modeling. We inserted a note to refer readers to "Element 4, Environmental covariates" section for more information on the environmental covariates used.

32. Page 15, Box Plot. The authors give good rational for conducting peak abundance surveys during the 4 week period beginning November 28th; however by looking at the box plot it looks like it doesn't matter as long as the surveys are conducted between November 28th and March 27th.

    If we allowed surveys to be conducted over a 4-month period instead of a small temporal window, surveys would be less comparable from year to year. For example, if surveys were conducted during December one year resulting in an estimate of 270 then March the next year resulting in an estimate of 260, one might be tempted to suggest that the population declined between those two years. However, the second estimate accounts for winter mortality (or emigration) whereas the first estimate does not. To ensure comparability from one year to the next, surveys need to be conducted during the same time period. To facilitate comparison with the traditional technique which aimed to provide estimates of "peak" abundance (i.e., abundance post fall-migration prior to any winter mortality), then December is the most appropriate time period.

33. Page 16, line 2-3. I think this sentence is missing something. Maybe it should stay "3-6 surveys will be required to obtain a CV(N) low enough to detect a 10% decline." In addition the stated goal is to be able to detect a 10-15% decline over 3 years that would be a 3-5% decline each year. According to figure A2, regardless of time (2 year or 3 years) the method should be able to detect a 10-15 decline which will require a CV(N) of between .035 and .053.

    See our response to Reviewer's comment #21; we have rewritten the section as per our response in comment #21.

34. Page 17, line 8-21. The statement that the population is approximately 15 years from reaching 400 birds does not seem to be supported by (Butler et al. 2013). By looking a Figure 1 in this citation it looks to me like 400 birds could be attained as soon as 2017 and at the latest 2027. Even the text gives a 50% chance of reaching 400 birds by 2023. It seems likely that we could have 400 birds in the next 7 years; therefore to suggest that monitoring be conducted every other year seems inappropriate. I would say that reaching a potential downlisting criterion in as few as 4 years seems pretty imminent.

    The recovery probability (i.e., probability of reaching 400 birds) did not exceed 80% until 2025. The 15 years out was from winter 2010 (last year of the data used in Butler et al. 2013). We have revised this statement to read "this whooping crane population is ≈12 years from reaching 400 individuals." The Reviewer is correct that we have a 50/50 chance of reaching 400 birds by 2023. However, reaching 400 birds by 2017 is by no means imminent (4% probability).

    I would suggest this section be rewritten to simply state that the monitoring will be conducted annually and that frequency will be revisited with each major revision of this document.

    We choose to keep this discussion about the utility of annual monitoring since it is an important topic one must consider given limited budgets and much priority work. If the precision of abundance estimates from the new technique reach the levels predicted by Appendix A (now that the bugs have been worked out of the protocol), biennial monitoring must be considered given the reasons discussed in the section.

35. Page 17, line 28. The web link does not work. I suggest you remove the link.

    We have corrected the web link. TPWD recently moved the data. Thank you.

36. Page 17, line 41. Delete the sentence “Tests of marks on struts…..” I am not sure why marks on struts was ever explored, even the traditional technique used DOQQ’s.

    The use of marks on struts to measure distance from transect during aerial surveys is a common technique (e.g., Caughley et al. 1976, Guenzel 1997, Butler et al. 2007). That is why we considered it. We choose not to delete this sentence.

37. Page 18, line 30. Sentence beginning “However,….” needs a citation, or change the word “will” to “should”

    We have provided citations, thank you.

38. Page 20, line 30. The use of gloves is probably not practical.

    Leather gloves maybe used instead of Nomex gloves; see ALSE Handbook. We changed “Nomex gloves” to “Nomex or leather gloves.”

39. Page 21, line 1-7. General Comment: Having a ridged standardized protocol and a good repeatable survey design means that just about anybody should be able to conduct the survey and get similar results. If this is true it might open the door to have the surveys contracted out. I am certainly not advocating this approach now, but down the road once all the kinks are worked out, significant cost savings could be realized.

    Perhaps contracting the survey in the future is possible. However, regardless of the future potential for contracting the work, at least any USFWS employee with a little training will be able to conduct the survey.

40. Page 24, line 24. Change the word “follow” to “following”

    Corrected, thank you.

41. Page 24, line 45. Web link does not work.

    We have corrected the web link. TPWD recently moved the data. Thank you.

42. Page 24, line46-Page 25, line 7. Incorporate this language into Page 17 line 23-33 and Page 12 line 36-42.

    Good idea. We add “The percent of each 1-km^2 transect segment is determined for 6 general vegetation types: saltmarsh, open water, wetland, saltmarsh-shrubland, upland, and urban (Appendix E). Though these covariates are only rudimentary, strong relationships with whooping crane abundance has been demonstrated with some of them (Strobel et al. 2012)." to the "Element 3, Environmental covariates" section.

43. Page 44, Appendix C. Conduct data analyses and prepare reports. Appendix C Makes no mention of reports and who is responsible for them. Somewhere in this document it should specifically state who will be writing the reports.

    You are correct that preparing reports is not discussed in Appendix C. We have corrected this in the "Overview of the Whooping Crane Abundance Protocol" section. We have also added "Compilation of reports will be a collaborative effort among the Lead Biologist, Regional Biometrician, Regional Data Manager, and Whooping Crane Recovery Coordinator (see Element 8, Roles and responsibilities)." to the "Element 7, Reports" section and the "Element 8, Roles and responsibilities" section.

44. Page 87, Appendix C: General comment: This appendix is well written with the exception of a typo on Page 92, line 2.

    Thank you, the sentence now reads "If a significant (typically $\alpha = 0.15$ is used) negative slope is found, this suggests larger groups tend to be detected at greater distance than smaller ones."

    In the paragraph starting on line 30 of Page 97 the authors recommend pooling data from repeated surveys prior to running the model. Because cranes are territorial groups detected along repeated transects are likely to be correlated. I am not sure how this correlation affects model results but I would think you would want to look at how closely repeated transects are correlated prior to pooling them; however, I am not a statistician.

    We are unsure what the comment is trying to get at. Pooling data from transects is standard practice for distance sampling-based surveys (see Buckland et al. 2001). We pool repeated transects to avoid treating them as if a repeated survey is an independent sample. We do not treat additional surveys of a transect as independent surveys. Instead, we pool data from repeat visits of a transect and treated it as one transect which is the correct way to account for the dependence described in the comment. This ensures we are not inflating the sample size at the transect level.

General Comments:

1. Overall, I am pleased to see the Service move to a standardized method that allows for quantifying error associated with estimating crane abundance.

    Thank you. We are glad to see this Reviewer understands the importance of standardizing survey techniques for whooping cranes.

    I have made numerous suggested changes within this document in regards to the use of the term "scientifically defensible". Although the authors are technically correct to use this language, in this situation, I would refrain from it. In my opinion, the authors spent an inordinate amount of time pointing out flaws in the original census method that were presumably used to justify changing methods. A simple short paragraph detailing that the original census technique lacked a formal repeatable protocol and did not provide quantitative estimates of error would suffice. After all, this is intended to be a written standardized protocol not a justification for changing methods.

We disagree that too much of the protocol was spent on critiquing the traditional technique. As stated before, less than 4 pages of a document containing over 150 pages was devoted to critiquing the traditional technique. Many Reviewer comments revealed misconceptions about the traditional technique which has further emphasized the need for critiquing it. Therefore, we have chosen to include the description and critique of the traditional survey technique. We feel that to "justify changing methods" is an important component of any new survey protocol.

The new protocol is without doubt statistically rigorous, so there is no need to use the term "scientifically defensible". The repeated use of this language throughout this document seems to convey to readers that past practices were not defensible. This is a mistake that should be avoided because the Service is not only judged in courts of law but also in the court of public opinion.

The term "scientifically defensible" was only used twice in the review draft and the term "defensible" was used 6 times. The term "defensible" now only appears twice. The new technique is "scientifically defensible" whereas the old technique was not. It is not a mistake to point out deficiencies in our methods so we can understand them and make corrections. We hope future efforts improve the new techniques when needed.

It is ironic that the very data in question with all its unquantifiable flaws was used by the authors to publish Butler et al 2012 and that publication used in this document to determine precision and suggest less frequent monitoring. This irony will not be lost on other readers.

The traditional technique resulted in 4 to 21 surveys per year (mean = 12.7, SD = 4.2; Butler et al. in prep). We are planning on conducting 6 surveys per year. Sure that is fewer, on average, than the traditional technique but we did not use data from the traditional technique to determine power. We based power decisions on our pilot efforts and the first year of surveys using the new technique. To determine the precision needed, we had to determine the amount of change that needed to be detected. The Butler et al. (2013) paper used data from the traditional technique to better understand this population's dynamics. We are sure the Butler et al. (2013) authors would have preferred to have used data with fewer flaws but nothing else was available. None the less, that work shows a 10 to 15% decline must occur for 2 to 3 years to substantially delay recovery. In the absence of better survey data, we used the best available data to inform our monitoring objectives. Data were used cautiously, based on the assumptions used to acquire them.

2. With any new technique there will be growing pains and, unfortunately, since this method has been used in the last two seasons it has yielded what should be considered unacceptable levels of variation. I think that the CV(N) was around 0.12 in the first year and close to 0.13 in the second. Based on the table provided, on Page 83, it would take a 40 to 50% decline over a 4 year time period before a statistically significant difference could be shown. This certainly does not approach the stated goal of detecting a 10 to 15% decline over 3 years. Much effort should be expended to understand why the technique has performed so poorly. As a person that has been in the plane I can positively state that I have contributed to this variation due to at least one instance of voice recording error. This technique has many moving parts and does require a fair bit of training. I concur with the authors' recommendations for training of new counters and becoming very familiar with the equipment and software prior to conducting surveys. Although training of counters will help decrease variation I do not think it will solve the whole problem.

The first year of the new survey resulted in a CV of 12% and the second year of the new survey resulted in a CV of 19%. Due to unfortunate constraints during the first year, only 3 surveys were conducted that met the protocol criteria. During the second year, new observers misunderstood some of the protocol requirements and data collection procedures which resulted in only one useable survey for that year. Now that all the kinks have been worked out, the full survey effort of 6 surveys should result in the precision discussed in Appendix A (CV $\leq$ 8%) which is enough to detect the change outlined in sampling objective 1.

A more rigorous and in-depth decoy study would help in understanding all of the sources of variation.

The decoy study we conducted was elaborate and much was learned (see Strobel and Butler 2014). We see no reason at this time to conduct another decoy study since all the decoy study does is help us better understand the detection process. Most of the variation in the estimate is due to variation in encounter rates not the detection process. The variation in encounter rates (i.e., the spatial distribution of whooping crane abundance) cannot be effectively studied with a decoy experiment.

3. The technique relies on being able to accurately develop a detection curve, but when there are two observers each may have different detection probabilities. How are these reconciled when half of one transect and therefore, half of each 1 km^2 have different detection probabilities?

   Distance sampling is pooling robust which means that it is extremely robust to variation in detectability due to factors other than distance, such as observers, habitat conditions, and weather (Thomas et al. 2006).

4. Are all the transects of a given observer on the same day used to model the detection curve or are curves modeled for each transect?

   There are not enough detections on a given transect to model a detection curve for each transect nor is modeling transect-specific detection curves normal practice for distance sampling. There are not enough detections on a particular survey day to model a detection curve for each survey either (though we could use survey day as a covariate in the detection model). See discussion about pooling robustness above. We are considering using habitat covariates in the detection models but doubt it will improve the precision of the final abundance estimates much.

5. Were the decoy experiments conducted with two observers? I think much could be learned through an elaborate decoy study.

   Yes, the decoy experiments were conducted with two observers. We added a note in this section that two observers were used. This was an elaborate decoy study and much was learned (see Strobel and Butler 2014).

6. Are each of the 6 surveys within the two week window used as separate samples or is all the data pooled as seems to be suggested in Appendix C?

   All the data are pooled in the analysis which is appropriate since multiple surveys of the same transect cannot be treated as independent samples. See page 79 in Buckland et al. (2001).

7. Finally I would like to commend the authors for developing such and in-depth protocol and series of standard operating procedures. As biologists and ecologists, we should always strive to collect the most meaningful data possible and ensure that our techniques are properly documented and tested.

   Thank you for the complement; this protocol would not have been possible without the contribution of many others, as we now note in the acknowledgements section of the protocol.

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Appendix. R code to demonstrate generalized HDS for a "full-coverage design."

```
library("MASS")
library("unmarked")

R=10 # number of transects
tr=6  # number of replicates
sw=50 # Strip width (transect half-widt).
tl=sw*2*R # Transect length.
Q=tl/(sw*2)
# This results in 10 transects that are 100 m wide over a landscape that
# is 1,000 x 1,000 m.  Therefore, this landscape would be composed of
# 100 grid cells that are 10,000 m².

# Average abundance/grid cell for the two habitat types.
lambda1=2.0
lambda2=0.5

sigma=30 # Half-normal shape parameter for the detection curve.

# Home range shape.
hr.shape=matrix(c(500,0,0,500),2,2)

# So we want animals to be moving in and out of each cell. This plot
# demonstrates the posible distances moved between surveys.
plot(mvrnorm(1000,c(0,0),hr.shape))

# Function to locate each animal during a survey.
location=function(n,center){mvrnorm(n,center,hr.shape)}

it=1000 # Number iterations.

# Make a data frame to hold results.
A=as.data.frame(matrix(NA,it,6))
names(A)=c("phi","lambda1","lambda2","abun.pred","abun.est","abun.true")

# Start the simulation loop.
for (B in 1:it){

  # Make grid cell centers.
  cell.centers=cbind(sort(rep(seq(sw,R*sw*2-sw,sw*2),R)),rep(seq(sw,tl-
      sw,sw*2),R))

  # Split the landscape into 2 habitat types.

      cell.centers=cbind(cell.centers,sample(c(rep(1,floor((R*Q)/2)),rep(0,ce
      iling((R*Q)/2)))))

  # Make an empty column to add lambdas.
  cell.centers=cbind(cell.centers,matrix(NA,R*Q,1))

  # Assign lambdas to their habitat types.
  for (i in 1:(R*Q)){
    if (cell.centers[i,3]==1)
      cell.centers[i,4]=lambda1
    else
      cell.centers[i,4]=lambda2
  }

  # Make cell.centers a data frame and name variables.
  cell.centers=as.data.frame(cell.centers)
  # Add an empty column to add the randomly selected abundance for each cell.
  cell.centers=cbind(cell.centers,matrix(NA,R*Q,1))
  names(cell.centers)=c("c.x","c.y","type","lambda","n")
```

```
# Randomly select abundance for each cell based on Poisson distribution.
for (i in 1:(R*Q)){
  cell.centers$n[i]=rpois(1,cell.centers$lambda[i])
}

# Make a data frame to hold the home range centers for each animal in the
    population.
home.center=as.data.frame(matrix(NA,1,5))
names(home.center)=c("c.x","c.y","type","lambda","n")

# Fill up the home range centers data frame.
for (i in 1:(R*Q)){
  if (cell.centers$n[i]>0)
    for (j in 1:cell.centers$n[i]){
      home.center=rbind(home.center,cell.centers[i,1:5])
    }
  else
    home.center=rbind(home.center,cell.centers[i,1:5])
}
home.center=home.center[-1,]

# Make two empty columns to hold the x and y for the home range centers.
home.center=cbind(home.center,matrix(NA,length(home.center$n),2))
names(home.center)=c("c.x","c.y","type","lambda","n","hr.x","hr.y")

# Randomly select the home range centers.
for (i in 1:length(home.center$n)){
  if (home.center$n[i]>0)
    home.center$hr.x[i]=home.center$c.x[i]+runif(1,-45,45)
  else
    home.center$hr.x[i]=NA
  if (home.center$n[i]>0)
    home.center$hr.y[i]=home.center$c.y[i]+runif(1,-45,45)
  else
    home.center$hr.y[i]=NA
}

# Make a plot to visualize where the animals in the population live.
#
    plot(home.center$c.x[home.center$type==1],home.center$c.y[home.center$t
    ype==1],pch=18,col="red",xlim=c(-50,R*sw*2+sw),ylim=c(-50,tl+sw))
#
    points(home.center$c.x[home.center$type==0],home.center$c.y[home.center
    $type==0],pch=18,col="blue")
#
    points(home.center$hr.x[home.center$type==1],home.center$hr.y[home.cent
    er$type==1],pch=4,col="red")
#
    points(home.center$hr.x[home.center$type==0],home.center$hr.y[home.cent
    er$type==0],pch=4,col="blue")

# A data frame to hold animal locations during each survey.
movement=cbind(home.center,matrix(NA,length(home.center$n),tr*2))

# Just some code to name the columns.
x=factor(seq(1,tr,1))
aa=NA
for (i in 1:length(x)){
  aa=c(aa,paste("x.",x[i],sep=""),paste("y.",x[i],sep=""))
}
aa=aa[-1]
names(movement)=c("c.x","c.y","type","lambda","n","hr.x","hr.y",aa)
```

```
# Randomly select each animals location during a survey; location based on
    home range center and shape.
for (i in 1:length(movement$n)){
  for (t in 0:(tr-1)){

    movement[i,(t+t+8):(t+t+9)]=location(1,c(movement$hr.x[i],movement$hr.y
    [i]))
  }
}

# Make a plot to visualize where the animals in the population live and
    their movement.
#
    plot(home.center$c.x[home.center$type==1],home.center$c.y[home.center$t
    ype==1],pch=18,col="red",xlim=c(-50,R*sw*2+sw),ylim=c(-50,tl+sw))
#
    points(home.center$c.x[home.center$type==0],home.center$c.y[home.center
    $type==0],pch=18,col="blue")
#
    points(home.center$hr.x[home.center$type==1],home.center$hr.y[home.cent
    er$type==1],pch=4,col="red")
#
    points(home.center$hr.x[home.center$type==0],home.center$hr.y[home.cent
    er$type==0],pch=4,col="blue")
# for (i in 0:(tr-1)){
#   points(movement[,(i+i+8)],movement[,(i+i+9)],pch=20)
# }

# Remove all locations that are outside of the sampling frame.

    movement[cbind(matrix(TRUE,length(movement$type),7),(movement[,8:(7+tr*
    2)]>0))==FALSE]=NA

    movement[cbind(matrix(TRUE,length(movement$type),7),(movement[,8:(7+tr*
    2)]<(sw*2*R))==FALSE]=NA
for (i in 0:(tr-1)){
  movement[is.na(movement[,(i+i+8)]),(i+i+9)]=NA
  movement[is.na(movement[,(i+i+9)]),(i+i+8)]=NA
}

# Make a plot to visualize where the animals in the population live and
    their movement.
#
    plot(home.center$c.x[home.center$type==1],home.center$c.y[home.center$t
    ype==1],pch=18,col="red",xlim=c(-50,R*sw*2+sw),ylim=c(-50,tl+sw))
#
    points(home.center$c.x[home.center$type==0],home.center$c.y[home.center
    $type==0],pch=18,col="blue")
#
    points(home.center$hr.x[home.center$type==1],home.center$hr.y[home.cent
    er$type==1],pch=4,col="red")
#
    points(home.center$hr.x[home.center$type==0],home.center$hr.y[home.cent
    er$type==0],pch=4,col="blue")
# for (i in 0:(tr-1)){
#  points(movement[,(i+i+8)],movement[,(i+i+9)],pch=20)
# }

# Make a data frame to hold distance data.
locs=as.data.frame(matrix(NA,1,5))

# Fill that data frame.
for (i in 0:(tr-1)){
```

```
  x=(findInterval(movement[,(i+i+8)],seq(0,tl,sw*2))-
    findInterval(movement$c.x,seq(0,tl,sw*2)))*100
  y=(findInterval(movement[,(i+i+9)],seq(0,tl,sw*2))-
    findInterval(movement$c.y,seq(0,tl,sw*2)))*100
  x[is.na(x)]=0
  y[is.na(y)]=0

    locs=rbind(locs,(cbind(movement$c.x+x,movement$c.y+y,i+1,movement[,(i+i
    +8)],movement[,(i+i+9)])))
}
names(locs)=c("c.x","c.y","time","x","y")
locs=locs[-1,]

# Assign habitat types.
for (j in 1:length(locs$c.x)){

    locs$type[j]=cell.centers$type[(cell.centers$c.x==locs$c.x[j])&(cell.ce
    nters$c.y==locs$c.y[j])]
}

# Calulate distance from transects.
locs$dist=abs(locs$c.x-locs$x)

# Estimate detection probability.
locs$p=exp(-locs$dist^2/(2*sigma^2))

# Determine if it was detected or not.
locs$det=rbinom(length(locs$c.x),1,locs$p)
locs$det[locs$det==0]=NA
locs$det.dist=locs$det*locs$dist
# Make cell IDs.
locs$ID=paste(locs$c.x,locs$c.y,sep="")

# Get a list of unique cell IDs.
ids=unique(locs$ID)

# Distance breaks.
breaks=seq(0,50,by=10)

# An array to put the data in.
y=array(NA,c(R*R,length(breaks)-1,tr))

# Fill the array.
for (t in 1:tr){
  for (i in 1:length(ids)){

    y[i,,t]=table(cut(locs$det.dist[(locs$time==t)&(locs$ID==ids[i])],break
    s,include.lowest=TRUE))
  }
}

# Convert array to matrix
y=matrix(y,nrow=R*R) # convert array to matrix

# Organize the data for analysis with unmarked.

    umf=unmarkedFrameGDS(y=y,survey="line",unitsIn="m",dist.breaks=breaks,t
    length=rep(sw*2,R*R),numPrimary=tr,siteCovs=data.frame(type=cell.center
    s$type))

# Fit the generalized HDS model.
m1=gdistsamp(~type,~1,~1,umf,output="density")

# Get lambda estimates from the model.
```

```
  A[B,2:3]=exp(coef(m1,type="lambda"))

  # Get phi estimate from the model.
  A$phi[B]=(exp(coef(m1,type="phi"))/(1+exp(coef(m1,type="phi"))))

  # Get predicted abundance (unadjusted) from the model.
  A$abun.pred[B]=sum(predict(m1,type="lambda")$Predicted)

  # Get predicted abundance (adjusted) from the model.
  A$abun.est[B]=sum((predict(m1,type="lambda")$Predicted)*A$phi[B])

  # Get true abundance of the population.
  A$abun.true[B]=sum(cell.centers$n)

}

# True abundance.
true.abundance=(lambda1*(R*Q)/2)+(lambda2*(R*Q)/2)

# Estimate Bias.
A$Bias=(true.abundance-A$abun.est)/A$abun.true
mean(A$Bias)
quantile(A$Bias,probs=c(0.025,0.975))

# Look at mean lambdas.
mean(A$lambda1)
quantile(A$lambda1,probs=c(0.025,0.975))
mean(A$lambda2)
quantile(A$lambda2,probs=c(0.025,0.975))

# Look at the adjusted abundance estimates.
mean(A$abun.est)
quantile(A$abun.est,probs=c(0.025,0.975))

# Look at the adjusted abundance estimates.
mean(A$abun.pred)
quantile(A$abun.pred,probs=c(0.025,0.975))
```