United States Department of the Interior
U.S. GEOLOGICAL SURVEY
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MEMORANDUM

Date: September 25, 2024

To: Kate Martin, U.S. Coordinator, Sea Duck Joint Venture
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From: Jon Amberg, Center Director

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Date: 2024.09.25 11:13:57 -05'00'

Subject: Memorandum of Compliance for the Inter-Agency Agreement titled '*Visibility correction factors for multiple species of sea ducks and diving ducks using an aerial remote sensing approach*', October 1, 2023 to September 30, 2024.

This memorandum documents how the U.S. Geological Survey Upper Midwest Environmental Sciences Center (UMESC) fulfilled tasks associated with the Inter-Agency Agreement for the project titled '*Visibility correction factors for multiple species of sea ducks and diving ducks using an aerial remote sensing approach*' during Fiscal Year 2024, October 1, 2023 to September 30, 2024.

Sea Duck Joint Venture
Annual Project Summary
FY2024 (October 1, 2023 – September 30, 2024)

Project Title: Visibility correction factors for multiple species of sea ducks and diving ducks using an aerial remote sensing approach (SDJV Project #160)

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Project Description *(issue being addressed, location, general methodology):*

This project addresses the following high priority science needs identified by the Sea Duck Joint Venture (SDJV): 1) Develop or refine techniques to estimate detection probabilities, misidentification rates, and biases during aerial sea duck surveys and evaluate methods to improve the accuracy and reliability of aerial, boat, and ground survey methods, especially aspects relevant to sea and diving ducks and for areas outside of traditional survey areas, 2) contribute to developing and/or evaluating methods for efficiently automating counts of birds in aerial photographs of flocks, including birds with varying distributions and density patterns, and uniform vs. sexual dimorphic plumages, 3) contribute to testing feasibility of determining age and sex ratios (over a broad range) using ground surveys and/or aerial photos on fall/wintering areas to obtain an index of annual productivity for some species, specifically long-tailed ducks, and 4) contribute to identifying and characterizing attributes of key wintering and staging areas for long-tailed ducks at flyway or continental scale. In addition, the project is expected to address the following: 1) Support upper Mississippi River/Great Lakes Joint Venture research objectives relating to understanding the importance of wintering locations for bird populations that could depend on habitats within the Joint Venture region and 2) support Wisconsin Department of Natural Resources efforts to increase surveys of waterfowl during the non-breeding period.

Scope and Location

This study will take place on the Wisconsin waters of Green Bay, identified as an important stopover location for a variety of migrating waterfowl species (Prince et al. 1992; Harris 1998; Wisconsin Department of Natural Resources 2019). Due to the expanse and widespread use by waterbirds throughout the study area, aerial surveys provide the most efficient means of documenting waterbird use and distributions (Harris 1998).

Activities and Methods

<u>Flight missions</u>

Image collection was flown by U.S. Fish and Wildlife Service – Division of Migratory Bird Management (DMBM) pilot, Mark Koneff. The Kodiak aircraft (2008 Kodiak 100) used to conduct collections was equipped with a seven-by-one camera array of Lucid Atlas 31-megapixel CMOS cameras in combination with an Applanix POS AV 510M positioning and navigation system. The sensor array, placed in a 3-axis Somag gyro-stabilized mount, allows images to be geo-referenced. Flight speed was approximately 170 km/hr at an altitude of approximately 305 m above ground level (AGL), which resulted in a 1.0-cm ground sampling distance (GSD) covering an approximately 400 m-wide swath. Imagery was collected along fixed transects 4.8 km apart ($n = 7$ per survey) in Wisconsin waters of Green Bay (Figure 1).

Concurrent ocular surveys were flown during image collection. Ocular surveys were flown with a Wisconsin DNR aircraft (Cessna Skymaster 337) following the Kodiak at a safe distance. Transects for ocular surveys followed the same orientation of the image surveys but were offset 150 m to the left of the Kodiak's image survey line to better overlay the ocular survey area with the image survey area (Figure 1). Ocular surveys were flown at 60 m AGL and at 170 km/hr. During the ocular survey, trained observers, both on the same side of the plane, identified and tallied all waterfowl within a 200 m-wide strip transect following standard waterfowl aerial survey protocols (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1987; Smith 1995; Bowman 2014). Observations were recorded using an integrated GPS voice recording system (SWYM LLC 2021; Scribe User Guide 2021), which allowed for georeferencing of each bird observation along the transect line.

Image analysis

Targets (i.e., birds) in the imagery are being annotated to the lowest taxonomic level and with other attributes (e.g., gender, age, activity) when resolvable. We will be using a mixed method of manual and machine learning algorithms to annotate images in a two-step process. Step one is to eliminate any imagery that is unlikely to contain a target. For this step, we initially contracted with HiveAI to annotate imagery collected during our 09 November 2021 flight mission at a high level (e.g., annotate targets as avian, manmade, and non-avian wildlife). For the remaining two flights, we will use machine learning algorithms that are being developed at UMESC (see **Project Status** – *Image Analysis* for additional details). Development of these algorithms should support other science programs that are working with large amounts of aerial imagery. Step two is to use in-house wildlife experts to annotate targets to the lowest taxonomic level (e.g., species) with other attributes when resolvable. Any images sorted by machine learning algorithms will be manually verified before comparing to ocular counts. Targets will be georeferenced by Quantaero (developer of the SEABirD imaging hardware), after completion of all annotations, to reduce overlapping instances of the same targets that occur in the endlap and sidelap portions of each image.

Statistical analysis

To estimate visibility correction factors, we will follow previously established methods developed by Cochran (1977) and revised by Smith (1995). Recent research has demonstrated how spatial and temporal variability along with waterfowl density influences visibility correction factor estimates (Lewis et al. 2019). Therefore, we will evaluate differences in visibility correction factor estimates that are derived from covariates that include survey date, transect location, and waterfowl density of transects. Although we expect to encounter a variety of sea duck and diving duck species, we anticipate variable abundances of individual species which could result in differential levels of precision in visibility correction factor estimates (coefficient of variation <0.20). Accordingly, we will identify species that have sufficient data available to develop visibility correction factor estimates that can be used for survey correction.

Project Objectives:

The goal of this project is to determine visibility correction factors for multiple species of sea ducks and diving ducks that migrate through Green Bay. We will use advanced aerial remote sensors to develop visibility correction factors that can be applied to previous and future ocular surveys throughout the Great Lakes region. Specific objectives are to:

1. Collect high-resolution (1-1.5-cm) color imagery using advanced aerial remote sensors.
2. Annotate avian targets from collected imagery to the lowest taxonomic level. Incorporate annotated imagery to existing databases for training machine learning algorithms that would automate detection, enumeration, and classification of targets.

3. Conduct temporally paired fixed-width aerial ocular surveys with remotely sensed surveys allowing for the estimation of visibility correction factors and their uncertainties.
4. Evaluate visibility correction factors derived at variable spatial and temporal scales.
5. Explore the impact of variable waterfowl density on visibility correction factors.
6. Derive baseline relative abundance and spatial distribution estimates for multiple species of waterfowl and waterbirds in the Wisconsin waters of Green Bay using data from both methods.

Preliminary Results *(include maps, photos, figures/tables as appropriate):*

Flight missions

A total of three flight missions were conducted during November and December 2021. The first flight mission on 09 November 2021 was cut short due to transponder failure (safety equipment) in one of the aircraft, which resulted in only four of seven flight lines being flown. A total of 46,416 images were collected during the first flight mission. The second flight mission (10 November 2021), and third flight mission (01 December 2021) resulted in 71,714 and 67,989 images, respectively. Table 1 provides information on images captured on and off transect per mission. Table 2 provides ocular counts for each of the missions.

Image analysis

We are developing a workflow that is efficient in handling the number of images (186,119) collected during these missions. One of the main issues with this is eliminating imagery that contains no targets (e.g., images that don't contain avian targets), which can be >96% (Normandeau Associates Inc. 2018). Having an efficient workflow will save valuable time for annotators, focusing resources on determining species of an individual target.

Project Status *(e.g., did you accomplish objectives, encounter any obstacles, what are your future plans):*

Flight missions

Flight missions are complete. Although we originally planned to conduct seven missions, four in the fall and three in the spring, we were unable to do so due to changes in personnel within the U.S. Fish and Wildlife Service –DMBM. Leftover funds from flight missions, totaling $7,943, were applied to a contract with HiveAI (a private group already under contract with DMBM) to locate and label targets with high-level annotations (e.g., bird, manmade, non-bird wildlife). High-level annotations and eliminating imagery lacking avian targets will greatly expedite annotating targets to lower taxonomic levels (e.g., species) by in-house wildlife experts. Flight results, based on GPS data from both planes, indicate that we had enough overlap between the remotely sensed and ocular survey data (Figure 2). Environmental conditions were considered good to excellent (e.g., high cloud-cover that reduces glare) during all missions. Imagery collected during the missions was darker than anticipated; however, we still feel that most avian targets can be annotated to the species level (Figure 3).

Image analysis

We are evaluating the most efficient means of sorting through the large amount of imagery collected during the flight missions. We initially started by using a private contractor, HiveAI, to sort imagery into images that contain and do not contain targets. However, in reviewing that imagery we have noticed that there is a roughly 3% error for blank imagery and 8.5% error for imagery containing targets (Table 3). Given this error and the uncertainty of the HiveAI process, we are planning to develop a detection algorithm from our previously annotated data. The detection algorithm can then be applied to the remaining imagery, expediting the speed in which we can annotate the remaining imagery. We still anticipate error with the algorithm; thus, we will need to evaluate imagery with taxonomic experts. We feel this is the best option moving forward for two reasons: (1) The resulting algorithm will be provided to the science community and represent a starting point that can be modified for future image collections and (2) algorithms tend to over predict, so the probability that targets will be missed will decrease, making it easier on annotators to clean the resulting imagery. After potential targets are identified with the algorithm, lower-level annotations (e.g., species) will be applied by species experts (e.g., USGS staff). Algorithm development will be funded through a Region 3 FWS Science Support Partnership grant that will start in FY 25 (e.g., 01 October 2024 through 30 September 2025).

Statistical analysis

We plan to start statistical analysis following image annotation and anticipate that analysis will be conducted flight by flight as annotations are completed following algorithm implementation. In addition, we are investigating USGS capacities to recruit a post-doctoral research associate to conduct this analysis.

Literature Cited:

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Table 1. Total number of images captured, and number of images captured along transects for surveys flown over Wisconsin waters of Green Bay during November and December 2021.

Date	Total number of images collected during flight mission	Number of images collected along transect that will be used in future analyses[1]
09 Nov 2021	46,416	43,585
10 Nov 2021	71,714	67,100
01 Dec 2021	67,989	65,442

[1]Imagery that is considered on-transect extends fully onto the shoreline (southwest end of transects), past the Wisconsin state boundary (northeast end of transects) and contains 'S-turns' that are needed to keep the inertial measurement unit (IMU) of the camera system oriented.

Table 2. Raw total counts of waterfowl by species for ocular aerial surveys conducted over the Wisconsin waters of Green Bay during November and December 2021. Counts are provided for each observer during each mission.

		Waterfowl Species Identified during Ocular Counts											
Date	Observer	Unidentified Swan Species	Canada Goose (*Branta canadensis*)	Mallard (*Anas platyrhynchos*)	Unidentified Scaup Species	Canvasback (*Aythya valisineria*)	Bufflehead (*Bucephala albeola*)	Common Goldeneye (*Bucephala clangula*)	Unidentified Goldeneye	Long-tailed Duck (*Clangula hyemalis*)	Unidentified Scoter Species	Common Merganser (*Mergus merganser*)	**Total Waterfowl Observed**
09 Nov 21	Observer1	-	15	25	3,888	-	5	332	-	53	-	159	**4,477**
	Observer2	-	20	32	2,660	-	6	5	-	119	-	122	**2,964**
10 Nov 21	Observer1	8	144	89	4,099	-	4	479	-	55	-	176	**5,054**
	Observer2	-	-	168	5,216	1	4	-	-	13	-	87	**5,489**
01 Dec 21[1]	Observer1	7	525	308	6,641	-	9	200	-	17	6	108	**7,821**
	Observer2	4	75	101	9,581	-	8	-	25	12	-	7	**9,813**

[1]Recording harnesses for both observers had issues during this flight mission and a few counts may have been missed or lack GPS information.

Table 3. Comparison of HiveAI annotations to human expert annotations from imagery collected on 09 November 2021 by image and bird counts; comparison updated for imagery annotated through 05 September 2024.

	Images annotated and corrected by human annotators (% of total images collected on transect)	Images that contained additional bird targets that were not identified by HiveAI (% of annotated images)	Number of bird targets identified by HiveAI in imagery (range of targets per image)	Number of additional bird targets identified by human annotators that were not identified by HiveAI (range of targets per image when targets were missed)
Images considered to have a target by HiveAI	769 (1.8%)	66 (8.5%)	4,334 (1-200)	191 (1-17)
Images considered to be 'blank' by HiveAI	4,112 (9.4%)	120 (2.9%)	0 (0-0)	273 (1-22)
Totals	**4,881 (11.2%)**	**186 (3.8%)**	**4,334 (0-200)**	**464 (1-22)**

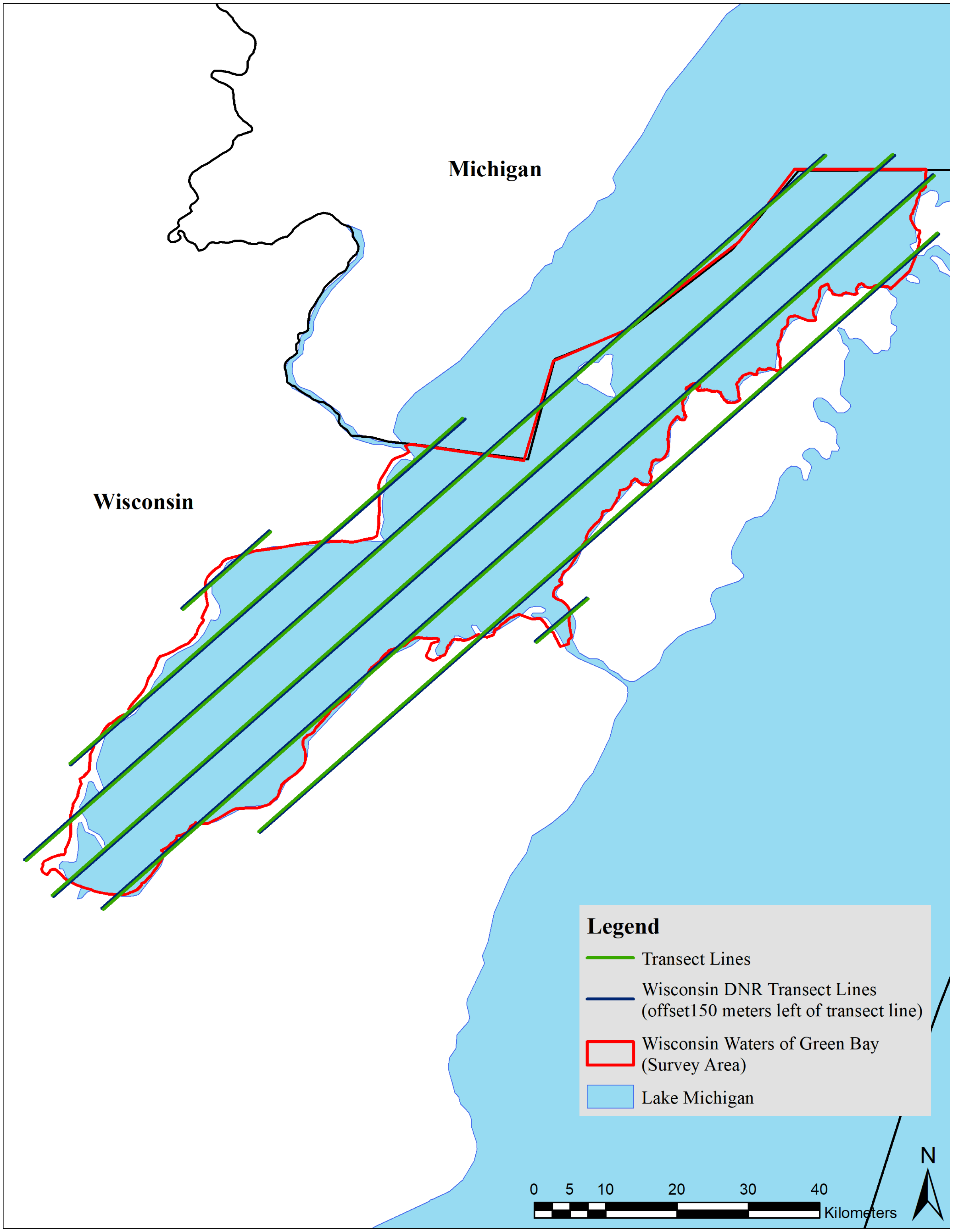

Figure 1. Seven transect lines flown by U.S. Fish and Wildlife Service aircraft with remote sensing capabilities (green lines) and those flown by Wisconsin Department of Natural Resources ocular survey plane (dark blue lines; offset 150 meters left of remote sensing lines) during surveys in November and December 2021.

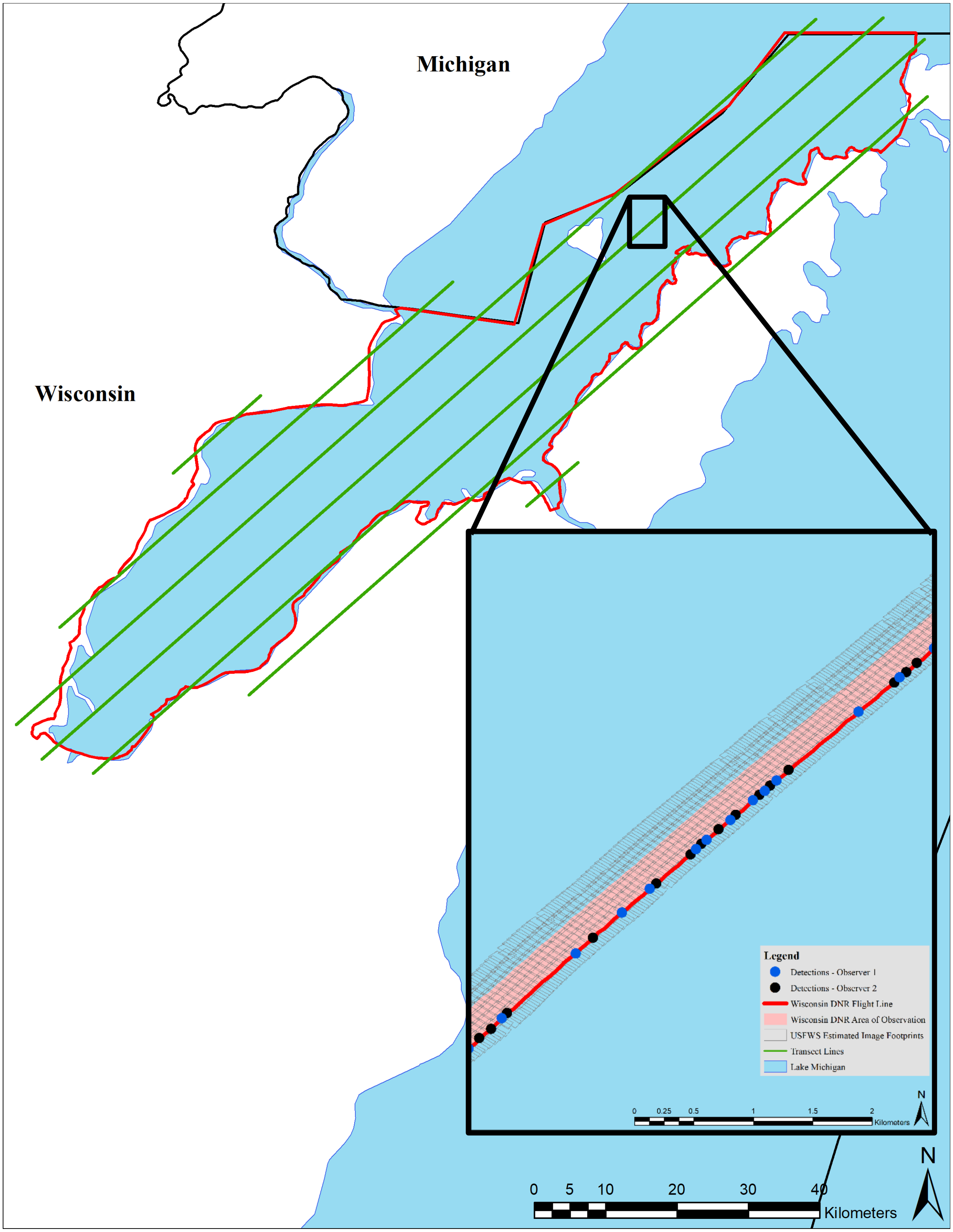

Figure 2. Example of the overlap achieved between the image survey (gray squares) and ocular survey (pink band) during the 09 November 2021 flight mission.

Figure 3. A single frame (e.g., parent image) from camera number two taken on 10 November 2021 captures a large flock of goldeneye. Zoomed in area shows individual targets more closely, which allows species level classification.