Quantifying the Use of New England's Premier River Herring Run by Bald Eagles

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innovative wildlife science

QUANTIFYING THE USE OF NEW ENGLAND'S PREMIER RIVER HERRING RUN BY BALD EAGLES

WILDLIFE SCIENCE CHANGING OUR WORLD

SUBMITTED TO:

American Eagle Foundation

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Pigeon Forge, Tennessee 37868

and

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Maine Department of Inland Fisheries and Wildlife

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Cover Photo: A subadult Bald Eagle wearing a satellite transmitter arrives at coveted perch as several others look on. © Jeanne Coleman

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1.0 Executive Summary

Maine is a stronghold for the Bald Eagle population in New England. We conducted aerial and ground-based surveys in early May through mid-July to estimate the abundance, age ratio, timing of use, and habitat use patterns of Bald Eagles using a five-mile portion of Maine's lower Sebasticook River during a 'river herring' (alewife and blueback herring) migration event. Ground-based surveys indicated the number of eagles using the corridor ranged up to 65 eagles per day, confirming this area likely hosts the largest eagle aggregation area in New England. Twenty or more eagles were counted on 61% of the survey days, and forty or more eagles were counted on 25% of the survey days. Approximately three quarters of individual eagle observations occurred between 29 May and 25 June (peak count: 19 June) while roughly three quarters of the upstream migrating fish counted at the Benton Falls dam passed between 11 May and 29 May (peak count: 18 May). We attribute the observed time lag between the numerical response of Bald Eagles and the available measure of prey density (counts of upstream-swimming river herring counted at the dam), to the presence of post spawning/downstream migrating river herring that are not represented in fish counts.

Subadults comprised ≥60% of eagles observed during daily counts on 64% (20/31) of days surveyed. The number of adults counted riverwide fluctuated minimally over the survey period (range 2 – 16, $\bar{x}$ ± SD: 7.1 ± 3.5, n = 31 days), while numbers of subadults fluctuated widely (range 0 – 51, $\bar{x}$ ± SD: 18.7 ± 15.1, n = 31). Overall, an influx of subadults during the middle of the surveyed period caused shifts in the observed daily age ratio. Aerial surveys documented similar changes in abundance and age ratios as ground-based surveys; however, aerial surveys underestimated the number of eagles compared to ground-based surveys. Application of a correction factor of 2.38 (Buehler et al. 1991*b*) notably lessened discrepancies between aerial and ground-based counts.

Bald Eagles were not evenly distributed throughout the study area. Upstream observation stations accounted for roughly three-quarters of the eagle observations. Optimized hotspot analyses of perching locations elucidated specific locations within each viewshed habitually used by eagles.

We additionally analyzed telemetry data from 21 eagles (20 subadults of mixed ages, and one adult) fitted with satellite transmitters throughout the state to determine if roosting locations could be identified within 15 km of the Sebasticook River corridor. Night locations were fixed throughout the study area and two roosting locations were identified; however, limited sample sizes preclude making conclusions about the importance of these potential roost areas to the population.

We monitored productivity of three Bald Eagle nests along the Sebasticook River corridor during 2014. These three nests produced a total of five young, resulting in favorable measures of productivity (1.7 young per occupied nest).

Information collected during this study demonstrates that the Sebasticook River corridor benefits both transient subadult and non-breeding adult eagles as well as the local breeding population. Given the survival benefits likely gained by eagles exploiting seasonally abundant fisheries, and the demonstrated importance of subadult and non-breeding eagles in stabilizing populations, efforts to promote conservation of this fishery and associated riparian habitats are warranted. We produced outreach materials to summarize study findings and to promote awareness about relationships between eagles, anadromous fisheries, and habitat conservation.

2.0 Introduction

The Sebasticook River is a unique and ecologically valuable river located in central Maine that runs approximately 50 miles from its headwaters near Dexter to the Kennebec River in Winslow. With a watershed covering about 606,000 acres, it is the largest tributary to the Kennebec River. The Sebasticook River is becoming increasingly well-known locally and regionally for its value in hosting the largest annual run of alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*), a group of anadromous fish collectively known as river herring, in all of New England. Every year, from mid-May through early July, millions of 'river herring' use riparian corridors like the Sebasticook to reach spawning habitat in lakes in interior Maine. While several other rivers host river herring migrations throughout the state, the number of fish easily distinguishes the Sebasticook from any other river in the region. Nearly 2.75 million river herring were counted passing through the Benton Falls Dam in 2011. While such levels of fish passage are noteworthy, river herring populations are drastically reduced compared to historic levels, which are estimated to have ranged in the tens of millions. While river herring populations have recovered in some areas, drastic range-wide population declines prompted their recent consideration for addition to the federal Endangered Species List in 2013, and populations continue to struggle. River herring have been central to contentious debates over habitat and fish restoration efforts on other Maine rivers for decades, including the Penobscot, the Presumpscot, and others. Perhaps most notably, fish passage was recently restored on the St. Croix River in eastern Maine, following a 30-year political conflict over the naturalized bass fishery (Willis 2009). The Sebasticook River has been praised as a success story by restoration proponents.

2.1 Historical Fish Passage on the Sebasticook River

River herring were once found in every coastal river in New England (Watts 2012). Historical accounts suggest that the annual herring runs on the Kennebec and Sebasticook Rivers were abundant and a major economic resource for surrounding residents during colonial times. A steady increase in the construction of dams fuelled by the growing paper industry in the 19^{th} and 20^{th} centuries resulted in blocked passage for river herring in rivers throughout New England. Over time, prolonged exclusion from spawning habitats and other factors precipitated dramatic declines in river herring populations.

In 1837, the Edwards Dam was erected across the Kennebec River at Augusta. With no provision for upstream fish passage, alewife, blueback herring, and other anadromous fish were cut off from the upstream reaches of the Kennebec River, the Sebasticook River and their upstream spawning habitats.

In 1908, the Fort Halifax Dam, was built across the Sebasticook River, just upstream of its confluence with the Kennebec River. Standing 29 foot tall and 553 feet long, the dam created a 417-acre reservoir that continued upstream for about 5.2 miles. The dam remained in place for 90 years. Then in 1998, Central Maine Power Company, then owners of the dam, along with the owners of several other hydro-electric projects in the region (known as the Kennebec Hydro Developers Group), entered into an agreement with the State of Maine, federal fisheries agencies, and a group of conservation organizations to help restore the dwindling anadromous fish population. This agreement provided the funds for removal of the Edwards Dam and set forth a schedule for establishing fish passage (i.e., fish ladders) at seven other dams in the Kennebec River Basin, including the Fort Halifax Dam. It was estimated, however, that the cost of fitting the Fort Halifax dam a fish ladder would cost $4.1 million. Since that estimate greatly exceeded revenue created by power generation at the dam, the owners of the dam elected to remove the dam instead. In the summer of 2008, after an extended 6-year litigation/regulatory process, the spillway section of the dam was breached. This marked the first time in 100 years that alewives, blueback herring, and other anadromous fish were able to freely swim up the Kennebec River and the lower reach of the Sebasticook River during their spring spawning run.

Five miles upstream from the now breached Fort Halifax dam lies another dam, the Benton Falls dam. The Sebasticook River has been dammed intermittently in the town of Benton Falls since before the Revolutionary War. The earliest dam at the ‘upper falls’ included a gap for fish passage. In 1809, a second dam was erected at the ‘lower falls’, standing 12-feet high with no fishway. It stood for only six years before the town selectman ordered its demolition, citing the deleterious effect it had on the fishery (Maine Commissioners of Fisheries 1869). In 1847, a new dam was built at the lower falls. In 1880, the Kennebec Fiber Company demolished this dam, and constructed yet another new dam just upstream (Kingsbury and Deyo 1892). The current dam at Benton Falls, constructed in 1984, is owned by Benton Falls Hydro Associates and has a generating capacity of 4.468 megawatts. In 1998, as part of the agreement that allowed the removal of the Edwards Dam, the Federal Energy Regulatory Committee (FERC) amended the original 1984 license for the Benton Falls Hydroelectric Project, requiring installation of upstream fish passage facilities. These facilities were completed in the spring of 2006, marking the first time in decades that river herring and other fish could swim ‘freely’ between the ocean and the spawning habitats throughout central Maine.

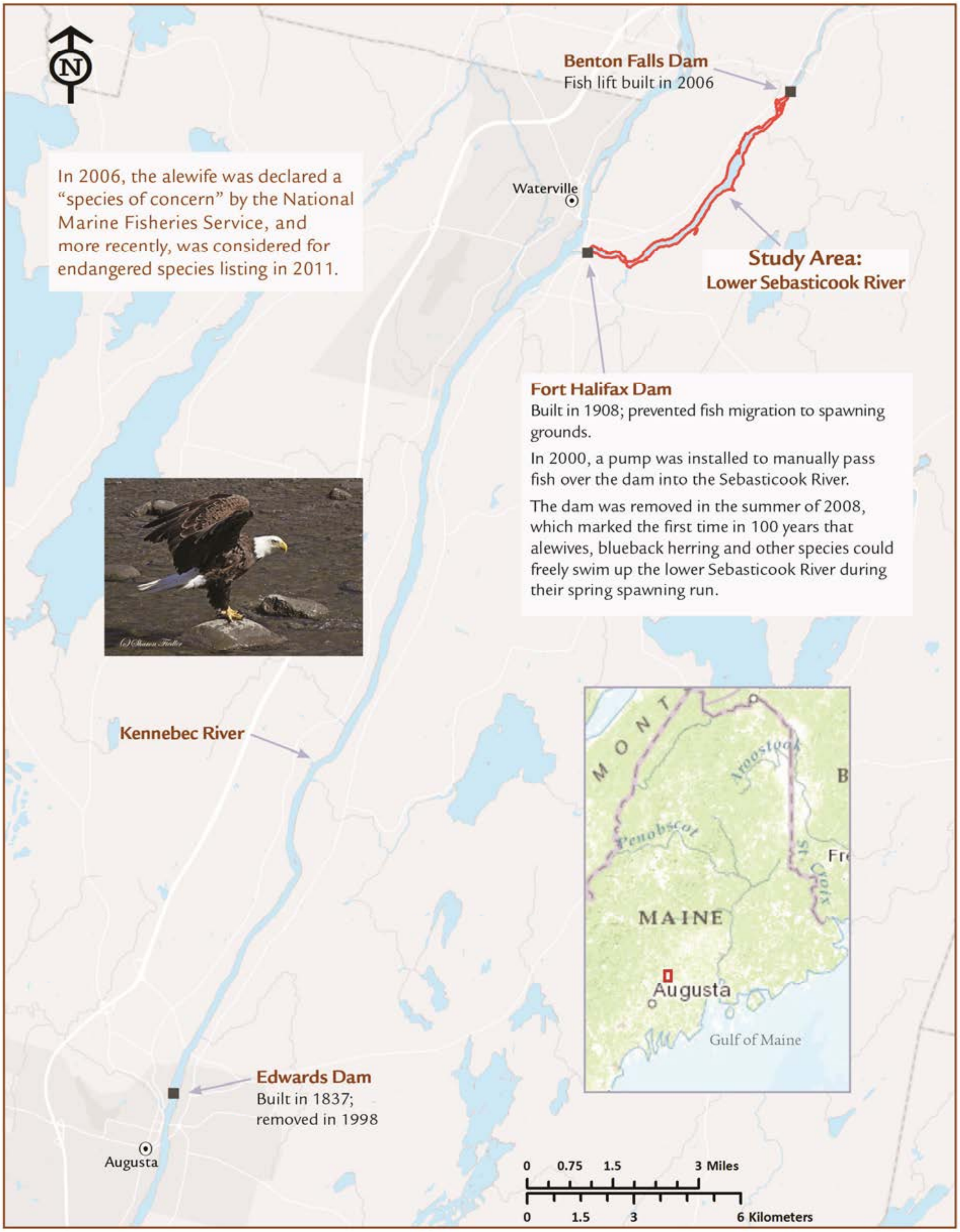

Figure 1. Areas of interest for chronology of dam removal and overall study area.

2.2 History of Bald Eagle Population & Recovery Effort

Reliable estimates of Maine's historic Bald Eagle population are lacking, however it is thought that eagles once numbered in the thousands. Evidence, such as the state's 70 lakes, ponds, streams, points of land, or islands named 'Eagle' or 'Swan' (from 'Sowangan', the Abenaki word for 'eagle') point to their historical prevalence (Palmer 1949). The earliest comprehensive inventories date back to 1962. Statewide surveys from 1962-1976 documented low abundance (21-41 pairs), high failure rates (72% of all nesting attempts failed), and lower productivity (i.e., 0.35 fledged young/pair) than other state populations (MDIFW 2004). Habitat degradation, illegal shooting, and especially the widespread use of insecticides containing DDT in the 1940's were blamed for the decline. By the time the Environmental Protection Agency banned the usage of DDT 1972, state biologists could only account for 29 nesting Bald Eagle pairs. A remnant of 30-60 nesting pairs in Maine and one in New York were the only Bald Eagles breeding in the northeast by the late 1970s, with Maine also serving as one of only five population centers for Bald Eagles nesting in the lower 48 states.

With, legal protections for Bald Eagles and their habitats, declining DDT residues, and considerable efforts by wildlife agencies, land trusts, and private landowners to protect nesting territories from disturbance, the Bald Eagle was removed from the Maine's Threatened and Endangered Species List two years following removal from the federal Endangered Species List in 2007. A statewide inventory in 2013 revealed 630 breeding Bald Eagle pairs, and the population is growing at roughly 8% annually (C. Todd, MDIFW, pers. comm.).

2.3 Bald Eagle Use of the Sebasticook River

In addition to being renowned as New England's premier river herring run, the Sebasticook is also locally renowned for the wildlife aggregations attracted to the seasonally abundant food supply that is otherwise unusual in the region. From mid-May to early-July, aggregations of Bald Eagles can be reliably observed in the reach of the lower Sebasticook River spanning from the Kennebec River five miles upstream to the Benton Falls Dam. Bald Eagle aggregations on the Sebasticook span well beyond the period of the fish run; anecdotal counts by ground and aerial observers regularly note Bald Eagle aggregations during late summer and winter months as well. Similar aggregations of Bald Eagles have few other analogs in the northeastern United States. Perhaps the most notable comparison in the northeast may be on the Delaware River in southern New York near the Cannonsville Reservoir, where Bald Eagles are attracted to tens of thousands of alewives stocked there annually (Nye 2008).

In many summer Bald Eagle aggregations, subadults (i.e., non-adult) are the predominant age class observed. The subadult and non-breeding individuals (often referred to as 'floaters') are critical in maintaining population stability. However, since traditional management efforts primary focus was protection of breeders and nesting habitat, 'floaters', and the habitats needed to support them, are often overlooked. Currently, the focus of Bald Eagle management efforts is shifting to protect 'floater' aggregation areas, which benefit transient, non-breeding, and local breeding populations.

2.4 Project Overview & Justification

While the success story of the Sebasticook River river herring restoration may be well-known in the fishery and habitat restoration community, research and outreach efforts targeting the general public and local communities are needed. Many residents throughout Maine remain unaware of the uniqueness of the Sebasticook River, the plight of river herring, or the relationships between fisheries and wildlife populations. Given the apparent value of the Sebasticook river to subadult and non-breeding eagles, and the demonstrated role that these individuals play in maintaining stable populations, it is often postulated that the Sebasticook plays a notable role in boosting the survivorship for large (but unknown) numbers of eagles in the broader region. However, to date, minimal efforts have been made to quantify the number of Bald Eagles using the corridor and characterize spatial and temporal riparian use patterns. In this study, we take first steps to estimate the abundance, age ratio, and habitat use patterns of Bald Eagles along the lower Sebasticook River. Such information is critical in developing responsible wildlife management and conservation priorities.

3.0 Study Area

We examined a 5.3 mile reach of the Sebasticook River from the Benton Falls Dam in Benton, ME southeast to the site of the old Fort Halifax Dam in Winslow, ME, which is 550 m (1800 ft.) upstream from its confluence with the Kennebec River. The upper third of the Sebasticook is shallower with greater expanses of riffles, while the lower two-thirds is generally deeper with few wavelets. Along the east/south bank, a narrow ribbon of deciduous (e.g., alders, willows, maples, oaks) and coniferous (e.g. eastern white pine) trees line the majority of the riverbanks. A similar ribbon of tree cover exists on the west/north river bank, but these trees are further from the shoreline. On this west/north bank, the floodplain is dissected more frequently by young early successional forest and traditional floodplain habitats have begun to regenerate since the Fort Halifax Dam removal in 2008. The river is roughly paralleled by two roads: Clinton Avenue / Halifax Street to the west and north, and Garland Road to the east and south. It is mostly bordered by private residences situated on relatively large lots, generally located>500 feet from the shoreline. Unmarked high tension power lines cross the river at four points along the study area; one at 1.1 km downstream from the Benton Falls Dam, and three more times at around 7.2, 7.8, and 8.6 km. The two most significant hydrologic inputs are an unnamed stream from Pattee Pond entering at 3.4 km downstream from Benton, and Outlet Stream originating from China Lake at 7.1 km. Three pairs of resident Bald Eagles nested successfully along the shoreline of the Sebasticook, at roughly 0.75, 4.7, and 8.0 km from the Benton Falls Dam (Figure 2).

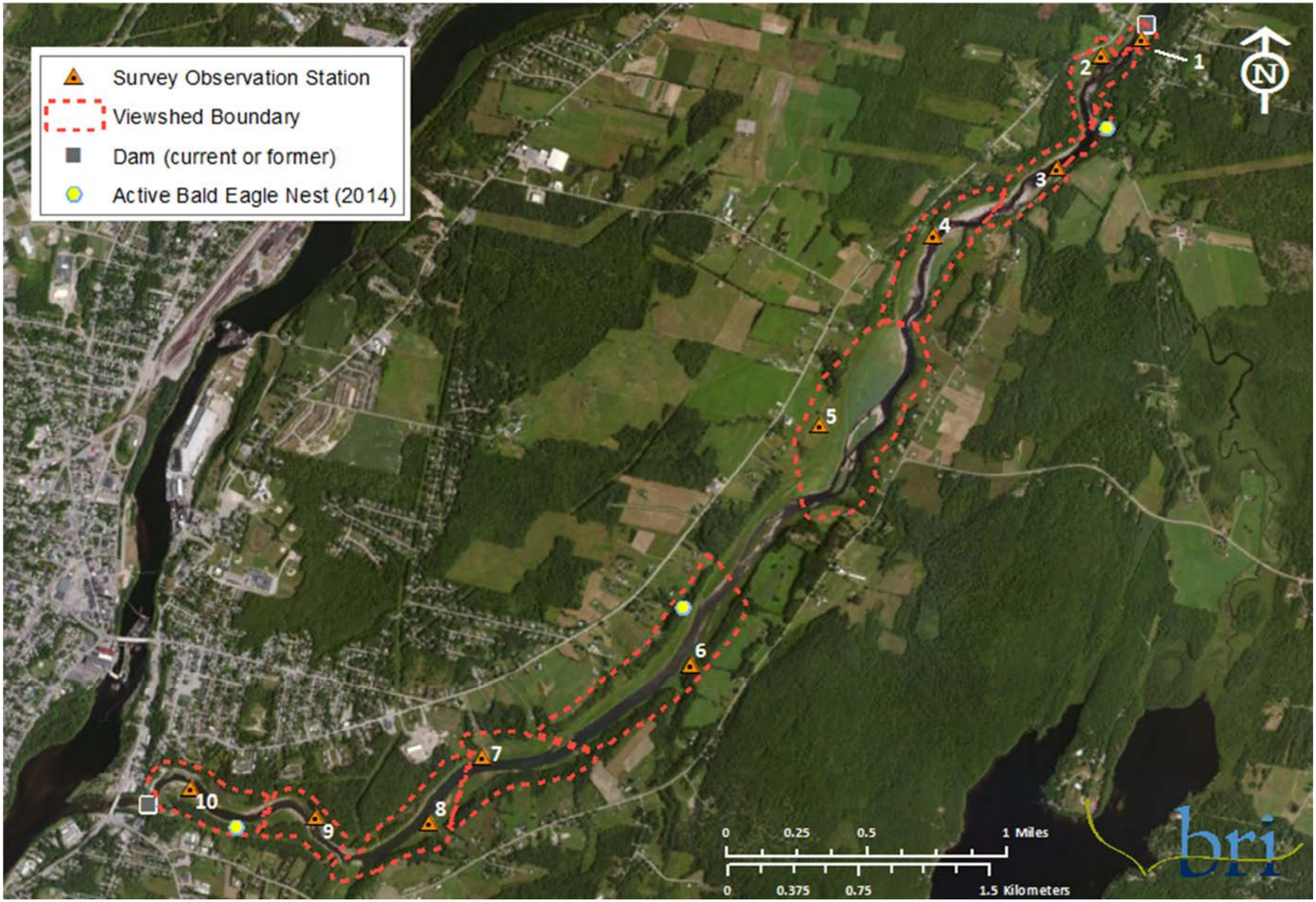

Figure 2. Lower Sebasticook River study area showing observation stations, viewshed boundaries, active Bald Eagle nests, and current/former dams.

4.0 Methods

4.1 Abundance

We conducted standardized surveys using ground observers to estimate the abundance of Bald Eagles (eagles hereafter), using the Sebasticook River study area from 2 May – 18 July. We used two different approaches to estimate the abundance of eagles utilizing the study area: (a) ground-based standardized surveys and (b) aerial surveys.

4.1.1 Ground-based surveys

Survey Station Establishment and Design: Ten observation stations were established along the river corridor, the northernmost being just below the Benton Falls Dam, and the southernmost being just above the breached Ft. Halifax Dam (Figure 2). We defined an observation station as a designated location at which observers stood for surveys. The locations of observation stations were chosen in order to maximize the amount of riparian habitat and shoreline visible to observers. We defined a 'viewshed' as a predesignated area visible when standing at the observation station. We attempted to keep viewshed size consistent whenever possible; however, turns in the river and differences amongst vantage points at observations stations caused variation. Viewshed areas ranged from 0.05 km^2 – 1.02 km^2 ($\bar{x}$ ± SD: 0.43 ± 0.31, n = 10) and covered the majority of the river corridor throughout study area. Distinctive natural features along shorelines and the horizon were used to delineate viewsheds. Eagles observed to be outside of the viewshed area were noted in the comments, but were not included in counts. All observers visited viewsheds together during a training period to ensure consistency in viewshed delineation during counts.

Survey Observations: At each observation station, single observers conducted three consecutive three-minute counts of all eagles that were detected flying or perched within each viewshed. Observers also counted all Ospreys and Great-blue Herons detected; however, they are not summarized in this report. Observers recorded the presence and location of human disturbances (such as anglers, kayakers, ATV/lawnmower use) occurring within viewsheds during sessions. Each three-minute observation period is referred to throughout this report as a 'session'. Upon arrival at each station, observers scanned the viewshed for five minutes using 10 x 42 binoculars to detect (but not count) eagles within the viewshed. At the end of the five-minute scan period, observers conducted three-minute counts of all eagles detected in the viewshed. Observers took a two-minute break between sessions to organize data for each session. Thus, surveys at each observation station would take a total of eighteen minutes; a five minute scan, three three-minute observation sessions, and two two-minute breaks between sessions. Active eagle nests were present in or near three of the 10 viewsheds. Nests at observation stations 6 and 10 were physically within viewshed boundaries, while the nest visible from observation station 2 was located outside the viewshed boundary. Since resident (i.e., territory-holding) eagles along the river could not be reliably distinguished from non-resident eagles once they left the nest, we included all eagles seen during counts (regardless of their nesting status). Survey efforts were postponed during heavy rain events as it negatively affected detectability of perched eagles.

Observers noted the location, age class (see section 4.3), and behavior of each eagle detected during each session. Datasheets for each observation station contained an aerial map of each viewshed to allow observers to note the location of each eagle (Appendix A). The behavior of detected individuals was categorized into one of the following at the time they were first observed: (a) perching in river/on ground, (b) perching in a tree, (c) flying (in an approximately linear fashion), or (d) circling overhead. Observers noted the weather conditions (cloud cover, temperature, wind speed) at the beginning of the 5-minute scan period for each survey.

Survey Types: Observers conducted surveys at all ten observation stations to estimate the total number of eagles using the study area daily. We used two approaches to survey the corridor: (a) condensed surveys , and (b) extended surveys.

Condensed Surveys: For the bulk of surveys 2-3 observers surveyed from different observation stations simultaneously (i.e., dividing the ten stations up amongst the available crew) and drove between stations (n = 36 surveys, 19 days; 23 May – 18 Jul[1]) until surveys were completed at all ten stations. Time elapsed over condensed surveys ranged from 1.55 – 3.30 hours ($\bar{x}$ ± SD: 2.37 ± 0.36, n = 36). We conducted condensed surveys at all stations twice daily. The 'morning' survey occurred between 8:00AM and 11:30AM (condensed morning) and afternoon surveys were conducted between 12:00PM and 3:00PM (condensed afternoon).

Extended Surveys: During extended surveys (n = 17 surveys, 12 days, 2 May – 26 Jun), a single observer commuted between all ten observation stations by kayak or by vehicle. Extended surveys conducted by vehicle were employed when only a single observer was available as these surveys took the longest to complete. Extended surveys were explored early during this study for potential incorporation into a future citizen-based science approach. Observers commuted between stations by car and kayak. Time elapsed over extended surveys ranged from 4.58 – 6.15 hours ($\bar{x}$ ± SD: 5.33 ± 0.44, n = 17 overall; kayak range: 4.75 – 6.15; $\bar{x}$ ± SD: 5.39 ± 0.46, n = 11; vehicle range: 4.58 – 5.73, $\bar{x}$ ± SD: 5.22 ± 0.41, n = 6). The number of eagles counted at the ten observation stations was summed to generate a daily count over the study area. We did not include data from days when surveys were conducted at <10 stations.

Time of day evaluation: Recall that three observation sessions were conducted at each station. To evaluate an effect of time of day on abundance measures, we compared the mean number of eagles observed riverwide between condensed morning and afternoon survey data using counts from the second of the 3 sessions.

Replicate session evaluation: To evaluate whether the mean of the three observation sessions was comparable to data collected from a single session (i.e., session 1, 2, or 3), we used condensed survey data to compare the number of eagles counted riverwide based upon the mean of three sessions at an observation station to mean counts using only the second session.

4.1.2 Aerial Surveys

We estimated the number of Bald Eagles present between the confluence of the Kennebec River and the Sebasticook River and the Benton Falls dam using aerial surveys. Aerial surveys were conducted from a Cessna C-172 fixed-wing aircraft (piloted by Ray Fogg and Frank Craig, d.b.a. Aerial Photo Services of Maine) flying 140-180 km/hr (90-110 mph) approximately 500 ft above the water surface. Surveys were conducted with the primary observer in the front right seat, and a secondary observer/data recorder in the rear/right

[1] We conducted one unpaired condensed morning survey on 30 May & one unpaired condensed afternoon survey on 20 June.

seat. The primary and secondary observers recorded data using aircraft headset-integrated digital audio recorders. The secondary observer additionally recorded observations on a data sheet. Ospreys were also noted during observations. Each flight day, we surveyed the river during two upstream, and two downstream 'passes', for a total of four passes (and two surveys) per day. We conducted aerial surveys on five days: 21 & 30 May; 6, 11, 19 June, and 2 July. Additional surveys were conducted on 21 May prior to the official survey in order to refine our search image and determine the most appropriate flight path, altitude, and observer configuration for all subsequent surveys.

During each pass, the plane was positioned approximately 100 ft from the water's edge over the shoreline on the left side of the plane, while both observers counted out of the right side of the plane simultaneously. This survey approach was preferred over common alternate approaches (i.e., flying the plane down the centerline of the river, having observers view out both sides of the plane simultaneously) because, in order to navigate the turns in the river at the altitude necessary to enable clear observations of eagles, the plane would necessarily deviate from the river corridor and the observers' view could be obscured (by the wing or the door) for an unacceptable amount of time (up to 10-12 seconds). Our chosen survey approach enabled observers to maintain an uninterrupted view of the greatest portion of the river for the longest period of time, but it relied upon little movement of individuals between stations. Eagles observed 'flushing' (flying from a perch due to disturbance) from the one side of the river to the other (recorded by the rear-seat observer) during an upstream pass would be noted and if present, would not be counted during the downstream pass. In general, the few bald eagles that flushed during the upstream passes (<10 total over all surveys; ca. 2 per survey) flushed during surveys from one side of the river to the other during upstream passes were easily accounted for during downstream passes based on location (due to a relatively low overall density of detectable bald eagles).

To estimate the number of eagles using the study area during aerial surveys, we summed the number of observations during consecutive single upstream and downstream passes into a single survey total. To evaluate if abundance measures differed between first- and second-flown surveys, we compared the means of these two groups.

4.1.3 Survey Comparisons

Same-day collection of both ground-based and aerial survey estimates of Bald Eagle abundance in our study area enabled coarse comparisons between these two estimation methods. Fixed-wing surveys are well-known to underestimate the number of Bald Eagles in an area due to perception bias and availability bias (Bowman and Schempf 1999). Of the six days in which aerial surveys were conducted, five occurred on days in which ground-based observers were collecting data used to generate riverwide eagle counts. While limited sample sizes preclude statistical analyses of this dataset, we evaluated the percent difference between riverwide aerial and ground-based Bald Eagle counts for the five 'same-day' survey estimates. For perspective, we also compared daily counts from the first aerial survey (21 May; for which there was no ground survey) with the ground-based survey conducted the following day. This comparison was of interest because foliage coverage likely causes the majority of measurement error, and the first survey was the only in which leaf-out was not 100% (it was 50%). Lastly, we applied a correction factor of 2.38 (Buehler et al. 1991*b*) to our aerial survey counts and then noted the change in percent difference between aerial and ground-based counts.

4.2 Timing and Relationship to Fish Abundance

To evaluate the relationship between eagle abundance and fish numbers in the study area, we used a compared daily riverwide eagles counts (collected during ground-based surveys) to daily river herring passage data. Fish passage count data from the 2014 upstream migrations at the Benton Falls dam was provided by the Maine Department of Marine Resources. At this facility, fish migrating upstream swim into a 600-gallon hopper that is lifted up to an exit flume. Fish are then discharged and allowed to swim upstream through the flume and over the spillway into the head pond above the dam. As the fish swim through the flume, they are counted automatically by an array of electronic counting tubes (Smith-Root model SR-1601), which measure electrical fields to detect and count passing individuals (ME DMR 2009). A fish excluder is employed to prevent non-target species from swimming through the counting tubes. In 2014, the lift operated from 7 May to 11 July. Post-spawning river herring migrating downstream from inland lakes are not counted at the dam, thus upstream fish counts are a less accurate depiction of prey density once fish begin migrating downstream (typically in June).

4.3 Age Class Ratio

To characterize the ratio of adult to subadult eagles in the study area during ground-based and aerial surveys, we summarized the percentage of eagles categorized in each age class for all pooled observations and riverwide daily counts. We characterized the proportion of observations that were adults or subadults during ground- and aerial-based surveys. All eagles with plumage typical of adults (i.e., white head/tail, approximately ≥3.5 yrs of age) as visible through binoculars were classified as adults; all other plumages were categorized as subadults (Knight and Knight 1983, McCollough 1989). Occasionally during both ground and aerial surveys, age classes were undeterminable due to foliage obscuring head/tail, or due to backlighting. In such cases, these eagles were denoted as 'unknown age'.

4.4 Habitat Use Patterns

We used two approaches to identify broad reaches and specific habitat parcels that appeared to be used by eagles during the fish run. First, to identify the viewsheds within which the highest numbers of eagles were observed, we calculated the mean number of eagles counted at each of the 10 different observation stations and made comparisons across them. Only observations from ground-based surveys were included in these analyses, as aerial survey observations were not geo-referenced. To determine if observation stations differed in the number eagles observed, we compared mean daily counts of eagles among ten stations.

To identify specific areas used by eagles, we digitized the locations of all bald eagles observed during surveys, and then used the Optimized Hot Spot Analysis tool in ArcMap 10.2™ (ESRI 2013) to identify statistically significant clusters of observations. To perform this analysis we used a subset only perching locations (flying and circling observations were omitted). The Optimized Hot Spot Analysis tool first overlays a grid of cells (using an algorithm to determine appropriate size) over an area with incident data (points representing perch locations) and computes the number of points contained within each grid cell. Then the Getis-Ord G_i^* statistic is calculated (see formula below) for each cell using the value from a user-specified attribute (count of perches in our study). The resultant Z-score indicates where features with either high or low values cluster spatially. The tool looks at each input feature (a 20- x 20-meter grid cell in our case) within the context of neighboring features. A cell with a high G_i^* value represents a cluster, but is not necessarily a statistically significant hot spot. A statistically significant hot spot is indicated by a cell with a high value surrounded by other cells with high values as well. The local sum for a cell and its neighbors is compared proportionally to the sum of all features; when the local sum is different than the expected local sum, and that difference is too large to be the result of random chance, a statistically significant Z-score is returned (Getis and Ord 1992). Grid cells comprising a statistically significant hot spot were symbolized based on confidence level (90, 95, or 99%) and overlaid on the “Parcels- organized towns” composite property boundary GIS coverage (Maine Office of Geographic Information Systems). This coverage shows property boundaries for the town of Winslow; however, boundaries for the town of Benton remain un-digitized as of the most recently published coverage (28 Jan, 2015).

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \bar{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \qquad \bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \qquad S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\bar{X}\right)^2}$$

$\boldsymbol{X_j}$ is the attribute value for feature $\boldsymbol{j}$, and $\boldsymbol{w_{i,j}}$ is the spatial weight between feature $\boldsymbol{i}$ and $\boldsymbol{j}$, $\boldsymbol{n}$ is equal to the total number of features. The G_i^* statistic is a z-score so no further calculations are required.

4.5 Identifying Roost Areas

Using data from eagles fitted by BRI with satellite transmitters as nestlings (n=20) and adults (n=1), we examined the study area for communal roost sites between 1 May to 30 September. Employing methods similar to those outlined in Watts and Mojica (2012), we selected the one GPS or Doppler fix as close to the midnight hour as possible per animal per night (n= 226) spent within 15 km of the lower Sebasticook River corridor. Due to variances in unit type (GPS-enabled, n=16; Doppler-only, n=5) and individual unit programming, a GPS or Doppler location was not always fixed precisely at midnight. Thus timing of fixes used in this analysis ranged from 10 PM to 2 AM. Locations from nestlings were not used until they began roosting away from their natal site. Boundaries of communal roost sites were delineated by minimum convex hulls computed in CrimeStat III (Levine 2010) using a Nearest Neighbor Hierarchical Spatial Clustering script. Cluster parameters were set to search a fixed distance of 100 m with a minimum of 5 midnight/near-midnight fixes per cluster (Watts and Mojica 2012). Roosts being used by only one individual were manually removed from the dataset.

4.6 Productivity Evaluation of Local Resident Pairs

Since overall monitoring of eagle pairs throughout Maine is now very limited since state delisting, we monitored nest success and evaluated productivity for three nests within our study area. All chicks surviving in mid-July (approximate age of fledging) were used in calculating the number of chicks fledged per occupied nest to estimate productivity (Postupalsky 1974, Steenhof and Newton 2007). Nests were checked during ground-based surveys ≥ once per week using a 30x spotting scope and 10 x 42 binoculars. We observed nests for ≥15 minutes from a distance of 300-400 m during which the number of chicks present at each nest could generally be verified. Nests were generally viewed from observation station 2 (nest #1), 6 (nest #2), and 10 (nest #3) (Figure 2). Of the three nests, nest #1 was located for the first time during the 2014 breeding season. Nests 2 and 3 correspond to breeding territories identified by MDIFW in previous years. All three nests were constructed in large eastern white pine (*Pinus strobus)* trees ≤ 50 m from the river’s edge.

4.7 Data Analysis and Mapping

We checked for normality of datasets using a Goodness of Fit Test. Since data in this study was rarely normally distributed, we used a non-parametric Wilcoxon test (i.e., Kruskall-Wallis) to compare means. We used a Spearman Rank Correlation to compare riverwide eagle counts from ground-based surveys to daily upstream fish counts. All statistical analyses were conducted using JMP® 9.0.0 (SAS Institute Inc. 2010). All spatial analyses and mapping was conducted in ArcMap™ 10.2.

5.0 Results

5.1 Abundance

5.1.1 Ground-based surveys

Survey effort: We conducted a total of 53 complete riverwide surveys (36 condensed, 17 extended) on 31 different days. These surveys comprised 530 visits to observation stations, during which 1,590 sessions, or 4,756 minutes of observations were collected.

Our analyses suggested no differences in eagle abundance measures existed when using second observation session data ($\bar{x}$ ± SD: 28.6 ± 16.7, n = 17) vs. the mean of three consecutive sessions ($\bar{x}$ ± SD: 28.8 ± 18.0, n = 17) (p = 0.88, χ^2 = 0.024). Therefore, we used a dataset comprised of the second session counts for all analyses this study. Using a dataset comprised of second session data from morning and afternoon condensed surveys, we evaluated whether the time of day affected our survey counts. We found no significant difference in the mean number of eagles counted during morning ($\bar{x}$ = 2.9 ± 3.7, n = 170 sessions) and afternoon ($\bar{x}$ = 2.5 ± 3.4, n = 170 sessions) (p = 0.48, χ^2 = 0.50) surveys. As a result, we used condensed morning survey data (using the second session) for analyses on days in which >1 survey was conducted. We used data collected from afternoon condensed surveys and extended surveys when no other data was available. After excluding replicate session and time of day datasets, information from 31 complete river surveys (19 condensed, 12 extended) conducted on 31 different survey days (representing 310 survey sessions and 930 survey minutes) were used for analyses (referred to as the 'analysis dataset' hereafter).

Our surveys confirmed the presence of large aggregations of eagles along the river corridor during the study period. Observers recorded 806 individual eagle observations over the entire study period. The number of eagles counted during all pooled 3-minute observation sessions used in analyses ranged from 0 – 21 eagles per session[2] ($\bar{x}$ ± SD: 2.6 ± 3.6 eagles per session, n = 310). Ten or more eagles were observed in survey sessions on 17 different occasions (5.5% of surveys), and five or more Bald Eagles were observed on 64 different survey sessions (21%).

The daily total of eagles counted riverwide (i.e., all 10 stations combined) during surveys ranged from 2 – 65 eagles per day ($\bar{x}$ ± SD: 26 ± 18 eagles/day, n = 31). Over all riverwide survey days (n = 31), five or more eagles were counted on 87% (n = 27) of survey days, ten or more were counted on 71% (n = 22), 20 or more were counted on 61% (n = 19), 30 or more were counted on 45% (n = 14), 40 or more were counted on 25% (n = 8), and 50 or more were counted on 10 % (n = 3), and 60 or more were counted on 3% of survey days (n = 1).

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[2] 23 eagles was the maximum number of eagles observed over all observation sessions; this data was excluded in the dataset containing exclusively data collected during the second of three consecutive observation sessions.

5.1.2 Aerial Surveys

We conducted a total of twelve riverwide aerial surveys of the study area on six different days. We did not find differences in the number of eagles detected daily between first- ($\bar{x}$ ± SD: 14 ± 7.3, n = 6) and second-flown ($\bar{x}$ ± SD: 12 ± 7.9, n = 6) daily surveys (p = 0.33, t = -0.46); therefore, we used data from the first-flown daily surveys in aerial survey-based calculations. Thus, six riverwide aerial surveys, representing a total of 42 minutes of survey time, were used in analyses.

Aerial surveys confirmed and documented the presence of eagle aggregations in the study area; however, as would be expected, counts were generally lower than those collected during ground-based surveys (Figure 3). A total of 84 individual eagle observations were recorded when pooling all survey data from the six riverwide surveys used in analyses. The daily total of eagles counted during riverwide surveys ranged from 2 – 24 eagles / day ($\bar{x}$ ± SD: 14 ± 7.2 eagles / day, n = 6).

Similar to ground-based methods, aerial surveys reflected numerical shifts in eagle abundance in the study area during the study period; however, the magnitude of changes in abundance were less dramatic in comparison to ground-based survey measures (Figure 3). Aerial surveys detected a similar number of eagles during the 21 May (14 eagles) and 30 May (12 eagles) surveys (14 and 12, respectively). The peak eagle count during aerial surveys occurred on 6 June (24 eagles). Surveys on 11 June and 19 June detected 14 and 18 eagles, respectively. The abundance of eagles counted riverwide declined by the final 2 July survey during which two eagles were detected.

5.1.3 Survey Comparisons

Riverwide estimates of eagle abundance from aerial surveys in our study were consistently lower than estimates gathered by ground observers. Not including the first survey (21 May) in which no ground survey was conducted, first-flown aerial surveys ranged from 92 – 500% ($\bar{x}$ ± SD: 242 ± 137%) lower than ground-based observations (Figure 3). The abundance estimate of eagles on the first aerial survey (21 May) was 43% lower than the ground-based estimate on the following day. The five subsequent surveys were lower than ground-based surveys by 192% (30 May), 92% (6 June), 214% (11 June), 211% (19 June), and 500% (2 July). Limited sample sizes precluded statistical comparisons of these datasets; however, application of a 2.38 correction factor as suggested in Buehler et al. (1991) lessened differences to: 23%, 19%, 32%, 31% and 152% ($\bar{x}$ ± SD: 51 ± 51%). The large discrepancy between aerial and ground-based counts on the final (2 July) survey – both with and without the correction factor – reflects a large discrepancy between the aerial survey (which detected 2 individuals; one adult, one subadult) and the ground survey (which detected 12 individuals, four adults, eight subadults). Aerial survey estimates were consistently lower than ground-based surveys within age classes. The mean difference between aerial and ground-based estimates were still notable for subadults ($\bar{x}$ ± SD: 264 ± 224%, n = 5) and adults ($\bar{x}$ ± SD: 266 ± 124%, n = 4; there was one day in which aerial surveys detected no adults and ground surveys detected 10). On 29 May, Ed Friedman (Friends of Merrymeeting Bay) conducted one upstream, and one downstream helicopter survey in our study area. He detected 28 eagles during the upstream survey (23 subadults, 5 adults), and 23 eagles during the downstream survey (18 subadults, 5 adults). Ground-based surveys on 29 May counted 28 eagles (21 subadult, 7 adult) on this day.

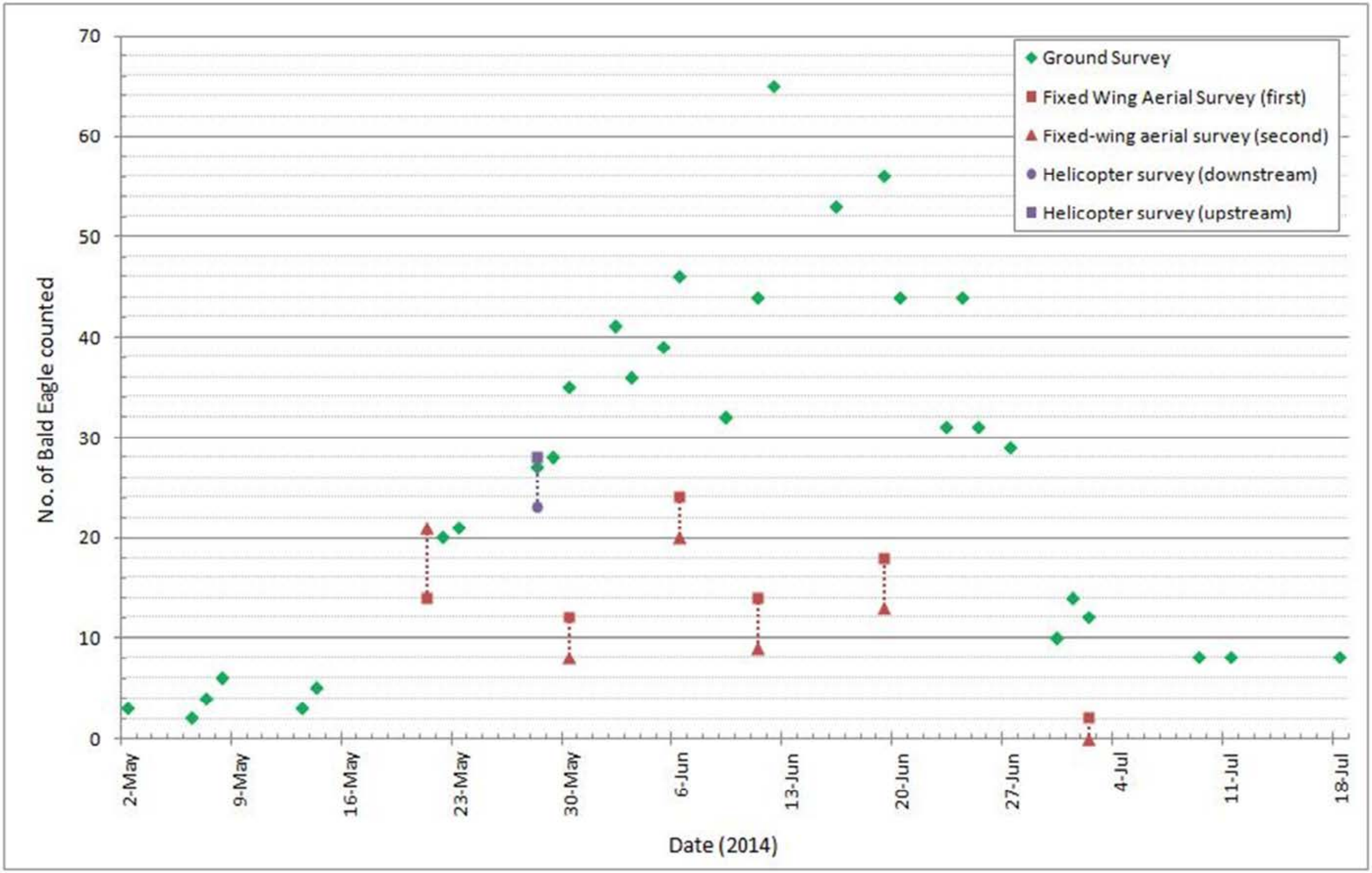

Figure 3. Ground-based, fixed-wing, and helicopter-based aerial survey estimates of the number of Bald Eagles utilizing the lower Sebasticook River corridor, May - July 2014.

5.2 Timing and Relation to Fish Abundance

Daily counts elucidated seasonal changes in eagle abundance on the Sebasticook River corridor during the study period. We observed a numerical response, characterized by an increase, peak, and subsequent decline in the number of eagles observed during the study period (Figure 4). During the first two weeks of surveys (i.e., wks 18-20; surveys 5/2 – 5/13), the number of eagles counted daily ranged from 2 – 6 eagles / day (weekly means 4.0 eagles / day). The daily total increased steadily during week (week of the year) 21 (20 – 21 eagles, $\bar{x}$ ± SD: 20.5 ± 0.70, n = 2d), week 22 (27 – 28 eagles, $\bar{x}$ ± SD: 30 ± 4.3, n = 3d), week 23 (36 – 46 eagles / day, $\bar{x}$ ± SD: 40.5 ± 4.2, n = 4d) and week 24 (32 – 65 eagles, $\bar{x}$ ± SD: 47± 16.7, n = 3d). The highest daily riverwide count occurred during week 24 (12 June; 65 eagles); however, the highest daily mean count occurred during week 25 (44 – 56 eagles, $\bar{x}$ ± SD: 51.0 ± 6.2, n = 3). Subsequent mean daily riverwide counts declined during week 26 (29 – 44 eagles, $\bar{x}$ ± SD: 33.7 ± 6.9, n = 4) and then dropped substantially during weeks 27 (10 – 14 eagles, $\bar{x}$ ± SD: 12.0 ± 2.0, n = 3), 28 (8 - 8 eagles, $\bar{x}$ ± SD: 8 ± 0, n = 2), and 29 (8 eagles, n = 1).

We began conducting surveys on 2 May, five days prior to the initiation of 2014 fish lift operations at the Benton Falls dam (N. Gray, ME DMR, personal communication). Counts of river herring passing through the Benton Falls fish lift upstream increased rapidly after operations began; on 12 May, an estimated 98,000 herring were passed through the fish lift (Figure 4). The peak daily river herring passage count at the dam occurred on 18 May when 118,245 were counted. The observed numerical response of eagles generally appeared to mirror, but lag behind the upstream river herring passage measured at the dam. The peak of eagle counts was 19 June, roughly 31 days after the peak number of daily fish counts (18 May). Of the fish passing through the fish lift during operations, 75% occurred between 11 May and 29 May (Figure 4). By comparison, 77% (625/806) of the individual Bald Eagle observations occurred between 29 May and 25 June[3]. Riverwide counts of eagles were not significantly correlated with counts of upstream migrating river herring counted at the dam (r = -0.10, P = 0.45 Spearman Rank Correlation).

5.3 Age Class Ratio

Ground-based surveys: The majority of eagles detected in the study area during our ground-based surveys were subadults. Of 806 individual observations in our analysis dataset, adults accounted for 27% (220) of observations, while 72% (581) were categorized as subadults (5 eagles were unknown age, <1%). The number of adults counted daily riverwide fluctuated minimally over the survey period (range 2 – 16, $\bar{x}$ ± SD: 7.1 ± 3.5, n = 31 days) in comparison to subadults (range 0 – 51, $\bar{x}$ ± SD: 18.7 ± 15.1, n = 31).

The mean proportion of eagles falling into adult and subadult classes during daily riverwide counts were 42% adult and 58% subadult; however, the age class ratio shifted notably over time (Figure 4). The percentage of subadults comprising daily observations varied from 0 – 83%, with percentages of subadults ≥60% on 64% (20/31) of days surveyed. Observations showed a relatively rapid shift from an adult-dominated population during the first two weeks of May (2 – 22 May surveys), to a predominantly (≥70%) subadult-dominated population in the fourth through the tenth week of the study (23 May – 30 June surveys). Daily riverwide age ratios ranged from 50-67% during the tenth and eleventh week of the study (1 – 11 July), and dropped to 13% subadults during the final survey in the twelfth week of the study (18 July survey).

[3] Unlike fish counts, individual eagle observations likely include individuals counted on multiple days.

Aerial Surveys: Due to their lower frequency, aerial surveys provided fewer measures of abundance and age class ratio data compared to ground-based surveys. After excluding replicate daily flight data (see 5.1.2 Aerial Surveys) data from six riverwide aerial surveys were used for analysis. Of the pooled 81 individual eagles observations (of known age) recorded during aerial surveys, adults accounted for 20% (17 eagles), subadults comprised 76% (64 eagles), and eagles of unknown age comprised the remaining 4% (3 Bald Eagles) (Table 1)

Table 1. Number and age of Bald Eagles counted during six fixed-wing aerial surveys of the Sebasticook River corridor, summer 2014.

Date	Adult	Subadult	Unknown	Total	% Adult	% Subadult	% Unknown
21-May	6	8	0	14	43%	57%	0%
30-May	2	10	0	12	17%	83%	0%
6-Jun	5	18	1	24	21%	75%	1%
11-Jun	0	14	0	14	0%	100%	0%
19-Jun	3	13	2	18	17%	72%	2%
2-Jul	1	1	0	2	50%	50%	0%
Total:	**17**	**64**	**3**	**84**	25%	73%	1%

*non-bolded, italicized percentages in final row represent column means. Figures in table that do not match those in text result from exclusion of unknown-age individuals.

After excluding three eagles of unknown age, the percentage of subadults comprising the surveyed population riverwide ranged from 50% - 100% ($\bar{x}$ ± SD: 75.0 % ± 18, n = 6). Overall, aerial observations detected a roughly similar proportion of eagles in both age classes during the first (21 May; 57% subadult, 43% adult) and last (2 July; 50% subadult, 50% adult) surveys. Subadults comprised a substantial proportion of eagles counted during our survey in late May and the surveys in June (Table 1). Unlike ground-based surveys, no adults were detected on one survey, 11 June.

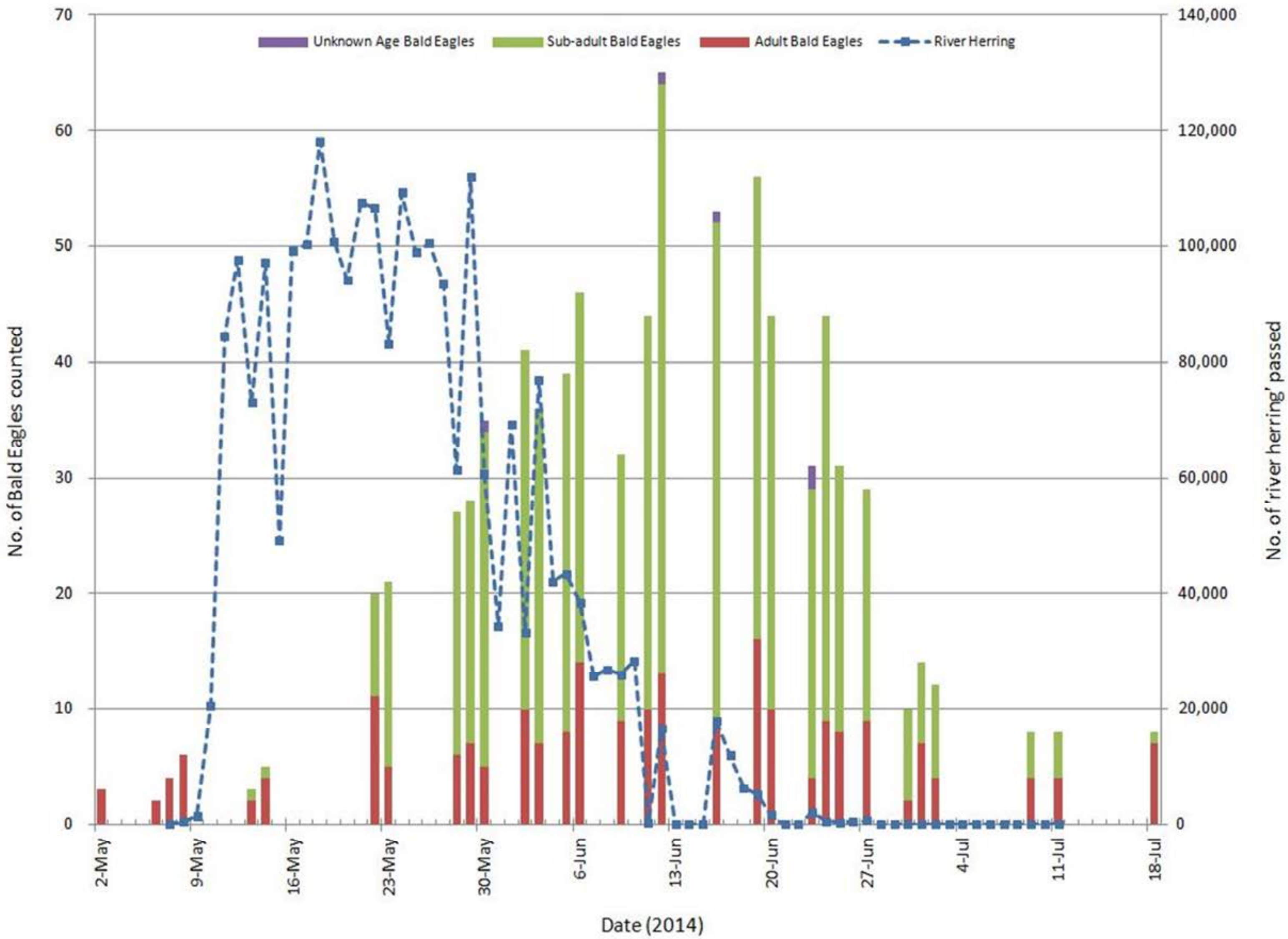

Figure 4. Daily riverwide estimates of adult and subadult Bald Eagles counted along a 5-miles stretch of the lower Sebasticook River, Maine, compared with numbers of 'river herring' (alewives and blueback herring) passed upstream through the Benton Falls fish lift. Fish passage data provided by the Maine Department of Marine Resources.

5.4 Habitat Use Patterns

Ground based standardized surveys documented that eagles were not evenly distributed throughout the study area (Figure 5, Figure 6). Observation stations varied significantly in the mean number of Bald Eagles observed ($p < 0.0001$, $\chi^2 = 116.14$).

Table 2. Descriptive statistics for daily counts of Bald Eagles detected at ten different observations stations along the lower Sebasticook River corridor study area, May – July 2014.

Station	Mean no. Bald Eagles counted/day	SD	Min – Max	Total counted	% of Total
1	0.2	0.6	0 - 3	5	1%
2	5.5	5.5	0 - 21	170	21%
3	3.8	3.7	0 - 14	117	15%
4	4.9	4.7	0 - 20	152	19%
5	4.2	4.5	0 - 16	131	16%
6	2.8	2	0 - 8	86	11%
7	0.5	0.9	0 - 3	14	2%
8	2.9	2.5	0 - 9	90	11%
9	0.3	0.7	0 - 3	9	1%
10	1	0.8	0 - 2	32	4%

Daily counts (n = 31) conducted at all stations using 3-minute observation periods. Total counted reflects sum of all eagles during entire survey period at each observation station.

The highest numbers of eagles were counted at upstream stations 2 – 5 (mean eagles per station ranging 3.8 – 5.5 per session; total eagles per station ranging 117 – 170). With the exception of station 1 just below the Benton Falls Dam, eagles were most commonly encountered in the upper half of the river; of the 806 eagle observations used in analyses, 71% (570) occurred in stations 2 through 5. Intermediate numbers of eagles were counted at stations 6 and 8 (mean eagles per station ranging 2.8 – 2.9 per session). These two stations comprised 22% (176/806) of all individual Bald Eagle observations. The lowest measures of Bald Eagles were observed at the upstream-most station, station 1, and downstream stations 7, 9, and 10. Measures of Bald Eagles counted at these four stations during observation sessions ranged from 0.16 – 1.03 Bald Eagles/session (total Bald Eagles per station ranged 5-32) and only comprised 3% (23/806) of the overall number of Bald Eagles counted.

Optimized hotspot analyses of perching locations further elucidated specific locations within each viewshed that were most commonly used by Bald Eagles. Our analyses identified roughly twelve clusters of varying sizes in the upper half of the river (stations 1-5, Figure 5) and roughly 6 clusters in the downstream portion of the river (stations 6-10, Figure 6). Clusters tended to be immediately on shorelines versus setback in large trees visible in upland habitats.

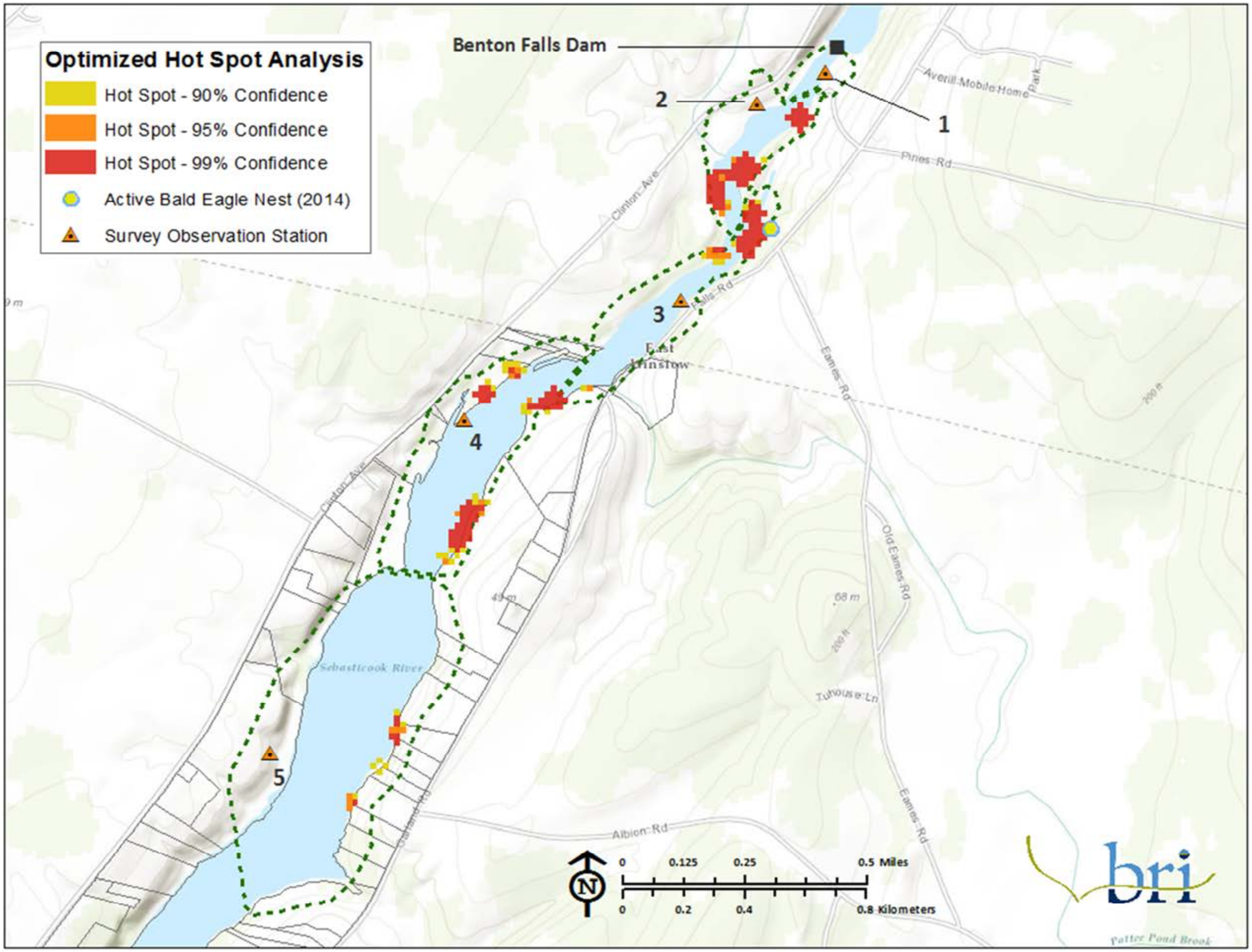

Figure 5. Spatial clusters, or “hot spots”, identified during surveys indicating important foraging areas along the lower Sebasticook River; upstream observation stations 1-5.

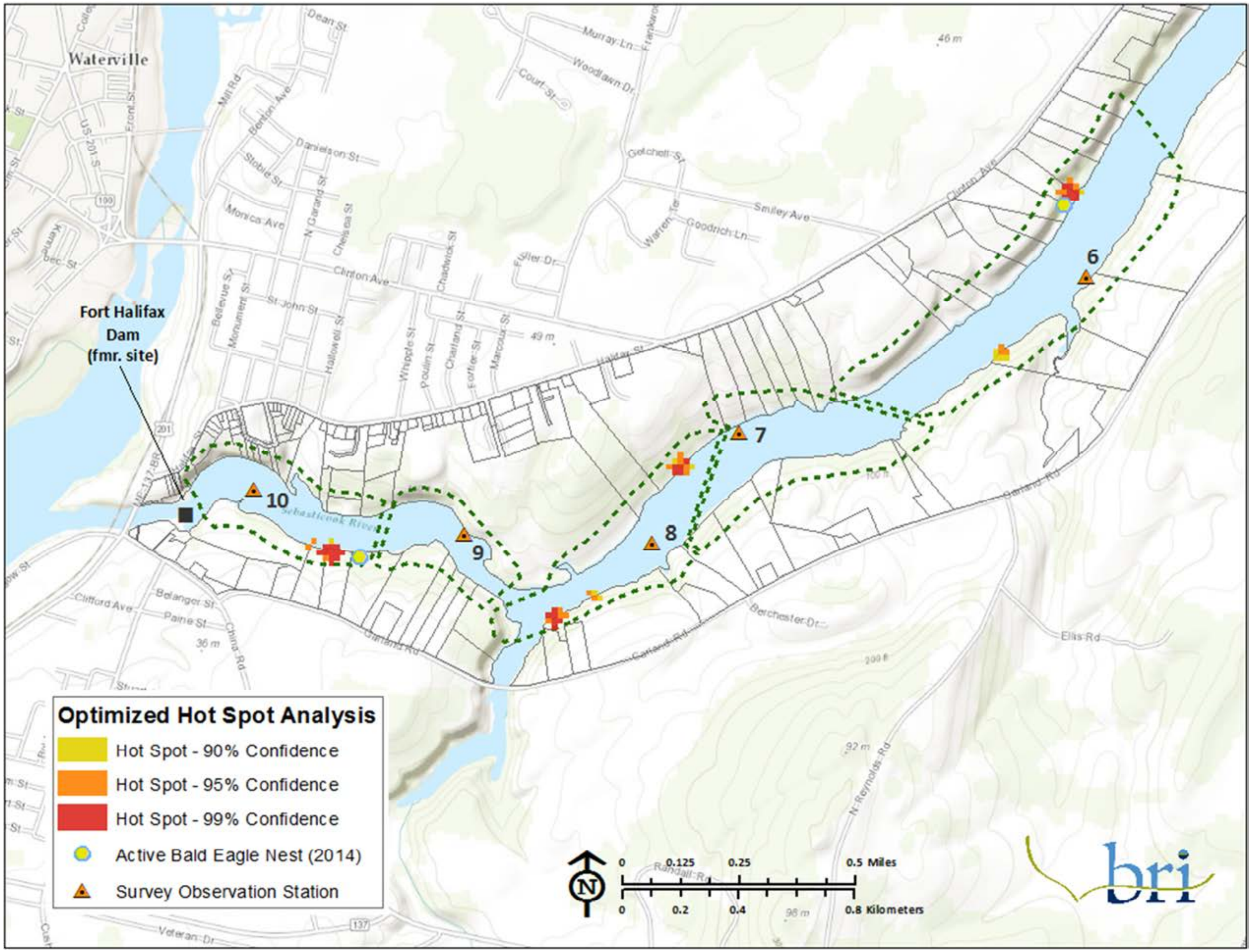

Figure 6. Spatial clusters, or "hot spots", identified during surveys indicating important foraging areas along the lower Sebasticook River; downstream observation stations 6-10.

5.5 Identifying Roost Areas

Using the parameters specified in Watts and Mojica (2012), only two roosting areas were identified within 15 km of the lower Sebasticook River study corridor. Of these, only one of these qualified as a communal roost ("2" on Figure 7), with only one near-midnight Doppler fix (Argos class 3, estimated error <250m) being contributed by the second individual. The other roost identified, though not a communal one, was located on the Kennebec River about 5 km downstream from the mouth of the Sebasticook River ("1" on Figure 7). This roost was associated with a single individual – "HY06 Winslow" – originating from a nearby nest returning to its natal area in years subsequent to dispersal. Use of a 200 m search distance failed to identify additional communal roosts.

A more qualitative approach indicates that five of our 21 eagles fitted with satellite transmitters spent a total of 226 roost-nights within 15 km of the study area from 1 May to 30 September since 2011 (Figure 7). Of these five individuals, the locally fledged "HY06 Winslow" accounted for 46% of the nights. This individual has displayed a high natal site fidelity in the Sebasticook River vicinity since it fledged in 2011. Other roosting individuals originated from nests as far away as 130 km ("HY02 Saco") and 170 km ("HY09 Rocky Lake") from the study area.

5.6 Productivity Evaluation of Local Resident Pairs

The three nests monitored fledged a total of five eaglets in 2014. Nest #1 (northernmost) fledged two young, nest #2 fledged two young, and nest #3 (near the confluence) fledged one young. Thus, productivity for these three pairs averaged 1.7 young per occupied nest. Nest #1 was among the most advanced nests in the state in terms of nesting chronology; fledglings were observed regularly during surveys in the nesting area and along the river corridor.

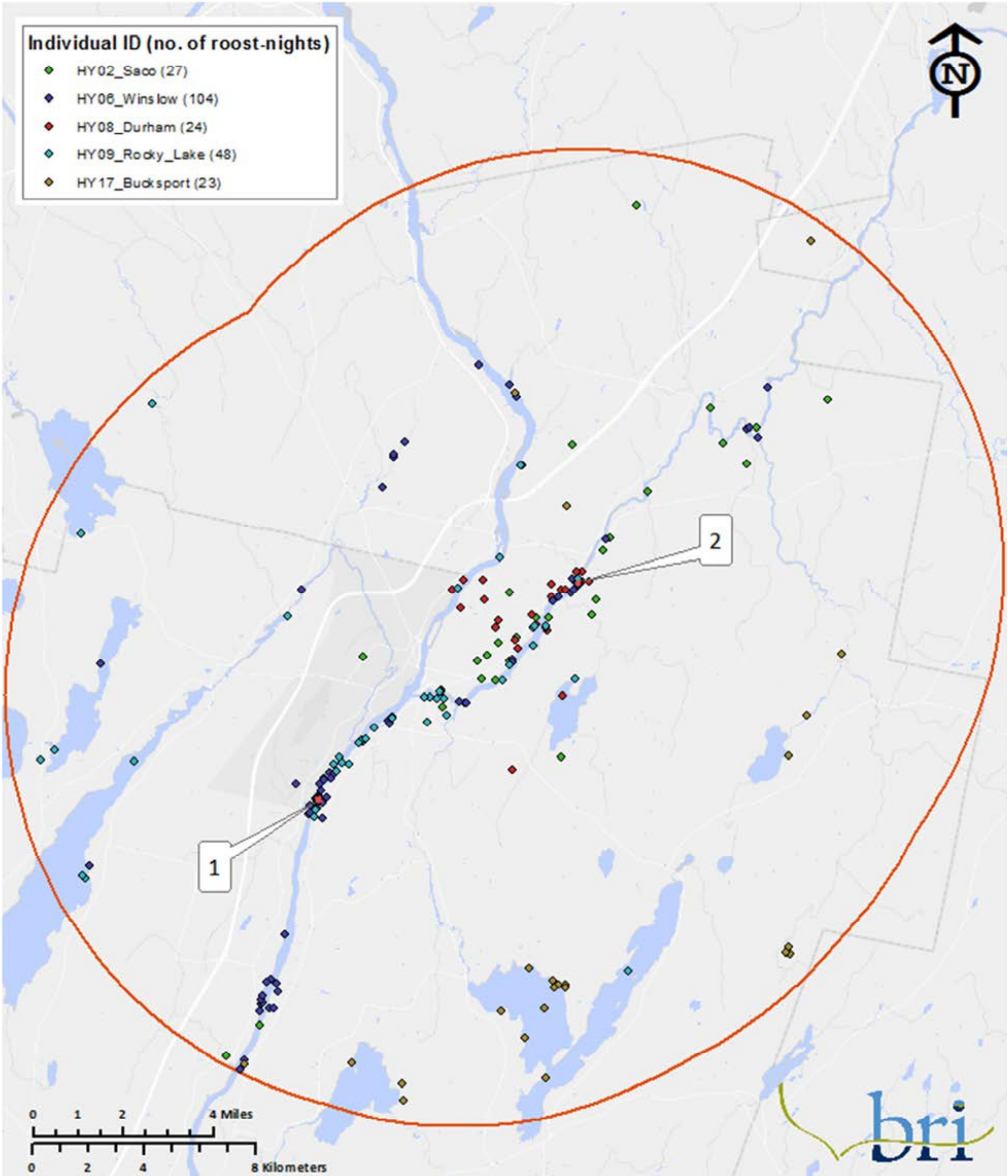

Figure 7. Night-time location estimates from five of 21 satellite-transmitter equipped Bald Eagles from 1 May to 30 September (2011-2014) that occurred within 15 km (indicated by red polygon) of the lower Sebasticook River study. Roosting areas identified in preliminary analyses highlighted by 1 and 2.

6.0 Discussion

6.1 Abundance

Efforts to conduct ground- and aerial-based surveys in this study have documented and quantified the abundance, distribution, age ratio, spatial use, and temporal use patterns of eagles along the Sebasticook River corridor during early May through mid-July.

Ground-based abundance estimates gathered in this study probably represent the largest aggregation of eagles documented in Maine, and most likely any New England state during any season. The number of eagles observed during 3-minute observation sessions ranged from 0 – 21 eagles in our analysis dataset. Perhaps most meaningful ecologically, abundance estimates of the total number of eagles using the river corridor study area ranged from 2 – 65 eagles during ground-based surveys, and 2-24 during aerial surveys during the survey period. We suspect that ground and especially aerial-based eagle counts underestimate the number of eagles actually present (see below). Our figures should be very cautiously compared to anecdotal reports or surveys elsewhere due to differences in survey methodology. While our sessions were precisely timed to 3-minute intervals within specific geographic viewsheds, this unit of measure is perhaps most feasibly coarsely compared to counts of eagle observed elsewhere.

Bald Eagles commonly become gregarious when food is both scarce (i.e., winter months) and abundant (Stalmaster 1987). Despite the high level of piracy and aggression in eagles (Stalmaster and Gessaman 1984, Bennetts et al. 1990), individuals benefit from foraging in groups (Knight and Knight 1983, Stalmaster 1987, Restani et al. 2000). Numerous studies have documented significant eagle aggregations during winter (Griffin et al. 1980, Restani et al. 2000) and summer seasons (Watts and Byrd 1999, 2002, Elliot et al. 2004), as well as during migration (Restani 2000, Restani et al. 2000). Most commonly, eagles of mixed age groups converge upon seasonally abundant food resources such as spawning, spawned, or migrating fish. For example, Elliot et al. (2004) counted up to 110 (March) and 150 (June) eagles feeding on spawning Plainfin Midshipman (*Porichthys notatus*) in a tidal-influenced area in British Columbia, Canada. Hundreds of migrant eagles converge upon Hauser Lake, Montana (Restani et al. 2000), and Glacier National Park (Bennetts et al. 1990, Bennetts and McClelland 1997) annually to feed upon spawning kokanee salmon (*Oncorhynchus nerka*) during the autumn and early winter months. Similarly, spawned bodies of coho salmon (*Oncorhynchus kisutch*) and chum salmon (*Oncorhynchus keta*) attract hundreds of eagles to the Nooksack River, Washington (Knight and Knight 1983, 1986, Stalmaster 1987, Knight and Skagen 1988). Along the Atlantic coast, a complex mixture of resident and migrant eagles form large aggregations centered on the Chesapeake Bay and its abundant resources (Watts et al. 2007).

Other than occasional anecdotal reports from single locations, few or no reports of summer month eagle aggregations exist for comparison in New England, thus emphasizing the uniqueness of the Sebasticook. Small, but undocumented groups of eagles are regularly and predictably noted in association with other Maine rivers with smaller river herring runs, including the Damariscotta River, the Orland River, the Androscoggin River, and the Presumpscot River. There are no rivers in Maine with a similar number of migrating river herring as the Sebasticook. In 2011, 2.7 million river herring were counted at the Benton Falls dam. Eagle aggregations should be expected to increase at other sites statewide in response to recovering fisheries. Due in part to the influence of the Kennebec River corridor, estuary, and associated resources, central Maine supports a respectable subpopulation of Maine's inland breeding eagles (MDIFW 2004, 2008).

Given clear evidence of short natal dispersal distances for Maine eagles (Millsap et al. 2014, BRI, unpublished data) and evidence that the Sebasticook attracts eagles from throughout the state, it can be expected that the number of eagles using the corridor may increase – possibly dramatically – over the next decade as eagle and fishery populations continue to recover.

Measurement Error in Aerial Surveys: As would be expected, aerial surveys of the Sebasticook River corridor detected fewer eagles compared to ground-based surveys. In Prince William Sound, Alaska, aerial surveys were estimated to detect 79% and 51% of 'observable' adult and subadult eagles, respectively (Bowman and Schempf 1999). That study also found that 21% of adult eagles were 'unavailable' for detection due to concealment from aircraft observers. After combining both types of biases, authors of that study determined that 62% of adult eagles were detected during surveys – and thus a visibility correction factor of 1.6 was developed. Studies in Chesapeake Bay derived higher correction factors than those estimated in Alaska (2.38, Buehler et al. 1991); however, a factor of 2.5 has also been suggested in Alasaka (Bowman and Schempf 1999). Authors in the Bowman and Schempf study noted their findings were most relevant to surveying eagles in coniferous coastal forests such as those in Alaska and British Columbia. Detection probabilities of eagles in our study will likely be higher before leaf out compared to Bowman and Schempf's estimates, and lower following leaf out in late May. We suspect leaf out, which was 100% for all but the first survey, significantly lessened the accuracy of both ground and especially aerial-based counts. Interestingly, a single helicopter survey conducted by Ed Friedman, Friends of Merrymeeting Bay, closely matched the ground survey data for that day. Other studies have reported higher measurement error during fixed-wing aerial surveys compared to minimal error during helicopter surveys to determine Osprey productivity (Ewins and Miller 1995). Unlike fixed-wing aircraft, low-level helicopter surveys often flush some eagles from perches ahead of the aircraft (C. Todd, MDIFW, pers. comm.), possibly increasing the detectability of some individuals that might otherwise be missed. Further efforts to develop a New England specific correction factor for aerial surveys that considers foliage coverage would improve the utility of aerial survey methodology for future research and management use.

Measurement Error in Ground-based Surveys: We have no means of estimating either perception bias or availability biases (Bowman and Schempf 1999) during our ground-based surveys. Observations during our study lead us to believe that ground-based eagle abundance estimates are underestimated due to several factors limiting eagle detection rates. Our study began before, and concluded well after leaf-out, which was noted as complete by at least 30 May. Following leaf-out, ground-based observers commonly noted eagles flying to perch sites that completely obscured them from view by foliage. Following our survey protocol, eagles that were not actually observed within a 3-minute observation session could not be counted. Therefore, in several cases, eagles known to be present (because they flew in/out or became visible during the scan period or between sessions) were not counted. Additionally, detection rates likely varied among some viewsheds due to differences in size (i.e., 5 and 6 are larger than 1, 2, or 10) or the number of habitual perching locations they contained. Habitual perches were commonly located near shallow water areas that presumably offered better foraging opportunities. Subadults were much more likely to escape detection due to inconspicuous plumage compared to adults (Bowman and Schempf 1999).

Ground-based survey estimates could be biased if eagles counted at one observation station left the viewshed and were subsequently counted during an observation session at a different observation station. Thus high mobility of eagles along the corridor could bias riverwide counts upwards – but only if they were detected elsewhere. While this presumably occurred occasionally, most eagles appeared to show fidelity to foraging and perching areas during observations and throughout the day. Overall, our counts showed little variability in the number of eagles counted during consecutive observation sessions (overall mean standard deviation of triplicate observation sessions: 0.78 eagles, 95% CI range: 0.64 – 0.88; n = 368 survey visits; n = 1,104 pooled sessions where ≥0 eagles were detected). The accuracy of riverwide survey counts likely decreases as the time required to survey the entire corridor increases. As a result, extended surveys may be less accurate compared to condensed surveys. Further efforts to estimate measurement error in ground-based surveys would help improve future estimations using this survey technique.

Survey Comparisons: Consistent with studies elsewhere, riverwide counts of eagles collected aerial surveys were notably lower compared to counts tallied during ground-based surveys. We note however, that our study was not designed to make rigorous comparisons of aerial vs. ground-based survey data. Notable differences existed in the amount of time required to conduct a full aerial survey (i.e., roughly 8-10 minutes) compared to a ground survey (roughly 2.5 hours for condensed surveys, 5 hours for extended surveys). Additionally, eagles outside established viewsheds (see methods) were not counted by ground-based observers; however, aerial surveyors had no such restrictions. Lastly, method comparisons assumed ground-based counts were the 'true' representation of eagles using the study area; however, similar to aerial surveys, ground-based surveys are also associated with unknown measurement error. Nonetheless, both methods estimated the total number of eagles along the entire river corridor study area, and no standardized surveys of eagle aggregations along this corridor have been previously conducted or documented. Findings from our coarse survey comparisons are consistent with studies elsewhere noting a substantial limitation in detecting eagles from aircraft. If we assume that ground-based riverwide surveys are relatively accurate, the application of the correction factor derived by Buehler et al. (1991) appeared to improve the accuracy of aerial survey counts. This correction factor is likely more appropriate for use in Maine compared to those developed in Alaskan coastal coniferous forests. Fixed-wing, helicopter, and ground-based survey methods are associated with differing advantages and disadvantages, including cost, safety, efficiency, and accuracy. We feel that, particularly if correction factors for aerial surveys can be developed, each survey method has value to wildlife management, research, and conservation efforts.

Abundance Summary: While the number of eagles not detected during surveys is unknown, we suspect that session and riverwide eagle counts were often underestimated due to detection limitations of observers related to foliage coverage. These limitations likely outweighed the potential for bias related to double-counting individuals between stations during riverwide counts. If we assume that ground-based survey counts underestimated the abundance of eagles by 10% and 20%, the maximum number of eagles counted riverwide during the peak survey day would have been approximately 72, and 78 individual eagles, respectively. While these estimates may provide insights on the number of eagles using the corridor on a single day, the number of eagles benefiting from the resource over the course of the fish run, or the entire year, remains unknown.

6.2 Timing and Relationship to Fish Abundance

We documented substantial shifts in eagle abundance throughout the survey period. In brief, relatively low overall numbers of eagles were detected riverwide (daily totals 2 – 6) early in the survey period (i.e. 1st two weeks of May). Starting roughly the third week of May, the number of eagles increased relatively consistently until reaching the daily peak on 12 June (65 eagles). This approximate level may have been maintained for a week before overall numbers counted began declining in the last week of June. The overall number of eagles ranged from 8 – 14 eagles from the end of June to mid July (18 July; our final survey).

The timing of the 2014 peak in daily fish passage occurred later than it has in recent years (3 May in 2010, 4 May in 2013, 6 May in 2009, 14 May in 2011) likely due to delayed warming of upstream waters. In 2014, river herring volume, as indexed by daily fish passage at the Benton Falls Dam, exceeded 50,000 fish per day by 11 May, four days after the facility began operating for the season. The observed numerical response of eagles lagged behind the bulk passage and peak of the river herring run. The peak eagle count (12 June) occurred 31 days after the peak in daily fish counts (18 May). Seventy-seven percent of individual eagle observations occurred between 29 May and 25 June, while 75% of the upstream migrating fish counted at the dam passed between 11 May and 29 May. If the upstream counts were a realistic representation of the prey density, this finding would be unexpected and contrary to findings reported elsewhere. Numerical responses of eagles and other raptors can respond synchronously to changes in food abundance depending on species' ecology, age class and mobility (Phelan and Robertson 1978). Restani et al. (2000) found numbers of migrant subadult eagles at Hauser Lake, Montana showed relative synchrony with the density of salmon carcasses compared to adult eagles. Eagles, particularly transient subadults, will regularly travel substantial distances in search of food, and they rely upon social mechanisms to relay information about the location of food resources (Stalmaster 1987, Knight and Skagen 1988).

We suspect the apparent time lag between the numerical response of eagles, and our measure of prey density, counts of upstream going river herring counted at the dam, can be explained by a significant abundance of post spawning, downstream migrating river herring that are not counted at the dam. Annual observations of downstream migrating river herring start increasing in number in early- to mid-June, around the same timeframe in which counts of daily upstream migrating river herring are notably decreasing (Nate Gray, Maine Department of Marine Resources, pers. comm.). Thus, counts of upstream migrating river herring at the dam do not adequately reflect local prey availability. If available, inclusion of downstream migrant river herring data in fish counts would likely result in a greater appearance of synchrony between overall fish availability and eagle abundance. Large numbers of upstream migrant river herring likely attract large numbers of eagles (i.e., 20- 40 daily) to the Sebasticook from late May to early June, after which point daily upstream river herring counts are declining rapidly. However, before declining prey availability causes eagles to start searching for food elsewhere, downstream river herring numbers increase and continue to attract more eagles to the area. Eagles' regular preference for obtaining food through piracy over direct foraging (Knight and Knight 1983, 1986, Stalmaster 1987, Knight and Skagen 1988, Bennetts et al. 1990) may prolong individuals' residence time in foraging areas even as food availability – in this case, upstream swimming river herring – starts to decline. Only counts of downstream migrating fish and functional response studies (i.e., measuring consumption rates) could clarify observed numerical response patterns and to measure the changes in prey availability (i.e., upstream and downstream fish) and its relationship with foraging eagles during June, July and beyond. The value of the Sebasticook to eagles can be assumed to extend well beyond the summer months associated with the upstream fish migration. For example, on 18 July, 2013, BRI biologists observed approximately 24 eagles from Observation station 2, and on 23 October, a Clinton citizen noted 1 adult and 12 subadult eagles near the Benton Falls Dam (E. Call/Peggy Blair, pers. comm.). Smaller aggregations of eagles are consistently observed in the area throughout July and into the fall. Given that the downstream river herring migration can extend well into November, eagles likely continue relying on downstream river herring and probably other species (i.e., waterbirds) attracted to fish runs.

6.3 Age Class Ratio

Both aerial and ground-based surveys elucidated a shift in the age ratio during the study period. Since the number of adults counted riverwide fluctuated minimally over the survey period in comparison to subadults, the observed shift in age ratio observed over the period can be assumed to be caused by an influx of subadults to the study area. Small numbers of adults (2 – 6) and no subadults characterized riverwide eagle counts during the first four surveys (2 – 8 May). Subadults arrived in small numbers (1 - 9) during the next 3 surveys (13 – 22 May). Subadults comprised ≥70% of daily eagles counted riverwide on all but one (27 June, 69% subadult) of the subsequent surveys between 23 May and 30 June, comprising 58% (n = 18) of all days surveyed.

An understanding of age ratios is an important aspect of population dynamics (Caughley 1977, Grier 1980). Findings in this study showing that subadults predominate the Sebasticook River eagle aggregation is consistent with numerous studies elsewhere (Stalmaster 1987, Buehler 2000). However, the season in which aggregations occur may influence the observed age ratio given the breeding season and other factors limit the mobility of breeders. Even during the autumn and early winter months when adult eagles are migrating, subadult eagles at Hauser Reservoir, Montana, still outnumbered adults by roughly two times (Restani et al. 2000). Perhaps most intriguing about our age ratio findings is the clear shift from an adult-dominated, low numerical count to a subadult-dominated count ranging up to 65 individuals. The observed shift from an adult-dominated age ratio to one dominated by subadults occurred approximately 4-10 days after the daily number of fish counted first exceeded 80,000, suggesting that subadults responded relatively quickly to the rapid change in food availability in the system. Subadult eagles in Montana were found to be more synchronous with prey density compared to adults (Restani et al. 2000). Maine subadult eagles are highly transient and show a strong fidelity to their natal region (Millsap et al. 2014, BRI, unpublished data). While a gap in our early survey coverage limits precise assessments, subadult numbers began to respond within ≤11 days of the rapid increase in food availability on the Sebasticook (Figure 4).

The general consistency in the overall number of adult eagles detected using the river corridor throughout counts likely reflects regular use by local resident and non-breeding eagles. Approximately 15 nesting territories lie within 15 km of the Sebasticook River, including three within our survey area. It is reasonable that a significant proportion of eagle pairs nesting within commuting distance to the Sebasticook can be presumed to rely heavily, if not exclusively, on the river corridor to feed themselves and their young (Harmata and Montopoli 2001). In addition to local resident eagles, a portion of adults likely represent non-breeders.

Non-breeders represent a component of a segment of the population referred to as 'floaters' (Penteriani et al. 2005, 2011). Floaters, which represent reproductively capable non-breeders, are increasingly the focus of developing conservation strategies because they are considered 'secretive presences' that reduce extinction risk of populations (Penteriani et al. 2011). Increased mortality in the floater population has been linked to negative influences on the stability of the breeding segment of Spanish Imperial Eagles (*Aquila adalberti*). This finding is consistent with previous research emphasizing that survival can be more important than reproduction in maintaining stable populations (Young 1968, Grier 1980). In addition to non-breeders, subadults also play an important role in population stability of eagle populations (Stalmaster 1987, Buehler 2000). Due to their demonstrated lower efficiency in finding food, subadults are more vulnerable to mortality, particularly during periods of food shortage (Stalmaster and Gessaman 1984, Knight and Skagen

1988). While traditional management approaches focused on the breeding sector of the population by increasing productivity through nest protection and other measures, current conservation strategies are increasingly focusing on protecting seasonally abundant food resources. During the breeding season, such areas are predominated by non-breeders and subadults. Increased conservation measures focusing on areas important to this sector of the population are critical in managing future population stability.

6.4 Habitat Use Patterns

Our two approaches to characterizing habitat use patterns of eagles along the corridor helped identify river reaches and specific land parcels associated with eagle use along the river corridor. Both analysis approaches found upstream stations to be the most commonly used by eagles along the corridor. Mid-river stations showed moderate use, while downstream stations showed comparatively lower use. Spatial clustering analyses of perch locations statistically identified specific riparian areas preferred by eagles for perching and presumed foraging.

Spatial habitat use information should be considered when prioritizing management and conservation measures aimed at benefiting eagles or other wildlife taking advantage of the seasonally abundant river herring fishery.

One notable exception to the generally high use at upstream stations was observation station 1, which was among the stations with the lowest overall number of eagle detections. This was not particularly surprising given the small size of this viewshed, as well as regular human activity in this vicinity by dam staff, commercial river herring harvesters, and the general public. Most likely, swift, deeper waters that deter foraging, and a general scarcity of perch trees along shorelines also deterred eagles from using this area, particularly when favorable perching and foraging characteristics existed immediately downstream. This station was included to account for a 'blind spot' in our survey coverage from observation station 2 in the area near the dam. A variety of factors likely coincide to cause eagles to emphasize the upstream portion of the river. First, given the number of fish migrating upstream commonly exceeds the capacity of the fish lift, a 'bottleneck' occurs in this region. Perhaps equally important, upstream reaches of the river often contain shallower, 'riffled' water that facilitates foraging and wading. Lastly, the upper reaches of the river contain a greater abundance of perching opportunities immediately adjacent to (<25 meters), or sometimes partially over the river.

Eagles were observed with the lowest frequency at stations 7 and 9; observations at these stations comprised only 3% (23/806) of overall observations used in analyses. Factors contributing to low usage within viewshed 7 may be explained by diminished prey accessibility and visibility due to water depth and lack of foraging perches. Lower eagle use in viewshed 9 is likely related to its proximity to an active breeding territory. We counted (but noted) eagles presumed or known to be associated with nest sites during surveys. Hotspot clusters associated with nests in observation stations 6 and 10 were almost exclusively a function of resident breeder activity; however, clusters on the shoreline opposite the nest visible from observation station 6 were often observed to be associated with subadults apparently tolerated by resident breeding pairs. Given the territorial nature of the species, shoreline nest sites in these two observation stations also likely explain the relative lack of activity in these regions beyond the nest site. The eagle nest visible from observation station 2 was set back from the shoreline and while visible, it was not included the viewshed. Adults from this nest were likely among those present along the river corridor, but only occasionally could they be distinguished from other individuals. One variable that may further explain lacking apparent perching of eagles along some sections of the river is the availability of perching habitat. This factor was suspected to moderate the numerical response for eagles on Hauser Reservoir, Montana (Restani et al. 2000). Removal of the Fort Halifax dam in 2008 exposed floodplain habitat that is now regenerating. Thus, the distance between perching trees and the shoreline in observation stations 4, 5, and 6 may deter eagles from perching there compared to other areas along the river where trees are closer to the shoreline. Overall, proximity to the dam, water depth and swiftness, and availability of perching trees along the shoreline likely all have strong influences on the spatial patterns of eagles observed along the Sebasticook. Efforts to identify important perching areas in this study provide a means of prioritizing habitats and parcels for conservation and should be noted by wildlife agencies and conservation organizations.

6.5 Identifying Roost Areas

Given the small sample size of satellite transmitter equipped individuals and the limited spatial (within 15 km of our river study area) and temporal (1 May to 30 September) scope of our roost analysis, it was unsurprising that we did not detect roosting locations along the Sebasticook. We elected to perform the analysis during this limited scope under the assumption that any potential roosts identified may be attributable to the abundance of prey availability in the lower Sebasticook River during the upstream (early May to early June) and downstream (late June to late October) river herring migration.

Bald Eagle populations in Maine may not display roosting characteristics similar to that of well-studied populations elsewhere. Seasonally abundant food supplies, which are considered to influence roost site selection (Keister Jr. and Anthony 1983, Stalmaster 1987, Gessaman and Wilson 2003), remain relatively rare in the state. Furthermore, while recovering and a New England stronghold, Maine's breeding eagle population remains a fraction in size compared to populations such as those in Chesapeake Bay or several western U.S. states often associated with notable communal or solitary roost sites (MDIFW 2008, Watts et al. 2008). A study of roost site selection in the Northern Chesapeake Bay area (Buehler et al. 1991*a*) found communal and solitary roosts averaged 2.82 and 2.0 km, respectively, from the nearest small river. Similarly, Knight and Knight (1983) found wintering eagles regularly utilized communal night roosts located ≤1.5 km from the river during chum salmon (*Oncorhynchus keta*) and coho salmon (*O. kisutch*) spawning events along the Noosack River in Washington.

Preliminary analyses of roost data in this study were the first conducted in the state; however, sample sizes were limited and the geographic extent of our analysis was small. Additional analyses at the statewide scale may reveal other more significant roost areas. We suspect the numerical response of eagles to the fish run will increase in parallel the recovering fishery. Such increases in food abundance on the Sebasticook and elsewhere may change the dynamics of the population over time such that individual and communal roosts may be identified in the area. Satellite telemetry represents one of the most practical means of learning about nocturnal and secretive behavior (Watts et al. 2008).

6.6 Productivity Evaluation of Local Resident Pairs

The three nests monitored along the Sebasticook River had favorable productivity (1.7 chicks per occupied nest), substantially above the level required to maintain stable populations. Nests in this region commonly display favorable productivity and probably act as a population source for the region. While we did not evaluate the diet of these pairs or conduct feeding studies, we did observe adults from each nest foraging in their respective territories, particularly for nest #1. Given the abundance of food available to them and the communal nature of foraging, we presume these pairs are almost exclusively feeding on river herring during the study period, and that non-limiting food resources during a significant portion of the chick rearing period played a significant role in the favorable productivity of these three nests. In addition to the benefits that food abundance plays for local pairs, consumers of river herring are also likely to have significantly lower levels of exposure to mercury compared to the majority individuals feeding on lakes and rivers throughout Maine (Welch 1994, Evers et al. 2005, Mierzykowski et al. 2013). Mercury is a persistent problem in Maine and other New England states, and Maine's inland eagle population contains some of the highest tissue mercury concentrations in North America (Welch 1994, DeSorbo and Evers 2006, Desorbo 2007, Desorbo et al. 2009). Thus, an increasing dietary emphasis on anadromous fisheries by eagles and other wildlife will lessen their exposure to the potentially harmful effects of mercury demonstrated in other species in Maine (Evers et al. 2008). Further efforts to evaluate productivity of breeding pairs of eagles and other fish-eating birds near abundant food resources may help further demonstrate the broad-reaching ecological influence of this fishery.

7.0 Conclusions and Recommendations

7.1 Conclusions

Using ground-based and aerial surveys, we collected information about eagle use of the Sebasticook River corridor that was previously lacking. While anecdotal observations commonly reported aggregations of several dozen eagles - most of them subadults - using the river, the number of eagles using the corridor has never been estimated. Additionally, no efforts have been made to determine the age ratio of eagles using the corridor, or to characterize their spatial and temporal use patterns. Information documenting eagle use patterns on the Sebasticook can be used to demonstrate its importance to the region's eagle population and promote conservation measures to protect the river herring fishery and fish-eating wildlife populations. Findings in our study documenting that the majority of eagles using the Sebasticook are subadults is an important finding given the key role this poorly studied age class plays in maintaining population stability. Efforts to boost survival of subadult and non-breeding eagles by protecting eagle aggregation areas and minimizing disturbance to foraging eagles are increasingly important components in developing wildlife management strategies. The Sebasticook River corridor hosts the most abundant river herring fishery in all of New England and loss of riparian habitat along its banks would likely be detrimental to fisheries and wildlife populations. While recreational use of the corridor appears to be moderate, notable increases in recreational activity during May – July could lessen eagles' inclination to feed. Alewives and blueback herring were recently considered for listing under the federal ESA and further measures to promote conservation of this fishery are warranted. Efforts in this study to identify habitats important to eagles are a key first step in prioritizing areas for conservation. Given its charismatic nature, regulatory priority, and public appeal, eagles offer an opportunity to educate the general public about fishing birds, anadromous fisheries and habitat conservation.

7.2 Recommendations

In their 2004 Bald Eagle Assessment, MDIFW outlined a goal to encourage and support restoration of anadromous fisheries in Maine. This goal recognizes links between functioning anadromous fisheries and eagle survivorship, key to population recovery and continued stability. Consistent with that goal, we the following recommendations were developed to promote conservation of eagle aggregation areas.

7.2.1 Shoreline habitat management

Bald eagles employ a "sit-and-wait" foraging strategy. The effectiveness of this strategy depends on site-specific factors including the availability of mature trees in shoreland zones. A study by Chandler et al. (1995) found that eagles in the Chesapeake Bay area used shoreline that had more suitable perch trees and more forested cover than unused areas, and that the distance from the shore to the nearest suitable perch tree was shorter for used shoreline segments than unused segments (see also Restani et al. 2000). Private landowners should consider leaving large mature trees standing, especially eastern white pines close to waterways. These trees provide important perch sites during foraging and can be used for nesting, roosting, and shelter. Even dead trees or those with a diameter >12 inches can provide perches for birds.

The National Bald Eagle Management Guidelines encourage land owners to “protect and preserve potential roost and nest sites by retaining mature trees and old growth stands, particularly within ½-mile from water” (USFWS 2007). Furthermore, in Maine, the Shoreland Zoning Act (38 MRSA §§435-449) provides guidelines for setbacks, vegetation clearing, and land uses within 250 feet of large water bodies. Activities in these riparian areas that permanently alter important foraging areas and communal roost sites may eliminate fundamental elements essential for feeding and sheltering eagles.

Preserving existing shoreline trees and other vegetation also serves to stabilize river banks and reduce sedimentation in streams supporting fish populations. Refraining from heavy application of lawn fertilizers on river-adjacent parcels and choosing phosphate-free fertilizer alternatives can help avoid nutrient loading and decreased concentrations of dissolved oxygen detrimental to fish.

7.2.2 Minimizing disturbance

While eagles vary in the degree to which they acclimate to human disturbance, several studies have demonstrated that eagles in some regions avoid areas frequented by humans (Stalmaster and Newman 1978, Knight and Knight 1984, Buehler et al. 1991*c*, McGarigal et al. 1991).

The Bald and Golden Eagle Protection Act of 1940 provides criminal penalties for disturbing eagles “to a degree that causes, or is likely to cause, based on best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.”

To avoid disturbance at important foraging areas, the National Bald Eagle Management Guidelines (2007) recommends avoiding recreational and commercial boating and fishing during peak feeding times (early- to mid-morning and late-afternoon) near critical foraging areas. Disturbance to eagles is typically correlated to noise level and distance (Buehler et al. 1991*c*, McGarigal et al. 1991, Stalmaster and Kaiser 1997). Eagles in Hancock Co, Maine, flushed at distances averaging 1,650 feet from intrusions (Matz 1997). Recreationalists using riparian habitat (i.e., fishing, boating) observing respectful noise and distance levels, particularly during peak periods of eagle activity, can significantly lessen disturbance to foraging eagles.

7.2.3 Marking powerlines

Bird collisions with transmission lines can be a detriment to local populations in areas of biological significance (Avian Power Line Interaction Committee [APLIC] 2006). Faanes (1987) asserts that “the greatest risk for eagle collisions with power lines exists in the mid-span area where power lines cross open expanses of river.” It is likely that the risk of collisions increases when birds are concentrated, such as in foraging areas. The National Bald Eagle Management Guidelines recommends employing industry-accepted best management practices to prevent eagles from colliding with or being electrocuted by utility lines, towers, and poles- and where possible, bury utility lines in important eagle areas.

Unmarked transmission lines cross the Sebasticook River at four locations in the study area. Perhaps most notably are the lines that cross at approximately 0.7 miles downstream from the Benton Falls Dam, along the Winslow-Benton town line. These lines cross the river between two heavily utilized foraging areas along the river. Birds are more susceptible to line strikes where lines cross movement corridors (Bevanger 1994, Manosa and Real 2001). Studies have shown that employing line markers can facilitate decreased collision mortality among birds (Barrientos et al. 2012, Sporer et al. 2013). We recommend the town of Winslow, Benton, and appropriate utilities explore options for marking these lines with industry-approved power line markers (i.e, P&R Tech BirdMark Flapper, P&R Tech Firefly Flapper, or the Preformed Line Products Swan Flight Diverter).

7.2.4 Data gaps and future survey efforts

Our study reasonably characterized eagle use of the Sebasticook River corridor in May – mid-July by collecting survey information 2-3 days per week in morning and early afternoon periods. Our study did not detect differences in the number of eagles detected due to time of day differences; however, due to the location of the field site from our housing (ca. 1.5 hrs), we did not conduct surveys prior to 8 am or after 3-4 pm. Other studies have found differences in eagle activity according to the time of day (Stalmaster 1987), and further investigation may be warranted. More importantly, use of the Sebasticook by eagles during mid-July through late April remains undocumented. Anecdotal reports indicate eagles continue using the Sebasticook well into the fall, likely in response to the downstream river herring migration, and smaller aggregations have been reported during winter months. Further efforts to characterize the year-round use of the corridor would help better characterize the overall ecological benefits of the corridor to resident and migrating eagles.

The river survey protocol we utilized lends itself well to a citizen-science based approach to support future survey and monitoring efforts. Several areas of Maine are currently being surveyed by organized citizen volunteers (the Maine River Bird Network), which can serve as a model for conducting further monitoring at eagle aggregation areas.

Findings from our study enable confident refinement in protocols in order to increase survey efficiency and accuracy. For example, our study found that we can conduct fewer observation sessions at observation stations with little compromise in data quality. We also identified areas with little or no eagle activity (Obsevation stations 1, 7, 9) that could be eliminated from surveys. We would also recommend minor changes in viewshed boundaries to lessen the area of larger viewsheds. Ultimately, surveys employing numerous observers conducting observations simultaneously would improve survey accuracy.

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