Riverbird distributions and habitat use

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Students determine habitat use by a variety of bird species associated with rivers. Students collect data on birds and habitats while traveling downriver in boats. They compare habitat structures used by each species relative to habitats available by estimating resource selection functions with the R open source statistical environment. Results can be used to compare habitat use among species, river reaches, river management regimes, or between river basins.

Description

Riverbirds are widespread components of river systems. Diverse riverbird species use riparian habitats in differing ways. Riverbirds are mobile, allowing them to respond rapidly to changing river conditions. Most riverbirds are positioned several trophic levels above direct impacts to river systems, facilitating their use as integrative measures of ecosystem responses to anthropogenic and non-anthropogenic impacts.

This project describes a simple sampling protocol, to support data collection on riverbirds and riparian habitats. Data are recorded while traveling down river in boats. The protocol can be implemented on multiple river reaches and along diverse rivers to facilitate comparisons or synthesis across river basis. Riverbird habitat use is analyzed using logistic regression. This approach is easier to conduct and involves less uncertainty than conventional methods using ratios of random variables (Manly et al. 2002, McDonald et al. 2012). Data and analyses in this project can be used in diverse contexts to evaluate restoration or riparian management programs.

Files:

1 Conceptual background

2 Instructions: field data collection

3 Instructions: data analysis

4 Riverbird data form

5 Habitat data form

6 Data analysis template

7 Example: riverbird data and analysis.

8 References cited

Student Learning Objectives

Field Learning Objectives

Improve field observation skills.

Develop bird identification skills.

Recognize habitat categories under field conditions.

Improve organizational ability in dynamic environments.

Data analysis Learning Objectives

Organize raw data into categories for analysis.

Become familiar with the R statistical environment.

Understand logistic regression models, resource selection functions, and how to fit them.

Ability to plot habitat selection functions for different species.

Understand model uncertainty, in numerical and graphical representations.

Ecology Learning Objectives

Develop conceptual understanding of riverbird-habitat relationships.

Develop recognition of species-specific differences in habitat use.

Develop stronger appreciation of structural diversity in riparian environments.

Recognize expression of riverbird-habitat relationships in field settings.
(i.e., discern patterns within complexity of nature)

Scientific Learning Objectives

Increased understanding of scientific inquiry.

Improved ability to translate questions into hypotheses and predictions.

Ability to interpret evidence for hypotheses: strong, weak, or contradictory.

Experiential knowledge about field science in practice.

Relevant for the following courses

Wildlife ecology, Freshwater biology, Ornithology, Behavioral ecology, Conservation biology, Restoration ecology

Appropriate for students at the following levels

Upper division students and graduate students

Lower division students with simplified data analysis. For example compare relative abundances among species or reaches; replace Resource Selection Function analysis with selection ratios or Chi-squared tests for selection among habitat types (McDonald et al. 2012).

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1 Conceptual Background

Birds are nearly ubiquitous in river systems. River-dependent bird abundances, distributions, and species composition vary across space and time in response to diverse drivers and causal pathways (Figure 1). Riverbird responses reveal changes in river systems and changes in the ecological functions performed by riverbirds. Identifying and delineating these changes are important to understanding riverbirds, river systems, and impacts of natural and anthropogenic drivers.

Many riverbird populations are in decline, reflecting anthropocene impacts on river habitats and food sources (Palmer 2004, Vorosmarty et al. 2010, Reid et al. 2018, Rosenberg et al. 2019). Worldwide, nearly 40% of riverbirds and other birds associated with aquatic habitats are declining, a fraction twice as large as the number increasing (Wetlands International 2012). Although waterbird populations are less threatened in North America, a third of species on the continent are declining (Wetlands International 2012), while many waterfowl are increasing (Rosenberg et al. 2019). Future changes in riverbirds are expected to result from changes in land use, riparian development, river restoration, and climate change (Northrup et al. 2018, Rosenberg et al. 2019, Adde et al. 2020a).

Detecting changes in riverbird populations requires collecting data on riverbird locations and abundances. Understanding those changes requires developing knowledge about riverbird habitat use. This research module provides a sampling protocol to collect riverbird and habitat data, and an analytical approach to quantify habitat use for each species. These results can be used to evaluate hypotheses about riverbird habitat relationships, riverbird responses to habitat changes, or effects of river management (Figure 1) at scales ranging from local reaches to multiple basins (Adde et al. 2020b).

Studying riverbird-habitat relationships has relevance beyond ornithology and behavioral ecology. Riverbirds also provide useful measures of effects of river restoration, habitat loss, contaminant impacts, and climate change (Silvy et al. 2012, Ogden et al. 2014a,b, McCaffery et al. 2018, Silverthorn et al. 2018, Adde et al. 2020a,b). Several factors make studying riverbirds broadly useful as measures of river system status and response. First, riverbirds are conspicuous and easy to detect. Second, pre-intervention baseline data often exist for riverbirds due to broad societal and scientific interest. Third, many mechanisms of riverbird habitat use are well-understood, which facilitates interpretation of riverbird responses. Fourth, riverbird habitat requirements correspond to conditions ranging from early to late stages in succession, suggesting that riverbirds may span several temporal scales in restoration or impact. Fifth, many riverbird species potentially occur in multiple river reaches and river basins, facilitating assessments across spatial scales (Weins et al. 2008). Sixth, because riverbirds function two or more trophic levels above primary producers (Figure 1), they represent an integrative measure of ecosystem status. Finally, broad public interest in riverbirds can translate into greater support for river monitoring, conservation, and restoration.

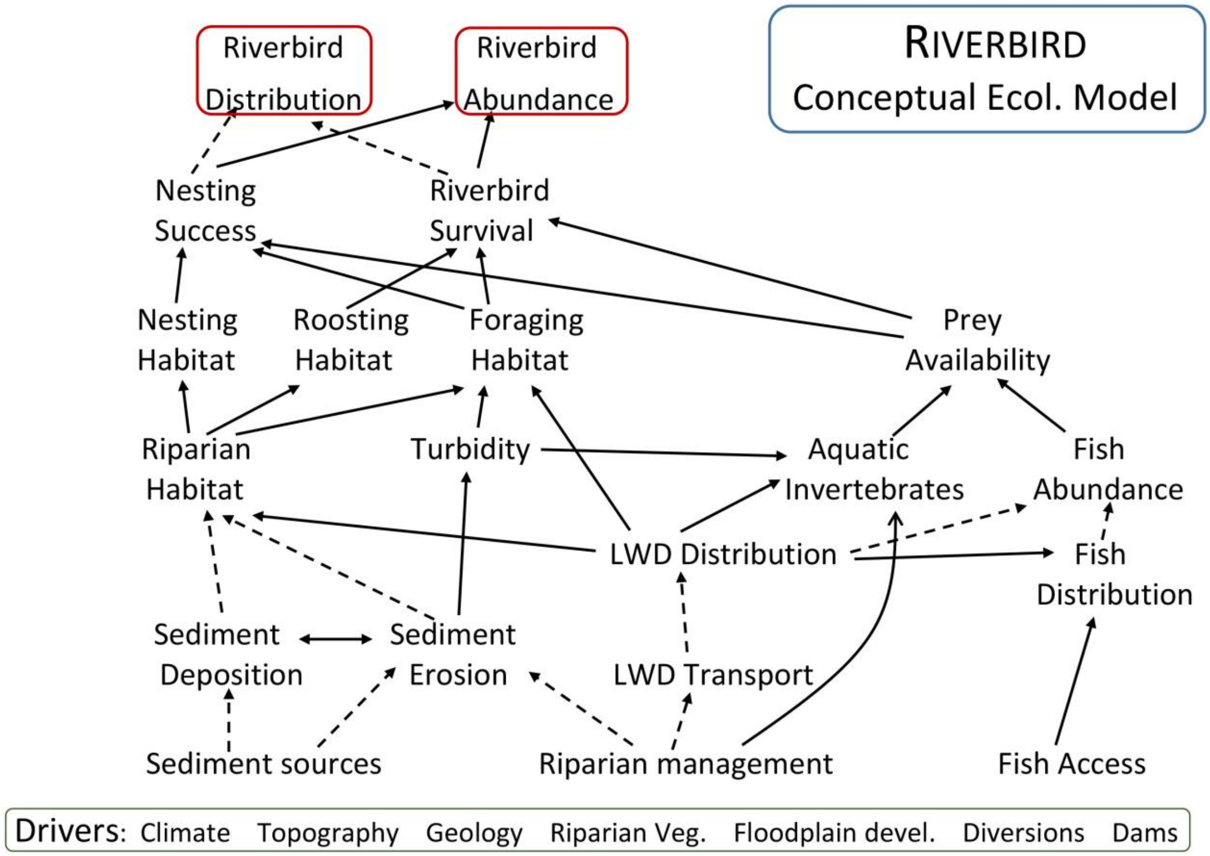

Figure 1. Riverbird conceptual ecological model, linking system drivers to riverbird responses. Direct and indirect links are identified with solid and dashed arrows. Many drivers, components, and links are omitted.

In this project, students will record riverbird locations and habitat types while traveling downriver in boats. These data can be used to estimate the following quantities.

(1) Counts of each riverbird species, an index of relative abundance for each species.

(2) Frequency that each riverbird species was detected in association each bank habitat type.

(3) Frequency that each riverbird species detected in each water surface type.

(4) Extent of each bank habitat type and each water surface type in the sampled reach.

These estimates can be used to compare riverbird relative abundances among species, reaches, or river basins. Frequencies of riverbird detections in each habitat type can be compared to extent of habitat available to determine habitat selection, as described in data analysis instructions. Habitat selection values can be used to evaluate hypotheses about riverbird responses to drivers of river system change, as depicted in the Conceptual Ecological Model, Figure 1. These comparisons and analyses require the following assumptions about data collection and riverbird behavior.

Assumptions in habitat use analysis

(1) Riverbirds are equally visible among habitat types.

(2) Riverbirds select habitat types independently of each other, within and between species.

(3) Riverbirds have access to the entire study area.

(4) Observers detect riverbirds before they flush; initial riverbird locations are not affected by observers.

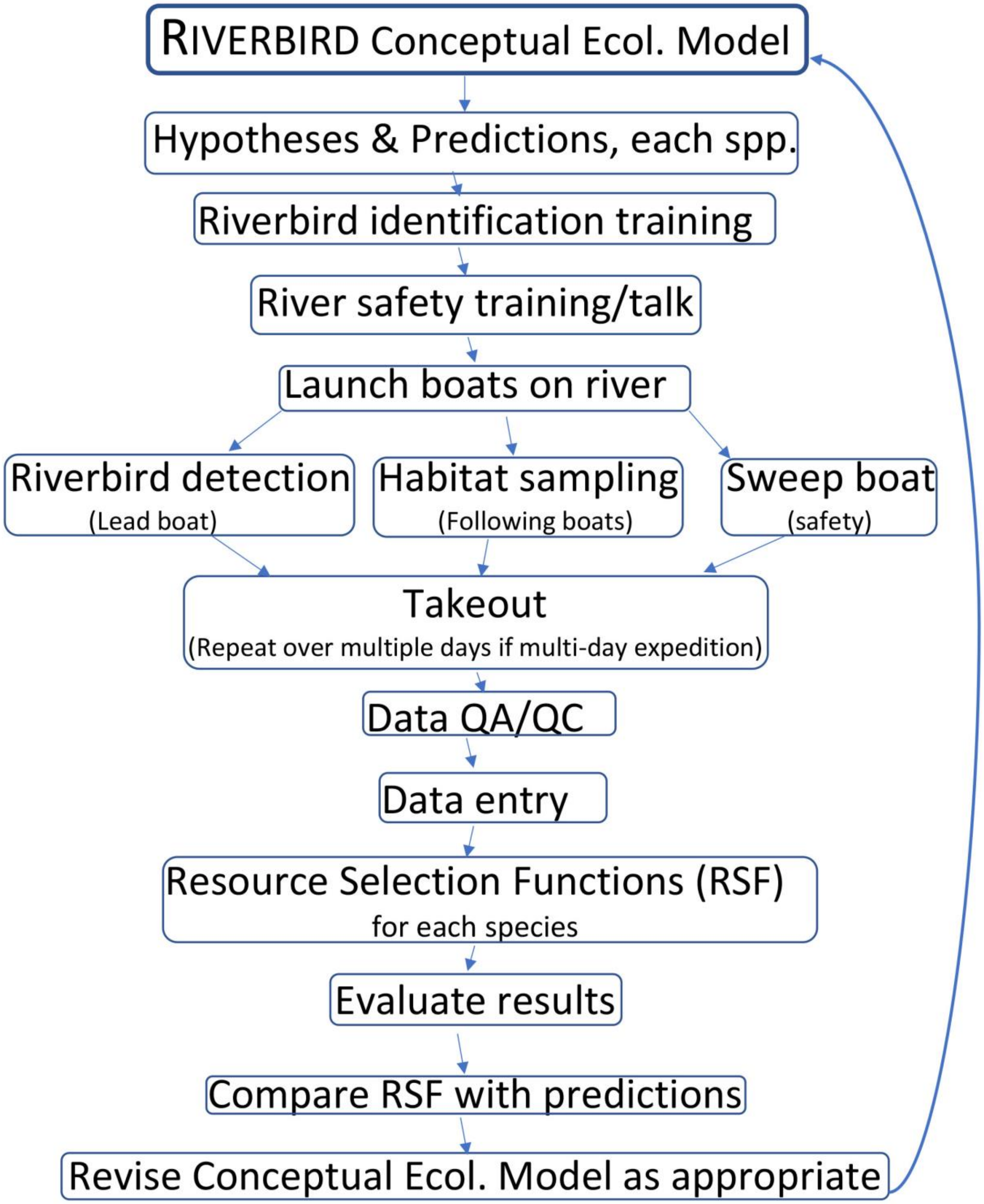

Figure 2. Riverbird research module schematic. The module can be implemented during a single-day sampling period or during multi-day river expeditions. Completing the module across multiple years or river basins facilitates study of temporal and spatial patterns in riverbird-habitat relationships.

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2 Field Instructions

Sampling Equipment

1 Stopwatch or other timing device
2 Data forms (paper or electronic)
3 Bird identification guide
4 GPS receiver
5 Binoculars

Preparation on land

1 Review identifying characteristics of each anticipated riverbird species.
    Give special attention to characteristics visible to the naked eye, when bird is in flight.
    (i.e., prepare to identify flushed birds that fly beyond view within seconds)

2 Assign recording tasks to each boat in the group, or multiple observers/recorders within each boat. The following assignments are needed:
    (1) Riverbird detections
    (2) Left bank habitat characteristics
    (3) Right bank habitat characteristics
    (4) River surface characteristics

Riverbird detections should be assigned to observers in the lead boat, to support accurate determination of original riverbird locations if boats flush birds.

3 Prepare all recording gear for use.

4 Record information at the top of bird and habitat data forms.

On the water

Riverbird observations

5 As your boat travels downriver, search for riverbirds on the river and along both left and right banks.

6 Whenever observers detect a riverbird, mark the habitat category on the data form where the bird was first observed. Mark both water and bank characteristics. If the bird was detected on the water, record characteristics of the bank closest to the bird. If the bank contains more than one habitat component, mark all relevant categories. For example, if logs lie along a forested bank with grasses at the waters edge, one would mark “LWD,” “Forest,” and “Herb” categories. Also record the river mile (km) or other location information, if known.

If the bird flushes as the boat approaches, try to determine the original location of the bird and record bank and river characteristics at that location.

Do not record “flyovers” – birds first observed flying up or down river.

7 Record each bird once only. If a bird flushes and lands downriver, do not record the bird’s new location.

8 If a group of multiple birds of a species are detected, record only one location for the group. (Locations of birds in a group are not independent. Recording location characteristics for multiple birds in a group would violate assumptions of independence among data points.)

9 Continue searching for riverbirds and recording habitat categories at detection locations until your group stops or decides to cease data collection. You will need at least 30 detections of a focal species, for confidence in results of your data analysis.

Habitat Sampling

10 After launching onto the river, select a random point or starting time (For example, select a 2-digit random number or 100^{ths} of a second on a stopwatch; start that many seconds downriver).

11 When your boat reaches the starting point or time, record (mark) on the habitat data form the water characteristic (calm, riffle, rapid) and habitat categories for left and right banks. Left and right are defined as river left and river right: directions as viewed while facing down river. If a bank contains more than one habitat component, mark all relevant categories. For example, if logs lie along a forested bank with grasses at the waters edge, one would mark “LWD,” “Forest,” and “Herb” categories. Also record the river mile (km) or other location information, if known.

12 While your boat continues to travel downriver, wait five minutes after your starting point or time.

13 After five minutes, record habitat categories (water surface, Left bank, Right bank) at the five minute point.

14 Repeat step 13 every five minutes as you travel downriver. Pause timing whenever your boat stops traveling downriver, e.g., during lunch breaks, scouting rapids, or stopping in eddies to wait for other boats.

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3 Data Analysis Instructions

Data analysis in brief

(1) Tally number of riverbird observations in each habitat, for each species.

(2) Tally number of observations for each habitat category, recorded at 5-minute intervals.

(3) Enter tallies of riverbird observations and habitat types into R.

(4) Create variables consisting of binary values (0,1) for each riverbird species and for each habitat category. Each variable should span all bird detection and habitat sampling locations.

(5) For each riverbird species, fit logistic regression models for each habitat category.

(6) Calculate the Resource Selection Function (RSF) for each riverbird species. Exponentiate coefficient values for each habitat category: exp(coefficient).

(7) Determine uncertainty in resource selection function values for each habitat type using standard error values for each habitat type coefficient.

(8) Plot the RSF with standard errors (or confidence intervals) for each riverbird species.

Data Entry

(1) Tally number of riverbird observations in each habitat, for each species.

(2) Tally number of observations for each habitat category, recorded at 5-minute intervals.

Data Analysis

(3) Enter tallies of riverbird observations and habitat types into R.

(4) Create variables consisting of binary values (0,1) for each riverbird species and for each habitat category. Each variable should span all bird detection and habitat sampling locations.

(5) For each riverbird species, fit logistic regression models for each habitat category.

(6) Exponentiate coefficient values for each habitat category: exp(coefficient).
The set of exponentiated coefficients for each habitat type is the resource selection function (RSF) for that riverbird species.

$RSF = \exp(\beta_i)$ where β_i is the logistic regression model coefficient for the i^{th} habitat type.

A value of 1 indicates no selection: the riverbird species was detected in that habitat type in equal proportion to the availability of that habitat type. Values larger than one indicate riverbirds selected that habitat type. Values less than one imply riverbirds tended to avoid that habitat type, i.e., they were detected in that habitat at lower proportion than its availability.

(7) Determine uncertainty in resource selection function values for each habitat type. RSF values plus or minus one standard error are given by the following expression.

$\exp(\beta_i \pm s_{\bar{X}})$ where β_i is the logistic regression model coefficient for the i[th] habitat type,
$s_{\bar{X}}$ is the standard error of β_i

95% confidence limits for RSF values are given by the following.

$\exp(\beta_i \pm 1.96\, s_{\bar{X}})$ where β_i is the logistic regression model coefficient for the i[th] habitat type,
$s_{\bar{X}}$ is the standard error of β_i

(8) Plot the RSF with standard errors (or confidence intervals) for each riverbird species.

Conducting the Data Analysis

Instructions and R commands for step (3) are in the data analysis template file.

After completing step (3) R commands for steps (4)-(8) can be copied from the template and pasted into R to complete the analysis. The commands also generate a plot of the RSF, with standard errors, similar to Figure 1.

An example of the entire analysis completed for Canada Goose data is in the data analysis example file.

Interpretation

The analysis outlined above applies field data to estimate a RSF for a riverbird species in an environment consisting of distinct habitat categories. The RSF is estimated from the data using logistic regression, which determines the ratio of probabilities for each habitat type: the probability that a riverbird species uses a habitat type relative to the probability that it does not use that habitat type (McDonald et al. 2012). When RSF=1, the riverbird was found in a given habitat type in the same proportion as that habitat is found in the study area. RSF=1 indicates the riverbird neither selects nor avoids that habitat type. RSF values larger than one indicates riverbirds selected that habitat type disproportionately often. Values less than one imply riverbirds tended to avoid a habitat type, i.e., they were detected in that habitat at a lower proportion than its availability. Note that RSF values are determined by exponentiating logistic regression coefficients (β_i). An RSF value of 1 is equivalent to $\beta_i = 0$. The magnitude of RSF values measure the strength of habitat selection or avoidance. If RSF=10 for a given habitat type, the riverbird species was found in that habitat ten times more often than would be expected by chance.

Confidence in conclusions about riverbird selection for or avoidance of habitat types depends on the magnitude of RSF values relative to uncertainty. In the context of statistical hypothesis testing, concluding riverbird selection or avoidance of a habitat type with (95%) confidence requires RSF values to be at least two (1.96) standard errors above or below 1. Alternatively, the logistic regression coefficient for a given habitat category must be at least two (1.96) standard errors above or below zero. In graphical form, this equivalent to the height of the RSF bar being at least twice the length of the standard error bar above or below 1. Figure 1 illustrates these results: Canada Geese strongly selected herbaceous habitat, strongly avoided shrub habitat, and were found on bare substrates at a rate that cannot be distinguished from availability with confidence. Similar conclusions can be drawn from logistic regression model results in the example analysis R transcript.

Although statistical hypothesis testing is informative, ecological interpretation of the analysis is more important. One should evaluate the magnitude of RSF values relative to the riverbird natural history, its ecological role in the river system, the distribution of habitat types, and the larger research questions motivating your project.

More information about using logistic regression to estimate Resource Selection Functions is in McDonald et al. (2012).

Additional Analyses to Consider

The analysis described above combines data on riverbird detections and habitat sampling to evaluate riverbird habitat selection. The data also could be used to assess riverbird abundances and distribution of habitat types. Habitat data collected following instructions in this module constitute a systematic sample with a random starting point. Hence the habitat data can be used as a representative sample of riparian habitat types in the study area. Riverbird detection data are counts that represent minimum estimates of study area abundances. During travel downriver, observers likely overlook some riverbirds. Consequently, count data provide an index of riverbird abundances in the study area. If one assumes that riverbird detection probability is equal among rivers, river reaches, or between years, then riverbird count data can be compared across space and time to draw inferences about riverbird responses to ecological differences, restoration programs, riparian management, or other factors. Below are suggestions for additional analyses that could be conducted with riverbird and habitat data.

(1) Compare riverbird abundances recorded in several river reaches with the amount of preferred habitat types recorded along those reaches.

(2) Compare abundances of different riverbird species with amounts of their preferred habitat types.

(3) Compare riverbird abundances and/or habitat type distributions among river reaches with differing riparian management practices.

(4) Apply data from multiple rivers to conduct (1)-(3) across multiple river basins.

(5) Apply data on riverbird abundances and habitat distributions collected over multiple years to evaluate effects of riparian restoration or changes in management practices.

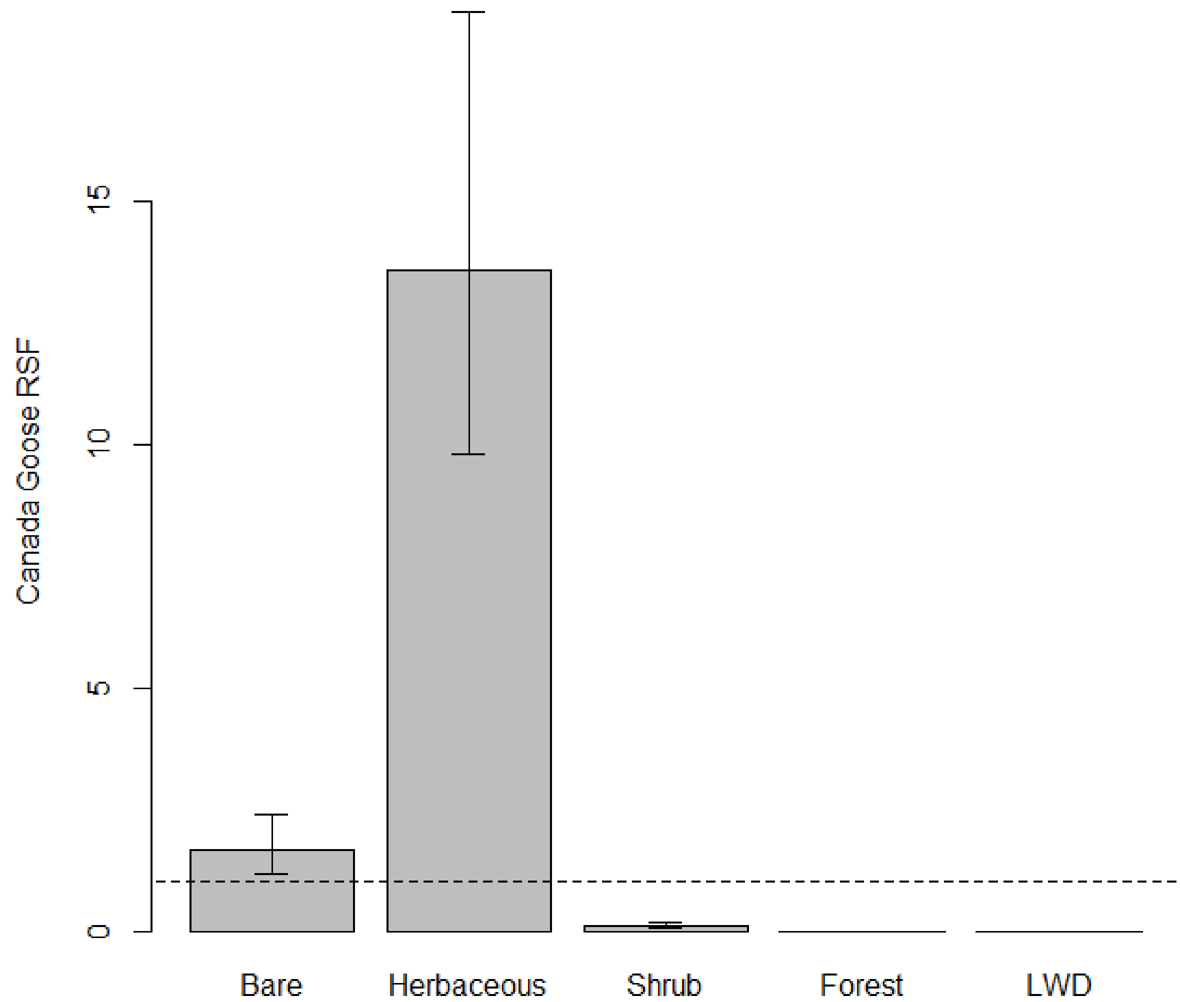

Figure 1. Resource Selection Function (RSF) for Canada Goose on the Grande Ronde River, May 2019. Bar heights are RSF values for each habitat type. The dashed line at RSF=1 is equivalent to habitat use at the same proportion as habitat availability, or no selection. Bars above 1 indicate selection for that habitat type, and bars below 1 indicate avoidance. Error bars are one standard error above and below RSF values. Error bars are asymmetric about the RSF bar height because the exponential function expands larger values more than smaller values.

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