

## U.S. Fish and Wildlife Service Great Lakes Airspace Map Decision Support Tool.

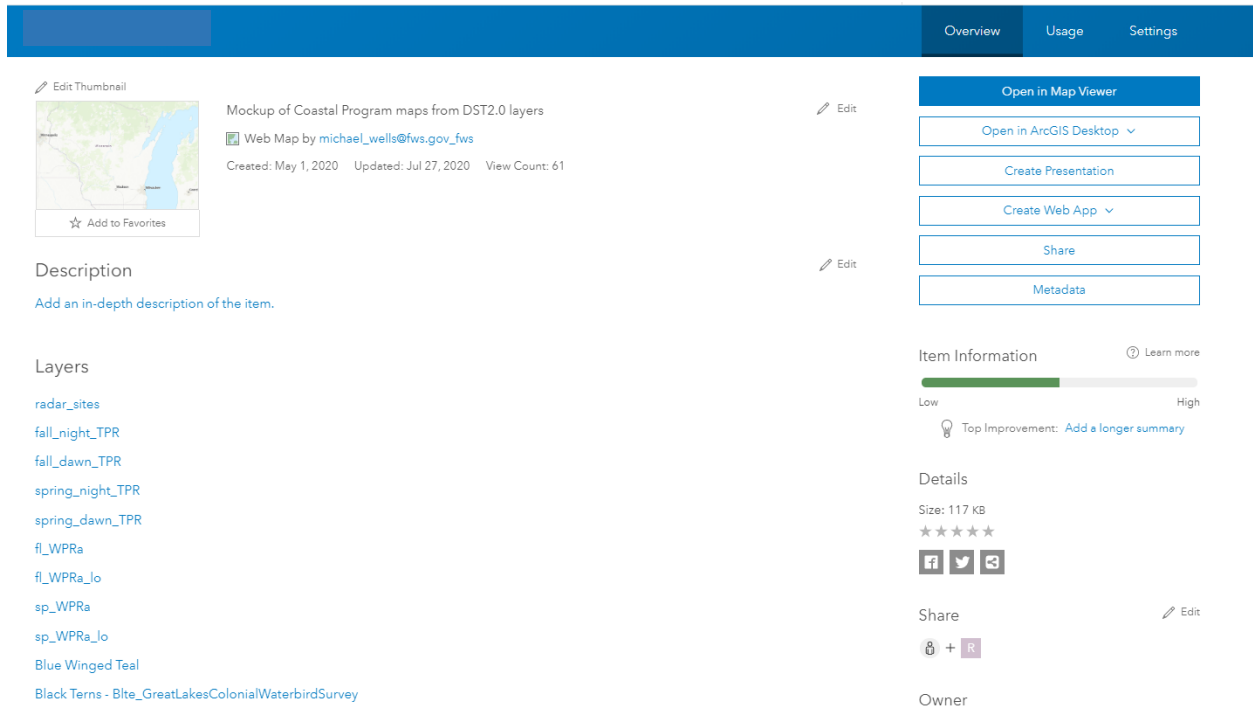
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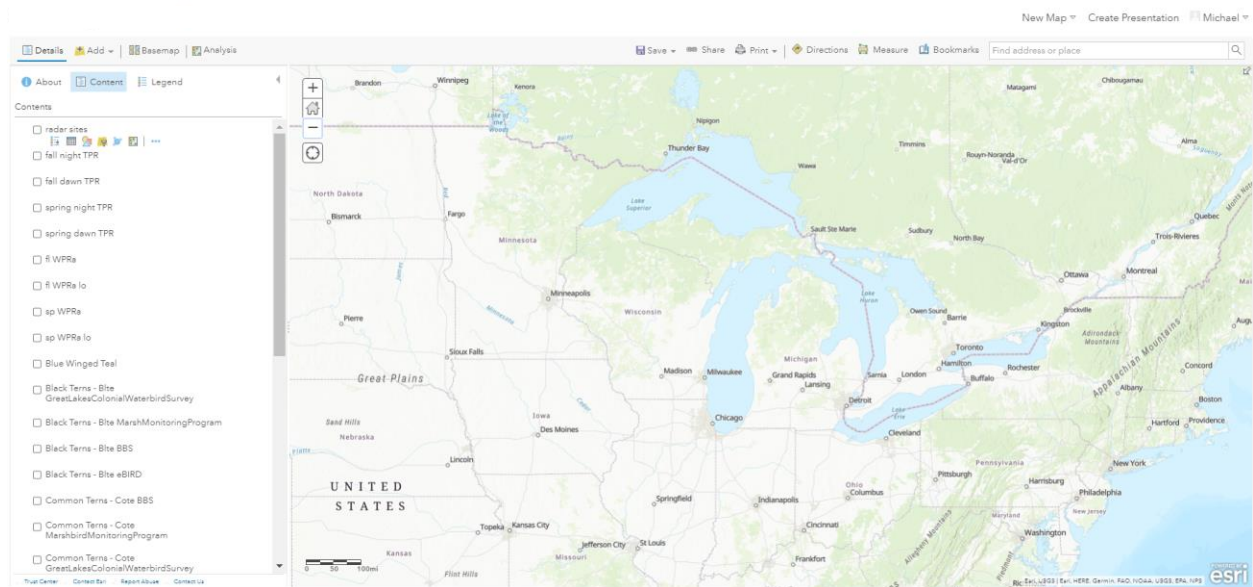
**User Guide to the Great Lakes Airspace Map Decision Support Tool (GLAM DST):** This guide is intended to help navigate and interpret the Service’s decision support tool to inform conservation options and decisions in the Great Lakes Basin. The guide provides a short overview of the mapping process as a whole, description of the ways in which the radar data maps are structured in time, data type, and outputs. We also offer suggestions as to how the values of these maps may be ranked in conservation decision-making. Lastly, we work through a hypothetical conservation decision using the Great Lakes Airspace Map DST as an example.

**Map access:** You will need an ArcGIS Online account to access the map. Once your account is set up you can access the map directly here (<https://fws.maps.arcgis.com/home/item.html?id=eb3b0465a8c8472fb795fc7e0c030b16>) or go to (<https://www.arcgis.com/home/index.html>), log in using your organization or personal credentials and search for ‘Great Lakes Airspace Map DST’. You should see the map overview page, you can click on “Metadata” for more information on data collection (Fig. 1). Click “Open in Map Viewer” to access map (Fig. 1). You will see a map displayed and a set of map layers on the left. These layers can be turned on or off as needed by clicking the check boxes (Fig 2). Some layers may be grayed out, to view these layers you will need to zoom in (or out) to the viewable range. Layers included here were made from avian radar data and bat acoustic data from the Avian Radar Project. Publicly available layers are listed in Appendix 1. Users must save a copy of this map (e.g. copy and save to “my content”) to edit and save changes to the map. Once you become the “owner” of the copied map you will be able to add other layers of interest by clicking the add button (“+Add” in the map ribbon). You can add publicly available layers (e.g. “Browse living atlas layers”) or add your own project layers (e.g. “Add layer from file”). If you add public layers, these may be updated periodically by the layer owners. You may receive a notice of an error or replacement for a layer. If this happens you can delete the public layer by clicking options for that layer, e.g. “...” and you have an option to “remove” the layer. You can then add the updated/new layer from the “living atlas layers” content.

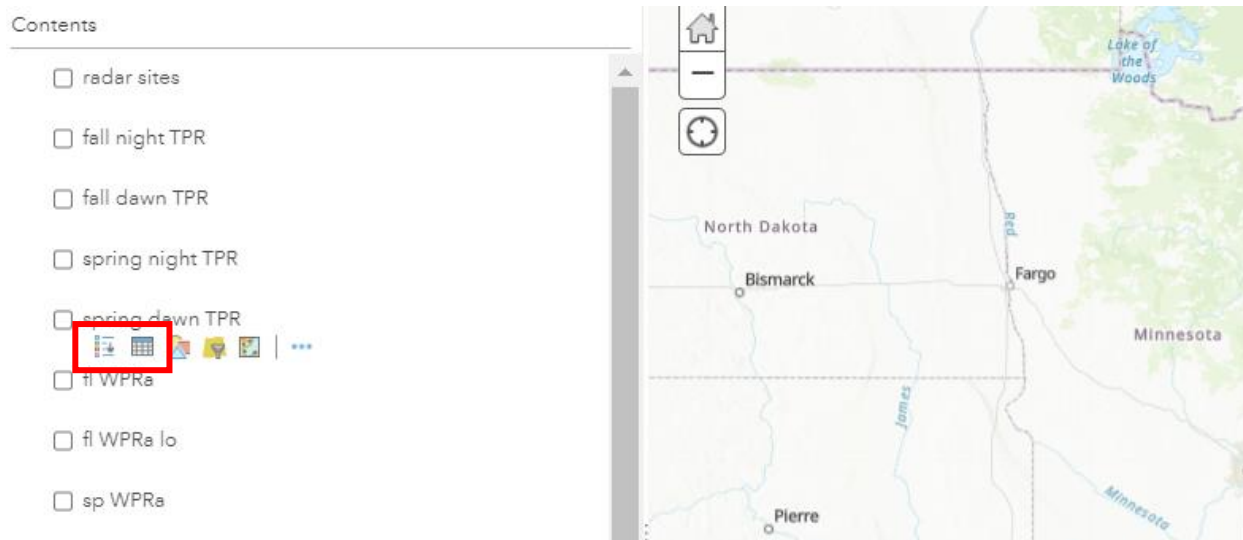
Below the name of each layer is a set of icons that allows users to manipulate and display additional details on the map layer, to view the data, and perform analyses. For the purposes of this guide, we focus on only the two leftmost icons (Fig. 3); the legend and the raw data. The leftmost legend icon toggles the legend on or off for the particular map. These provide substantial information on interpreting the map and should be toggled on when the map layer is activated for reference (Fig. 3). The second icon is the table icon that provides a table of values and spatial references for layers. The point location tables in particular contain data that may be useful to the user (Fig. 3).



**Fig. 1: Map overview page. This page provides an overview of map layers, metadata, and descriptions of the map. To open the map, click on the blue ‘Open in Map Viewer’ in the upper right side of the page.**



**Fig. 2: Newly opened DST Map. The opened map will default to a base map. Map layers can be turned on or off using the left-hand menu.**



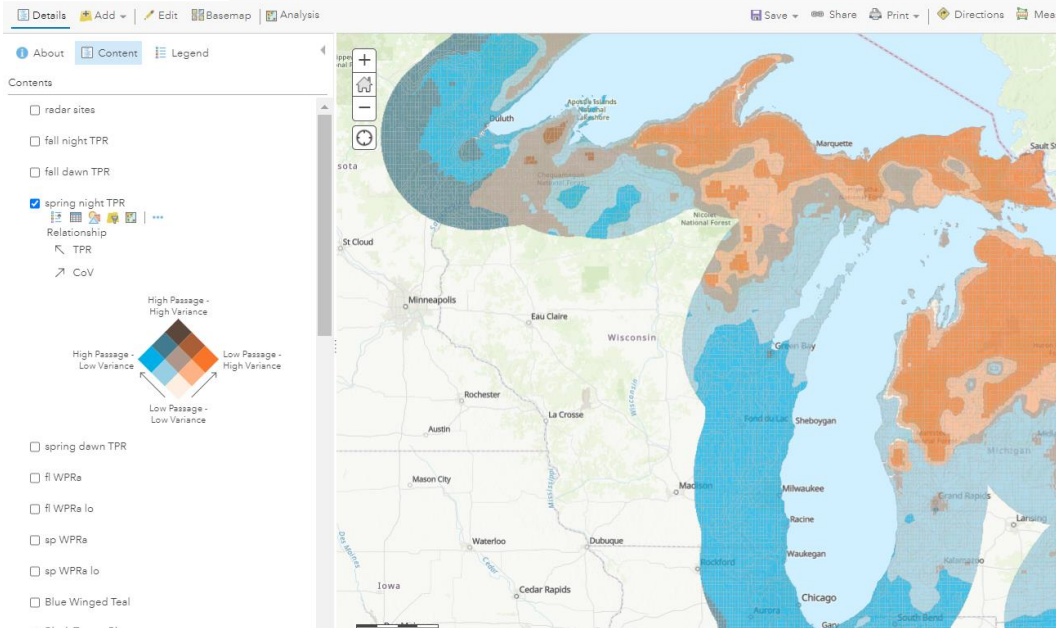
**Fig. 3:** Each layer item on the left hand menu has multiple icons below the layer name. These provide additional information and options for displaying the map. The most important for users are the two leftmost icons, highlighted in the red box. The leftmost icon is the legend for the layer, while the second leftmost is a display of the map data.

**Overview:** The Great Lakes Airspace Map DST uses radar data collected from around the Great Lakes basin from 2011-2018 during spring and fall migration seasons. Data were collected using two mobile radar units (SS200DE MERLIN Avian Radar Systems (DeTect Inc., Panama City, FL, USA)) and were placed throughout the U.S. side of the Basin. Critically, the radar system can track enormous numbers of migrants simultaneously, especially nocturnally, when most birds and all bats migrate. However the radar system cannot determine the species of migrants beyond being confident they are vertebrates. The data collected provide two measures of migrant activity, the first is target passage rate (TPR) corrected for effort and split into day, night, dusk and dawn time periods. The second is window passage rate (WPR), that addresses site-specific interference or clutter caused by structures or landscape features near the radar, as well as altitude differences. Both TPR and WPR are corrected for several hardware and software upgrades over the course of the study. We recommend the use of TPR for most applications, TPR uses a standard front processing that provides both a way to control for radar interference and matches current industry standards for tracking biotic targets using radar. WPR is most useful when working on conservation questions that require altitude data for the separation of high- and low-flying migrants. Radar data are interpolated based on a spatial regression with other spatial data, including landcover data (National landcover database, Homer et al. 2015), night time anthropogenic light sources (known to affect migrant behavior, especially nocturnal migration), and proximity to the shoreline of the Great Lakes (known to affect migrant behavior, especially at dawn, Heist et al 2018) to produce continuous layer estimating migration intensity between the coast and up to 100 km inland. Combined, all of these data allow us to estimate migrant activity across the Great Lakes Basin.

**Presentation of migration activity estimates:** Estimates of migrant activity are mapped in several ways, including for different aspects of migration in decision-making, for clarity, or due to biological differences in how migrants are using the landscape. Broadly, spring and fall migration are provided separately due to major differences in movement and habitat use. We provide a measure of passage rate and variation around that rate in all maps (Fig. 4).

In the GLAM DST, we present seven prediction layers based on bat acoustic data and thirteen layers based on avian radar data. The radar location layer presents seasonal flight direction for spring or fall migration at each deployment location. The other twelve layers are prediction layers, six of these present findings using TPR data, the other six use WPR data. Radar predictive layers are categorized by season and time periods (night, dusk, and dawn, TPR only) or altitude (high, low, and the two combined in “all”, WPR only). All models and estimates are subject to uncertainty and understanding this uncertainty is important to decision making; therefore, we integrated a measure of uncertainty, the coefficient of variation, directly into the radar prediction map layers. The Avian Radar Project layers are listed below for easy reference; we provide more detail on layers and best practices for use in the following narrative.

- Bat Acoustic Sites, provides the location of bat recording devices
- Hoary bat, activity heat map
- Big brown and silver-haired bat, activity heat map
- Eastern red bat, activity heat map
- Non-migratory *Myotis* bats, activity heat map
- Migratory tree bats (eastern red, hoary, and silver-haired bats), activity heat map
- All bats, activity heat map
- Radar site provides the location of each radar site, while also showing the mean direction of travel at the site. Green arrows indicate spring sites, orange arrows indicate autumn sites.
- Fall Night TPR is the predicted target passage rate for fall nights
- Fall Dawn TPR is the predicted target passage rate at dawn in the fall
- Fall Day TPR is the predicted target passage rate for a fall day
- Fall Dusk TPR is the predicted target passage rate at dusk in the fall
- Spring Night TPR is the predicted target passage rate for spring nights
- Spring Dawn TPR is the predicted target passage rate for spring dawns
- Spring Day TPR is the predicted target passage rate for a spring day
- Spring Dusk TPR is the predicted target passage rate during dusk in the spring
- Fall WPRa is the predicted window passage rate during fall at all altitudes
- Fall WPRa high is the predicted window passage rate during fall at high altitudes
- Fall WPRa low is the predicted window passage rate during fall at low altitudes
- Spring WPRa is the predicted window passage rate during spring at all altitudes
- Spring WPRa high is the predicted window passage rate in spring at high altitudes
- Spring WPRa low is the predicted window passage rate in spring at low altitudes



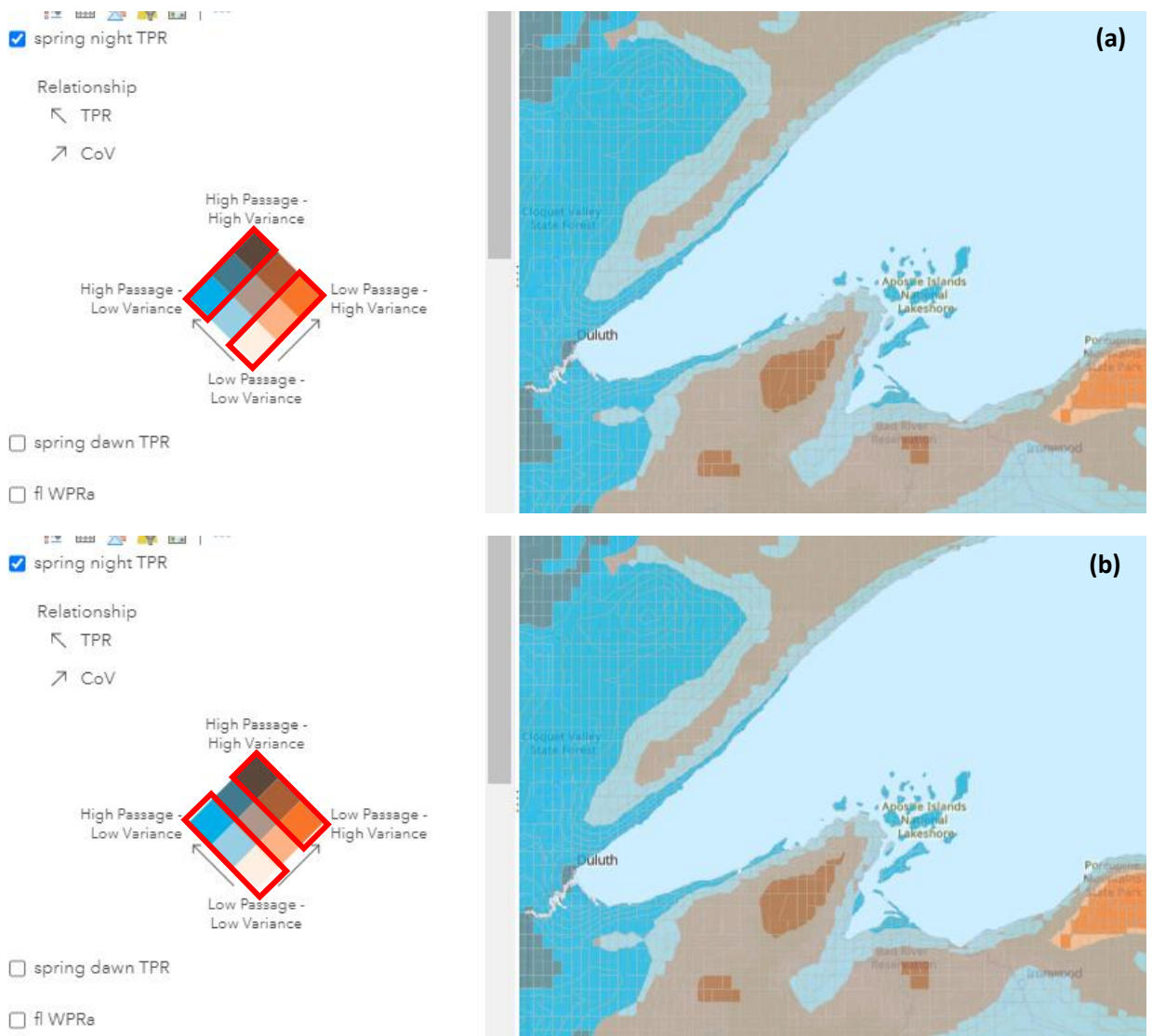
**Fig. 4:** Example of an opened radar prediction layer, in this case spring night TPR. Note the legend for the map is also opened by clicking on the leftmost icon under the layer title.

**Season:** Analysis of our data has revealed that migration occurs differently during spring and fall, with different areas of importance, possibly reflecting differences in migration route and presence of young animals. For the purposes of decision-making, both spring and fall are important to consider for conservation: changes that benefit spring migration route while endangering fall routes may not provide any improvements to wildlife. In general, areas of high use during both spring and fall migration are best; areas of high use for one of the two seasons are good, and areas of low use during both seasons are least desirable from a migration standpoint. As most areas considered are likely to be high use in only one season, conservation actions can be targeted to season. For instance, if a site being considered for restoration has high potential for stopover in spring alone, conservation actions can focus on improving spring food resources (e.g. providing native plants that flower early, host caterpillars, and fruit early or retain fall fruit) to enhance the sites value during migration.

**Passage Rate:** Passage rate is the inferred, season-wide passage rate for each point on the map (Fig. 5a). This passage rate is informed by how the data are split by season, time period, and migration altitude, and is provided in separate layers to allow these different aspects of migration to be used as needed. Passage rate is the estimate for the season and can vary substantially (see coefficient of variation below). Because of this, passage rate must be interpreted together with variation. Larger passage rates suggest more migrants are using the area across a season.

**Coefficient of Variation:** Coefficient of variation is the variance estimate of the interpolation, it is calculated as the standard error of the predicted interpolation divided by TPR/WPR for each site (Fig 5b). However, the coefficient of variation is affected by the overall rate of movement, with larger coefficients of variation occurring in areas with lower passage rates.

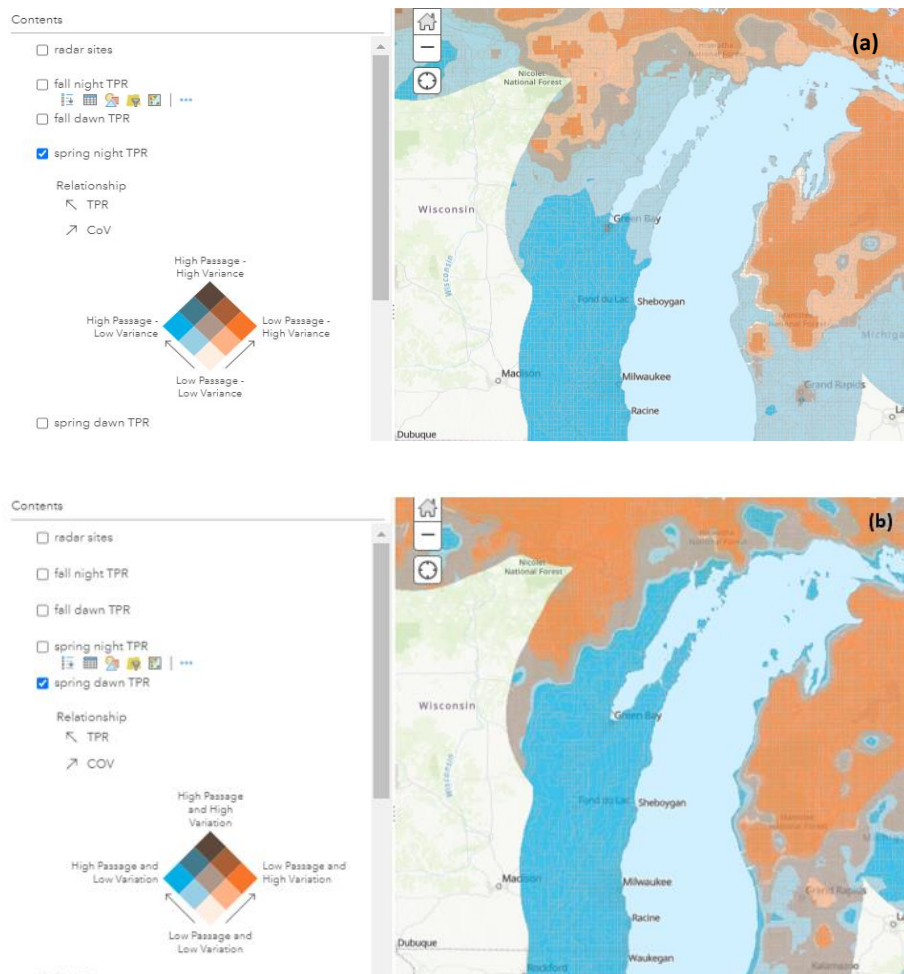
Overall, areas with high passage rates and low coefficients of variation are areas that we are most certain will have high migration traffic. Areas with high passage and high variation are still important to consider, as these areas may be important under certain circumstances. Areas of low use but high variation indicate that these areas, while not heavily used, may still have some conservation value, again likely under certain circumstances. This finding also could be an artifact of calculating the coefficient of variation and should be used as support with caution. Finally, areas of low use and low variation are the least likely to benefit migrants through conservation action.



**Figure 5: Passage rate and variance. (a) Passage rate is highlighted with the red boxes on the legend, with high passage in cool colors and low passage in warm colors. (b) Coefficient of Variation (CoV) of passage rate is highlighted with red boxes on the legend, with darker shades indicating higher variance (i.e. greater uncertainty of passage rate), and lighter shades indicating lower variance. Both are important to understanding the use of the airspace by migrants.**

**Time Period:** Time period provides information on migrant activity during different parts of the diel cycle in the TPR layers. These time period categories also provide information about overall migrant numbers and behavior that can be used for conservation decisions. Three time periods are mapped, night, dawn, and dusk (Fig 6).

*Night* is when most migration occurs and provides information about migrant movement (Fig 6a). The airspace in high use areas is crucial for migrants. Barriers to the use of the airspace (e.g. anthropogenic lighting, tall structures) can be important for conservation and mitigation. Importantly, night data *do not* necessarily mean that migrants are using stopover habitat in these areas. However, at a regional or basin scale, areas of conservation interest embedded in large areas of high use are likely to have some animals landing. Likewise, combining data from night, the peak of migration activity, with other data such as time periods correlated to stopover or areas of likely refuge can help inform conservation activities for protection or restoration of stopover habitat.

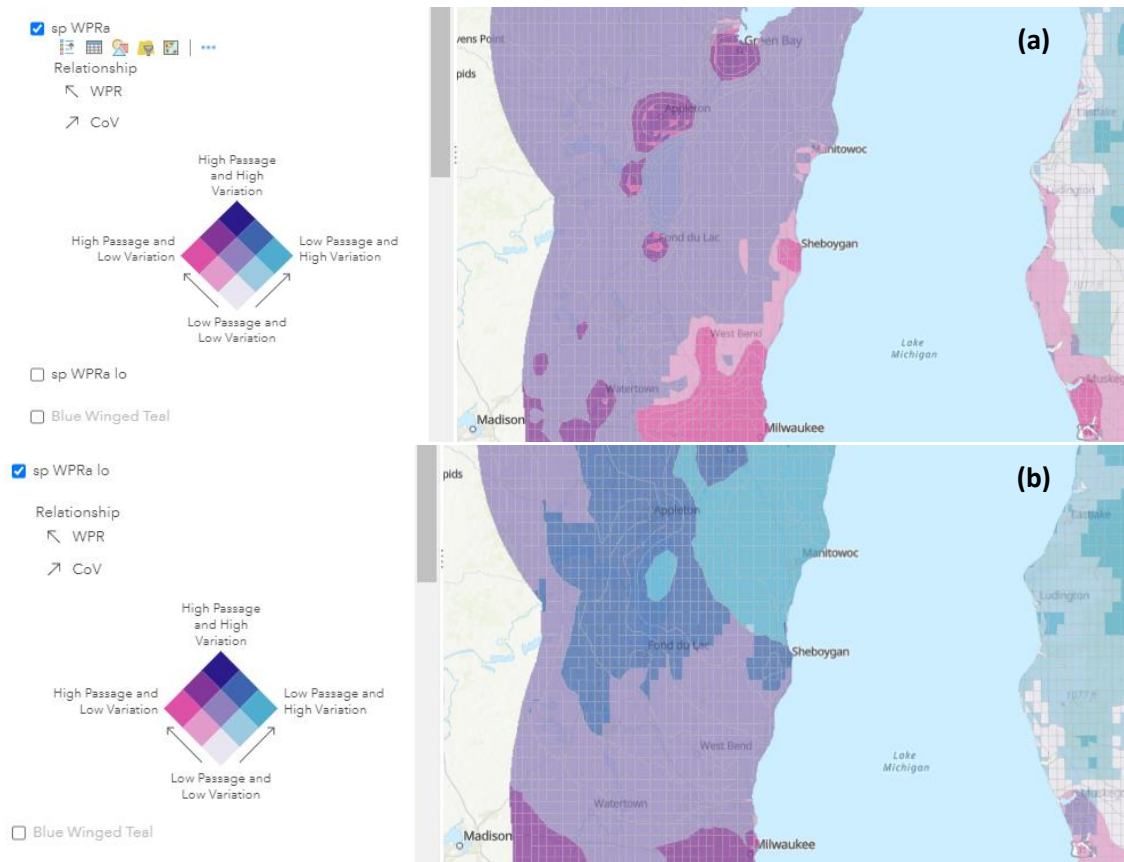


**Figure 6: Example of differences between (a) night and (b) dawn time periods. Note the differences in passage rate and coefficient of variation between the different time periods, especially near the coast, where over-water migrants concentrate in the mornings as they seek landing areas.**

During *dawn* nocturnal migrants generally are attempting to land in order to shelter from predators, to rest and to feed (Fig 6b). Areas of high use during this period are more likely to correspond with stopover habitat. Likewise, *dusk*, the time period of exodus for nighttime migration, also may be more related to stopover habitat.

There is little activity during *daytime*, and it is impossible to determine if migrant or resident birds are being detected. From a behavioral perspective, significant migratory activity is not captured during this time period; therefore, we do not recommend using daytime TPR for decision making, though we have included daytime layers here for completeness.

**Altitude:** Migrant altitude provides information on the risk of anthropogenic obstacles, as well as the potential use of stopover habitat (Fig 7). These values are available only in the WPR layers. The low altitude map layer provides migrant information at altitudes from approximately 100-1,000 m above ground level, while high altitude map layer provides migrant data at altitudes from approximately 1,000-2,800 m above ground level. Areas of high use by high altitude



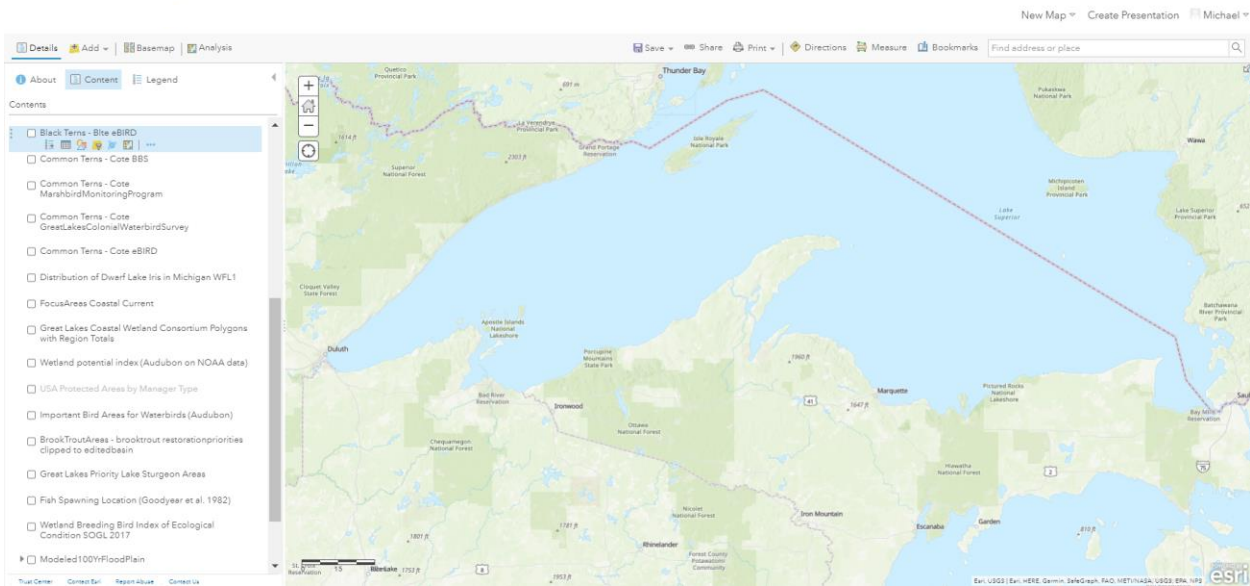
**Figure 7: Differences in predicted passage rate and coefficient of variation between (a) all altitudes and (b) low (100-1,000 m) altitudes. Note the increase in predicted passage rate around cities in (a), and the generally higher coefficient of variation at low altitudes in (b).**



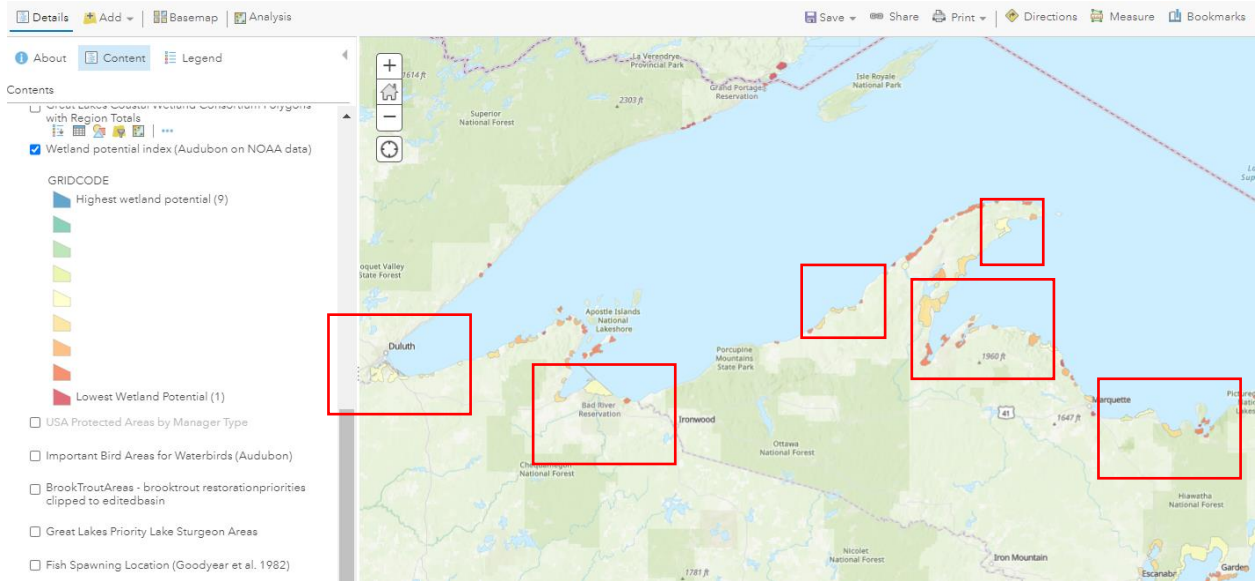
migrants are less likely to be affected by anthropogenic obstacles and are less likely to use nearby stopover habitat. However, they may be more affected by some anthropogenic attractants, such as city lights at greater distances as migrants are able to observe them at higher altitudes (Fig 7a). Areas of high use by low altitude migrants are more likely to be affected by anthropogenic obstacles, such as high structures and disorienting light sources. They also may be more likely to use stopover habitat in these areas (Fig 7b).

**Hypothetical example – using the GLAM DST in a conservation decision:** A habitat restoration biologist needs to determine new coastal areas for work with partners on land purchase and conservation projects on Lake Superior. Ideal locations will have wetland or potential wetland restoration opportunities or be in the 100-year floodplain for wetland restoration and flood control. These habitats will provide potential for restoring both fish and bird habitat, in general, and on previously identified priority species, such as black tern, common tern, lake sturgeon, and brook trout, if possible. Stopover and migration habitat are both important to include in the area. The challenge for the biologist is to identify only one area that covers as many of the focal species as possible.

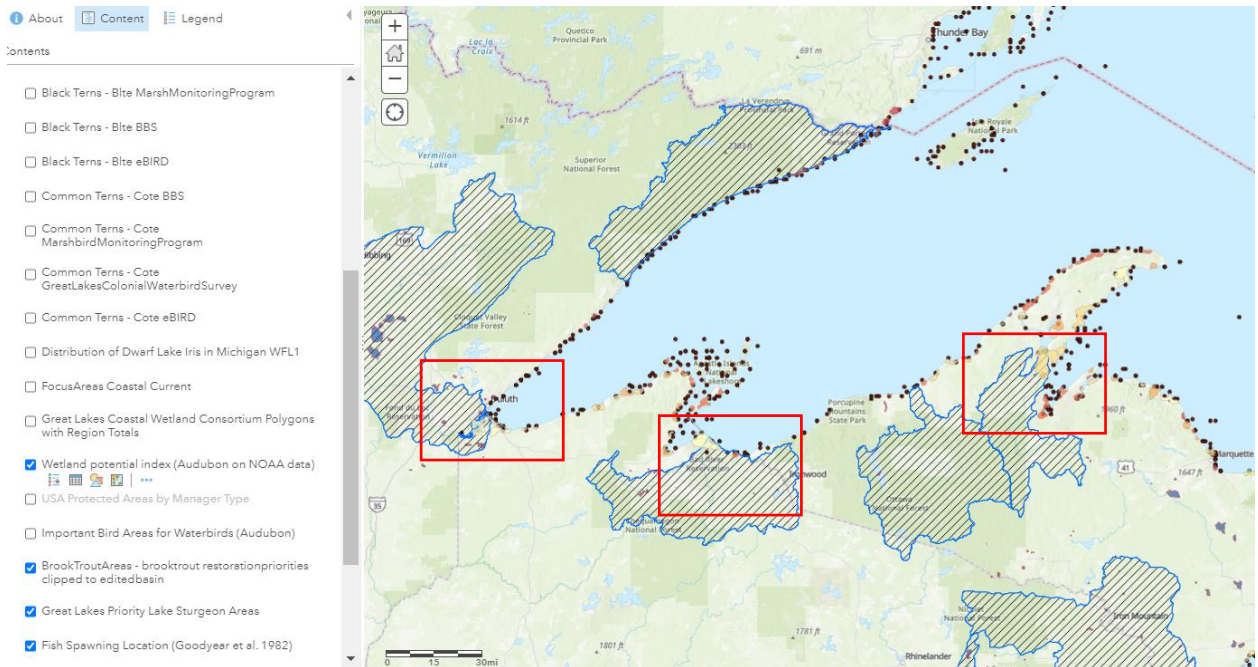
First, access the GLAM DST and zoom to the Lake Superior region.



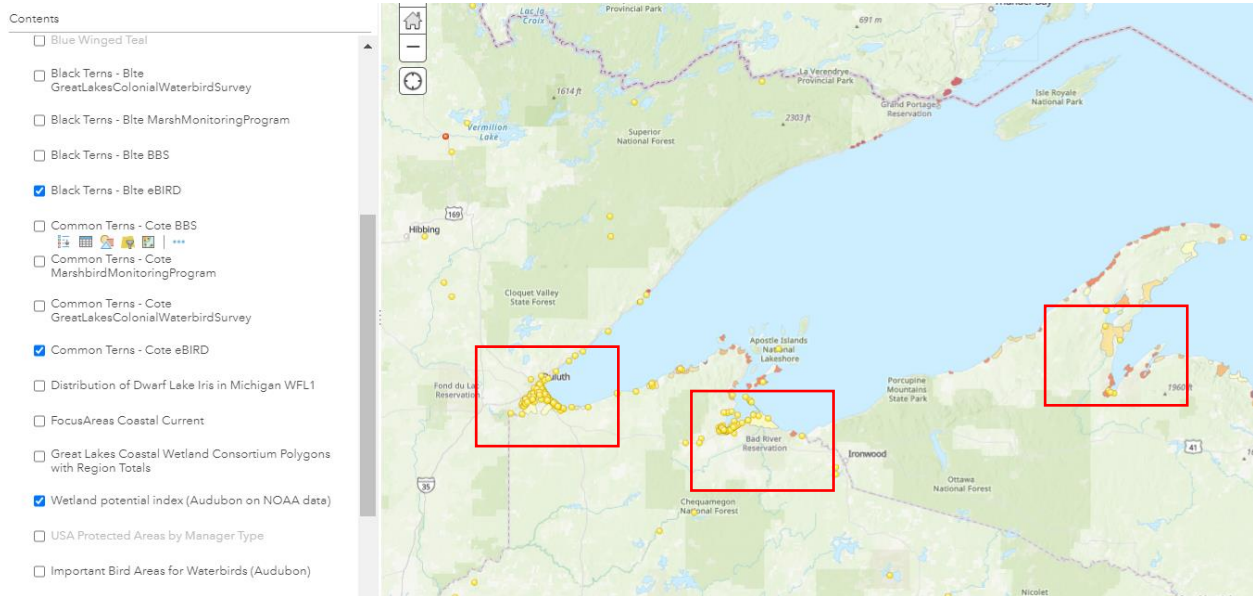
Next, use the map layers to determine floodplain and wetlands habitat. Since we are interested in potential bird habitat, we use the Audubon’s wetland potential index layer. We have opened the legend to help interpret and are looking for areas of high potential. In western Lake Superior, we see multiple wetland areas, most with low to moderate wetland potential but with several candidates (red boxes).



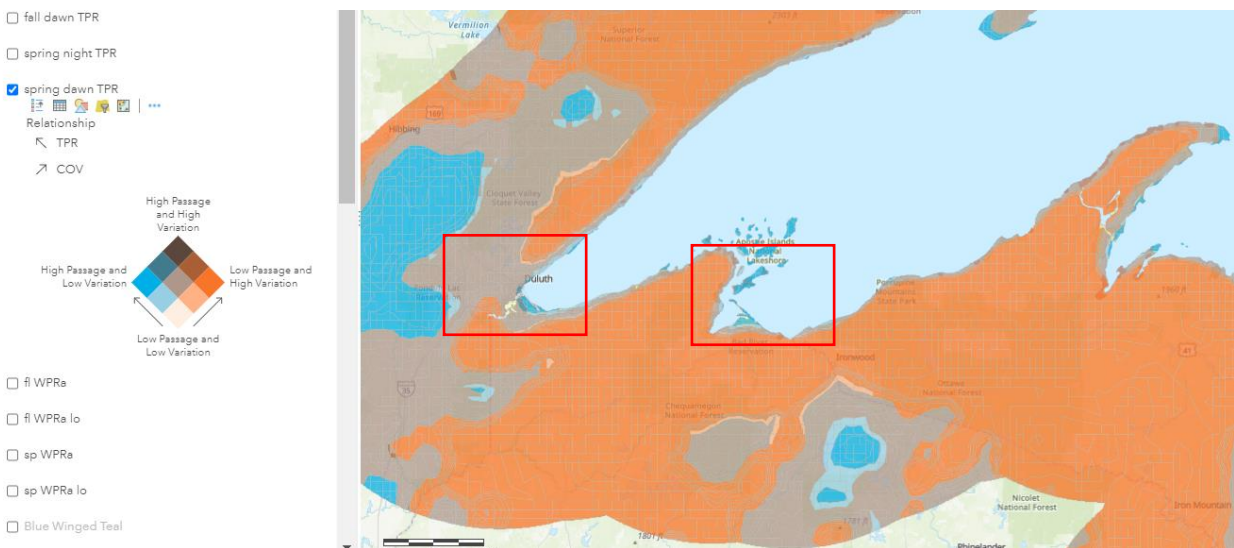
What about the potential for fish restoration in these areas? Is there overlap? We use three layers to see if there is overlap: brook trout priority areas (in blue with red border), lake sturgeon priority areas (blue border with black hatching), and fish spawning locations (black point locations). We find there is little overlap in brook trout locations but several areas of overlap with lake sturgeon priority areas and fish spawning locations near Duluth, the Apostle Islands, and the Eastern Keweenaw Peninsula (red boxes).



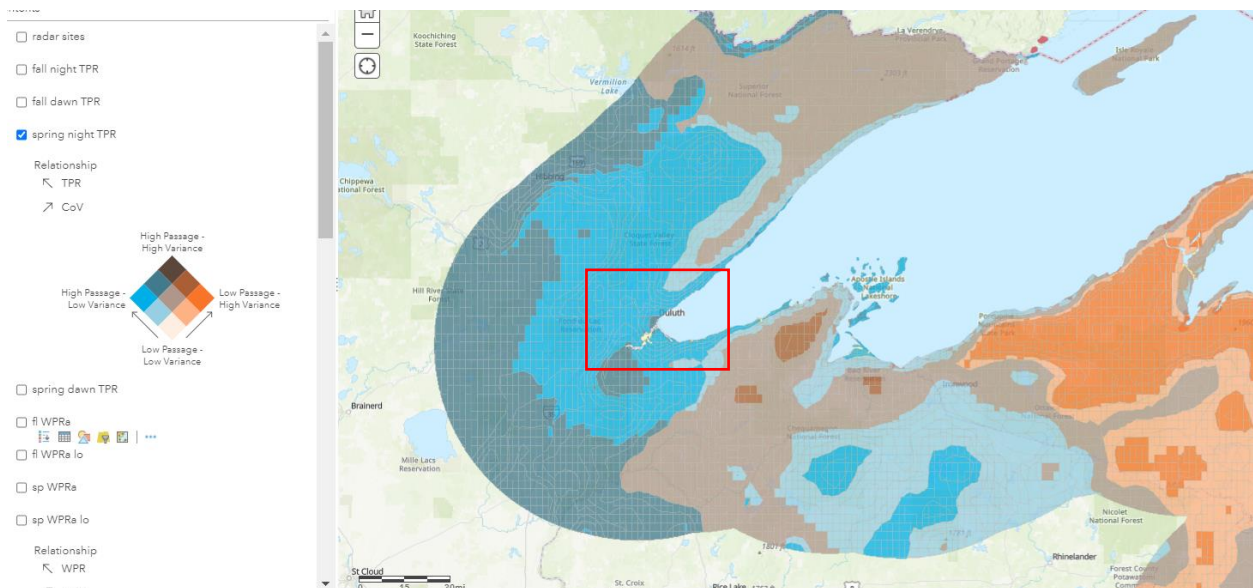
How well do these areas associate with our bird species of concern the black and common terns? Here we use eBird sighting data to see if either black (red points) or common (yellow points) terns are in any of the three identified areas. We find there are no black terns in any of the areas, and common terns in all three areas.



Finally, can we identify migrant stopover habitat that might reduce our area to one place? Here we use the dawn radar maps to identify coastal stopover habitat, since we know that migrants over the water will head towards shore. There are two seasons, a spring and a fall, and we would like to look at both. Looking first at the spring dawn TPR map (below); we would like to find areas with high passage and low variation, which are identified by bright blue on the map. Fall dawn TPR shows all three areas are still candidates (not pictured). However, spring dawn shows that the western two areas near Duluth and the Apostle Islands both contain more areas migrants are predicted to use at dawn, while the Keweenaw site is less used.



We next look to see if there's a difference in overall night migration between these two sites. This could indicate overall high use for stopover habitat. Again, we are looking for bright blue areas. We see here that the area around the Duluth site has substantially higher passage than the Apostle Islands site, although the Apostle Islands site does include some use. The larger area of high passage around Duluth suggests a much more concerted area of use and is more likely to have higher subsequent stopover habitat value. Also, note that the Keweenaw site is not heavily used at night compared to the other two sites, further suggesting it is not the best candidate.



#### Literature Cited:

Heist, K. W., Bowden, T. S., Ferguson, J., Rathbun, N. A., Olson, E. C., Nolfi, D. C., ... & Wells, M. T. (2018). Radar quantifies migrant concentration and Dawn reorientation at a Great Lakes shoreline. *Movement ecology*, 6(1), 15.

Homer, C., Dewitz, J., Yang, L., Jin, S., Danielson, P., Xian, G., ... & Megown, K. (2015). Completion of the 2011 National Land Cover Database for the conterminous United States—representing a decade of land cover change information. *Photogrammetric Engineering & Remote Sensing*, 81(5), 345-354.

Román, M.O. et al. (2018) NASA's Black Marble nighttime lights product suite. *Remote Sensing of Environment*. 210, 113-143.

Appendix 1: Included in the GLAM DST are map layers that were not produced by the radar team but may provide additional details and data for context and decision support.

Species of conservation priority or concern:

- Blue-winged Teal (source: Mohammed Al-Saffar, USFWS Upper Mississippi Joint Ventures <https://umgljv.org/planning/maps-gis/>)
- Black Tern (4 layers using different data sources) (source: Mohammed Al-Saffar, USFWS Upper Mississippi Joint Ventures <https://umgljv.org/planning/maps-gis/>)
- Common Tern (4 layers using different data sources) (source: Mohammed Al-Saffar, USFWS Upper Mississippi Joint Ventures <https://umgljv.org/planning/maps-gis/>)
- Dwarf Lake Iris (source: Darini\_umich map layer; no additional metadata [https://services1.arcgis.com/4ezfu5dIwH83BUNL/arcgis/rest/services/Distribution\\_of\\_Dwarf\\_Lake\\_Iris\\_in\\_Michigan\\_WFL1/FeatureServer](https://services1.arcgis.com/4ezfu5dIwH83BUNL/arcgis/rest/services/Distribution_of_Dwarf_Lake_Iris_in_Michigan_WFL1/FeatureServer))

General bird and fish layers:

- National Fish Passage Program Priority Watersheds R3 (source: USFWS, Andrew\_Stevens@fws.gov)
- Important bird areas for waterbirds (source: Audubon, bpickens\_audubon)

Wetland and conservation layers:

- Focus areas for Coastal Program 2015-2019 (source: USFWS Radar project staff)
- Wetland consortium polygons for coastal Great Lakes (source: EPA, cwinter\_EPA [https://services.arcgis.com/cJ9YHowT8TU7DUyn/arcgis/rest/services/site\\_view\\_regions\\_totals/FeatureServer](https://services.arcgis.com/cJ9YHowT8TU7DUyn/arcgis/rest/services/site_view_regions_totals/FeatureServer))
- Wetland potential index. Describes areas suitable for wetland restoration based on NOAA data (feature source: GIS\_Help\_audubon)
- US protected areas by management type (source: USGS Protected Areas Database of the United States version 2.0 esri\_landscape2 [https://services.arcgis.com/P3ePLMYs2RVChkJx/arcgis/rest/services/Agency\\_Type/FeatureServer](https://services.arcgis.com/P3ePLMYs2RVChkJx/arcgis/rest/services/Agency_Type/FeatureServer))