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COVER: Northwest Territories BioBlitzes, 2017. See News and Comment, pages 386–396. Centre: spotting scope setup along the Boot Lake Trail in Inuvik illustrates the importance of BioBlitzes to children. Photo: Brenda Kostiuk. The inset photos (counter clockwise from top left) are: Narrow-leaved Saw-wort (*Saussurea angustifolia*), Red-necked Phalarope (*Phalaropus lobatus*), Prickly Rose (*Rosa acicularis*), Wood Frog (*Lithobates sylvaticus*), and the MacKenzie River shoreline. Photos: Paul Catling.

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# Autumn Raptor Migration in Yellowstone National Park, 2011–2015

LISA M. BARIL[1], DAVID B. HAINES[1], LAUREN E. WALKER[1, 2], and DOUGLAS W. SMITH[1]

[1]National Park Service, P.O. Box 168, Mammoth, Wyoming 82190 USA
[2]Corresponding author: lauren_walker@nps.gov

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Raptors are wide-ranging, vagile avian predators whose populations can be difficult and costly to monitor on their breeding or winter range. However, monitoring raptors during their annual northbound or southbound migration is a cost-effective and efficient alternative to time-intensive, single-species breeding surveys. In 2010, we observed numerous Swainson's Hawks (*Buteo swainsoni*) and Red-tailed Hawks (*Buteo jamaicensis*) migrating through the Hayden Valley in central Yellowstone National Park, prompting an investigation into raptor migration patterns in the park. Our objectives were to monitor annual autumn raptor migration in Hayden Valley from 2011 to 2015 and to determine the relative role of this undocumented migration site by comparing our observations to simultaneously collected migration data from three other sites in the Rocky Mountain Flyway. From 2011 to 2015, we observed 6441 raptors of 17 species across 170 d and 907 h of observation. Red-tailed Hawks, Swainson's Hawks, and Golden Eagles (*Aquila chrysaetos*) accounted for 51% of the total individuals observed over five years. Overall counts from Hayden Valley were comparable to counts from the three migration sites in the Rocky Mountains, although abundance of individual species varied by site. Data from this study suggest that Hayden Valley may serve as a stopover site for migrating raptors and presents an opportunity for future research. By improving our understanding of where raptors migrate and the characteristics of stopover areas in the Rocky Mountains, land managers may develop effective strategies for protecting raptor populations and habitat from threats including development and climate change.

Key Words: Migration; raptor; birds; Yellowstone National Park; Rocky Mountain Flyway; Wyoming

## Introduction

Raptors are wide-ranging, vagile avian predators whose populations are difficult and costly to monitor using time-intensive, single-species surveys on their breeding or wintering grounds. However, as raptors concentrate along mountainous ridgelines during their annual northbound or southbound migration, counts of multiple raptor populations can be conducted simultaneously by relatively few personnel. Thus, migration offers a unique opportunity to assess raptor populations in a relatively efficient and cost-effective manner (Bildstein *et al.* 2007). Each year, millions of raptors migrate from their breeding areas to wintering grounds following traditional migratory pathways throughout North America (McCarty and Bilstein 2005). Along these corridors, observers have identified hundreds, or even thousands, of raptors across multiple species in individual seasons (Hoffman and Smith 2003; Lott 2006). Over time, these data have been used to detect trends in populations of individual species (Farmer *et al.* 2007; Bildstein *et al.* 2008), determine changes in the timing of migration (Jaffré *et al.* 2013), and identify important migratory pathways (Bedrosian *et al.* 2015).

Migration requires raptors to navigate long-distances through potentially risky terrain (e.g., wind farms; Johnston *et al.* 2013) and locate stopover areas with reliable sources of prey (Pocewicz *et al.* 2013; Vardanis *et al.* 2016). Many raptors migrate across international and even continental boundaries (Kochert *et al.* 2011). For example, Swainson's Hawks (*Buteo swainsoni*) have one of the longest migration routes of any raptor in the world (Fuller *et al.* 1998; Bechard *et al.* 2010; Kochert *et al.* 2011). Each year tens of thousands of Swainson's Hawks leave their breeding grounds in west-central North America for wintering areas in the open grasslands or pampas of Argentina in South America, a roundtrip of over 20000 km (Bechard *et al.* 2010; Kochert *et al.* 2011). Even short-distance migrants such as Golden Eagle (*Aquila chrysaetos*) and Rough-legged Hawk (*Buteo lagopus*) cross international boundaries from breeding areas in Alaska and Canada to wintering grounds throughout the western United States and Mexico (Bechard and Swem 2002; McIntyre *et al.* 2008).

In 2010, we observed a large number of Swainson's Hawks and Red-tailed Hawks (*Buteo jamaicensis*) migrating through Hayden Valley in central Yellowstone National Park (YNP), prompting further interest in local migration patterns. While much is known about the migratory paths of raptors in the eastern USA (McCarty and Bildstein 2005), comparatively little is known about the migratory paths and stopover areas of raptors that use the Rocky Mountain Flyway (Hoffman and Smith 2003; Bedrosian *et al.* 2015; Craighead *et al.* 2016). The complex topography of the Rocky Mountains results in a broad migratory front as raptors are dispersed along competing ridgelines, making it difficult to assess migration patterns in this area (Fuller *et al.* 1998; Lott and Smith 2006; Craighead *et al.* 2016). Thus, we were broadly interested in both contributing to the general knowledge of autumn raptor migration within the Rocky Mountain Flyway and determining the particular importance, if any, of YNP to migrating raptors. In this study, our objectives were to 1) monitor the annual autumn raptor migration in Hayden Valley in central YNP from 2011 to 2015 and 2) learn how species diversity and the timing of autumn migration at this previously undocumented migration site compared with data collected during the same period at three additional migration sites in the Rocky Mountain Flyway.

## Study Area

We monitored raptor migration in the Hayden Valley of central YNP, Wyoming, USA (Figure 1) from atop a small hill approximately 0.5 km west of the road at 44.66°N, 110.47°W and at 2411 m elevation. The Hayden Valley is an approximately 75 $km^2$ subalpine valley located along the Yellowstone River. Vegetation in the bottomlands is dominated by Mountain Big Sagebrush (*Artemisia tridentata* var. *vaseyana* (Rydberg) B. Boivin), Silver Sagebrush (*Artemisia cana* Pursh), and Idaho Fescue (*Festuca idahoensis* Elmer), while Lodgepole Pine (*Pinus contorta* Douglas ex Loudon) dominates the uplands (Despain 1990). Climate in the region is characterized by short summers with an average temperature of 11.8°C during July and long cold winters with an average temperature of −10.8°C in December (Crait and Ben-David 2006). The region receives an average of 513 mm of annual precipitation, most of which falls as snow during the winter (Crait and Ben-David 2006).

Hayden Valley is a low-lying sagebrush steppe grassland bounded to the north by the east-west trending Washburn Range and by large forested plateaus on either side of the valley (Despain 1990). As many migration observation sites are located along mountain peaks and ridgelines (Hoffman and Smith 2003), Hayden Valley is distinctly atypical. Raptors migrating south through Hayden Valley in autumn must pass over the Washburn Range at a mean elevation of 2808 m before entering the valley. Although Hayden Valley may not provide the typical orographic uplift (lift provided by a steep elevational gradient such as the edge of a mountain range) that concentrates raptors at many migration observation sites, the river valley and surrounding topography may provide thermal lift as well as foraging opportunities that may appeal to migrating raptors (Bildstein *et al.* 2007). Thus, this site provides a unique and potentially valuable vantage point to monitor raptor migration in the western United States.

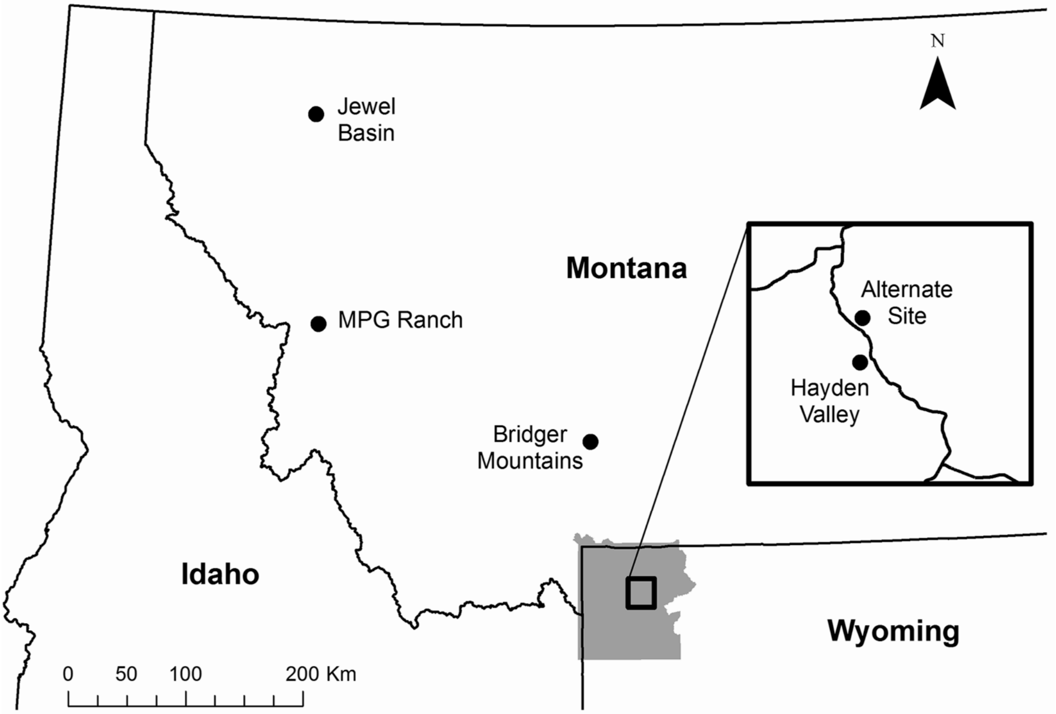

FIGURE 1. Location of raptor migration count sites in Yellowstone National Park (YNP; shaded grey), Wyoming, and three comparison sites in northern and western Montana. Exact locations of Hayden Valley count site and the alternate site are shown in the insert, along the Grand Loop Road through central YNP.

## Methods

### *Data Collection*

We monitored raptors during their southbound migration during September and October 2011–2015. Although the start and end dates varied by year, we generally began counts during the first week in September and continued through the third week in October. Beginning in late October, weather conditions in YNP generally prohibit travel throughout the southern portion of the park, including Hayden Valley. At the beginning of each autumn migration season, experienced counters trained observers in the field for a minimum of two weeks before observers were permitted to collect observation data on their own. Additionally, an experienced observer was present during counts at least three days per week and usually 4–5 days per week. We conducted counts a minimum of five days per week and observed for approximately 6 h per day, beginning at 1000 hours and ending at 1600 hours. Two to four primary observers conducted each daily count and dependent observers worked together to adequately cover the broad viewshed, avoid double-counting, and accurately identify raptors to species. On each count day, a single observer recorded all detections. We did not attempt to correct our observations for detectability. Occasionally additional observers joined the count efforts and the recorder noted this on the data sheet.

During each count, observers scanned the entire northern portion of the sky in a 180° arc and then scanned north in an up-and-down motion to cover the entire northern portion of the sky. Observers used 10×42 binoculars to detect raptors and a spotting scope with 20–60× magnification to identify individuals if necessary. We recorded all raptors observed moving past the site by species. Observers also scanned without optics, particularly when spotting raptors directly overhead or those close to the observation point. Observers recorded the start and end time of observation periods, which usually lasted the full day (6 h); however, occasional interruptions occurred as a result of weather (i.e., lightning, heavy rain, or snow) or wildlife (e.g., bears [*Ursus* spp.] or American Bison [*Bison bison*] near the count site). Observers also recorded weather data using a Kestrel 2500 Weather Meter (Nielsen-Kellermen, Chester, Pennsylvania, USA) at the start and end of each observation period, in addition to hourly intervals throughout the day. We collected weather data including sky condition (cloud type and percent cover), average wind speed (km/h), maximum wind speed (km/h), wind direction (degrees), temperature (°C), barometric pressure (mmHg), and an estimate of overall visibility distance (km) from the count site. For each hour of observation, observers also noted the number of observers, total number of minutes of observation for that hour, and primary horizontal movement of raptors (i.e., east, west, or overhead). At the end of each count day we summed the totals over all hours of observation and across all species. We also calculated the observer effort for each count day (the number of observers multiplied by the number of survey hours).

### *Data Analysis*

We summarized annual raptor counts and total observer effort (the sum of daily calculations of observer effort) for each study year. We also determined the average passage rate (the average number of raptors observed migrating over the count site per hour) for each of the five years and the average passage rate over the full time period. For species with more than 20 observations per year, we determined median and bulk passage dates over the five years. Bulk passage dates were defined as the range of dates between which the central 80% of the entire season's total for each species passed through the migration site (i.e., the first date is the date by which 10% of the season's cumulative sightings have been made and the last is the date by which 90% of the season's cumulative sightings have been made; Lott 2006).

Finally, we compared our migration count totals to counts from three additional sites in the Rocky Mountain Flyway, monitored during the same time period. All sites, including Jewel Basin, MPG Ranch, and Bridger Mountains, were located in Montana, USA, northwest of the Hayden Valley site (Figure 1). The three sites met the following criteria: 1) autumn migration data were collected from 2011 to 2015, 2) standard count procedures were used to collect migration data, and 3) permission was granted to use the data for comparisons with our dataset from YNP. To control for differences in the number of hours of observation among sites, and to make our data comparable to previous assessments of western raptor migration patterns (Hoffman and Smith 2003), we converted raptor observations to counts per 100 h of observation (raptors/100 observation hours = [total raptors counted/total hours of observation] × 100). We compared total raptor counts per 100 observation hours across all sites from 2011 to 2015 as well as counts per 100 h for ten of the most common species recorded at Hayden Valley.

## Results

### *Observation Effort and Count Totals*

We observed migrating raptors on a total of 170 d during September and October 2011–2015 with an average of 34 d per season (Table 1). On average, we observed migrating raptors for 181 h per season with observer effort (hours × observers) averaging 490 h per season.

The Hayden Valley count site posed numerous challenges during the study period. In 2011, the area surrounding the count site was closed as a result of two fatal Grizzly Bear (*Ursus arctos*) attacks. Therefore, we conducted all observations in 2011 from an alternate count site located approximately 4 km north in Hayden Valley (Figure 1). This alternate site had a similar view to our standard count site; although a small portion of

TABLE 1. Effort expended at the migration count site during 2011–2015 in Hayden Valley, Yellowstone National Park.

| | 2011 | 2012 | 2013 | 2014 | 2015 | Mean | Total |
|---|---|---|---|---|---|---|---|
| Days | 35 | 38 | 22 | 40 | 35 | 34 | 170 |
| Mean observers per day | 2.53 | 2.79 | 2.81 | 2.86 | 2.49 | 2.70 | 2.70 |
| # hours | 177 | 202 | 116 | 222 | 190 | 181 | 907 |
| Observer effort* | 448 | 564 | 326 | 636 | 474 | 490 | 2448 |

*Mean number of observers × number of hours of observation.

the western viewshed was blocked by a small hill in the foreground, a one-day comparison-count between the two sites revealed remarkable similarity in species' composition and abundance. We acknowledge a one-day comparison may not fully represent the variability between these sites; however, we feel our observations from the alternate site are comparable to what we would have observed from the regular Hayden Valley site and thus have included these data in our analyses.

From 2012 to 2015, we generally conducted counts from the standard count site. In 2012, however, several fires burning in Idaho and in YNP severely reduced visibility at the standard count site and contributed to poor observing conditions. The United States government sequestration (a shutdown of all non-essential government activities, including national parks) in 2013 prevented observers from data collection in Hayden Valley beginning 1 October, effectively ending the migration monitoring season three weeks early. Finally, in 2015, we occasionally counted migrating raptors from the alternate site due to high Grizzly Bear use in the area of the standard count site.

Despite these difficulties, observers recorded 6441 raptors belonging to 17 species (Table 2). Three species (Red-tailed Hawk, Swainson's Hawk, and Golden Eagle) accounted for about half (51%) of the total birds observed across all years. Red-tailed Hawk was by far the most numerous species across all years. We recorded fewer than 30 individuals per year for seven species of raptor, including Osprey (*Pandion haliaetus*), Turkey Vulture (*Cathartes aura*), Broad-winged Hawk (*Buteo platypterus*), Merlin (*Falco columbarius*), Northern Goshawk (*Accipiter gentilis*), Peregrine Falcon (*Falco peregrinus*), and Prairie Falcon (*Falco mexicanus*). Observers recorded the highest number of raptors in 2011 (*n* = 1846), most of which were Red-tailed Hawk, and the fewest in 2013 (*n* = 717).

### *Passage Rate and Timing*

The average passage rate over the five years was 7 birds/h (Figure 2). During any given observation day, however, passage rate was lowest during the first hour of observation, peaked between 1100–1300 hours as air temperature increased, and thermals likely developed, and then tapered the rest of the day (Figure 2). Average passage rate was highest in 2011 (9.9 birds/h) and lowest in 2012 (4.8 birds/h).

Only seven species occurred with enough frequency to calculate average median and bulk passage dates (Table 3). We excluded 2013 data from this analysis because there was a 20-day period during which no data were collected. The bulk of raptors (80%) migrated

TABLE 2. Annual total, mean, coefficient of variation (CV), and proportion of raptors observed migrating through Hayden Valley in Yellowstone National Park during 2011–2015. Raptor species are sorted from highest to lowest number of observations.

| Species | 2011 | 2012 | 2013 | 2014 | 2015 | Total | Mean | CV | % of Total |
|---|---|---|---|---|---|---|---|---|---|
| Red-tailed Hawk (*Buteo jamaicensis*) | 571 | 235 | 177 | 382 | 402 | 1767 | 353 | 74 | 27 |
| Swainson's Hawk (*Buteo swainsonii*) | 357 | 46 | 171 | 208 | 68 | 850 | 170 | 123 | 13 |
| Golden Eagle (*Aquila chrysaetos*) | 241 | 134 | 35 | 187 | 105 | 702 | 140 | 95 | 11 |
| American Kestrel (*Falco sparverius*) | 73 | 62 | 64 | 155 | 104 | 458 | 92 | 73 | 7 |
| Unidentified raptors | 198 | 44 | 19 | 80 | 102 | 443 | 89 | 133 | 7 |
| Sharp-shinned Hawk (*Accipiter striatus*) | 65 | 72 | 68 | 109 | 80 | 394 | 79 | 38 | 6 |
| Rough-legged Hawk (*Buteo lagopus*) | 70 | 130 | 23 | 108 | 61 | 392 | 78 | 90 | 6 |
| Northern Harrier (*Circus cyaneus*) | 55 | 30 | 27 | 119 | 131 | 362 | 72 | 117 | 6 |
| Bald Eagle (*Haliaeetus leucocephalus*) | 93 | 68 | 26 | 95 | 60 | 342 | 68 | 70 | 5 |
| Cooper's Hawk (*Accipiter cooperii*) | 31 | 32 | 28 | 75 | 85 | 251 | 50 | 94 | 4 |
| Ferruginous Hawk (*Buteo regalis*) | 34 | 20 | 32 | 29 | 10 | 125 | 25 | 66 | 2 |
| Osprey (*Pandion haliaetus*) | 12 | 14 | 18 | 22 | 11 | 77 | 15 | 49 | 1 |
| Turkey Vulture (*Cathartes aura*) | 9 | 22 | 0 | 29 | 2 | 62 | 12 | 171 | 1 |
| Broad-winged Hawk (*Buteo platypterus*) | 0 | 7 | 1 | 35 | 9 | 52 | 10 | 234 | 1 |
| Merlin (*Falco columbarius*) | 13 | 11 | 6 | 12 | 7 | 49 | 10 | 53 | 1 |
| Northern Goshawk (*Accipiter gentilis*) | 10 | 7 | 9 | 14 | 3 | 43 | 9 | 78 | 1 |
| Peregrine Falcon (*Falco peregrinus*) | 10 | 8 | 8 | 7 | 5 | 38 | 8 | 40 | 1 |
| Prairie Falcon (*Falco mexicanus*) | 4 | 11 | 5 | 11 | 3 | 34 | 7 | 96 | 1 |
| Total | 1846 | 953 | 717 | 1677 | 1248 | 6441 | 1288 | 62 | 100 |

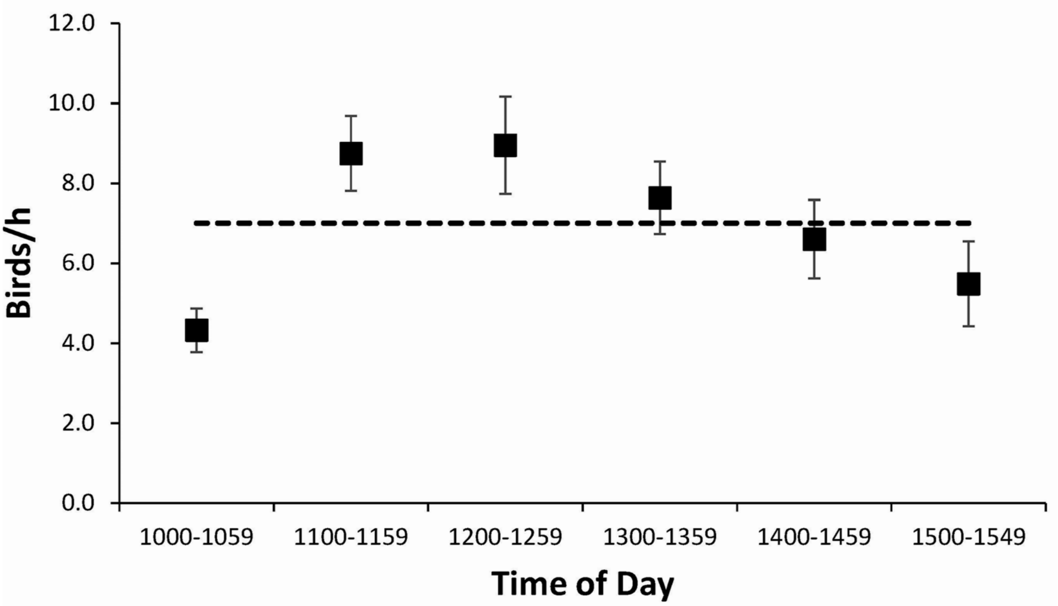

FIGURE 2. Mean hourly passage rate (birds/h) of raptors observed migrating through Hayden Valley in Yellowstone National Park during 2011–2015. Error bars are standard error and the horizontal dashed line is the overall average passage rate.

through Hayden Valley beginning in the first week in September through the third week in October. Although this roughly corresponds with our observation season, we saw a substantial decline in raptor observations by mid-October that suggests our season adequately captures the migration of most species through the study area. The bulk of Swainson's Hawks passed through the migration site during September. The bulk of Northern Harriers (*Circus cyaneus*), Red-tailed Hawks, Cooper's Hawks (*Accipiter cooperii*), and Sharp-shinned Hawks (*Accipiter striatus*) occurred from mid-September until mid-October. Golden Eagles and Rough-legged Hawks migrated primarily from early October through the end of our count period. Both Swainson's Hawks and Rough-legged Hawks exhibited the shortest duration of migration through Hayden Valley, while Sharp-shinned Hawks, Northern Harriers, and Red-tailed Hawks exhibited the longest migration through Hayden Valley.

### *Comparison to Other Migration Sites*

Mean counts of raptors per 100 h of observation at Hayden Valley were comparable to counts per 100 h of observation at MPG Ranch and the Bridger Mountains, while Jewel Basin surpassed all three sites (Table 4). For individual species, Hayden Valley exhibited the highest Swainson's Hawk, Rough-legged Hawk, Northern Harrier, Bald Eagle (*Haliaeetus leucocephalus*), Ferruginous Hawk (*Buteo regalis*), and Red-tailed Hawk counts after controlling for hours of observation (Table 5). The average number of American Kestrel (*Falco sparverius*) and Cooper's Hawk was somewhat comparable to the other sites, but far fewer Golden Eagles and Sharp-shinned Hawks migrated

TABLE 3. Bulk passage dates summarized from 2011–2015, including 80% passage date range and median date, for migrating raptors with more than 20 observations per year at Hayden Valley, Yellowstone National Park. Standard deviations (SD) are given for the number of days over which 80% of birds were observed and for the median passage date.

| Species | 80% passage dates | Days | SD | Median date | SD |
|---|---|---|---|---|---|
| Swainson's Hawk (*Buteo swainsonii*) | 7 Sep–19 Sep | 12 | 4 | 13 Sep | 5 |
| American Kestrel (*Falco sparverius*) | 8 Sep–30 Sep | 24 | 5 | 19 Sep | 3 |
| Northern Harrier (*Circus cyaneus*) | 10 Sep–13 Oct | 33 | 8 | 27 Sep | 5 |
| Cooper's Hawk (*Accipiter cooperii*) | 14 Sep–11 Oct | 27 | 7 | 28 Sep | 3 |
| Sharp-shinned Hawk (*Accipiter striatus*) | 11 Sep–18 Oct | 37 | 5 | 29 Sep | 4 |
| Red-tailed Hawk (*Buteo jamaicensis*) | 13 Sep–15 Oct | 32 | 7 | 5 Oct | 7 |
| Golden Eagle (*Aquila chrysaetos*) | 1 Oct–20 Oct | 20 | 5 | 10 Oct | 3 |
| Rough-legged Hawk (*Buteo lagopus*) | 10 Oct–22 Oct | 12 | 2 | 16 Oct | 4 |

TABLE 4. Total individual raptors counted per 100 hours of observation for four migration sites in the Rocky Mountain Flyway. Counts for Hayden Valley (this study) are shown in bold.

| Year | Jewel* | MPG† | Bridger‡ | **Hayden§** |
|---|---|---|---|---|
| 2011 | 889 | 498 | 696.0 | **1042** |
| 2012 | 831 | 570 | 680.0 | **472** |
| 2013 | 721 | 1175 | 689.0 | **618** |
| 2014 | 983 | 778 | 720.0 | **755** |
| 2015 | 1090 | 862 | 822.0 | **657** |
| Mean | 903 | 777 | 721.4 | **709** |

*Jewel Basin, Montana; data provided and used with permission by Daniel Casey (Flathead Audubon, Montana and American Bird Conservancy).
†MPG Ranch, Montana; data provided and used with permission by Adam Shreading (Raptor View Research).
‡Bridger Mountains, Montana; data provided and used with permission by Steve Hoffman (Montana Audubon and Hawkwatch International).
§Hayden Valley, Wyoming.

through Hayden Valley than the other sites, with the exception of Golden Eagles at MPG Ranch. Counts from Hayden Valley were most similar to MPG Ranch.

## Discussion

We conducted autumn counts of migrating raptors from 2011 to 2015 in Hayden Valley, Yellowstone National Park. Hayden Valley is a broad grassland river valley, atypical among migration observation sites. Furthermore, as the first effort to evaluate raptor migration in Yellowstone, this study helps fill both a geographic and topographic gap in our knowledge of raptor migration in the western United States. Our observations, including 6441 individuals belonging to 17 raptor species, were consistent to those from other migration count sites within the Rocky Mountain Flyway.

Our observations of bulk passage date indicate that, while our observation season likely captured the majority of autumn raptor migration, we may have truncated observations for some species by ending our season in late October. Several species, notably Rough-legged Hawks and Golden Eagles, were still migrating in the third week in October when our counts ended and may continue their migration through early December (McIntyre *et al.* 2008). Raptor observation in the southern portion of Yellowstone becomes logistically difficult after late October due to inclement weather and road closures. Additionally, both Rough-legged Hawks and Golden Eagles are residents in Yellowstone during the winter and it can be difficult to distinguish between migrants and residents in late autumn. However, extending the season into early November would be consistent with other autumn migration monitoring stations in the western United States (Hoffman and Smith 2003). Thus, we recommend that, if migration observation continues in Hayden Valley, future counts should consider a longer observation season, when possible, to better capture the migration patterns of all species. A longer observation season, combined with a long term dataset, may also help capture climate change effects on the timing of migration. For example, on Lake Superior, along the northern United States border, long spring and autumn migration monitoring periods revealed that the median raptor migration date advanced in spring and was delayed in autumn, and that these effects were particularly strong for short-distance migrants including Bald Eagle, Northern Harrier, and Sharp-shinned Hawk (Buskirk 2012).

During our study, a number of factors disrupted counts and resulted in inconsistent data collection methods. In 2011 and 2015, we were forced to count from an alternate site and, in 2012, fires reduced visibility and likely affected the overall count. In 2013, the United States government sequestration forced an early end to the season. Despite these factors, the number of raptors counted at Hayden Valley from the standard and alter-

TABLE 5. Raptor species counted per 100 hours of observation for four migration sites in the Rocky Mountain Flyway. Counts for Hayden Valley (this study) are shown in bold.

| Species | Jewel* | MPG† | Bridger‡ | **Hayden§** |
|---|---|---|---|---|
| Red-tailed Hawk (*Buteo jamaicensis*) | 72 | 190 | 64 | **195** |
| Swainson's Hawk (*Buteo swainsonii*) | 0 | 5 | 1 | **94** |
| Golden Eagle (*Aquila chrysaetos*) | 162 | 17 | 316 | **77** |
| American Kestrel (*Falco sparverius*) | 24 | 64 | 34 | **50** |
| Sharp-shinned Hawk (*Accipiter striatus*) | 412 | 98 | 125 | **43** |
| Rough-legged Hawk (*Buteo lagopus*) | 7 | 31 | 14 | **43** |
| Northern Harrier (*Circus cyaneus*) | 14 | 31 | 21 | **40** |
| Bald Eagle (*Haliaeetus leucocephalus*) | 15 | 16 | 21 | **38** |
| Cooper's Hawk (*Accipiter cooperii*) | 126 | 50 | 55 | **28** |
| Ferruginous Hawk (*Buteo regalis*) | 0 | 1 | 1 | **14** |

*Jewel Basin, Montana; data provided and used with permission by Daniel Casey (Flathead Audubon, Montana and American Bird Conservancy).
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§Hayden Valley, Wyoming.

nate count sites was similar to counts at the Bridger Mountains and the MPG Ranch monitoring sites. The relative abundance of individual species, however, varied by survey location, highlighting the importance of the information provided by this previously unmonitored migration site.

The number of Red-tailed Hawks was similar between Hayden Valley and the MPG Ranch, but was considerably higher than for Jewel Basin and the Bridger Mountains. While Swainson's Hawks were considerably more abundant at Hayden Valley than at the other three locations, fewer Golden Eagles were observed migrating through Hayden Valley than at Jewel Basin or the Bridger Mountains. The latter site was established primarily because of the large number of Golden Eagles observed migrating there (S. Hoffman, personal communication).

Golden Eagles rely more on orographic uplift during autumn migration than other raptors (Katzner *et al.* 2012). Because the Bridger Mountain site and the Jewel Basin migration site are located on a peak along a ridgeline, these sites are likely to offer more orographic lift than the low-lying Hayden Valley where thermals are more likely to develop (Katzner *et al.* 2012). Conversely, Red-tailed and Swainson's Hawks tend to rely more on thermal uplift (Preston and Beane 2009; Bechard *et al.* 2010), which probably explains the large number of those species observed in Hayden Valley. More buteos were observed migrating through Hayden Valley compared with the other comparison sites, suggesting that Hayden Valley may provide unique features required for some raptors and counts here may better represent migration patterns for these species.

In 2011, we observed the highest total number of raptors during the five years of surveys. This was surprising considering the viewshed at the alternate site was partially blocked to the west. We suspect, however, that at least some of the Swainson's and Red-tailed Hawks observed during 2011 were counted more than once. At the standard count site during subsequent years, observers noticed that as some raptors entered the valley from the north, they then descended into the valley and began making wide circular flights while foraging. From the standard count site, it was easier for observers to notice this pattern because the site was set farther back in the valley and the viewshed was larger. In the future, we may improve upon our count estimates and better detect differences among observation sites by conducting more rigorous counting protocols or analyses (e.g., independent observers or calculating detection probabilities).

Although foraging raptors may have led to an overestimation of the number of individuals passing through Hayden Valley in 2011, it also suggests that Hayden Valley may provide key foraging opportunities and serve as a valuable stopover location for migrating raptors. Stopover areas are important for raptors to rest, forage and replenish fat reserves, and to complete molt (Kirby *et al.* 2008; Kochert *et al.* 2011; Pocewicz *et al.* 2013; Craighead *et al.* 2016; Vardanis *et al.* 2016). Hayden Valley represents an undisturbed region within the Rocky Mountain Flyway in which raptors may recuperate after long flights. Although no formal studies have been conducted, observers witnessed numerous foraging events during most survey days, most commonly in the morning hours. Additionally, there appears to be an abundance of grasshoppers and other insects as well as a high small mammal population upon which Swainson's Hawks and other raptors may forage (Sherrod 1978; Schmutz *et al.* 1980; Johnson *et al.* 1987; Bednarz 1988; Woodbridge *et al.* 1995).

Migratory birds spend much of their annual life cycle travelling between their breeding grounds and wintering ranges, and migration can incur a high cost (Kirby *et al.* 2008). Mortality is six times greater during migration than during other times of the year, and time spent on migration accounts for half of all raptor mortality (Klaassen *et al.* 2014). Understanding where individual species migrate and identifying vital stopover areas is essential for developing effective management strategies for vulnerable or declining raptor populations. The data collected in this study may provide a baseline for comparison with future raptor migration studies. We found that a large number of raptors migrate through Hayden Valley in YNP during autumn and future investigations should further evaluate this region's importance as a stopover location for raptors using the Rocky Mountain Flyway, especially Swainson's Hawks and other buteos. Additionally, further collaboration among regional partners and landowners may help elucidate trends in raptor migration patterns throughout the Rocky Mountain region, identify key habitats that support migrating raptors, and develop more effective raptor management plans in the face of a developing landscape and warming climate.

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## Literature Cited

**Bechard, M. J.,** and **T. R. Swem.** 2002. Rough-legged Hawk (*Buteo lagopus*). *In* The Birds of North America Online. *Edited by* P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York. Accessed 16 October 2016. https://birdsna.org/Species-Account/bna/species/rolhaw.

**Bechard, M. J., C. S. Houston, J. H. Saransola,** and **A. S. England.** 2010. Swainson's Hawk (*Buteo swainsoni*). *In* The Birds of North America Online. *Edited by* P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York. Accessed 15 October 2016. https://birdsna.org/Species-Account/bna/species/swahaw.

**Bednarz, J. C.** 1988. A comparative study of the breeding ecology of Harris' and Swainson's hawks in southeastern New Mexico. The Condor 90: 311–323. https://doi.org/10.2307/1368559

**Bedrosian, B. E., S. L. Cain, S. Wolff,** and **D. J. Craighead.** 2015. Migratory pathways, timing, and home ranges of southern Greater Yellowstone Osprey. Journal of Raptor Research 49: 325–332. https://doi.org/10.3356/JRR-14-42.1

**Bildstein, K. L., J. P. Smith, E. Ruelas Inzunza,** and **R. R. Veit.** 2008. State of North America's Birds of Prey. Nuttall Ornithological Club and American Ornithologists' Union Series in Ornithology No. 3. Cambridge, Massachusetts and Washington, DC, USA.

**Bildstein, K. L., J. P. Smith,** and **R. Yosef.** 2007. Migration counts and monitoring. Pages 101–115 *in* Raptor Research and Management Techniques. *Edited by* D. M. Bird and K. L. Bildstein. Hancock House Publishers, Washington, DC, USA.

**Buskirk, J. V.** 2012. Changes in the annual cycle of North American raptors associated with recent shifts in migration timing. The Auk 129: 691–698. https://doi.org/10.1525/auk.2012.12061

**Craighead, D., R. H. Crandall, R. N. Smith,** and **S. L. Cain.** 2016. Migration of Red-tailed Hawks (*Buteo jamaicensis*) from northwest Wyoming. Wilson Journal of Ornithology 128: 150–158. https://doi.org/10.1676/wils-128-01-150-158.1

**Crait, J. R.,** and **M. Ben-David.** 2006. River otters in Yellowstone Lake depend on a declining cutthroat trout population. Journal of Mammalogy 87: 485–494. https://doi.org/10.1644/05-MAMM-A-205R1.1

**Despain, D.** 1990. Yellowstone vegetation: consequences of environment and history in a natural setting. Roberts Rinehart Press, Boulder, Colorado, USA.

**Farmer, C. J., D. J. T. Hussell,** and **D. Mizrahi.** 2007. Detecting population trends in migratory birds of prey. The Auk 124: 1047–1062. https://doi.org/10.1642/0004-8038(2007)124[1047:DPTIMB]2.0.CO;2

**Fuller, M. R., W. S. Seegar,** and **L. S. Schueck.** 1998. Routes and travel rates of migrating Peregrine Falcons *Falco peregrinus* and Swainson's Hawks *Buteo swainsoni* in the western hemisphere. Journal of Avian Biology 29: 433–440. https://doi.org/10.2307/3677162

**Hoffman, S. W.,** and **J. P. Smith.** 2003. Population trends of migratory raptors in western North America, 1977–2001. The Condor 105: 397–419. https://doi.org/10.1650/7146

**Jaffré, M., G. Beaugrand, É. Goberville, F. Jiguet, N. Kjellén,, G. Troost, P. J. Dubois, A. Leprêtre,** and **C. Luczak.** 2013. Long-term phenological shifts in raptor migration and climate. PLoS ONE 8: e79112. https://doi.org/10.1371/journal.pone.0079112

**Johnston, N. N., J. E. Bradley, A. C. Pomeroy,** and **K. A. Otter.** 2013. Flight paths of migrating Golden Eagles and the risk associated with wind energy development in the Rocky Mountains. Avian Conservation and Ecology 8(2): 12. https://doi.org/10.5751/ACE-00608-080212

**Johnson, C. G., L. A. Nickerson,** and **M. J. Bechard.** 1987. Grasshopper consumption and summer flocks of nonbreeding Swainson's Hawks. The Condor 89: 676–678. https://doi.org/10.2307/1368663

**Katzner, T. E., D. Brandes, T. Miller, M. Lanzone, C. Maisonneuve, J. A. Tremblay, R. Mulvihill,** and **G. T. Merovich, Jr.** 2012. Topography drives migratory flight altitude of Golden Eagles: implications for on-shore wind energy development. Journal of Applied Ecology 49: 1178–1186. https://doi.org/10.1111/j.1365-2664.2012.02185.x

**Kirby, J. S., A. J. Stattersfield, S. H. M. Butchart, M. I. Evans, R. F. A. Grimmett, V. R. Jones, J. O'Sullivan, G. M. Tucker,** and **I. Newton.** 2008. Key conservation issues for migratory land- and waterbird species on the world's major flyways. Bird Conservation International 18: S49–S73. https://doi.org/10.1017/S0959270908000439

**Klaassen, R. H. G., M. Hake, R. Strandberg, B. J. Koks, C. Trierweiler, K. Exo, F. Bairlein,** and **T. Alerstam.** 2014. When and where does mortality occur in migratory birds? Direct evidence from long-term satellite tracking of raptors. Journal of Animal Ecology 83: 176–184. https://doi.org/10.1111/1365-2656.12135

**Kochert, M. N., M. R. Fuller, L. S. Schueck, L. Bond, M. J. Bechard, B. Woodbridge, G. L. Holroyd, M. S. Martell,** and **U. Banasch.** 2011. Migration patterns, use of stopover areas, and austral summer movements of Swainson's Hawks. The Condor 113: 89–106. https://doi.org/10.1525/cond.2011.090243

**Lott, C. A.** 2006. A new raptor migration monitoring site in the Florida Keys: counts from 1999–2004. Journal of Raptor Research 40: 200–209. https://doi.org/10.3356/0892-1016(2006)40[200:ANRMMS]2.0.CO;2

**Lott, C. A.,** and **J. P. Smith.** 2006. A geographic-information-system approach to estimating the origin of migratory raptors in North America using stable hydrogen isotope ratios in feathers. The Auk 123: 822–835. https://doi.org/10.1642/0004-8038(2006)123[822:AGATET]2.0.CO;2

**McCarty, K.,** and **K. L. Bildstein.** 2005. Using autumn hawk watch to track raptor migration and to monitor populations of North American birds of prey. Pages 718–725 *in* Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference, Volume 2. *Edited by* C. J. Ralph and T. D. Rich. General Technical Report PSW-GTR-191. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California, USA.

**McIntyre, C. L., D. C. Douglas,** and **M. W. Collopy.** 2008. Movements of Golden Eagles (*Aquila chrysaetos*) from interior Alaska during their first year of independence. The Auk 125: 214–224. https://doi.org/10.1525/auk.2008.125.1.214

**Pocewicz, A., W. A. Estes-Zumpf, M. D. Andersen, H. E. Copeland, D. A. Keinath,** and **H. R. Griscom.** 2013. Modeling the distribution of migratory bird stopovers to inform landscape-scale siting of wind development. PLoS ONE 8: e75363. https://doi.org/10.1371/journal.pone.0075363

**Preston, C. R.,** and **R. D. Beane.** 2009. Red-tailed Hawk (*Buteo jamaicensis*). *In* The Birds of North America Online. *Edited by* P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York. Accessed 15 October 2016. https://birdsna.org/Species-Account/bna/species/rethaw.

**Schmutz, J. K., S. M. Schmutz,** and **D. A. Boag.** 1980. Coexistence of three species of hawks (*Buteo* spp.) in the prairie-parkland ecotone. Canadian Journal of Zoology 58: 1075–1089. https://doi.org/10.1139/z80-151

**Sherrod, S. K.** 1978. Diets of North American Falconiformes. Raptor Research 12: 49–121.

**Vardanis, Y., J. Nillson, R. H. G. Klaassen, R. Strandberg,** and **T. Alerstam.** 2016. Consistency in long-distance bird migration: contrasting patterns in time and space for two raptors. Animal Behavior 113: 177–187. https://doi.org/10.1016/j.anbehav.2015.12.014

**Woodbridge, B., K. K. Finley,** and **S. T. Seager.** 1995. An investigation of the Swainson's Hawk in Argentina. Journal of Raptor Research 29: 202–204.

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# Note

## Sora (*Porzana carolina*) Parasitism of Red-winged Blackbird (*Agelaius phoeniceus*) Nests

Lawrence D. Igl

United States Geological Survey, Northern Prairie Wildlife Research Center, 8711 37th Street SE, Jamestown, North Dakota 58401-7317 USA; email: ligl@usgs.gov

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Sora (*Porzana carolina*) is a conspecific brood parasite that also occasionally parasitizes nests of other species. Sora parasitism in nests of passerines is rare. Of 129 Red-winged Blackbird (*Agelaius phoeniceus*) nests found in North Dakota in 2009 and 2010, two (1.6%) were parasitized by Soras. The conditions favouring this rare parasitic behaviour may include competition for nest sites and high Sora density.

Key Words: Sora; *Porzana carolina*; Red-winged Blackbird; *Agelaius phoeniceus*; brood parasitism; North Dakota

### Introduction

Conspecific brood parasitism has been reported in various bird taxa and over 230 bird species (Davies 2000; Yom-Tov 2001; Lyon and Eadie 2008). This behaviour is more prevalent among avian species with precocial young than in species with altricial young (Rohwer and Freeman 1989; Lyon and Eadie 2008). Conspecific parasitism has been described in territorial rails, including Sora (*Porzana carolina*; Allen 1939; Sorenson 1995) and several species of moorhens (*Gallinula angulate, G. chloropus, G. galeata*; Gibbons 1986; Ueda *et al*. 1993; McRae 1996; Jamieson *et al.* 2000; Post and Seals 2000) and coots (*Fulica americana, F. armillata, F. atra*, *F. cristata, F. rufifrons*; Arnold 1987; Lyon 1993; Jamieson *et al.* 2000; Lyon and Eadie 2004; Samraoui and Samraoui 2007).

Although the extent of this reproductive behaviour in Soras is poorly known, Sora hosts are known to exhibit conspecific egg discrimination and rejection (Sorenson 1995), a rare defensive tactic to mitigate the costs of conspecific brood parasitism (Davies 2000; Lyon 2003). There are also reports of heterospecific brood parasitism in Soras, including Soras laying eggs in nests of other rail species, e.g., Virginia Rail (*Rallus limicola*; Tanner and Hendrickson 1954), King Rail (*R. elegans*; Swales 1896), and other rail species laying eggs in Sora nests, e.g., Virginia Rail (Miller 1928). Sora parasitism in nests of non-rallid taxa has been reported once (Gollop 1949). Here, I report the second and third records of Soras parasitizing nests of a passerine, Red-winged Blackbird (*Agelaius phoeniceus*).

### Observations

In 2009 and 2010, during a study of the immune system of the brood-parasitic Brown-headed Cowbird (*Molothrus ater*), observers located nests of a common cowbird host, the Red-winged Blackbird (hereafter redwing), at an experimental wetland facility maintained by the United States Geological Survey's Northern Prairie Wildlife Research Center, about 3 km east of Jamestown (46°53'N, 98°38'W) in south-central North Dakota.

The facility consisted of 20 constructed earthen wetlands arranged in a four by five array covering an upland and wetland area of 2.66 ha. Individual wetland cells were approximately 22 × 22 m (0.05 ha) in flooded surface area, 1.2 m in maximum depth, and contoured to a 1:4 basin slope. Wetland plant communities were well established in the experimental wetlands, and the dominant emergent was cattails (*Typha* spp.), which occurred mainly in dense monospecific stands. These wetlands were functioning much like natural semi-permanent prairie wetlands.

Between late May and early July in both 2009 and 2010, observers visited the experimental wetlands at 1–4 day intervals to locate active redwing nests. Nests were located by flushing females from nests while walking along the adjacent upland berms or wading into the flooded cattails of each wetland cell. Each cell was occupied by one or two territorial male redwings and one to four female redwings. Knowledge of behavioural cues of nesting redwings and the small size of the wetland cells allowed observers to find a large number of redwing nests: 129 total nests (56 in 2009 and 73 in 2010). Redwing nests were built 5–65 cm (average 34.3 cm) above the water in cattails. Water depth beneath redwing nests was 10–94 cm (average 38.2 cm). Cowbird parasitism in redwing nests was moderate (25%) in 2009 and low (< 5%) in 2010; such variation between years is not unusual (Igl and Johnson 2007).

Observers found 26 active Sora nests (14 in 2009 and 12 in 2010; up to three per wetland cell) incidentally while searching for redwing nests. Sora nests were crudely woven platforms constructed of cattail stalks and leaves and attached at the base of live and senescent cattails; the lips of the nest platforms were 3–12 cm (average 6.6 cm) above the standing water (nest cup depth was not measured). Water depth beneath Sora nests was 0–70 cm (average 26.1 cm). Sora nests contained 6–16 Sora eggs (average 8.3 eggs per clutch), although individual clutch sizes may have been underestimated if incomplete or partly hatched clutches were mistaken for full clutches. Most Sora nests were not systematically monitored after initial discovery.

Two (1.6%) of the 129 redwing nests contained the equivalent of full redwing clutches and a single Sora egg. During the morning of 7 June 2009, a female redwing was flushed from a nest containing five redwing eggs and one Sora egg (Figure 1). The Sora egg was not present six days earlier when this nest was first located with a single redwing egg. No Sora nests were located in this wetland cell in 2009, but Sora nests were found in three adjacent wetland cells that year. The nearest known Sora nest was about 27 m from the parasitized redwing nest and contained 16 Sora eggs, which is a large clutch for this species and may reflect conspecific parasitism by one or more Sora females. The parasitized redwing nest was 61 cm above the water, and the water depth beneath the nest was 94 cm. Cattail density in the vicinity of the nest was sparse. Both redwing eggs and the Sora egg were candled to determine viability and incubation stage and to estimate hatching dates (Weller 1956; Lokemoen and Koford 1996). Embryo development suggested that the redwing eggs and the Sora egg had been incubated for about three days, indicating that the Sora egg had been deposited before the host's clutch was completed. Using published estimates of incubation stages for the redwing (11–13 days; Yasukawa and Searcy 1995) and Sora (16–20 days; Melvin and Gibbs 2012), the hatching dates were estimated to be 14–16 June and 19–23 June for the redwing eggs and the Sora egg, respectively. These estimates were based on the assumption that the Sora's larger egg (Figure 1) would not interfere with the length of the incubation period for the redwing eggs or their hatchability.

After discovery of the Sora egg in this nest, the redwing nest was visited almost daily until its fate was known. By mid-morning on 15 June, three of the five redwing eggs had hatched. On 16 June, the nest contained four redwing nestlings, a redwing egg, and the Sora egg; candling on that day indicated that the Sora embryo was in an advanced stage of development. On 18 June, the remaining redwing egg was missing, but the Sora egg remained. On 22 June, the nest contained three redwing nestlings and half of a Sora eggshell with a slightly detached membrane, suggesting that the Sora egg had hatched. A dead Sora hatchling and a dead red-

FIGURE 1. Red-winged Blackbird (*Agelaius phoeniceus*) nest parasitized by a Sora (*Porzana carolina*) in June 2009 in south-central North Dakota. Photo: L. D. Igl.

wing nestling were found floating in the water beneath the nest. Neither had visible injuries, and it is uncertain why they were dispelled from the nest. The three remaining redwing nestlings fledged from the nest on 25 or 26 June.

On 19 June 2010, a redwing nest was found with one redwing egg, one Sora egg, and three redwing nestlings that were approximately nine days old. Both eggs were heavily encrusted with bird excrement. The nest was 46 cm above the water, and the water depth beneath it was about 70 cm. Candling revealed no evidence of embryo development in the redwing egg; the Sora egg appeared to be addled (fertile but decomposing). A Sora nest with eight eggs was located in the same wetland cell, about 2.5 m east of the parasitized redwing nest. On 21 June, three newly fledged redwing young were perched near the redwing nest. The redwing egg disappeared from the nest between 26 and 28 June, and the Sora egg disappeared on 29 or 30 June. This nest was about 150 m from the parasitized redwing nest found in 2009; there was no evidence (e.g., egg size, shape, maculation) to suggest that the two Sora eggs found in the redwing nests in 2009 and 2010 were laid by the same female Sora.

## Discussion

Reports of precocial species of rails laying eggs in nests of altricial or semi-altricial species are rare, e.g., American Coots (*F. americana*) parasitizing Least Bittern (*Ixobrychus exilis*) nests (Peer 2006); and Common Moorhen (*G. chloropus*) parasitizing Yellow Bittern (*I. sinensis*) nests (Ueda and Narui 2004). Reports of rails laying eggs in passerine nests are even rarer, with only two known cases previously reported in the literature. In South Carolina, Post and Seals (1989) found a Common Moorhen egg in a Boat-tailed Grackle (*Quiscalus major*) nest containing three host eggs. Gollop (1949) found a redwing nest with three host eggs and a Sora egg in southern Quebec. Given the numerous studies of redwing nesting biology in North America and the scarcity of similar parasitism records in the literature, Sora parasitism of redwing nests is undoubtedly rare.

Although Soras and redwings occupy the same marsh habitats during the breeding season, the two species have strikingly different nesting biologies and life history strategies, with little or no overlap in clutch size, nest type and location, nest dimensions and height, egg colour and size, onset and length of incubation, parental care, and discrimination of foreign eggs (Walkinshaw 1940, 1957; Yasukawa and Searcy 1995; Melvin and Gibbs 2012). The differences between the two species highlight the unusualness of these cases of heterospecific parasitism. Sora is a monogamous, solitary-nesting rail, and the redwing is a polygynous, colonial-nesting passerine. Redwings build open, cup-shaped nests 20–80 cm above the water surface in wetland emergent vegetation, and Soras build loosely woven nest platforms over shallow water. Soras typically lay 8–11 buff-coloured eggs (average length 32.0 mm, average breadth 22.8 mm) that are irregularly spotted with brown or russet (Figure 1). Redwings lay four or five pale blue-green to grey eggs (average length 24.7 cm, average breadth 17.8 cm) that are irregularly (sometimes heavily) marked with black or brown streaks, blotches, or spots (Figure 1). Sora eggs are incubated by both sexes for 16–20 days; incubation begins any time from the laying of the first egg to the ninth egg but at least three days before the last egg is laid, and hatching occurs asynchronously. Redwing eggs are incubated by the female only, usually beginning after the penultimate egg is laid, and eggs hatch asynchronously within 11–13 days after the onset of incubation. Newly hatched Sora chicks are precocial but semi-nidifugous, i.e., chicks may leave the nest within 24 h of hatching but generally do not leave the nest until 3–4 days after hatching unless disturbed. Redwing nestlings are altricial: chicks depart the nest 10–12 days after hatching.

Despite these differences, an observation of a female redwing accepting a Sora egg is not surprising. Although differences in egg appearance (i.e., shape, size, maculation, ultraviolet reflectance, brightness, colour) are used by many avian species to identify and remove heterospecific eggs from their nests (Rothstein 1974; Jackson 1998; Croston and Hauber 2014), previous experiments have shown that redwings invariably accept foreign and artificial eggs (Rothstein 1975; Røskaft *et al.* 1990), although they are capable of removing them (Ortega and Cruz 1988). In the northern Great Plains, redwing nests are moderately to heavily parasitized by Brown-headed Cowbirds, and the species is considered a preferred cowbird host in this region (Igl and Johnson 2007).

It is much easier to understand how a female redwing would accept a Sora egg in its nest than to explain why a female Sora would lay its egg in an elevated and dissimilar nest of a seemingly unsuitable non-rallid host. Several hypotheses have been proposed to explain parasitic egg-laying by conspecific parasites (Lyon 1993) and may be important to understanding these rare cases of heterospecific parasitism in the Sora. These hypotheses include: (1) floater females without nests or territories of their own may depend entirely on nesting females to raise their offspring; (2) nesting females who lose their nests during laying and have eggs ready to lay but no nest to lay them in may be forced to lay their eggs in nests of other females; (3) nesting females may delay their own nest initiation because of some constraint (e.g., condition of their mate or territory) and lay parasitically until conditions improve; or (4) nesting females can increase their immediate or lifetime reproduction and spread the risk of predation by laying surplus eggs in the nests of other females (Lyon 1993). These hypotheses overlap with the motivations proposed by Wiens (1971) to explain egg dumping, i.e., incidental laying of eggs in other species' nests. These hypotheses also reflect Sealy's (2015) interpretation of egg laying in nests of inappropriate, non-passerine hosts by Brown-headed Cowbirds.

Each of these hypotheses predicts a different pattern to the distribution and timing of parasitic or inappropriate egg laying. For Soras at this study site, observers did not record information on abundance, the presence of floater females, nest fate, constraints, or lifetime reproduction, and, thus, we lack a full understanding of these key hypotheses. However, high densities of Soras in these experimental ponds and competition for nest sites may have contributed to these rare cases of parasitism. The experimental ponds supported one of the highest nest densities of Soras reported in the literature: 14 and 12 nests/ha of wetland surface area in 2009 and 2010, respectively. Local density estimates for Sora pairs elsewhere range from 0.1 pairs/ha in central North Dakota (Kantrud and Stewart 1984) to 2.5 pairs/ha in northwest Iowa (Griese *et al.* 1980). In some waterfowl and colonial waterbird species, the probability of being parasitized by a conspecific increases with nest density (Rohwer and Freeman 1989; Petrie and Møller 1991; Fournier 2000). Competition for or limited availability of nest sites has been implicated in some parasitic laying by waterfowl (Sayler 1992).

Finally, although it is unlikely that redwings would provide the type of parental care needed to raise precocial Sora young successfully, these observations represent the first report of successful hatching of a Sora egg found in a redwing nest. In one of the parasitized redwing nests in this study, the Sora egg hatched six or seven days after the redwing eggs hatched. This is within the known incubation period for Sora (Melvin and Gibbs 2012). Previous experiments have shown that redwings are capable of prolonged incubation up to 13–14 days beyond their typical incubation period (Holcomb 1970, 1974). Other studies have reported icterid species hatching non-passerine eggs several days after the host eggs hatched. In Post and Seals' (1989) report of a Common Moorhen egg in a Boat-tailed Grackle nest, the moorhen egg hatched 10 days after the last grackle egg, and the moorhen chick jumped from the nest and swam away. Yasukawa (2010) reported a case of a female redwing hatching and feeding a Yellow-billed Cuckoo (*Coccyzus americanus*) chick, despite a 3- to 4-day delay in hatching of the cuckoo egg compared with the host eggs. Craik (2010) argued that, although mixed clutches of altricial and precocial eggs might seem incompatible, it is imprudent to assume that all unsuitable combinations are doomed to fail. Had the Sora chick survived in the above nest, it could have parasitized parental care from neighbouring conspecifics or its own biological parents (*sensu* Davies 2000). Conspecific parasitism is not particularly well studied in Sora, and the observations of heterospecific parasitism reported here raise additional questions and highlight the need for more studies regarding the factors influencing brood parasitism in this species.

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## Literature Cited

**Allen, A. A.** 1939. The Golden Plover and Other Birds. Comstock Publishing, Ithaca, New York, USA.

**Arnold, T. W.** 1987. Conspecific egg discrimination in American Coots. Condor 89: 675–676. https://doi.org/10.2307/1368662

**Craik, J. C. A.** 2010. Mixed clutches at seabird colonies in west Scotland 1996–2009. Seabird 23: 41–52.

**Croston, R.,** and **M. E. Hauber.** 2014. Spectral tuning and perceptual differences do not explain the rejection of brood parasitic eggs by American Robins (*Turdus migratorius*). Behavioral Ecology and Sociobiology 68: 351–362. https://doi.org/10.1007/s00265-013-1649-8

**Davies, N. B.** 2000. Cuckoos, Cowbirds and Other Cheats. T. and A. D. Poyser, London, United Kingdom.

**Fournier, M. A.** 2000. Incidents of mixed clutches among scaup and Ring-billed Gulls. Waterbirds 23: 114–116.

**Gibbons, D. W.** 1986. Brood parasitism and cooperative nesting in the Moorhen, *Gallinula chloropus*. Behavioral Ecology and Sociobiology 19: 221–232.

**Gollop, B.** 1949. Sora's egg in red-wing's nest. Canadian Field-Naturalist 63: 42. Accessed 20 March 2018. https://www.biodiversitylibrary.org/item/89254#page/52/mode/1up.

**Griese, H. J., R. A. Ryder,** and **C. E. Braun.** 1980. Spatial and temporal distribution of rails in Colorado. Wilson Bulletin 92: 96–102.

**Holcomb, L. C.** 1970. Prolonged incubation behaviour of the Red-winged Blackbird incubating several eggs sizes. Behaviour 36: 74–83. https://doi.org/10.1163/156853970X00051

**Holcomb, L. C.** 1974. Incubation constancy in the Red-winged Blackbird. Wilson Bulletin 86: 450–460.

**Igl, L. D.,** and **D. H. Johnson.** 2007. Brown-headed Cowbird, *Molothrus ater*, parasitism and abundance in the northern Great Plains. Canadian Field-Naturalist 121: 239–255. https://doi.org/10.22621/cfn.v121i3.471

**Jackson, W. M.** 1998. Egg discrimination and egg-color variability in the Northern Masked Weaver. Pages 407–416 *in* Parasitic Birds and Their Hosts: Studies in Coevolution. *Edited by* S. I. Rothstein and S. K. Robinson. Oxford University Press, New York, New York, USA.

**Jamieson, I. G., S. B. McRae, M. Trewby,** and **R. E. Simmons.** 2000. High rates of conspecific brood parasitism and egg rejection in coots and moorhens in ephemeral wetlands in Namibia. Auk 117: 250–255. https://doi.org/10.1642/0004-8038(2000)117[0250:HROCBP]2.0.CO;2

**Kantrud, H. A.,** and **R. E. Stewart.** 1984. Ecological distribution and crude density of breeding birds on prairie wetlands. Journal of Wildlife Management 48: 426–437. https://doi.org/10.2307/3801174

**Lokemoen, J. T.,** and **R. R. Koford.** 1996. Using candlers to determine the incubation stage of passerine eggs. Journal of Field Ornithology 67: 660–668.

**Lyon, B. E.** 1993. Conspecific brood parasitism as a flexible female reproductive tactic in American Coots. Animal Behaviour 46: 911–928. https://doi.org/10.1006/anbe.1993.1273

**Lyon, B. E.** 2003. Egg recognition and counting reduce costs of avian conspecific brood parasitism. Nature 422: 495–499. https://doi.org/10.1038/nature01505

**Lyon, B. E.,** and **J. McA. Eadie.** 2004. An obligate brood parasite trapped in the intraspecific arms race of its hosts. Nature 432: 390–393. https://doi.org/10.1038/nature03036

**Lyon, B. E.,** and **J. McA. Eadie.** 2008. Conspecific brood parasitism in birds: a life-history perspective. Annual Review of Ecology, Evolution, and Systematics 39: 343–363. https://doi.org/10.1146/annurev.ecolsys.39.110707.173354

**McRae, S. B.** 1996. Brood parasitism in the moorhen: brief encounters between parasites and hosts and the significance of an evening laying hour. Journal of Avian Biology 27: 311–320. https://doi.org/10.2307/3677262

**Melvin, S. M.,** and **J. P. Gibbs.** 2012. Sora (*Porzana carolina*). *In* The Birds of North America. *Edited by* P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.250

**Miller, R. F.** 1928. Virginia Rail lays in Sora's nest. Oologist 45: 132.

**Ortega, C. P.,** and **A. Cruz.** 1988. Mechanisms of egg acceptance by marsh-dwelling blackbirds. Condor 90: 349–358. https://doi.org/10.2307/1368563

**Peer, B. D.** 2006. American Coot parasitism on Least Bitterns. Wilson Journal of Ornithology 118: 415–418. https://doi.org/10.1676/05-096.1

**Petrie, M.,** and **A. P. Møller.** 1991. Laying eggs in others' nests: intraspecific brood parasitism in birds. Trends in Ecology & Evolution 6: 315–320. https://doi.org/10.1016/0169-5347(91)90038-Y

**Post, W.,** and **C. Seals.** 1989. Common Moorhen parasitizes a Boat-tailed Grackle nest. Wilson Bulletin 101: 508–509.

**Post, W.,** and **C. A. Seals.** 2000. Breeding biology of the Common Moorhen in an impounded cattail marsh. Journal of Field Ornithology 71: 437–442. https://doi.org/10.1648/0273-8570-71.3.437

**Rohwer, F. C.,** and **S. Freeman.** 1989. The distribution of conspecific nest parasitism in birds. Canadian Journal of Zoology 67: 239–253. https://doi.org/10.1139/z89-035

**Røskaft, E., G. H. Orians,** and **L. D. Beletsky.** 1990. Why do Red-winged Blackbirds accept eggs of Brown-headed Cowbirds? Evolutionary Ecology 4: 35–42. https://doi.org/10.1007/BF02270713

**Rothstein, S. I.** 1974. Mechanisms of avian egg recognition: possible learned and innate factors. Auk 91: 796–807. https://doi.org/10.2307/4084731

**Rothstein, S. I.** 1975. An experimental and teleonomic investigation of avian brood parasitism. Condor 77: 250–271. https://doi.org/10.2307/1366221

**Samraoui, F.,** and **B. Samraoui.** 2007. The reproductive ecology of the Common Coot (*Fulica atra*) in the Hauts Plateaux, Northeast Algeria. Waterbirds 30: 133–139. https://doi.org/10.1675/1524-4695(2007)030[0133:TREOTC]2.0.CO;2

**Sayler, R. D.** 1992. Ecology and evolution of brood parasitism in waterfowl. Pages 290–322 *in* Ecology and Management of Breeding Waterfowl. *Edited by* B. D. J. Batt, A. D. Afton, M. G. Anderson, D. D. Ankeny, D. H. Johnson, J. A. Kadlec, and G. L. Krapu. University of Minnesota Press, Minneapolis, Minnesota, USA.

**Sealy, S. G.** 2015. Egg laying in inappropriate nests by the Brown-headed Cowbird (*Molothrus ater*): acts of parasitism or emergency egg dumping? Canadian Field-Naturalist 129: 60–69. https://doi.org/10.22621/cfn.v129i1.1668

**Sorenson, M. D.** 1995. Evidence of conspecific nest parasitism and egg discrimination in the Sora. Condor 97: 819–821. https://doi.org/10.2307/1369192

**Swales, B. H.** 1896. A full set of rail's. Nidiologist 3: 142.

**Tanner, W. D.,** and **G. O. Hendrickson.** 1954. Ecology of the Virginia Rail in Clay County, Iowa. Iowa Bird Life 24: 65–70.

**Ueda, K.,** and **Y. Narui.** 2004. A new breeding tactic of the Common Moorhen: interspecific brood parasitism of bittern nests. Ornithological Science 3: 163–166. https://doi.org/10.2326/osj.3.163

**Ueda, K., H. Uchida,** and **T. Matsuda.** 1993. Egg-dumping by the Moorhen, *Gallinula chloropus*, in Japan. Japanese Journal of Ornithology 42: 21–25. https://doi.org/10.3838/jjo.42.21

**Walkinshaw, L. H.** 1940. Summer life of the Sora rail. Auk 57: 153–168. https://doi.org/10.2307/4078743

**Walkinshaw, L. H.** 1957. Incubation period of the Sora rail. Auk 74: 496. https://doi.org/10.2307/4081750

**Wiens, J. A.** 1971. "Egg-dumping" by the Grasshopper Sparrow in a Savannah Sparrow nest. Auk 88: 185–186. https://doi.org/10.2307/4083990

**Weller, M. W.** 1956. A simple field candler for waterfowl eggs. Journal of Wildlife Management 20: 111–113. https://doi.org/10.2307/3797414

**Yasukawa, K.** 2010. Yellow-billed Cuckoo hatched and fed by a Red-winged Blackbird. Wilson Journal of Ornithology 122: 402–405. https://doi.org/10.1676/09-132.1

**Yasukawa, K.,** and **W. A. Searcy.** 1995. Red-winged Blackbird (*Agelaius phoeniceus*). *In* The Birds of North America. *Edited by* P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.184

**Yom-Tov, Y.** 2001. An updated list and some comments on the occurrence of intraspecific nest parasitism in birds. Ibis 143: 133–143. https://doi.org/10.1111/j.1474-919X.2001.tb04177.x

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# Changes to the Population Status of Horned Grebes (*Podiceps auritus*) and Red-necked Grebes (*Podiceps grisegena*) in Southwestern Manitoba, Canada

GORD HAMMELL

P.O. Box 37, Erickson, Manitoba R0J 0P0 Canada; email: gmhammell@gmail.com

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Continental trend data for North America suggest that Horned Grebe (*Podiceps auritus*) breeding populations are declining and Red-necked Grebe (*P. grisegena*) populations are increasing. However, data reliability is low due to lack of survey routes in the northern boreal and taiga ecozones, areas encompassing much of the breeding range of both species. Locally in the southern Manitoba prairie ecozone, reliability of long-term trend data is also considered low and these data suggest that Horned Grebe populations are declining faster than the continental trend and that Red-necked Grebe populations are increasing rapidly. The lack of current quantitative information on population densities of these two species in southern Manitoba prompted me to compare 1970s historical data from two sites to recent data collected at the same locations in 2008–2016. I surveyed 42 (1970–1972) and 38 (2008–2016), and 144 (2009–2015) Class III-V wetlands at Erickson and Minnedosa, Manitoba, respectively. Historical Minnedosa data were available from previous field studies. At both locations, Horned Grebe breeding populations have fallen significantly, and Red-necked Grebe populations have risen significantly since the 1970s. The results of this study corroborate the Breeding Bird Survey's trend data for Horned and Red-necked Grebes in southwestern Manitoba pothole habitat.

Key Words: Horned Grebe; *Podiceps auritus*; Red-necked Grebe; *Podiceps grisegena*; Manitoba prairie-potholes; species at risk; population status

## Introduction

Horned Grebes (*Podiceps auritus*) and Red-necked Grebes (*P. grisegena*) are highly-specialized waterbirds that nest over-water in or near emergent vegetation on semi-permanent or permanent ponds. Horned Grebes prefer small (less than 2 ha) open-water wetlands for nest sites in Manitoba, Saskatchewan, and North Dakota (Faaborg 1976; Sugden 1977; Ferguson and Sealy 1983) whereas the larger Red-necked Grebe usually occupy wetlands greater than 2 ha (Riske 1976 as cited in Stout and Nuechterlein 1999; De Smet 1983 as cited in Stout and Nuechterlein 1999; the current study; but see Fournier and Hines 1998). For both species, males and females are similar in appearance and difficult to distinguish in the field. They are intra- and inter-specifically territorial. Both species have Holarctic distributions and, in North America, the majority of their populations have a similar breeding range, extending from northwestern Ontario and the northwestern United States to the Northwest Territories and Alaska (Stout and Nuechterlein 1999; Stedman 2000). The Horned Grebe Western population is listed as special concern but the small (less than 15 birds), disjunct Magdalen Island population in the Gulf of St. Lawrence is listed as endangered under the *Species at Risk Act* following their 2009 assessments by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; SARA Registry 2017a,b). Red-necked Grebe was last assessed by COSEWIC in 1982 as 'not at risk' (SARA Registry 2017c). Although the reproduction and behaviour of the species have been studied extensively in Eurasia and North America (Stout and Nuechterlein 1999; Stedman 2000; Klatt 2003; Nuechterlein *et al.* 2003; Klatt *et al.* 2004; Kuczynski *et al.* 2012), accurate information on population trends for breeding and wintering populations in North America is still lacking (Stout and Nuechterlein 1999; Stedman 2000; COSEWIC 2009). Breeding Bird Survey (BBS) data suggest continental declines for Horned Grebe and increases for Red-necked Grebe (yearly % change 1966–2015: Horned Grebe −0.47, Red-necked Grebe +0.65; Sauer *et al.* 2017). But BBS data have limited value, as much of the breeding range of both species lies in the northern boreal and taiga ecozones, areas with few BBS survey routes. Thus, potential data are missing and results are biased towards southern prairie-parkland populations (COSEWIC 2009).

Locally in the parklands of southern Manitoba, the reliability of BBS data for Horned Grebe and Red-necked Grebe are considered low due to small sample sizes but the data suggest that Horned Grebe populations are decreasing and Red-necked Grebe populations are increasing (Manitoba Prairie-potholes long-term trend 1970–2015 yearly % change: Horned Grebe −2.94; Red-necked Grebe +10.7; Environment and Climate Change Canada 2017). No corroborative, multi-year studies of reproduction have been conducted in this area in over 30 years (Ferguson and Sealy 1983;

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De Smet 1987). Intensive monitoring at a local scale can provide additional trend information, and in conjunction with landscape data (e.g., BBS), may allow more accurate decisions regarding the need for possible intervention (e.g., small wetland construction for Horned Grebe; Kuczynski *et al.* 2012). Accordingly, personal anecdotal evidence suggesting changes in grebe populations in southwestern Manitoba and the lack of current quantitative information prompted me to examine the extent of any change. I took advantage of historical data from two locations in southwestern Manitoba (Erickson and Minnedosa) and compared these data to those collected in 2008–2016 at the same locations.

## Study Area

The study areas are in the parkland pothole region of southwestern Manitoba (Figure 1). The topography of the region is rolling hills with numerous ponds and lakes; the uplands are a mixture of cereal and oilseed crops, hay, pasture, and native woodland (mainly poplars, *Populus* spp.). The Erickson study area (50.470351°N, 99.895847°W) consists of a 6.8 km² area established by the author in 1970, and contained 12 seasonal (Class III: 0.4 ± 0.3 ha, 0.1–1.3 [average ± SD, range]), seven semi-permanent (Class IV: 0.5 ± 0.3 ha, 0.2–0.9), and 23 permanent (Class V: 2.0 ± 2.3 ha, 0.1–8.7 [18 natural, five constructed dugouts]) wetlands during 1970–1972 (~ 6 wetlands/km²; classification according to Stewart and Kantrud [1971]). In 2008–2016, two Class III and two small Class V wetlands (dugouts) had been lost due to draining or filling. The 7.1 km² Minnedosa study area (50.125001°N, 99.844663°W), established in 2009 by the author, is about 27 km south of the Erickson site and is a 17.7 km × 0.4 km roadside transect (0.2 km either side) and

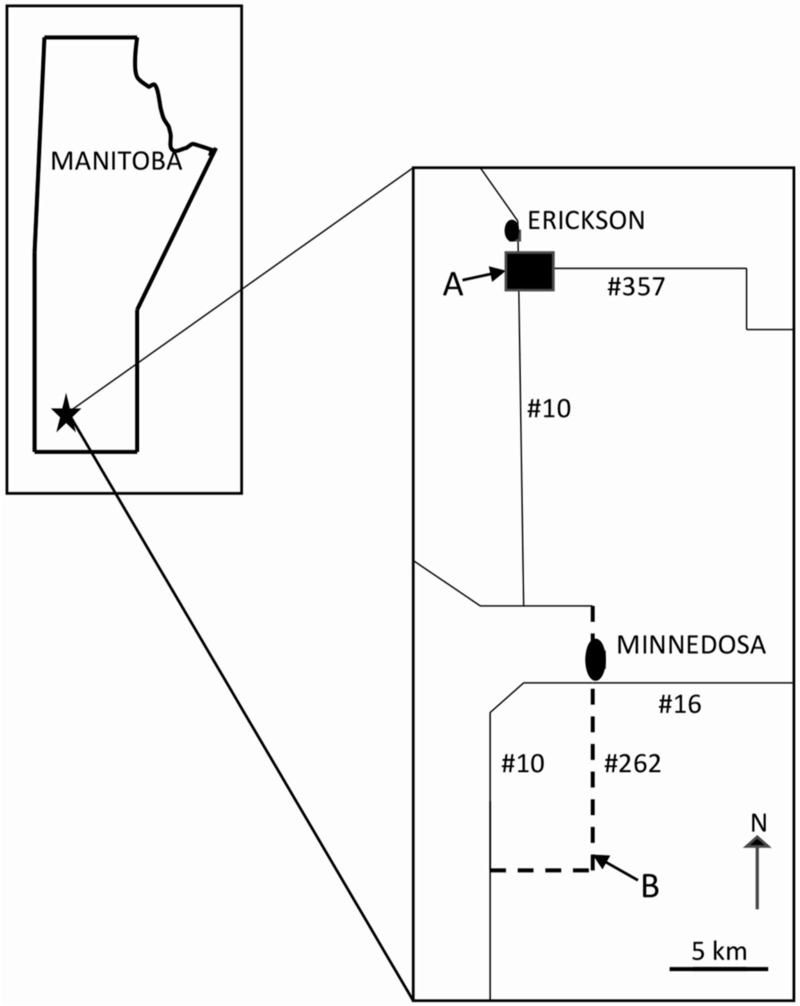

FIGURE 1. Location of Red-necked Grebe (*Podiceps grisegena*) and Horned Grebe (*Podiceps auritus*) study areas in southwest Manitoba, Canada: 6.8 km² Erickson site (black square A: 1970–1972, 2008–2016), and 7.1 km² Minnedosa transect (dashed line B: 2009–2015).

contained ten Class III (0.1 ± 0.07 ha, 0.02 – 0.22), 118 Class IV (0.9 ± 0.9 ha, 0.03–4.0), and 16 Class V (1.6 ± 1.1 ha, 0.06–3.6 [nine natural; seven {five flooded} dugouts]) wetlands (~ 20 wetlands/km$^2$). The latter study site is part of a larger site intensively studied for Horned Grebe in 1974–1975 (Ferguson 1977). Using 1964 and 2011 aerial photos of the Minnedosa transect (Aerial Data Survey Base, Natural Resources Canada and Google Earth, respectively), I estimated about a 2% loss (four Class IV lost, one dugout added) of Class IV and V wetlands between 1964 and 2011. Because Horned Grebes and Red-necked Grebes occupy Class IV and V wetlands almost exclusively during the breeding season, both study sites have experienced little grebe habitat loss between the 1970s and 2000s.

At Erickson, wetland water levels were high in the springs of 1970–1972 and in all years in the 2000s except 2012 (unpublished data). At Minnedosa, wetlands were wet in spring 1974–1975 (Ferguson 1977) and in all years 2009–2015 except 2012, and 2013 when the north section of the transect was dry (personal observation). Mean total yearly precipitation (*Precip*), 1981–2010, for Wasagaming, Manitoba ~21 km north of the Erickson site and for Brandon, Manitoba ~23 km south of the Minnedosa transect was 488 mm and 474 mm, respectively (Environment Canada Historical Climate Data 2016). Both early and recent study period *Precip* was greater than long-term averages (Erickson [Wasagaming] *Precip* 1970–1972 and 2009–2015 was 514 mm and 592 mm, respectively; Minnedosa [Brandon] *Precip* 1974–1975 and 2009–2015 was 529 mm and 506 mm, respectively). At Erickson, most wetlands were wetter (and some were larger) during 2008–2016 than during 1970–1972. Good wetland conditions are necessary to attract grebes to settle on territories (Stout and Nuechterlein 1999; Stedman 2000).

## Methods

As both species require wetlands with open water for breeding (Stout and Nuechterlein 1999; Stedman 2000), I restricted my observations to ponds equal to or greater than Class III (some Class III wetlands have open water, cover type 3 and 4; Stewart and Kantrud 1971). Both species are thought to attain full nuptial plumage at 1-year old, but some adults may not breed until greater than 1-year old (Stout and Nuechterlein 1999; Stedman 2000). The number of non-breeding Red-necked Grebes and Horned Grebes observed on the breeding ponds is assumed to be low (Riske 1976 as cited in Stout and Nuechterlein 1999; Fjeldså 1973 as cited in Stedman 2000). Thus, I assumed that all birds observed represented members of breeding pairs. At Erickson, one or two observers walked a fixed route at approximately weekly intervals from early May to late June 1970–1972 and from mid-May to mid-June 2008–2016. All wetlands were scanned with binoculars and spotting scopes from one or more elevated locations between 0600 and 1400 hours. At the Minnedosa transect, late May was the optimal census period to observe the greatest number of Horned Grebes when only one survey was conducted (Arnold 1994). One observer conducted one late-May survey beginning at ~ 0600 hours (1100 hours in 2009) at the southwest end and proceeded east, then north (6–10 hrs to complete) in all years except 2014 (June 5th). Each wetland within 200 m of the road was approached by vehicle or on foot and quickly scanned in its entirety then rescanned for 1 min or more, according to Arnold (1994). If the transect line bisected a large wetland (*n* = 3), I included only those grebes in the analysis observed within the transect. Horned Grebes were recorded as single birds or pairs (two birds in close proximity, not displaying aggressive behaviour) and a single bird on a wetland was assumed to represent a pair on that wetland (but see below for differing analysis of Minnedosa Horned Grebe data). Rarely does more than one pair of Horned Grebe occupy a given wetland at the Minnedosa site (Ferguson 1977) but at Erickson, larger wetlands allow for more pairs, and greater scrutiny was necessary. Similarly, for Red-necked Grebes, territory establishment and initial egg-laying occurs in May in Manitoba (egg-laying peaked in late May; De Smet 1987), and counts taken during mid to late May would best represent the breeding population (Stout and Nuechterlein 1999; personal observation). Red-necked Grebes were recorded as pairs or single birds (representing a probable pair). Many pairs could occupy larger lakes (especially at Erickson after 1999) so long observation times (to 0.5 hr) were necessary to estimate numbers. Repeated total counts from several elevated viewpoints combined with field maps of bird locations (to determine territories) aided estimation. At Minnedosa, the relatively smaller Class IV and V wetlands generally precluded the occurrence of more than one pair of Red-necked Grebe at a site.

For 2009 and 2010, time constraints allowed only a partial census of the Minnedosa transect (40% of total Class III wetlands, 66% of Class IV and V combined). Consequently, to estimate the number of pairs on the entire transect for those years, I developed a correction factor using 2011–2015 data (see method in Hammell 2016). This analysis indicated that the number of Horned Grebe and Red-necked Grebe pairs recorded in 2009 and 2010 on the partially surveyed transect represented 80% and 89%, respectively, of total pairs that would have been seen on the entire transect and this adjustment was applied to the 2009 and 2010 raw data.

Horned and Red-necked Grebes differ in their willingness to remain visible at disturbance. At the sight of the observer, Horned Grebes generally dive underwater, sometimes swimming into emergent vegetation to hide (Arnold 1994; personal observation). At Erickson, repeated wetland visits over the season increased the accuracy of Horned Grebe pair estimates and data presented for this site are considered reasonable estimates. However, at Minnedosa, because only one survey was conducted, lowered observability necessitated the application of a correction factor using my total adult bird numbers (i.e., estimating density using single birds and assumed pairs as described above for Erickson might bias breeding pair results downward for Minnedosa). Arnold (1994) estimated Horned Grebe visual detection of total adults for a single survey at Minnedosa as 62% based on known nesting populations determined from repeated nest searches. Therefore, an estimate of the number of initial nests (and the presumed breeding population) can be calculated using visible adults and the correction factor (Horned Grebe adults recorded/0.62 = estimate of total adults/2 = number of initial nests or breeding pairs; T. Arnold, personal communication). In contrast, Red-necked Grebes generally remain in open water on the surface. If they are not obvious at arrival, usually one or both pair members swim out from emergent vegetative cover after a short wait (personal observation). Therefore, recorded pair estimates are considered reasonably accurate, and no correction factor has been applied to Red-necked Grebe raw numbers.

Recent estimates of pairs/km$^2$ after 1999 were compared to estimates from my historical data at Erickson, and for Minnedosa, to estimates calculated from data in Ferguson (1977) and Stoudt (1982). Ferguson (1977: 36) found 34 and 36 initial nests in 1974 and 1975, respectively, on his 34.4 km$^2$ (29.2 km$^2$ roadside transect + 5.2 km$^2$ adjacent block) study area. I used these data to calculate Horned Grebe breeding pair densities for those years. Red-necked Grebes were not included in species lists nor discussion for two waterbird studies at Minnedosa during 1961–1972 (Stoudt 1982) and 1974–1975 (Ferguson 1977). So, I assumed them not to be present or in very low densities prior to 1980 and used the number, 0 pairs / km$^2$, to represent density for that period. Densities were still very low in the mid-1980s (T. Arnold, personal communication; K. De Smet, personal communication). I compared historical and recent data with non-parametric Wilcoxon rank-sum test via *t*-test on rank transformed data (data analysis using Microsoft Excel, Redmond, Washington, USA), and considered differences significant at $P \leq 0.05$, because the distribution of variables was unknown and sample sizes were small. Means are expressed as ± SD, range (McDonald 2014). Areas were determined by dot grid overlay or Acme Planimeter (http://acme.com/planimeter).

## Results

### *Horned Grebes*

At Erickson, Horned Grebes used some of the same wetlands in the 2000s as in the 1970s (1970s: 2.8 ± 2.8 ha, 0.6–8.7, $n = 14$; 2000s: 6.3 ha, 1.2–11.3, $n = 2$). In 2016, one pair occupied a large Class V wetland (11.3 ha) with four pairs of Red-necked Grebes. At Minnedosa, Horned Grebes in the 2000s used semi-permanent and permanent wetlands similar in size to those used in the 1970s (1974–1975: 1.2 ± 1.3 ha, 0.1–8.4, $n = 65$; Ferguson and Sealy 1983; 2009–2015: 1.3 ± 0.9 ha, 0.2–3.1, $n = 10$) and were not recorded on a wetland occupied by a Red-necked Grebe.

Horned Grebe pairs/km$^2$ changed significantly from historical to recent times (Table 1). At Erickson, Horned Grebe density fell from 1.8 pairs/km$^2$ in 1970 (mean = 1.3, 1970–1972) to 0 pairs/km$^2$ for most years in the 2000s (mean = 0.0; $t = -4.37$, $P = 0.001$). Similarly, at Minnedosa, Horned Grebe density fell from 1.0 pairs/

TABLE 1. Estimated breeding pairs per km$^2$ (total pairs in parentheses) of Horned Grebes (*Podiceps auritus*; HOGR) and Red-necked Grebes (*Podiceps grisegena*; RNGR), Erickson and Minnedosa, Manitoba study sites. Period-specific estimates: Hammell (1970–1972), Ferguson (1974–1975), Stoudt (1961–1972), and Hammell (2008–2016).

| | Study Site | | | |
|---|---|---|---|---|
| | Erickson (6.8 km$^2$) | | Minnedosa (7.1 km$^2$) | |
| Year | HOGR | RNGR | HOGR | RNGR |
| 1970 | 1.8 (12.0) | 0.0 (0.0) | no data | 0.0 (0.0) |
| 1971 | 1.2 (8.0) | 0.1 (1.0) | no data | 0.0 (0.0) |
| 1972 | 0.9 (6.0) | 0.0 (0.0) | no data | 0.0 (0.0) |
| Mean | 1.3 (8.7) | 0.0 (0.3) | no data | 0.0 (0.0) |
| 1974 | no data | no data | 1.0 (34.0) | 0.0 (0.0) |
| 1975 | no data | no data | 1.0 (36.0) | 0.0 (0.0) |
| Mean | no data | no data | 1.0 (35.0) | 0.0 (0.0) |
| 2008 | 0.1 (1.0) | 2.6 (18.0) | no data | no data |
| 2009 | 0.1 (1.0) | 2.5 (17.0) | 0.4 (3.0) | 1.0 (7.0) |
| 2010 | 0.0 (0.0) | 2.6 (18.0) | 0.6 (4.0) | 2.0 (14.0) |
| 2011 | 0.0 (0.0) | 2.8 (19.0) | 0.0 (0.0) | 2.7 (19.0) |
| 2012 | 0.0 (0.0) | 2.6 (18.0) | 0.4 (3.0) | 2.8 (20.0) |
| 2013 | 0.0 (0.0) | 2.6 (18.0) | 0.0 (0.0) | 2.2 (16.0) |
| 2014 | 0.0 (0.0) | 3.1 (21.0) | 0.4 (3.0) | 2.5 (18.0) |
| 2015 | 0.0 (0.0) | 2.9 (20.0) | 0.1 (1.0) | 2.5 (18.0) |
| 2016 | 0.1 (1.0) | 2.9 (20.0) | no data | no data |
| Mean | 0.0 (0.3) | 2.7 (19.0) | 0.3 (2.0) | 2.2 (16.0) |

$km^2$ in both 1974 and 1975 (mean = 1.0) to a range of 0 to 0.6 pairs/$km^2$ during the 2000s (mean = 0.3; $t = -2.94$, $P = 0.021$).

*Red-necked Grebes*

At Erickson, Red-necked Grebes occupied natural Class V (or former Class IV adjacent to and included in Class V wetlands due to flooded conditions) wetlands exclusively and consistently (5.1 ± 3.4 ha, 0.9–11.3, $n = 11$). Eight of the 11 (73%) wetlands contained pairs all nine years of the study and total pair count on the study area was similar every year (Table 1). At Minnedosa, of the 35 wetlands (34 natural, one flooded dugout) with a recorded pair in 2009–2015 (2.1 ± 0.9 ha, 0.5–4.0, $n = 35$), Red-necked Grebes occupied 26 Class IV (74%) and nine Class V (26%) wetlands but were less consistent than at Erickson. None of 35 wetlands were occupied all seven years but 16 of 35 (46%) were occupied equal to or greater than four years. Total pair count was similar each year after 2010.

Red-necked Grebe pairs/$km^2$ also changed significantly from historical to recent times (Table 1). At Erickson, Red-necked Grebe density increased dramatically from very low values of 0.1 or 0 pairs/$km^2$ in the 1970s (mean = 0.0, 1970–1972) to values of greater than 2 pairs/$km^2$ in all years in the 2000s (mean = 2.7; $t = 3.59$, $P = 0.005$). Similarly, at Minnedosa, Red-necked Grebe density increased from 0 pairs/$km^2$ during 1974 and 1975 to values of greater than 2 pairs/$km^2$ in all but one year (1.0 in 2009) in the 2000s (mean = 2.2; $t = 2.87$, $P = 0.028$).

## Discussion

The results of this study corroborate the BBS trend data for Horned Grebes and Red-necked Grebes in southwestern Manitoba pothole habitat. At Erickson and Minnedosa sites in the 2000s, the density of Horned Grebe breeding pairs has fallen to less than one third of the mean level in the 1970s and the density of Red-necked Grebe breeding pairs has risen dramatically from nil or essentially nil in the 1970s to densities in the 2000s of greater than or equal to 2.0 pairs/$km^2$. Red-necked Grebes nest in colonial groups in some areas (Nuechterlein *et al.* 2003) but not on my study sites, and for solitary-nesting pairs, my Red-necked Grebe densities are higher than any reported in North America by Stout and Nuechterlein (1999). Although sample sizes (i.e., number of years) were small in the early period, pair density differences were statistically significant. Lack of breeding Horned Grebe pairs at the Erickson site in 2010–2015 does not suggest absence of breeding in the greater Erickson area during those years but may be the result of the small size of the study area. Horned Grebes were indeed noted on a few lakes just outside the Erickson study area but at densities incomparable to the past because of the lack of local historical data. In a broader Canadian context, BBS trend data for Saskatchewan pothole habitat shows a large positive change for Red-necked Grebes and a small positive trend for Horned Grebes for 1970–2015, and negative trends for both species in Alberta potholes (Environment and Climate Change Canada 2017). The Alberta data are corroborated by a long-term study in east-central Alberta pothole habitat that also shows negative changes in numbers of breeding Horned Grebes and Red-necked Grebes in 1989–2004 (Corrigan 2007). But these declines may have been influenced by long-term drought (C. Paszkowski, personal communication).

Several potential biases could affect my results. Across southern Manitoba, wetland type and number have changed over time due to agricultural draining and filling and such change may have affected numbers of pairs settling in the recent period. However, at the Erickson and Minnedosa sites, wetland loss between the 1970s and 2000s has been minimal and most of the ponds lost have been small, temporary, and not usually used by grebes. Thus, wetland loss on my study areas was not considered to be a significant factor explaining grebe population change. Moreover, macrohabitat conditions in almost all years, across the two study periods, appeared favourable for breeding grebes (i.e., wet). Microhabitat conditions (e.g., emergent vegetation configuration and width) may have changed, but such analysis is beyond the scope of this study and was not done. However, Horned Grebes at both sites were recorded on the same size and class of wetland as in the past suggesting that habitat conditions still may be adequate for this species. At Minnedosa, differences between observers and methodologies could have confounded the comparison. I have attempted to reduce biases there by duplicating study area and observational techniques, and applying correction factors where necessary.

Suggested reasons for the continental and local declines of Horned Grebe populations include pesticide contamination, oiling on marine wintering areas, ingestion of plastics, and breeding habitat degradation; but there are no definitive answers (Stedman 2000). In southwestern Manitoba, the arrival of Raccoon (*Procyon lotor*) at Minnedosa and Erickson in the mid-1950s and 1960s, respectively (Stoudt 1982; Hammell 2011), may have had negative effects on Horned Grebe reproduction but Raccoons are significant predators of Red-necked Grebe nests as well (Ferguson and Sealy 1983; De Smet 1987). Red-necked Grebes are larger than Horned Grebes (males: red-necked 1330.9 ± 192.9 g, $n = 15$; horned range 320–515 g, $n = 13$; Stout and Nuechterlein 1999; Stedman 2000) and exhibit interspecific aggression towards most waterbirds entering their territory (Stout and Nuechterlein 1999; personal observation). Accordingly, the increase in Red-necked Grebe populations may have restricted Horned Grebe breeding pairs from preferred habitat, forcing settlement elsewhere. I have little evidence of direct aggression to Horned Grebes because the two species were rarely seen together and when they were, Horned Grebes kept their distance from Red-necked Grebes. I did however observe Red-necked Grebes continually chasing a Horned Grebe pair on one study lake in late spring; the Horned Grebe pair had left by next survey.

At Erickson, Red-necked Grebes demonstrated strong annual fidelity to wetlands, and 57% of 14 ponds with Horned Grebe pairs for at least one year (present for two or more counts) during 1970–1972 are now occupied most or every year by Red-necked Grebes (5.66 ± 3.02 ha, 2.2–9.4, *n* = 8). At Minnedosa, 47% of 35 ponds with a recorded Red-necked Grebe pair for at least one of the years during 2009–2015 are within the Horned Grebe preferred size of less than 2 ha (1.38 ± 0.48 ha, 0.5–1.9, *n* = 17). Red-necked Grebe wetland fidelity was lower at Minnedosa than at Erickson and may have reflected the use of smaller wetlands at Minnedosa (mean 5.1 versus 2.1 ha, respectively) which may not provide adequate resources to attract this species every year. Red-necked Grebes usually occupy wetlands greater than 2 ha in the southern part of their range (Riske 1976 as cited in Stout and Nuechterlein 1999; De Smet 1983 as cited in Stout and Nuechterlein 1999) but Fournier and Hines (1998) reported that, although median pond size used by Red-necked Grebes in Northwest Territories was 2.4 ha (3.7 ± 0.2 ha SE, 0.1–18.2, *n* = 110), a few pairs did occupy very small wetlands when surrounded by adjacent wetlands (seven of 110 ponds used were less than 0.3 ha). Similarly, in high wetland-dense Minnedosa habitat, Red-necked Grebes are occupying small wetlands and possibly excluding Horned Grebes. Horned Grebes are never found on smaller wetlands occupied by Red-necked Grebes, but they can occur together on larger ones (greater than 11 ha; personal observation; M. Fournier, personal communication).

In addition, Pied-billed Grebes (*Podilymbus podiceps*) are territorial and very aggressive and may be increasing in southern Manitoba (Manitoba prairie-potholes long-term trend 1970–2015 yearly % change: +1.91, BBS data; Environment and Climate Change Canada 2017). Average annual Pied-billed Grebe abundance on BBS routes in southern Manitoba during 2000–2015 is almost double that from 1970–1979 (1.13 ± 0.19 versus 0.64 ± 0.07, respectively; unpublished analysis from Environment and Climate Change Canada 2017). Although similar in size to Horned Grebes (mass: 474.0 ± 60.6 g, 321–568, *n* = 36; Muller and Storer 1999), Pied-billed Grebes are known to replace Horned Grebes on breeding ponds and may contribute to a reduced local breeding population as well (Faaborg 1976; Osnas 2003). Horned Grebes arriving on a local pond in the spring will stay and raise a brood if not disturbed but are often attacked continually by Pied-billed Grebes; the Pied-bill Grebe pair then nests after the Horned Grebes abandon the pond (H. Proven, personnel communication).

A comparison of the number of estimated pairs of Pied-billed Grebe on the Erickson site in the 1970s and 2000s also suggests an increase in the recent period; this increase was most notably on three smaller wetlands (0.7 ± 0.15 ha, 0.6–0.7) not used by Red-necked Grebes that were regularly used by Horned Grebes during 1970–1972 (unpublished data). However, sample sizes are very small and Pied-billed Grebes are extremely furtive and difficult to observe on larger wetlands resulting in some unknown degree of pair underestimation. Thus, my Pied-billed Grebe data for the Erickson site has low reliability and should be viewed with caution.

Nonetheless, all of the above suggests that Horned Grebes may be facing increased competition and territorial aggression from Red-necked Grebes and Pied-billed Grebes. Reduced Horned Grebe recruitment over many years resulting from Horned Grebe exclusion from larger and smaller wetlands by Red-necked Grebes and Pied-billed Grebes, respectively, could produce low breeding pair return rates that might explain the low density of Horned Grebes at Erickson now. Obviously, other factors occurring on or off the breeding grounds may be responsible for the decline.

Reasons for the marked increase in Red-necked Grebes in southwestern Manitoba are unclear, but change in environmental contaminant uptake may be important. Red-necked Grebes, positioned near the top of the aquatic food chain, ingest large amounts of contaminants (organochlorides, mercury, and other heavy metals) that are often found in adults, eggs, and young (Stout and Nuechterlein 1999). These contaminants are thought to have caused eggshell-thinning, unviable eggs, and high mortality at hatch leading to reduced productivity (southwest Manitoba, 1980–1981: De Smet 1987; central Alberta, 1970–1976: Riske 1976 as cited in Stout and Nuechterlein 1999). Reduction in the release of these toxins into the environment began in the mid-1970s (e.g., DDT banned in 1972 in Canada; Forsyth *et al.* 1994) and Red-necked Grebe eggs collected during 1982–1986 in Manitoba and Saskatchewan, showed a slight decline in mean organochloride residues compared to those from Manitoba collected in 1981 and Wisconsin collected in 1970 (De Smet 1987; Forsyth *et al.* 1994). To my knowledge, more recent Red-necked Grebe data have not been published. Red-necked Grebes from Manitoba are thought to winter primarily along the eastern coast of North America and accumulate contaminants during this period of their life cycle (Forsyth *et al.* 1994). Recent studies of avian species that inhabit the same marine habitats as Red-necked Grebes for some or all of their yearly cycle have shown thicker eggshells (Common Murre [*Uria aalge*]), reduced contaminant levels (Northern Gannet [*Morus bassanus*], Double-crested Cormorant [*Phalacrocorax auritus*], Atlantic Puffin [*Fratercula arctica*], Leach's Storm Petrel [*Oceanodroma leucorhoa*]), and improved reproductive performance (Northern Gannet) compared to historical observations (Pearce *et al.* 1989; Rail *et al.* 2013; Pirie-Hay and Bond 2014). These results are consistent with a reduction of contaminants in the marine environment and reduced uptake by birds, including Red-necked Grebes. If Red-necked Grebe breeding success was low due to ingested contaminants during the period prior to the 1980s, and success improved more recently due to a reduction of the contaminant load in their environment, then the resultant increase in juvenile recruitment and need for additional breeding habitat might produce the observed increases in breeding pairs noted at Erickson and Minnedosa.

In conclusion, this study indicates that a change in Horned Grebe and Red-necked Grebe breeding populations has occurred in southwestern Manitoba over the last four decades. Reasons for these observed changes are unresolved. More current data on contaminant levels in grebes in southwestern Manitoba, and changes in population and contaminant levels in other prairie-parkland areas where historical data exist should prove valuable (Riske 1976 as cited in Stout and Nuechterlein 1999; Sugden 1977; Forsyth *et al.* 1994; Corrigan 2007). For example, current contaminant levels could be compared with levels from carcasses and egg shells from museum specimens. Other priorities include the need for surveys at the provincial, national, and continental levels to determine breeding and wintering population trends (Stout and Nuechterlein 1999; Stedman 2000).

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## Literature Cited

**Arnold, T. W.** 1994. A roadside transect for censusing breeding coots and grebes. Wildlife Society Bulletin 22: 437–443.

**Corrigan, R. M.** 2007. Effectiveness of nest boxes in influencing population trends for Common Goldeneye (*Bucephala clangula*) and Bufflehead (*B. albeola*) in the Buffalo Lake Moraine. M.Sc. thesis, University of Alberta, Edmonton, Alberta, Canada.

**COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2009. COSEWIC assessment and status report on the Horned Grebe *Podiceps auritus*, Western population and Magdalen Islands population, in Canada. COSEWIC, Environment Canada, Gatineau, Quebec, Canada. Accessed 12 February 2016. http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_horned_grebe_0809_e.pdf.

**De Smet, K. D.** 1983. Breeding ecology and productivity of Red-necked Grebes in Turtle Mountain Provincial Park, Manitoba. M.Sc. thesis, University of North Dakota, Grand Forks, North Dakota, USA.

**De Smet, K. D.** 1987. Organochlorines, predators and reproductive success of the Red-necked Grebe in southern Manitoba. Condor 89: 460–467.

**Environment and Climate Change Canada.** 2017. North American Breeding Bird Survey – Canadian Trends Website, Data-version 2015. Environment and Climate Change Canada, Gatineau, Quebec, Canada. Accessed 10 October 2017. http://wildlife-species.canada.ca/breeding-bird-survey-results.

**Environment Canada.** 2016. Historical Climate Data. Environment Canada, Ottawa, Ontario, Canada. Accessed 24 March 2016. http://weather.gc.ca/city/pages/mb-31_metric_e.html.

**Faaborg, J.** 1976. Habitat selection and territorial behavior of the small grebes of North America. Wilson Bulletin 88: 390–399.

**Ferguson, R. S.** 1977. Adaptations of the Horned Grebe for breeding in prairie pothole marshes. M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, Canada.

**Ferguson, R. S.,** and **S. G. Sealy.** 1983. Breeding ecology of the Horned Grebe, *Podiceps auritus*, in southwestern Manitoba. Canadian Field-Naturalist 97: 401–408. Accessed 25 March 2018. https://www.biodiversitylibrary.org/item/89042#page/423/mode/1up.

**Fjeldså, J.** 1973. Territory and the regulation of population density and recruitment in the Horned Grebe *Podiceps auritus arcticus* Boje, 1822. Videnskabelige Meddelelser Dansk Naturhistorisk Forening 136: 117–189.

**Forsyth, D. J., P. A. Martin, K. D. De Smet,** and **M. E. Riske.** 1994. Organochlorine contaminants and eggshell thinning in grebes from prairie Canada. Environmental Pollution 85: 51–58. https://doi.org/10.1016/0269-7491(94)90237-2

**Fournier, M. A.,** and **J. E. Hines.** 1998. Breeding ecology and status of the Red-necked Grebe, *Podiceps grisegena*, in the subarctic of the Northwest Territories. Canadian Field-Naturalist 112: 474–480. Accessed 25 March 2018. https://www.biodiversitylibrary.org/item/106776#page/490/mode/1up.

**Hammell, G. S.** 2011. Lesser scaup and raccoons: are there links in southwestern Manitoba? Blue Jay 69: 54–69.

**Hammell, G. S.** 2016. Reproductive rates in Lesser Scaup (*Aythya affinis*) in southwestern Manitoba: another look at the data. Canadian Field-Naturalist 130: 110–121. https://doi.org/10.22621/cfn.v130i2.1834

**Klatt, P. H.** 2003. Territorial behavior and nesting dispersion in Red-Necked Grebes. Waterbirds 26: 94–99. https://doi.org/10.1675/1524-4695(2003)026[0094:TBANDI]2.0.CO;2

**Klatt, P. H., G. L. Nuechterlein,** and **D. Buitron.** 2004. Frequency and distribution of behaviour of Red-Necked Grebes breeding colonially and in classic territories. Behaviour 141: 263–277. https://doi.org/10.1163/156853904322981842

**Kuczynski, E. C., C. A. Paszkowski,** and **B. A. Gingras.** 2012. Horned Grebe habitat use of constructed wetlands in Alberta, Canada. Journal of Wildlife Management 76: 1694–1702. https://doi.org/10.1002/jwmg.421

**McDonald, J. H.** 2014. Handbook of Biological Statistics. Third edition. Sparky House Publishing, Baltimore, Maryland, USA.

**Muller, M. J.,** and **R. W. Storer.** 1999. Pied-billed Grebe (*Podilymbus podiceps*). *In* The Birds of North America. *Edited by* P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.410

**Nuechterlein, G. L., D. Buitron, J. L. Sachs,** and **C. R. Hughes.** 2003. Red-Necked Grebes become semicolonial when prime nesting substrate is available. Condor 105: 80–94. https://doi.org/10.1650/0010-5422(2003)105[80:RNGBSW]2.0.CO;2

**Osnas, E. E.** 2003. The role of competition and local habitat conditions for determining occupancy patterns in grebes. Waterbirds 26: 209–216. https://doi.org/10.1675/1524-4695(2003)026[0209:TROCAL]2.0.CO;2

**Pearce, P. A., J. E. Elliot, D. B. Peakall,** and **R. J. Norstrom.** 1989. Organochlorine contaminants in eggs of seabirds in the northwest Atlantic, 1968–1984. Environmental Pollution 56: 217–235. https://doi.org/10.1016/0269-7491(89)90039-0

**Pirie-Hay, D. W.,** and **A. L. Bond.** 2014. Thickness of Common Murre (*Uria aalge*) eggshells in Atlantic Canada. Canadian Field-Naturalist 128: 72–76. https://doi.org/10.22621/cfn.v128i1.1553

**Rail, J.-F., L. Champoux, R. A. Lavoie,** and **G. Chapdelaine.** 2013. Monitoring of the population and contamination of the Northern Gannet in Quebec, 1966–2009. Technical Report Series Number 528. Canadian Wildlife Service (Quebec Region). Environment Canada, Ottawa, Ontario, Canada.

**Riske, M. E.** 1976. Environmental and human impacts on grebes breeding in central Alberta. Ph.D. thesis, University of Calgary, Calgary, Alberta, Canada.

**SARA (Species at Risk) Registry.** 2017a. Species profile, Horned Grebe Western population. Accessed 29 September 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=1045.

**SARA (Species at Risk) Registry.** 2017b. Species profile, Horned Grebe Magdalen Islands population. Accessed 29 September 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=1046.

**SARA (Species at Risk) Registry.** 2017c. Species profile, Red-necked Grebe. Accessed 29 September 2017. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=322.

**Sauer, J. R., D. K. Niven, J. E. Hines, D. J. Ziolkowski, Jr., K. L. Pardieck, J. E. Fallon,** and **W. A. Link.** 2017. The North American Breeding Bird Survey, Results and Analysis 1966–2015. Version 2.07.2017. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA. Accessed 9 October 2017. https://www.mbr-pwrc.usgs.gov.

**Stedman, S. J**. 2000. Horned Grebe (*Podiceps auritus*). *In* The Birds of North America. *Edited by* P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.505

**Stewart, R. E.,** and **H. A. Kantrud.** 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish and Wildlife Service Resource Publication 92. Washington, DC, USA.

**Stoudt, J. H.** 1982. Habitat use and productivity of Canvasbacks in southwestern Manitoba 1961–72. United States Fish and Wildlife Service Special Scientific Report Wildlife No. 248. Washington, DC, USA.

**Stout, B.,** and **G. L. Nuechterlein.** 1999. Red-necked Grebe (*Podiceps grisegena*). *In* The Birds of North America. *Edited by* P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.465

**Sugden, L. G.** 1977. Horned Grebe breeding habitat in Saskatchewan parklands. Canadian Field-Naturalist 91: 372–376. Accessed 25 March 2018. https://www.biodiversitylibrary.org/item/89182#page/398/mode/1up.

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# Note

## First Report of Dealfish, *Trachipterus arcticus* (Lampriformes: Trachipteridae), from Canadian Waters

Craig F. Purchase

Department of Biology, Memorial University, St. John's, Newfoundland and Labrador A1B 3X9 Canada; email: cfpurchase@mun.ca

Purchase, C. F. 2017. First report of Dealfish, *Trachipterus arcticus* (Lampriformes: Trachipteridae), from Canadian waters. Canadian Field-Naturalist 131(4): 325–327. https://doi.org/10.22621/cfn.v131i4.1912

In November 2014, a recently dead specimen of the meso-pelagic Dealfish, *Trachipterus arcticus*, was found on a fjord beach in northern Newfoundland. This represents the first record of the species in Canadian waters.

Key Words: Dealfish; *Trachipterus arcticus*; Newfoundland; range extension

Dealfish, *Trachipterus arcticus* (Brünnich, 1788), is a large but rarely seen meso-pelagic lampriform from the North Atlantic (Wheeler 1969) and one of ten species in the family Trachipteridae (ribbonfishes). Here, I report the first instance of this species in Canadian waters.

In November 2014, a large silver fish was noticed on the beach below a 10-m cliff on the south side of Northern Arm in the Bay of Exploits, Newfoundland, Canada (49.156061°N, 55.363428°W; Table 1). It was there at least 3–4 days (~5°C) before being retrieved by Greg Mercer and was apparently in very good condition (i.e., recently dead). The next day, it was brought to my attention, but, before pictures could be taken, birds had inflicted serious damage to it. However, enough of the animal remained (Figure 1) for a positive identification (Wheeler 1969; Palmer 1986), which was subsequently supported by Lou Van Guelpen (curator of fishes, Atlantic Reference Centre) using photographs.

The specimen is scaleless, and the lateral line has forward-directed spines. It is long and extremely compressed, with a long dorsal fin. The pectorals are very small and the pelvic fins could not be located. Although the exact length of the animal cannot be determined, it exceeds 75 cm, and the isopropyl preserved eye is 63.6 mm in diameter. Its live appearance is illustrated in Figure 2.

*Trachipterus arcticus* does not appear in the records of Atlantic Fishes of Canada (Scott and Scott 1988) nor Fishes of the Gulf of Maine (Collette and Klein-MacPhee 2002). Previous sightings have been concentrated in the northeast Atlantic, from Norway and Iceland south to Madeira Island (Palmer 1986). The Global Biodiversity Information Facility (2017) indicates that

Table 1. Occurrences of Dealfish (*Trachipterus arcticus*) in North American waters.

| Year | Month | Location | Latitude, ° | Longitude, ° | Source | Collection record |
|---|---|---|---|---|---|---|
| 2014 | 11 | Northeast Newfoundland | 49.16 | 55.36 | Dead on beach | The Rooms Provincial Museum Division* |
| 2003 | 8 | Atlantic coast of Florida | 29.28 | 81.06 | Dead on beach | Florida Museum of Natural History |
| 2003 | 5 | Southeast of Cape Cod | 39.95 | 67.79 | Research survey | Museum of Comparative Zoology, Harvard University |
| 2003 | 5 | Southeast of Cape Cod | 39.87 | 67.26 | Research survey | Museum of Comparative Zoology, Harvard University |
| 2002 | 12 | Gulf of Mexico | 29.00 | 86.00 | Tuna longliner† | Florida Museum of Natural History |
| 2002 | 11 | Gulf of Mexico | 29.00 | 86.00 | Captured at sea‡ | Florida Museum of Natural History |
| 1966 | 3 | Gulf of Mexico | 28.95 | 94.78 | Unknown | Natural History Museum of Los Angeles County |
| 1953 | 10 | Long Island, New York | 40.98 | 72.09 | Dead on beach | American Museum of Natural History |

*Provincial Museum Division, The Rooms Corporation of Newfoundland and Labrador (NFM).
†Caught using monofilament leaders at night.
‡Also captured at night.
Sources: Froese and Pauly (2017); Global Biodiversity Information Facility (2017).

FIGURE 1. Remains of Dealfish (*Trachipterus arcticus*) found in northern Newfoundland in November 2014. The carcass was in good condition before being consumed by birds. Photos: C. Purchase.

FIGURE 2. Artist reconstruction of the Dealfish (*Trachipterus arcticus*) carcass showing missing parts (top, mouth open) and drawing of a fresh specimen of this species (bottom, mouth closed). Illustrator: Marco Graziano.

11 specimens were collected in Greenland from 1890 to 1967, but exact locations are not available. Seven specimens have been reported from United States waters (Table 1); Robins and Ray (1986) suggest these could be a separate species, although they give no reasons. Three of these were caught in the Gulf of Mexico, two off the continental slope southeast of Cape Cod, and dead specimens were found on beaches on the Atlantic coast of Florida and on eastern Long Island (New York). The specimen from Newfoundland was ~1400 km northeast of the captures offshore of Cape Cod. It has been preserved and is held by the Provincial Museum Division, of The Rooms Corporation of Newfoundland and Labrador (accession number NFM PI-118).

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## Literature Cited

**Collette, B.,** and **G. Klein-MacPhee.** 2002. Bigelow and Schroeder's Fishes of the Gulf of Maine. Third edition. Smithsonian Institution Press, Washington, DC, USA.

**Froese, R.,** and **D. Pauly.** 2017. *Trachipterus arcticus*: occurrence records. *In* Fishbase: World Wide Web electronic publication. Accessed 7 March 2017. http://www.fishbase.ca/museum/OccurrencesList.php?genus=Trachipterus&species=arcticus.

**Global Biodiversity Information Facility.** 2017. *Trachipterus arcticus* (Brünnich, 1788). GBIF Secretariat, Copenhagen, Denmark. Accessed 7 March 2017. http://www.gbif.org/species/2400507.

**Palmer, G.** 1986. Trachipteridae. Pages 729–732 *in* Fishes of the North-eastern Atlantic and the Mediterranean, Volume 2. *Edited by* P. J. P. Whitehead, M. L. Bauchot, J. C. Hureau, J. Nielsen, and E. Tortonese. United Nations Educational, Scientific and Cultural Organization, Paris, France.

**Robins, C. R.,** and **G. C. Ray.** 1986. A Field Guide to Atlantic Coast Fishes of North America. Houghton Mifflin Company, Boston, Massachusetts, USA.

**Scott, W. B.,** and **M. G. Scott.** 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219. Department of Fisheries and Oceans, Ottawa, Ontario, Canada.

**Wheeler, A.** 1969. Ribbon-fish, Deal-fish and Opah. Pages 190–192 *in* The Fishes of the British Isles and North-west Europe. Macmillan, London, United Kingdom.

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# Note

## Reversed Clover, *Trifolium resupinatum* L. (Fabaceae), Confirmed in Canada

COLIN J. CHAPMAN[1, 3] and MICHAEL J. OLDHAM[2]

[1]Atlantic Canada Conservation Data Centre, 146 Main Street, Sackville, New Brunswick E4L 1A8 Canada
[2]Ontario Natural Heritage Information Centre, Ministry of Natural Resources and Forestry, 300 Water Street, 2nd Floor, North Tower, Peterborough, Ontario K9J 8M5 Canada
[3]Corresponding author: cchap032@gmail.com

Chapman, Colin J., and Michael J. Oldham. 2017. Reversed Clover, *Trifolium resupinatum* L. (Fabaceae), confirmed in Canada. Canadian Field-Naturalist 131(4): 328–330. https://doi.org/10.22621/cfn.v131i4.1866

We report two populations of *Trifolium resupinatum* (Reversed Clover, trèfle résupiné) from southern Ontario, confirming it as established in Canada. This Eurasian and north African species was reported in the late 1800s in New Brunswick and Quebec, where it apparently did not persist. Its distribution across the United States is sporadic.

Key Words: *Trifolium resupinatum*; Reversed Clover; Persian Clover; Fabaceae; new record; Ontario; Canada

With this report of two populations in southern Ontario, *Trifolium resupinatum* L. (Reversed or Persian Clover) is confirmed as established within the flora of Canada.

Twelve species in the genus *Trifolium* are reported in the flora of Ontario (Oldham 2016). The first Ontario record of *T. resupinatum* is based on a specimen collected by Michael Oldham, K. McIntyre, J. Labrecque, R. Gould, N. Cavallin, and N. Lavoie on 25 August 2005, at the St. Clair Region Conservation Authority's McAlpine Tract in Middlesex County. *Trifolium resupinatum* was subsequently collected by Colin Chapman on 17 June 2016, in Desjardins Canal Park, in the City of Hamilton, Ontario.

Among known Ontario *Trifolium* species, *T. resupinatum* is most similar to *T. fragiferum* L. (Strawberry Clover, trèfle fraisier), which is also rare in the province. It is distinguished from *T. fragiferum*, the only other Ontario species with inflated calices, by its resupinate flowers and the absence of stolons. Because of their similarly coloured flowers, there is also a superficial resemblance between *T. resupinatum* and the common *T. pratense* L. (Red Clover, trèfle rouge). However, *T. resupinatum* is distinguished from *T. pratense* by its smaller inflorescence (10–20 mm in diameter), the presence of floral bracteoles, and resupinate flowers. The resupinate flowers (Figure 1A), floral bracteoles, and inflated calices (Figure 1B) in fruit readily distinguish *T. resupinatum* from the other *Trifolium* species of Ontario (Haines 2011).

*Trifolium resupinatum* is an annual species native to Mediterranean Europe and northern Africa east to

FIGURE 1. Distinguishing features of Reversed Clover (*Trifolium resupinatum*): (A) resupinate corollas and (B) inflated calices in fruit. Photos: Colin Chapman.

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Afghanistan and central Asia, where it occurs in fields, streambanks, roadsides, and waste places. It has been introduced elsewhere in Europe as well as in Australia, North America, tropical and southern Africa, and South America (Davis 1970; Zohary 1972; Townsend and Guest 1974; Meikle 1977; Zohary and Heller 1984).

In North America, *Trifolium resupinatum* has been used for silage, hay, pasture, and occasionally in lawn seed mixtures (Magness *et al*. 1971; Gillett and Cochrane 1973). The species has a scattered distribution throughout the United States; it was first found in Louisiana in 1928 and is now locally established from Texas to New England (Magness *et al.* 1971; Haines 2011). It is not known from Michigan, adjacent to Ontario (Voss and Reznicek 2012).

*Trifolium resupinatum* was first reported in Canada in Saint John, Saint John County, New Brunswick, in 1879, on ballast waste "with *T. ornithopodioides* L. and a few other foreign species" (Fowler 1879). Hinds *et al.* (2000) knew of no subsequent New Brunswick records and did not expect it to have persisted in the province. With no supporting herbarium specimen known for *T. resupinatum*, its provincial status is "Reported but unconfirmed" (Stephen Clayden and Sean Blaney, personal communications).

Macoun (1883–1890) reported it from "near Quebec City", Quebec, but again, no herbarium specimen exists. Brouillet *et al*. (2010+) list it as "excluded", with the comment "old report, not established" for both New Brunswick and Quebec.

Magness *et al*. (1971) reported that *Trifolium resupinatum* used for agricultural purposes naturally reseeds, but does not tolerate low winter temperatures. However, the species has been shown to persist in western North Dakota, producing over 200 seedlings/m$^2$ in plots that had been seeded in the previous year (Carr *et al*. 2005). Most of the state of North Dakota is within plant hardiness zones 4a and 3b (USDA 2012). Much of Atlantic Canada and the southern portions of the remaining Canadian provinces are within plant hardiness zones equal to or warmer than North Dakota; Middlesex County is in plant hardiness zone 6b (Natural Resources Canada 2016). The warmer average annual extreme minimum temperature suggests that *T. resupinatum* is likely able to persist in southern Canada and may reseed from agricultural sites.

The McAlpine Tract population was found on a roadside in a rural, agricultural area, presumably introduced through use as a pasture plant. It is not clear how long the population has been established at that site. The Desjardins Canal Park population arose from soil salvaged (in 2014) from a development site in Oakville, Ontario (A. Bell, personal communication) for site restoration purposes. The Desjardins Canal Park population, then, may have persisted here for as long as two years.

*Trifolium resupinatum* remains a rarely reported introduction in Canada. However, its discovery in two widely separated southern Ontario sites in different habitats suggests that it may be found elsewhere in agricultural regions of southern Canada.

*Voucher specimens*

Canada, Ontario: Middlesex County, McAlpine Tract, St. Clair Region Conservation Authority property, weedy roadside, flowers small and pink, rare, mixed with *T. hybridum*, 42.7953°N, 81.8296°W, 25 August 2005, *M. J. Oldham, K. McIntyre, J. Labrecque, R. Gould, N. Cavallin, and N. Lavoie*, Collection Number 31945 (NHIC, MICH); City of Hamilton, Desjardins Canal Park, Hamilton Conservation Authority property, roughly 50 plants scattered on disturbed ground, with *Lolium perenne*, *Lotus corniculatus*, *Trifolium repens*, *Melilotus officinalis*, *Medicago sativa*, *Bromus hordeaceus*, *Vicia cracca*, 43.26699°N, 79.94208°W, 17 June 2016, *C. J. Chapman,* Collection number 2016-135 (HAM, DAO, NHIC).

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## Literature Cited

**Brouillet, L., F. Coursol, M. Favreau, M. Anions, P. Bélisle,** and **P. Desmet.** 2010+. VASCAN, the database of vascular plants of Canada. Accessed 30 June 2016. http://data.canadensys.net/vascan.

**Carr, P. M., W. W. Poland,** and **L. J. Tisor.** 2005. Forage legume regeneration from the soil seed bank in Western North Dakota. Agronomy Journal 97: 505–513. https://doi.org/10.2134/agronj2005.0505

**Davis, P. H.** 1970. Flora of Turkey and the East Aegean Islands. Edinburgh University Press, Edinburgh, United Kingdom.

**Fowler, J.** 1879. List of New Brunswick plants. Report of the Secretary for Agriculture [1878], Appendix B. Fredericton, New Brunswick, Canada. https://doi.org/10.5962/bhl.title.63546

**Gillett, J. M.,** and **T. S. Cochrane.** 1973. Preliminary reports on the flora of Wisconsin, no. 63. The genus *Trifolium* – the clovers. Transactions of the Wisconsin Academy of Science 61: 59–74.

**Haines, A.** 2011. Flora Novae Angliae, A Manual for the Identification of Native and Naturalized Higher Vascular Plants of New England. Yale University Press, New Haven, Connecticut, USA.

**Hinds, H. R., C. M. Young,** and **S. R. Clayden.** 2000. Flora of New Brunswick: A Manual for the Identification of the Vascular Plants of New Brunswick. Department of Biology, University of New Brunswick, Fredericton, New Brunswick, Canada.

**Macoun, J.** 1883–1890. Catalogue of Canadian Plants. Parts I–V. Geological Survey of Canada, Ottawa, Ontario, Canada. https://doi.org/10.5962/bhl.title.54137

**Magness, J. R., G. M. Markle,** and **C. C. Compton.** 1971. Food and feed crops of the United States: a descriptive list classified according to potentials for pesticide residues. Bulletin. New Jersey Agricultural Experiment Station, New Brunswick, New Jersey, USA.

**Meikle, R. D.** 1977. Flora of Cyprus. Royal Botanical Gardens, Kew, London, United Kingdom.

**Natural Resources Canada.** 2016. Plant Hardiness Zone by Municipality. Natural Resources Canada, Ottawa, Ontario, Canada. Accessed 3 July 2016. http://www.planthardiness.gc.ca/?m=22&lang=en.

**Oldham, M. J.** 2016. Ontario Vascular Plants List. Ontario Natural Heritage Information Centre, Ontario Ministry of Natural Resources and Forestry, Toronto, Ontario, Canada. Accessed 16 June 2016. http://www.sse.gov.on.ca/sites/MNR-PublicDocs/EN/ProvincialServices/Ontario_Vascular_Plants.xlsx.

**Townsend, C. C.,** and **E. Guest.** 1974. Flora of Iraq, Volume 3: Leguminales. Ministry of Agriculture & Agrarian Reform, Baghdad, Iraq.

**USDA (United States Department of Agriculture).** 2012. Plant hardiness zone map. Agricultural Research Service, USDA, Washington, DC, USA. Accessed 3 July 2016. http://planthardiness.ars.usda.gov.

**Voss, E. G.,** and **A. A. Reznicek.** 2012. Field Manual of Michigan Flora. University of Michigan Press, Chicago, Illinois, USA. https://doi.org/10.3998/mpub.345399

**Zohary, M.** 1972. Flora Palaestina, Part 2: Platanaceae to Umbelliferae. Israel Academy of Sciences and Humanities, Jerusalem, Israel.

**Zohary, M.,** and **D. Heller.** 1984. The Genus *Trifolium*. Israel Academy of Sciences and Humanities, Jerusalem, Israel.

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# Note

## First Occurrence of a Juvenile Chain Pickerel (*Esox niger*) in Ontario Waters of Lake Ontario

Brian P. Morrison[1, 2, 4] and Daniel J. Moore[3]

[1]Ganaraska Region Conservation Authority, 2216 County Road 28, Port Hope, Ontario L1A 3V8 Canada
[2]Current address: 2620 Farmcrest Avenue, Peterborough, Ontario K9L 1H7 Canada
[3]Central Lake Ontario Conservation Authority, 100 Whiting Avenue, Oshawa, Ontario L1H 3T3 Canada
[4]Corresponding author: brianmorrison@trentu.ca

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This paper documents the first juvenile Chain Pickerel (*Esox niger*) captured in Ontario waters of Lake Ontario. It was found during August 2016 monitoring activities at Port of Newcastle. Its occurrence represents a significant westward range expansion from recently documented adults in the eastern basin of Lake Ontario/Bay of Quinte/St. Lawrence River, likely colonizing from United States waters of Lake Ontario.

Key Words: *Esox niger*; Chain Pickerel; range expansion; Ontario; Lake Ontario

### Introduction

Chain Pickerel (*Esox niger*) is a small- to medium-sized (adult total length 381–762 mm), largely piscivorous member of the pike family (Esocidae), which usually inhabits lakes and large rivers with associated submerged aquatic vegetation and water depths of less than 3 m (Scott and Crossman 1998). Its native range is principally the Atlantic coastal plains, including parts of the St. Lawrence River, the New York (south) shore of Lake Ontario, and portions of Quebec. It is considered naturalized in New Brunswick, Nova Scotia, and other parts of Quebec (Greeley 1939; Coffie 1998; Page and Burr 2011; Carlson *et al.* 2016), with introductions expanding its range west of this (Coffie 1998).

Chain Pickerel has been widely introduced as a sport fish and has subsequently expanded its range in many parts of the United States and eastern Canada (Coffie 1998). Adult Chain Pickerel, native to the United States waters of Lake Ontario (Holm *et al.* 2009), were first confirmed in the eastern basin of Lake Ontario between 2008 and 2010 (Hoyle and Lake 2011). Adult Chain Pickerel have continued to be present in the upper St. Lawrence/eastern Lake Ontario basin (J. Hoyle, personal communication), with evidence of natural reproduction on the New York side of the eastern basin of Lake Ontario (Carlson *et al.* 2016). Hoyle and Lake (2011) speculated that range expansion west of the Bay of Quinte may be more difficult because the shoreline is largely devoid of warm, vegetated waters.

This paper documents the first occurrence of a juvenile Chain Pickerel in Canadian waters of Lake Ontario and a significant range expansion to the north shore of Lake Ontario.

### Methods

Annual monitoring occurs across a series of Lake Ontario coastal wetland habitats as part of the Durham Region Coastal Wetland Monitoring Program (DRCWMP) and Bay of Quinte Remedial Action Plan. Sixteen wetlands are sampled annually in the Durham region and 15 wetlands are sampled on a 3-year rotation in the Bay of Quinte (Figure 1). The DRCWMP protocol is used at both locations; it notes fisheries, vegetation, and chemical characteristics of each wetland at the time of sampling (Environment Canada and Central Lake Ontario Conservation Authority 2007; Moore 2016).

Fishes are sampled via boat electrofishing along a linear transect, with six sampling points located 8 m apart, resulting in approximately 4-m-diameter sampling points along the 44-m transect. Each point along the transect is sampled for 20 electrofishing seconds, with one crew member netting all fishes for later processing. Genetic species identification was conducted by barcoding at the CO1 mitochondrial gene and cross-referencing sequences with the GENBANK database.

### Results

On 22 August 2016, a 153-mm total length, 19-g juvenile Chain Pickerel (Figure 2) was captured by boat electrofishing at Port of Newcastle wetland (43°53'50.0172"N, 78°34'37.7322"W) during annual monitoring activities. The fish was considered a juvenile based on its size. It was preserved in 95% ethanol and sent to the Royal Ontario Museum for verification (ROM 101354).

The specimen had 15 branchiostegal rays, fully scaled gill covers, a prominent suborbital bar that does not slope backward, four pores on the ventral side of each mandible, and snout length greater than the distance from back of eye to top of gill slit (Table 1). In addition, DNA was extracted from the Chain Pickerel and it was positively identified using the GENBANK database, i.e., the CO1 mitochondrial gene (barcode) matched other Chain Pickerel sequences (799 base pairs

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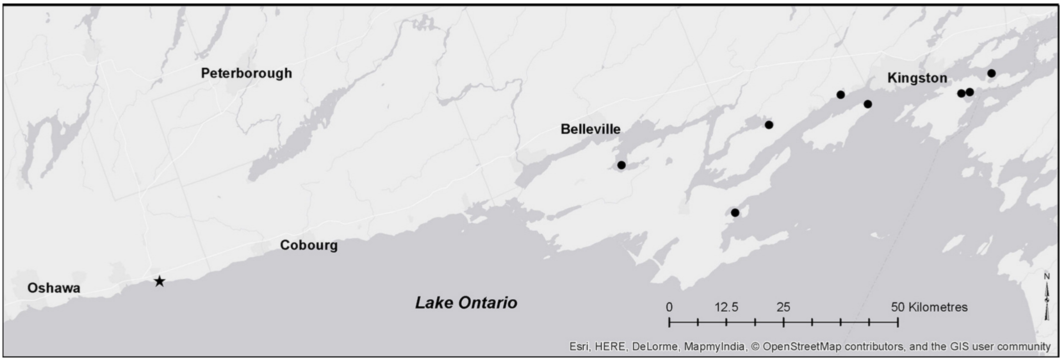

FIGURE 1. Location of juvenile Chain Pickerel (*Esox niger*) captured at Port of Newcastle (star) and recent adult Chain Pickerel captures in the Bay of Quinte and eastern basin of Lake Ontario (black dots).

FIGURE 2. First juvenile Chain Pickerel (*Esox niger*) caught in Ontario (total length 153 mm). Photo: B. Morrison.

of 802 matched; E. Holm and H. Haddrath, personal communications). Subsequent supplemental monitoring on 1 September 2016, using both boat electrofishing and seining, failed to detect any additional specimens.

Other fish species captured on 22 August 2016 in the Port of Newcastle wetland included Common Carp (*Cyprinus carpio*), Johnny Darter (*Etheostoma nigrum*), Largemouth Bass (*Micropterus salmoides*), Pumpkinseed (*Lepomis gibbosus*), Rock Bass (*Ambloplites rupestris*), and Round Goby (*Neogobius melanostomus*). Turbidity and conductivity in this coastal wetland were 5–15 nephelometric turbidity units (NTU) and 300–500 µS/cm, respectively, based on sampling in 2016 and earlier. Total aquatic plant cover at this location was around 60% and included Curly-leaved Pondweed (*Potamogeton crispus* L.), Eurasian Water-milfoil (*Myriophyllum spicatum* L.), Small Pondweed (*Potamogeton pusillus* L.), and Leafy Pondweed (*Potamogeton foliosus* Rafinesque). The substrate was quite coarse, consisting of a mix of contents from old gabion baskets and silt/sand. Aquatic vegetation throughout the marsh was inter-

TABLE 1. Identification features of Ontario esocids.

| Species | No. branchiostegal rays | Gill cover | Suborbital bar | No. lower jaw pores |
|---|---|---|---|---|
| Chain Pickerel (*Esox niger*) | 14–17 | Fully scaled | | 8 (4 on each side) |
| Grass Pickerel (*Esox americanus vermiculatus*) | 11–13 | Fully scaled | Prominent | 8 (4 on each side) |
| Northern Pike (*Esox lucius*) | 14–15 | Partly scaled | | 10 (5 on each side) |
| Muskellunge (*Esox masquinongy*) | 16–19 | Partly scaled | | 12–18 (6–9 on each side) |

spersed with pockets of well-vegetated areas, but most of the area had little cover. Port of Newcastle is considered a drowned river mouth; a portion has been dredged for a marina.

## Discussion

Chain Pickerel is believed to be native in New York waters of Lake Ontario (Carlson *et al.* 2016, and references within), but it has recently colonized Ontario waters in the eastern basin and upper St. Lawrence River, with increasing abundance in the former (Hoyle and Lake 2011). The capture of this Chain Pickerel is significant, as it is both the first juvenile captured, and its location was more than 100 km west of the closest record in Ontario waters.

Chain Pickerel have remained elusive in the Lake Ontario basin despite significant sampling in warm, highly vegetated habitats. Since 2002, 185 wetland sampling events have been completed in the Durham region and 50 in the Bay of Quinte under the DRCWMP. In addition, other agencies, largely the Ontario Ministry of Natural Resources and Forestry, carry out sampling in the Bay of Quinte using numerous gear types, and commercial fisheries expend a large amount of effort in the bay (Ontario Ministry of Natural Resources and Forestry 2016). Although significant wetland sampling occurs in the Durham region, limited sampling is done in adjacent Lake Ontario nearshore waters. The absence of adult records in the Durham region could be attributed to low abundance, a low sampling effort in areas with water depth greater than 2 m, and the timing of DRCWMP sampling, i.e., after adult fish have spawned and left wetland habitats (Environmental Canada and Central Lake Ontario Conservation Authority 2007; Sauvanet *et al.* 2013). Samarasin *et al.* (2017) have noted that sampling effort should be greater (either single or replicate sampling) in areas with more species and in larger wetlands to improve chances of detection. In addition to varying effort, challenges differentiating juvenile Chain Pickerel from other Esocidae could be complicating the recognition of range expansion.

Range expansion is difficult to monitor because of the rarity of a species at its leading edge and the potential for misidentification and hybridization with similar species. Although, not certain, it is unlikely that this specimen was introduced (e.g., via bait bucket or aquarium release); thus, this capture is likely evidence that the range of the Chain Pickerel is expanding westward in Ontario and that natural reproduction may have occurred in the Port of Newcastle wetland. It is unclear what role a significant drought in 2016 may have played in forcing fishes out of small coastal wetlands and concentrating them in larger wetland complexes with easy access from Lake Ontario, such as Port of Newcastle. Continued monitoring, with increased emphasis on areas that have been poorly sampled, should help determine abundance and confirm natural reproduction of Chain Pickerel in the Ontario waters of Lake Ontario.

Although the captured specimen appears to be a pure Chain Pickerel, it is possible that hybrids between Chain Pickerel and Northern Pike (*Esox lucius*) maybe present. Such a hybrid would be difficult to identify, and we recommend that any *Esox* that is not clearly a Northern Pike or Grass Pickerel be preserved and a tissue sample saved for genetic analysis. Specimens and tissues can be submitted for identification to the Royal Ontario Museum.

Limitations on the Chain Pickerel's range expansion are thought to be related to water temperatures and the amount of suitable habitat. Mandrak (1989) predicted that climate warming might lead to further expansion and establishment of Chain Pickerel in Ontario waters of Lake Ontario or connected waterbodies. Hoyle and Lake (2011) indicated that the lack of warm, heavily vegetated habitats in portions of Lake Ontario could create physical barriers to Chain Pickerel dispersal. Although the north shore of Lake Ontario has limited habitat for Chain Pickerel, the fish appears to have bridged this barrier. It is unknown how such habitat features affect dispersal of Chain Pickerel at various life stages or what mechanisms prompt movement or colonization. It is also not known what impact this species might have on existing fish communities, its potential for hybridization with other Esocidae (e.g., *E. lucius*), or its effect on recreational and commercial fisheries. Chain Pickerel have been implicated in simplifying fish communities, reducing overall fish abundance, and truncating the size spectrum of fishes in waterbodies where it has been introduced (Mitchell *et al.* 2010), but these effects may be muted because piscivorous species are already present in the existing fish community. Continued monitoring is encouraged to track the continued presence and establishment of Chain Pickerel in Ontario waters.

## Acknowledgements

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## Literature Cited

**Carlson, D. M., R. A. Daniels**, and **J. J. Wright.** 2016. Atlas of Inland Fishes of New York. Volume 7. New York State Museum, Albany, New York, USA.

**Coffie, P. A.** 1998. Status of the Chain Pickerel, *Esox niger*, in Canada. Canadian Field-Naturalist 112: 133–140. Accessed 27 March 2018. https://www.biodiversitylibrary.org/item/106776#page/141/mode/1up.

**Environment Canada and Central Lake Ontario Conservation Authority**. 2007. Durham Region Coastal Wetland Monitoring Project: Methodology Handbook. Central Lake Ontario Conservation Authority, Oshawa, Ontario, Canada.

**Greeley, J. R.** 1939. Fishes of the watershed with annotated list. *In* A Biological Survey of the Lake Ontario Watershed (Including all Waters from Little Sandy Creek Westward Except the Genesee and Oswego River Systems): Supplement to the Twenty-ninth Annual Report, 1939, Volume 16. New York (State) Conservation Department, Albany, New York, USA.

**Holm, E., N. Mandrak,** and **M. Burridge.** 2009. The ROM Field Guide to Freshwater Fishes of Ontario. Royal Ontario Museum, Toronto, Ontario, Canada.

**Hoyle, J. A.,** and **C. Lake.** 2011. First occurrence of Chain Pickerel (*Esox niger*) in Ontario: possible range expansion from New York waters of eastern Lake Ontario. Canadian Field-Naturalist 125: 16–21. https://doi.org/10.22621/cfn.v125i1.1116

**Mandrak, N. E.** 1989. Potential invasion of the Great Lakes by fish species associated with climatic warming. Journal of Great Lakes Research 15: 306–316. https://doi.org/10.1016/S0380-1330(89)71484-2

**Mitchell, S. C., J. E. LeBlanc,** and **A. J. Heggelin.** 2010. Impact of introduced Chain Pickerel (*Esox niger*) on lake fish communities in Nova Scotia, Canada. Nova Scotia Department of Fisheries and Aquaculture, Halifax, Nova Scotia, Canada.

**Moore, D. M.** 2016. The use of historical data to describe changes in fish communities over time. M.E.Sc. thesis, University of Toronto, Scarborough, Ontario, Canada.

**Ontario Ministry of Natural Resources and Forestry.** 2016. Lake Ontario fish communities and fisheries: 2015 annual report of the Lake Ontario Management Unit. Ontario Ministry of Natural Resources and Forestry, Picton, Ontario, Canada.

**Page, L. M.,** and **B. M. Burr.** 2011. A Field Guide to Freshwater Fishes of North America North of Mexico. Houghton Mifflin Harcourt, Boston, Massachusetts, USA.

**Samarasin, P., S. M. Reid,** and **N. E. Mandrak.** 2017. Optimal sampling effort required to characterize wetland fish communities. Canadian Journal of Fisheries and Aquatic Sciences 74: 1251–1259. https://doi.org/10.1139/cjfas-2016-0424

**Sauvanet, J., G. Bourdier, J. Colombet, A. Viallefont, C. Lemarchand,** and **C. Desvilettes.** 2013. Estimating *Esox lucius* (Esocidae, Esociformes) density and population structure in a large European alluvial river: the Allier (France). Journal of Ichthyology 53: 617–627. https://doi.org/10.1134/S003294521305010X

**Scott, W. B.,** and **E. J. Crossman.** 1998. Freshwater Fishes of Canada. Galt House Publications, Oakville, Ontario, Canada.

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# Note

# A Bilaterally Partitioned Colour Variant of an Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) from Eastern Pennsylvania

SEAN M. HARTZELL

Department of Biological and Allied Health Sciences, Bloomsburg University of Pennsylvania, 400 East 2nd Street, Bloomsburg, Pennsylvania 17815 USA; email: smh14844@huskies.bloomu.edu

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This observation of a bilaterally partitioned colour phenotype of an Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) from Fishing Creek, Columbia County, Pennsylvania, USA, appears to be the first report of such an aberrant phenotype for this species. The pattern is similar to that reported previously in Papershell Crayfish (*Orconectes immunis*) and American Lobster (*Homarus americanus*). Although the cause of the colour pattern in the specimen of *C. b. bartonii* could not be determined, hypotheses related to previous cases in aquatic crustaceans include bilateral partition of primary and secondary sexual characteristics (bicoloured gynandromorphy) and mutation during embryogenesis.

Key Words: Appalachian Brook Crayfish; *Cambarus bartonii bartonii*; colour variation; bilateral partition; bicoloured gynandromorphy; Pennsylvania

Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) is a small- to medium-sized crayfish occupying primarily lotic habitats from Quebec, Ontario, and New Brunswick in Canada south to Georgia, South Carolina, and Alabama in the United States (Hobbs 1989). Colouration in *C. b. bartonii* typically ranges from a single shade of olive green through amber, brown, and chestnut (Ortmann 1906; Martin 1997; Loughman 2010).

On 22 September 2016, I collected a single atypically coloured *C. b. bartonii* from among 108 crayfish captured while conducting a crayfish survey of Fishing Creek, a tributary of the North Branch Susquehanna River, near the municipality of Stillwater, Columbia County, Pennsylvania, USA (41°07'46.6"N, 76°21'37.1"W; Hartzell and Rier 2017). Here I provide a description and context for the significance of this observation.

The atypical specimen was captured by hand from under a piece of cobble at the margin of Fishing Creek, identified to species, photographed, measured, and released at the site of capture. The specimen, carapace length 2.6 cm and undetermined sex, exhibited a largely bilaterally partitioned colour pattern from the posterior portion of the cephalothorax through to the telson, with the left half of the body a dark, olive green and the right half a light amber in colour. The anterior portion of the cephalothorax was dark, olive green (Figure 1). The specimen appeared to be in excellent condition and displayed normal, unimpeded behaviour (e.g., walking, a righting response, aggressive defense with chelae during handling).

FIGURE 1. Appalachian Brook Crayfish (*Cambarus bartonii bartonii*) from northeastern Pennsylvania displaying a bilaterally partitioned colour phenotype. Photo: Sean M. Hartzell.

The colour pattern reported here suggests a condition referred to as "bilateral gynandromorphy", which has been documented in various crustaceans, including lobsters, crabs, prawns, and other decapods (e.g., Chace

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and Moore 1959; Farmer 1972; Syslo and Hughes 1981; Taylor 1986; Micheli 1991), as well as in other invertebrates, such as ants (Taber and Francke 1986) and even vertebrates, such as birds (Peer and Motz 2014). These individuals may display a bilateral partition of colouration, termed "bicoloured bilateral gynandromorphy". The condition is most obvious in species with sexually dimorphic colour patterns (e.g., Peer and Motz 2014). In Pennsylvania, *C. b. bartonii* appears to exhibit an ontogenetic colour shift from greener hues in younger individuals to darker brown in older specimens (Ortmann 1906), but does not appear to exhibit obvious sexual dimorphism in colouration. Although Ortmann (1906) reported two specimens of *C. b. bartonii* from Pennsylvania that displayed a mixture of male and female sexual characteristics, his lack of comment on colouration suggests that they were of normal phenotype.

Bicoloured gynandromorphy may also occur among species lacking distinct sexual dimorphism in colouration, but where some degree of colour variation is prevalent. Chace and Moore (1959) described an American Lobster (*Homarus americanus*) with a bilaterally distinct colour partition made evident by the absence of blue pigment on the left side of the body and the absence of red, yellow, and black pigments on the right side. This occurred in conjunction with bilateral partition of primary and secondary sexual characteristics. An observation of colour bilateralism similar to that reported here involves Papershell Crayfish (*Orconectes immunis*; Dowell and Winier 1969). Dowell and Winier (1969) rejected gynandromorphy as a causative mechanism because this crayfish displayed only female external sexual characteristics, and they speculated that its bicolouration was the result of a mutation during embryogenesis. However, because neither the specimen reported by Dowell and Winier (1969) nor the *C. b. bartonii* reported here was examined internally to determine sex or intersexual status, any suggestion of the lack of a link between colour pattern and gynandromorphy in these specimens remains speculative.

Colouration in crayfish can vary and change because of environmental factors, including the hue of the background substrate (Bowman 1942; Thacker *et al.* 1993). However, it is unlikely that the colour pattern I observed may be attributed to background colour matching because of the striking bilateral partitioning. In addition, the specimen remained in a white cooler for approximately an hour with other crayfish collected at the site before being photographed, measured, and released, with no obvious shift in colour pattern.

Given that all other *C. b. bartonii* captured in Fishing Creek during the 2016 survey displayed typical colour phenotypes (i.e., a single colour varying from olive green to light amber) and that the observation reported here appears to be unique for the species, the bilaterally partitioned phenotype would appear to be exceedingly rare in *C. b. bartonii*. Collection and dissection, or genomic analysis, of additional specimens of crayfish showing colour bilateralism may provide insight into the cause of this phenomenon.

## Acknowledgements

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## Literature Cited

**Bowman, T. E.** 1942. Morphological color change in crayfish. American Naturalist 76: 332–336. https://doi.org/10.1086/281051

**Chase, Jr., F. A.,** and **G. M. Moore.** 1959. A bicolored gynandromorphy of the lobster, *Homarus americanus*. Biological Bulletin 116: 266–231. https://doi.org/10.2307/1539207

**Dowell, V. E.,** and **L. P. Winier.** 1969. A bilateral color anomaly in the crayfish *Orconectes immunis* (Hagen). Proceedings of the Iowa Academy of Science 76: 487–492.

**Farmer, A. S.** 1972. A bilateral gynandromorph of *Nephrops norvegicus* (Decopoda: Nephropidae). Marine Biology 15: 344–349. https://doi.org/10.1007/BF00401394

**Hartzell, S. M.,** and **S. T. Rier.** 2017. A crayfish survey of the Fishing Creek watershed in northeastern Pennsylvania reveals widespread prevalence of a non-indigenous species and the absence of an indigenous congener. Journal of the Pennsylvania Academy of Science 91: 1–10. https://doi.org/10.5325/jpennacadscie.91.1.0001

**Hobbs, Jr., H. H.** 1989. An Illustrated Checklist of the American Crayfishes (Decapoda: Astacidae, Cambaridae, Parastacidae). Smithsonian Institution Press, Washington, DC, USA. https://doi.org/10.5479/si.00810282.480

**Loughman, Z. J.** 2010. Crayfishes of western Maryland: conservation and natural history. Southeastern Naturalist 9 (special issue 3): 33–62. https://doi.org/10.1656/058.009.s303

**Martin, S. M.** 1997. Crayfishes (Crustacea: Decapoda) of Maine. Northeastern Naturalist 4: 165–188. https://doi.org/10.2307/3858712

**Micheli, F.** 1991. Bilateral gynandromorph of the fresh-water crab *Potamon fluviatile* Herbst (Decapoda: Brachyura). Journal of Crustacean Biology 11: 561–568. https://doi.org/10.2307/1548526

**Ortmann, A. E.** 1906. The crawfishes of the state of Pennsylvania. Memoirs of the Carnegie Museum 2: 343–523. https://doi.org/10.5962/bhl.title.10407

**Peer, B. D.,** and **R. W. Motz.** 2014. Observations of a bilateral gynandromorph northern cardinal (*Cardinalis cardinalis*). Wilson Journal of Ornithology 126: 778–781. https://doi.org/10.1676/14-025.1

**Syslo, M.,** and **J. T. Hughes.** 1981. Reproductive behavior of a bicolored gynandromorphic American lobster. Progressive Fish-Culturalist 43: 214–216. https://doi.org/10.1577/1548-8659(1981)43[214:RBOABG]2.0.CO;2

**Taber, S. W.,** and **O. F. Francke.** 1986. A bilateral gynandromorph of the western harvester ant, *Pogonomyrmex occidentalis* (Hymonoptera: Fromicidae). Southwestern Naturalist 31: 274–276. https://doi.org/10.2307/3670583

**Taylor, D. M.** 1986. A bilateral gynandromorph of the snow crab, *Chionoecetes opilio*, from Newfoundland, Canada. Crustaceana 51: 309–312. https://doi.org/10.1163/156854086X00502

**Thacker, R. W., B. A. Hazlett, L. A. Esman, C. P. Stafford,** and **T. Keller.** 1993. Color morphs of the crayfish *Orconectes virilis*. American Midland Naturalist 129: 182–199. https://doi.org/10.2307/2426447

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# Increased Bufflehead (*Bucephala albeola*) Breeding Activity in Minnesota

Susan N. Ellis-Felege[1, 4], Cassandra G. Skaggs[1, 3], and Gregory A. Knutsen[2]

[1]Biology Department, University of North Dakota, 10 Cornell Street, Stop 9019, Grand Forks, North Dakota 58202-9019 USA
[2]U.S. Fish and Wildlife Service, Glacial Ridge and Rydell National Wildlife Refuges, 17788 349th Street SE, Erskine, Minnesota 56535 USA
[3]Louisiana State University, School of Renewable Natural Resources, LSU Agricultural Center, Baton Rouge, Louisiana 70803 USA
[4]Corresponding author: susan.felege@email.und.edu

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Buffleheads (*Bucephala albeola*) predominantly nest in the boreal forests and aspen parklands of Canada and Alaska. Historically, Buffleheads were common migrants but not summer residents in Minnesota. However, recent observations in Minnesota and surrounding states suggest increased breeding activity in the region. In 1978, the first Bufflehead brood in Minnesota was recorded at East Park Wildlife Management Area. Annually, Agassiz National Wildlife Refuge (NWR) has conducted pair and brood surveys, with species-specific records available from 1990 to 2014. We report an increase in numbers of Bufflehead breeding pairs and broods at Agassiz NWR and new pair observations in surrounding areas.

Key Words: Breeding range; *Bucephala albeola;* Bufflehead; cavity nesting; expansion; Great Plains; upper midwest

## Introduction

Buffleheads (*Bucephala albeola*) are a secondary cavity-nesting species that frequently use the cavities of Northern Flickers (*Colaptes auratus*) and, to a lesser extent, Pileated Woodpeckers (*Dryocopus pileatus*). Nest cavities used by Buffleheads are most common in live or dead poplar or aspen trees (*Populus* spp.). They also will use nest boxes (Gauthier 1988). Most Bufflehead nesting activity occurs in Canada and Alaska, with a smaller portion of the breeding population extending into parts of Washington, California, Oregon, Idaho, Montana, and Wyoming (Erskine 1972; Gauthier 2014). Although this small, cavity-nesting duck is a common fall and spring migrant throughout much of Minnesota, it is considered a rare summer resident (Janssen 1987; Gauthier 2014). Erskine (1972) suggested Buffleheads may have been present in early summer in northwestern Minnesota, but that most of these individuals were subadults or non-breeding adults that would remain in the region into the breeding season. Scattered historical breeding records do exist for North Dakota (1873), Iowa (1880s), Wisconsin (1903), South Dakota (1949), Idaho (1953), and more recently Nevada (Floyd *et al.* 2007). It was not until 1978, however, that the first Bufflehead brood in Minnesota was documented at East Park Wildlife Management Area (WMA) in the northwestern part of the state (Davis 1978). An increasing number of reports of breeding activity occurred over the next 10 years across northwestern Minnesota (Heidel 1983; Mattsson 1986). Since 1985, Bufflehead broods have been observed at Agassiz National Wildlife Refuge (NWR), located in northwestern Minnesota, almost every year.

Recent observations have documented Bufflehead breeding activity in the southern half of Minnesota, including a 2012 brood in Cottonwood County in southern Minnesota (Pfannmuller *et al.* 2017). Additionally, broods have recently been confirmed in southeastern Wisconsin (Bahl and Bartholmai 2011), south-central and eastern North Dakota (Knutsen and King 2004; M. R. Fisher, personal communication, 2012), and northeastern South Dakota (Whitt 1999). Scattered observations reported to eBird document Buffleheads during June and July in areas as far south as Texas and Louisiana (eBird 2012). These observations across the upper midwest (Wisconsin, Minnesota, North Dakota, South Dakota) and Great Plains suggest that Buffleheads may be increasing their breeding activities. Our objective was to evaluate changes in Bufflehead reproductive activity in northwestern Minnesota and summarize recent accounts of breeding activity across the upper midwest region.

## Study Area

Long-term monitoring of Bufflehead reproduction was conducted at Agassiz NWR (centroid 48.315836°N, 95.947023°W), Marshall County, Minnesota (Figure 1). Agassiz NWR was established in 1937 as a "refuge and breeding ground for migratory birds and other wildlife". The refuge is 24 889 ha in total, including 15 136 ha of wetland habitat, 4715 ha of shrubland, 4007 ha of woodland (primarily aspen), and 737 ha of grassland. Wetland area includes 26 impoundments that range in size from 12 to > 4000 ha and are managed as sedge meadow and emergent marsh habitats (USFWS 2005). Recent man-

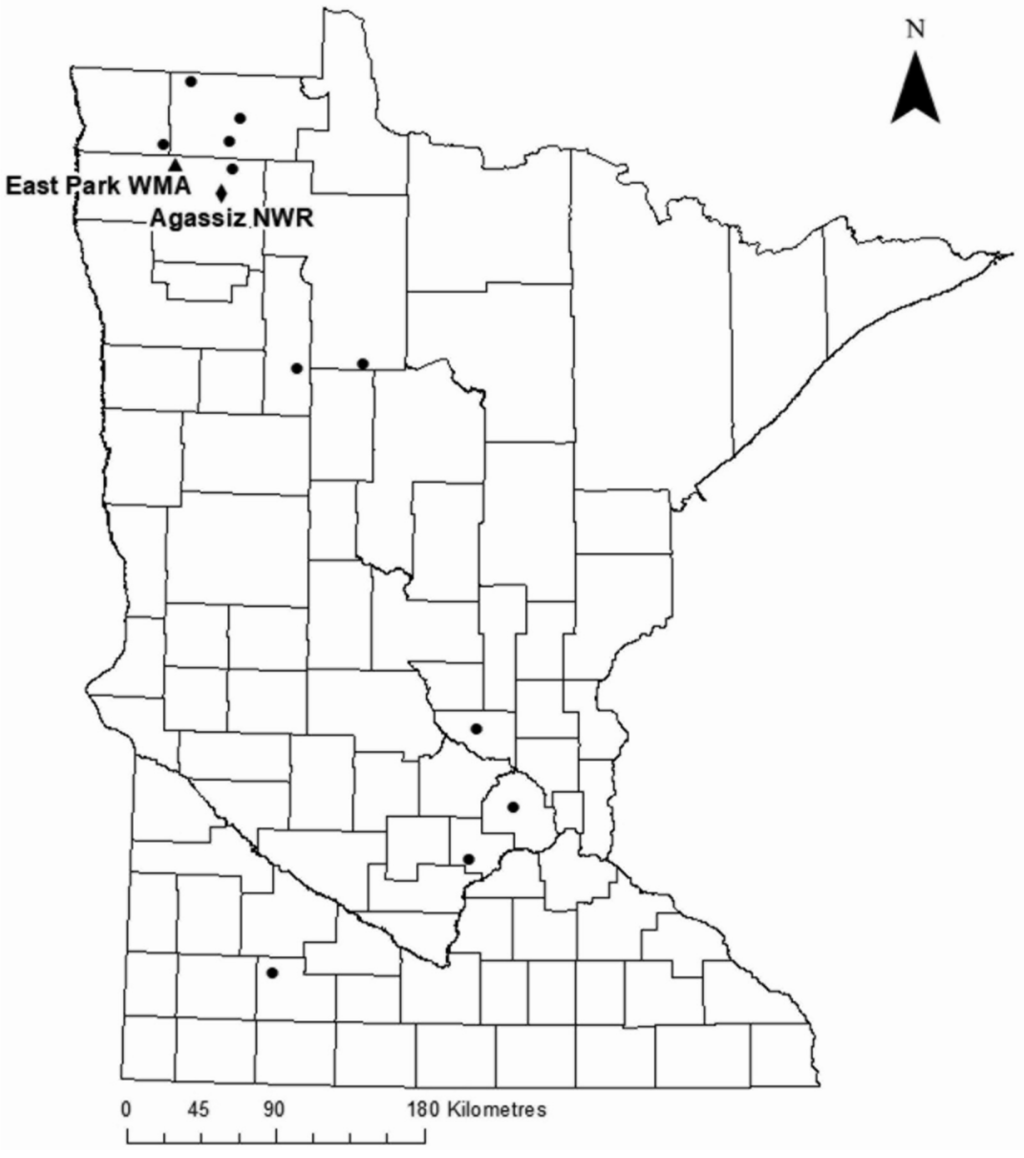

FIGURE 1. Reported or suspected Bufflehead (*Bucephala albeola*) breeding activity in Minnesota, 1978–2014. East Park Wildlife Management Area (WMA) had the first Bufflehead observation in 1978 (triangle), and Agassiz National Wildlife Refuge (NWR) had the most observations overall (diamond). Observations outside study area (solid circles) were obtained from Pardieck *et al.* (2016).

agement efforts have focussed on controlling overabundant cattails across the refuge.

Historically, the area that is now Agassiz NWR was a boggy wilderness, checkered with wetlands and ponds. After European settlement in the 1890s, wetlands were drained for agriculture which resulted in more than 1900 km of county and legal drainage ditches. Agassiz NWR lies within the aspen parkland transitional zone (USFWS 2005). Climatic conditions at the refuge are typical of the region, where variation in temperatures is wide and extreme, including cold winters with moderate snowfall and approximately 56 cm of annual precipitation (USFWS 1978).

In addition to Agassiz NWR, we conducted roadside surveys at six wildlife management areas, two flood storage impoundments, and one state park in northwestern Minnesota to determine the extent of breeding occurrences in the region (Table 1). Of these, five sites had no prior reports of Bufflehead activity during the breeding season whereas five others did (Table 1).

TABLE 1. Maximum number of Bufflehead (*Bucephala albeola*) pairs observed during spring roadside surveys at five sites with previous records of pairs (noted with an *) and five sites with no previous records located in northwestern Minnesota, 2012–2013.

| | Bufflehead Breeding Pair Summary for 2012 and 2013 | | | | | Max. pairs detected outside of survey constraints (2012/2013)† |
|---|---|---|---|---|---|---|
| Site | Max. pairs 2012 | Max. pairs 2013 | Change in pairs from 2012 | Newly detected site 2012 | Newly detected site 2013 | |
| Agassiz NWR East* | 10 | 8 | −2 | – | – | 2/4 |
| Agassiz NWR South* | 3 | 2 | −1 | – | – | 2/0 |
| Agassiz NWR West* | 5 | 4 | −1 | – | – | 2/2 |
| Agassiz Valley Project | 0 | 0 | 0 | No | No | 0/1 |
| East Park WMA* | 2 | 2 | 0 | – | – | 3/2 |
| Hayes Lake State Park | 0 | 0 | 0 | No | No | 0/0 |
| Moose River Impoundment | 0 | 2 | 2 | No | Yes | 0/0 |
| Nereson WMA* | 0 | 3 | 3 | – | – | 1/2 |
| Red Lake WMA | 0 | 1 | 1 | No | Yes | 0/0 |
| Roseau River WMA* | 4 | 3 | −1 | – | – | 3/1 |
| Thief Lake WMA* | 1 | 1 | 0 | – | – | 0/1 |
| Twin Lakes WMA | 1 | 0 | −1 | Yes | No | 0/0 |

*Known breeding locations before 2012.

†Pairs observed but not included in our other counts (e.g., pairs observed outside of our defined survey area or between points). The first number is the maximum number of pairs observed in 2012 and the second number is the maximum number of pairs observed in 2013.

## Methods

Breeding duck pair and brood surveys are conducted annually at Agassiz NWR (USFWS 2008). A double sampling method of ground and aerial surveys was used to estimate pairs across one third of the refuge. Ground surveys were conducted using roadside pair counts on a single morning each spring between 16 and 24 May. Observers drove 8–16 km/h on transects totalling 80.5 km within the refuge. Pairs were recorded by species out to 200 m from each transect. Indicated pairs included one male and one female, a lone male, or males in groups of two to five (Hammond 1969). During the completion of ground surveys, 17 aerial transect surveys were flown in a fixed-wing aircraft at an altitude of 45–46 m over the refuge. Two observers, not including the pilot, recorded all indicated duck pairs and classified them as either "diving ducks" or "dabbling ducks" within 200 m on each side of the aircraft. Approximately 38.5 km were concurrently surveyed by both air and ground to provide a ground/air correction factor.

Only ground surveys were used to calculate duck brood estimates. Two separate brood surveys were conducted by driving the same transects as for pair surveys. Surveys were conducted between 5–12 July and 15–23 August, with a minimum of 42 days between surveys to minimize duplicate brood counts. All broods within 200 m of each side of the transect were recorded, identified to species, and aged according to Gollop and Marshall (1954). During the second (August) survey, only ducklings age class IIc (Gollop and Marshall 1954) and younger were counted by trained observers to avoid double counting broods that were recorded during the first survey.

Pair and brood surveys were conducted only on days without steady precipitation and winds not exceeding 24 km/h for pairs and 8 km/h for broods (Giudice 2001). Each survey was initiated 30 min after sunrise and took approximately 3.5–4 h to complete. Due to staff limitations, brood surveys were not conducted in 2013 or 2014.

In 2012 and 2013, we expanded surveys across northwest Minnesota to include other sites where Bufflehead breeding activity may potentially occur. Of the ten sites selected, five had documented broods in past years, whereas five had no documented Bufflehead breeding activity, but possessed potential habitat (Figure 1). Given that aerial surveys were not available across these sites, we conducted repeat count surveys to allow examination of detection while estimating occurrence of potential breeding pairs. Similar to the ground surveys for pairs conducted at Agassiz NWR, roadside surveys were conducted 18–30 May. Observers stopped at points (250 m apart) along routes to count pairs within 200 m of the survey point, because not all wetlands allowed for equal road-based visibility of wetlands.

For the initial Agassiz NWR surveys conducted from 1990 until 2014, we estimated breeding Bufflehead pairs based upon aerial and ground surveys. The total number of pairs for dabbling ducks and diving ducks were calculated from both aerial and ground surveys. The ratio of ground to air (total number of pairs counted from ground/total number of pairs counted from aerial surveys) provides a correction factor between survey methods. Because aerial surveys effectively sampled one third of the refuge, the total number of diver and dabbler pairs tallied during the aerial survey was multiplied by three and the ground/air correction factor to estimate total number of divers on the refuge. Finally, the number of Bufflehead pairs was obtained by estimating the proportion of divers that were classified as Buffleheads on the ground survey.

We only report summary statistics from broods detected along survey routes for each year, given we had limited information on other aspects of the reproductive process (e.g., nest success, brood survival) that influence productivity. Prior to 2001, surveys were conducted from the bed of the pickup truck with higher elevation. Beginning in 2001, federal safety policy required that all observers conduct surveys from inside the truck's cab instead. Thus, broods observed after 2001 are corrected for detections estimated from concurrent bed and cab surveys that found a 0.65 detection rate from the cab (Agassiz NWR, unpublished data, 1999–2001).

For the 2012–2013 data, we used the maximum pairs or broods detected across three repeated surveys. This allowed us to account for detection issues of missing pairs or broods during some surveys. Due to a limited sample size of wetlands that we could monitor, we did not conduct a formal occupancy analysis to estimate detection (MacKenzie *et al.* 2006).

## Results

Bufflehead breeding pair numbers have increased across Agassiz NWR since 1990, with an estimated average of 329 breeding pairs across the refuge over the most recent 10 years (2004–2014) of data (Figure 2). Over that 10-year period, there was an 84% increase in number of pairs using the refuge. Similarly, the number of brood sightings has an increasing trend since 1990, with an average of 11 (range 0–26) Bufflehead broods detected along survey routes from 2002 through 2012 at Agassiz NWR.

The 2012 and 2013 pair surveys revealed three locations with new occurrences of potential breeding pairs (Table 1). These include new observations at Moose River Impoundment, Red Lake WMA, and Twin Lakes WMA. However, we did not detect broods at any of the sites other than Agassiz NWR during brood surveys in 2012.

## Discussion

Based on aerial-ground surveys conducted by U.S. Fish and Wildlife Service since 1990, Bufflehead breeding activity in northwestern Minnesota has rapidly increased since the first brood observation at Agassiz NWR in 1985. Additional observations in North Dakota and the southwest corner of Minnesota (i.e., Cottonwood County) demonstrate other areas with possible breeding populations. Given some historical observations, there may be increased Bufflehead breeding activity occurring in areas south of what was thought to be the traditional breeding range of the species. A southward range expansion in California also has been docu-

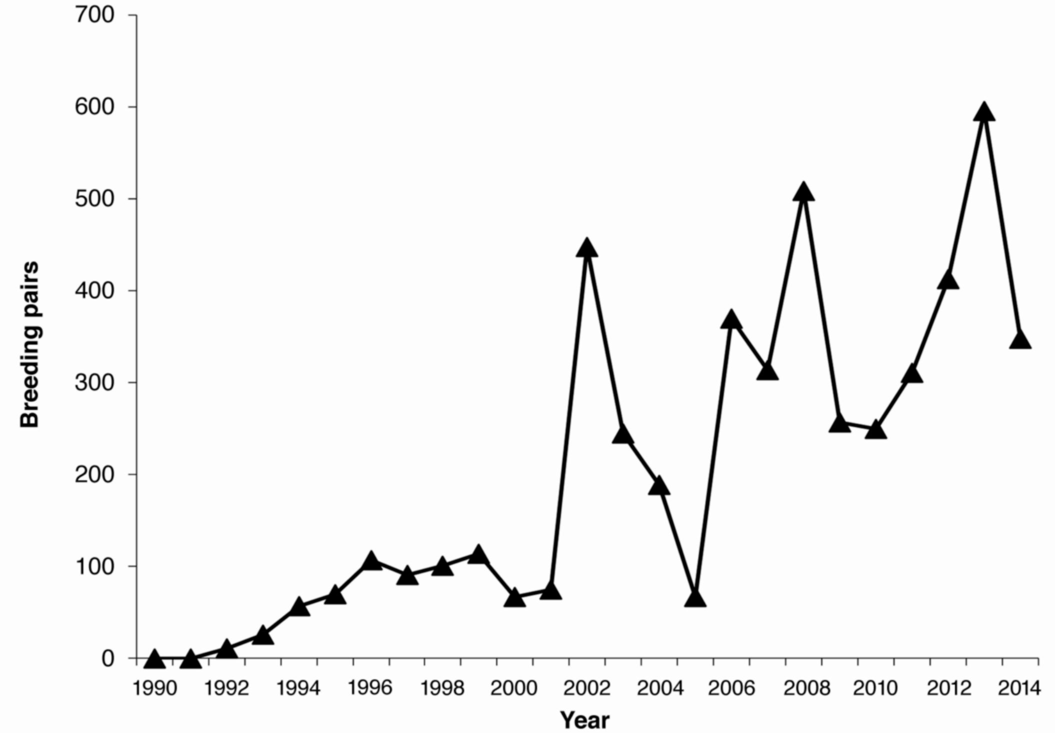

FIGURE 2. Estimated number of breeding Bufflehead (*Bucephala albeola*) pairs each May at Agassiz National Wildlife Refuge, based on 1990–2014 aerial-ground surveys.

mented, with Bufflehead breeding activity observed as far as 850 km south of their traditional breeding range (Richardson 2004).

The North American Bufflehead population trend shows an increasing overall population (1955–1992: Gauthier 2014) and a stable to increasing breeding population (1955–2010: Zimpfer *et al.* 2010; 1966–2010: Sauer *et al.* 2011). While the Bufflehead population in the boreal forests of Canada undergoes annual fluctuations, it has a stable long-term population trend (Fast *et al.* 2011).

There are several possible explanations for observing increased Bufflehead breeding activity in Minnesota as shown by the increased number of pairs and occurrences of potential breeding in new locations. Because Buffleheads nest in cavities and cavities can be a limiting factor, one possible explanation is that Buffleheads are finding more suitable nesting cavities along historical migratory routes. Aging trees or increases in the number of dead standing trees caused by flooding or insects could be involved.

In Minnesota, aspen stand ages may be reaching an appropriate diameter at breast height (DBH; Denton *et al.* 2012) for Northern Flickers to create more nesting cavities for Buffleheads. Martin *et al.* (2004) found Buffleheads using Trembling Aspen (*Populus tremuloides* Michaux) with an average DBH of 33 cm. The wet period recently experienced in the upper midwest and Great Plains (Millet *et al.* 2009) also could have increased the availability of dead standing trees near wetlands; warmer temperatures can facilitate the spread of pests such as beetles that may increase the amount of dead timber and cavities on the landscape (Dale *et al.* 2001).

Although aging or flooded or insect killed aspen stands may increase the number of potential breeding sites on a regional level, they do not entirely explain the southward expansion of the breeding range in California that likely is the result of a combination of factors (Richardson 2004). Hooded Mergansers (*Lophodytes cucullatus*), another cavity nesting species, appear to be expanding their breeding activity southward in California, likely as the result of an increasing population and available nesting cavities (Pandolfino *et al.* 2006). Increases in numbers of pairs and broods of this species have been documented at Agassiz NWR (USFWS, unpublished data, 1990–2014).

While many breeding bird ranges appear to be shifting northward (Whitaker 2017), Zuckerberg *et al.* (2009) found 43% of 129 avian species in New York state showed a southward shift in their mean breeding range latitude between 1980 and 2005. They found a shift of 34 km southward for Common Loons (*Gavia immer*), another boreal nesting, but not cavity-nesting, species.

Nest box programs could increase breeding opportunities for cavity-nesting ducks like Buffleheads. Even though a modest number of nest boxes (< 30) were erected on state Wildlife Management Areas adjacent to Agassiz NWR by the Minnesota Department of Natural Resources around 2010, there has not been an active nest box program at Agassiz NWR since Bufflehead breeding activity was first documented at the refuge.

While habitat changes or shifts in breeding range are plausible explanations for increases in breeding activity observations for Buffleheads, some could be due to the increased ease and opportunity to report breeding activities. For example, eBird (eBird 2012) and several of the breeding bird state atlases (e.g., Minnesota) now have convenient ways for birders to report observations with detailed location and date information. As a result, some of the increased breeding observations across the United States could simply be an artifact of improved reporting and access to such reports rather than true range extensions or increases in breeding activity. However, the observations at Agassiz NWR appear to be increased activity, likely as the result of increased breeding success and suitable habitat available for Buffleheads given their high levels of natal philopatry.

Learning about the role of more southern latitude breeding sites could provide information on how Bufflehead populations are responding to climate, habitat changes, and even information about reporting of such observations. Furthermore, because limited research on Bufflehead has been conducted outside of British Columbia, Canada, studies are needed to understand habitat preferences in this newly utilized breeding range. In an era when many species are declining, it is important to understand factors contributing to stable or increasing populations.

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## Literature Cited

**Bahls, J.,** and **J. Bartholmai.** 2011. Bufflehead nesting in Wisconsin. Wood Duck Newsgram 63: 9–11.

**Dale, V. H., L. A. Joyce, S. McNulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, L. C. Irland, A. E. Lugo, C. J. Peterson, D. Simberlopp, F. J. Swanson, B. J. Stocks,** and **B. M. Wotton.** 2001. Climate change and forest disturbances. BioScience 51: 723–734. https://doi.org/10.1641/0006-3568(2001)051[0723:CCAFD]2.0.CO;2

**Davis, G.** 1978. Bufflehead brood in Marshall County. The Loon 50: 213–214.

**Denton, J. C., C. L. Roy, G. J. Soulliere,** and **B. A. Potter.** 2012. Change in density of duck nest cavities at forests in the north central United States. Journal of Fish and Wildlife Management 3: 76–88. https://doi.org/10.3996/112011-JFWM-067

**eBird.** 2012. eBird: An online database of bird distribution and abundance. eBird, Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed 21 September 2017. http://www.ebird.org.

**Erskine, A. J.** 1972. Buffleheads. Canadian Wildlife Service Monograph Series (4). Information Canada, Ottawa, Ontario, Canada.

**Fast, M., B. Collins,** and **M. Gendron.** 2011. Trends in breeding waterfowl in Canada. Canadian biodiversity: ecosystem status and trends 2010, technical thematic report no. 8. Canadian Councils of Resource Ministers. Ottawa, Ontario, Canada. Accessed 21 September 2017. http://www.biodivcanada.ca/default.asp?lang=En&n=9F45F292-1.

**Floyd, T., C. S. Elphick, G. Chisholm, K. Mack, R. G. Elston, E. M. Ammon,** and **J. D. Boone.** 2007. Atlas of the Breeding Birds of Nevada. University of Nevada Press, Reno, Nevada, USA.

**Gollop, J. B.,** and **W. H. Marshall.** 1954. A guide for aging duck broods in the field. Mississippi Flyway Council Technical Section. Northern Prairie Wildlife Research Center Online. Accessed 7 October 2017. http://archive.is/fpqWk.

**Gauthier, G.** 1988. Factors affecting nest-box use by Buffleheads and other cavity-nesting birds. Wildlife Society Bulletin 16: 132–141.

**Gauthier, G.** 2014. Bufflehead (*Bucephala albeola*). *In* The Birds of North America. *Edited by* P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed 21 September 2017. https://birdsna.org/Species-Account/bna/species/buffle.

**Giudice, J. H.** 2001. Visibility bias in waterfowl brood surveys and population ecology of dabbling ducks in central Washington. Ph.D. thesis, University of Idaho, Moscow, Idaho, USA.

**Hammond, M. C.** 1969. Notes on conducting waterfowl breeding pair surveys. Pages 238–258 *in* Saskatoon wetlands seminar. Canadian Wildlife Service report series 6, Environment Canada, Ottawa, Ontario, Canada.

**Heidel, K.** 1983. Bufflehead and ducklings found in Carver Park Reserve. The Loon 55: 123–124.

**Janssen, R. B.** 1987. Birds in Minnesota. University of Minnesota Press for the James Ford Bell Museum of Natural History, Minneapolis, Minnesota, USA.

**Knutsen, G. A.,** and **J. C. King.** 2004. Bufflehead breeding activity in south-central North Dakota. Prairie Naturalist 36: 187–190.

**Martin, K., K. E. H. Aitken,** and **K. L. Wiebe.** 2004. Nest sites and nest webs for cavity-nesting communities in interior British Columbia, Canada: nest characteristics and niche partitioning. Condor 106: 5–19. http://doi.org/10.1650/7482

**MacKenzie, D. I., J. Nichols, J. Royle, K. Pollock, J. E. Hines,** and **L. L. Bailey.** 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species. Academic Press, Burlington, Massachusetts, USA.

**Mattsson, J.** 1986. Another Bufflehead brood at Agassiz NWR. The Loon 58: 140.

**Millet, B., W. C. Johnson,** and **G. Guntenspergen.** 2009. Climate trends of the North American prairie pothole region 1906–2000. Climatic Change 93: 243–267. https://doi.org/10.1007/s10584-008-9543-5

**Pandolfino, E. R., J. Kwolek,** and **K. Kreitinger.** 2006. Expansion of the breeding range of the Hooded Merganser within California. Western Birds 37: 228–236.

**Pardieck, K. L., D. J. Ziolkowski, Jr., M.-A. R. Hudson,** and **K. Campbell.** 2016. North American Breeding Bird Survey Dataset 1966–2015, version 2015.1. U.S. Geological Survey, Patuxent Wildlife Research Center. https://doi.org/10.5066/F7C53HZN

**Pfannmuller, L., G. Niemi, J. Green, B. Sample, N. Walton, E. Zlonis, T. Brown, A. Bracey, G. Host, J. Reed, K. Rewinkel,** and **N. Will.** 2017. Minnesota Breeding Bird Atlas (2009–2013). Accessed 13 March 2018. https://mnbirdatlas.org/species/bufflehead.

**Richardson, T. W.** 2004. Expansion of the breeding range of the Bufflehead in California. Western Birds 35: 168–172.

**Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr.,** and **W. A. Link.** 2011. The North American Breeding Bird Survey, results and analysis 1966–2010. Version 12.07.2011. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

**USFWS (U.S. Fish and Wildlife Service).** 1978. Agassiz National Wildlife Refuge, master plan. U.S. Department of the Interior, Fish and Wildlife Service, Middle River, Minnesota, USA.

**USFWS (U.S. Fish and Wildlife Service).** 2005. Agassiz National Wildlife Refuge, comprehensive conservation plan. U.S. Department of the Interior, Fish and Wildlife Service, Middle River, Minnesota, USA.

**USFWS (U.S. Fish and Wildlife Service).** 2008. Agassiz National Wildlife Refuge wildlife inventory and monitoring plan. U.S. Department of the Interior, Fish and Wildlife Service, Middle River, Minnesota, USA.

**Whitaker, D.** 2017. Expanded range limits of boreal birds in the Torngat Mountains of Northern Labrador. Canadian Field-Naturalist 131: 55–62. https://doi.org/10.22621/cfn.v131i1.1957

**Whitt, M. B.** 1999. Bufflehead brood in northeastern South Dakota. Prairie Naturalist 31: 119–120.

**Zimpfer, N., W. Rhodes, E. D. Silverman, G. Zimmerman,** and **M. D. Koneff.** 2010. Trends in duck breeding populations, 1955–2010. U.S. Fish and Wildlife Service Publication 417, Laurel, Maryland, USA.

**Zuckerberg, B., A. M. Woods,** and **W. F. Porter.** 2009. Poleward shifts in breeding bird distributions in New York State. Global Change Biology 15: 1866–1883. https://doi.org/10.1111/j.1365-2486.2009.01878.x

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# Note

## New Breeding Record for Merlin (*Falco columbarius*) in Southwestern Yukon

RYAN P. LAMOUREUX[1, 2], MELANIE R. BOUDREAU[1], and JACOB L. SEGUIN[1]

[1]Environmental and Life Sciences, Trent University, Peterborough, Ontario K9J 0G2 Canada
[2]Corresponding author: ryanlamoureux@trentu.ca

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On 3 May 2016, we observed two Merlins (*Falco columbarius*) copulating near Hungry Lake in southwestern Yukon. We recorded Merlins frequently from May until the beginning of July and observed them defending the area from Common Ravens (*Corvus corax*) on two occasions, an activity indicative of a nesting pair. This is the first breeding record for Merlins in southern Yukon, as previous records have documented the breeding range only in central and northern parts of the territory. Here, we summarize historical sightings and breeding reports throughout southern Yukon since 1975 and fill a gap in the breeding range of this species.

Key Words: Merlin; *Falco columbarius*; breeding range; Kluane National Park; Yukon

### Introduction

Merlins (*Falco columbarius*) have a wide distribution, ranging from northern Peru to the northern treeline in Alaska and Canada (Warkentin *et al.* 2005). Although Merlins are relatively uncommon in Yukon (Sinclair *et al.* 2003), they have been documented breeding in the Richardson and Ogilvie Mountains of central Yukon and in the British Mountains, as well as along the Porcupine River and Old Crow Flats in northern Yukon (Sinclair *et al.* 2003). While they are suspected of nesting in southern Yukon based on signs of aggressive behaviour, nesting has not yet been documented there (Sinclair *et al.* 2003; eBird 2017).

Merlins are habitat generalists, preferring fairly open country, such as willow (*Salix* spp.) or birch (*Betul*a spp.) scrub and shrubland, as well as taiga forest, moorland, and grasslands, such as steppe and prairies (White 1994). Merlins generally inhabit ecosystems that have a mix of low and medium-height vegetation with interspersed trees and avoid dense forests as well as treeless arid regions (White 1994). Within their breeding range, they are found in open to semi-open habitat, often nesting in forest openings, fragmented woodlots, and near rivers, lakes, or bogs (Warkentin *et al*. 2005).

Merlins do not create nests of their own, but rather use abandoned nests (of corvids or hawks) in conifer or mixed tree stands (Sieg and Becker 1990; White 1994). Nests are rarely found in tree cavities, on cliffs, or on the ground (Bent 1938; Fox 1964), but are often highly concealed from predators by conifers (Warkentin and James 1988; Sieg and Becker 1990). In Yukon, breeding pairs are often associated with riverside cliffs or trees; they start arriving in mid-April and initiate nesting by the end of May (Sinclair *et al*. 2003).

Here, we report the first record of breeding Merlins in southern Yukon.

### Observations

On 3 May 2016, we photographed (Figure 1) two Merlins copulating (60.9824°N, 138.1372°W), 1 km east of Hungry Lake in southwestern Yukon, near Kluane National Park. The pair occupied an area with vegetation cover dominated by White Spruce (*Picea glauca* (Moench) Voss), Grey Willow (*Salix glauca* L.), and Bog Birch (*Betula glandulosa* Michaux). Historical pipeline trails offer 10-m wide strips without a dense spruce canopy. Between 3 May and 1 July, we spent 36 mornings in the area and recorded the Merlins frequently, including two occasions on which we observed them defending the area from Common Ravens (*Corvus corax*), as indicated by aerial chase, dives, and loud calls.

We searched eBird, a citizen science database of bird observations, for all recorded Merlin sightings from 1975 to 2016 during the breeding season (April–August; eBird 2017). There were 19 records of Merlins within approximately 20 km of our location: one in April (1975), three in June (1990, 2002, 2016), and the other 15 in August. There were no records from May, during the peak egg-laying and incubation period, or July, when young are still in the nest and are typically highly vocal. Of the 19 reported sightings in southwestern Yukon, only one was of a pair, observed on the Sheep Mountain Trail (approximately 22 km northwest of our observed breeding site). Of the 606 sightings across southern Yukon during the breeding seasons from 1975–2016, only 7% reported two Merlin and none indicate a breeding pair was observed (eBird 2017).

### Discussion

Although Merlins are relatively uncommon in Yukon, nesting has been documented in the northern and central portions of the territory, but not in the south (Sinclair *et al.* 2003; eBird 2017). We were unable to locate the

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FIGURE 1. (a) A female Merlin (*Falco columbarius)* photographed at 0923 and (b) a male Merlin (*Falco columbarius)* copulating with a female Merlin at 0925. Both photographs were taken near Hungry Lake, southwestern Yukon (60.9824°N, 138.1372°W) on 3 May 2016. Photos: R. P. Lamoureux.

Merlins' nest, but copulation and defense against corvids by both males and females is a reliable indicator of a nearby nest site (Sodhi 1991; Sodhi *et al.* 1992), typically within 800 m (Hardey *et al.* 2006). In addition, the landscape surrounding the observed Merlins included a small pond just over 350 m from the point of copulation, as well as two larger lakes, Hungry Lake and Thirsty Lake, approximately 1 and 1.3 km away, respectively. Both lakes have steep sand embankments over 40 m in height and the surrounding area is dominated by White Spruce with willow and birch understorey (Krebs *et al.* 2001). Our observations are consistent with known nesting habitat characteristics and nesting behaviour of Merlins (White 1994; Warkentin *et al.* 2005; Sinclair *et al.* 2003).

Our documentation of copulation, coupled with a habitat seemingly suitable for nesting, provides evidence for the first breeding record of the Merlin in southern Yukon. Whether this represents range expansion for nesting Merlins or, alternatively, is a function of low sampling effort for the species in southern Yukon compared with other parts of their range is unknown. Although we cannot confirm nesting, the evidence suggests that the southern Yukon may be more suitable for Merlin breeding than previously indicated by breeding records and may show that current knowledge of breeding range for this species is limited.

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## Literature Cited

**Bent, A. C.** 1938. Life Histories of North American Birds of Prey (Part 2). Orders Falconiformes and Strigiformes. Bulletin of the United States Natural Museum 170. Smithsonian Institution, Washington, DC, USA. https://doi.org/10.5479/si.03629236.170.i

**eBird.** 2017. eBird: an online database of bird distribution and abundance. Audubon and Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed January 2017. https://tinyurl.com/y7k8gupd.

**Fox, G. A.** 1964. Notes on the western race of the Pigeon Hawk. Blue Jay 22: 140–147.

**Hardey, J., H. Q. P. Crick, C. V. Wernham, H. T. Riley, B. Ethridge,** and **D. B. A. Thompson.** 2006. Merlin, *Falco columbarius*. *In* Raptors: A Field Guide to Survey and Monitoring. Stationery Office, Edinburgh, Scotland.

**Krebs, C. J., S. Boutin,** and **R. Boonstra.** 2001. Ecosystem Dynamics of the Boreal Forest: The Kluane Project. Oxford University Press. New York, New York, USA.

**Sieg, C. H.,** and **D. M. Becker.** 1990. Nest-site habitat selected by Merlins in southeastern Montana. Condor 92: 688–694. https://doi.org/10.2307/1368687

**Sinclair, P. H., W. A. Nixon, C. D. Eckert,** and **N. L. Hughes.** 2003. Birds of the Yukon Territory. UBC Press, Vancouver, British Columbia, Canada. https://doi.org/10.1086/382423

**Sodhi, N. S.** 1991. Pair copulations, extra-pair copulations, and intraspecific nest intrusions in Merlin. Condor 93: 434–437. https://doi.org/10.2307/1368960

**Sodhi, N. S., P. C. James, I. G. Warkentin,** and **L. W. Oliphant.** 1992. Breeding ecology of urban Merlins (*Falco columbarius*). Canadian Journal of Zoology 70: 1477–1483. https://doi.org/10.1139/z92-204

**Warkentin, I. G., N. S. Sodhi, R. H. M. Espie, A. F. Poole, L. W. Oliphant,** and **P. C. James.** 2005. Merlin (*Falco columbarius*). *In* The Birds of North America Online. *Edited by* P. G. Rodewald. Cornell Laboratory of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.44

**Warkentin, I. G.,** and **P. C. James.** 1988. Nest-site selection by urban Merlins. Condor 90: 734–738. https://doi.org/10.2307/1368372

**White, C. M.** 1994. Merlin. Page 267 and plate 27 *in* Handbook of Birds of the World. Volume 2: New World Vultures to Guineafowl. *Edited by* J. Del Hoyo, J. Sargatal, and A. Elliot. Lynx Editions, Barcelona, Spain.

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# Note

# Evidence for a Negative Effect of Double-crested Cormorants (*Phalacrocorax auritus*) on Invasive European Fire Ants (*Myrmica rubra*)

ADITI GUPTA[1], KRISTI RUDMIK[1], and GAIL S. FRASER[1, 2]

[1]Faculty of Environmental Studies, York University, Toronto, Ontario M3J 1P3 Canada
[2]Corresponding author: gsfraser@yorku.ca

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Nesting of Double-crested Cormorants (*Phalacrocorax auritus*) in western Lake Ontario is associated with reduced abundance and nest density of European Fire Ants (*Myrmica rubra*). The impact on fire ants may be substrate related. It is of potential importance because of the negative effect of fire ants on ground-nesting water birds.

Key Words: Double-crested Cormorant; *Phalacrocorax auritus*; European Fire Ant; *Myrmica rubra*; invasive species; ant nest density; non-native; guano; soil

The invasive European Fire Ant (*Myrmica rubra*) is established in many regions of North America (Wetterer and Radchenko 2011). Locally, its abundance and distribution are influenced by soil moisture and temperature: it prefers moist soils shaded by vegetation (Groden *et al.* 2005). North American populations may be unusually abundant, and nest densities may be high (Groden *et al.* 2005; Naumann and Higgins 2015). Infestations can have long-term consequences for ground-nesting birds, such as Herring Gulls (*Larus argentatus*; DeFisher and Bonter 2013).

Double-crested Cormorant (*Phalacrocorax auritus*) is a water bird, native to North America (Dorr *et al.* 2014), whose numbers have increased greatly in parts of the Great Lakes region over the past few decades. At high densities, tree-nesting cormorants alter soil chemistry, reducing plant ground cover and species richness (Weseloh *et al.* 2002) as well as arthropod diversity (Craig *et al.* 2012); however, these changes can also provide habitat for ground-nesting birds (e.g., Foster and Fraser 2013). When trees fall, cormorants move to adjacent forest, eventually killing the next set of trees, or they nest on the ground (McGrath and Murphy 2012). In this study, we examined how cormorant-induced forest alterations affected fire ant abundance, distribution, and nest density in a protected area.

Created in the 1970s as the Leslie Street Spit, Tommy Thompson Park (TTP) is a human-made headland extending 5 km into Lake Ontario. In 1990, cormorants started nesting there and have caused deforestation on three of the four peninsulas (Taylor *et al.* 2011). In 2015, peninsula C (43°37'37.80"N, 79°20'15.10"W) had 2561 cormorant nests in trees (22% of the 11 908 cormorant nests at TTP; Toronto and Region Conservation Authority, unpublished data; see also Taylor *et al.* 2011). It is unknown when fire ants first colonized TTP.

In August 2010 and 2015, we examined ant abundance and nest density at 12 stations located 50 m apart along a 550-m transect through the cormorant colony on peninsula C. At each station, five pitfall traps were placed flush with the ground, half filled with salted distilled water containing a drop of unscented detergent, and left out for 48 h. Four species of ants, identified using Fisher and Cover (2007), were collected, dried, and weighed. Because of their great abundance at some stations, the number of European Fire Ants per station was estimated from the average weight of a randomly selected subsample of dried and counted ants across stations: 200 ants in 2010, 150 in 2015. We also measured ant nest density (Groden *et al.* 2005) and estimated percentage plant ground cover (Elzinga *et al.* 1998) in a 1-m$^2$ quadrat 10 m east of each station.

The transect crossed three habitats: field (open with few or no trees mostly covered in grass and forbs), healthy forest (trees alive, strong under-canopy foliage), and dying forest (trees dead or in poor condition and little understorey). Two general linear models and *post hoc* Tukey tests (Minitab 17.1.0) were used to evaluate changes in 1) ant abundance and 2) plant ground cover (both log-transformed; Zar 2010) for year and habitat type. Ant nest density was not included in the models because no nests were observed in field and dying forests (see below). Differences in ant nest density between the two study years in healthy forests were evaluated using a Mann–Whitney *U* test (Zar 2010).

Between 2010 and 2015, four stations changed habitat categories: one from healthy to dying forest (station E) and three from dying forest to field (stations A–C). At stations A–C, ground cover increased in 2015 (primarily Stinging Nettle [*Urtica dioica* L.]). Ground cover varied by habitat type, but not by year. Dying forest had significantly less ground cover compared with field and healthy forest, and there was no significant difference between the latter two categories (Table 1). Means ± standard deviation (SD) were: dying forest 3.3% ± 2.6%, field 88.9% ± 8.9%, healthy forest 88.9% ± 22.5%.

Table 1. Habitat characterization, ground cover, and abundance of European Fire Ants (*Myrmica rubra*) at sampling stations under Double-crested Cormorant (*Phalacrocorax auritus*) nests in Tommy Thompson Park, Toronto, Ontario, 2010 and 2015.

| | Habitat characterization* | | Ground cover†, % | | Total ant abundance in five traps‡ | |
|---|---|---|---|---|---|---|
| Station | 2010 | 2015 | 2010 | 2015 | 2010 | 2015 |
| A | DF | Field | 5 | 80 | 0.0 | 16.0 |
| B | DF | Field | 5 | 80 | 0.0 | 16.0 |
| C | DF | Field | 0 | 90 | 0.0 | 0.0 |
| D | DF | DF | 5 | 5 | 0.0 | 0.0 |
| E | HF | DF | 100 | 0 | 2524.8 | 8.0 |
| F | HF | HF | 100 | 95 | 4915.7 | 13 476.0 |
| G | HF | HF | 90 | 90 | 8797.7 | 7812.0 |
| H | HF | HF | 30 | 95 | 8036.9 | 17 359.5 |
| I | HF | HF | 100 | 100 | 4927.1 | 3061.5 |
| J | Field | Field | 80 | 80 | 234.0 | 3711.0 |
| K | Field | Field | 95 | 95 | 0.0 | 0.0 |
| L | Field | Field | 100 | 100 | 0.0 | 0.0 |

*DF = dead and dying forest, HF = healthy forest. Cormorants nested at stations A, B, C, and D in 2010 and at stations D and E in 2015.

†Ground cover varied by habitat type, but not by year (habitat: $F_{2,23} = 62.2$, $P < 0.0001$; year: $F_{1,23} = 0.07$, $P = 0.78$). Field and healthy forest did not differ in % ground cover, but both habitats differed from dying forest (Tukey pairwise comparison, $P < 0.05$).

‡Fire ant abundance differed by habitat type, but not by year (habitat: $F_{2,23} = 38.2$, $P < 0.0001$; year: $F_{1,23} = 0.6$, $P = 0.42$). Healthy forest differed in ant abundance compared with dying forest and field (Tukey pairwise comparison, $P < 0.05$).

Fire ant abundance differed by habitat type, but not by year; ant abundance was higher in healthy forest compared with field and dying forest (Table 1). Based on the 1-m$^2$ quadrat samples, no fire ant nests were observed in field or dying forest, and there was no difference in ant nest density in healthy forest between study years (mean ± SD): 2010 ($n = 6$) 1.2 ± 1.8 nests/m$^2$, 2015 ($n = 5$) 0.2 ± 0.4 nests/m$^2$ (Mann–Whitney $U = 39.0$, $P > 0.2$). At station E, which changed to dying forest, a substantial decline in fire ant abundance and ant nest density occurred (from three nests to zero; Table 1).

The presence of nesting cormorants appears to have a negative effect on fire ant abundance. The relatively low numbers of fire ants in forest declining because of cormorant nesting and the clear decrease in fire ant abundance and ant nest density at one station where cormorant nesting led to forest decline suggest that soil changes associated with cormorants may reduce suitability for fire ant habitation. This is of interest because other ground-nesting water birds occupying deforested areas may benefit from reducing or eliminating fire ants (see DeFisher and Bonter 2013). Future deliberations on cormorant management (e.g., Wires 2014 describes and critiques North American cormorant management) should consider the potentially positive impact of nesting cormorants on reducing fire ant infestations where the two species co-occur.

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## Literature Cited

**Craig, C. E., B. S. Elbin, A. J. Danoff-Burg,** and **I. P. Palmer.** 2012. Impacts of Double-Crested Cormorants and other colonial waterbirds on plants and arthropod communities on islands in an urban estuary. Waterbirds 35: 4–12. https://doi.org/10.1675/063.035.sp102

**DeFisher, L. E.,** and **D. N. Bonter.** 2013. Effects of invasive European Fire Ants (*Myrmica rubra*) on Herring Gull (*Larus argentatus*) reproduction. PLoS ONE 8(5): e64185. https://doi.org/10.1371/journal.pone.0064185

**Dorr, B. S., J. J. Hatch,** and **D. V. Weseloh.** 2014. Double-crested Cormorant (*Phalacrocorax auritus*). *In* The Birds of North America. *Edited by* P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.441

**Elzinga, C. L., D. W. Salzer,** and **J. W. Willoughby.** 1998. Measuring and monitoring plant populations. Technical reference 1730-1. Bureau of Land Management, U.S. Department of the Interior, Denver, Colorado, USA. Accessed 23 June 2017. https://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf.

**Fisher, B. L.,** and **S. P. Cover.** 2007. Ants of North America: A Guide to the Genera. University of California Press, Oakland, California, USA.

**Foster, J.,** and **G. S. Fraser.** 2013. Predators, prey and the dynamics of change at the Leslie Street Spit. Pages 211–224 *in* Urban Explorations: Environmental Histories of the Toronto Region. *Edited by* L. A. Sandberg, S. Bocking, C. Coates, and K. Cruikshank. L. R. Wilson Institute for Canadian Studies, Hamilton, Ontario, Canada.

**Groden, E., F. A. Drummond, J. Garnas,** and **A. Franceour.** 2005. Distribution of an invasive ant, *Myrmica rubra* (Hymenoptera: Formicidae), in Maine. Journal of Economic

Entomology 98: 1774–1784. https://doi.org/10.1093/jee/98.6.1774

**McGrath, M. D.,** and **D. S. Murphy.** 2012. Double-crested Cormorant (*Phalacrocorax auritus*) nesting effects on understory composition and diversity on island ecosystems in Lake Erie. Environmental Management 50: 304–314. https://doi.org/10.1007/s00267-012-9878-6

**Naumann, K.,** and **R. J. Higgins.** 2015. The European Fire Ant (Hymenoptera: Formicidae) as an invasive species: impact on local ant species and other epigaeic arthropods. Canadian Entomology 174: 592–601. https://doi.org/10.4039/tce.2014.69

**Taylor, B., D. Andrews,** and **G. S. Fraser.** 2011. Double-crested cormorants and urban wilderness: conflicts and management. Urban Ecosystems 14: 377–394. https://doi.org/10.1007/s11252-011-0165-8

**Weseloh, D. V. C., C. Pekarik, T. Havelka, G. Barrett,** and **J. Reid.** 2002. Population trends and colony locations of double-crested cormorants in the Canadian Great lakes and immediately adjacent areas, 1990–2000: a manager's guide. Journal of Great Lakes Research 28: 125–144. https://doi.org/10.1016/S0380-1330(02)70571-6

**Wetterer, J. K.,** and **A. G. Radchenko.** 2011. Worldwide spread of the ruby ant, *Myrmica rubra* (Hymenoptera: Formicidae). Myrmecological News 14: 87–96.

**Wires, L. R.** 2014. The Double-crested Cormorant: Plight of a Feathered Pariah. Yale University Press, New Haven, Connecticut, USA.

**Zar, J. H.** 2010. Biostatistical Analysis (Fifth Edition). Pearson Prentice-Hall, Upper Saddle River, New Jersey, USA.

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# Diverse Ecological Pathways of Salmon Nutrients Through an Intact Marine-terrestrial Interface

THOMAS E. REIMCHEN

Department of Biology, University of Victoria, P.O. Box 3020, Victoria, British Columbia V8W 3N5 Canada; email: reimchen@uvic.ca

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Based on five years of field studies (1992, 1993, 1994, 1998, 2000), I quantified bi-directional movement of salmon nutrients through an estuary, stream, and old growth forest in a large protected reserve on Haida Gwaii, British Columbia. In 1993, when most data were collected, about 6000 Chum Salmon (*Oncorhynchus keta*) entered the river of which 22% of the total biomass of senescent carcasses were swept downstream into the estuary and were scavenged by gulls ($n$ = 350) and subtidal invertebrates. Of the 3700 salmon (10 000 kg) transferred by American Black Bear (*Ursus americanus*) to the riparian zone and partially consumed along the 800 m of stream channel, 5070 kg of salmon tissues abandoned by the bears were scavenged by Northwestern Crows (*Corvus caurinus*; $n$ = 200) but mostly (4100 kg) by calliphorid blowfly larvae resulting in larval densities averaging 240/m$^2$ throughout the riparian zone. Total nitrogen input to the soils from the combined effects of bear and scavenger activity as well as carcass input was 18 g/m$^2$ within 10 m of the stream channel. $\delta^{15}$N of foliar tissues of Lanky Moss (*Rhytidiadelphus loreus)*, Red Huckleberry (*Vaccinium parvifolium*), Salal (*Gaultheria shallon*), and Western Hemlock (*Tsuga heterophylla*) ranged about 15‰ to 20‰ among adjacent microsites in each species, with higher values occurring in salmon carcass zones. Total nitrogen in foliar tissues ranged from 1% to 2.4% among microsites and was best predicted by positive correlations with foliar $^{15}$N values and secondarily by presence/absence of salmon carcasses. This is the first study to integrate estuarine to riparian ecological processes in the cycling of salmonid nutrients and identifies a range of ecological baselines that can inform the multiple restoration programs underway in degraded watersheds in the North Pacific.

Key Words: Ancient forest; Calliphoridae; *Corvus*; ecological baselines; energy flow; Haida Gwaii; *Larus*; *Oncorhynchus*; spawning migration; *Ursus*

## Introduction

A dominant cross-boundary subsidy at the marine-terrestrial interface in the North Pacific is the yearly migration of adult salmon (*Oncorhynchus* spp.) to their natal spawning rivers. The importance of these migrations is widely recognized, not only for the marine predators and scavengers that aggregate in coastal and inshore waters (summaries in Willson and Halupka 1995; Cederholm *et al.* 1999, 2000; Hilderbrand *et al.* 2004), but also for terrestrial predators such as bears that disperse from higher elevation or inland areas to rivers and estuaries (Gilbert and Lanner 1995; Hilderbrand *et al.* 1996; Reimchen 2000; Gende *et al.* 2004). Historical records of salmon show declining biomass throughout the coast, particularly in southern watersheds (California, Oregon, Washington) where up to 95% of the salmon biomass has been lost over the last 100 years (Gresh *et al.* 2000). Presumably, this loss has negatively influenced the taxa that were trophically coupled to salmon biomass. While this is a reasonable inference for taxa such as bears (Gilbert and Lanner 1995), the influences on other consumers are unknown. This data deficiency emerges in part because the empirical partitioning of salmon biomass by multiple predator and scavenger taxa has not been described for any watershed and estuary in the North Pacific. Identifying such data in an intact marine-terrestrial food web would be useful not only for assessing basic trophic interactions among species but also for evaluating the potential impact of the historical decline in abundance of salmon.

The southern end of the Haida Gwaii archipelago, 100 km off the west coast of Canada, is a largely intact ecosystem with old growth forest and numerous small streams, most with spawning runs of Chum Salmon (*Oncorhynchus keta*) or Pink Salmon (*O. gorbuscha*). Salmon have declined in these watersheds and are approximately at 50% of the decadal averages observed during the 1940s and 1950s when yearly records were initiated (Marshall *et al.* 1978; Reimchen 2000). During autumn 1992, 1993, and 1994, I quantified predator and scavenger use of adult salmon in the estuary, stream, and riparian zones at Bag Harbour, one of the typical watersheds in the region. Several novel observations emerged during this early study, including the frequent nocturnal foraging by American Black Bear (*Ursus americanus*; Reimchen 1998) and their high transfer rate of salmon carcasses from the stream to the riparian zone (Reimchen 2000). This bear-mediated uploading of salmon had positive effects on annual growth of Sitka Spruce (*Picea sitchensis* (Bongard) Carriere), which was greater in microsites where carcasses were prevalent and greater during years when spawning runs were elevated (Reimchen and Fox 2013). In the current manuscript, I estimate the total mass of salmon used by each of the major mammalian, avian, and invertebrate foragers for the estuary, stream, and riparian habitats, estimate the total input of nitrogen into riparian soils, quantify the extent of enrichment of the marine-derived nitrogen ($^{15}N$) in riparian plants, and examine foliar %N as a proxy for primary productivity across a spatial gradient of carcasses and bear activity.

## Methods

Bag Harbour (52.347°N, 131.366°W) occurs in a mountainous area on Moresby Island near the south end of Haida Gwaii (Figure 1). The small shallow harbour (33 ha, maximum depth ~16 m) has a broad intertidal zone with extensive cover of macrophytes (*Fucus* spp.) and lower intertidal and subtidal beds of eel grass (Zosteraceae). The harbour is bordered by ancient forest dominated by Sitka Spruce, Western Hemlock (*Tsuga heterophylla* (Rafinesque) Sargent), and Red Cedar (*Thuja plicata* Donn ex D. Don) with trees reaching 1000 years of age (Reimchen and Fox 2013) and classified as a very wet hypermaritime subzone 3 (CWHvh3 Site Series 110; Banner *et al*. 2014). There is a single major salmon-bearing stream (5–10 m width, < 0.5 m depth, < 1° gradient) which extends 1500 m between the estuary and a small headwater lake. Most of the spawning gravels are found from 300 to 800 m upstream from the estuary. Between 2300 and 6300 salmon enter the stream yearly, the majority (> 90%) of which are Chum Salmon with additional Pink Salmon, and Coho Salmon (*O. keta*), the latter using tributary streams to the headwater lake. Field surveys were initially made in 1992 during the second half of the salmon spawning period (8–21 October) and in 1993 throughout the spawning period (28 September–26 October) with a supplemental survey two weeks after completion of the spawning run (13–14 November). In 1994, I made carcass counts midway through the spawning run (12–13 October) and near the end of the run (2–4 November). The site was also visited in 1998 (10–11 October) and again in 2000 (19–20 September). Additional details are given in Reimchen (1998, 2000) and Reimchen and Fox (2013). In 1992 and 1993, the major mammalian and avian foragers and scavengers were counted daily in early morning, midday, and late afternoon. Intermittently throughout the day, I recorded general predator and scavenging forag-

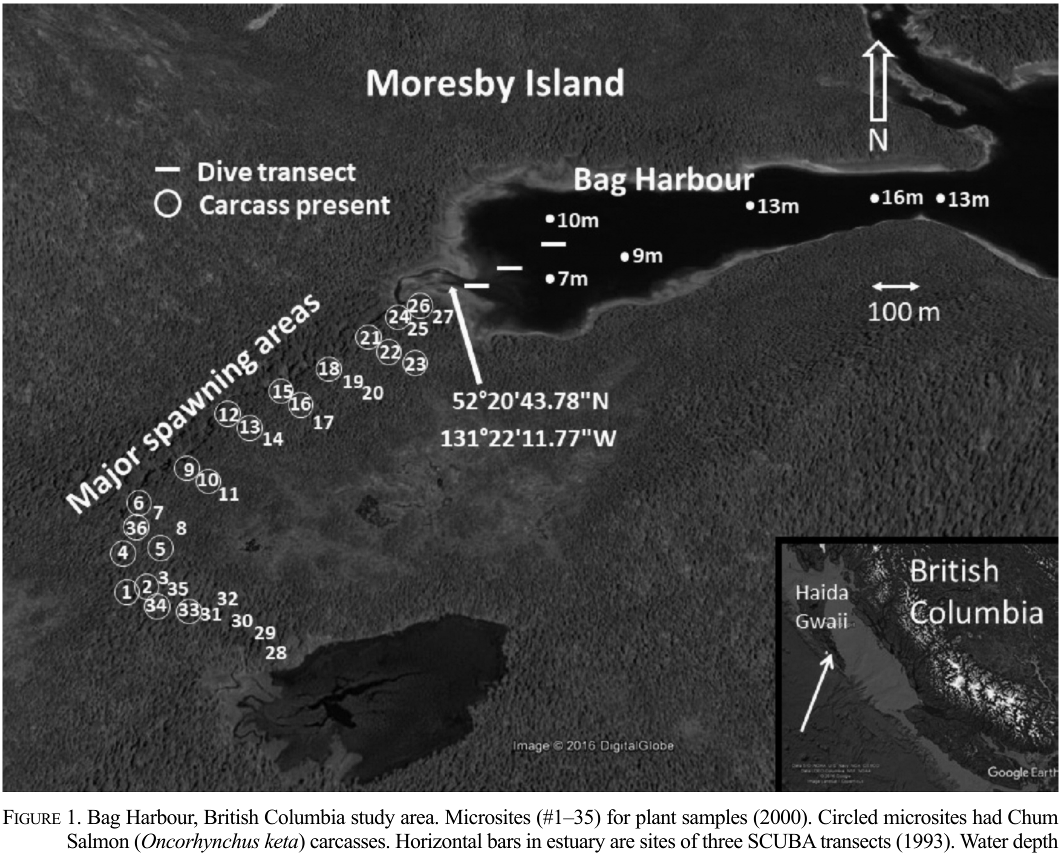

FIGURE 1. Bag Harbour, British Columbia study area. Microsites (#1–35) for plant samples (2000). Circled microsites had Chum Salmon (*Oncorhynchus keta*) carcasses. Horizontal bars in estuary are sites of three SCUBA transects (1993). Water depth (closed circle) shown in meters (m). Source: Bag Harbour, Moresby Island, 52°20'43.78"N, 131°22'11.77"W. Google Earth. Imagery date: 6 September 2016. Accessed:1 March 2017.

ing activity of each focal species and, where possible, type of tissues consumed (fresh salmon, senescent carcasses, eggs). Fungal and bacterial decomposers as well as stream macroinvertebrates were present on some carcasses, but the extent of their carcass use was not quantified. Songbirds, rodents, and shrews, although present in the watershed, were not commonly seen during the autumn surveys and were not quantified. In 1993, observations were extended throughout the night using helmet-mounted night-viewing goggles (Reimchen 1998). In October 1993, 40 undamaged salmon carcasses collected from the stream were measured for individual mass (± 10 g) and tethered every 3.4 m along each of three subtidal rope transects at 10 m, 75 m, and 150 m distance from the stream mouth at depths increasing from 3 m to 10 m (Figure 1). Every 24 hours over the following seven days, I used SCUBA to survey each of the carcasses and recorded numbers of the dominant marine scavengers on the carcasses. During each survey, after removing scavengers, the carcass was brought to the surface and wet mass (± 100 g) determined, returned to the bottom, and re-tethered to the rope transect. By the fifth day, carcasses had begun to disintegrate and further weights were not possible.

The complete riparian zone between the estuary and the headwater lake was surveyed for carcasses during the spawning period twice in 1992, five times in 1993, and twice in 1994 yielding a cumulative yearly total transfer at the completion of the run of 1150, 3611, and 1596 carcasses, respectively; for a 3 kg Chum Salmon, bears consumed an average of 1.6 kg/carcass and abandoned 1.4 kg (full details in Reimchen 2000). The majority of salmon carcasses were distributed within a 50 m riparian band adjacent to the dominant spawning reaches in the stream and with highest densities occurring within 10 m of the stream.

Carcass consumption by scavengers other than bears was determined with two methods. First, I tagged and weighed 152 fresh *in situ* complete salmon carcasses (1992, $n = 89$; 1993, $n = 63$) abandoned by bears in the riparian zone and on successive days monitored any foraging activity on the carcasses. Following a foraging bout by a flock of birds, I re-examined the carcass and noted the type of tissues extracted. All carcasses were re-weighed every two days. Loss of mass from tissue dehydration was minimal due to the shade, moist substrate, and high humidity. Secondly, I used daily metabolic requirements combined with total days of presence for the common avian scavengers (e.g., Birt-friesen *et al.* 1989; Christie and Reimchen 2006). Blow flies (predominantly Calliphoridae) deposited eggs on carcasses within the first two days following transfer to the riparian zone and typically after three to five days, larvae dominated the carcasses. I estimated numbers of larvae per carcass using three separate methods: assume a density of 8 larvae per gram of tissue based on experimental forensic studies of Calliphorid larvae consuming liver (Goodbrod and Goff 1990), empirically-derived regression (number of larvae = 268 + 3.0 times carcass mass) based on dipteran larval production on Chum Salmon carcasses from mainland British Columbia (Hocking and Reimchen 2002), and empirical estimates of 22.4 larvae per g Sockeye Salmon (*Oncorhynchus nerka*) carcasses in Washington (Meehan *et al.* 2005). To determine density on the forest floor, I counted all larvae at seven plots (20 cm × 20 cm) positioned at 0 m, 1 m, 2 m, and 3 m from the bony remnants one day after no further larvae were visible on the remnants.

To assess soil invertebrates, I took paired 175 cc soil plugs, the first from beneath the bony remnants, and a second 0.5 m distant from the first but on a similar substrate. The sites for the plugs were about 5 m from the stream bank and from 17 different sites extending over 100 m along the stream channel in the reaches of high spawning densities. Soil plugs were dried in separate Berlese funnels and all extracted invertebrates counted and identified to Order or Family.

In October 2000, a vegetation sampling grid was established in this watershed at 35 riparian sites between the estuary and the headwater lake, including 11 transects perpendicular from the stream into the forest across a previously documented gradient of high to low salmon carcass densities (Reimchen 2000). Within a 5 m radius of each targetted Sitka Spruce, the primary focus for the grid (Reimchen and Fox 2013), I sampled up to six plant species, the number dependent on their occurrence at each site: Lanky Moss (*Rhytidiadelphus loreus* (Hedw.) Warnst.), Deer Fern *(Blechnum spicant* (L.) Roth), Red Huckleberry (*Vaccinium parvifolium* Smith), False Azalea (*Menziesia ferruginea* J. E. Smith), Salal (*Gaultheria shallon* Pursh), and Western Hemlock seedlings, the latter from intact nurse logs which were typically large fallen Sitka Spruce. For each of the sites, I measured distance (m) from the stream edge into the forest (DistForest). There was a gentle slope (~5°) across the riparian zone. For each species and from each of three separate plants, I collected up to six leaves or needles that were later oven-dried at 60°C for 2–3 weeks. One mg of tissue was powdered, packaged, and processed for nitrogen isotope signatures and total nitrogen at the Stable Isotope Facility, University of Saskatchewan, using a Europa Scientific ANCA NT gas/solid/liquid preparation module coupled to a Europa Scientific Tracer 20-20 mass spectrometer (PDZ Europa, Cheshire, England). Four species were common throughout the sampling grid and I restrict analyses to these ($n = 314$). Natural abundance of $^{15}N$ is expressed as the deviation from atmospheric $N_2$ (‰) and calculated as $\delta^{15}N = (R_{sample}/R_{standard} - 1)$ where R is the ratio of $^{15}N/^{14}N$ stable isotopes. Measurement precision is ± 0.35‰.

Relative contribution of marine-derived nitrogen (%MDN) for each of the four plant species was calculated using:

$$\%MDN_1 = (OBS_1 - TEM_1)/(MEM - TEM_1)$$

where $OBS_1$ is the $\delta^{15}N$ value for species 1, $TEM_1$ is the terrestrial end member for species 1, and MEM is the value ($\delta^{15}N = 11.1‰$) for Chum Salmon, the marine end member (Johnson and Schindler 2009). For each species, I used a TEM for non-carcass sites that are sites greater than 60 m from the stream where no carcasses were observed, as well as sites greater than 1200 m upstream beyond the upper distribution of spawning gravels and where no carcasses were observed (#20, 17, 14, 8, 11, 32, 30, 29, 28; Figure 1).

*Statistics*

All analyses were run using SPSS v.24 (IBM, USA). For the 17 pairs of adjacent soil plugs, numbers of individuals (ln transformed) for each taxon were compared with paired *t*-tests while diversity was estimated using Shannon Diversity (H) and Equitability (E) indices. Foliar $\delta^{15}N$ values for each of the four riparian species were normally distributed while %N values violated assumptions of normality due to the strong positive skew of the data (Shapiro-Wilk, $P > 0.05$). Log transformations did not normalize the data so I used Box-Cox rank transformations. To visualize the spatial trends in the data, I initially plotted $\delta^{15}N$ for each species on a grid of the riparian microsites for distance upstream from the estuary and for distance into the forest in relation to presence or absence of salmon carcasses at the microsite. Secondly, I saved the $\delta^{15}N$ residuals for each species and plotted the combined data on the grid. In each species, $\delta^{15}N$ and %N were positively correlated with each other. To identify whether the presence/absence of a carcass was associated with these nitrogen variables, I ran a multivariate general linear model (GLM) using $\delta^{15}N$ and %N as dependents, Carcass (absence/presence) as a categorical independent variable, and DistForest as covariate. I then tested the main effect of Carcass on $\delta^{15}N$ and %N for each species.

## Results

*Basic food web*

A simplified energy flow diagram of salmon at Bag Harbour is shown in Figure 2. Of the 6300 pre-spawned salmon returning from the open ocean in 1993, predation in the estuary, primarily by bears and pinnipeds, resulted in a 4% reduction of the total salmon biomass. The majority of salmon (96%) migrated upstream for spawning and approximately 20% of the post-reproductive carcasses were swept downstream into the estuary. These carcasses were scavenged by avian taxa and subtidal invertebrates. In the stream channel, bears captured or scavenged about 65% of the salmon, most of which ($n = 3700$) were transferred to the riparian zone, where bears consumed about one-half of each carcass. Gulls and crows scavenged about 7% of total carcass biomass on stream gravel bars and 12% of the carcass biomass in the riparian zone. Most of the soft tissues of riparian carcasses abandoned by bears were consumed by calliphorid larvae. In 1992, there were approximately half the carcasses compared with 1993. Taxonomic diversity and total numbers of individual taxa seen in the estuary and watershed are summarized in Table 1. Most species were uncommon in the watershed prior to the salmon migration.

*Mammals*

Pinnipeds occurred in the estuary throughout the salmon spawning period, usually in low numbers during both years. Foraging on salmon was observed both during daylight and darkness, the latter facilitated by extensive bioluminescence produced during movement of the salmon. In autumn 1992, I recorded 42 daylight pursuits by Harbour Seals (*Phoca vitulina*) of which five were successful (12%). I could not determine success of the nocturnal pursuits. Handling and ingestion occurred at the surface and typically involved secondary scavenging by gulls (primarily Herring [*Larus argentatus*] and Glaucous-winged [*L. glaucescens*]) on the floating tissue remnants. Based on these observations, the total number of 'seal days' as well as the average daily salmon consumption of Harbour Seals (1.9 kg/day) in an estuary in southern British Columba (P. Olesiuk, personal communication, December 1994), I estimated total capture/spawning run of approximately 80 salmon (1992: 266 kg; 1993: 239 kg). Up to four Steller Sea Lion (*Eumetopias jubatus*) also occurred in the estuary over the spawning period during both years, primarily during twilight and darkness. I could not reliably determine their foraging activities but combining the total 'sea lion days' at Bag Harbour and the daily salmon consumption of sea lions on Vancouver Island (G. Ellis, personal communication, December 1994), I estimated salmon consumption by sea lions in 1992 and 1993 at 80 and 10 salmon respectively (1992: 240 kg; 1993: 30 kg).

From four to eight Black Bears occurred in the watershed throughout the salmon spawning period. Summarizing from Reimchen (1994, 2000), a total of 4790 salmon were captured in 1993 of which 1030 were consumed in the stream channel while 3700 (10 970 kg) were transferred into the riparian zone for consumption (the others were in the estuary). These carcasses were most prevalent in riparian zones adjacent to high stream spawning densities. Most (80%) carcasses were dropped within 10 m of the stream with numbers declining at greater distances into the forest. Occasional carcass remnants could be found on bear trails up to 80 m from the stream. Mass of individual carcass remnants abandoned by bears averaged 1.3 kg ($n = 689$) and ranged from 2% to 98% (average = 44%) of original carcass mass estimated from jaw length (Reimchen 2000). Percentage of each carcass abandoned by the bears was higher (~75%) following new migration of spawners into the stream (during rainfall and increased stream flow) and was lower (~35%) when salmon densities in the stream were low (following multiple days without rainfall). Based on the overall distribution and abundance of bear-transferred carcasses throughout the watershed, general density of abandoned tissues

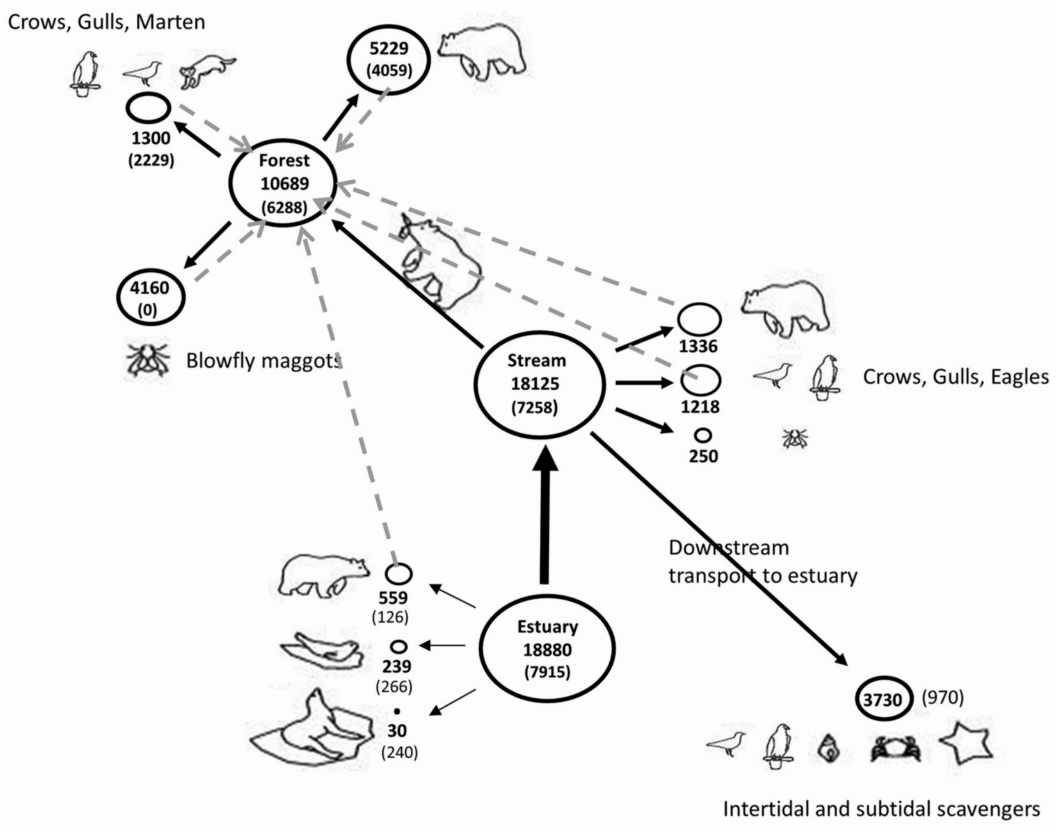

FIGURE 2. Summarized Chum Salmon (*Oncorhynchus keta*) nutrient flow at Bag Harbour, British Columbia for 1993 and 1992 (in brackets). All values shown in kg. Area of circle proportional to original biomass entering estuary. Dashed lines show dominant sources of nitrogen input to soil. See Table 1 for a complete list of all major taxa examined.

was 2730 kg/ha within a 10 m band adjacent to the stream and 171 kg/ha further into the forest (10–50 m).

Small mammals were also resident in the watershed. Two American Marten (*Martes americana*) were commonly observed on the stream banks feeding on fresh carcass tissues abandoned by bears. I did not see any use of the much more abundant senescent carcasses by this scavenger. Based on direct observation, I estimated total salmon consumption by marten of ~20 kg in 1993. During a mid-November visit to the stream two weeks after the spawning run, I found 14 freshly killed gulls cached under trees adjacent to the stream channel where marten had been previously observed dragging fresh salmon remnants and I infer that these caches were made by the marten. On multiple occasions, gulls were seen resting on stream banks following extended bouts of salmon carcass consumption and I suspect this made them highly susceptible to capture by marten. As I only searched about a quarter of the root cavities in the spawning reaches, the 14 carcasses are probably a substantial underestimate of the total in the watershed. Several resident River Otter (*Lontra canadensis*) foraged for Coho Salmon in the tributary streams to the headwater.

### *Birds*

Twenty-seven species of birds were recorded in the watershed during the study period (Table 1). Most were uncommon prior to and early in the spawning migration but increased over the duration of the spawning run. Scavenging occurred in nine species including multispecies flocks of gulls (primarily Herring and Glaucous-winged) reaching a maximum ($n = 375$) in mid-October and then declining towards the end of the spawning run. Near dawn and dusk, gulls consumed salmon eggs drifting from the stream into the estuary but also scavenged carcasses in the intertidal zone. During daylight, most gulls moved upstream from the estuary where they foraged on dislodged salmon eggs, senescent carcasses in the stream channel, and bear-abandoned carcasses on the gravel bars and stream banks. Based on the daily loss of carcass mass in addition to number of 'gull days', I estimate a total consumption of 900 kg of salmon tissues. Using daily metabolic requirements and cumulative 'gull days' yields an independent but similar estimate of 1160 kg of tissue. Northwestern Crows (~200) were prevalent on the estuary during the first two weeks of the spawning run but shifted upstream to riparian habitats in the

TABLE 1. Major taxa examined at Bag Harbour watershed, Haida Gwaii, British Columbia, during Chum Salmon (*Oncorhynchus keta*) migration. Counts of individual animals show daily maxima and averages for 1993 (most detailed) and 1992 (brackets). Chum Salmon spawning numbers are 6300 (1993) and 2700 (1992). Riparian vegetation samples were collected in October 2000 (for $\delta^{15}$N and %N) and show sample sizes for each species. nc = not counted.

| Species showing direct consumption of salmon | Daily maximum | Daily average |
|---|---|---|
| PRIMARY VERTEBRATES IN THE WATERSHED | | |
| Black Bear *Ursus americanus* | 8 (4) | 1.7 (0.9) |
| Steller's Sea Lion *Eumetopias jubatus* | 1 (4) | |
| Harbour Seal *Phoca vitulina* | 19 (8) | 2.8 (3.3) |
| Marten *Martes Americana* | 2 | |
| River Otter *Lutra Canadensis* | 1 | |
| Bald Eagle *Haliaeetus leucocephalus* | 4 (4) | 1.5 (1.3) |
| Gulls[*] *Larus* spp. | 375 (300) | 121.6 (64.9) |
| Northwestern Crow *Corvus caurinus* | 200 (300) | 49.2 (102.5) |
| Common Raven *C. corax* | 1 (4) | 0.2 (0.2) |
| American Dipper *Cinclus mexicanus* | nc | nc |
| Winter Wren *Troglodytes troglodytes* | nc | nc |
| Varied Thrush *Ixoreus naevius* | nc | nc |
| TERRESTRIAL INVERTEBRATES[†] | nc | nc |
| MARINE INVERTEBRATES[‡] | nc | nc |
| SECONDARY VERTEBRATES IN THE WATERSHED | | |
| Bat *Myotis* spp. | nc | nc |
| Common Loon *Gavia immer* | 3 (5) | 1.5 (7.5) |
| Pacific Loon *G. pacifica* | 30 (65) | 1.4 (10.5) |
| Horned Grebe *Podiceps auritus* | 3 (3) | 0.4 (0.5) |
| Red-necked Grebe *P. grisegena* | 4 (5) | 1.1 (1.8) |
| Western Grebe *Aechmophorus occidentalis* | 8 (1) | 2.0 (0.8) |
| Doubled-crested Cormorant *Phalacrocorax auritus* | 1 (0) | 0.0 (0.0) |
| Mallard *Anas platyrhynchos* | 45 (4) | 2.0 (0.3) |
| Green-winged Teal *A. crecca* | 0 (23) | 0.0 (2.5) |
| Scaup *Aythya* spp. | 1 (10) | 1.0 (2.2) |
| Common Goldeneye *Bucephala clangula* | 0 (3) | 0.0 (0.2) |
| Bufflehead *B. albeola* | 4 (14) | 1.4 (3.5) |
| Harlequin *Histrionicus histrionicus* | 13 (10) | 4.6 (4.7) |
| White-winged Scoter *Melanitta deglandi* | 20 (68) | 11.6 (44.0) |
| Surf Scoter *M. perspicillata* | 16 (0) | 0.7 (0.0) |
| Common Merganser *Mergus merganser* | 0 (15) | 0.0 (3.0) |
| Red-breasted Merganser *M. serrator* | 6 (0) | 0.4 (0.0) |
| Hooded Merganser *Lophodytes cucullatus* | 5 (14) | 0.6 (3.8) |
| Common Murre *Uria aalge* | 0 (3) | 0.0 (0.5) |
| Belted Kingfisher *Ceryle alcyon* | 1 (1) | 0.3 (0.6) |
| Great Blue Heron *Ardea herodias* | 1 (0) | 0.1 (0.0) |
| VEGETATION | | |
| Lanky Moss *Rhytidiadelphus loreus* | 88 | |
| Red Huckleberry *Vaccinium parvifolium* | 41 | |
| Salal *Gaultheria shallon* | 88 | |
| Western Hemlock *Thuja heterophylla* | 97 | |

[*] Primarily Glaucous-winged Gull (*Larus glaucescens*) and Herring Gull (*L. argentatus*).
[†] Terrestrial invertebrate data obtained in October 1993 (24 taxa; Figure 3).
[‡] Gastropoda, Crustacea, Echinodermata.

second half of the run (30 September to 20 October). They usually occurred in small flocks (10–30 individuals) in the immediate vicinity of bears that were feeding on freshly-captured salmon in the stream or the riparian zone and would quickly occupy the remnants when the bears abandoned the carcass. I did not observe crows foraging on senescent carcasses or on fly larvae that were prevalent in the riparian zone. Combining daily estimates of crow abundance (2800 'crow days') and their general foraging activity throughout the spawning run yields an estimated total consumption of 270 kg. Two weeks after the end of the spawning run, no crows were observed in the estuary, stream, or riparian zone.

Among the birds foraging in the estuary, 21 species occurred that were either minor salmon consumers or were not directly associated with carcasses. Bald Eagle (*Haliaeetus leucocephalus*; maximum four) occurred daily throughout the spawning period and based on direct observation of their foraging activity, I estimate a total consumption of ~ 20 kg of fresh salmon tissues abandoned by bears. However, based on daily salmon consumption rates of captive Bald Eagles at 5 °C (Stalmaster and Gessaman 1982), the four Bald Eagles at Bag Harbour would consume 60 kg over the spawning period. Common Ravens were intermittently present (maximum four) and foraged on fresh salmon carcass remnants abandoned by bears and I estimate total consumption at 5 kg. American Dipper (*Cinclus mexicanus*; maximum three) foraged on salmon eggs in the stream throughout the study period (no biomass estimated). Eighteen bird species, not seen in direct association with salmon carcasses, appeared in the estuary following the onset of the spawning run and were present throughout the duration of the run. Foraging by each species was common every day. During SCUBA transects, I observed large schools of clupeid-like fish in areas where diving birds (primarily Pacific Loon [*Gavia pacifica*]) were present and I infer these were the target of the divers. White-winged Scoters (*Melanitta fusca*) were prevalent near the stream mouth and consumed drifting salmon eggs, carcass remnants, and small crustaceans associated with the submerged salmon carcasses. Mallards (*Anas platyrhynchos)* became very common on the estuary after the completion of spawning run but I was not able to identify prey items of these dabblers.

### *Terrestrial invertebrates*

Invertebrate scavengers, primarily calliphorid blowfly larvae, were major consumers of salmon carcasses but their abundance was highly variable among years. In autumn 1992, when 2000 salmon were transferred by bears to the riparian zone, I did not observe any carcasses with blowfly eggs or larvae. In contrast, in autumn 1993, when 3700 carcasses were transported by bears to similar regions of the riparian areas as in 1992, 95% of carcasses had blowfly egg masses and these hatched within several days resulting in high densities of larvae that fully enveloped the carcass remnants. Daily surveys to these carcasses showed consumption of all soft tissues by the larvae in five to seven days. Total counts of larvae per carcass, assuming a 1.3 kg average carcass mass of abandoned tissues, are estimated at 4200 based on estimates derived from Hocking and Reimchen (2002), 10 400 based on the eight larvae/gram of tissue from Goodbrod and Goff (1990), and 29 000 based on empirical counts on Sockeye Salmon by Meehan *et al.* (2005). I will assume the conservative estimate. Larvae dispersed radially from the bony remnants and direct counts of dispersing larvae ranged from ~7000/m$^2$ within a half meter radius of the remnants to 200/m$^2$ at 3 m distance from any carcass remnants. Pre-pupal larvae burrowed into the moss-substrate, under and within woody debris, and were observed under the bark several metres up the vertical trunks of trees. Based on 95% of the carcasses with larvae, I estimate there would be 14.7 million larvae produced during the 1993 spawning run. As 80% of the carcasses were within 10 m of the stream bank, average densities of dispersing larvae on the substrate would be 738/m$^2$ while further into the riparian zone (10–50 m) this would be reduced to 31 larvae/m$^2$ along the 800 m riparian band on each side of the spawning gravels. I found minimal evidence for mortality of the larvae either at the carcass site or during their subsequent dispersal on the forest floor. Despite monitoring hundreds of carcasses, the pungent odour and high temperatures of the dense larval masses appeared to exclude most other scavengers. Among the multiple bear scats observed, a single scat had large volumes of digested larvae indicating occasional consumption of these larvae-dominated carcasses or of dispersing larvae. Some larvae dispersed over the stream bank and were swept downstream.

Paired soil plugs (‘below’ bony remnants versus ‘adjacent’ to bony remnants) extracted from each of 17 separate carcass sites yielded 24 invertebrate taxa of which mites (Acari), springtails (Collembola), and dipteran larvae were the most abundant. Overall Shannon diversity (H) and Equitability indices were similar for ‘below’ and ‘adjacent’ microsites ($H = 1.15$ and 1.7, $E = 0.36$ and 0.36, respectively). While twenty of these taxa showed no statistical difference between the two microsites (paired *t*-test, $P > 0.1$ in all cases), four groups (mites, springtails, pseudoscorpions, and spiders) were more prevalent in the ‘adjacent’ microsite ($P < 0.05$ in each taxa) and two taxa (dipteran larvae and staphylinid beetles) were more common ‘beneath’ the bony remnants ($P < 0.05$ and $P < 0.001$, respectively; Figure 3).

### *Marine invertebrates*

SCUBA surveys of 40 tethered subtidal carcasses yielded 10 species of macro-invertebrate scavengers. In the shallow transect (5 m), the dominant scavenger on the carcasses was Dire Welk (*Lirabuccinum dirum*; average = 7, range 0–250) and less frequently hermit crabs (*Pagurus* spp. average = 2.5, range 0–10), beach crab (*Hemigrapsus* spp. average = 0.4, range 0–10), Red-rock Crab (*Cancer productus* average = 0.9, range 0–4), broken-back shrimp (*Heptacarpus* spp. average = 0.1, range 0–5), and starfish (*Evasterias* spp. average = 0.1, range 0–1). The middle depth transect (10 m) had Dire Welk (average = 20, range 0–125), hermit crabs (average = 1.2, range 0–4), and broken-back shrimp (average = 2.7, range 0–15) while the deep transect (15 m) had Red-rock Crab (average = 1.4, range 0–6), starfish (*Pisaster* spp. average = 0.1, range 0–2), bat star (*Asterina* sp. average = 1.1, range 0–9), Sunstar (*Pycnopodia helianthoides* average = 0.1, range 0–1) and Leather Star (*Dermasterias imbricata* average = 0.1, range 0–1). Based on the daily mass measurements of each carcass, there was an average loss of 200 g/day/carcass. Tissues became progressively softer and after five to seven days of submersion, attempted handling of these carcasses produced a cloudy fine suspension of tissues into the water column. This dissolution was more rapid in carcasses from the shallow transects where *Lirabuccinum* snails dominated the carcasses. Secondary interactions with *Lirabuccinum* could be occurring after the spawning run as there was high abundance of recent crab-predated *Lirabuccinum* that had previously dominated the carcasses.

### *Riparian nitrogen input*

Overall contribution of salmon-derived nitrogen to the riparian zone was estimated for the 1993 field season. Nitrogen comprises about 3.3% of total Chum Salmon mass (Gende *et al*. 2007) and when salmon are consumed by bears, most nitrogen is excreted as urine (96%) or faeces (3%; Hilderbrand *et al*. 1999). Therefore, of the 10 690 kg uploaded by bears in 1993 along the 800 m of stream, 5230 kg was consumed, and 171.6 kg of nitrogen would be deposited on the forest floor. Of the 5460 kg of tissues abandoned by the bears in the riparian zone, most of this nitrogen (180 kg) would remain in the riparian zone from calliphorid larvae which pupated in the soil, scavenging by flocks of crows and gulls whose guano was scattered throughout the riparian zone, and by decomposition and direct leaching of the carcasses into the substrate. In total, 352 kg of salmon-derived nitrogen would be added to the riparian zone during the eight-week salmon spawning period. Eighty percent of the carcasses were within a 10 m band adjacent to the stream channel throughout the 800 m of the spawning activity. This zone contained most of the bear activity, calliphorid larval density, and avian scavenger activity. Nitrogen concentration would average 17.6 g N/m$^2$ in this band and 1.1 g N/m$^2$ in the 10 m–50 m zone band further into the forest. These could be conservative estimates as they do not include any contribution of the 1600 kg of salmon consumed directly in the stream channel by bears and avian scavengers. Both bears and crows typically moved into the riparian zone between foraging bouts and would have further supplemented excretory nitrogen to the soils. This would add an additional 88 kg if all excretion occurred in the riparian zone between foraging bouts. Gulls foraging in the

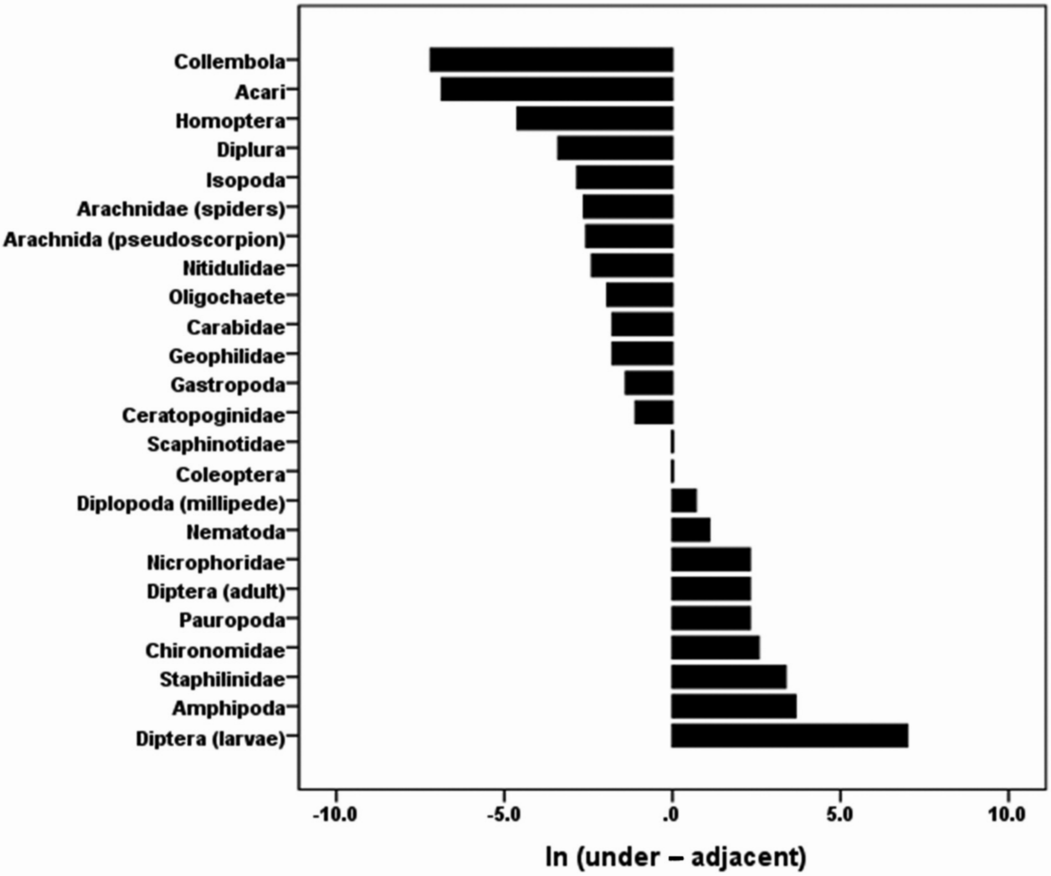

FIGURE 3. Differences in invertebrate diversity in paired soil plugs under and adjacent to Chum Salmon (*Oncorhynchus keta*) carcasses. All sites grouped. Data from October 2000. Bars show ln (number of individuals under carcass minus number of individuals adjacent to carcass). Values > zero indicate greater abundance under carcass.

stream channel could be observed resting on the stream banks and could supplement riparian nitrogen, but I will assume that the majority of their guano production took place in the stream channel, the estuary, or the headwater lake where gulls spent nights. Therefore, an upper range of nitrogen deposition to the 10 m riparian band along the 800 m of stream would be 405 kg or 20.9 g N/m$^2$.

*Nitrogen signatures in riparian plants*

Foliar δ$^{15}$N values were highly variable within each species (Lanky Moss, $n = 88$, $\bar{x} = -0.89$‰, range −10.4 to 9.9; Huckleberry, $n = 41$, $\bar{x} = 0.45$‰, range −8.2 to 6.5; Salal, $n = 88$, $\bar{x} = 1.07$‰, range −9.6 to 9.8; Western Hemlock, $n = 97$, $\bar{x} = -0.81$‰, range −8.3 to 7.2) with significant differences among the species ($F_{3,310} = 5.4$, $P < 0.001$). This variation in isotopic values showed spatial structure across the riparian zone (Figure 4) with $^{15}$N depleted values in each species occurring at sites close to the estuary (< 200 m), at sites greater than 1000 m upstream and also those at increased distances (> 50 m) into the forests. Correspondingly, $^{15}$N was more enriched from 300 to 800 m upstream, concordant with the general stream distribution of spawning gravels but also with site-specific carcass presence or absence. Among the habitat variables, Carcass was a more significant predictor of δ$^{15}$N than DistForest in three of the four species (Lanky Moss: Carcass $F_{1,85} = 7.4$, $P < 0.005$, Distforest $F_{1,85} = 0.45$, $P = 0.5$; Huckleberry: Carcass $F_{1,38} = 1.53$, $P = 0.22$, Distforest $F_{1,38} = 3.64$, $P = 0.06$; Salal: Carcass $F_{1,85} = 7.89$, $P < 0.005$, Distforest $F_{1,85} = 0.47$, $P = 0.5$; Western Hemlock: Carcass $F_{1,94} = 21.83$, $P < 0.001$, Distforest $F_{1,94} = 5.10$, $P < 0.03$). I equalized means among the four species and plotted residuals for the combined data and this much larger dataset (Figure 5) shows clear spatial structure and carcass associations in isotopic enrichment (ANOVA: Carcass $F_{1,311} = 24.2$, $P < 0.001$; Distforest $F_{1,311} = 6.2$, $P < 0.02$).

Total foliar nitrogen (%N) varied among species (Lanky Moss: $\bar{x} = 0.91$%, range 0.5 to 1.8; Huckleberry: $\bar{x} = 1.61$, range 0.7 to 2.3; Salal: $\bar{x} = 1.02$%, range 0.7 to 2.1; Western Hemlock: $\bar{x} = 1.11$%, range 0.5 to 2.3; ANOVA: $F_{3,310} = 49.6$, $P < 0.001$). In each of the species, %N was positively correlated with δ$^{15}$N (Lanky Moss: $r = 0.39$, $P < 0.01$; Huckleberry: $r = 0.62$, $P < 0.01$; Salal: $r = 0.35$, $P < 0.01$; Western Hemlock: $r = 0.36$, $P < 0.01$). Scatterplots of δ$^{15}$N against %N separated for absence/presence of carcasses are shown in Figure 6. The paired slopes ($B$) did not differ statistically from each other ($P > 0.3$ for Huckleberry, Salal, and Western Hemlock although $P = 0.06$ for Lanky Moss). Multivariate GLM with δ$^{15}$N

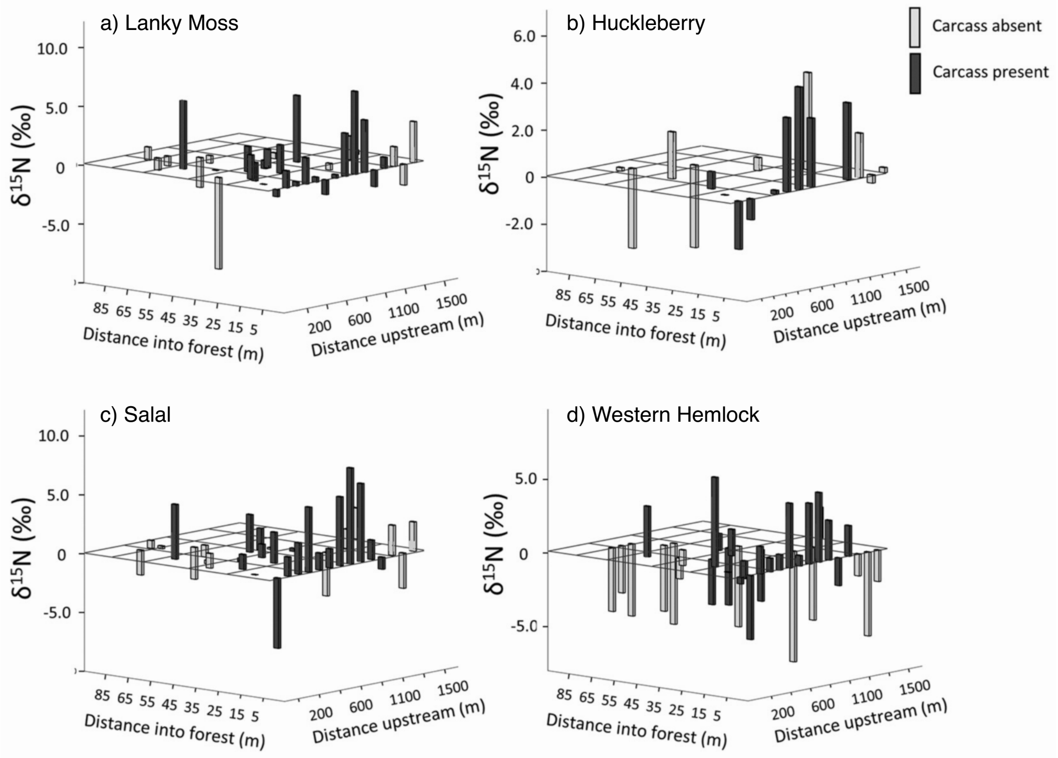

FIGURE 4. Average foliar nitrogen isotope values (‰) for riparian microsites separated by species. Note different scales for distance upstream and distance into the forest. False floor shows 0‰.

and %N as dependents, and Carcass and DistForest as predictors (Table 2) yielded significant models for both dependents although the explained variance (partial eta$^2$) for the full models is low and usually between 10% and 30%. However, in each species except Huckleberry, %N and $\delta^{15}$N were significantly higher in sites where carcasses were present. Additionally, %N decreased into the forest for Lanky Moss while $\delta^{15}$N decreased into the forest for Western Hemlock.

%MDN in the foliar tissues varied with respect to species and microsite. It was lowest in Huckleberry ($\bar{x}$ = 11.1%, range −67% to 60%), intermediate in Lanky Moss ($\bar{x}$ = 13.6%, range −90% to 90%) and in Salal ($\bar{x}$ = 16.6%, range −81% to 89%), and highest in Western Hemlock ($\bar{x}$ = 24.9%, range −32% to 73%; $F_{3,227}$ = 2.5, $P$ = 0.06). Negative %MDN values occurred when $\delta^{15}$N values were lower than the control sites.

## Discussion

Yearly migration of anadromous salmon (*Oncorhynchus* spp.) from the open ocean to coastal habitats of the North Pacific has great antiquity extending back at least 10 000 years in northern latitudes (Pielou 1991) and up to 10 million years south of the ice fronts (Alexandrou *et al.* 2013). Despite the expanding recognition of the importance of this nutrient pulse to coastal ecosystems (Ben-David *et al.* 1998; Jauquet *et al.* 2003; reviews in Helfield and Naiman 2006; Johnson and Schindler 2009; Darimont *et al.* 2010), a characterization of a basic food web at the marine-terrestrial interface for a salmon spawning run has not been previously undertaken.

Estuarine congregations of gulls during salmon migration are well-known with their abundance generally proportional to total salmon spawning biomass (Field and Reynolds 2013). At two mainland estuaries, with salmon spawning runs of about 30 000 and 50 000 salmon, there were 2000 and 3500 gulls, respectively (6.5% and 7.2% of salmon numbers) and these consumed 20% of the total post-reproductive salmon biomass in each locality (Christie and Reimchen 2006). At Bag Harbour, 100 km off the west coast of the mainland, gulls were also one of the dominant scavengers. During the 1992 and 1993 spawning runs, gull numbers were 8% and 6% of salmon numbers, respectively, and consumed 30% and 10% of the spawning biomass, respectively, broadly similar to mainland watersheds. This concentrated foraging by gulls on a largely unrestricted nutrient source over multiple weeks is probably

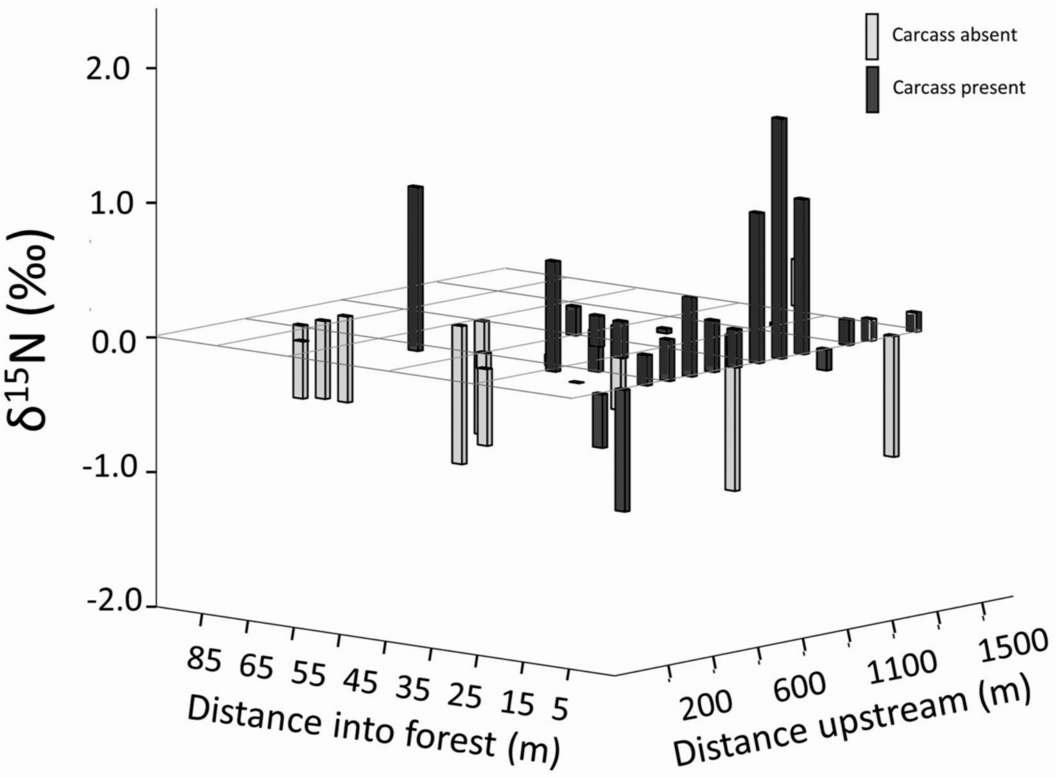

FIGURE 5. Average residual foliar nitrogen isotope values (‰) for riparian microsites with all species combined. Values represent residuals derived separately for each species. Note different scales for distance upstream and distance into the forest. False floor shows 0‰.

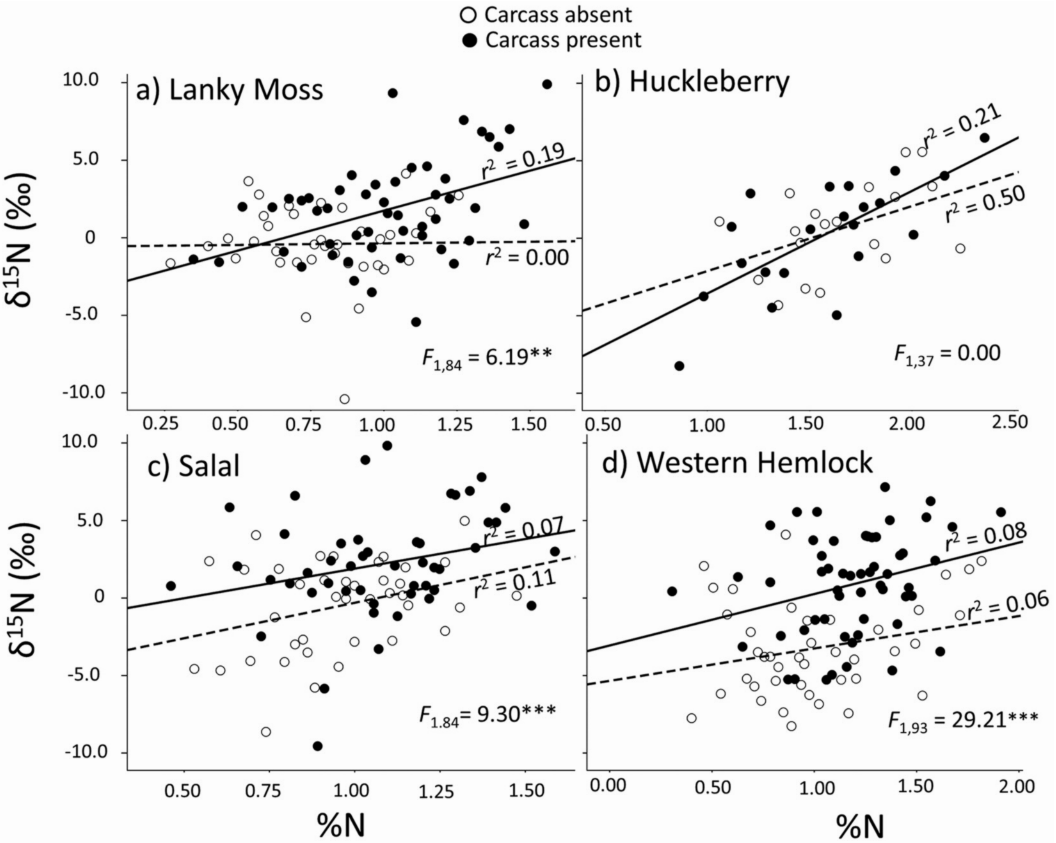

FIGURE 6. Associations between foliar $\delta^{15}$N and percent nitrogen (%N) for riparian taxa. Plots show $r^2$ and $F$ statistic for comparisons between the regression line marginal means for sites with Chum Salmon (*Oncorhynchus keta*) carcasses absent or present. The paired slopes did not differ statistically from each other ($P > 0.3$ in Huckleberry [*Vaccinium parvifolium*], Salal [*Gaultheria shallon*], and Western Hemlock [*Tsuga heterophyll*] and $P = 0.06$ in Lanky Moss [*Rhytidiadelphus loreus*]). All %N data are normalized using Box-Cox transformation (see Methods). *** $P < 0.001$ ** $P < 0.01$.

of considerable importance. As in many marine birds, food constraints are common during their life history, particularly during winter (Lack 1966; Coulter 1975), so it is likely that the geographical distribution of salmon spawning runs in addition to the biomass of each run will influence gull life histories throughout the north Pacific. The serendipitous observation of multiple gull carcasses cached beneath trees by resident marten extends the trophic linkages of the gull aggregations.

The extent of salmon carcass consumption by estuarine subtidal scavengers has received limited attention. Large decapods such as the Dungeness Crab (*Cancer magister*) and Red-rock Crab are geographically widespread scavengers (Thorne *et al.* 2006). But while present in Bag Harbour estuary, Dungeness Crab were not observed on carcasses. Such absence might reflect the low tissue quality of senescent carcasses (Winder *et al.* 2005) or possibly that they were more active during darkness rather than daylight when I surveyed (e.g., McGaw 2005). At Bag Harbour, ~3700 kg of salmon biomass was washed into the estuary and the major scavengers I observed in shallow depths were gastropods and species of hermit crab with prawns and echinoderms at greater depths. High densities of these scavengers on the carcasses may be an important trophic link in productivity and diversity in estuaries. Fujiwara and Highsmith (1997) identified a positive feedback loop in which the downstream accumulation of salmon carcasses in estuaries increased nitrates and phosphates that stimulated growth of the macrophyte *Ulva*. *Ulva*, in turn, was the major food of harpacticoid copepods, the latter comprising an important prey of juvenile salmon. As well, watershed size and salmon density were positively associated with growth responses in estuarine intertidal bivalves (Harding *et al.* 2015). Cak *et al.* (2008) also found estuarine increases in nutrients from salmon carcasses, but without effects on primary productivity. During my SCUBA surveys at Bag Harbour, full dissolution of the carcasses into the estuarine water column occurred after 5–7 days of submergence that would have increased organic carbon, nitrates, and phosphates. The partially restricted tidal entrance to

TABLE 2. Multivariate general linear model for foliar $\delta^{15}$N and foliar %N using Chum Salmon (*Oncorhynchus keta*) Carcass (absence/presence) as a fixed factor and DistForest as covariate for riparian species in Bag Harbour, British Columbia. Source (Model, Carcass, Distforest) shows slope (±) of regression line. Model represents the corrected model. All significant results are shown in bold.

| Species | Dependent | Source | $F_{df}$ | $P$ | Partial eta$^2$ |
|---|---|---|---|---|---|
| Lanky Moss | **$\delta^{15}$N** | **Model+** | **$5.97_{2,84}$** | **0.004** | **0.12** |
| | | **Carcass+** | **$7.17_{1,84}$** | **0.009** | **0.08** |
| | | DistForest- | $0.40_{1,84}$ | 0.530 | 0.01 |
| | **%N** | **Model+** | **$12.51_{2,84}$** | **0.000** | **0.23** |
| | | **Carcass+** | **$5.58_{1,84}$** | **0.020** | **0.06** |
| | | **DistForest-** | **$7.51_{1,84}$** | **0.008** | **0.08** |
| Huckleberry | $\delta^{15}$N | Model+ | $1.86_{2,37}$ | 0.170 | 0.09 |
| | | Carcass- | $1.69_{1,37}$ | 0.200 | 0.04 |
| | | DistForest- | $3.52_{1,37}$ | 0.070 | 0.09 |
| | %N | Model+ | $0.88_{2,37}$ | 0.430 | 0.05 |
| | | Carcass- | $1.45_{1,37}$ | 0.240 | 0.04 |
| | | DistForest- | $1.13_{1,37}$ | 0.300 | 0.03 |
| Salal | $\delta^{15}$N | **Model+** | **$6.98_{2,87}$** | **0.002** | **0.14** |
| | | **Carcass+** | **$10.69_{1,87}$** | **0.002** | **0.11** |
| | | DistForest- | $0.08_{1,87}$ | 0.790 | 0.00 |
| | %N | **Model+** | **$4.67_{2,87}$** | **0.012** | **0.10** |
| | | **Carcass+** | **$8.76_{1,87}$** | **0.004** | **0.09** |
| | | DistForest+ | $3.72_{1,87}$ | 0.060 | 0.04 |
| Western Hemlock | **$\delta^{15}$N** | **Model+** | **$22.83_{2,93}$** | **0.000** | **0.33** |
| | | **Carcass+** | **$20.72_{1,93}$** | **0.000** | **0.18** |
| | | **DistForest-** | **$5.38_{1,93}$** | **0.023** | **0.06** |
| | **%N** | **Model+** | **$5.95_{2,93}$** | **0.004** | **0.11** |
| | | **Carcass+** | **$11.71_{1,93}$** | **0.001** | **0.11** |
| | | DistForest+ | $3.882_{1,93}$ | 0.052 | 0.04 |

Bag Harbour (see Figure 1) would limit the daily mixing of tidal waters that would extend the duration of nutrients and benefits to productivity and may have contributed to the high densities of schooling fish and avian piscivores during, and after, the spawning run.

In stream channels, salmon nutrients make significant contributions to primary productivity (Cederholm *et al*. 1989; Thomas *et al*. 1999), to diversity and abundance of aquatic invertebrate scavengers (Nakajima and Ito 2003; Quamme and Slaney 2003; Wipfli *et al*. 2003), and to juvenile salmonid production (Bilby *et al*. 1996; Slaney *et al*. 2003; review in Stockner and Ashley 2003). This is in addition to their direct use by predators such as bears, wolves, marten, and birds (Ben-David *et al*. 1997; Cederholm *et al*. 1999; Hilderbrand *et al*. 1999; Klinka and Reimchen 2002, 2009; Darimont *et al*. 2003). In each year of my study, throughout much of the 800 m of the stream spawning areas, large flocks of gulls and crows were active throughout the day while bears occurred throughout daylight and darkness (Reimchen 1998). Aquatic invertebrate scavengers were not dominant in Bag Harbour stream channel during my study. Many of the senescent carcasses that accumulate in pools and are typically exploited by these scavengers had low residence time during my study as carcasses were usually swept downstream into the estuary by the high water flows. This would limit the contribution to both primary and invertebrate scavenger productivity during high flow years.

Predator-mediated uploading of salmon carcasses to the riparian zone and their use by scavengers was first systematically documented in the Olympic Peninsula, western Washington, by Cederholm *et al.* (1989). My studies at Bag Harbour, Haida Gwaii, broadened the evidence for the major contribution of bears in such uploading (Reimchen 1992, 1994, 2000), while independent studies in coastal Alaska show a major role of Grizzly Bear (*Ursus arctos*) in the transfer of salmon nutrients to riparian zones (Hilderbrand *et al.* 1999, 2004; Gende *et al.* 2004). Although more limited in their effect, other predators such as Gray Wolf (*Canis lupus*), marten, and avian scavengers including gulls and eagles can be locally important in some watersheds (Ben-David *et al.*1997; Darimont *et al.* 2003; Christie and Reimchen 2006). Flooding during heavy rainfall can also have an effect in low gradient watersheds (Ben-David *et al.* 1998; Bilby *et al.* 2003).

Despite the ecological importance of the contribution of salmon to riparian zones, the densities of riparian carcasses have not been previously quantified in studies of the marine-terrestrial interface. Data for Bag Harbour demonstrate an average occurrence of 2.3 carcasses per linear metre on each side of the stream, or approximately one carcass per 5 square metres in the 10 m wide riparian band. While scavengers such as crows and marten exploited this resource, the principal consumers of the soft tissues were dipteran larvae. In 1993, 95% of the carcasses were fully enveloped in dipteran larvae resulting in consumption of most tissues. Published estimates of total dipteran larvae per carcass vary from 4000 to 29 000 (Goodbrod and Goff 1990; Hocking and Reimchen 2002; Meehan *et al.* 2005). I used the most conservative of these values and this predicts the total abundance of 15 million larvae in the Bag Harbour riparian zone or approximately 740/m$^2$. Soil plugs extracted from multiple microsites yielded 24 invertebrate taxa, including predatory arthropods such as staphylinid and carabid beetles that would exploit both larvae and pupae (e.g., Allen and Hagley 1990; Hocking and Reimchen 2002). Recent studies on mainland watersheds indicate a rich assemblage of 60 invertebrate species including a diversity of Diptera, predatory beetles, and predatory wasps directly or indirectly associated with salmon carcasses (Hocking and Reimchen 2006; Hocking *et al.* 2009; Juen and Tragott 2007). Such diversity benefits vertebrate insectivores (Jauquet *et al.* 2003; Christie and Reimchen 2008; Christie *et al.* 2008).

Riparian densities of calliphorid larvae differed dramatically between sequential years. Larvae were not observed on any of the 800+ riparian carcasses observed in autumn 1992 yet these dominated the majority of carcasses in autumn 1993 (Figure 2). This large yearly difference was unexpected for an intact old growth forest because the major ecological players (salmon, bears, Diptera) were present each year of the study. While there could be cyclicity in calliphorid population trends, I suspect the yearly effects are due to temperature and insect flight activity. Average October daytime air temperatures for Bag Harbour (extracted from the closest Environment Canada meteorological station at Sandspit, British Columbia) were 5.6 °C in 1992 and 9.2 °C in 1993 while lowest daytime temperatures were 2.0 °C and 7.5 °C, respectively. Relative flight activity of large dipterans as well as larval development is greatly reduced below 10 °C (Chappell and Morgan 1987; Heaton *et al.* 2014) and could be the principal cause for the lack of egg production of the dipterans during the low 1992 temperatures. Such covariation between yearly autumn temperatures and trophic associations in the riparian zone suggests broader geographical trends among salmon watersheds from southern and northern latitudes or among salmon species that spawn at different times of the year. It also implies microspatial heterogeneity in trophic associations with sun exposure and temperature regime of individual carcasses. For example, salmon carcasses abandoned by bears in shaded areas of the riparian zone (i.e., shaded side of a tree trunk) would be less likely to receive visits from egg-laying dipterans and these carcasses would have extended use by vertebrate scavengers. Comparable trends in development rate have been observed in experimental forensic studies with blowfly larvae on shaded and unshaded pig carcasses (Shean *et al.* 1993). Such heterogeneity might contribute to the large differences in isotopic values among microsites in the riparian zones in this study, a trend also seen in microgeographical differences in isotopic signatures of bryophytes of mainland salmon watersheds (Wilkinson *et al.* 2003) as well as soil nitrogen signatures in riparian zones of Alaskan salmon rivers (Holtgrieve *et al.* 2009).

Estimates of salmon-derived nitrogen subsidies to riparian soils from predator and scavenger activity in the northeast Pacific are highly variable within and among watersheds. Based on salmon consumption rates by Alaskan Brown Bears (= Grizzly Bears), nitrogen contributions to the riparian soils were estimated at 0.005 g N/m$^2$, of which 97% is added via urine (Hilderbrand *et al.* 1999). Gende *et al.* (2007), also investigating Alaskan Brown Bears, calculated contributions of 1.4 g N/m$^2$ to 10.5 g N/m$^2$ in a riparian band immediately adjacent to the salmon stream. Recent experimental evidence involving bear exclusion zones indicate substantive deficiencies in soil nitrogen processing compared with sites with bear activity (Holtgrieve *et al.* 2009). For the Bag Harbour watershed, I have incorporated carcass, bear and avian activity as well as invertebrate sources and estimate an average input of 18.8 g N/m$^2$ within a 10 m band of the stream and a 1.12 g N/m$^2$ at greater distances (10–50 m) along the riparian zone adjacent to the 800 m length of spawning gravels. If these groups were distributed uniformly over the entire riparian area (0–50 m band) rather than predominantly within the 10 m band where most of the carcasses, faeces, and scavenger activity were observed, then average nitrogen input would be 4.7 g N/m$^2$, which is about three to 30 times higher than those observed for Alaskan Brown Bears. Atmospheric nitrogen fixers such as Red Alder (*Alnus rubra* Bongard) are also sources of the soil nitrogen pool in coastal riparian zones with yearly fixation ranging from 3.5 g N/m$^2$ to 13.0 g N/m$^2$ (Binkley 1982). Alder is uncommon in the riparian zone at Bag Harbour watershed and as such, my estimates from the uploading of salmon nutrients by Black Bears over the eight weeks are equivalent to that of the yearly nitrogen fixation for a pure stand of Red Alder. Other limiting nutrients, such as phosphorus, that can constrain plant growth in coastal forests (Blevins *et al.* 2006), would also be supplemented with the salmon carcasses. Some of this riparian soil nitrogen could be lost due to groundwater movement and hyporheic flow into the stream and estuary (O'Keefe and Edwards 1993; Ben-David *et al.* 1997) although meta-analysis of attenuation rates indicates high nitrogen retention in undisturbed riparian zones, particularly in watersheds with low relief (Ranalli and Macalady 2010), which is the case for Bag Harbour.

The last three decades have seen a major expansion of stable isotope techniques in ecological studies (Fry 2006) including the identification of marine-derived nitrogen in foliar tissues of riparian habitats adjacent to salmon rivers (e.g., Ben-David *et al.* 1998; Hilderbrand *et al.* 1999; Bilby *et al.* 2003; Reimchen *et al.* 2003; Nagasaka *et al.* 2006; Naiman *et al.* 2009). However, numerous processes can result in $^{15}$N enrichment in foliar tissues including increased annual temperature, reduced rainfall, increased root depth, reduction in mycorrhizal fungi, and increased soil nitrogen availability (Craine *et al.* 2009, 2012, 2015), each of which can potentially produce false signals of marine-derived nitrogen sources in vegetation. Paired sampling across sharp ecological gradients in salmon carcass density (Mathewson *et al* 2003; Wilkinson *et al.* 2005; Reimchen and Fox 2013), in bear activity zones (Hilderbrand *et al.* 1999) as well as experimental addition of salmon carcasses to virgin sites (Hocking and Reynolds 2012) provide improved confidence in interpreting nitrogen isotope signatures and sources. My study showed that higher isotopic ratios occurred in zones of high carcass density and bear foraging activity close to the spawning gravels and that ratios were reduced at greater distances into the forest where carcasses were absent and bear activity reduced. Although this is suggestive of a causal relationship, such a riparian isotopic gradient also occurs in Alaska streams without salmon and reflects denitrification (and subsequent enrichment) in the soils adjacent to streams (Bilby *et al.* 2003). This could be contributory to the gradient I observed but given that enrichment occurs at replicated carcass sites and depletion at adjacent non-carcass sites, the differences in ratios are consistent with the proximal effects of carcasses rather than effects of denitrification. Furthermore, the greatest reduction in $\delta^{15}$N occurred near the upper reaches of the spawning gravels across a sharp gradient in carcass density yet within the same narrow riparian band adjacent to the stream. Comparable sharp isotopic differentiation in multiple riparian herbs and shrubs occurred on mainland watersheds immediately below and above waterfall barriers to salmon migration (Mathewson *et al.* 2003), as well as among bryophytes separated by several meters on and off bear trails (Wilkinson *et al.* 2005).

Among the four plant species I examined at Bag Harbour, isotopic values among microsites ranged from a minimum of −10.4‰ to a maximum of 9.9‰. In an assessment of $^{15}$N variability of multiple plant taxa from a diversity of geographical latitudes, temperatures, precipitation, and edaphic conditions, Craine *et al.* (2015) found that 95% of the isotopic data ranged between −7.8‰ and 8.7‰. As such, even when factoring in the positive relationship between sample size and isotopic range (Craine *et al.* 2009), the Bag Harbour data equal or exceed the maximum range observed in the global survey. This high microsite variability cannot be due to taxonomic bias as it occurred in each taxa including a bryophyte, two ericads, and a gymnosperm. This variability is probably representative of the level of microspatial heterogeneity in edaphic conditions, including nitrogen availability that may differentiate salmon watersheds from non-salmon watersheds.

Estimates of the relative contribution of marine-derived nutrients (%MDN) depend on geography and taxonomy but tend to vary from 10% to 30%, with occasional higher values (Bilby *et al.* 1996, 2003; Hilderbrand *et al.* 1999; Helfield and Naiman 2001; Mathewson *et al.* 2003). I estimated that %MDN averaged 18% at Bag Harbour with maximum estimates for individual plants of 60% in Huckleberry to 89% in Lanky Moss and Salal. Such high estimates have been reported for individual growth rings in Sitka Spruce from this location (Reimchen and Fox 2013), as well as from shrubs in high salmon density watersheds on the British Columbia mainland (Mathewson *et al.* 2003). However, I suspect that true estimates at Bag Harbour could be even higher, due to two factors. Firstly, for a terrestrial end member for each species, I used $^{15}$N values from plants collected above the upper distribution of spawning gravels as well as those distant into the forest beyond the outer distribution of salmon carcasses. Yet even in such ‘control’ sites, there was possible input of guano from flocks of crows or urine from bears moving through the sites. As such, the samples would be enriched relative to a ‘true’ control site resulting in lower %MDN estimates. Moving greater distances away from the stream to minimize such occasional nutrient influences increases the confounding impacts of the multiple abiotic and mycorrhizal associations known to influence nitrogen isotope ratios in plants (Craine *et al.* 2009). Secondly, artificially low estimates are indicated by the occasional negative %MDN where foliar $^{15}$N values are less than the control. As these negative values occurred at sites with very high bear activity, I suspect that these soils were nitrogen saturated. Plants will discriminate against $^{15}$N when nitrogen supply exceeds requirements and as a result, foliar tissues will be depleted in the heavy isotope (Nadelhoffer and Fry 1994). This implies that the extent of isotopic enrichment should scale positively with the relative loading of salmon-derived nutrients when the supply of nitrogen is less than that required by the plants but then scale negatively (increased fractionation) as the supply begins to exceed requirements (see Bilby *et al.* 2003; Hocking and Reimchen 2009; Hocking and Reynolds 2011). Most forests around the north Pacific are nitrogen-limited (Waring and Franklin 1979; Littke *et al.* 2014) but when large allochthonous nitrogen pulses occur, as in the bear-mediated uploading of salmon nutrients, surplus nitrogen is possible. Consequently, estimates of %MDN based on the absolute values of $\delta^{15}$N in relation to a TEM, will greatly underestimate %MDN when nitrogen supplies to specific microsites exceed requirements. Such fractionation against $^{15}$N should occur particularly for seedlings and small shrubs where surplus loading is possible. In large trees, nitrogen surplus would rarely occur. One would also predict that if the soil is nitrogen saturated, there would be elevated %N in the tissues. The elevated %N that I detected occurred in three of the four plant species collected in the high bear activity zones close to the estuary.

Does this input of salmon-derived nutrients increase riparian primary productivity? Such a positive effect could be expected given that most forests around the north Pacific are nitrogen limited (Waring and Franklin 1979). Enhanced growth rates in the riparian zone have been shown for Sitka Spruce in Alaska (Helfield and Naiman 2001) and at Bag Harbour, where there were significant positive growth responses in microsites where carcasses were prevalent and in years when spawning runs were elevated (Reimchen and Fox 2013). Foliar %N is also a proxy for primary production because a doubling of foliar nitrogen results in a 50% increase in chlorophyll content (Yoder and Pettigrew-Crosby 1995), which is itself directly correlated with primary productivity both for canopy and under-canopy habitats (Dawson *et al.* 2003). Craine *et al.* (2012) observed that foliar $\delta^{15}$N and %N in many species are positively correlated with each other across broad geographical areas, independent of marine associations, and that both are elevated where soil nitrogen levels are high. In each plant species in my study, there was also a significant positive relationship between $\delta^{15}$N and %N. Higher values for both proxies occurred in the highest carcass transfer zones suggesting a direct increase in primary productivity in the high bear activity sites.

My observations at Bag Harbour on estuarine, stream, and riparian movement of salmon biomass, bear transfer, scavenger diversity, and nitrogen uptake by riparian vegetation are taxonomically and trophically more detailed than previous studies and are probably representative for an intact watershed from current time periods. Yet numbers of returning salmon in 1993, when most detailed field data were obtained, were approximately one-half the yearly average (10 000) and one-sixth the maximum (35 000) number of salmon returning to this watershed between 1947 and 2000 (Marshall *et al.* 1978; Reimchen 1994). Further, these greater numbers in the recent past may seriously underestimate numbers from the late 1800s prior to the expansion of the commercial fishing industry (Gresh *et al.* 2000). Developing restoration targets for compromised habitats is facilitated with insight on the ‘pre-disturbance’ state but for much of the globe, ecological baselines have not been identified. This deficiency is confounded by expanding anthropogenic influences on all aquatic and terrestrial ecosystems that result in continuously shifting baselines that further limits the identification of pre-disturbance states using present day habitats (Arcese and Sinclair 1997). Even in well-studied taxa such as the great herds of African ungulates or the immense schools of marine clupeids, prehistorical densities are either unknown or at best interpolated (e.g., Finney *et al.* 2002).

Restoration of degraded stream and riparian habitats is an important component of reclamation in the Pacific Northwest (Lackey 2003). An overview of restoration practices for the western United States (Kauffman *et al.* 1997; Slaney and Martin 1997) examined the importance of salmon to stream habitats but failed to address their role in riparian habitats, presumably because such information was still poorly known. However, during the last 20 years, multiple studies have identified the major contributions of salmon nutrients to riparian habitats and the resulting trophic cascades on species diversity and productivity. Yet, despite this accumulating evidence, a recent synthesis and development of policy guidelines for the restoration of stream and riparian habitats in the Columbia River basin (Rieman *et al.* 2015) again excludes assessment of carcasses in the riparian zone. The current study at Bag Harbour provides empirical data on carcass densities, their scavengers, and total nitrogen input that can inform ecological baselines and restoration targets.

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## Literature Cited

**Alexandrou, M. A., B. A. Swartz, N. J. Matzke**, and **T. H. Oakley.** 2013. Genome duplication and multiple evolutionary origins of complex migratory behavior in Salmonidae. Molecular Phylogenetics and Evolution 69: 514–523. https://doi.org/10.1016/j.ympev.2013.07.026

**Allen, W. R.**, and **E. A. C. Hagley.** 1990. Epigeal arthropods as predators of mature larvae and pupae of the apple maggot (Diptera: Tephritidae). Environmental Entomology 19: 309–312. https://doi.org/10.1093/ee/19.2.309

**Arcese, P.**, and **A. R. E. Sinclair.** 1997. The role of protected areas as ecological baselines. Journal of Wildlife Management 61: 587–602. https://doi.org/10.2307/3802167

**Banner, A., W. H. MacKenzie, J. Pojar, A. MacKinnon, S. C. Saunders**, and **H. Klassen.** 2014. A field guide to ecosystem classification and identification for Haida Gwaii. B.C. Land Management Handbook 68. Province of British Columbia, Victoria, British Columbia, Canada. Accessed 14 March 2018. http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh68.htm.

**Ben-David, M., R. W. Flynn**, and **D. M. Schell.** 1997. Annual and seasonal changes in diets of martens: evidence from stable isotope analysis. Oecologia 111: 280–291. https://doi.org/10.1007/s004420050236

**Ben-David, M., T. A. Hanley**, and **D. M. Schell.** 1998. Fertilization of terrestrial vegetation by spawning Pacific salmon:

the role of flooding and predator activity. Oikos 83: 47–55. https://doi.org/10.2307/3546545

**Bilby, R. E., E. W. Beach, B. R. Fransen, J. K. Walter,** and **P. A. Bisson.** 2003. Transfer of nutrients from spawning salmon to riparian vegetation in western Washington. Transactions of the American Fisheries Society 132: 733–745. https://doi.org/10.1577/T02-089

**Bilby, R. E., B. R. Fransen,** and **P. A. Bisson.** 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences 53: 164–173. https://doi.org/10.1139/cjfas-53-1-164

**Binkley, D.** 1982. Nitrogen-fixation and net primary production in a young Sitka alder stand. Canadian Journal of Botany 60: 281–284. https://doi.org/10.1139/b82-036

**Birtfriesen, V. L., W. A. Montevecchi, D. K. Cairns,** and **S. A. Macko.** 1989. Activity-specific metabolic rates of free-living northern gannets and other seabirds. Ecology 70: 357–367. https://doi.org/10.2307/1937540

**Blevins, L. L., C. E. Prescott,** and **A. Van Niejenhuis.** 2006. The roles of nitrogen and phosphorus in increasing productivity of western hemlock and western redcedar plantations on northern Vancouver Island. Forest Ecology and Management 234: 116–122. https://doi.org/10.1016/j.foreco.2006.06.029

**Cak, A. D., D. T. Chaloner,** and **G. A. Lamberti.** 2008. Effects of spawning salmon on dissolved nutrients and epilithon in coupled stream-estuary systems of southeastern Alaska. Aquatic Sciences 70: 169–178. https://doi.org/10.1007/s00027-008-8090-5

**Cederholm, C. J., D. B. Huston, D. L. Cole,** and **W. J. Scarlett.** 1989. Fate of coho salmon (*Oncorhynchus kisutch*) carcasses in spawning streams. Canadian Journal of Fisheries and Aquatic Sciences 46: 1347–1355. https://doi.org/10.1139/f89-173

**Cederholm, C. J., D. H. Johnson, R. E. Bilby, L. G. Dominguez, A. M. Garrett, W. H. Graeber, E. L. Greda, M. D. Kunze, B. G. Marcot, J. F. Palmisano, R. W. Plotnikoff, W. G. Pearcy, C. A. Simenstad,** and **P. C. Trotter.** 2000. Pacific salmon and wildlife-ecological contexts, relationships, and implications for management. Special edition technical report. Wildlife-habitat relationships in Oregon and Washington. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

**Cederholm, C. J., M. D. Kunze, T. Murota,** and **A. Sibatani.** 1999. Pacific salmon carcasses: essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries 24: 6–15. https://doi.org/10.1577/1548-8446(1999)024<0006:PSC>2.0.CO;2

**Chappell, M. A.,** and **K. R. Morgan.** 1987. Temperature regulation, endothermy, resting metabolism, and flight energetics of tachinid flies (Nowickia sp.). Physiological Zoology 60: 550–559.

**Christie, K. S., M. D. Hocking,** and **T. E. Reimchen.** 2008. Tracing salmon-derived nutrients in riparian foodwebs: isotopic evidence in a ground-foraging passerine. Canadian Journal of Zoology 86: 1317–1323. https://doi.org/10.1139/Z08-110

**Christie, K. S.,** and **T. E. Reimchen.** 2006. Post-reproductive Pacific salmon as a major nutrient source for large aggregations of gulls. Canadian Field-Naturalist 119: 202–207. https://doi.org/10.22621/cfn.v119i2.107

**Christie, K. S.,** and **T. E. Reimchen.** 2008. Presence of salmon increases passerine density on Pacific North-west streams. Auk 125: 51–59. https://doi.org/10.1525/auk.2008.125.1.51

**Coulter, M. C.** 1975. Post-breeding movements and mortality in the Western Gull, *Larus occidentalis*. Condor 77: 243–249. https://doi.org/10.2307/1366220

**Craine, J. M., E. N. J. Brookshire, M. D. Cramer, N. J. Hasselquist, K. Koba, E. Marin-Spiotta,** and **L. Wang.** 2015. Ecological interpretations of nitrogen isotope ratios of terrestrial plants and soils. Plant and Soil 396: 1–26. https://doi.org/10.1007/s11104-015-2542-1

**Craine, J. M., A. J. Elmore, M. P. M. Aidar, M. Bustamante, T. E. Dawson, E. A. Hobbie, A. Kahmen, M. C. Mack, K. K. McLauchlan, A. Michelsen, G. B. Nardoto, L. H. Pardo, J. Peñuelas, P. B. Reich, E. A. G. Schuur, W. D. Stock, P. H. Templer, R. A. Virginia, J. M. Welker,** and **I. J. Wright.** 2009. Global patterns of foliar nitrogen isotopes and their relationships with climate, mycorrhizal fungi, foliar nutrient concentrations, and nitrogen availability. New Phytologist 183: 980–992. https://doi.org/10.1111/j.1469-8137.2009.02917.x

**Craine, J. M., E. G. Towne, T. W. Ocheltree,** and **J. B. Nippert.** 2012. Community traitscape of foliar nitrogen isotopes reveals N availability patterns in a tallgrass prairie. Plant and Soil 356: 395–403. https://doi.org/10.1007/s11104-012-1141-7

**Darimont, C. T., H. Bryan, S. M. Carlson, M. D. Hocking, M. MacDuffee, P. C. Paquet, M. H. H. Price, T. E. Reimchen, J. D. Reynolds,** and **C. C. Wilmers.** 2010. Salmon for terrestrial protected areas. Conservation Letters 3: 379–389. https://doi.org/10.1111/j.1755-263X.2010.00145.x

**Darimont, C. T., T. E. Reimchen,** and **P. C. Paquet.** 2003. Foraging behaviour by gray wolves on salmon streams in coastal British Columbia. Canadian Journal of Zoology 81: 349–353. https://doi.org/10.1139/Z02-246

**Dawson, T. P., P. R. J. North, S. E. Plummer,** and **P. J. Curran.** 2003. Forest ecosystem chlorophyll content: implications for remotely sensed estimates of net primary productivity. International Journal of Remote Sensing 24: 611–617. https://doi.org/10.1080/01431160304984

**Field, R. D.,** and **J. D. Reynolds.** 2013. Ecological links between salmon, large carnivore predation, and scavenging birds. Journal of Avian Biology 44: 9–16. https://doi.org/10.1111/j.1600-048X.2012.05601.x

**Finney, B. P., I. Gregory-Eaves, M. S. V. Douglas,** and **J. P. Smol.** 2002. Fisheries productivity in the northeastern Pacific Ocean over the past 2,200 years. Nature 416: 729–733. https://doi.org/10.1038/416729a

**Fry, B.** 2006. Stable Isotope Ecology. Springer-Verlag, New York, New York, USA.

**Fujiwara, M.,** and **R. C. Highsmith.** 1997. Harpacticoid copepods: potential link between inbound adult salmon and outbound juvenile salmon. Marine Ecology Progress Series 158: 205–216. https://doi.org/10.3354/meps158205

**Gende, S. M., A. E. Miller,** and **E. Hood.** 2007. The effects of salmon carcasses on soil nitrogen pools in a riparian forest of southeastern Alaska. Canadian Journal of Forest Research 37: 1194–1202. https://doi.org/10.1139/X06-318

**Gende, S. M., T. P. Quinn, M. F. Willson, R. Heintz,** and **T. M. Scott.** 2004. Magnitude and fate of salmon-derived nutrients and energy in a coastal stream ecosystem. Journal of Freshwater Ecology 19: 149–160. https://doi.org/10.1080/02705060.2004.9664522

**Gilbert, B. K.,** and **R. M. Lanner.** 1995. Energy, diet selection and restoration of brown bear populations. Pages 231–240 *in* Density-dependent Population Regulation of Black, Brown, and Polar Bears. Proceedings of the 9th International Conference on Bear Research and Management. *Edited by* M. Taylor and D. L. Garshelis. International Association for Bear Research and Management, Missoula, Montana, USA.

**Goodbrod, J. R.,** and **M. L. Goff.** 1990. Effects of larval population density on rates of development and interactions between two species of *Chrysomya* (Diptera: Calliphoridae) in laboratory culture. Journal of Medical Entomology 27: 338–343. https://doi.org/10.1093/jmedent/27.3.338

**Gresh, T., J. Lichatowich,** and **P. Schoonmaker.** 2000. An estimation of historic and current levels of salmon production in the northeast Pacific ecosystem: evidence of a nutrient deficit in the freshwater systems of the Pacific Northwest. Fisheries 25: 15–21. https://doi.org/10.1577/1548-8446(2000)025<0015:AEOHAC>2.0.CO;2

**Harding, J. M. S., M. R. Segal,** and **J. D. Reynolds.** 2015. Location is everything: evaluating the effects of terrestrial and marine resource subsidies on an estuarine bivalve. PLoS ONE 10(5): e0125167. https://doi.org/10.1371/journal.pone.0125167

**Heaton, V., C. Moffatt,** and **T. Simmons.** 2014. Quantifying the temperature of maggot masses and its relationship to decomposition. Journal of Forensic Sciences 59: 676–682. https://doi.org/10.1111/1556-4029.12396

**Helfield, J. M.,** and **R. J. Naiman.** 2001. Effects of salmon-derived nitrogen on riparian forest growth and implications for stream productivity. Ecology 82: 2403–2409. https://doi.org/10.2307/2679924

**Helfield, J. M.,** and **R. J. Naiman.** 2006. Keystone interactions: salmon and bear in riparian forests of Alaska. Ecosystems 9: 167–180. https://doi.org/10.1007/s10021-004-0063-5

**Hilderbrand, G. V., S. D. Farley, T. A. Hanley, C. C. Schwartz,** and **C. T. Robbins.** 2004. Importance of salmon to wildlife: implications for integrated management. Ursus 15: 1–9. https://doi.org/10.2192/1537-6176(2004)015<0001:IOSTWI>2.0.CO;2

**Hilderbrand, G. V., S. D. Farley, C. T. Robbins, T. A. Hanley, K. Titus,** and **C. Servheen.** 1996. Use of stable isotopes to determine diets of living and extinct bears. Canadian Journal of Zoology 74: 2080–2088. https://doi.org/10.1139/z96-236

**Hilderbrand, G. V., T. A. Hanley, C. T. Robbins,** and **C. C. Schwartz.** 1999. Role of brown bears (*Ursus arctos*) in the flow of marine nitrogen into a terrestrial ecosystem. Oecologia 121: 546–550. https://doi.org/10.1007/s004420050961

**Hocking, M. D.,** and **T. E. Reimchen.** 2002. Salmon-derived nitrogen in terrestrial invertebrates from coniferous forests of the Pacific Northwest. BioMed Central Ecology 2: 4–14. https://doi.org/10.1186/1472-6785-2-4

**Hocking, M. D.,** and **T. E. Reimchen.** 2006. Consumption and distribution of salmon (*Oncorhynchus* spp.) nutrients and energy by terrestrial flies. Journal of Fisheries and Aquatic Sciences 63: 2076–2086. https://doi.org/10.1139/F06-110

**Hocking, M. D.,** and **T. E. Reimchen.** 2009. Salmon species, density and watershed size predict magnitude of marine enrichment in riparian food webs. Oikos 118: 1307–1318. https://doi.org/10.1111/j.1600-0706.2009.17302.x

**Hocking, M. D.,** and **J. D. Reynolds.** 2011. Impacts of salmon on riparian plant diversity. Science 331: 1609–1612. https://doi.org/10.1126/science.1201079

**Hocking, M. D.,** and **J. D. Reynolds.** 2012. Nitrogen uptake by plants subsidized by Pacific salmon carcasses: a hierarchical experiment. Canadian Journal of Forest Research 42: 908–917. https://doi.org/10.1139/X2012-045

**Hocking, M. D., R. A. Ring,** and **T. E. Reimchen.** 2009. The ecology of terrestrial invertebrates on Pacific salmon carcasses. Ecological Research 24: 1091–1100. https://doi.org/10.1007/s11284-009-0586-5

**Holtgrieve, G. W., D. E. Schindler,** and **P. K. Jewett.** 2009. Large predators and biogeochemical hotspots: brown bear (*Ursus arctos*) predation on salmon alters nitrogen cycling in riparian soils. Ecological Research 24: 1125–1135. https://doi.org/10.1007/s11284-009-0591-8

**Jauquet, J., N. Pittman, J. A. Heinis, S. Thompson, N. Tatyama,** and **C. J. Cederholm.** 2003. Observations of chum salmon consumption by wildlife and changes in water chemistry at Kennedy Creek during 1997–2000**.** Pages 71-88 *in* Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity. *Edited* by J. G. Stockner. American Fisheries Society Symposium 34, Bethesda, Maryland, USA.

**Johnson, S. P.,** and **D. E. Schindler.** 2009. Trophic ecology of Pacific salmon (*Oncorhynchus* spp.) in the ocean: a synthesis of stable isotope research. Ecological Research 24: 855–863. https://doi.org/10.1007/s11284-008-0559-0

**Juen, A.,** and **M. Traugott.** 2007. Revealing species-specific trophic links in soil food webs: molecular identification of scarab predators. Molecular Ecology 16: 1545–1557. https://doi.org/10.1111/j.1365-294X.2007.03238.x

**Kauffman, J. B., R. L. Beschta, N. Otting,** and **D. Lytjen.** 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries 22: 12–24. https://doi.org/10.1577/1548-8446(1997)022<0012:AEPORA>2.0.CO;2

**Klinka, D. R.,** and **T. E. Reimchen.** 2002. Nocturnal and diurnal foraging behaviour of Brown Bears (*Ursus arctos*) on a salmon stream in coastal British Columbia. Canadian Journal of Zoology 80: 1317–1322. https://doi.org/10.1139/Z02-123

**Klinka, D.,** and **T. E. Reimchen.** 2009. Adaptive coat colour polymorphism in the Kermode Bear of coastal British Columbia. Biological Journal of the Linnean Society 98: 479–488. https://doi.org/10.1111/j.1095-8312.2009.01306.x

**Lack, D.** 1966. Population Studies of Birds. Oxford University Press, London, United Kingdom.

**Lackey, R. T.** 2003. Nutrient addition to restore salmon runs: considerations for developing environmental protection policies and regulations. Pages 283–285 *in* Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity. *Edited* by J. G. Stockner. American Fisheries Society Symposium 34, Bethesda, Maryland, USA.

**Littke, K. M., R. B. Harrison, D. Zabowski,** and **D. G. Briggs.** 2014. Assessing nitrogen fertilizer response of coastal Douglas-fir in the Pacific Northwest using a paired-tree experimental design. Forest Ecology and Management 330: 137–143. https://doi.org/10.1016/j.foreco.2014.07.008

**Marshall, D. E., R. F. Brown, G. A. Buxton, V. D. Chahley,** and **D. G. Demontier.** 1978. Preliminary catalogue of salmon streams and spawning escapements of Statistical Area 2E (Queen Charlotte Islands). Fisheries and Marine Service Data Report #72. Enhancement Services Branch, Fisheries and Marine Service, Department of Fisheries and Oceans and Environment, Vancouver, British Columbia, Canada.

**Mathewson, D., M. H. Hocking,** and **T. E. Reimchen.** 2003. Nitrogen uptake in riparian plant communities across a sharp ecological boundary of salmon density. BioMed Central Ecology 2003 3: 4. https://doi.org/10.1186/1472-6785-3-4

**McGaw, I. J.** 2005. Burying behaviour of two sympatric crab species: *Cancer magister* and *Cancer productus*. Scientia Marina 69: 375–381. https://doi.org/10.3989/scimar.2005.69n3375

**Meehan, E. P., E. E. Seminet-Reneau,** and **T. P. Quinn.** 2005. Bear predation on Pacific salmon facilitates colonization of carcasses by fly maggots. The American Midland Naturalist 153: 142–151. https://doi.org/10.1674/0003-0031(2005)153[0142:BPOPSF]2.0.CO;2

**Nadelhoffer, K. J.,** and **B. Fry.** 1994. Nitrogen isotope studies in forest ecosystems. Pages 22–44 *in* Stable Isotopes in Ecology and Environmental Science. *Edited by* K. Lajtha and R. H. Michener. Blackwell Scientific, Boston, Massachusetts, USA.

**Nagasaka, A., Y. Nagasaka, K. Ito, T. Mano, M. Yamanaka, A. Katayama, Y. Sato, A. L. Grankin, A. I. Zdorikov,** and **G. A. Boronov.** 2006. Contributions of salmon-derived nitrogen to riparian vegetation in the northwest Pacific region. Journal of Forest Research 11: 377–382. https://doi.org/10.1007/s10310-006-0226-7

**Naiman, R. J., J. M. Helfield, K. K. Bartz, D. C. Drake,** and **J. M. Honea.** 2009. Pacific salmon, marine-derived nutrients, and the characteristics of aquatic and riparian ecosystems. American Fisheries Society Symposium 69: 395–425.

**Nakajima, M.,** and **T. Ito.** 2003. Aquatic animal colonization of chum salmon carcasses in Hokkaido, northern Japan. American Fisheries Society Symposium 34: 89–97.

**O'Keefe, T. C.,** and **R. T. Edwards.** 2003. Evidence for hyporheic transfer and removal of marine-derived nutrients in a sockeye stream in southwest Alaska. Pages 99–107 *in* Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity. *Edited* by J. G. Stockner. American Fisheries Society Symposium 34, Bethesda, Maryland, USA.

**Pielou, E. C.** 1991. After the Ice Age: The Return of Life to Glaciated North America. University of Chicago Press, Chicago, Illinois, USA.

**Quamme, D. L.,** and **P. A. Slaney.** 2003. The relationship between nutrient concentration and stream insect abundance. Pages 163–175 *in* Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity. *Edited by* J. G. Stockner. American Fisheries Society Symposium 34, Bethesda, Maryland, USA.

**Ranalli, A. J.,** and **D. L. Macalady.** 2010. The importance of the riparian zone and in-stream processes in nitrate attenuation in undisturbed and agricultural watersheds – A review of the scientific literature. Journal of Hydrology 389: 406–415. https://doi.org/10.1016/j.jhydrol.2010.05.045

**Reimchen, T. E.** 1992. Mammal and bird utilization of adult salmon in stream and estuarine habitats at Bag Estuary, Moresby Island. Canadian Wildlife Service, Queen Charlotte City, British Columbia, Canada.

**Reimchen, T. E.** 1994. Further studies of black bear and chum salmon in stream and estuary habitats at Bag Harbour, Gwaii Haanas. Canadian Parks Service, Queen Charlotte City, British Columbia, Canada.

**Reimchen, T. E.** 1998. Nocturnal foraging behaviour of Black Bears, *Ursus americanus*, on Moresby Island, British Columbia. Canadian Field-Naturalist 112: 446–450. Accessed 10 April 2018. https://www.biodiversitylibrary.org/item/106776#page/462/mode/1up.

**Reimchen, T. E.** 2000. Some ecological and evolutionary aspects of bear-salmon interactions in coastal British Columbia. Canadian Journal of Zoology 78: 448–457. https://doi.org/10.1139/z99-232

**Reimchen, T. E.,** and **C. H. Fox.** 2013. Fine-scale spatiotemporal influences of salmon on growth and nitrogen signatures of Sitka spruce tree rings. BioMed Central Ecology 2013 13: 38. https://doi.org/10.1186/1472-6785-13-38

**Reimchen, T. E., D. Mathewson, M. D. Hocking, J. Moran,** and **D. Harris.** 2003. Isotopic evidence for enrichment of salmon-derived nutrients in vegetation, soil and insects in riparian zones in coastal British Columbia. Pages 59–69 *in* Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity. *Edited* by J. G. Stockner. American Fisheries Society Symposium 34, Bethesda, Maryland, USA.

**Rieman, B. E., C. L. Smith, R. J. Naiman, G. T. Ruggerone, C. C. Wood, N. Huntly, E. N. Merrill, J. R. Alldredge, P. A. Bisson, J. Congleton, K. D. Fausch, C. Levings, W. Pearcy, D. Scarnecchia,** and **P. Smouse.** 2015. A comprehensive approach for habitat restoration in the Columbia Basin. Fisheries 40: 124–135. https://doi.org/10.1080/03632415.2015.1007205

**Shean, B. S., L. Messinger,** and **M. Papworth.** 1993. Observations of differential decomposition on sun exposed v. shaded pig carrion in coastal Washington State. Journal of Forensic Sciences 38: 938–949. https://doi.org/10.1520/JFS13492J

**Slaney, P. A.,** and **A. D. Marten.** 1997. The watershed restoration program of British Columbia: accelerating natural recovery processes. Water Quality Research Journal of Canada 32: 325–346.

**Slaney, P. A., B. R. Ward,** and **J. C. Wightman.** 2003. Experimental nutrient addition to the Keogh River and application for the Salmon River in coastal British Columbia. Pages 111–126 *in* Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity. *Edited by* J. G. Stockner. American Fisheries Society Symposium 34, Bethesda, Maryland, USA.

**Stalmaster, M. V.,** and **J. A. Gessaman.** 1982. Food consumption and energy requirements of captive Bald Eagles. Journal of Wildlife Management 46: 646–654. https://doi.org/10.2307/3808555

**Stockner, J. G.,** and **J. I. Ashley.** 2003. Salmon nutrients: closing the circle. Pages 3–15 *in* Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity. *Edited* by J. G. Stockner. American Fisheries Society Symposium 34, Bethesda, Maryland, USA.

**Thomas, S. C., C. B. Halpern, D. A. Falk, D. A. Liguori,** and **K. A. Austin.** 1999. Plant diversity in managed forests: understory responses to thinning and fertilization. Ecological Applications 9: 864–879. https://doi.org/10.1890/1051-0761(1999)009[0864:PDIMFU]2.0.CO;2

**Thorne, R. E., G. L. Thomas,** and **M. A. Bishop.** 2006. Alternative seafood waste disposal procedures for Alaskan waters. Oceans 14: 49–52. https://doi.org/10.1109/OCEANS.2006.306979

**Waring, R. H.,** and **J. F. Franklin.** 1979. Evergreen coniferous forests of the Pacific Northwest. Science 204: 1380–1386. https://doi.org/10.1126/science.204.4400.1380

**Wilkinson, C. E., M. H. Hocking,** and **T. E. Reimchen.** 2005. Uptake of salmon-derived nitrogen by mosses and liverworts in Coastal British Columbia. Oikos 108: 85–98. https://doi.org/10.1111/j.0030-1299.2005.13277.x

**Willson, M. F.,** and **K. C. Halupka.** 1995. Anadromous fish as keystone species in vertebrate communities. Conservation Biology 9: 489–497. https://doi.org/10.1046/j.1523-1739.1995.09030489.x

**Wipfli, M. S., J. P. Hudson, J. P. Caouette,** and **D. T. Chaloner.** 2003. Marine subsidies in freshwater ecosystems: salmon carcasses increase the growth rates of stream-resident salmonids. Transactions of the American Fisheries Society 132: 371–381. https://doi.org/10.1577/1548-8659(2003)132<0371:MSIFES>2.0.CO;2

**Yoder, B. J.,** and **R. E. Pettigrew-Crosby.** 1995. Predicting nitrogen and chlorophyll content and concentrations from reflectance spectra (400–2500 nm) at leaf and canopy scales. Remote Sensing of Environment 53: 199–211. https://doi.org/10.1016/0034-4257(95)00135-N

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# Note

# Effects of Nesting Bald Eagles (*Haliaeetus leucocephalus*) on Behaviour and Reproductive Rates in a Great Blue Heron (*Ardea herodias*) Colony in Ontario

BILL THOMPSON

93 Donald Street, Barrie, Ontario L4N 1E6 Canada; email: thompsonbi@rogers.com

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Bald Eagles (*Haliaeetus leucocephalus*) and Great Blue Herons (*Ardea herodias*) are known to occasionally nest in mixed colonies, even though the former is one of the primary predators of the latter. I observed the two species in four heron colonies near Lake Simcoe, Ontario during two field seasons to assess whether rates of heron chick mortality or nest abandonment were greater in a colony that supported a nesting pair of Bald Eagles than in three nearby single-species colonies. I assessed the effects of eagle presence on heron behaviour using heron movement rates, the number of heron sentries left in colonies during the nesting period, heron nest mortality rates, and the average number of successfully fledged herons per nest. There was no statistically significant difference in movement rate among the four colonies, proportion of birds remaining as sentries, nor nest mortality rates. However, nests in the mixed colony successfully fledged significantly more heron young per nest than did nests in the single-species colonies. The mixed colony was located in a wetland and open lake system that provided extensive foraging habitat and an abundance of the preferred fish prey species of both Great Blue Herons and Bald Eagles, thus reducing predation pressure on the herons.

Key Words: Lake Simcoe; colonial nesting bird; reproduction; nest predation

## Introduction

Bald Eagle (*Haliaeetus leucocephalus*) numbers have been increasing in the Great Lakes basin since the 1980s (Steenhof *et al.* 2002; Eakle *et al.* 2015), leading to its delisting as a species at risk in both the United States (Eakle *et al.* 2015) and Ontario (Armstrong 2014). While this is a conservation success, there may be impacts on other wildlife species.

Bald Eagles sometimes nest in Great Blue Heron (*Ardea herodias*) colonies and are known to prey upon Great Blue Heron adults, young, and eggs (Gostomski and Matteson 1999; Vennesland and Butler 2011). In British Columbia, where Great Blue Heron populations have been rapidly increasing, the occurrence of co-nesting eagles has also been increasing (Jones *et al.* 2013), and eagle predation may be one of the most significant factors lowering heron productivity (e.g., Norman *et al.* 1989; Vennesland 1996; Vennesland and Butler 2004). Great Blue Herons nesting in the Strait of Georgia responded more to the presence of eagles than to any other predator, and eagles were responsible for the majority of documented nesting failures, either through direct predation or because of colony abandonment (Vennesland 1996; Vennesland and Butler 2004; Van Damme and Colonel 2007). While previous studies of the interactions between these two species at heron colonies have been conducted in British Columbia, co-nesting of the two species is widespread (though uncommon) across North America (Gostomski and Matteson 1999), and perhaps increasing.

More Great Blue Herons live in the Great Lakes basin than in British Columbia (Vennesland and Butler 2011), but colony size tends to be smaller (Graham *et al.* 1996; Vennesland and Butler 2004). Herons nesting in small colonies may be more subject to predation by eagles (Caldwell 1986), which suggests that a continued increase in Bald Eagle populations in the Great Lakes basin could lead to reductions in Great Blue Heron populations, through predation or colony abandonment or both.

The objective of this study was to assess whether the presence of Bald Eagles led to higher rates of heron chick mortality or nest abandonment.

## Methods

I conducted weekly surveys of four heron colonies near Lake Simcoe, Ontario (44.4°N, 79.35°W) in 2014 and 2015. The heronries included one where a pair of Bald Eagles had been nesting for at least three successive years (near Keswick) and three with no recent records of nesting eagles (near Barrie, Carden, and Lagoon City). The four colonies were 21–61 km from each other. Surveys were conducted from heron arrival in the second week of April until heronry abandonment (defined as three weeks with no nesting herons observed), or the end of the nesting season.

I made observations from a vantage point (80–300 m) that maximized nest visibility with no evidence of disturbance to the colony. To reduce disturbance at Keswick, I surveyed only the 20 nests within 50 m of the

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eagle nest. At the outset of each observation period I recorded the number of heron adults and nestlings in the colony and the number of active nests. Over 60 min I recorded heron and eagle movements, including the time at which each individual entered or exited the colony or moved to a different tree in the colony. Any interactions between herons and potential predators (including eagles) were noted, as was any evidence of food being brought to a nest by either species.

I defined movement rate as the number of times a heron entered, exited, or moved within a colony during the observation period divided by the number of adult herons present. I further defined the number of sentries left in the colony as the minimum percentage of nests that included an adult standing at or near a nest during each observation period. I defined mortality rate as the number of nestlings in the colony dying between observation periods, divided by the number of days between observations (Mayfield 1975). Success was identified when fledglings were observed flying.

I tested each variable for normality (Shapiro and Wilk 1965), and log-transformed those (productivity, mortality rate, and movement rate) that were significantly non-normal ($P < 0.05$). The effects of sharing a colony with eagles on each of these response variables were tested using analysis of variance (ANOVA). When significant differences were found among the four colonies, orthogonal contrasts were used to determine if the mixed colony was significantly different than the single-species colonies. All the analyses were done using R (R Core Team 2015).

## Results

The Keswick colony had at least 64 nesting heron pairs and one nesting pair of eagles in a tree adjacent to some of the heron nests. Lagoon City had eight heron pairs, Barrie three, and Carden three. The Carden colony was abandoned by 15 June 2014 (prior to any evidence of hatching) and was not active in 2015. The four colonies were occupied by herons by the second week in April, whereas eagles began nesting at Keswick in February. At Keswick, one or both eagles were observed on their nest or on a perch in the colony during at least part of every observation period (except once per year). In five observation periods, one or both eagles flew over heron nests, either to act as sentries for their own nest or to travel between the nest and the lake. Herons never responded to the eagles by relocating among nests to protect nestlings, and in only one case did a sentry heron make an alarm call due to the proximity of an eagle. At Lagoon City, however, I observed a subadult (second-year) eagle hunting heron nestlings on 31 May. As the eagle circled the uppermost nest three times with talons extended, two adult herons in the nest made alarm calls with their beaks extended and lunged at the eagle. After the eagle abandoned the hunt, one of the herons flew to a different nest. No other evidence of attempted predation by other species was observed in any of the colonies.

No statistically significant difference in movement rate was found among the four colonies ($F_{3,27} = 0.915$, $P = 0.45$). However, Keswick herons often traded places: when a heron returned to the colony after foraging, a second heron from a nearby nest would leave the colony within one or two minutes, suggesting that the herons ensured that sentries remained at the colony to protect it from eagle predation. I did not observe this behaviour at the three other colonies. However, there was no significant difference in the minimum proportion of nests with adults present among colonies ($F_{2,19} = 0.801$, $P = 0.46$).

Predation and other disturbance may have easily occurred while I was not observing. There was, however, no significant difference in mortality rates among the three colonies that were not abandoned ($F_{2,19} = 2.194$, $P = 0.14$). Nor was there a significant difference in the proportion of nests abandoned in colonies shared with Bald Eagles, and single-species colonies ($F_{1,5} = 0.342$, $P = 0.58$). However, the Keswick colony fledged significantly more young per nest than the single-species colonies ($F_{2,19} = 17.76$, $P < 0.0001$).

## Discussion

Productivity rates in Great Blue Herons typically range from 0.5 to 2.7 fledglings per nest attempt (Vennesland and Butler 2011). In my study area, it ranged from 1 to 2.5 per nest, with the highest rate occurring at Keswick. A rate of 1.91 has been estimated to be required to maintain a stable population (Henny and Bethers 1971). In the current study, only Keswick had a rate this high. It was also the largest of the four colonies studied, and other authors have also found that large colonies tend to support greater productivity (Forbes *et al.* 1985; Vennesland and Butler 2004). Large colonies may be more productive due to a higher ratio of older birds (Forbes *et al.* 1985), or because they tend to be located near larger or more productive foraging habitat (Gibbs and Kinkel 1997). Great Blue Herons typically forage in water between 15 and 25 cm deep (Willard 1977) and they tend to prefer prey between 2.5 and 7.6 cm long during the breeding season (Willard 1977). The Keswick colony is located in a wetland and open lake system that provides over 5.5 km$^2$ of such habitat, and supports a fish community with abundant small fishes (e.g., Emerald Shiner [*Notropis atherinoides*], Spottail Shiner [*N. hudsonius*], and Trout-perch [*Percopsis omiscomaycus*]; Evans *et al.* 1996; Trumpickas *et al.* 2012).

There is a potential reproductive trade-off between access to abundant food resources and increased disturbance or predation in co-located Great Blue Heron colonies and Bald Eagle nests. In other locations, Bald Eagles can be predators of Great Blue Herons (Norman *et al.* 1989; Gostomski and Matteson 1999; Vennesland and Butler 2011). In the Keswick colony, however, there were no occurrences of depredation by eagles, and limited evidence for behavioural response to the presence of a nesting pair of eagles during 23 hours of observation.

The preferred food source for Bald Eagles varies among habitats (Vennesland and Butler 2011), but in the Great Lakes basin it includes species such as Brown Bullhead (*Ameiurus nebulosus*) and White Sucker (*Catostomus commersonii*; Todd *et al.* 1982; Kozie and Anderson 1991), both of which are abundant in Lake Simcoe (Evans *et al.* 1996). Over the course of the 80 hours of observation in this study, three occurrences of Bald Eagles bringing food to nestlings were observed; in all three cases, the food item was a fish. Thus, in this study area, Lake Simcoe may provide enough of an alternate food source for eagles, reducing predation pressure on nesting herons—a species that will actively defend itself and its young.

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## Literature Cited

**Armstrong, E. R.** 2014. Management plan for the Bald Eagle (*Haliaeetus leucocephalus*) in Ontario. Ontario Management Plan Series. Prepared for the Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario, Canada.

**Caldwell, G. S.** 1986. Predation as a selective force on foraging herons: effects of plumage color and flocking. The Auk 103: 494–505.

**Eakle, W. L., L. Bond, M. R. Fuller, R. A. Fischer,** and **K. Steenhof.** 2015. Wintering Bald Eagle count trends in the conterminous United States, 1986–2010. Journal of Raptor Research 49: 259–268. https://doi.org/10.3356/JRR-14-86.1

**Evans, D. O., K. H. Nicholls, Y. C. Allen,** and **M. J. McMurtry.** 1996. Historical land use, phosphorus loading, and loss of fish habitat in Lake Simcoe, Canada. Canadian Journal of Fisheries and Aquatic Sciences 53: 194–218. https://doi.org/10.1139/f96-012

**Forbes, L. S., K. Simpson, J. P. Kelsall,** and **D. R. Flook.** 1985. Reproductive success of Great Blue Herons in British Columbia. Canadian Journal of Zoology 63: 1110–1113. https://doi.org/10.1139/z85-167

**Gibbs, J. P.,** and **L. K. Kinkel.** 1997. Determinants of the size and location of Great Blue Heron colonies. Colonial Waterbirds 20: 1–7. https://doi.org/10.2307/1521757

**Gostomski, T. J.,** and **S. W. Matteson.** 1999. Bald Eagles nest in heron rookery in the Apostle Islands. The Passenger Pigeon 61: 155–159.

**Graham, K., B. Collier, M. Bradstreet,** and **B. Collins.** 1996. Great Blue Heron (*Ardea herodias*) populations in Ontario: data from and insights on the use of volunteers. Colonial Waterbirds 19: 39–44. https://doi.org/10.2307/1521805

**Henny, C. J.,** and **M. R. Bethers.** 1971. Population ecology of the Great Blue Heron with special reference to western Oregon. Canadian Field-Naturalist 85: 205–209. Accessed 10 April 2018. https://www.biodiversitylibrary.org/item/89145#page/229/mode/1up.

**Jones, I. M., R. W. Butler,** and **R. C. Ydenberg.** 2013. Recent switch by the Great Blue Heron, *Ardea herodias fannini*, in the Pacific northwest to associative nesting with Bald Eagles (*Haliaeetus leucocephalus*) to gain predator protection. Canadian Journal of Zoology 91: 489–495. https://doi.org/10.1139/cjz-2012-0323

**Kozie, K. D.,** and **R. K. Anderson.** 1991. Productivity, diet, and environmental contaminants in bald eagles nesting near the Wisconsin shoreline of Lake Superior. Archives of Environmental Contamination and Toxicology 20: 41–48. https://doi.org/10.1007/BF01065326

**Mayfield, H.** 1975. Suggestions for calculating nest success. Wilson Bulletin 87: 456–466.

**Norman, D. M., A. M. Breault,** and **I. E. Moul.** 1989. Bald Eagle incursions and predation at Great Blue Heron colonies. Colonial Waterbirds 12: 215–217. https://doi.org/10.2307/1521343

**R Core Team.** 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Accessed 31 July 2016. http://www.R-project.org.

**Shapiro, S. S.,** and **M. B. Wilk.** 1965. An analysis of variance test for normality (complete samples). Biometrika 52: 591–611. https://doi.org/10.2307/2333709

**Steenhof, K., L. Bond, K. K. Bates,** and **L. L. Leppert.** 2002. Trends in midwinter counts of Bald Eagles in the contiguous United States, 1986–2000. Bird Populations 6: 21–32.

**Todd, C. S., L. S. Young, R. B. Owen,** and **F. J. Gramlich.** 1982. Food habits of Bald Eagles in Maine. Journal of Wildlife Management 46: 636–645. https://doi.org/10.2307/3808554

**Trumpickas, J., A. Smith, M. M. Robillard,** and **J. K. L. La Rose.** 2012. Temporal shifts in the biodiversity of nearshore small fishes in Lake Simcoe. Journal of Great Lakes Research 38: 643–652. https://doi.org/10.1016/j.jglr.2012.09.006

**Van Damme, L. M.,** and **C. Colonel.** 2007. Bald Eagle predation and other disturbance factors at Double-crested Cormorant and Great Blue Heron nesting colonies in the Creston Valley, British Columbia. Wildlife Afield 4: 213–232.

**Vennesland, R. G.** 1996. The effects of disturbance from humans and predators on the breeding decisions and productivity of the Great Blue Heron in south-coastal British Columbia. M.Sc. thesis, Simon Fraser University, Burnaby, British Columbia, Canada.

**Vennesland, R. G.,** and **R. W. Butler.** 2004. Factors influencing Great Blue Heron nesting productivity on the Pacific Coast of Canada from 1998 to 1999. Waterbirds 27: 289–296. https://doi.org/10.1675/1524-4695(2004)027[0289:FIGBHN]2.0.CO;2

**Vennesland, R. G.,** and **R. W. Butler.** 2011. Great Blue Heron (*Ardea herodias*). *In* The Birds of North America. *Edited by* P. G. Rodewald. Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed 31 July 2016. http://bna.birds.cornell.edu/bna/species/025.

**Willard, D. E.** 1977. The feeding ecology and behavior of five species of herons in southeastern New Jersey. Condor 79: 462–470. https://doi.org/10.2307/1367726

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# Book Reviews

**Book Review Editor's Note**: *The Canadian Field-Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well as books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

**Currency Codes** – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

## POETRY

### Welcome to the Anthropocene

By Alice Major. 2018. The University of Alberta Press. 136 pages, 19.95 CAD, Paper.

Poets work like naturalists or scientists. What they do is based on what has gone before. Alexander Pope wrote *Essay on Man*, one of the most quoted poems in the English language, in the 18th century. It is in Heroic Couplets, five-beat lines that rhyme AA, BB, CC, and so on. This collection is written in Alberta, in the 21st century. Its title poem, "Welcome to the Anthropocene", has the same metre and rhyme scheme, and uses Pope's poem as a platform for a survey of the world the poet sees.

Pope, writing in the century of Newton, Leibniz, and The Great Chain of Being, could explore his universe and conclude, emphatically, "Whatever is, is right". Alice Major was born in Scotland, grew up in Toronto, has worked in British Columbia, was Poet Laureate of Edmonton, and now lives in Calgary. She writes in the age of quantum physics and climate change, and has her doubts. Pope's heroic couplets march across the page with the regularity dictated by the Laws of Motion, and can tire the reader. Major softens her verse with offbeats and imperfect rhymes:

Nature solves
her vast equations without fuss – the scrawls
of protein folding, evolving puzzles
posed by careering quantum particles.

Pope rebukes some of his contemporaries for the sin of pride. Major explores "post-natural creation":

Welcome, transgenic zebrafish. Your shades
of trademarked colours—*Starburst red,*
*Electric Green*, and *Cosmic Purple*—bred
to decorate aquariums
in colour schemes to match our rainbow whims.

"Welcome to the Anthropocene" is a long poem, 21 pages. The poet's wry, somewhat sad wit, leavened by her scientific knowledge, comes to a not unhopeful conclusion:

We might not unite
behind Pope's verse *Whatever is, is right*.
Still, whatever is, matters, in a wholeness where
everything is common and everything is rare.

There are a number of other fine poems, of varying lengths, touching a lot of subjects, with influences that seem to range from Gerard Manley Hopkins to a Peterson Field Guide. Major is good at inventing verse forms that suit the material she wants to address. In English poetry there is not likely another poem with a title like this:

Catena
2.71828 1828 4590 4523 5360 2874 7135 2…

There is a note that explains the mathematical significance of the formula, but the poem is a moving meditation on the randomness of genetics and one of the things poetry tries hardest to deal with:

The slowing increments of loss
when it can't get any worse, or
any better. The sad slog up, to stand
on something that approaches solid ground.

A poet living on the prairies can be expected to set some of her poems on farmland. This poet doesn't mind a dirty pun, in "Annual Grains":

Agriculture's pornographic fact:
……No truly wild plant spends
so much of its energy on sex,
on putting out, on hanging on
to seed heads that should scatter, shatter
small grains into earth's soft box

Major apparently lives in the city though, and works in an office:

hickory dickory click
of computer mice from adjoining cubicles
tick tick-tick tick

The reader will find more mice, but birds are the fauna that have always most attracted poets. There are a lot of birds, including the marvellous corvid that in eastern Canada we don't get:

Magpie as neighbour. You've moved in,
hold your raucous parties, shout at the kids.
Fix up your house – a slipshod DIY
endeavour that always seems half-done. Twigs
strewn all around the yard.

The poet has had fun writing these poems, which is a good sign for the reader. The poems are serious, but the reader can expect to have fun reading them.

The following is excerpted from "Welcome to the Anthropocene" by Alice Major:

Now, welcome to the Anthropocene
you battered, tilting globe. Still you gleam,
a blue pearl on the necklace of the planets.
This home. Clouds, oceans, life forms span it
from pole to pole, within a peel of air
as thin as lace lapped round an apple. Fair
and fragile bounded sphere, yet strangely tough—
this world that life could never love enough.
And yet its loving-care has been entrusted
to a feckless species, more invested
in the partial, while the total goes unnoticed.

MURRAY CITRON
Ottawa, ON, Canada

## BOTANY

### Plant Ecology: Origins, Processes, Consequences. Second Edition

By Paul Keddy. 2017. Cambridge University Press. 624 pages, 74.95 CAD, Cloth, 52.00 USD, E-book.

I was excited to be asked to review this book. In the middle of heavily revising my second-year introductory plant ecology course, I have been wanting for inspiration. Though we have never met in person, Paul Keddy has heavily influenced my academic career. His 2001 book *Competition* was a central influence on my Ph.D. work, particularly the sections on the intensity and importance of competition. While there is much to recommend in this revised plant ecology text book, in the end I came away disappointed.

I will start with the positives. First, and most important, this book is that rare find in the textbook world: an entertaining read. The personal anecdotes and historical digressions are well chosen and add colour and interest. The book is well organized for an instructor. Chapters are built around themes covering first the major biotic and abiotic mechanisms that influence individual plants, then population- and community-level processes. The book is greatly enhanced by the chapters that are not present: missing are the (often endless) chapters on biogeochemical cycles that dominate the first third of many introductory ecology textbooks. Instead, Keddy recognizes that most readers will already be familiar with topics such as elemental cycles, and all that is needed is a succinct summary focussing on important links to plants. Similarly missing is the traditional parade of biomes that invites the memorization of factoid after factoid. Rather, we are presented, only four figures into the book, with the plot first introduced by Whittaker relating the major global biomes to gradients in mean annual temperature and precipitation (p. 6, Figure 1.4). Time and again Keddy returns to that plot as topics such as ecophysiology, disturbance, and herbivory are raised. By the end the attentive reader can reconstruct the core features of any biome from the causal mechanisms. Features like this that invite thoughtful inquiry-based teaching and learning are the best aspects of this book.

Now to the negatives. While the book is entitled "Plant Ecology", it could be perhaps better titled "Paul Keddy's View of Plant Ecology". While the book is marketed as a general textbook, it presents a biased and misleading view of our field. The examples draw far too heavily on Keddy's own research, creating an imbalance in the topics covered and views presented. This is evidenced by 31 citations to work where Keddy is the lead author (and many more to his students' and collaborators' work), while other leaders in our field are rarely mentioned. There are, for example, only three citations to papers led by Tilman and two by Chapin. This trend extends to some sub-topic choices within the book. To cite only one example, two full pages are devoted to the theory of centrifugal community organization while the far more influential work by Grace on multivariate controls of diversity is relegated to only a single citation without comment. A second very significant problem with this book is the currency of the literature. There appears to have been little effort to update the literature between the first (2007) and the second edition. Keddy makes the excellent point that older examples remain valid and should not be discounted. In many cases he is right, yet science has moved forward in the last decade. This is particularly the case in fields where major progress has been driven by advancing technology. How is it acceptable, for example, that a section on mycorrhizae mentions the insights arising from next-generation sequencing only in passing, or that a section on ordination advises readers to consult sources from the 1970s and 1980s? When I see such examples in areas where I am intimately familiar with both the current and older literature, I am left questioning what I am reading in areas where I have read less deeply.

Would I recommend this book? For a Ph.D. student preparing for their comprehensive exam—yes. Keddy provides a broad and engaging summary of much of the history of plant ecology, a perspective invaluable to an emerging scholar. Would I assign the book to an undergraduate course? No. While this book has much to offer the experienced reader, I fear that an introductory student will be left with an incomplete view of the science of plant ecology.

**Literature Cited**

**Keddy, P. A.** 2001. Competition. Second Edition. (Population and Community Biology Series). Chapman & Hall, London, United Kingdom.

ERIC LAMB

Department of Plant Sciences, University of Saskatchewan. Saskatoon, SK, Canada

## Exploring the Limestone Barrens of Newfoundland and Labrador

By M. Burzynski, H. Mann, and A. Marceau. 2017. Gros Morne Co-operating Association, Rocky Harbour. 368 pages, 26.95 CAD, Paper.

At least once in their life, every Canadian botanist should do this … stand in the midst of a silent (but for the wind), forever expanse of seaside limestone barren at the northern tip of the island of Newfoundland. One immediately appreciates that this is like nowhere else in their experience, nor like any other place on this continent. There is a whole lot of Arctic here—the offshore icebergs are a clue—plus a good dollop of Nordic European flavour to the Barrens experience. And of course, there's the omnipresence of the sea. Botanizing this unique rocky landscape with the very real possibility of being interrupted at any time by a breaching Humpback Whale (*Megaptera novaeangliae*) not many metres offshore is extraordinary.

The Barrens are dripping in rare and extraordinary plants growing in a variety of otherworldly habitats. Barrens biota are diverse—surprisingly so for such a northern place (>50°N)—and colourful too. Acres of ladyslippers, milkvetch, gentians, and a myriad of other floristic wonders dominate rocky slopes and low, healthy meadows from wind-swept ridges right down to the sea. It is hard to credit the term "Barrens", frankly, if you're there at the peak of bloom. Legendary numbers of blackflies are there too—and all too real—but everything comes with a price. And besides, it's always windy!

All of that (perhaps not the blackflies) is beautifully expressed and explained in this terrific field guide. *Exploring the Limestone Barrens* purports to be a natural history guide but, truth be told, it is a botanical guide with beyond-superb introductory chapters explaining the formation and diversity of this rare landscape.

The biogeographically-unique Barrens were made famous initially through the explorations and publications of botanist Merritt Fernald and his associates in the early decades of the 20th century. As *Exploring the Limestone Barrens* explains, these pioneer field naturalists discovered not only a remarkable array of disjunct species from the Arctic, western North America, and even northwestern Europe that had persisted here for thousands of years from post-glacial times, but endemic taxa as well. Many new species were described, particularly within such still-perplexingly complexes as *Antennaria* and *Astragalus* (there was, as in contemporary times, something of a taxonomic splitting frenzy going on then). A number of these taxa have stood the test of time, however, and are still recognized today.

Botanical 'stars' include endemic species such as Fernald's Braya mustard (*Braya fernaldii* Abbe) which can sometimes 'tower' as much as 7 cm over Barrens shore alvars but usually does not get much above 2 cm, and the sprawling Barrens Willow (*Salix jejuna* Fernald). 'Low and sprawling' is a common theme for plants making a go of it in this daunting landscape of limey, nutrient-poor substrates, very long winters, low light, and constant exposure to wind and sea spray.

*Exploring the Limestone Barrens* is as colourful as the Barrens in bloom, with hundreds of bright photos providing superb illustrations of a substantial proportion of the flowering plants and ferns of the Barrens species. Comparably high-quality images of representative of non-flower vascular plant groups (sedges, grasses, and rushes) and non-vasculars (bryophytes and lichens) as well as fungii, are also provided. The text provided for each species is spare due to space limitations and the images are small, but in combination they work. A moderately experienced field botanist 'from away' should be able to identify pretty much everything they encounter on the Barrens with reference to this small (18 × 11 cm), durable, and jam-packed volume. It is a credit to the Gros Morne Co-operating Association that they were able to produce such a physically attractive and substantial product at such an accessible price.

The greatest compliment I can offer the authors of this guide is that they have honestly reflected and represented the visual beauty, ecological complexity, and wonderful wildness of the Barrens. This guide will inspire you to visit these remarkable landscapes if you have not already done so. If you do, you will be well-served having *Exploring the Limestone Barrens* in your back pocket. And you can even use it to swat blackflies!

DANIEL F. BRUNTON

Ottawa, ON, Canada

## Flora of Florida Volume IV (Dicotyledons, Combretaceae through Amaranthaceae)

By R. P. Wunderlin, B. F. Hansen, and A. R. Franck. 2017. University Press of Florida. 384 pages, 69.95 USD, Cloth.

Richard Wunderlin and Bruce Hanson began their comprehensive, multi-volume *Flora of Florida* with the 2000 publication of *Volume I, Pteridophytes and Gymnosperms* (University Press of Florida). When more than a decade passed without another volume appearing, it seemed that the task might have just been too big an order. The publication of Volumes II and III in 2015 importantly demonstrated that the *Flora of Florida* project was indeed alive and well and that plans were underway to see all 10 volumes published by 2020 (see reviews in *The Canadian Field-Naturalist* 130: 248–249). Happily, the publication of Volume IV indicates that progress continues to be made.

Volume IV follows the format and structure of its predecessors, being a sturdily bound, hard-cover book with small but easily-readable type. The native and non-native species of the 31 families are covered, each providing detailed, clear physical descriptions employing precise but not overly technical terminology. No glossary (nor illustrations) are provided although representative generic illustrations are tentatively planned for future volumes (R. Wunderlin, personal communication, 2016).

The number of taxa covered in Volume IV is unstated but using as a measure the species per page coverage of Volume I where that number is provided, it seems there are approximately 450 species discussed here. Volumes I through IV then, now cover about 45% of the over 4000 vascular plants known to occur in Florida. In addition to a significant number of uniquely or predominately southern/tropical plants in groups such as Rutaceae and Melastomataceae, Volume IV includes species treatments of large families that are important and familiar to Canadian botanists, including Polygonaceae, Brassicaceae, Caryophyllaceae, and Onagraceae. This is one of the strengths of the *Flora* for northern users: providing a very different regional perspective on complicated taxa that we struggle with here, like the *Polygonum aviculare* L., *Brassica rapa* L., and *Oenothera biennis* L. species complexes. Once again, effective species identification keys taken or updated from Wunderlin's *Guide to the Vascular Plants of Florida* (1998, University Press of Florida) are placed immediately after each genus description. Alphabetically arranged species treatments follow, each beginning with a comprehensively annotated list of synonyms. The thoroughness of synonymy is truly impressive: there are 38 provided for Field Mustard *Brassica rapa (=Brassica campestris* L.) alone. These constitute valuable taxonomic/nomenclatural histories that are of use in taxonomic studies anywhere.

I will repeat the same complaint lodged in reviews of Volumes II and III regarding the absence of page headers to identify the family to which that page's treatments apply; such headers would greatly simplify finding particular treatments without frequent reliance on the (thankfully very good) index. The absence of Florida range maps for each taxon reduces the clarity of the broadly expressed distributional statements. However, the online *Atlas of Florida Plants* (http://florida.plantatlas.usf.edu) serves this purpose admirably. For the present, at least.

This volume and its companions are important contributions to floristic documentation in North America *per se*, not just in regard to botanical investigations in the third most floristically diverse part of the United States. This window into such an important part of the continental flora is also worthwhile for Canadian studies involving the many species of northern North America that also reach the Deep South. And, of course, *Flora of Florida* is a great resource for serious Canadian botanical "Snow Birds", of which there are a large and growing number.

Daniel F. Brunton
Ottawa, ON, Canada

### ZOOLOGY

## The Wolf: A True Story of Survival and Obsession in the West

By Nate Blakeslee. 2017. Random House Canada. 320 pages, 32.00 CAD, Cloth, 15.99 CAD, E-book.

*The Wolf* (published as *American Wolf* in the United States) was a great read about Yellowstone wolves and the political and sociological aspects of wolf recovery in the west. It focussed on a particularly famous female wolf (dubbed "O-Six" for the year she was born) who ruled the Lamar Valley region of the park until her untimely death on 6 December 2012. I related easily to this book because I regularly visit the Yellowstone region and call Rick McIntyre and Laurie Lyman friends. They are the two main human characters in the book in addition to Steven Turnbull (pseudonym), the man who shot and killed O-Six. O-Six was a striking 97-pound grey-coloured wolf, captured by accident and given a research radio-collar and scientific ID #832.

I had numerous sightings of O-Six on my many trips to the park and regard watching her with my son as one of the most rewarding experiences of my life. Those were mighty special experiences for me, and Nate Blakeslee brings these moments back to life by recounting the enthralling story of the rise and reign of O-Six, a most celebrated Yellowstone wolf. The author goes into depth describing the people who loved her and those who feared her, and focusses on Yellowstone's wolf watchers, led by Rick McIntyre, a park biologist who, according to Wolf Project leader Doug Smith, is the glue that holds everyone in that community together (p. 265). "Wolf Watchers" is an unofficial group of people who regularly visit (one or twice a year or more) or live near the park, focussing their time looking for and watching wolves interact with other members of Yellowstone's wild community including Elk (*Cervus canadensis*), bison, bears, Coyotes (*Canis latrans*), foxes, Pronghorns (*Antilocapra americana*), and many other creatures. I try to visit Yellowstone once or twice a year and spend a lot of quality time with Rick and Laurie and other people while watching wolves in a pristine and beautiful environment.

The book is unique in that it focusses on a particular female wolf from Yellowstone but tries to also tie back to some of the larger reasons why people have had such a troubled relationship with wolves. Once abundant in North America, wolves were hunted to near extinction in the lower 48 states by the 1920s (p. 14). In recent decades, Blakeslee notes, conservationists have brought wolves back to the Rockies, igniting a battle over the very soul of the west. Blakeslee uses the O-Six female as a sort of frontline battle between the old guard (people who exterminated wolves and still hate them, both for their ability to kill ungulates like Elk as well as the political interventions that they represent) and the new guard, like the wolf watchers, who appreciate having wolves around.

O-Six was beloved by many, particularly Rick McIntyre. Over the course of her 6.75-year life (2006–2012), she became something of a social media star, with followers around the world. Part of her allure was that thousands of people were privileged to see her and her pack in the wild and watched her raise three litters of pups (2010–2012), protect her pack from Grizzly Bears (*Ursus arctos*) that came near her den, compete with rival wolf packs (sometimes fatally), hunt Elk, and survive in an often-hostile world with cold temperatures, lots of snow, and human hunters waiting at the park's borders. As noted on the book's cover-leaf, *The Wolf* is a riveting multigenerational saga of hardship and triumph that tells a larger story about the ongoing cultural clash in the west: between those fighting for a vanishing way of life and those committed to restoring one of the country's most iconic landscapes. It is fascinating as the book frequently toggles between describing these larger, generational shifts in attitudes towards preserving iconic carnivores like Grey Wolves (*Canis lupus*) to focussing on O-Six and Rick and their personal trials and tribulations. Given that Rick has made over 85 000 wolf sightings (p. 268), aided by radio-telemetry, spotting scopes, and a cadre of wildlife watchers assisting him, it is safe to assume that he has observed more wild wolves than any human in history. His iron man 15-year streak of going into the park every day, including a stint where he saw wolves on 891 straight days (p. 147), is unlikely to be topped.

Many of Blakeslee's digressions from O-Six and Rick describe the history of wolf recovery, using a thorough literature review as well as film-maker Bob Landis's four nature documentaries on Yellowstone's wolves. This historical information provides perfect background material to make this book a great stand-alone read for novices to Yellowstone wolves.

Interestingly, Blakeslee was also able to track down and meet with the person who shot O-Six east of Yellowstone National Park. They agreed to use the pseudonym Steven Turnbull. I felt that a fair and non-biased description was given of Turnbull. While he leans anti-wolf, he does not claim to particularly hate them like others do in the area; he seemed to have more of a resentment for wolves changing his way of life including part of the reason why there are fewer Elk around Yellowstone. But Turnbull was fascinated with Bob Landis's videos, watching the one on O-Six (titled *She-Wolf*) multiple times, and showed Blakeslee O-Six's pelt with admiration. While many in Turnbull's position have a bitterness for what they perceive as out-of-staters dictating how they need to live (i.e., with wolves), many people (including myself) feel a bit of distain for locals around Yellowstone who feel they have more rights than the average American over our collective vast federal lands. This has brought land disputes and even rebellions all over the west, many of which are described in the book. And wolves are just the latest struggle between insiders and outsiders over control of the vast western United States. Blakeslee does a great job of highlighting these struggles without going too much in depth.

I highly recommend *The Wolf*. Easy-to-read and absorbing, it does a unique job of focussing on individuals—both wolves and humans—yet entertains the bigger, political picture of wolf recovery. Given the number of dedicated wolf watchers discussed at length, many of whom take images of their experiences, I was very surprised there were no pictures of O-Six in the book, even black and white ones. And the main title is pretty generic; it could have better reflected O-Six and the Yellowstone region.

I'd like to conclude with Blakeslee's thoughts on seeing O-Six's pelt in Turnbull's cabin in Crandall, Wyoming: "It was impossible not to think of the countless stories I'd heard about what she'd done with those tireless legs and those formidable teeth, the elk she'd taken down single-handedly, the territorial battles she'd won, the pups she'd reared, the loyalty and love and fear she'd inspired and the enormous and magnificent stage upon which she'd done it all, in front of her thousands of fans" (p. 261). I am proud to call myself one of O-Six's fans and hope this book helps bring about the recognition of the importance of individual animals, as well as the knowledge of the key ecological role that wild canines play throughout North America. They all have unique stories to tell. Wolves (and other wild canids) are intelligent, sentient, family-oriented animals who deserve much more respect than is currently given by our governments, both state and federal. Don't believe me? Then read this book and I'm sure you'll change your mind.

JONATHAN (JON) WAY

Eastern Coyote/Coywolf Research, Osterville, MA, USA

## Marine Fishes of Arctic Canada

Edited by Brian W. Coad and James D. Reist. 2017. University of Toronto Press. 632 pages and 200 illustrations, 74.96 CAD, Cloth or E-book.

Thoroughly describing the marine fishes of Arctic Canada is an enormous undertaking. Not only are there many known species (221), but the Arctic marine environment is notoriously difficult to survey owing to the presence of sea ice, remoteness, and the extreme environmental conditions. Many species will therefore be underrepresented in studies owing to small survey effort, and entire regions may be entirely unsampled, especially in the northernmost areas where sea ice never melts. In *Marine Fishes of Arctic Canada*, the authors expertly describe all 221 species of marine fishes that are known in Arctic Canada but, most importantly, acknowledge the data limitations for these species. Unlike other guides that attempt to draw species ranges on maps, this guide simply shows the locations where the species has been found in Arctic Canada and puts it in the context of where the species is found in the rest of the world. These points on the map are a direct acknowledgement of the vast, remote nature of the region and that, with more survey effort, these species may be found in other areas. These 221 species include 37 species that were not previously included in lists of Canadian Arctic marine fishes. The "Checklist of Species" also lists extralimital species that are found adjacent to Canadian Arctic waters, and may be found in the Canadian Arctic with increased survey effort.

The authors also provide impressive details about each species, with more than 400 pages dedicated to species accounts. The amount of information presented for each species is tempered by how common they are in the region and how much they have been studied. For example, 6.5 pages are devoted to Arctic Char (*Salvelinus alpinus*), whereas Threadfin Grenadier (*Gadomus longifilis*) is described in just over one page. While Arctic Char is found throughout the Canadian Arctic, Threadfin Grenadier has only been observed once in the Canadian Arctic. When applicable, an exhaustive list of common names is included, such as the 57 different names for Arctic Char.

While most of the text is devoted to detailed species accounts, the first 72 pages focus on defining the context of the book, including rationale for the book and history of fisheries research in the Canadian Arctic, providing background information on the Arctic (environment, climate, and habitat), sources of knowledge used in the text (scientific research, traditional ecological knowledge, and fisheries), and information on scientific names, technical terms, and the collection and preservation of specimens. This background information allows the less knowledgeable reader to gain a fuller appreciation of the amount of effort put into this volume and provides important context for the species accounts. Finally, for novice ichthyologists, the authors provide a detailed key for identification of families and species. Not only do they provide good drawings of the species, but they also draw the characteristics being described in the key, which can be very useful for those unfamiliar with fish anatomy.

Overall, *Marine Fishes of Arctic Canada* is an excellent text for anyone interested in detailed accounts of fish in the Canadian Arctic. The guide includes sufficient details and references for serious scientists, but also provides excellent coverage of information for the amateur naturalist or interested lay-person.

WILLIAM D. HALLIDAY

Wildlife Conservation Society Canada, Whitehorse, YT, and Department of Biology, University of Victoria, Victoria, BC, Canada.

## Encyclopedia of Whales, Dolphins and Porpoises

By Erich Hoyt. 2017. Firefly Books. 300 pages, 49.95 CAD, Cloth.

Written by a British-based, dual-citizen Canadian who is a research scientist, conservationist, and author, the *Encyclopedia of Whales, Dolphins and Porpoises* provides an interesting and beautiful global overview of cetaceans. Part pictorial guide, part research overview, part coffee table book, and part call to action, and brimming with incredibly beautiful photographs showing cetaceans in action, this book will appeal to many readers in its attractive, easy-to-read format.

The reader will learn a great deal. The book contains many interesting facts about this hugely popular yet mystical group of marine mammals. In recounting the history of cetacean research and monitoring, the author emphasized the major progress made with the realization that individual animals could be photographed and identified by distinctive species-specific features, such as flukes, dorsal fins, pigmentation patterns, scars, and wounds. This led to great advances in previously difficult areas to research such as migration, distribution, and social behaviour. In a general book such as this obviously not all biological facts can be provided, but it does provide an interesting and sometimes astounding array of biological information. It is quite enlightening how little is still known about some cetacean species, even breeding areas and species taxonomy, and how recently much of the known scientific information has been gathered. It was sobering to learn that almost half of all cetaceans globally are considered

Data Deficient, with insufficient data to determine status. The book is filled with many fascinating and interesting facts on cetacean life history, with the author often sharing insights and observations from his own research. The discussion on Killer Whale (*Orcinus orca*) ecotypes (fish-, mammal- and shark-feeding) was particularly well done.

The author conveys successfully the essence of the breadth and methods of various research approaches used today, such as transect surveys, acoustic studies, and faecal analysis. Consistent with his concerns about conservation, he delved into some detail on the potentially harmful nature of invasive studies, such as satellite tagging, outlining a series of questions for researchers considering whether such research should be conducted.

The book is logically laid out, although the content is not always well organized. Chapters on the shared history of humans and cetaceans, cetacean research, basic biology, conservation, and future prospects bracket three central chapters containing species accounts devoted to the life history and social behaviour of the three main cetacean groups: baleen whales, toothed whales, and dolphins and porpoises. Unfortunately, these latter chapters treat individual species inconsistently and do not cover all species, with no clear rationale for what species are and are not included. These chapters do not always build on information in a logical progression, sometimes beginning with a discussion of a specific species and only later in the chapter describing the general characteristics of that particular group of cetaceans, often within the section for one specific species. This confusion is in part due to the use of extensive insert boxes, often placed in the midst of other accounts. This is especially disruptive when extensive insert boxes (e.g., two pages) have been placed in the midst of text, and even in the midst of sentences. They are usually indistinguishable from regular text except for different colouration; in most cases, it would have been less confusing and more effective to treat the information in the text box as just another sequential section in the chapter. Although these three central chapters account for one-third of the book's length, they are less useful for between-species comparisons than the appendix, which provides consistent information on all 90 currently recognized species of cetaceans, including illustrations and brief but standard summaries of size, habitat, range, diet, social aspects, and conservation status. However, the size comparison charts of the three major cetacean groups at the end of each chapter are very illustrative. Each species in these charts is cross-referenced with the species summary in the appendix; further cross-references linked to those species addressed in the central three chapters would have been useful.

Although the author does an admirable job, it is difficult to produce a book such as this that is suitable for lay readers while also covering the necessary scientific detail. One example would be the discussion on taxonomy, where in one complex paragraph the author tries to describe in overview the relationships between and among 14 species of baleen whales (Mysticetes) in four families, and 76 species of toothed whales (Odontocetes) comprising the large-, medium-, and small-sized toothed whales, all with examples. Some inadvertent technical language was occasionally introduced with inadequate explanation, e.g., the term "fluid fusion fission societies" is introduced at one point but not actually explained until almost 60 pages later and most fully explained 100 pages on. There is also the occasional inadvertent duplication of information, sometimes in close proximity.

A glossary would have been very helpful, even though most terms are described somewhere in the text. Given the general/overview nature of the book, the absence of referenced citations is perhaps not surprising, although I often found myself wanting to know the source of, or to follow-up on, some specific interesting fact. The list of select references for the main sources used also provides recommended further reading. The index is useful and comprehensive, although the print is very small.

A relatively few apparent errors, inconsistencies, or areas of potential confusion in the species status section were noted. A figure showing the four humpback dolphin species switched identification for two of them. Maui Dolphin was referred to inconsistently as both a population and a subspecies of Hector's Dolphin (*Cephalorhynchus hectori*), perhaps a consequence of its relatively recent recognition as a subspecies. A reference to and a photograph of Antarctic Minke Whale (*Balaenoptera bonaerensis*) were included within the species account for Common Minke Whale (*Balaenoptera acutorostrata*) rather than in a separate section. Although listed by the International Union for Conservation of Nature (IUCN) as Critically Endangered, Baiji (*Lipotes vexillifer*) of the Yangtze River is variously described as "extinct", "considered extinct", "driven to extinction", and, perhaps most accurately, as "probably extinct". The Critically Endangered Vaquita (*Phocoena sinus*) is described as the "most endangered cetacean in the world, the one closest to extinction", a designation that only makes sense if one concludes that Baiji is extinct.

Figures are not numbered, and information on them is often presented out of order relative to the text, often by several pages. In many cases, linking a text description to a specific figure to demonstrate what is being explained would have been helpful. Global distribution maps would have been a very valuable addition for all species. For example, two of five populations of Bowhead Whale (*Balaena mysticetus*) globally are identified as Endangered but with no indication of the location of these populations.

The author quite appropriately places a great deal of emphasis on the conservation of and future prospects for cetaceans. Future challenges facing the world's cetaceans are many, and addressing them will take long-term, dedicated commitment from society as a whole. The future of cetaceans is addressed objectively and realistically, neither glossing over the challenges and probable upcoming extinctions nor giving in to despair or hopelessness. There are many initiatives underway or proposed that would improve the future prospects for many cetacean species. The author also suggests a number of practical measures people can take to get involved as citizen scientists and "whale savers". While not all species are treated equally, the plight of some of the most imperilled species is eloquently and evocatively described.

The discussion of conservation issues and challenges is extremely interesting and useful, although not always well organized or easy to find. A specific chapter is devoted to this topic, but the author often delves deeply into conservation status or issues in the midst of the species accounts, creating some confusion over where to look for conservation information. Given the recent spate of deaths of North Atlantic Right Whales (*Eubalaena glacialis*) in Canada, it was disappointing that the book's discussion of threats to this species concentrated almost solely on USA waters. The IUCN status of cetacean species is inconsistently referenced in the species accounts, being identified for some species but not others; it is, however, consistently referenced in the appendix.

This book is very ambitious in its scope and meets many of its objectives. Comprehensive, colourful, and full of interesting facts, it does an excellent job of showing the diversity of cetaceans around the world and raising awareness of conservation challenges and concerns for their future. It does treat some species in more detail than others, sometimes inconsistently addresses different life history components, and specific information is not always easy to find. However, as an overview to the diversity, ecology, and life history of cetaceans and a summary of major conservation challenges facing them now and into the future, it is an excellent addition to your natural history and conservation library.

TED ARMSTRONG
Thunder Bay, ON, Canada

## Great White Shark: Myth and Reality

By Alexandrine Civard-Racinais. Photographs by Patrice Héraud. 2017. Firefly Books. 144 pages, 19.95 CAD, Paper.

I have read many good books by the publisher of this book, but, "Firefly … your luciferase was low for this one". This book just did not glow. I read this book in one three-hour stint, making comments in my notebook regarding errors, misleading/difficult text, and contradictions. I filled more than two pages.

The book is divided into three sections: "Portrait of the Great White", which largely covers the species' anatomy; "Searching for the Great White", a description of the conservation efforts, including techniques used to identify and track the sharks; and "Requiem for the Great White?", which is about the relationship between this fish and humans, from attacks to ecotourism.

It is the first section of the book which dominates my notebook entries; this is not surprising given that (a) there is no indication that the author has any background in anatomy and (b) the reviewer does. However, some responsibility must lie with the publisher who should have had the manuscript reviewed prior to publication. One ludicrous example should suffice. Most bony fishes have gas bladders to help adjust their buoyancy; sharks and their allies do not. Sharks store oil in their livers, and it is this low-density oil which provides one of several mechanisms by which sharks maintain their position in the water column. There is no *pool* of oil, rather it is distributed within the liver's cells. And yet the author claims, "This oil allows sharks to adjust their buoyancy and move rapidly up and down without expending much energy" (p. 24). Just how would they do that…spit out the oil to make them sink? And what could they do to "rapidly move up" … very quickly synthesize more oil from a denser substrate in their bodies?

One of the themes of the book is to educate the reader that although the Great White Shark (*Carcharodon carcharias*) is a top predator, some of its behaviours (e.g., curiosity) have been misinterpreted as aggression. The author wants to dispel the rhetoric which gives this animal its bad name. Why then, in a caption, does the author refer to the shark as "marauding", especially when there is no evidence in the picture that the shark is doing anything but swimming?

I found the second and third sections of the book interesting and less riddled with errors. The story of the formation of the Fox Shark Research Foundation and a description of its work was both motivating and satisfying. The research vessel, tools of the trade (shark cages, transmitters, and more), and some of the neighbouring wildlife were nicely described and photographed. The photography is excellent throughout: repetitive (how many jaw-agape photos does one need in a shark book?), but excellent.

This book is easy to read and aesthetically pleasing owing to the copious photographs. It could have been a great book, but unfortunately, just isn't.

RANDY LAUFF
Department of Biology, St. Francis Xavier University. Antigonish, NS, Canada

## The Skeleton Revealed: An Illustrated Tour of the Vertebrates

By Steve Huskey. 2017. Johns Hopkins University Press. 360 pages, 49.95 USD, Cloth or E-book.

This book features beautiful photographs of 200 cleaned, and sometimes incredibly posed, vertebrate skeletons, with the goal to show the reader some of the diversity which exists. Given the subtitle, one would expect to have either near-equal representation across the vertebrates or a selection reflective of the richness of each major group (fishes, amphibians, reptiles, mammals, birds). In other words, half the book would be fishes, then diminishing numbers through birds, reptiles, mammals, and amphibians. Huskey did get the number of illustrated fish to match their proportion of vertebrates in nature, but his bias with snakes skews everything else. And given that a snake skeleton (save for the skull) is about as simple as it gets (skull, followed by tons of vertebrae with ribs, followed by vertebrae without ribs), it's puzzling to see why so many were included, especially when amphibians, mammals, and birds (illustrated by two, ten, and six photographs, respectively), were given such short shrift.

Each photograph is accompanied by an informative species account. In most cases, a description of the animal (intact, not just the skeleton), its habitat, diet, predators, and sometimes a few other interesting topics are covered. Conservation notes are added, with comments on the pet trade and introduced species, for example. These accounts are just long enough to whet one's appetite to learn more. There is no apparent order to the presentation of the species, and this almost allows Huskey to get away with some strategic copy and paste moments in the accounts. For example, for all six chameleons, we read exactly the same thing about their "hodge-podge of anatomical novelties", their independently moving eyes, their two-thumbed feet, the prehensile tail, and ballistic tongues. Spitting cobras, triggerfish, and vipers have similarly repeated passages.

The only other text is the short introduction, and it is fine. Although Huskey mentions that dermestid beetles were used to clean the skeletons, a more detailed methodology would have been nice. For example, what treatment was used on the skeletons to make them so shiny and white? How were the cartilaginous skeletons preserved? How were the skeletons rearticulated (especially for those notorious fish skulls)? Are they on display in a museum now? Photographers may want to know how the photographs were made. Were they digitally post-processed?

This book can be compared with *Evolution* (de Panafieu and Gries 2011), a book with equally beautiful photographs of skeletons, one of which was contributed by Huskey. Of the two books, *Evolution* shows a more diverse array of skeletons (including a few invertebrates) and the specimens are organized by topic, usually with a several-page description introducing each topic, which just seems to work better. Nonetheless, *The Skeleton Revealed* is informative, and the photographs are just a pleasure to view.

RANDY LAUFF

Department of Biology, St. Francis Xavier University. Antigonish, NS, Canada

### Literature Cited

**de Panafieu, J.-B.,** and **P. Gries.** 2011. Evolution. Seven Stories Press. New York, New York, USA.

OTHER

## Pilgrims of the Air: The Passing of the Passenger Pigeons

By John Wilson Foster. 2014 / 2017. Notting Hill Editions. 230 pages, 14.99 GBP, 29.95 CAD, Cloth.

*Pilgrims of the Air* is an extended contemplation in the history of ideas, searching out the myriad paths that lead to an understanding of arguably the most famous extinction of an avian species. Scientists still work to puzzle out definitive answers to the questions of why and how the Passenger Pigeon (*Ectopistes migratoria*), once numbering in the billions, could within a century cease to exist. On the surface, it's a well-known tale, but the full understanding has proven and still proves elusive. John Wilson Foster is a man of as many parts as the story he relates, and the esoteric Notting Hill Editions is a curiously appropriate vehicle for the telling of this story. Born in Ireland, educated there and in the United States, Foster taught in Ireland then at the University of British Columbia before returning as professor emeritus to the National University, Galway. He has been engaged in historical, cultural questions his entire career, authoring several critical studies on Irish politics and culture. But he also has extensive experience as a naturalist and birder in several parts of the world and editor of *Natural History of Ireland* (McGill-Queen's University Press), published in 1997, primary catalysts for this essay.

And it is an essay: Notting Hill Editions specializes in printing non-fiction essays characterized by excellence of writing and, as the press puts it, "the virtues of brevity, soul and wit". The extinction of a species is hardly a source for wit, but brevity (in the best sense) and soul are evident here. Foster has a poet's clear-eyed capacity to collect and summarize numerous themes in his exploration here, including attitudes toward nature exhibited by the Aboriginal peoples, several tribes of whom held Pigeon Dances (pp. 51ff), and the Europeans, beginning with the Puritans, who came to settle the lands we call the United States of America. Although he dips even further back to Aristotle, his primary focus is on the long, 19th century lead-up to the early 20th century decades during which the Passenger Pigeon disappeared and subsequent attempts to determine what happened. The beginnings of science in America, and especially the history of natural history, are traced through the works of such early naturalist explorers as John Lawson, Mark Catesby, Peter Kalm, and Alexander Wilson. The efforts of these and other men resulted in extensive knowledge of "Pigeon Countrie" (Chapter 7), and the pigeons did indeed travel the country, true nomads in search of sources of food. Fossil evidence and distribution maps for their favoured mast tree, the beech, and also the oaks, revealed their extensive range. To a degree, asserts Foster, the fate of the birds was tied to the fate of the trees and the heavy deforestation of the colonial period (p. 107).

We are all familiar with the images of Passenger Pigeons blocking the sun for hours as they flew overhead, but Foster provides extensive descriptions of accounts over the years. We learn of the complex patterns of the birds' movements in time and space, their nesting sites, which could cover hundreds of hectares and contain millions of birds, the destruction these sites wreaked on the forests, and, perhaps most curiously, of the habit of males and females taking turns on the nest. This meant that at feeding time, the vast flocks leaving the nests were composed in turn of males and females, which proved a vulnerability in the face of extensive hunting.

And how extensive the hunting was! The most disturbing part of the story is Foster's detailed accounts, in Chapter 9, "Such Dreadful Havock", and Chapter 10, "Flesh and Feathers both for Use and Ease", of the settlers' capacity to kill anything within range of a gun. This went beyond providing food: any romantic notions of the hunter going off in the woods seeking food for his family are dispelled forever by the rapacious, wanton, almost joyous delight in killing for its own sake. Add to this the industrialization of the killing, discussed in Chapter 12, "Things Future and Things Past", the improvements in communication (such as newspapers, railways, and the telegraph) that facilitated year-round locating and reaching nesting sites and moving the resulting huge loads of birds to processing plants in the cities, coupled with ongoing destruction of habitat as settlement moved west, and the wonder is that Passenger Pigeons lasted as long as they did. Naturalists are not excluded here, their collecting practices coming under scrutiny, although these were minor compared to the almost universal hunting everywhere the pigeons appeared. As pigeon numbers declined, attention turned to other bird species, such as plovers, curlews, and auks, often valued only for their feathers. A telling image is provided of one ornithologist doing some birding in New York City and identifying over 40 species: all from the feathers in ladies' hats (pp. 164–165).

But the ornithologists were slow to pick up on what was happening in the field, their awareness lagging behind the decline of the Passenger Pigeon. Their extinction was difficult to accept and the final passing of captive Martha in 1914 "took ornithologists by surprise and exposed the meagerness of their knowledge" (p. 212). The serious study of Passenger Pigeon natural history was made on the few specimens remaining in captivity. This theme of the ornithologists' belated role opens and closes the book, an instructive reminder of the potential importance of that role and the very human fragility underlying it.

Almost by definition, the essay is a 'popular' medium, in the best sense: a well-written, engaging, thought-provoking, enlightening narrative. Small in dimensions, comfortable in the hand, pleasingly designed, sewn binding including a red-ribbon bookmark, the book is an interesting artifact in itself. Field naturalists will find it of value, especially those with a historical bent. My only criticism is around the back matter: no index or notes, likely standard for Notting Hill, and a list of "Select References" that frequently did not include authors and titles mentioned in the text. I can't resist mentioning one of these, a certain Howitt (p. 114), whose observations of the flight of Passenger Pigeons over Guelph, Ontario, in the 1860s, were recounted in an article published in 1932 in *The Canadian Field-Naturalist* (Howitt 1932).

BARRY COTTAM
Ottawa, ON, Canada

### Literature Cited

**Howitt, H.** 1932. A short history of the Passenger, or wild, Pigeon. Canadian Field-Naturalist 47: 27–30. Accessed 23 May 2018. https://www.biodiversitylibrary.org/item/89295#page/41/mode/1up.

## NEW TITLES

Prepared by Barry Cottam

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Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

### BOTANY

***Woody Plants of the Northern Forest: A Photographic Guide.** By Jerry Jenkins. 2018. Cornell University Press. 64 pages, 25.50 USD, Paper.

***Woody Plants of the Northern Forest: Quick Guide.** By Jerry Jenkins. 2018. Cornell University Press. Foldout Chart, 11.95 USD, Paper.

**The Hidden Life of Trees: What They Feel, How They Communicate—Discoveries from a Secret World.** By Peter Wohlleben. Translated by Jane Billinghurst. Foreword by Tim Flannery. 2018. Greystone Books. 288 pages, 21.95 CAD, Paper.

**The Book of Seeds: A Life-Size Guide to Six Hundred Species from Around the World.** Edited by Paul Smith. 2018. University of Chicago Press. 656 pages, 55.00 USD, Cloth, 44.00 USD, E-book.

**Blossoms and the Genes that Make Them.** By Maxine F. Singer. 2018. Oxford University Press. 176 pages, 22.95 CAD, Cloth. Also available as an E-book.

**Sunflowers.** By Stephen A. Harris. 2018. University of Chicago Press. 256 pages, 27.00 USD, Cloth.

**Palm.** By Fred Gray. 2018. University of Chicago Press. 256 pages, 27.00 USD, Cloth.

**The Story of Soy.** By Christine M. Du Bois. 2018. Reaktion Books. 216 pages, 40.00 USD, Cloth.

**The Ethnobotany of Eden: Rethinking the Jungle Medicine Narrative.** By Robert A. Voeks. 2018. University of Chicago Press. 328 pages, 45.00 USD, Cloth or E-book.

**Joseph Hooker's Rhododendrons of Sikkim-Himalaya.** By Joseph Hooker. Introduction by Virginia Mills and Cam Sharp Jones and an Essay by Ed Ikin. 2018. Royal Botanic Gardens, Kew. 104 pages and 30 colour plates, 35.00 USD, Cloth.

### ENTOMOLOGY

**The Dynastine Scarab Beetles of the USA and Canada (Coleoptera: Scarabaeidae: Dynastinae). Bulletin of the University of Nebraska State Museum, Volume 30.** By Brett C. Ratcliffe and Ronald D. Cave. 2017. 298 pages, 40.00 USD.

**Insects: Evolutionary Success, Unrivaled Diversity, and World Domination.** By David B. Rivers. 2017. Johns Hopkins University Press. 488 pages, 99.95 USD, Cloth or E-book.

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### OTHER

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# News and Comment

## Upcoming Meetings and Workshops

### Association of Field Ornithologists and Wilson Ornithological Society Joint Meeting

The 2018 joint meeting of the Association of Field Ornithologists and the Wilson Ornithological Society to be held 7–9 June 2018 at the Chattanooga Convention Center, Chattanooga, Tennessee. Registration is currently open. More information is available at http://www.cvent.com/events/2018-afo-wos-meeting/event-summary-9bb245ec39b4492280fa6c65382e9f83.aspx.

### Entomological Society of America, Pacific Branch Meeting

The 102nd annual meeting of the Pacific Branch of the Entomological Society of America to be held 10–13 June 2018 at the Atlantis Casino Resort Spa, Reno, Nevada. Registration is currently open. More information is available at https://www.entsoc.org/pacific/2018-branch-meeting.

### International Association of Great Lakes Research Conference

The 61st annual International Association of Great Lakes Research Conference, hosted by the University of Toronto: Scarborough, to be held 18–22 June 2018 in Scarborough, Ontario. The theme of the conference is: ‘Great Science for Tomorrow’s Solutions’. Registration is currently open. More information is available at http://iaglr.org/index.php/iaglr2018.

### Eastern Bird Banding Association Annual Meeting

The annual meeting of the Eastern Bird Banding Association to be held 22–24 June 2018 at the Schoodic Institute at Acadia National Park, Schoodic Peninsula, Maine. Registration is currently open. More information is available at http://www.easternbirdbanding.org/2018-ebba-meeting.

### American Society of Mammalogists Annual Meeting

The 98th annual meeting of the American Society of Mammalogists to be held 25–29 June 2018 at Kansas State University, Manhattan, Kansas. Registration is currently open. More information is available at http://www.mammalmeetings.org.

### Canadian Society for Ecology & Evolution Meeting

The Canadian Society for Ecology & Evolution Meeting to be held 18–21 July 2018 at the University of Guelph, Guelph, Ontario. The theme of the conference is: ‘Fundamentals in Ecology and Evolution: Now and into the Future’. Registration is currently open. More information is available at http://www.csee2018.ca.

### North American Congress for Conservation Biology

The North American Congress for Conservation Biology, hosted by the Wildlife Conservation Society – Canada, University of Toronto, and Society for Conservation Biology’s Toronto Chapter, to be held 21–26 July 2018 at the Westin Harbour Castle, Toronto, Ontario. The theme of the congress is: ‘Conservation science, policy, & practice: connecting the urban to the wild’. Registration is currently open. More information is available at https://scbnorthamerica.org/index.php/naccb2018.

### Botany 2018

Botany 2018 to be held 21–25 July 2018 at the Rochester Civic Center, Rochester, Minnesota. The theme of the meeting is: ‘Thriving with diversity’. Registration is currently open. More information is available at http://www.botany-conference.org.

### Phycological Society of America and the International Society of Protistologists Joint Meeting

The joint meeting of the Phycological Society of America and the International Society of Protistologists to be held 29 July–2 August 2018 at the University of British Columbia, Vancouver, British Columbia. Registration is currently open. More information is available at http://psaisop2018.botany.ubc.ca.

### NEPARC Annual Meeting

The annual meeting of the Northeast Partners in Amphibian and Reptile Conservation (NEPARC) to be held 31 July–2 August 2018 at Hampshire College, Amherst, Massachusetts. More information is available at http://northeastparc.org/next-meeting-info.

## Highlights from the Northwest Territories BioBlitzes

To mark Canada's 150th anniversary, BioBlitz Canada 150, a national partnership of nature organizations, brought together the Canadian public with scientists to explore the richness of Canada's biodiversity and to engage our passion to know, celebrate, and conserve our natural heritage. It became known as "Canada's Nature Selfie". The Canadian Wildlife Federation with BioBlitz Canada and other partners in conservation, carried out a series of public BioBlitzes across the nation (Canadian Wildlife Federation 2017). A BioBlitz is an intense period of biological surveying (usually 24 hours) by scientists, naturalists, volunteers, and keen members of the public, in an attempt to record as many living species as possible from a given area. These day-long BioBlitz events are hugely valuable for public outreach, education, and for collecting biological data, including discovery of species not previously known from an area.

The Government of the Northwest Territories organized BioBlitz events in five communities: Inuvik, Tuktoyaktuk, Norman Wells, Fort Simpson, and Yellowknife. New species records for the region are not the only results. Just as important are examples of new information on environmental changes, sharing local knowledge, and helping children to protect and understand nature.

***Tuktoyaktuk*** (28 July 2017, Government Offices, The Point, 69.4507°N, 133.0370°W). The main BioBlitz event took place on the tip of the peninsula in town, locally called "The Point". This area had hundreds of plants of the spectacular Marsh Felwort (*Lomatogonium rotatum* (L.) Fries). This bright blue-flowered plant is characteristic of cold seashores. The 5 cm long benthic marine isopod *Saduria entomon* (Figure 1) was recorded along the shoreline. Although not the first time it was observed in Tuktoyaktuk—or "Tuk"—(Percy 1983), it may have been the first time this circumarctic creature had been called by its international (scientific) name. Meadow Slug, *Deroceras laeve,* observed in Tuk and along the shoreline to the west of town is one of the northernmost records in Canada. Among the birds observed in Tuk was the Red-necked Phalarope (*Phalaropus lobatus*; Figure 2), which has experienced major declines in some migratory staging areas. This phalarope has been recently designated as "Special Concern" (COSEWIC 2014a) by the national committee that assesses species at risk in Canada and recommends species for listing under the federal *Species at Risk Act*. Our observations of these birds (and those of others) may help to understand the environmental changes that have caused these declines (and that may influence many other species). We wondered whether American Robins (*Turdus migratorius*) around town may be a new record in Tuk, but in fact these birds were reported over a century ago from groups of trees on the barren lands by Preble (1908).

FIGURE 1. The isopod crustacean, *Saduria entomon* (Chaetiliidae) from the Beaufort Sea, Tuktoyaktuk. 27 July 2017. Photo: P. M. Catling.

FIGURE 2. Red-necked Phalarope (*Phalaropus lobatus*) in a pool on Ocean Drive, Tuktoyaktuk. 26 July 2017. Photo: P. M. Catling.

Local people had the most significant bird observations. We were told that 15 years ago there were very few Bald Eagles (*Haliaeetus leucocephalus*) around Tuk but they have become more common along the Arctic Coast and at the time of the BioBlitz there were 20 observed during our stay in town. We also learned that more Arctic Char (*Salvelinus alpinus*) were being caught and the salmon caught recently had not been caught before. Also, there were several observations of Bowhead (*Balaena mysticetus*) and Beluga (*Delphinapterus leucas*) whales in August (2016 and 2017).

One of the most fascinating biological areas of town included the south pingo. We completed numerous vegetation transects across the pingo that yielded detailed plant lists which will provide a basis for future monitoring related to climate change. Many of the plants on the pingo have a restricted northwestern Arctic distribution, such as Narrow-leaved Saw-wort (*Saussurea angustifolia* (L.) de Candolle; Figure 3). A true wild orchid, Early Coralroot (*Corallorhiza trifida* Châtelain) was also found in this unusual plant assemblage.

Numerous bumble bees were noted in Tuktoyaktuk including Brown-tailed Bumble Bee (*Bombus mixtus*), Red-tailed Bumble Bee (*Bombus sylvicola*; Figure 4), Yellow-faced Bumble Bee (*Bombus flavifrons*), and Orange-rumped Bumble Bee (*Bombus melanopygus*). These species have been recorded from the Northwest Territories (NWT) before, but noting their abundance in Tuk confirms their distribution in the area and also provides a baseline for future study.

***Inuvik*** (30 July 2017, Aurora Centre to Boot Lake Trail, 68.3558°N, 133.7206°W). The BioBlitz event in Inuvik attracted over 35 people of all ages and followed the main trail part way around Boot Lake (Figure 5). Three hundred plants of the unusual cone-like parasite (on alder) Ground-Cone (*Boschniakia rossica* (Chamis-

FIGURE 3. Narrow-leaved Saw-wort (*Saussurea angustifolia*) on Tuktoyaktuk's south pingo. 25 July 2017. Photo: P. M. Catling.

so & Schlechtendal) B. Fedtschenko) were found, more than had been observed in one small area before. Along the Mackenzie River were occasional Wood Frogs (*Lithobates sylvaticus*; Figure 6), which are abundant elsewhere in the Mackenzie River delta (for example at Aklavik). The Mackenzie River Delta Wood Frog population is the northernmost population of any frog in Canada.

On the day prior to the Inuvik BioBlitz, both Grizzly Bears (*Ursus arctos*) and Black Bears (*Ursus americanus*) were seen on the Boot Lake trail, but to the relief of some attendees our noisy group of 35 people discouraged an appearance. Everyone wanted to know about what looked like fluorescent orange spray paint on the wild Prickly Roses (*Rosa acicularis* Lindley). To many people's surprise, this was not paint but the spectacular powdery rust fungus, *Phragmidium* (Figure 7). The equally remarkable prickly gall on the rose plants along the trail was caused by a minute chalcidoid gall wasp of the genus *Diplolepis* (possibly *D. bicolor*; Figure 8). An interesting observation was that of Bill Halliday, who identified a Northern Red-backed Vole (*Myodes rutilus*) from bones regurgitated by an owl along the Boot Lake trail.

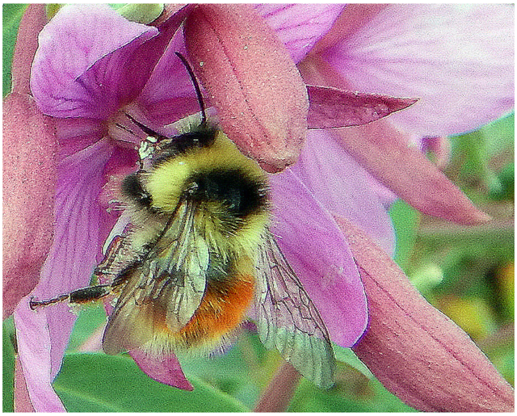

FIGURE 4. Red-tailed Bumble Bee (*Bombus sylvicola*) at Tuktoyaktuk. 27 July 2017. Photo: J. Heron.

FIGURE 6. Wood Frog (*Lithobates sylvaticus*) from Twin Lakes, Inuvik. The Mackenzie Delta population are the northernmost frogs in Canada. 30 July 2017. Photo: P. M. Catling.

The gravelly open areas along roadsides, around utilidors (utility pipes), and in yards of Inuvik are rich in native vascular plant species, unlike such habitats further south. These included attractive wildflowers such as Alpine Milk-vetch (*Astragalus alpinus* L. var. *alpinus*), Marsh Grass-of-Parnassus (*Parnassia palustris* L.), Nodding Locoweed (*Oxytropis deflexa* (Pallas) de Candolle subsp. *foliolosa* (Hooker) Cody), and Raup's Paintbrush (*Castilleja raupii* Pennell). Rich native wildflower habitats of this kind are uncommon

FIGURE 5. Monitoring ducks on Boot Lake during the Inuvik BioBlitz. 30 July 2017. Photo: B. Kostiuk.

FIGURE 7. Powdery rust fungus, *Phragmidium*, on wild Prickly Rose (*Rosa acicularis*). Boot Lake Trail. 30 July 2017. Photo: P. M. Catling.

FIGURE 8. Prickly gall on wild Prickly Rose (*Rosa acicularis*) caused by a minute chalcidoid gall wasp of the genus *Diplolepis* (possibly *D. bicolor*). 30 July 2017. Photo: P. M. Catling.

outside of town and may be indicators of a kind of a habitat more frequent in the past and/or localized in the delta region.

***Norman Wells*** (2 August 2017, Historical Centre and the Mackenzie River shoreline, 65.2782°N, 126.8175°W). The biological inventory of Norman Wells included the Mackenzie River shoreline and numerous habitats and trails around town. The diversity and complexity of the Mackenzie River flood shore was a major highlight. The highest water level, indicated by the accumulation of driftwood, was at least 15 m above the water level in early August when we visited (Figure 9). Since the spring, the river had gradually receded leaving land exposed for varying lengths of time and allowed the growth of a diversity of plants at different zones along the shoreline. This led to unusually high plant and animal species diversity. Many of the species present are restricted to this habitat type. Data were collected to evaluate the extent of invasion of the floodshore by the non-native plant, White Sweet-clover (*Melilotus albus* Medikus). This is a fast-growing, fast-spreading, and highly competitive plant and the prospect of losing native plants to this and other non-native competitors before we have discovered all of their values is at least a little worrying. Other plants, such as the rare (in NWT) Alaska Wild Rhubarb (*Aconogonon alaskanum* (W. Wight ex Harshberger) Soják), are potentially important as new Arctic crops. During our visit we found out that the southern limit of this plant (and the site of the population most adapted to a warming climate) was at Tulita.

A gall caused by the Poplar Petiole Gall Aphid, *Pemphigus,* possibly *P. populitransversus* (Figure 10), on Balsam Poplar (*Populus balsamifera* L.) along the Mackenzie was something that we had not seen before. This turned out to be even more interesting because one of the galls contained a parasitic fly larva 1.5 cm long. Aphids that induce closed galls are usually parasitoid free, but parasitoids have been identified from galls in Japan (Takada *et al*. 2010). This may be one of the few cases of parasitism of gall-forming aphids reported in North America.

The Graceful Sedge Grasshopper (*Stethophyma gracile*; Figure 11) recorded at Norman Wells is only the second record for the species in NWT and is 700 km northwest of the previous record from near Kakisa on the south side of Great Slave Lake (Catling 2008). This extension of known range may be a result of a climate that is changing faster than many other regions of the world (Environment and Natural Resources 2016).

Three insect species that have been assessed by the Committee on the Status of Endangered Wildlife in Canada were recorded in Norman Wells: Transverse Lady Beetle (*Coccinella transversoguttata*) and Yellow-banded Bumble Bee (*Bombus terricola*), both species of "Special Concern" (COSEWIC 2016, 2015, respectively), and Gypsy Cuckoo Bumble Bee (*Bombus bohemicus*, Figure 12) an "Endangered" species (COSEWIC 2014b). Numerous other more common bumble bee species were also recorded. These are exciting results, especially Gypsy Cuckoo Bumble Bee, because this bee historically ranged throughout Canada although in the last decade has only been found in northern Canada (COSEWIC 2014b).

***Fort Simpson*** (9 August 2017, Town Golf Course, 61.8586°N, 121.3547°W). This event focussed on macrofungi, lichens, and mosses and involved a group of experts in these groups (see authors and acknowledgements). The community was invited to a walk at the golf course to find examples and later to examine some of the species collected on display tables. Collecting around the Yellowknife area continued from 10 to 12 August. While it was extremely dry during this period, the diversity of macrofungi was surprisingly high (Figure 13). Around 115 collections were made from the Fort Simpson area and 78 from the Yellowknife area. It is estimated that there were 130–150 species found. The icicle fungi *Hericium abietis* (Figure 14), *H. coralloides*, and *H. erinaceus* were spectacular. Most species collected were first reports for NWT. Because *Hebeloma* expert, Dr. Henry Beker, was present, collecting focussed on finding as many *Hebelomas* as possible. None were found at Fort Simpson, but at least three different species were found in Yellowknife. The collections continue to be examined and they will contribute to the very incomplete documentation of these groups in NWT. Only eight species were listed in NWT

FIGURE 9. Mackenzie River flood shore. Within this habitat the Yellow-banded Bumble Bee (*Bombus terricola*) and Transverse Lady Beetle (*Coccinella transversoguttata*), both species of "Special Concern" (COSEWIC 2015, 2016) were observed in abundance. 2 August 2017. Photo: P. M. Catling.

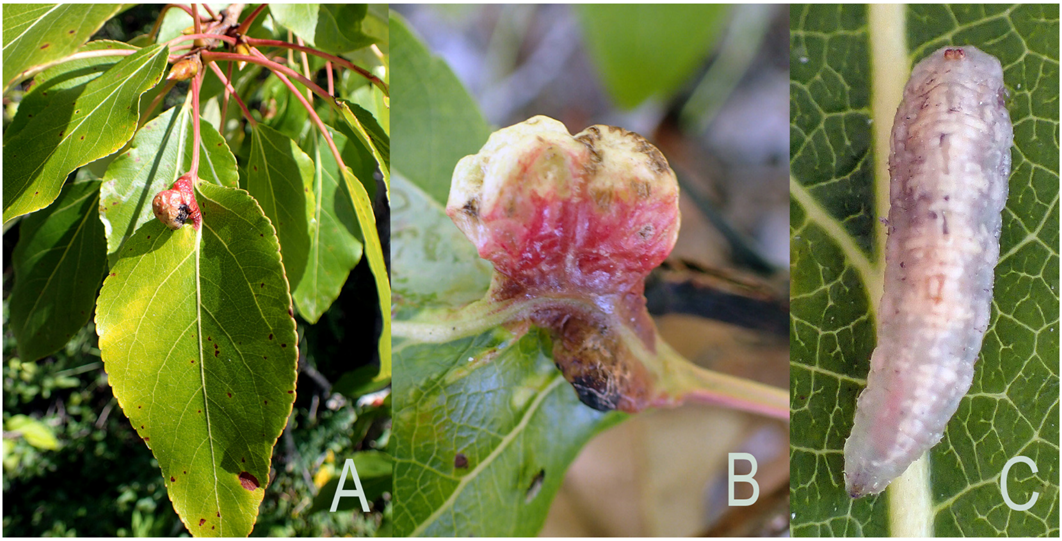

FIGURE 10. A) A gall caused by the Poplar Petiole Gall Aphid, *Pemphigus cf. populitransversus*; B) closer view of gall; and C) fly larva from inside gall. 2 August 2017. Photo: P. M. Catling.

FIGURE 11. The Graceful Sedge Grasshopper (*Stethophyma gracile*) found at Norman Wells was only the second record for the Northwest Territories and a range extension of 700 km northwest. 2 August 2017. Photo: P. M. Catling.

Species 2016–2020 (Working Group on General Status of NWT Species 2016).

***Yellowknife*** (12 August 2017, Prince of Wales Heritage Centre, 62.4575°N, 114.3776°W). In Yellowknife, the outdoor exploratory part of the BioBlitz included the areas near the museum at the west end of Frame Lake and northwest to Niven Lake. Clear-winged Grasshopper (*Camnula pellucida*), common in dry open ground, was a new record for the Yellowknife area. Eighteen species of birds were recorded in two hours during an early morning bird survey at Niven Lake led by Suzanne Carrière. Earthworms were found at a few places in town and later as far away as the Prelude Lake boat launch. They are not native to NWT but introduced, likely from Europe via southern Canada. Also notable was the Black Meadowhawk dragonfly (*Sympetrum danae*) which was the most common (68 seen) of eight dragonfly species in the BioBlitz area. It is usually local and uncommon and none have been seen in the previous dragonfly counts in this area, but

FIGURE 12. This Gypsy Cuckoo Bumble Bee (*Bombus bohemicus*) was one of many unusual insects found in Norman Wells. It is a nationally "Endangered Species" (COSEWIC 2014b). Like several other endangered species, its northern populations are the most viable in Canada. 31 July 2017. Photo: C. Sheffield.

FIGURE 13. Mushrooms at Fort Simpson. 8 August 2017. Photo: Linda Davies.

FIGURE 14. Lion's Mane (*Hericium abietis*), an icicle fungus, from near Mackenzie River 1 km north of N'Dulee Ferry Crossing. August 2017. Photo: Sharmin Gamiet.

those counts were in July. Bumble bees were popular with children during the BioBlitz event here and elsewhere (Figure 15). Although the declines in NWT have been less than elsewhere (Working Group on the Status of NWT Species 2016), some bumble bees are rapidly declining in NWT. To assist in monitoring this group of valuable pollinators and environmental indicators, the Government of the Northwest Territories (2017) has produced a free guide.

On the day before the main BioBlitz event at Yellowknife, there was a related event: a tour with members of the non-profit organization, the Yellowknife Association for Community Living. It supports people with disabilities and their families, across their lifetime and aims to help them live meaningful lives and be active in all aspects of community life. The event took place at the Yellowknife River day-use area on the Ingraham Trail. It was well attended; 30 children and youth ages 5 to 15 years joined us for a walk through the woodland trails along the shores of the river. Large insects and spiders were the main attraction, the first observation being a large female orb spider who the group affectionately named "Susan". There were numerous questions about Susan's biology, life cycle, number of eggs, lifespan, and hibernation. Interest in the spider was only exceeded by a pair of huge (15 cm wingspan, 5–8 cm long) Lake Darner dragonflies (*Aeshna eremita*), a female and male that were captured by net while holding each other in a mating position (in tandem). Everyone wanted to hold a dragonfly and all were given the opportunity; each participant held the dragonfly carefully by the folded wings and noted the difference between the sexes, their spectacular colours, and their huge eyes. The giant insects were then passed gently to the next person. After each person had their turn at holding each dragonfly, the insects were placed on an open palm and after only brief hesitation, flew away unharmed. No damage after a handhold by each of 30 kids! What a wonderful demonstration of care and sensitivity.

BioBlitzes are special events that bring together community members with a common interest in nature and in learning more about the natural world. We were delighted to be part of these events to make new friends in each of these communities, learn from them, and share a respect for nature.

The species observed during the BioBlitz Canada project were recorded using iNaturalist. Species lists can be viewed by following the links below.

**Tuktoyaktuk**: http://inaturalist.ca/projects/tuktoyaktuk-bioblitz-2017-de-tuktoyaktuk.

**Inuvik**: http://inaturalist.ca/projects/inuvik-bioblitz-2017-de-inuvik.

**Norman Wells**: http://inaturalist.ca/projects/norman-wells-bioblitz-2017-de-norman-wells.

**Yellowknife**: http://inaturalist.ca/projects/yellowknife-bioblitz-2017-de-yellowknife.

FIGURE 15. Monique Chapman assists in bee identification at the Norman Wells BioBlitz. 2 August 2017. Photo: B. Kostiuk.

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## Literature Cited

**Aiken, S. G., M. J. Dallwitz, L. L. Consaul, C. L. McJannet, R. L. Boles, G. W. Argus, J. M. Gillett, P. J. Scott, R. Elven, M. C. LeBlanc, L. J. Gillespie, A. K. Brysting, H. Solstad,** and **J. G. Harris.** 2007. Flora of the Canadian Arctic Archipelago: descriptions, illustrations, identification, and information retrieval. NRC Research Press, National Research Council of Canada, Ottawa, Ontario, Canada. Accessed 27 December 2017. http://nature.ca/aaflora/data.

**Canadian Wildlife Federation.** 2017. BioBlitz Canada 150 events. Accessed 27 December 2017.

http://bioblitzcanada.ca.

http://bioblitzcanada.ca/about_bbc.aspx.

http://bioblitzcanada.ca/events_map.aspx.

http://bioblitzcanada.ca/events_community-northwest-territories.aspx.

http://bioblitzcanada.ca/project_bioblitz-in-a-box.aspx#toc—2-10-check-list-of-items-to-include-in-final-report-to-the-canadian-wildlife-federation-.

**Catling, P. M.** 2008. Grasshoppers and related insects of Northwest Territories and adjacent regions. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada.

**COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2014a. COSEWIC assessment and status report on the Red-necked Phalarope, *Phalaropus lobatus,* in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 18 May 2018. http://sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Red-necked Phalarope_2014_e.pdf.

**COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2014b. COSEWIC assessment and status report on the Gypsy Cuckoo Bumble Bee *Bombus bohemicus* in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 17 May 2018. http://sararegistry.gc.ca/virtual_sara/files/cosewic/sr_GypsyCuckooBumbleBee_2014_e.pdf.

**COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2015. COSEWIC assessment and status report on the Yellow-banded Bumble Bee *Bombus* *terricola* in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 17 May 2018. http://sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Yellow-banded_BumbleBee_2015_e.pdf.

**COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2016. COSEWIC assessment and status report on the Transverse Lady Beetle *Coccinella transversoguttata* in Canada. COSEWIC, Ottawa, Ontario, Canada. Accessed 17 May 2018. http://sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Transverse_Lady_Beetle_2016_e.pdf.

**Environment and Natural Resources.** 2016. NWT state of the environment report – highlights 2016. Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada. Accessed 27 December 2017. http://www.enr.gov.nt.ca/sites/enr/files/state_of_environment_highlights_2016.pdf.

**Government of the Northwest Territories.** 2017. A Field Guide to the Bumble Bees of the Northwest Territories. Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada.

**Takada, H., K. Kamijo,** and **H. Torikura.** 2010. An aphidiine parasitoid *Monoctonia vesicarii* (Hymenoptera: Braconidae) and three chalcidoid hyperparasitoids of *Pemphigus matsumurai* (Homoptera: Aphididae) forming leaf galls on *Populus maximowiczii* in Japan. Entomological Science 13: 205–215. https://doi.org/10.1111/j.1479-8298.2010.00374.x

**Percy, J. A.** 1983. Distribution of arctic marine isopods of the Mesidotea (=*Saduria*) complex in relation to depth, temperature, and salinity in Southern Beaufort Sea. Arctic 36: 341–249.

**Preble, E. A.** 1908. A biological investigation of the Athabasca–Mackenzie region. North American Fauna 27. United States Department of Agriculture, Bureau of Biological Survey, Washington, DC, USA.

**Working Group on General Status of NWT Species.** 2016. NWT Species 2016–2020 — general status ranks of wild species in the Northwest Territories. Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada. Accessed 27 December 2017. http://www.nwtspeciesatrisk.ca/sites/default/files/nwtspecies_2016_2020_report_final_w_properties.pdf.

PAUL M. CATLING, BRENDA KOSTIUK
Ottawa, ON, Canada

JENNIFER HERON
B.C. Ministry of Environment, Surrey, BC, Canada

RUNEL JIMENEZ
Yellowknife, NWT, Canada

MONIQUE CHAPMAN
Halifax, NS, Canada

SHARMIN GAMIET
Mycology Resources, Abbotsford, BC, Canada

VELMA STERENBERG
Yellowknife, NWT, Canada

# Editorial

## Celebration of 40 years of COSEWIC and its Close Association with *The Canadian Field-Naturalist*

The year 2017 was celebrated by many as the 150th anniversary of Canada. Some also celebrated the 40th anniversary of the establishment of The Committee on the Status of Endangered Wildlife in Canada (COSEWIC). While the inaugural meeting of COSEWIC occurred in 1977, the first species assessed by COSEWIC occurred in 1978. Federal, provincial, and territorial ministers responsible for wildlife recognized COSEWIC as the source for independent advice on the status of species at risk in Canada in the 1998 *Accord for the Protection of Species at Risk*. When the *Species at Risk Act* (SARA) became law in 2002, COSEWIC was formally established (S. 14) as the body that assesses the risk of extinction or extirpation for all wild flora and fauna within Canada, with the exception of bacteria and viruses, and recommends to the federal government legal listing and protection under SARA.

There has always been a close but informal association between COSEWIC and *The Canadian Field-Naturalist* (CFN). Currently, five Associate Editors of CFN—and yours truly—are, or used to be, members of COSEWIC. Similarly, the numerous reviewers of manuscripts submitted to CFN not only include current and former COSEWIC members but also members of the various Species Specialist Subcommittees, who are tasked with awarding the contracts for and then reviewing the multiple stages of the species status reports, the documents COSEWIC uses to assign status. Many of these status reports, especially those on fishes and marine mammals, were published in CFN from 1984 through 2002 (Halliday 2017). After 2002, COSEWIC status reports have been readily available at sararegistry.gc.ca. While the need to publish COSEWIC status reports in CFN has ended, articles, notes, and thematic collections published in CFN continue to reference COSEWIC status reports or the SARA listings based on COSEWIC status reports. For example, in the four issues of CFN volume 131 for 2017, there are 14 references to COSEWIC status reports or to COSEWIC itself and another six references to species profiles posted on sararegistry.gc.ca resulting from COSEWIC status reports.

Original descriptions and information on a species' former and current distribution, abundance, behaviour, and interactions with the environment are essential data needed by COSEWIC to assign status. I have long suspected that many articles published in CFN contain these essential data but was surprised to find that there were 62 references to articles published in CFN in the status reports for the 45 wildlife species recently assessed by COSEWIC (see https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html for the results of the April 2018 Wildlife Species Assessment Meeting). More astonishing is that one of the references cited in a COSEWIC status report was for an article (Latchford 1887) published in the first volume of *The Ottawa Naturalist*, a precursor to CFN (Brunton 1986, 2004)—a nice link to help celebrate 40 years of COSEWIC and CFN.

### Literature Cited

**Brunton, D. F.** 1986. Additions to the documentation of the publication history of *The Canadian Field-Naturalist* and its predecessors. Canadian Field-Naturalist 100: 423–426. Accessed 8 May 2018. https://www.biodiversitylibrary.org/item/89211#page/441/mode/1up.

**Brunton, D. F.** 2004. Origins and history of The Ottawa Field-Naturalist's Club. Canadian Field-Naturalist 118: 1–38. https://doi.org/10.22621/cfn.v118i1.879

**Halliday, W. D.** 2017. Publication trends in *The Canadian Field-Naturalist*, 1980–2015. Canadian Field-Naturalist 131: 1–9. https://doi.org/10.22621/cfn.v131i1.1949

**Latchford, F. R.** 1887. Report on the Conchological Branch. Ottawa Naturalist 1: 107–108. Accessed 8 May 2018. https://www.biodiversitylibrary.org/item/95417#page/113/mode/1up.

DWAYNE LEPITZKI

Editor-in-Chief, *The Canadian Field-Naturalist*
Member of COSEWIC

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