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COVER: Julius Csotonyi's depiction of an adult *Spinops sternbergorum* defending her offspring from an attack by an albertosaurine tyrannosaur during the Cretaceous Period of the Mesozoic Era. See the article by Mallon *et al.* (pp. 294–299) of a newly discovered fossil, most likely *Spinops sternbergorum*, a ceratopsid species previously known only from Dinosaur Provincial Park, Alberta, from near Unity, Saskatchewan. See also <https://www.csotonyi.com> for more paleoart.

Effects of prescribed fire on a drought-stressed Trembling Aspen (*Populus tremuloides*) stand

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Abstract

A small stand of drought-stressed Trembling Aspen (*Populus tremuloides*) near Saskatoon, Saskatchewan, Canada, was surveyed before and after a prescribed fire. A headfire in grass understorey fuel caused near complete mortality of established stems and of all aspen saplings. In the second and third years post-fire, only limited establishment of saplings was observed. Woody encroachment by aspen into grassland is challenging to control in the Aspen Parkland ecoregion; our results indicate that combining prescribed burning with secondary stress from drought conditions can enhance the fire effects.

Key words: Trembling Aspen; *Populus tremuloides*; prescribed fire; woody plant control

Introduction

The encroachment of woody species into grasslands is an issue of significant ecological and economic concern (Van Auken 2000; Soubry and Guo 2022). In the Aspen Parkland on the northern edge of the Great Plains (Coupland 1961), expansion of both low shrub species such as Snowberry (*Symphoricarpos occidentalis* Hooker) and Wolf Willow (*Elaeagnus commutata* Bernhardt ex Rydberg) and trees such as Trembling Aspen (*Populus tremuloides* Michaux) is common (Romo *et al.* 1993; Romo 2003). The consequences of this woody encroachment include reduced cattle grazing capacity, fragmentation of areas of grassland habitat, reduced connectivity between grassland fragments, and reduced grassland biodiversity through habitat loss (Romo 2003; Twidwell *et al.* 2013). The causes of these increases in woody plant abundance are complex and likely include the post-European-settlement reduction in the frequency and intensity of fire, a change in grazing regime from one dominated by migratory bison to one dominated by sedentary cattle, and changing climatic conditions (Chen *et al.* 2017; Soubry and Guo 2022).

Methods, such as mulching and herbicides, can be used for woody plant control (e.g., Waddington and Bittman 1987; Zentner and Bowes 1991; Paragi and Haggstrom 2007), but suffer from poor public acceptance and may not be suitable on lands where conservation is a management objective. Improved methods for controlling woody encroachment that align with

natural disturbance processes are of interest to range-land managers with both conservation and grazing objectives.

Prescribed fire is increasingly being used for grassland management as social acceptance of fire as a management technique becomes more widespread and the organizational capacity to safely conduct fire improves (Twidwell *et al.* 2013; Gross and Lamb 2025). Regionally relevant fire prescriptions are needed for diverse management objectives, including control of aspen and other woody species (Gross 2023). Past studies have found that fire, as an isolated control tactic, will readily kill mature aspen stems, but it is often ineffective for long-term control of aspen encroachment because it stimulates vegetative reproduction (i.e., suckering) and creates soil conditions necessary for seedling establishment (Bartos and Mueggler 1981; Brown and DeByle 1987; Ripley and Archibold 1999; Fraser *et al.* 2004; Paragi and Haggstrom 2007; Guedo and Lamb 2013; Margolis and Farris 2014). After fire, aspen's regeneration response can result in thousands of saplings per hectare (Fraser *et al.* 2004; Kreider and Yocom 2021). Thus, long-term control is typically thought to require repeat fires, high intensity fires, or secondary control methods (Bartos and Mueggler 1981; Guedo and Lamb 2013). However, repeat and high-intensity prescribed fires are difficult to implement because of high costs and such limitations as the availability of personnel and the right weather conditions (Gross and Lamb 2025).

Given these challenges, it is important to explore the combination of fire with secondary control factors. Combined burning and grazing, for example, was highly successful in mitigating post-fire suckering in European Aspen (*Populus tremula* L.) in southern Europe (Ascoli *et al.* 2013), and fire can open dense shrub canopies sufficiently to allow grazing animals to enter shrubby areas (Tarleton and Lamb 2021). Drought may be a relevant secondary factor, because aspen is drought-sensitive and exhibits lower growth rates and increased mortality under dry conditions (Michaelian *et al.* 2011; Worrall *et al.* 2013; Chen *et al.* 2017). Given that stressed plants can be more vulnerable to fire (Nolan *et al.* 2021), greater efficacy of prescribed fire on aspen might be expected under drought conditions.

We report a case study of the application of prescribed fire to an aspen stand experiencing drought stress: a small aspen stand that was observed to be dying back during a dry period was subject to a spring-prescribed fire. The objectives of the study were to assess post-fire mortality and recovery in this stand, including how the pre-fire size of individual mature trees influenced mortality rates and rates of sapling re-establishment post-fire.

Methods

Field site and study design

The study was conducted on Kernen Prairie (52°10'N, 106°33'W), a 130-ha relic fescue grassland on the east side of Saskatoon, Saskatchewan, Canada (Pylypec 1986). The site is on the southern edge of the Aspen Parkland ecoregion (Coupland 1961) and is characterized by Plains Rough Fescue (*Festuca hallii* (Vasey) Piper) grassland communities with several small (<0.5 ha) isolated stands of *P. tremuloides* in low and moist areas underlain by Dark Brown Chernozem soils (Saskatchewan Land Resource Unit 2009).

Our study focussed on a 0.45-ha aspen stand in the northeast corner of Kernen Prairie. The stand, which is visible in 1960s aerial photographs, has had a static boundary for at least 20 years and no record of a previous fire. Anecdotal observation of the stand suggested that it was under drought stress, because the area had experienced drought conditions for the previous four years (Agriculture and Agri-Food Canada 2023), and many individual stems died between 2017 and 2020. In spring 2020, one year before the fire, an electric fence was established around the aspen stand to prevent grazing by cattle and to allow for the accumulation of understorey grass litter, primarily Smooth Brome (*Bromus inermis* Leysser) fuel. The fence was removed to avoid fire damage, then replaced post-fire to exclude cattle during the study.

The stand was burned in April 2021 with the objective of reducing woody cover. Blacklines, or burned fireguards, were established by ignition off mowed fireguards in open grassland ~50 m outside the perimeter of the aspen stand. Blacklines width was increased by allowing backfires to creep into the burn unit. Headfires, or fires pushed by the wind, were started from the north and west sides and burned through the stand. Headfire flame lengths (3–5 m) reached into the tree canopy; consumption of grass fuel was complete on the stand margins, but several small patches of unburned understorey fuel remained in the interior. Mop-up, or final extinguishment of the fire, was conducted using hand tools and backpack sprayers; fallen logs were turned over during mop-up but no standing trees were cut or otherwise disturbed.

Field sampling

The stand was surveyed in 2020 (before the fire) and annually post-fire from 2021 to 2023. Before the fire in July and August 2020, the stand was surveyed comprehensively, with all mature stems (≥ 2 m high) mapped and tagged; saplings (<2 m) were surveyed in a 623 m² area in the north half of the stand. All surveyed stems were located using a differential Global Positioning System receiver (Geo7x; Trimble Inc., Westminster, Colorado, USA), measured for diameter at breast height, and classified as live or dead (green leaves present or absent). All stems were marked using a numbered aluminum tag. Post-fire sampling in August or September 2021, 2022, and 2023 included the relocation of each mature stem for a visual measure of injury class (Table 1), adapted from Brown and DeByle (1987). In 2021, each pre-fire sapling location was checked. Because all pre-fire saplings were dead in 2021 (generally completely consumed), we did not resurvey for them in subsequent years. The area of the stand previously surveyed for saplings was resurveyed for new saplings each year.

Statistical analysis

We examined how pre-fire mature tree size affected survival using a generalized linear model (GLM). Specifically, live and dead stem diameters were compared using a model with diameter as the response variable, status (live or dead) as a categorical predictor, and a binomial family. Models were fit using the *glm* function in R version 4.2.1 (R Development Core Team 2022).

Results

The pre-fire stand included 1047 mature trees of which 374 (35.6%) were alive (Figure 1). Live trees were significantly larger in diameter than dead ones (live: 15.1 cm $\pm$ 2.5 SD, dead: 2.6 cm $\pm$ 2.8; $F_{1, 1045} = 208.9$; $P < 0.001$); following the fire in 2021, only 114 of the 374 trees living in 2020 remained alive

TABLE 1. Injury classes of surviving Trembling Aspen (*Populus tremuloides*) and corresponding indicators of fire damage at Kernen Prairie near Saskatoon, Saskatchewan, Canada.*

Injury class	Damage characteristics
1. Dead	Stems charred for full circumference for at least one metre in height; no green foliage
2. Major damage	Majority of fire-damaged stem area charred with some browning; trace amounts of green foliage present
3. Moderate damage	Fire-damaged stem area is equal parts charring and browning; moderate amounts of green foliage present
4. Minor damage	Majority of fire-damaged stem area is browned with some charring; most branches support green foliage
5. Healthy	No apparent fire damage; abundant green foliage

*Adapted from Brown and DeByle (1987).

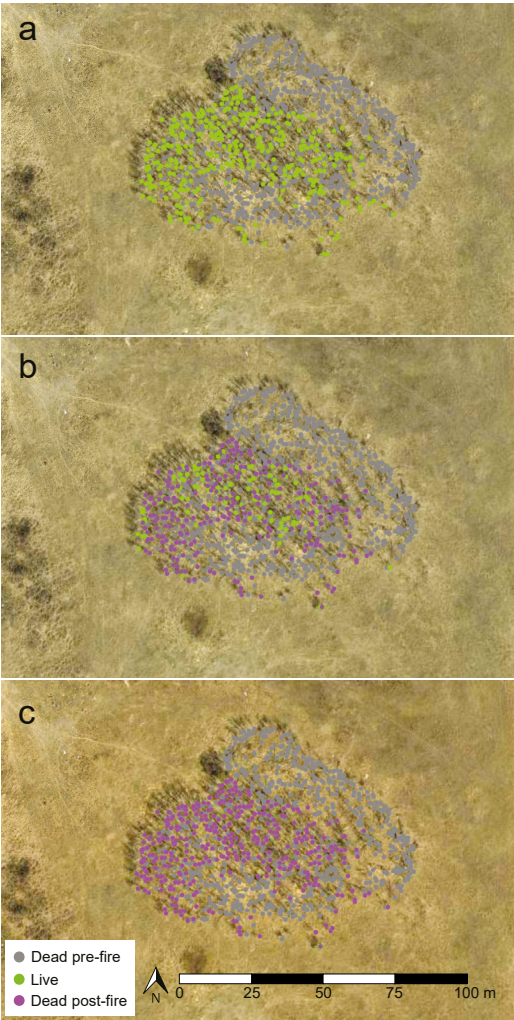


FIGURE 1. Map of mature Trembling Aspen (*Populus tremuloides*) stems at Kernen Prairie near Saskatoon, Saskatchewan, Canada, in the stand pre-fire (a) and one- (b), and two years (c) post-fire. Dead post-fire stems were alive pre-fire.

(Figure 2; Table 2). Of the living trees post-fire in 2021, 64.0% were in injury class 2 (major injury), 35.1% in class 3 (moderate injury), and 0.9% in class 4 (minor injury). No stems were injury free (class 5). Size did not influence survival, because there was no difference in stem diameter between live individuals in 2020 that were dead in 2021 and those that had survived (live: 15.4 cm $\pm$ 2.5, dead: 15.0 cm $\pm$ 2.4; $F_{1,372} = 2.3$, $P = 0.132$). Mortality was almost complete in follow-up surveys. In 2022, only two of the 114 live individuals from 2021 remained alive (injury class 2). In 2023, eight live stems were observed; the two live stems observed in 2022 that were classified as injury class 3 and six stems classified as live in 2021 (injury class 1–3) but not considered live in 2022 showed evidence of recovery (healthy bark, budding, and small numbers of leaves). There was no clear spatial pattern to the mortality of mature individuals (Figure 1).

The pre-fire stand included 424 saplings in a 623-m² subset of the stand (6806 saplings/ha or ~3060 saplings in the 0.45-ha stand). Post-fire in 2021, there were no surviving saplings, and no new sapling emergence was documented. In 2022, 11 of the pre-fire saplings were found alive, resprouting from a burned stem base marked with a tag before the fire, and 189 new saplings were documented in the sampling area (3210 saplings/ha). In 2023, four of the 11 pre-fire saplings observed in 2022 were confirmed alive and one dead. Missing tags precluded confirmation of the fate of the remaining six saplings. Thirty-eight of the new 2022 saplings were located and confirmed alive in 2023 and 145 new saplings were identified (3002 saplings/ha).

Discussion

As observed in many studies (Brown and DeByle 1987; Ripley and Archibold 1999), prescribed fire was effective in killing mature Trembling Aspen stems with 30% survival one year after fire and only 2% survival three years post-fire. Our survival rates were slightly higher than those of some previous

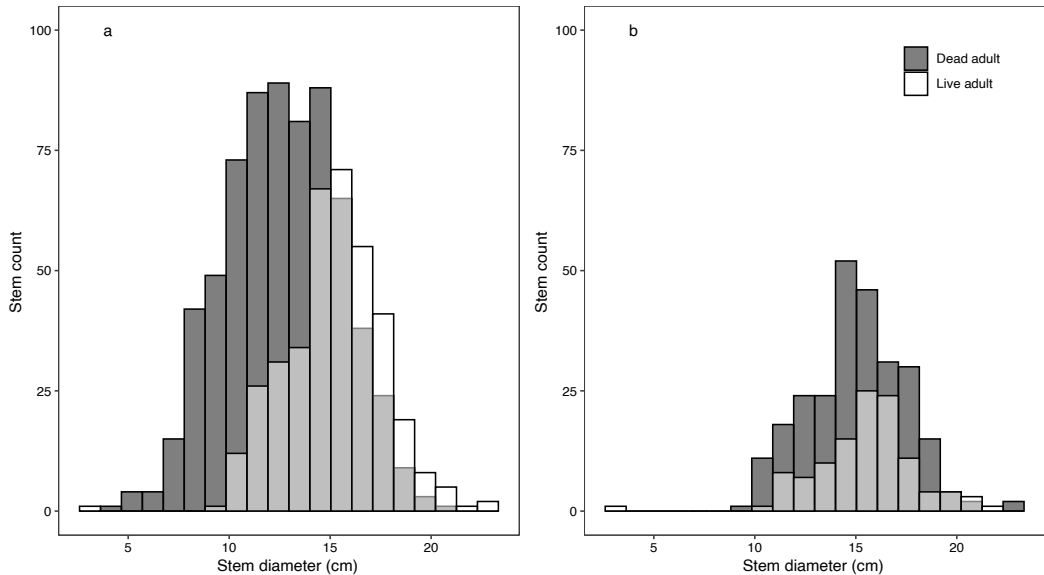


FIGURE 2. Stem diameter distributions of a. living and dead pre-fire (2020) and b. post-fire (2021) mature stems of Trembling Aspen (*Populus tremuloides*) at Kernen Prairie near Saskatoon, Saskatchewan, Canada. Post-fire stems include only those that were alive pre-fire in 2020. Light grey shading indicates overlap between live and dead stem counts.

TABLE 2. Characteristics of surviving mature stems of Trembling Aspen (*Populus tremuloides*) at Kernen Prairie near Saskatoon, Saskatchewan, Canada, including stem counts and basal area (m²/ha) by diameter and injury class one year post-fire (2021).

DBH	Major damage (2)		Moderate damage (3)		Minor damage (4)	
	Count	Basal area	Count	Basal area	Count	Basal area
<10 cm	1	0.002	0	0.000	0	0.000
10–15 cm	25	0.754	16	0.504	0	0.000
15–20 cm	43	2.138	24	1.123	1	0.042
>20 cm	4	0.308	0	0.000	0	0.000
Total	73	3.202	40	1.627	1	0.042

Note: DBH = diameter at breast height.

studies, which found near complete mortality within the first year after the fire. Aspens with larger diameters often have lower fire-related mortality (Brown and DeByle 1987; Alexander and Sando 1989); however, we found no differences in survival based on size in our study. Size effects in our study may be more limited than those in other post-fire studies because of the much smaller maximum size and narrow size range typical in small stands at the southern edge of the Aspen Parkland (Cordes 1965). In our prescribed fire, flames nearing maximum tree height (3–5 m) were achieved with the heavy understorey grass fuels, whereas in larger stands with more woody surface fuel, flames well below the upper canopy would be expected.

The fire achieved complete sapling kill; no sap-

lings were observed one year after the fire, when abundant suckering would normally be expected (Brown and DeByle 1987; Ripley and Archibold 1999; Fraser *et al.* 2004; Paragi and Haggstrom 2007; Guedo and Lamb 2013; Margolis and Farris 2014). The lack of saplings we observed contrasts with the rapid establishment of aspen saplings observed following a spring 1995 prescribed fire in a similar aspen stand at the same site (Ripley and Archibold 1999). The 1995 fire was conducted during a relatively moist period (Bonsal and Regier 2007), in contrast to the prevailing drought conditions of our study beginning in 2016 and continuing post-fire until 2023 (Agriculture and Agri-Food Canada 2023). Together, our observations are consistent with the hypothesis that drought-stressed plants are

more vulnerable to fire (Nolan *et al.* 2021) and that prescribed fire under dry conditions can increase its efficacy for aspen control.

Some longer-term recovery was evident, with densities of ~3000 saplings/ha observed two and three years after the fire. These sapling densities are small relative to the tens of thousands per hectare commonly observed post-fire (Ripley and Archibold 1999; Fraser *et al.* 2004; Kreider and Yocom 2021). Overall, although the aspen stand was not eliminated by the single fire, substantial control was achieved, with post-fire sapling densities ~43% of pre-fire densities. Most saplings were likely vegetative suckers rather than seedlings; seedling establishment is likely extremely rare at the site, as intensive surveys of the site over many years have not identified aspen saplings in any location except in the vicinity of established stands (Attanayake 2020; Bell *et al.* 2020). The emergence of saplings two to three years after fire indicates that the stand will likely recover in the long-term; additional management will be required to revert the site completely to grassland.

Cattle grazing was excluded during the recovery period in our study, so we cannot evaluate how post-fire grazing might impact the sapling densities. Cattle preferentially rest in the shade of trees or tall shrubs at this site (E.G.L. pers. obs.); they would also likely be attracted by improved forage quality post-fire (Winter *et al.* 2014; Gross 2023; Vera-Velez *et al.* 2023). Intensive grazer activity could have positive (e.g., reduced competition from grasses) and negative (e.g., trampling and browsing of saplings) effects (Margolis and Farris 2014; Tarleton and Lamb 2021). A controlled grazing exclusion study would be required to evaluate the role of grazing.

In summary, the available evidence suggests that the prevailing dry conditions and moisture stress induced by the drought were responsible for the limited recovery of the stand. These results suggest that prescribed fire under drought conditions is likely more effective than fire under wet or normal conditions to achieve long-term aspen control in the Aspen Parkland ecoregion. Prescribed fire planning for aspen control should prioritize fires in woody areas over open grassland during drought periods. Excluding grazing from target aspen stands starting in mid-summer will allow grass understorey fuel buildup for sufficiently intense spring fires during the leaf bud period. Allowing grazer access immediately post-fire will maximize the potential for browsing and trampling to impact any aspen saplings that do emerge.

Author Contributions

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Literature Cited

- Agriculture and Agri-Food Canada.** 2023. Canadian drought monitor. Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada. Accessed 17 January 2024. <https://agriculture.canada.ca/en/agricultural-production/weather/canadian-drought-monitor>.
- Alexander, M., and R. Sando.** 1989. Fire behavior and effects in aspen-northern hardwood stands. Pages 17–21 in *Proceedings of the 10th Conference on Fire and Forest Meteorology*. Edited by D.C. MacIver, H. Auld, and R. Whitewood. Canadian Forest Service and Environment Canada, Ottawa, Ontario, Canada.
- Ascoli, D., M. Lonati, R. Marzano, G. Bovio, A. Cavallero, and G. Lombardi.** 2013. Prescribed burning and browsing to control tree encroachment in southern European heathlands. *Forest Ecology and Management* 289: 69–77. <https://doi.org/10.1016/j.foreco.2012.09.041>
- Attanayake, A.U.** 2020. Incorporating plant community structure in species distribution modelling: a species co-occurrence based composite approach. Ph.D. thesis, University of Saskatchewan, Saskatoon, Saskatchewan, Canada. Accessed 18 April 2025. <http://hdl.handle.net/10388/12579>.
- Bartos, D.L., and W.F. Mueggler.** 1981. Early succession in aspen communities following fire in western Wyoming. *Journal of Range Management* 34: 315–318. <https://doi.org/10.2307/3897859>
- Bell, J.K., S.D. Siciliano, and E.G. Lamb.** 2020. A survey of invasive plants on grassland soil microbial communities and ecosystem services. *Scientific Data* 7: 86. <https://doi.org/10.1038/s41597-020-0422-x>
- Bonsal, B., and M. Regier.** 2007. Historical comparison of the 2001/2002 drought in the Canadian Prairies. *Climate Research* 33: 229–242. <https://doi.org/10.3354/cr033229>
- Brown, J.K., and N.V. DeByle.** 1987. Fire damage, mortality, and suckering in aspen. *Canadian Journal of Forest Research* 17: 1100–1109. <https://doi.org/10.1139/x87-168>
- Chen, L., J.G. Huang, S.A. Alam, L. Zhai, A. Dawson, K.J. Stadt, and P.G. Comeau.** 2017. Drought causes reduced growth of Trembling Aspen in western Canada. *Global Change Biology* 23: 2887–2902. <https://doi.org/10.1111/gcb.13595>
- Cordes, L.D.** 1965. An ecological study of isolated *Populus tremuloides* stands. M.Sc. thesis, University of North Dakota, Grand Forks, North Dakota, USA. Accessed 18 April 2025. <https://commons.und.edu/theses/3868>.
- Coupland, R.T.** 1961. A reconsideration of grassland clas-

- sification in the Northern Great Plains of North America. *Journal of Ecology* 49: 135–167. <https://doi.org/10.2307/2257431>
- Fraser, E., S. Landhäusser, and V. Liefers. 2004. The effect of fire severity and salvage logging traffic on regeneration and early growth of aspen suckers in north-central Alberta. *Forestry Chronicle* 80: 251–256. <https://doi.org/10.5558/tfc80251-2>
- Gross, D.V. 2023. Applications of and barriers to prescribed fire for grassland management in Saskatchewan. Ph.D. thesis, University of Saskatchewan, Saskatoon, Saskatchewan, Canada. Accessed 18 April 2025. <https://hdl.handle.net/10388/15210>
- Gross, D.V., and E.G. Lamb. 2025. Strategies to reintroduce prescribed fire as a grassland management process on the Canadian prairies. *Ecological Solutions and Evidence* 6: e70035. <https://doi.org/10.1002/2688-8319.70035>
- Guedo, D.D., and E.G. Lamb. 2013. Prescribed burning has limited long-term effectiveness in controlling Trembling Aspen (*Populus tremuloides*) encroachment into fescue grassland in Prince Albert National Park. *Canadian Field-Naturalist* 127: 50–56. <https://doi.org/10.22621/cfn.v127i1.1407>
- Kreider, M.R., and L.L. Yocom. 2021. Low-density aspen seedling establishment is widespread following recent wildfires in the western United States. *Ecology* 102: e03436. <https://doi.org/10.1002/ecy.3436>
- Margolis, E.Q., and C.A. Farris. 2014. Quaking Aspen regeneration following prescribed fire in Lassen Volcanic National Park, California, USA. *Fire Ecology* 10: 14–26. <https://doi.org/10.4996/fireecology.1003014>
- Michaelian, M., E.H. Hogg, R.J. Hall, and E. Arsenault. 2011. Massive mortality of aspen following severe drought along the southern edge of the Canadian boreal forest. *Global Change Biology* 17: 2084–2094. <https://doi.org/10.1111/j.1365-2486.2010.02357.x>
- Nolan, R.H., L. Collins, A. Leigh, M.K.J. Ooi, T.J. Curran, T.A. Fairman, V. Resco de Dios, and R. Bradstock. 2021. Limits to post-fire vegetation recovery under climate change. *Plant, Cell & Environment* 44: 3471–3489. <https://doi.org/10.1111/pce.14176>
- Paragi, T.F., and D.A. Haggstrom. 2007. Short-term responses of aspen to fire and mechanical treatments in interior Alaska. *Northern Journal of Applied Forestry* 24: 153–157. <https://doi.org/10.1093/njaf/24.2.153>
- Pylypec, B. 1986. The Kernen prairie—a relict fescue grassland near Saskatoon, Saskatchewan. *Blue Jay* 44: 222–231. Accessed 21 May 2025. <https://bluejayjournal.ca/in dex.php/bluejay/article/view/4733/4722>
- R Development Core Team. 2022. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Ripley, E.A., and O.W. Archibald. 1999. Effects of burning on prairie aspen grove microclimate. *Agriculture, Ecosystems & Environment* 72: 227–237. [https://doi.org/10.1016/s0167-8809\(98\)00182-0](https://doi.org/10.1016/s0167-8809(98)00182-0)
- Romo, J.T. 2003. Reintroducing fire for conservation of fescue prairie association remnants in the northern Great Plains. *Canadian Field-Naturalist* 117: 89–99. <https://doi.org/10.5962/p.353866>
- Romo, J.T., P.L. Grilz, R.E. Redmann, and E.A. Driver. 1993. Standing crop, biomass allocation patterns and soil-plant water relations in *Symphoricarpos occidentalis* Hook. following autumn or spring burning. *American Midland Naturalist* 130: 106–115. <https://doi.org/10.2307/2426279>
- Saskatchewan Land Resource Unit. 2009. SKSIDv4, Digital Soil Resource Information for Agricultural Saskatchewan, 1:100,000 scale. Agriculture and Agri-Food Canada, Saskatoon, Saskatchewan, Canada. Accessed 17 January 2024 via Saskatchewan Soil Information System (SKSIS Working Group 2024). <http://sksis.ca>
- Soubry, I., and X. Guo. 2022. Quantifying woody plant encroachment in grasslands: a review on remote sensing approaches. *Canadian Journal of Remote Sensing* 48: 337–378. <https://doi.org/10.1080/07038992.2022.2039060>
- Tarleton, P., and E.G. Lamb. 2021. Modification of plant communities by bison in Riding Mountain National Park. *Ecoscience* 28: 67–80. <https://doi.org/10.1080/11956860.2020.1850622>
- Twidwell, D., W.E. Rogers, S.D. Fuhlendorf, C.L. Wonka, D.M. Engle, J.R. Weir, U.P. Kreuter, and C.A. Taylor, Jr. 2013. The rising Great Plains fire campaign: citizens' response to woody plant encroachment. *Frontiers in Ecology and the Environment* 11: e64–e71. <https://doi.org/10.1890/130015>
- Van Auken, O.W. 2000. Shrub invasions of North American semiarid grasslands. *Annual Review of Ecology, Evolution, and Systematics* 31: 197–215. <https://doi.org/10.1146/annurev.ecolsys.31.1.197>
- Vera-Velez, R., S.A. Grover, B.K. Bischoff, C.N. Carlyle, and E.G. Lamb. 2023. Wildfire-grazing impact on forage quality assessed with near-infrared spectroscopy and generalized partial least squares regression. *Rangeland Ecology & Management* 87: 132–140. <https://doi.org/10.1016/j.rama.2023.01.003>
- Waddington, J., and S. Bittman. 1987. Control of brush regrowth in northeastern Saskatchewan by several concentrations of herbicides applied with a roller. *Canadian Journal of Plant Science* 67: 467–475. <https://doi.org/10.4141/cjps87-066>
- Winter, S.L., S.D. Fuhlendorf, and M. Goes. 2014. Patch-burn grazing effects on cattle performance: research conducted in a working landscape. *Rangelands* 36: 2–7. <https://doi.org/10.2111/rangelands-d-13-00079.1>
- Worrall, J.J., G.E. Rehfeldt, A. Hamann, E.H. Hogg, S.B. Marchetti, M. Michaelian, and L.K. Gray. 2013. Recent declines of *Populus tremuloides* in North America linked to climate. *Forest Ecology and Management* 299: 35–51. <https://doi.org/10.1016/j.foreco.2012.12.033>
- Zentner, R.P., and G.G. Bowes. 1991. Economics of chemical brush control in pastures of east-central Saskatchewan. *Canadian Journal of Plant Science* 71: 1133–1141. <https://doi.org/10.4141/cjps91-155>

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NOTE

Apparent predation of a bison (*Bison bison*) calf by a Grizzly Bear (*Ursus arctos*) in southwestern Yukon

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Abstract

Grizzly Bear (*Ursus arctos*) predation on American Bison (*Bison bison*)—particularly calves—was likely once common. However, with the range-wide collapse of bison near the close of the 19th century, the two species no longer co-occur across much of their current distributions. Over the past 60 years, efforts to reintroduce bison to their native range have resulted in a few small areas where the two species once again co-occur. Yet, predation of bison by bears is apparently rare and has not been observed outside Yellowstone National Park, where both species have existed for millennia. On 28 June 2023, we observed an adult male Grizzly Bear protecting a buried bison calf that it had apparently killed in Yukon, Canada. This is the first observation of apparent predation of a bison by a Grizzly Bear outside Yellowstone National Park. Our observation further highlights how reintroduced bison are becoming integrated into local food webs, which is a key indicator of ecological restoration.

Key words: American Bison; *Bison bison*; Grizzly Bear; *Ursus arctos*; boreal food web; ecological restoration; predation; predator-prey interactions

American Bison (*Bison bison*) are among the most formidable prey because of their large size, great strength, group defensive behaviour, and hyper-aggressiveness toward predators (Smith *et al.* 2001; Mech *et al.* 2004; MacNulty *et al.* 2014). Gray Wolf (*Canis lupus*), their primary predator, is capable of killing adults and calves when working as a pack (Carbyn and Trottier 1987, 1988; MacNulty *et al.* 2001; Smith *et al.* 2001; Jung 2011; Jung *et al.* 2023b). Grizzly Bear (*Ursus arctos*; Varley and Gunther 2002; Wyman 2002) and Coyote (*Canis latrans*; Smith *et al.* 2001; Sheldon *et al.* 2009) have also been observed killing bison in Yellowstone National Park, usually with a focus on calves. No other contemporary carnivores are known to have killed bison.

Grizzly Bear predation of bison—particularly calves—was likely once common. However, with the range-wide collapse of bison near the close of the 19th century, these species no longer co-occur across much of their current distribution in North America. Predation of bison by Grizzly Bears has not been observed outside Yellowstone National Park, where

both species have existed for millennia.

Over the past 60 years, efforts to reintroduce bison to their native range have resulted in a few areas where the two species once again co-occur. Southwestern Yukon is home to the Aishihik population of reintroduced bison (Jung *et al.* 2015, 2023a; Boonstra *et al.* 2018), which has shared its distributional range with resident Grizzly Bears since 1988. These bison migrate into alpine areas during summer when their calves are young (Jung *et al.* 2018), bringing them into close proximity to resident Grizzly Bears. Over the past 20 years, we have frequently observed large groups of bison in alpine habitat (Jung 2020), sometimes with Grizzly Bears within about 50–250 m of them, often seemingly hiding in tall shrubs or in drainages. However, we had no evidence of bears hunting or killing bison. Here, we provide the first record of apparent predation of a bison by a Grizzly Bear in the mountains of southwestern Yukon.

On 28 June 2023, from a helicopter, we observed an adult male Grizzly Bear protecting a buried carcass in alpine tundra in southwestern Yukon, Canada.

Approximately 2–3 km ahead of the bear and carcass, we observed a group of ~30 bison with calves. We suspected that the carcass was a bison, so we used the helicopter to chase the bear away from the cache site so that we could inspect it. We verified that the carcass was a small bison calf that likely weighed <30 kg. A bloody rib cage was evidence that it was freshly dead and had recently been fed on by the bear (Figure 1). Moreover, freshly displaced vegetation and turf showed that the carcass had been recently buried by the bear (Figure 1). After ~10 min of observation, we left the carcass and site as found.

We cannot confirm whether the Grizzly Bear killed the calf or found and scavenged it. However, the most likely scenario is that the bear preyed rather than found the calf already dead because live calves were more common on the landscape than dead calves and a maternal group of bison was seen nearby. Our observation was not a surprise because we had previously observed Grizzly Bears scavenging carcasses of winter-killed bison in this area. Moreover, during aerial surveys of bison during the summer, when calves are precocious, we had observed Grizzly Bears near bison groups; we interpreted this as bears looking for an opportunity to kill a young or injured bison. Grizzly Bears in our region often prey on neonatal Moose (*Alces americanus*) calves, rather than adults (Larsen *et al.* 1989).

This is the first observation of apparent predation of a bison by a Grizzly Bear outside Yellowstone National Park in modern times. The Aishihik reintroduced bison numbered ~1951 adult animals in 2022 (95% CI 1688–2295; Jung *et al.* 2023a) and do not appear to be strongly affected by predation (Jung 2011; Jung *et al.* 2023b). However, a small number of Grizzly Bears that learn to become effective predators of bison calves could begin to limit bison population growth. That said, the frequency of Grizzly Bear predation of neonatal bison calves and the extent to which they affect calf recruitment in the Aishihik population is unknown. Regardless, predation is a natural process that shapes the evolutionary ecology of bison (Laundré *et al.* 2001; Fortin *et al.* 2009) and has the potential to influence local mammal assemblages and food webs (Boonstra *et al.* 2018). Our observation further highlights how reintroduced bison are becoming integrated into local food webs, which is a key indicator of ecological restoration (Sanderson *et al.* 2008; Jung *et al.* 2023b).

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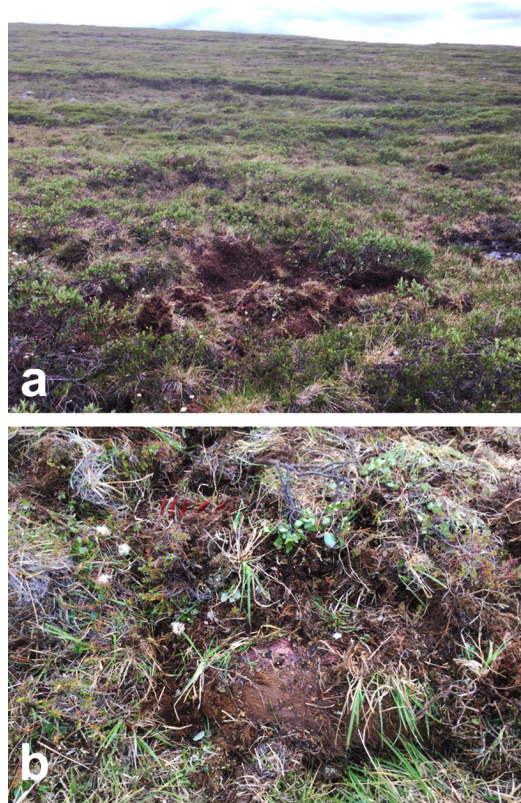


FIGURE 1. a. An American Bison (*Bison bison*) calf apparently killed, buried, and partly consumed by a Grizzly Bear (*Ursus arctos*) in the alpine tundra of southwestern Yukon, Canada. b. Close up of the buried calf carcass showing the rib cage and recently displaced vegetation. Photos: R. Drummond.

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Literature Cited

- Boonstra, R., S. Boutin, T.S. Jung, C.J. Krebs, and S. Taylor. 2018. Impact of rewilding, species introductions and climate change on the structure and function of the Yukon boreal forest ecosystem. *Integrative Zoology* 13: 123–138. <https://doi.org/10.1111/1749-4877.12288>
- Carbyn, L.N., and T. Trottier. 1987. Responses of bison on their calving grounds to predation by wolves in Wood Buffalo National Park. *Canadian Journal of Zoology* 65: 2072–2078. <https://doi.org/10.1139/z87-317>
- Carbyn, L.N., and T. Trottier. 1988. Descriptions of wolf attacks on bison calves in Wood Buffalo National Park. *Arctic* 41: 297–302. <https://doi.org/10.14430/arctic1736>
- Fortin, D., M.E. Fortin, H.L. Beyer, T. Duchesne, S. Courant, and K. Dancose. 2009. Group-size-mediated habitat selection and group fusion–fission dynamics of bison under predation risk. *Ecology* 90: 2480–2490. <https://doi.org/10.1890/08-0345.1>

- Jung, T.S.** 2011. Gray Wolf (*Canis lupus*) predation and scavenging of reintroduced American Bison (*Bison bison*) in southwestern Yukon. *Northwestern Naturalist* 92: 126–130. <https://doi.org/10.1898/10-07.1>
- Jung, T.S.** 2020. Investigating local concerns regarding large mammal restoration: group size in a growing population of reintroduced bison (*Bison bison*). *Global Ecology and Conservation* 24: e01303. <https://doi.org/10.1016/j.gecco.2020.e01303>
- Jung, T.S., R. Drummond, S.D. Taylor, K. Kuba, R. Osborne, C. Pinard, and T.J. Grantham.** 2023a. Results of the 2022 mark-resight survey of the Aishihik bison (*Bison bison*) population. Report SR-23-01. Fish and Wildlife Branch, Government of Yukon, Whitehorse, Yukon, Canada.
- Jung, T.S., N.C. Larter, C.J. Lewis, C. Thacker, and S.D. Taylor.** 2023b. Wolf (*Canis lupus*) predation and scavenging of reintroduced bison (*Bison bison*): a hallmark of ecological restoration to boreal food webs. *European Journal of Wildlife Research* 69: 50. <https://doi.org/10.1007/s10344-023-01676-0>
- Jung, T.S., N.C. Larter, and T. Powell.** 2018. Early and late births in high-latitude populations of free-ranging bison (*Bison bison*). *Canadian Field-Naturalist* 132: 219–222. <https://doi.org/10.22621/cfn.v132i3.1983>
- Jung, T.S., S.A. Stotyn, and S.M. Czetwertynski.** 2015. Dietary overlap and potential competition in a dynamic ungulate community in northwestern Canada. *Journal of Wildlife Management* 79: 1277–1285. <https://doi.org/10.1002/jwmg.946>
- Larsen, D.G., D.A. Gauthier, and R.L. Markel.** 1989. Causes and rate of Moose mortality in the southwest Yukon. *Journal of Wildlife Management* 53: 548–557. <https://doi.org/10.2307/3809175>
- Laundré, J.W., L. Hernández, and K.B. Altendorf.** 2001. Wolves, elk, and bison: reestablishing the “landscape of fear” in Yellowstone National Park, USA. *Canadian Journal of Zoology* 79: 1401–1409. <https://doi.org/10.1139/cjz-79-8-1401>
- MacNulty, D.R., A. Tallian, D.R. Stahler, and D.W. Smith.** 2014. Influence of group size on the success of wolves hunting bison. *PLoS ONE* 9: e112884. <https://doi.org/10.1371/journal.pone.0112884>
- MacNulty, D.R., N. Varley, and D.W. Smith.** 2001. Grizzly Bear, *Ursus arctos*, usurps bison calf, *Bison bison*, captured by wolves, *Canis lupus*, in Yellowstone National Park, Wyoming. *Canadian Field-Naturalist* 115: 495–498. <https://doi.org/10.5962/p.363829>
- Mech, L.D., R.T. McIntyre, and D.W. Smith.** 2004. Unusual behavior by bison, *Bison bison*, toward Elk, *Cervus elaphus*, and wolves, *Canis lupus*. *Canadian Field-Naturalist* 118: 115–118. <https://doi.org/10.22621/cfn.v118i1.892>
- Sanderson, E.W., K.H. Redford, B. Weber, K. Aune, D. Baldes, J. Berger, D. Carter, C. Curtin, J. Derr, S. Dobrott, and E.V.A. Fearn.** 2008. The ecological future of the North American Bison: conceiving long-term, large-scale conservation of wildlife. *Conservation Biology* 22: 252–266. <https://doi.org/10.1111/j.1523-1739.2008.00899.x>
- Sheldon, J.W., G. Reed, A.C. Burnett, K. Li, and R.L. Crabtree.** 2009. Coyote, *Canis latrans*, predation on a bison, *Bison bison*, calf in Yellowstone National Park. *Canadian Field-Naturalist* 123: 260–261. <https://doi.org/10.22621/cfn.v123i3.974>
- Smith, D.W., K.M. Murphy, and S. Monger.** 2001. Killing of a bison, *Bison bison*, calf by a wolf, *Canis lupus*, and four Coyotes, *Canis latrans*, in Yellowstone National Park. *Canadian Field-Naturalist* 115: 343–345. <https://doi.org/10.5962/p.363796>
- Varley, N., and K.A. Gunther.** 2002. Grizzly Bear predation on a bison calf in Yellowstone National Park. *Ursus* 13: 377–381.
- Wyman, T.** 2002. Grizzly Bear predation on a bull bison in Yellowstone National Park. *Ursus* 13: 375–377.

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A Spinops sternbergorum (Ornithsichia: Ceratopsia) parietal from the Dinosaur Park Formation (upper Campanian) of Muddy Lake, Saskatchewan

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Abstract

The upper Campanian deposits of the Dinosaur Park Formation at Muddy Lake, Saskatchewan, are known to contain the bones of one or more horned dinosaur species, but definitive diagnostic material has remained elusive. Here, we describe a newly recognized partial parietal from these deposits, bearing a single spike-like epiossification that projects posterolaterally from the frill margin. The element is most plausibly attributable to the centrosaurine *Spinops sternbergorum*, a species otherwise known only from Dinosaur Provincial Park, Alberta. Juvenile ceratopsids appear to be relatively abundant at the Muddy Lake locality, which was proximal to the Western Interior Seaway. We suggest that such lowland coastal settings might have been important breeding grounds for horned dinosaurs.

Key words: Horned dinosaurs; Ceratopsia; Muddy Lake; Saskatchewan; Dinosaur Park Formation; Campanian

Introduction

The Dinosaur Park Formation (DPF) at Dinosaur Provincial Park, Alberta, contains one of the best studied dinosaur assemblages in the world (Currie and Koppelhus 2005), as it documents the diversity and evolution of a single chronofauna (*sensu* Olson 1952) during the late Campanian (Ryan and Evans 2005; Mallon *et al.* 2012; Mallon 2019). The DPF is exposed elsewhere in southeastern Alberta and southwestern Saskatchewan (Eberth and Hamblin 1993; Gilbert *et al.* 2020), but those outcrops are neither as well exposed nor as fossiliferous as the DPF. Consequently, their fossil assemblages are not yet as well understood.

The northernmost exposure of the DPF occurs at Muddy Lake, ~12 km south of Unity, Saskatchewan (Figure 1). Exposures there are limited in geographic and stratigraphic extent, but they are fossil bearing and host a mixed microsite (Royal Saskatchewan Museum, Regina, Saskatchewan, Canada [RSKM] locality 73C06-0001) containing the remains of typi-

cal Late Cretaceous vertebrate taxa, including fishes, amphibians, mammals, champsosaurs, turtles, crocodilians, tyrannosaurids, ornithomimids, paravians, hadrosaurids, and ceratopsids (Eberth *et al.* 1990; Brinkman *et al.* 1998).

Isolated ceratopsid elements are also common. Two ceratopsid nasal horncores were described by Eberth *et al.* (1990). One of them (RSKM P2105.1) closely resembles the condition in *Centrosaurus apertus* and other members of the tribe Centrosaurini; however, Eberth *et al.* (1990) were unable to find a match for the other (RSKM P1990.6) among then-known ceratopsids, and they tentatively suggested that it might represent a new taxon. Unfortunately, because nasal horncores vary so widely in morphology even within a single taxon or population (e.g., Sampson *et al.* 1997; Frederickson and Tumarkin-Deratzian 2014), they are of limited diagnostic value at the species level. In isolation, the nasal horncores at Muddy Lake are probably not diagnoseable beyond Centrosaurini indeterminate.

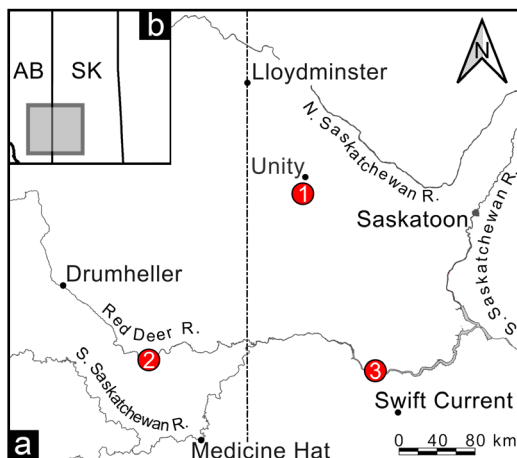


FIGURE 1. a. Map showing location of Muddy Lake exposures (1), Dinosaur Provincial Park (2), and Lake Diefenbaker bonebed (3) along b. the Alberta (AB)/Saskatchewan (SK) border.

In this contribution, we briefly review the ceratopsid material collected from the Muddy Lake badlands and describe a newly recognized parietal element, which is of greater diagnostic utility within Ceratopsia (Dodson *et al.* 2004). We also discuss the implications of the Muddy Lake fossils for matters of ceratopsid palaeobiology.

Geological Setting

The DPF is the youngest and most fossiliferous of three terrestrial formations (along with the Foremost and Oldman formations, in ascending order; Figure 2) that comprise the regressive-transgressive clastic wedge of the middle-upper Campanian Belly River Group (Eberth and Hamblin 1993; Eberth 2005). This clastic wedge is bounded below by the marine Pakowki Formation and the Lea Park Formation in Alberta and Saskatchewan, respectively, and is bounded above by the marine Bearpaw Formation in both provinces. The Belly River Group consists primarily of mudstones, sandstones, and occasional coaly layers that represent alluvial-coastal plain and nearshore deposits along the margin of the Western Interior Seaway. In the area of Dinosaur Provincial Park, Alberta, the group is ~270 m thick, with the uppermost ~90 m exposed in outcrop (Eberth 2005). Uranium-lead dating of the bentonite exposures here has recently yielded ages between 76.718 ± 0.020 and 74.289 ± 0.014 million years ago for the DPF (Ramezani *et al.* 2022).

The Belly River Group wedge thins eastward to a thickness of no more than 75 m (including sub-surface) in the area of Muddy Lake, Saskatchewan (Eberth *et al.* 1990), ~235 km northeast of Dinosaur

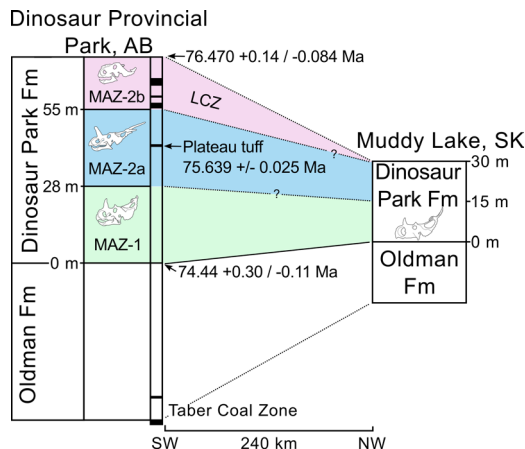


FIGURE 2. Correlation of the Dinosaur Park and Oldman formations in Dinosaur Provincial Park, Alberta (AB), with the equivalent formations at Muddy Lake, Saskatchewan (SK). Radiometric dates from Eberth *et al.* (2023), Dinosaur Provincial Park megaherbivore assemblage zones from Mallon *et al.* (2012). Note: Fm, Formation; LCZ, Lethbridge Coal Zone; Ma, mega-annum; MAZ, Megaherbivore Assemblage Zone.

Provincial Park. Here, the outcrop measures just 55 m thick, exposing part of the Oldman Formation (25 m) and the entirety of the DPF (30 m). Despite palynostratigraphic analysis (Eberth *et al.* 1990), more precise correlation with the deposits at Dinosaur Provincial Park has not yet been possible. Local fossil vertebrate remains are restricted to the lower 15 m of the DPF.

Review of Muddy Lake Ceratopsid Material

Beyond the mixed bonebed assemblage mentioned above, the exposures of the DPF at Muddy Lake have also yielded isolated bones, distributed over ~21 sites, collected primarily by T.T.T. during the late 1980s. Isolated ceratopsid bones—many quite small (juvenile size class of Ryan *et al.* 2001)—are most common, representing various parts of the skeleton (Figure 3). Two nasal horncores were ably described by Eberth *et al.* (1990), but we will comment further on the aberrant horncore (RSKM P1990.6). This horncore (Figure 3e) is notable for its relative shortness, subcircular cross-section, and forward inclination. We note, however, that it has buckled in two places—near the base and at mid-length—which somewhat exaggerates its slant. Nevertheless, the forward inclination of the horncore can only partly be explained by post-depositional factors, and we agree with Eberth *et al.* (1990) that the specimen is without equal in the ceratopsid fossil record. Despite its relatively small size (apicobasal length = 13 cm), the lack of an internasal

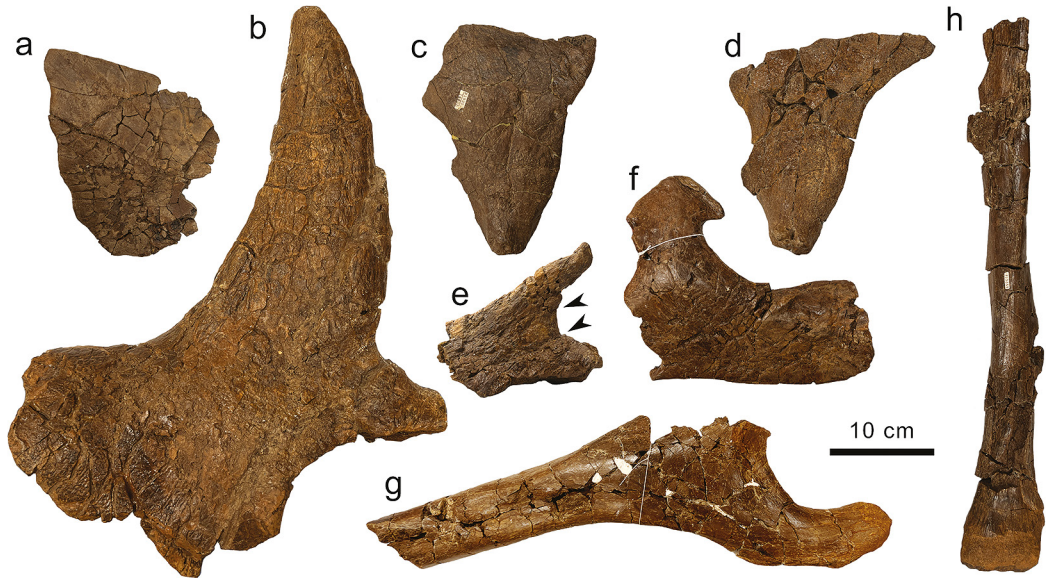


FIGURE 3. Ceratopsid material from the Dinosaur Park Formation at Muddy Lake, Saskatchewan, Canada. a. Right squamosal (RSKM 1951.65), lateral view. b. Nasal horncore (RSKM P2105.1), right lateral view. c. Right jugal (RSKM P1990.1), lateral view. d. Right jugal (RSKM P2159.25), lateral view. e. Nasal horncore (RSKM P1990.6), right lateral view; arrows indicate areas of buckling. f. Partial right dentary (RSKM P1951.68), right lateral view. g. Proximal right ischium (RSKM P2305.3), lateral view. h. Probable left fibula (RSKM 2305.4), anterior view. Photos: Jordan Mallon.

suture suggests that it may be somatically mature, although we cannot discount the alternative possibility that the unusual horncore is pathological or developmentally anomalous.

Other ceratopsid material from Muddy Lake is shown in Figure 3. Most of the elements are not diagnostic beyond the family level; however, aside from the nasal horncores described by Eberth *et al.* (1990), the single right squamosal (RSKM 1951.65; Figure 3a) can also be confidently attributed to the subfamily Centrosaurinae, based on its stout proportions and the presence of a “step” along the medial parietal contact (Dodson *et al.* 2004). The element is small (anteroposterior length ~20 cm, as preserved) and bears six episquamosal loci. It also exhibits a long-grained surface texture indicative of its immature status (Sampson *et al.* 1997; Brown *et al.* 2009). Two isolated jugals (RSKM P1990.1 and P2159.25) are likewise quite small and lack fused epijugals (Figure 3c,d), characteristic of juvenile ceratopsids (Sampson *et al.* 1997; Horner and Goodwin 2008).

Description of RSKM P2178.1

Originally identified in the field as a rib, this, in fact, proves to be a partial left transverse parietal bar bearing a large epioassification (Figure 4a,b; 3D model available for restricted download at <https://www.morphosource.org/concern/media/000>

701290?locale=en). As preserved, the transverse bar measures ~27 cm across. The contact with the median parietal bar is missing. The transverse bar is broken anteriorly, so it is not possible to determine whether a parietal fenestra was originally present, which is otherwise common in ceratopsids (Dodson *et al.* 2004). The surficial bone is smooth and without vascular sulci.

An enlarged (midline apicobasal length = 19 cm) epiparietal spike caps the margin of the transverse bar laterally. The basal suture is visible dorsally but not ventrally. The spike is narrow dorsoventrally, lies entirely within the plane of the frill, and projects posterolaterally, gently curving laterally along its length. The epioassification is scored lengthwise on the dorsal surface by two deep sulci. Similar sulci are otherwise seen on the marginal epioassifications and nasal horncores of some centrosaurines (e.g., Sampson *et al.* 1997; Mallon *et al.* 2022) and, very rarely, chasmosaurines (e.g., Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta, Canada [TMP] specimen 2015.018.0012). There are otherwise no other obvious signs of epioassifications or their attachments along the preserved transverse parietal bar.

We interpret RSKM P2178.1 as plausibly attributable to *Spinops sternbergorum*.

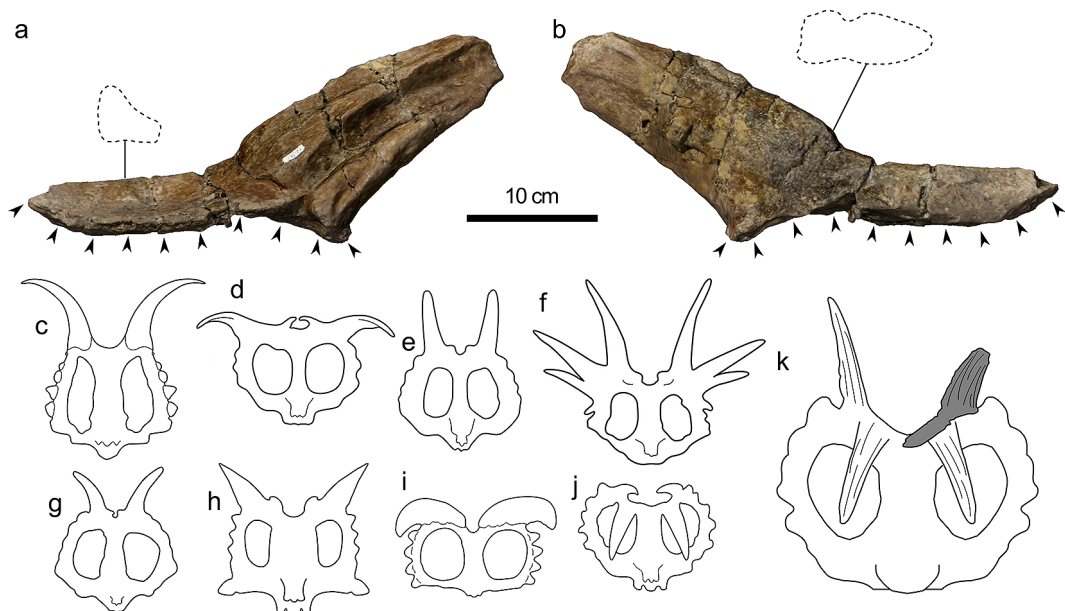


FIGURE 4. Parietal fragment of RSKM P2178.1 showing attached epioossification and centrosaurine frills for comparison. a. Anterior view (dashed outline shows cross-section of incomplete transverse parietal bar). b. Posterior view (dashed outline shows cross-section at base of epiparietal spike). Arrows in a and b point to broken bone margins. c. *Diabloceratops eatoni*. d. *Pachyrhinosaurus lakustai*. e. *Einiosaurus procurvicornis*. f. *Styracosaurus albertensis*. g. *Achelousaurus horneri*. h. *Xenoceratops foremostensis*. i. *Albertaceratops nesmoi*. j. *Centrosaurus apertus*. k. Outline of *Spinops sternbergorum* (NHMUK R16307) showing the proposed placement of RSKM P2178.1. Frill outlines in c–j modified from Ryan *et al.* (2012), in k modified from Farke *et al.* (2011); not to the same scale. Photos: Jordan Mallon.

Discussion

The centrosaurine *S. sternbergorum* is previously known only from Dinosaur Provincial Park (Farke *et al.* 2011). A spike-like epiparietal morphology is not yet known in any chasmosaurine from the DPF, and the avascular nature of the frill is more consistent with a centrosaurine identity. In some regards, the spike superficially resembles the posterolaterally projecting P3 epiparietal (see Sampson *et al.* 1997 for epiparietal numbering scheme) of some pachyrhinosaurins (e.g., *Einiosaurus procurvicornis*, *Achelousaurus horneri*; Figure 4e,g), which are represented in the DPF by just a single example lacking a parietal (Ryan *et al.* 2010). However, pachyrhinosaurin P3 epiparietals do not exhibit the deep sulci seen in RSKM P2178.1. The spike is most consistent with the P2 or P3 epiparietal (depending on the chosen homology scheme; see Farke *et al.* 2011) of *S. sternbergorum*, which similarly projects from the posterior margin of the frill and is deeply sulcate. In the only other known parietals of this species (Natural History Museum [NHMUK], London, United Kingdom specimens R16307 and R16308), the spike is straight and projects strongly posteriorly. However, epiparietal curvature and orientation are known to vary widely

within single centrosaurine populations (e.g., *Centrosaurus apertus*, Brown 2013; *Styracosaurus albertensis*, Brown *et al.* 2020; *Pachyrhinosaurus lakustai*, Currie *et al.* 2008), and the differences between the RSKM and NHMUK specimens are wholly within the expected realm of variation. In *S. sternbergorum*, the posteriorly projecting (P2 or P3) epiparietal spike is laterally adjacent to an anteriorly curled P1 epiparietal (Farke *et al.* 2011). This has likely broken away in RSKM P2178.1, but the dorsally raised bone surface here (Figure 4a) may indicate the base of this P1 epiparietal. Our taxonomic identification of the parietal element is consistent with the other Muddy Lake centrosaurine material noted above.

The original *S. sternbergorum* material described by Farke *et al.* (2011) was collected from a bonebed by Charles H. Sternberg in 1916. Unfortunately, the original locality within the Steveville badlands of Dinosaur Provincial Park is unknown, and it is therefore not possible to situate the material stratigraphically. Local exposures limit the locality to either the uppermost Oldman Formation or the lower DPF. Our identification of the Muddy Lake centrosaurine as *S. sternbergorum* suggests the latter might be the more likely host stratum. This interpretation is consistent

with the fact that the only centrosaurine presently known from the Oldman Formation in Dinosaur Provincial Park (and its equivalent in the Comrey Sandstone near Onefour, Alberta) is *Coronosaurus brinkmani*, known from hundreds of elements distributed between two bonebeds (Ryan and Russell 2005).

From the preferential preservation of ceratopsid microfossils (e.g., teeth) at Muddy Lake and other localities proximal to the ancient Western Interior Seaway, Brinkman *et al.* (1998) hypothesized that ceratopsids may have preferred living in the coastal lowlands. Further, based on the abundance of ceratopsid bonebeds ~235 km to the southwest at Dinosaur Provincial Park, distal to the ancient seaway, they reasoned that ceratopsids may have regularly migrated westward to more inland settings, where they lived communally for at least part of the year. However, Brinkman *et al.* (1998) were unable to situate the nesting grounds of these animals for lack of evidence.

It is remarkable that so many of the isolated bones from Muddy Lake belong to small, likely juvenile, ceratopsids. Similar remains are also known from Dinosaur Provincial Park (e.g., Dodson and Currie 1988; Currie *et al.* 2016), although apparently in lower relative abundance. If the inland-coastal migration hypothesis of Brinkman *et al.* (1998) is correct, it is conceivable that the eastern, lowland deposits at Muddy Lake represent ceratopsid nesting grounds. However, we note that embryonic and hatchling bones are yet unknown at Muddy Lake, as are eggshells, so this speculation may be premature (the apparently uncalcified eggshells of ceratopsians makes it less likely that supporting evidence is forthcoming; Norrell *et al.* 2020). The ichnologic record is uninformative regarding ceratopsid movements, being largely devoid of ceratopsid tracks. We note that the *C. apertus* bonebed at Lake Diefenbaker (Figure 1), recently described by Demers-Potvin and Larsson (2024), suggests that ceratopsids lived communally in coastal lowlands proximal to the ancient seaway, as well.

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Literature Cited

Brinkman, D.B., M.J. Ryan, and D.A. Eberth. 1998. The paleogeographic and stratigraphic distribution of ceratopsids (Ornithischia) in the upper Judith River Group

of western Canada. *Palaos* 13: 160–169. <https://doi.org/10.2307/3515487>

- Brown, C.M. 2013. Advances in quantitative methods in dinosaur palaeobiology: a case study in horned dinosaur evolution. Ph.D. thesis, University of Toronto, Toronto, Ontario, Canada. Accessed 6 August 2025. <https://utoronto.scholaris.ca/server/api/core/bitstreams/a02dbe12-af1b-4fdc-a18d-7bfa726f67cd/content>.
- Brown, C.M., R.B. Holmes, and P.J. Currie. 2020. A subadult individual of *Styracosaurus albertensis* (Ornithischia: Ceratopsidae) with comments on ontogeny and intraspecific variation in *Styracosaurus* and *Centrosaurus*. *Vertebrate Anatomy Morphology Palaeontology* 8: 67–95. <https://doi.org/10.18435/vamp29361>
- Brown, C.M., A.P. Russell, and M.J. Ryan. 2009. Pattern and transition of surficial bone texture of the centrosaurine frill and their ontogenetic and taxonomic implications. *Journal of Vertebrate Paleontology* 29: 132–141. <https://doi.org/10.1671/039.029.0119>
- Currie, P.J., R.B. Holmes, M.J. Ryan, and C. Coy. 2016. A juvenile chasmosaurine ceratopsid (Dinosauria, Ornithischia) from the Dinosaur Park Formation, Alberta, Canada. *Journal of Vertebrate Paleontology* 36: e1048348. <https://doi.org/10.1080/02724634.2015.1048348>
- Currie, P.J., and E.B. Koppelhus. 2005. Dinosaur Provincial Park: a Spectacular Ancient Ecosystem Revealed. Indiana University Press, Bloomington, Indiana, USA.
- Currie, P.J., W. Langston, Jr., and D.H. Tanke. 2008. A new species of *Pachyrhinosaurus* (Dinosauria, Ceratopsidae) from the Upper Cretaceous of Alberta, Canada. Pages 1–108 in *A New Horned Dinosaur from an Upper Cretaceous Bone Bed in Alberta*. Edited by P.J. Currie, W. Langston, Jr., and D.H. Tanke. NRC Research Press, Ottawa, Ontario, Canada.
- Demers-Potvin, A.V., and H.C. Larsson. 2024. Occurrence of *Centrosaurus apertus* (Ceratopsidae: Centrosaurinae) in Saskatchewan, Canada, and expanded dinosaur diversity in the easternmost exposure of the Late Cretaceous (Campanian) Dinosaur Park Formation. *Canadian Journal of Earth Sciences* 61: 1127–1155. <https://doi.org/10.1139/cjes-2023-0125>
- Dodson, P., and P.J. Currie. 1988. The smallest ceratopsid skull—Judith River Formation of Alberta. *Canadian Journal of Earth Sciences* 25: 926–930. <https://doi.org/10.1139/e88-090>
- Dodson, P., C.A. Forster, and S.D. Sampson. 2004. Ceratopsidae. Pages 494–513 in *The Dinosauria*. Second Edition. Edited by D.B. Weishampel, P. Dodson, and H. Osmólska. University of California Press, Berkeley, California, USA.
- Eberth, D.A. 2005. The geology. Pages 54–82 in *Dinosaur Provincial Park: a Spectacular Ancient Ecosystem Revealed*. Edited by P.J. Currie and E.B. Koppelhus. Indiana University Press, Bloomington, Indianapolis, USA.
- Eberth, D.A., D.R. Braman, and T.T. Tokaryk. 1990. Stratigraphy, sedimentology and vertebrate paleontology of the Judith River Formation (Campanian) near Muddy Lake, west-central Saskatchewan. *Bulletin of Canadian Petroleum Geology* 38: 387–406. <https://doi.org/10.35767/gscpbull.38.4.387>
- Eberth, D.A., and A.P. Hamblin. 1993. Tectonic, strati-

- graphic, and sedimentologic significance of a regional discontinuity in the upper Judith River Group (Belly River wedge) of southern Alberta, Saskatchewan, and northern Montana. *Canadian Journal of Earth Sciences* 30: 174–200. <https://doi.org/10.1139/e93-016>
- Farke, A.A., M.J. Ryan, P.M. Barrett, D.H. Tanke, D.R. Braman, M.A. Loewen, and G.R. Graham.** 2011. A new centrosaurine from the Late Cretaceous of Alberta, Canada, and the evolution of parietal ornamentation in horned dinosaurs. *Acta Palaeontologica Polonica* 56: 691–702. <https://doi.org/10.4202/app.2010.0121>
- Frederickson, J.A., and A.R. Tumarkin-Deratzian.** 2014. Craniofacial ontogeny in *Centrosaurus apertus*. *PeerJ* 2: e252. <https://doi.org/10.7717/peerj.252>
- Gilbert, M.M., L.A. Buatois, and R.W. Renaut.** 2020. Stratigraphy and depositional environments of the Belly River Group (Campanian) in southwestern Saskatchewan, Canada. *Bulletin of Canadian Petroleum Geology* 68: 31–63. <https://doi.org/10.35767/gscpgbull.68.2.31>
- Horner, J.R., and M.B. Goodwin.** 2008. Ontogeny of cranial epi-ossifications in *Triceratops*. *Journal of Vertebrate Paleontology* 28: 134–144. [https://doi.org/10.1671/0272-4634\(2008\)28\[134:ooceitj2.0.co;2](https://doi.org/10.1671/0272-4634(2008)28[134:ooceitj2.0.co;2)
- Mallon, J.C.** 2019. Competition structured a Late Cretaceous megaherbivorous dinosaur assemblage. *Scientific Reports* 9: 15447. <https://doi.org/10.1038/s41598-019-51709-5>
- Mallon, J.C., D.C. Evans, M.J. Ryan, and J.S. Anderson.** 2012. Megaherbivorous dinosaur turnover in the Dinosaur Park Formation (upper Campanian) of Alberta, Canada. *Palaeogeography, Palaeoclimatology, Palaeoecology* 350–352: 124–138. <https://doi.org/10.1016/j.palaeo.2012.06.024>
- Mallon, J.C., R.B. Holmes, and S.J. Rufolo.** 2022. Development and homology of the medial parietal ornamentation in centrosaurine ceratopsids (Dinosauria, Ornithischia). *Journal of Vertebrate Paleontology* 42: e2211637. <https://doi.org/10.1080/02724634.2023.2211637>
- Norell, M.A., J. Wiemann, M. Fabbri, C. Yu, C.A. Marsicano, A. Moore-Nall, D.J. Varricchio, D. Pol, and D.K. Zelenitsky.** 2020. The first dinosaur egg was soft. *Nature* 583: 406–410. <https://doi.org/10.1038/s41586-020-2412-8>
- Olson, E.C.** 1952. The evolution of a Permian vertebrate chronofauna. *Evolution* 6: 181–196. <https://doi.org/10.2307/2405622>
- Ramezani, J., T.L. Beveridge, R.R. Rogers, D.A. Eberth, and E.M. Roberts.** 2022. Calibrating the zenith of dinosaur diversity in the Campanian of the Western Interior Basin by CA-ID-TIMS U–Pb geochronology. *Scientific Reports* 12: 16026. <https://doi.org/10.1038/s41598-022-19896-w>
- Ryan, M.J., D.A. Eberth, D.B. Brinkman, P.J. Currie, and D.H. Tanke.** 2010. A new *Pachyrhinosaurus*-like ceratopsid from the upper Dinosaur Park Formation (late Campanian) of southern Alberta, Canada. Pages 141–155 in *New Perspectives on Horned Dinosaurs: The Royal Tyrrell Museum Ceratopsian Symposium*. Edited by M.J. Ryan, B.J. Chinnery-Allgeier, and D.A. Eberth. Indiana University Press, Bloomington, Indiana, USA.
- Ryan, M.J., and D.C. Evans.** 2005. Ornithischian dinosaurs. Pages 312–348 in *Dinosaur Provincial Park: a Spectacular Ancient Ecosystem Revealed*. Edited by P.J. Currie and E.B. Koppelhus. Indiana University Press, Bloomington, Indiana, USA.
- Ryan, M.J., and A.P. Russell.** 2005. A new centrosaurine ceratopsid from the Oldman Formation of Alberta and its implications for centrosaurine taxonomy and systematics. *Canadian Journal of Earth Sciences* 42: 1369–1387. <https://doi.org/10.1139/e05-029>
- Ryan, M.J., A.P. Russell, D.A. Eberth, and P.J. Currie.** 2001. The taphonomy of a *Centrosaurus* (Ornithischia: Ceratopsidae) bone bed from the Dinosaur Park Formation (Upper Campanian), Alberta, Canada, with comments on cranial ontogeny. *Palaio* 16: 482–506. [https://doi.org/10.1669/0883-1351\(2001\)016<0482:ttoaco>2.0.co;2](https://doi.org/10.1669/0883-1351(2001)016<0482:ttoaco>2.0.co;2)
- Sampson, S.D., M.J. Ryan, and D.H. Tanke.** 1997. Craniofacial ontogeny in centrosaurine dinosaurs (Ornithischia: Ceratopsidae): taxonomic and behavioral implications. *Zoological Journal of the Linnean Society* 121: 293–337. <https://doi.org/10.1111/j.1096-3642.1997.tb00340.x>

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Note

First records of Stonecat (*Noturus flavus*) in the Qu'Appelle River watershed, Saskatchewan

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Abstract

Stonecat (*Noturus flavus*) is a unique catfish species with a restricted distribution in western Canada; it is limited to a few rivers in the prairie provinces. In Saskatchewan, its presence has previously been recorded only from the Frenchman River watershed of the Upper Missouri basin. Here we present new records from the Qu'Appelle River in the Hudson Bay basin, ~150 river km upstream from its nearest known distribution at the confluence with the Assiniboine River.

Key words: Stonecat; *Noturus flavus*; catfish; Qu'Appelle River; Saskatchewan

Stonecat (*Noturus flavus*) is a catfish (Ictaluridae) occupying relatively warm, fast-flowing water in streams and rivers with rocky substrate and riffle habitats (Rohde 1980). It is considered a high-priority candidate for assessment then listing under the Canadian *Species at Risk Act* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2025). Well known from the Mississippi and upper Missouri drainages, Stonecat was historically known to occur in the Milk River watershed of southern Alberta, in the upper Missouri drainage, and was first discovered in Saskatchewan by C.B. Anderson (Royer and Anderson 1977) in the Frenchman River, a Milk River tributary, located in the semiarid mixed grasslands ecoregion. It has since been recorded throughout the Milk River watershed in Canada (Macnaughton *et al.* 2020). In the neighbouring Hudson Bay drainage in Canada, this fish species has only been recorded as recently as the 1960s (Stewart and Lindsey 1970). McCulloch (1994) later reported that Stonecat had dispersed up the Assiniboine River beyond its confluence with the Qu'Appelle River. However, despite collections near the river's mouth, no Stonecat was found during surveys conducted further upstream in

the Qu'Appelle River in Saskatchewan.

Here we report collecting two Stonecat specimens in the Lower Qu'Appelle River, south of Esterhazy, Saskatchewan (50.52949°N, 101.9641°W), on 27 August 2024, ~150 river km upstream from the Assiniboine River confluence (Figure 1). Although no specimens were retained, photographs were taken.

To date, only Black Bullhead (*Ameiurus melas*) and Channel Catfish (*Ictalurus punctatus*) have been recorded from the Qu'Appelle River in Saskatchewan (Atton and Merkowsky 1983). The Lower Qu'Appelle River is part of the Aspen Parkland ecoregion; it is dominated by farmland, with interspersed remaining stands of riparian vegetation including grasses, shrubs, Trembling Aspen (*Populus tremuloides* Michaux), and Green Ash (*Fraxinus pennsylvanica* Marshall). The Qu'Appelle River in Saskatchewan is a heavily regulated system, with six dams along its course, four of which are located on the Lower Qu'Appelle (Phillips *et al.* 2023).

The fish were caught using a gill net (two 10-m long attached panels, mesh size 25 mm and 51 mm) as part of a study by the Water Security Agency on the at-risk Mapleleaf mussel (*Quadrula quadrula*; whose

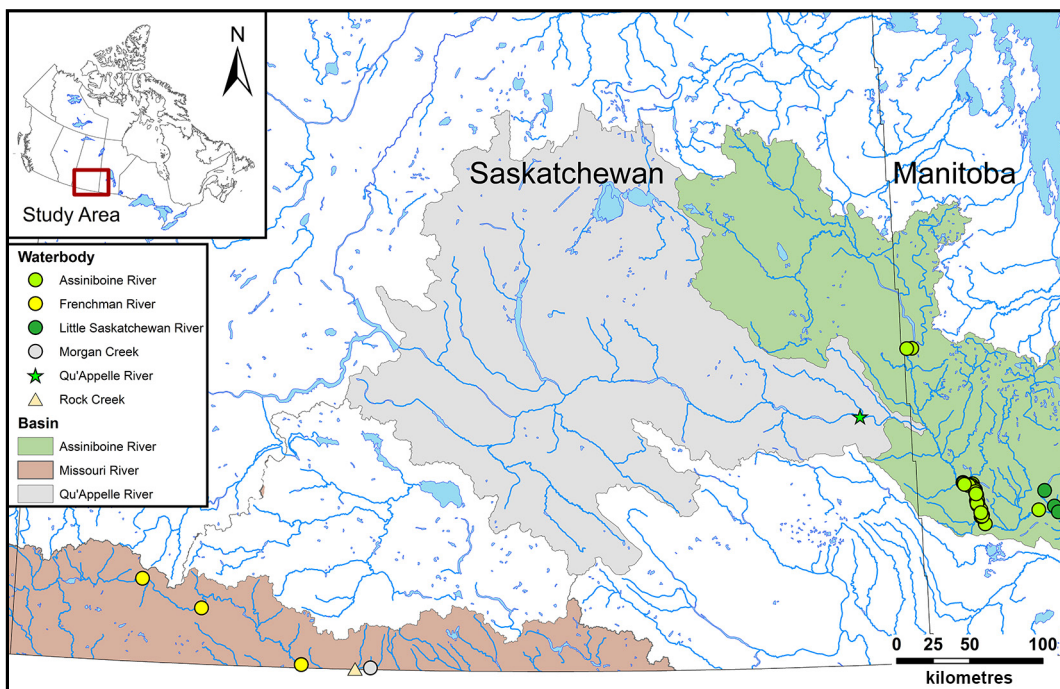


FIGURE 1. Location of a new record for Stonecat (*Noturus flavus*) in the Qu'Appelle River, Saskatchewan (star), and previous records from the Missouri and Assiniboine watersheds (Royer and Anderson 1977; McCulloch 1994; Macnaughton *et al.* 2020; Fisheries and Oceans Canada unpubl. data).

Saskatchewan–Nelson Rivers population is Threatened [SARA Public Registry 2025a]) and Lake Sturgeon (*Acipenser fulvescens*; whose Saskatchewan–Nelson Rivers population is assessed as Endangered but not listed [SARA Public Registry 2025b]) in the Lower Qu'Appelle River. The two Stonecat collected in 2024 measured 15.5 cm in length, 41 g and 21.5 cm, 90 g. More detailed records and photographs have been submitted to the Saskatchewan Conservation Data Centre and uploaded to iNaturalist (<https://inaturalist.ca/observations/238650244> and <https://inaturalist.ca/observations/238650160>). Similar-sized Stonecat captured from Ohio streams and lakes ranged from 6 to 9 years of age (Scott and Crossman 1973). The habitat in this reach of the Qu'Appelle River is dominated by a long cobble/gravel run and high freshwater mussel densities (see detailed description of “Reach 7” in WSA 2022). The mean width of the reach is 25.4 m, and although the depth varies greatly it did not exceed ~1 m when we made our collection.

At the time of sample collection, Stonecat was not believed to be present in the Qu'Appelle River system and were mistakenly recorded as Black Bullhead. On further examination, the fish were correctly identified as Stonecat. Like all ictalurid species, Stonecat exhibits an adipose fin, lack of obvious scales

(naked skin), a subterminal mouth, eight sensory barbels used to detect food in murky, dark waters, and a rounded anterior body, which becomes laterally compressed posterior to the dorsal and pelvic fins (Scott and Crossman 1973). The dorsal and pectoral fins are each equipped with a distinct serrate spine. A distinct adnate adipose fin (low ridge) extension of the caudal fin distinguishes Stonecat from most other catfishes (Stewart and Watkinson 2004). A premaxillary tooth patch with lateral extensions separates it from other species of its genus (Etnier and Starnes 1993). Stonecat is only one of two species found in Saskatchewan with an adnate adipose fin (the other is Tadpole Madtom [*Noturus gyrinus*]). In addition, this species is distinguished by a relatively short, wide head with small, dorsally located eyes and a short, deep caudal peduncle terminating in a truncate, rounded-to-square caudal fin. Stonecat can exhibit distinct colouration: strong tan to grey countershading dorsally with a yellow to white ventral surface and a pale margin outlining the caudal fin (Scott and Crossman 1973).

Five species and three genera of ictalurids occur in Saskatchewan (Black Bullhead, Brown Bullhead [*Ameiurus nebulosus*], Channel Catfish, Tadpole Madtom, and Stonecat). Stonecat and Tadpole Madtom belong to the genus *Noturus* and are the only two

catfish species in Saskatchewan that feature an adnate adipose fin. They are also among only three freshwater fish species in Canada capable of inflicting a painful venomous wound through their dorsal and pectoral spines (Scott and Crossman 1973).

The Qu'Appelle River basin is a highly managed ecosystem that provides a significant source of water, agricultural land, and recreational fishery for Saskatchewan (Phillips *et al.* 2023). The occurrence of this species in the Lower Qu'Appelle River adds to the unique biodiversity composition of this waterbody, wherein uncommon species of fish, freshwater mussels, amphibians, and reptiles are found but not well represented elsewhere in the province (WSA 2022). These new records emphasize the critical need for ongoing and contemporary ecological monitoring and observation, particularly in highly regulated waterways, to advance scientific understanding and inform effective management strategies. Additional monitoring throughout the Qu'Appelle River watershed may reveal expansion of this species' range further upstream in the Saskatchewan River watershed.

Author Contributions

Writing — Original Draft: I.D.P.; Writing — Review & Editing: K.S.P., G.F., L.E., and I.D.P.; Conceptualization: I.D.P.; Investigation: K.S.P., G.F., and L.E.; Study Design: K.S.P. and I.D.P.

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Literature Cited

Atton, F.M., J.J. Merkowsky. 1983. Atlas of Saskatchewan Fish. Fisheries technical report 83-2. Saskatchewan Department of Parks and Renewable Resources, Regina, Saskatchewan, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2025. COSEWIC candidate wildlife species: freshwater fishes. COSEWIC, Ottawa, Ontario, Canada. Accessed 5 August 2025. <https://www.cosewic.ca/index.php/en/reports/candidate-wildlife-species.html#fwf>.

Etnier, D.A., and W.C. Starnes. 1993. The Fishes of Tennessee. University of Tennessee Press, Knoxville, Tennessee, USA.

McCulloch, B.R. 1994. Dispersal of the Stonecat (*Noturus flavus*) in Manitoba and its interactions with resident fish species. M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, Canada. Accessed 20 September 2024. [\[mspace.lib.umanitoba.ca/items/fffc6047-895a-460b-9363-8877e325f957\]\(https://mspace.lib.umanitoba.ca/items/fffc6047-895a-460b-9363-8877e325f957\).](https://</p></div><div data-bbox=)

Macnaughton, C.J., D.A. Watkinson, and E.C. Enders. 2020. Standardized field sampling method for monitoring the distribution and relative abundance of the Stonecat (*Noturus flavus*) Missouri population in Canada. Canadian Technical Report of Fisheries and Aquatic Science 3355. Fisheries and Oceans Canada, Winnipeg, Manitoba, Canada. Accessed 3 March 2025. https://publications.gc.ca/collections/collection_2020/mpo-dfo/Fs97-6-3355-eng.pdf.

Phillips, I., T.D. Jardine, K.E. Lindenschmidt, C. Westbrook, and J. Pomeroy. 2023. Nelson and Churchill River Basins. Pages 794–834 in *Rivers of North America*. Second Edition. Edited by M.D. DeLong, T.D. Jardine, A.C. Benke, and C.E. Cushing. Academic Press, Elsevier, London, United Kingdom.

Rohde, F.C. 1980. *Noturus flavus*, Rafinesque Stonecat. Page 455 in *Atlas of North American Freshwater Fishes*. Edited by D.S. Lee, C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. North Carolina State Museum of Natural History, Raleigh, North Carolina, USA. Accessed 5 August 2025. <https://archive.org/details/atlasofnorthamer00unse/page/n465/>.

Royer, L.M., and C.B. Anderson. 1977. First record of the Stonecat in Saskatchewan waters. *Blue Jay* 35: 78. <https://doi.org/10.29173/bluejay4012>

SARA (*Species at Risk Act*) Public Registry. 2025a. Species summary: Mapleleaf (*Quadrula quadrula*), Saskatchewan – Nelson Rivers population. Government of Canada, Ottawa, Ontario, Canada. Accessed 8 July 2025. <https://species-registry.canada.ca/index-en.html#/species/934-641>.

SARA (*Species at Risk Act*) Public Registry. 2025b. Species summary: Lake Sturgeon (*Acipenser fulvescens*), Saskatchewan – Nelson Rivers population. Government of Canada, Ottawa, Ontario, Canada. Accessed 8 July 2025. <https://species-registry.canada.ca/index-en.html#/species/1362-985>.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa, Ontario, Canada.

Stewart, K.W., and C.C. Lindsey. 1970. First specimens of the Stonecat, *Noturus flavus*, from the Hudson Bay drainage. *Journal of the Fisheries Research Board of Canada* 27: 170–172. <https://doi.org/10.1139/f70-019>

Stewart, K.W., and D.A. Watkinson. 2004. The Freshwater Fishes of Manitoba. University of Manitoba Press, Winnipeg, Manitoba, Canada.

WSA (Water Security Agency). 2022. Mapleleaf mussel (*Quadrula quadrula* Rafinesque, 1820) search and freshwater mussel monitoring and assessment 2019–2022. Ecological and Habitat Assessment, WSA, Saskatoon, Saskatchewan, Canada.

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Get big fast! Patterns of first-year growth in seven species of minnows (Leuciscidae) from south-central Ontario

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Quinn, N.W.S., and A. Rooke. 2024. Get big fast! Patterns of first-year growth in seven species of minnows (Leuciscidae) from south-central Ontario. *Canadian Field-Naturalist* 138(4): 303–308. <https://doi.org/10.22621/cfn.v138i4.3045>

Abstract

Common patterns of growth are presented for the young-of-year of seven species of minnows (Leuciscidae) based on analysis of daily growth increments in the microstructure of otoliths. All seven species show a period of growth during May–September and reach approximately the same size (~4.3 cm) entering their first winter. The first annulus appears to develop in May. The most striking feature, observed in all seven species, is a sudden and marked increase in rate of growth at ~25 days post-hatch. The first 21 days of this surge in growth account for 29% of the first-year's growth. The growth surge may result from reaching a developmental milestone, such as the ossification of fin rays or flexion of the notochord that allows for greater mobility and capture of invertebrate prey. Given that small size is negatively associated with survival in juvenile fishes, achieving the growth surge in early life is likely important for survival. These results may be broadly applicable to leuciscids, an ecologically important and understudied group of fish.

Key words: Leuciscids; otolith; increments

Introduction

Fisheries biologists have found otoliths to be perhaps the most accurate, if not the easiest, structure to determine age of fishes. Otoliths are accretions of calcium carbonate (CaCO₃) that play a role in balance and hearing in fishes (Helfman *et al.* 2009). Annual demarcations (“annuli”) are readily observable in otoliths treated by sectioning and polishing. The annuli are formed as alternating opaque and translucent bands as the ratio of CaCO₃ to protein changes from the growing period to winter dormancy (e.g., Paxton *et al.* 2013). Less well known is that daily growth increments (DGIs) are also present in the microstructure of otoliths. The DGIs form similarly as opaque and translucent bands in a circadian rhythm (Campana 1992). Detailed growth of the otolith, revealed by DGI counts, is directly related to growth of the body of the fish (Campana and Neilson 1985) and has been used to reconstruct growth and timing of events in the early life history of fishes. For example, discontinuities in the deposition of DGIs have revealed the timing of settlement of pelagic larvae of coral reef fish (Wilson and McCormick 1999).

In this study we report patterns of DGI deposition in the lapillus otolith of young-of-year of seven leuciscid (minnow) species from south-central Ontario,

Canada. Our objective was to look for patterns of growth that would provide insight into the early life history and ecology of these fishes.

Methods

Seven leuciscid species, Creek Chub (*Semotilus atromaculatus*), Fathead Minnow (*Pimephales promelas*), Brassy Minnow (*Hybognathus hankinsoni*), Common Shiner (*Luxilus cornutus*), Golden Shiner (*Notemigonus crysoleucas*), Northern Redbelly Dace (*Chrosomus eos*), and Western Blacknose Dace (*Rhinichthys obtusus*) were captured with Gee traps (type of trap commonly used by bait fishers) from streams in the general vicinity of Bancroft, Ontario (45.062°N, 77.485°W) from spring through late fall 2018–2020. Smaller fish (generally <8 cm total length [TL]) were selected to focus on early life history. Fish were euthanized by immersion in a bath of 100 ppm tricaine methanesulfonate (MS 222; Syndel, Nanaimo, British Columbia, Canada) and TL was measured; voucher fishes were not retained. The lapillus otoliths were removed and stored in paper envelopes at room temperature for no more than one week. Age was determined by placing the lapillus, anti-sulcal side up, in a drop of immersion oil on a microscope slide painted black and counting annuli (rings) under low power of a

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compound microscope (Escot and Granado-Lorencio 1998). The annuli were often further revealed (Figure 1) as the specimen was treated (as described below) to reveal DGIs.

The otolith was then placed, sulcal side up, on a microscope slide and covered with a drop of thermoplastic cement (Buehler, Lake Bluff, Illinois, USA), a clear fixative, and left overnight to harden. The long axis of the otolith was then measured with an ocular micrometer. The specimen was ground in short intervals with a circular motion in a drop of immersion oil against 2000 grit sandpaper on a glass plate to erode the otolith matrix, gradually revealing the central core or nucleus and a plane along the long axis. If needed, the specimen was further worked against 30 μm lapping film to clarify the DGIs. Other examples of this procedure are described in Victor and Brothers (1982) and Huang *et al.* (2017). Studies (e.g., Victor and Brothers 1982) confirm our expectation that microincrements are deposited daily in the lapilli of leuciscids. The DGIs were counted from the nucleus into the posterior lobe of the lapillus, which grows more quickly than the anterior lobe (Escot and Granado-Lorencio 1998) and where the lines are spaced more widely.

The lapillus is also asymmetrical in lateral profile, and we found that in eroding the otolith matrix toward the nucleus, DGIs at varying distances from the core

appear (or are eroded away) sequentially, and it was unusual to be able to make a continuous count from the nucleus to the edge of the otolith (Brothers *et al.* 1976, also describe this problem).

Three counts were made. First, where the core area was clear, from the nucleus to the start of a nearly universal rapid surge in growth (Figure 2). This point, termed the transition zone (TZ), was usually abrupt but often occurred over several days and, in such cases, its precise location was an estimate. The DGIs inside the TZ were narrow and closely spaced (fine lines); those beyond it were markedly broad and widely spaced (bold lines, Figure 2). In specimens with DGIs clearly visible to the first annulus, this count was continued to the annulus to obtain a total period (days) of first-year growth. Where the core area was not clear, the DGIs were counted from the TZ to the annulus. The mean number of fine lines for the species was then added to this to get an estimate of total first-year growth. In a review of interpretation of the microstructure of fish otoliths, Campana (1992) noted that because of anomalous structures and the very fine nature of some lines, error is expected in counting long strings of DGIs and a 5% error rate is “acceptable”. Every annual series was counted twice and, if there was a difference in the total count, the mean was used. If the difference was greater than 5%,

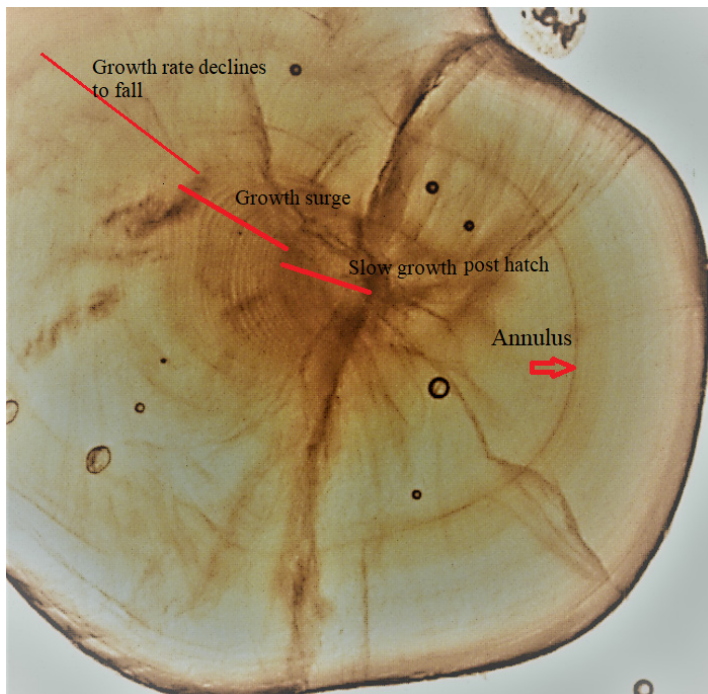


FIGURE 1. Section of a lapillus otolith from a yearling Creek Chub (*Semotilus atromaculatus*) showing the three zones of first year's growth and an annulus. Photo: Norman Quinn.

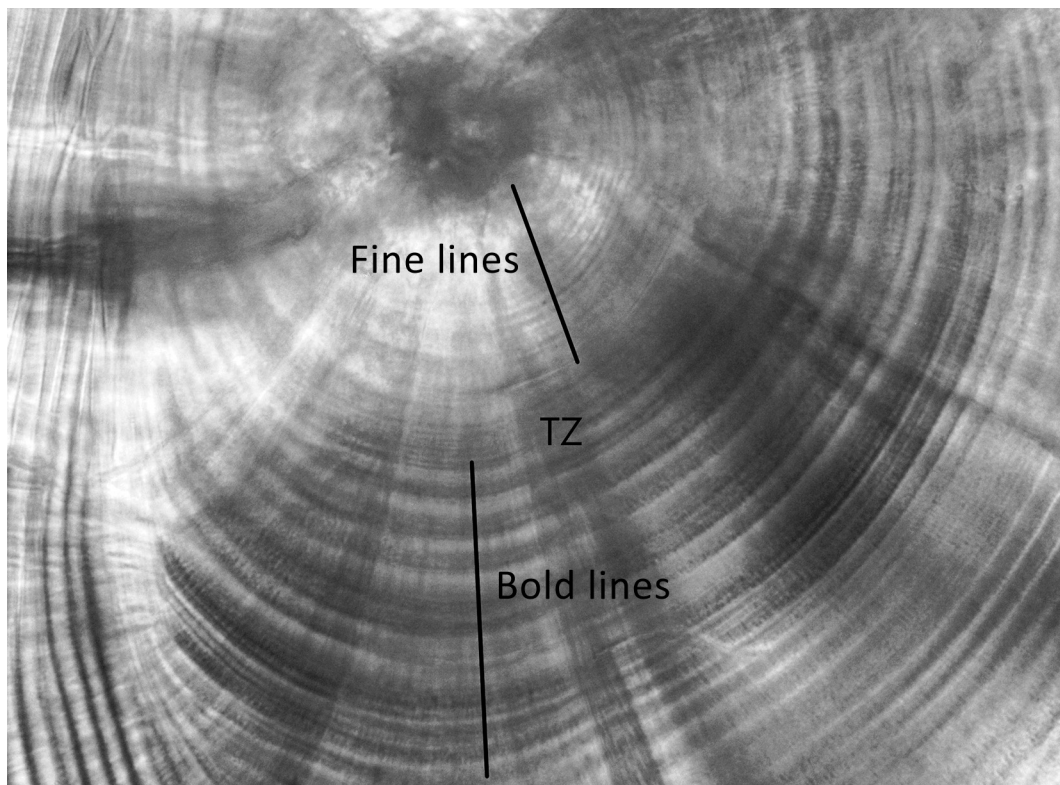


FIGURE 2. Detail of the core area of a lapillus otolith from a yearling Golden Shiner (*Notemigonus crysoleucas*) showing the fine lines around the nucleus, bolder lines of the growth surge, and transition zone (TZ) between the two. Photo: Norman Quinn.

the specimen was not used. All counts were made by N.W.S.Q.

Because there is some uncertainty about the timing of formation of the first annulus (Schemske 1974; Victor and Brothers 1982), we examined the edge of otoliths of one-year-old fish caught from April through mid-June to look for a clearly bolder line (assumed to be the annulus) forming amid the increments as evidence of timing of its formation.

The radius of the otolith from nucleus to posterior edge (LE) and length to the first annulus (LA) were measured with an ocular micrometer. Linear dimensions of otoliths and the body length of fish are strongly associated, and the relationship is normally linear (e.g., Morioka and Matsumoto 2007). The linear relationship of otolith radius and total length of our fish was strong in five of the seven species (r^2 for the linear model was 0.70 for Creek Chub, 0.87 for Brassy Minnow, 0.67 for Common Shiner, 0.71 for Golden Shiner, and 0.60 for Western Blacknose Dace). We considered the range of TL of the other two species (<2 cm) to be too narrow to test this. However, we assumed linearity for these two also because of its

expected occurrence as reported in the literature (e.g., Morioka and Matsumoto 2007). We estimated length at age one for all specimens having clear first annuli from $(LA / LE) \times TL$. The initial surge of growth is usually pronounced and our experience with examining the specimens showed this period to last about three weeks (N.W.S.Q. and A.R. pers. obs.). To assess the contribution of the growth surge to annual growth, we measured the distance covered by its first 21 days with the ocular micrometer and expressed this as a percentage of total first-year growth.

Results

We sampled 248 fish: 92 Creek Chub, 40 Fathead Minnow, 12 Brassy Minnow, 19 Common Shiner, 52 Golden Shiner, 22 Northern Redbelly Dace, and 11 Western Blacknose Dace. Of these, 130 were one-year-olds (caught during their second year of life), 92 were two-year-olds, 24 three-year-olds, and one was a four-year-old. Only one fish (a Creek Chub) was caught as a 0+, that is, during its year of hatch.

The range of TL at age one year among species was narrow (3.85–4.77 cm, mean 4.29; Table 1). The

TABLE 1. Featured elements (mean (*n*, range)) of growth and daily growth increment counts for young-of-year of seven species of minnows (Leuciscidae) from south-central Ontario.

Species	Size at 1 year, cm	Period of first year's growth, days	DGI count to TZ, days	% annual growth achieved in first 21 days of GS
Creek Chub (<i>Semotilus atromaculatus</i>)	4.54 (70, 3.00–6.47)	126 (17, 116–148)	26 (19, 18–35)	35 (35, 16–41)
Fathead Minnow (<i>Pimephales promelas</i>)	4.14 (26, 3.01–6.27)	136 (7, 125–151)	25 (9, 22–30)	26 (9, 22–28)
Brassy Minnow (<i>Hybognathus hankinsoni</i>)	4.77 (12, 3.94–6.47)	134 (4, 129–131)	25 (6, 19–29)	31 (6, 21–37)
Common Shiner (<i>Luxilus cornutus</i>)	4.08 (21, 2.78–5.44)	—*	27 (5, 21–29)	25 (5, 20–29)
Golden Shiner (<i>Notemigonus crysoleucas</i>)	4.27 (41, 2.71–6.19)	127 (13, 118–144)	24 (13, 19–29)	31 (20, 25–42)
Northern Redbelly Dace (<i>Chrosomus eos</i>)	3.85 (20, 1.89–6.29)	132 (7, 116–139)	22 (10, 18–26)	30 (4, 21–48)
Western Blacknose Dace (<i>Rhinichthys obtusus</i>)	4.41 (10, 3.18–5.73)	—*	26 (5, 25–27)	28 (4, 26–31)

Note: DGI = daily growth increment, GS = growth surge (the period of rapid growth of larvae following the TZ), TZ = transition zone (the point at which rapid growth of larvae begins).
*Fewer than three counts made.

annulus for most specimens appeared to be deposited during May: four of nine specimens (all species combined) caught in late April showed evidence of an annulus forming, eight of 20 in early May, 11 of 21 in late May, and 14 of 15 in the first two weeks of June. The area around the nucleus, where the otolith is thickest, was usually partly obscured. This problem, reported by others (e.g., Cavole *et al.* 2018), made counts of DGIs immediately around the nucleus difficult; clear counts could only be made in about one in five of our specimens.

Growth during the first year occurs in three phases (Figure 1): a period of slow growth immediately post-hatch (phase 1) followed by the abrupt onset of a period of fast growth into early summer (phase 2) and, finally, a gradual decline in rate of growth into fall (phase 3). Toward the end of annual growth (in fall), the DGIs become tightly compact, often forming an opaque band. Figure 2 shows detail of the core area showing the first two phases in a yearling Golden Shiner.

The mean period of first-year growth for five species for which there were more than three counts ranged from 126 to 136 days (Table 1).

Most specimens (195/209: 70/74 Creek Chub, 26/27 Fathead Minnow, 12/12 Brassy Minnow, 11/14 Common Shiner, 47/49 Golden Shiner, 20/23 Northern Redbelly Dace, and 9/10 Western Blacknose Dace), in which the central area of the otolith was sufficiently clear to show an overall pattern (if not actual count) of DGIs displayed the growth surge, i.e., the distinct increase in spacing of increments following narrow spacing post hatch. The growth surge begins at ~25 days post-hatch (dph; range 24–27) with the exception of Northern Redbelly Dace (dph of 22 days; Table 1). The first 21 days of the growth surge account for 29% of first-year growth (mean from Table 1, range 25%–35%).

Discussion

Five studies of leuciscids (or closely related Cypriniformes) show that the first DGI is deposited on the first day post-hatch (Smith and Walker 2003; Morioka and Matsumoto 2007; Paxton *et al.* 2013; Ding *et al.* 2015; Bounket *et al.* 2019). The period of active annual growth that we report for five species (126–130 days) corresponds to a period of about four months, from late May, when spawning usually begins in these species (Scott and Crossman 1973; Holm *et al.* 2022), to late September, with the onset of cooler weather. Size at age one year is essentially identical among the seven species, which is surprising because these species vary substantially in size as adults (Scott and Crossman 1973; Holm *et al.* 2022).

All seven species showed a rapid surge in growth of larval fish at ~25 dph, with the first 21 days accounting for nearly a third of first-year growth. Previous studies of larval leuciscids have documented slow growth (0.23–0.29 mm/day) in the first 14 dph (Weisel and Newman 1951; Faber 1985; Sakai 1990; Kupren *et al.* 2016; Yang *et al.* 2017; Bounket *et al.* 2019). Bounket *et al.* (2019) showed a pattern of growth through the first year from DGIs of the otolith of European Chub (*Squalius cephalus*) in France that is nearly identical to what we have documented: slow growth initially, with a sudden surge as late larvae, robust growth to early summer, and then a gradual decline into fall. The growth surge begins at 18 dph in *Squalius* raised in captivity (Bounket *et al.* 2019) and at 26 dph in wild fish (B. Bounket pers. comm. 27 January 2020).

A possible explanation for the growth surge is that these fish, as larvae, benefit from a profusion of foods as waters warm after they hatch in spring. However, this is unlikely because most leuciscids are batch spawners and spawn repeatedly through spring and

summer (Winfield and Nelson 1991). Batch spawning has been documented for six of our seven species (all but Golden Shiner; Gale and Buynak 1982; Powles *et al.* 1992; Quinn 2019). For example, Fathead Minnow spawns 16–26 times a season (Gale and Buynak 1982). Fish captured in our study would, therefore, probably have experienced variable food supply as developing larvae.

We propose that the growth surge is more likely a result of these larval fish reaching a developmental “milestone” resulting in increased mobility and ability to capture prey. In other words, they transform from passive drifting members of the zooplankton into active tiny predators. A marked change in diet, growth, or behaviour (swimming ability) of larval fishes is often linked to specific morphological developments (Reyes-Marchant *et al.* 1992; Ward and Cobourn 2008; Samarakis and Nikolioudakis 2010). Important milestones of development include inflation of the swim bladder, ossification of fin rays, and flexion of the notochord (e.g., Gozlan *et al.* 1999; Samarakis and Nikolioudakis 2010).

There is considerable literature on the larval and juvenile development of leuciscids. Metamorphosis, the transition from larva to juvenile, is commonly defined in fishes as the final absorption of finfolds into completely formed fins and achievement of an overall “adult” appearance (e.g., Kupren *et al.* 2016). Metamorphosis is usually reported to occur after 40 dph in leuciscids (e.g., Cooper 1980). The morphological developments in larvae that are reported to enhance mobility initiate shortly after hatch. Flexion of the notochord, for example, begins in leuciscids within a few dph and is completed by 25 dph (e.g., Cooper 1980; Huang *et al.* 2017). Flexion may be particularly important as Gozlan *et al.* (1999: 75) described it as vital to the “caudal–body connection” and Samarakis and Nikolioudakis (2010) proposed that it is the vital milestone of development for larval fish in general. Huang *et al.* (2017) believed that the completion of flexion at 19 dph in the leuciscid Mud Carp (*Cirrhinus molitorella*) of China allows the larvae to migrate to refuge in deeper water.

Rapid early growth facilitates escape from predators and is frequently linked to cohort strength in fisheries; indeed, the association is a common thread in population studies of fishes (Helfman *et al.* 2009). For example, Clark Barkalow *et al.* (2021) showed that larvae of the leuciscid Colorado Pikeminnow (*Ptychocheilus lucius*) begin to escape gape-limited predators after reaching 25 mm total length.

Leuciscids, formerly a subfamily of Cyprinidae (Nelson 2007), are widespread in North America and Eurasia and important in food webs, as bait-fish, and as food fish (Winfield and Nelson 1991). The

phenomenon we document, i.e., the rapid surge of larval growth at 25 dph for seven stream dwelling species in northeastern North America, may have broad application to their population biology. Its cause, in particular a possible common morphological development, should be further explored by a combination of field and laboratory (aquaria) studies.

Author Contributions

Writing – Original Draft: N.W.S.Q.; Writing – Review & Editing: A.R.; Conceptualization: N.W.S.Q. and A.R.; Methodology: N.W.S.Q. and A.R.; Formal Analysis: N.W.S.Q.

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Literature Cited

- Bounket, B., P. Gilbert, V. Gennotte, C. Argillier, G. Carrel, A. Maire, M. Logez, and F. Morat. 2019. Otolith shape analysis and daily increment validation during ontogeny of larval and juvenile European Chub *Squalius cephalus*. *Journal of Fish Biology* 95: 444–452. <https://doi.org/10.1111/jfb.13976>
- Brothers, E.B., C.P. Mathews, and R. Lasker. 1976. Daily growth increments in otoliths from larval and adult fishes. *Fishery Bulletin* 74: 1–8. Accessed 12 June 2024. <https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/1976/741/brothers.pdf>
- Campana, S.E. 1992. Measurement and interpretation of the microstructure of fish otoliths. Pages 59–71 in *Otolith Microstructure Examination and Analysis*. Edited by D.K. Stevenson and S.E. Campana. Canadian Special Publication Fisheries and Aquatic Sciences 117. Department of Fisheries and Oceans, Ottawa, Ontario, Canada. Accessed 20 August 2025. https://publications.gc.ca/collections/collection_2016/mpo-dfo/Fs41-31-117-eng.pdf
- Campana, S.E., and J.D. Neilson. 1985. Microstructure of fish otoliths. *Canadian Journal of Fisheries and Aquatic Sciences* 42: 1014–1032. <https://doi.org/10.1139/f85-127>
- Cavole, L.M., I.G. Cardoso, M.S. Almeida, and H. Haimovici. 2018. Unravelling growth trajectories from complicated otoliths — the case of Brazilian Codling, *Urophycis brasiliensis*. *Journal of Fish Biology* 92: 1290–1311. <https://doi.org/10.1111/jfb.13586>
- Clark Barkalow, S.L., M.J. Chavez, and S.P. Platania. 2021. Otolith microstructure analysis elucidates spawning and early life histories of federally endangered fishes in the San Juan River. *Ichthyology & Herpetology* 109:

- 860–873. <https://doi.org/10.1643/i2020011>
- Cooper, J.E.** 1980. Egg, larval and juvenile development of Longnose Dace, *Rhinichthys cataractae*, and River Chub, *Nocomis micropogon*, with notes on their hybridization. *Copeia* 1980: 469–478. <https://doi.org/10.2307/1444524>
- Ding, C., Y. Chen, D. He, and J. Tao.** 2015. Validation of daily increment formation in otoliths for *Gymnocypris selincuoensis* in the Tibetan Plateau, China. *Ecology and Evolution* 5: 3243–3249. <https://doi.org/10.1002/ec.31572>
- Escot, C., and C. Granado-Lorencio.** 1998. Morphology of the otoliths of *Barbus sclateri* (Pisces: Cyprinidae). *Journal of Zoology* 264: 89–94. <https://doi.org/10.1111/j.1469-7998.1998.tb00136.x>
- Faber, D.J.** 1985. The early development of the Northern Redbelly Dace, *Phoxinus eos* (Cope). *Canadian Journal of Zoology* 63: 1724–1729. <https://doi.org/10.1139/z85-258>
- Gale, W.F., and G.L. Buynak.** 1982. Fecundity and spawning frequency of the Fathead Minnow—a fractional spawner. *Transactions of the American Fisheries Society* 111: 35–40. [https://doi.org/10.1577/1548-8659\(1982\)111<35:fasfot>2.0.co;2](https://doi.org/10.1577/1548-8659(1982)111<35:fasfot>2.0.co;2)
- Gozlan, R.E., G.H. Copp, and J.N. Tourenq.** 1999. Early development of the Sofie, *Chondrostoma toxostoma*. *Environmental Biology of Fishes* 56: 67–77. <https://doi.org/10.1023/a:1007576222907>
- Helfman, G.S., B.B. Collette, D.E. Facey, and B.W. Bowen.** 2009. *The Diversity of Fishes: Biology, Evolution, and Ecology*. Wiley Blackwell, West Sussex, United Kingdom.
- Holm, E., N.E. Mandrak, and M.E. Burrige.** 2022. *A Field Guide to Freshwater Fishes of Ontario*. Royal Ontario Museum. Toronto, Ontario, Canada.
- Huang, Y., F. Chen, W. Tang, Z. Lai, and X. Li.** 2017. Validation of daily increment deposition and early growth of Mud Carp, *Cirrhinus molitorella*. *Journal of Fish Biology* 90: 1517–1532. <https://doi.org/10.1111/jfb.13250>
- Kupren, K., I. Rams, D. Źarski, and D. Kurharczyk.** 2016. Early development and allometric growth patterns of a rheophilic cyprinid Common Dace *Leuciscus leuciscus* (Cyprinidae: Leuciscinae). *Ichthyological Research* 63: 382–390. <https://doi.org/10.1007/s10228-016-0508-9>
- Morioka, S., and S. Matsumoto.** 2007. Otolith development and daily increment formation in larvae of the Kabyabya, a Malawian cyprinid, *Opsaridium tweddleorum*. *Ichthyological Research* 54: 44–48. <https://doi.org/10.1007/s10228-006-0372-0>
- Nelson, J.S.** 2007. *Fishes of the World*. Third Edition. Wiley, New Jersey, USA.
- Paxton, B.R., G.C. O'Brien, J.A. Slingsby, and R. Copin.** 2013. Validation of the periodicity of growth increment deposition in otoliths from larval and early juvenile stages of two cyprinids from Orange-Vaal river system South Africa. *African Journal of Aquatic Science* 38(suppl. 1): 49–54. <https://doi.org/10.2989/16085914.2013.775107>
- Powles, P.M., S. Finucan, M. van Haaften, and R.A. Curry.** 1992. Preliminary evidence for fractional spawning by the Northern Redbelly Dace, *Phoxinus eos*. *Canadian Field-Naturalist* 106: 237–240. <https://doi.org/10.5962/p.356935>
- Quinn, N.W.S.** 2019. Batch spawning in five species of minnows (Cyprinidae) from Ontario, Canada. *Canadian Field-Naturalist* 133: 325–328. <https://doi.org/10.22621/cfn.v133i4.1914>
- Reyes-Marchant, P., A. Cravinho, and N. Lair.** 1992. Food and feeding behaviour of Roach (*Rutilus rutilus*, Linné 1758) juveniles in relation to morphological change. *Journal of Applied Ichthyology* 8: 77–89. <https://doi.org/10.1111/j.1439-0426.1992.tb00670.x>
- Sakai, H.** 1990. Larval development intervals in *Tribolodon hakonensis* (Cyprinidae). *Japanese Journal of Ichthyology* 37: 17–28. <https://doi.org/10.11369/jji1950.37.17>
- Schemske, D.W.** 1974. Age, length and fecundity of the Creek Chub, *Semotilus atromaculatus* (Mitchill), in central Illinois. *American Midland Naturalist* 92: 505–509. <https://doi.org/10.2307/2424318>
- Scott, W.B., and E.J. Crossman.** 1973. *Freshwater Fishes of Canada*. Bulletin 184. Fisheries Research Board of Canada. Ottawa, Ontario, Canada.
- Smith, B.B., and K.F. Walker.** 2003. Validation of the ageing of 0+ carp (*Cyprinus carpio* L.). *Marine and Freshwater Research* 54: 1005–1008. <https://doi.org/10.1071/mf03010>
- Somarakis, S., and N. Nikolioudakis.** 2010. What makes a late anchovy larva? The development of the caudal fin seen as a milestone in fish ontogeny. *Journal of Plankton Research* 32: 317–326. <https://doi.org/10.1093/plankt/fbq132>
- Victor, B.C., and E.B. Brothers.** 1982. Age and growth of the Fallfish *Semotilus corporalis* with daily otolith increments as a method of annulus verification. *Canadian Journal of Zoology* 60: 2543–2550. <https://doi.org/10.1139/z82-326>
- Ward, S.A., and M.M. Cobourn.** 2008. Stepwise increases in maximum prey size of larval Creek Chubs, *Semotilus atromaculatus*, in an urbanized Ohio stream. *Northeastern Naturalist* 15: 349–362. <https://doi.org/10.1656/1092-6194-15.3.349>
- Weisel, G.F., and H.W. Newman.** 1951. Breeding habits, development, and early life history of *Richardsonius balteatus*, a northwestern minnow. *Copeia* 1951: 187–194. <https://doi.org/10.2307/1439094>
- Wilson, D.T., and M.I. McCormick.** 1999. Microstructure of settlement-marks in the otoliths of tropical reef fishes. *Marine Biology* 134: 29–41. <https://doi.org/10.1007/s002270050522>
- Winfield, I.J., and J.S. Nelson.** 1991. *Cyprinid Fishes: Systematics, Biology and Exploitation*. Chapman and Hall, London, United Kingdom.
- Yang, P., G. Jin, Y. Liu, J. Li, Z. Hu, and X. Luo.** 2017. Morphological development and allometric growth in hatchery-reared Caspian Shemaya (*Alburnus chalcoides*): from hatching to the juvenile stage. *Turkish Journal of Fisheries and Aquatic Sciences* 17: 427–435. https://doi.org/10.4194/1303-2712-v17_2_22

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Post-fire conifer regrowth in upper subalpine Grouseberry (*Vaccinium scoparium*) habitat used by Grizzly Bear (*Ursus arctos*) in Banff National Park, Alberta

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Abstract

Grouseberry (*Vaccinium scoparium*) communities in many open, upper subalpine sites within Banff National Park have abundant conifer seedlings, saplings, and small trees. Because fruit production typically decreases with increasing forest canopy cover, we predict that infilling by conifers will lead to reduced Grouseberry fruit availability for wildlife, including Grizzly Bear (*Ursus arctos*), a Threatened species in Alberta. We studied conifer recruitment in Grouseberry communities within recent (2001 prescribed fire) and old (1920 and 1889) burns in Banff National Park during 2008–2022. Most (55%) of the conifers in our plots were Engelmann Spruce (*Picea engelmannii*); an additional 34% were Subalpine Fir (*Abies lasiocarpa*), 11%, Lodgepole Pine (*Pinus contorta*), and <1%, Subalpine Larch (*Larix lyallii*). The density of small conifers (height >30 cm, diameter <10 cm) did not vary in communities that were 21, 102, and 133 years post-fire, but was lower in the 2001 burn 6–7 years post-fire. The mean density of small conifers in the 2001 prescribed burn increased from 15 ± 18 (SD) stems/100 m² in 2007–2008 (6–7 years post-fire) to 73 ± 67 stems/100 m² in 2022 (21 years post-fire). Conifer ingrowth has the potential to overgrow and shade Grouseberry habitat, with declining fruit production a predicted consequence. However, in Banff National Park, where lightning-caused fires are rare, managers have the option of applying prescribed fire to create openings in the upper subalpine forest and thus enhance fruit production in Grouseberry and other fruiting shrubs important to wildlife.

Key words: Forest fire; forest succession; forest understorey; prescribed fire; tree regeneration; wildfire

Introduction

Vaccinium fruits are important food for North American Grizzly (Brown) Bear (*Ursus arctos*; McLellan 2011). For some bears, the fruits of *Vaccinium* and other shrubby plants likely provide the dietary energy necessary for reproduction and winter hibernation, especially when salmon (*Oncorhynchus*) or hard mast (e.g., Whitebark Pine [*Pinus albicaulis* Engelmann], Limber Pine [*Pinus flexilis* E. James] seeds) are unavailable (Welch *et al.* 1997).

Banff National Park, Alberta, Canada, lies east of the Continental Divide, in a rain shadow of prevailing westerly weather systems that become increasingly arid with distance east of the divide, culminating in the dry prairies of central Alberta. Because of this moisture gradient, Tall Huckleberry (*Vaccinium membranaceum* Douglas ex Torrey, syn. *Vaccinium globulare* Rydberg) and Oval-leaf Blueberry (*Vaccinium ovalifolium* Smith)—important food for Grizzly Bears in the moister Columbia Mountains (Mundy

and Flook 1973; Hamer 1974), the northern Canadian Rocky Mountains (Munro *et al.* 2006; Ciarniello *et al.* 2007), and the Rocky Mountains of southern Alberta, southern British Columbia, and Montana (Martin 1983; Hamer *et al.* 1991; McLellan and Hovey 1995)—are uncommon in Banff National Park. However, two short-statured (10–30 cm high) *Vaccinium* species, Grouseberry (*Vaccinium scoparium* Leiberg ex Coville) and Myrtle Whortleberry (*Vaccinium myrtillus* L.), are abundant and known food for Grizzly Bears in the park (Hamer and Herrero 1987a,b).

Because *Vaccinium* fruit production typically correlates negatively with forest canopy cover (Martin 1983; Hamer 1996; Nielsen *et al.* 2004; Pengelly and Hamer 2014; McLellan 2018), conifer infilling in *Vaccinium* habitat is predicted to have a negative impact on fruit production. During 2008–2022 we conducted field studies in Banff National Park to assess the extent of conifer recruitment in *Vaccinium* habitat. We studied four sites in a 2001 prescribed

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burn and two sites in communities >70 years post-fire, in habitat where Grouseberry was abundant and Myrtle Whortleberry varied from absent to present in low abundance.

Study Area

Our study area included sites in both the Main Ranges and Front Ranges in the Rocky Mountains of Banff National Park, 3 km east and ~30–40 km east of the Continental Divide, respectively (Figure 1; see Table S1 for coordinates). Annual precipitation is estimated as 50–100 cm and 50–125 cm in the Main Ranges and Front Ranges study sites, respectively (Janz and Storr 1977).

Elevations in Banff National Park range from 1330 m to 3610 m, with treeline at ~2300 m. The subalpine zone extends from ~1500 m to 2350 m, with the upper subalpine (generally cooler and wetter, with deeper and longer-lasting snow) beginning at ~2000

m (Achuff 1982). Because Grouseberry is more prolific in the upper subalpine, we located our plots at elevations of 2060 m to 2380 m.

The eastern slopes of the Rocky Mountains have abundant Grouseberry cover. In Hamer’s (1985) study area (which falls within our Front Ranges study area), 28% of 123 km² was mapped as Engelmann Spruce (hereafter, spruce, *Picea engelmannii* Parry ex Engelmann)–Grouseberry forest and Lodgepole Pine (*Pinus contorta* Douglas ex Laudon)–Grouseberry forest. Myrtle Whortleberry appears less abundant than Grouseberry on the eastern slopes, but Myrtle Whortleberry and Grouseberry are difficult to separate, perhaps because they likely hybridize (Szczawinski 1962; Vander Kloet and Dickinson 1999). The fruits, however, are distinct; we identified <1% of the *Vaccinium* fruits in our Grouseberry study plots as Myrtle Whortleberry (Pengelly and Hamer 2014). Neither Tall Huckleberry nor Oval-leaf Blueberry

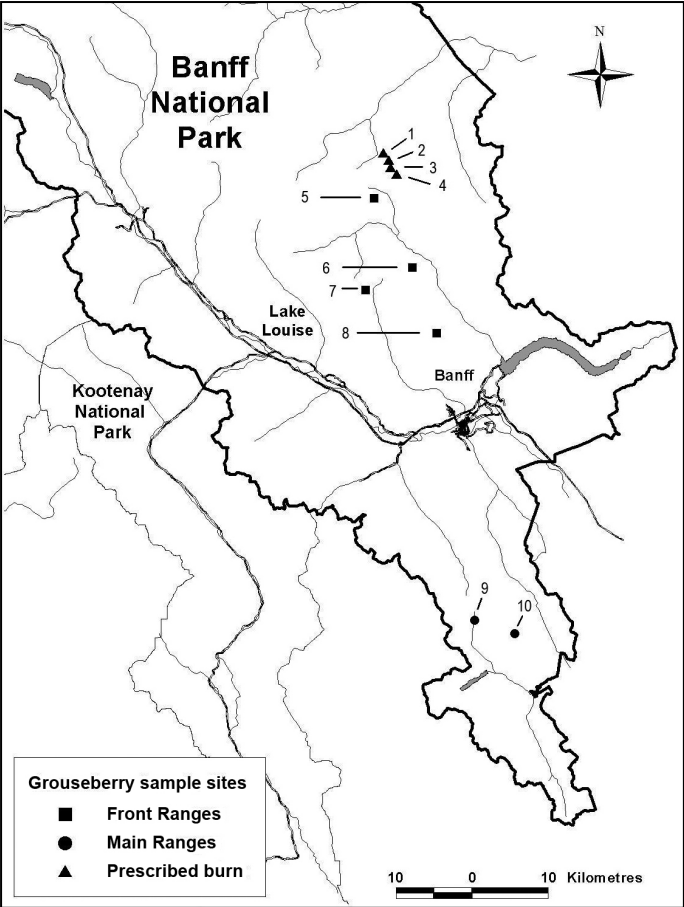


FIGURE 1. Location of Grouseberry (*Vaccinium scoparium*) study sites in Banff National Park, Alberta, 2004–2022. See Table S1 for study site coordinates.

occurs in the Front Ranges study area, to our knowledge, and neither was observed during our field work in the Main Ranges.

Forest cover in the study sites was mostly spruce. Using basal area as an index to mature trees, spruce had a relative abundance of 44%, Lodgepole Pine 21%, Subalpine Fir (*Abies lasiocarpa* (Hooker) Nuttall) 19%, and Subalpine Larch (*Larix lyallii* Parlature) 16%. Because of our sampling design, Grouseberry dominated the understorey of most plots.

Methods

We studied six sites, five in the Front Ranges and one in the Main Ranges (Table 1, Figure 1). These six sites are a subset of Pengelly and Hamer’s (2014) 10 sites (details in Table 1 footnote). Sites are numbered and named (based on nearby topographic features) in Table 1. The Front and Main ranges sites included burns of varying ages and areas known from direct observation to be locations used by Grizzly Bears feeding on Grouseberries (Table 1). We chose sites where Grouseberry was abundant and where at least a portion of the area had low to absent forest cover. The burns we sampled had experienced stand-replacing

fires in 1889, 1920, and 2001.

We established 33 plots in our six sites during 2004–2008 (Table 1), with 31 retained for the current study (we excluded two of the seven Allenby plots because they were outside the boundaries of the 1920 burn). We placed these plots in micro-sites with high Grouseberry cover (Pengelly and Hamer 2014). In 2022, we placed an additional 54 plots (Table 1) using systematic random sampling. We located these additional plots along randomly selected compass bearings, separated by a fixed global positioning system (GPS) distance (i.e., a fixed horizontal map distance). We located the first plot at a randomly selected GPS starting distance from the bearing’s originating point. Originating points were one of the original plots from 2004 to 2008, or one of seven GPS waypoints we established in 2022, which normally were on the perimeters of burned patches. In 2022 we also obtained new data from 20 of the original (2004–2008) plots: 11 in the burns at the Wigmore sites, four at Scoparium, and five at Allenby. The 11 matched plots in mature forests at Wigmore were not resurveyed in 2022 because the mature forests were stable climax communities.

TABLE 1. Grouseberry (*Vaccinium scoparium*) study sites in Banff National Park, Alberta. See Table S1 for coordinates of study sites.

Site*	Number of plots†	Elevation (m)	Slope aspect‡	Habitat
Front Ranges				
1. Wigmore One	4 + 2	2060–2100	SW	2001 prescribed burn; matched plots in burn and adjacent forest; all 2022 plots in burn
2. Wigmore Two	10 + 10	2070–2160	S–W	2001 prescribed burn; matched plots in burn and adjacent forest; all 2022 plots in burn
3. Wigmore Three	4 + 7	2110–2220	SW–W	2001 prescribed burn; matched plots in burn and adjacent forest; all 2022 plots in burn
4. Wigmore East	4 + 15	2230–2300	E–SE	2001 prescribed burn on opposite mountain face to the first three Wigmore sites; matched plots in burn and adjacent forest; all 2022 plots in burn
5. Cuthead Ridges	5	2270–2310	NE–E	
6. Scoparium	4 + 10	2080–2160	NW–NE, SE–W	1889 burn; Grizzly Bear (<i>Ursus arctos</i>) feeding area (Hamer and Herrero 1987a,b)
7. Forty Mile	5	2310–2380	E	
8. Cascade	7	2230–2350	NE, W–SW	
Main Ranges				
9. Allenby	7 + 10	2110–2200	NE, E–SW, NW	1920 burn in upper valley; Grizzly Bear feeding area
10. Turbulent	6	2140–2160	NE, E, S, W, NW	

*Sites are numbered 1–10 from north to south and correspond to numbers 1–10 in Figure 1. Sites 5, 7, 8, and 10 did not contribute data to this study; they are included to maintain continuity with Pengelly and Hamer (2014).
†First number: plots established during 2004–2012 (Pengelly and Hamer 2014); second number: additional plots established in 2022.
‡Aspect proceeds in a clockwise direction through the eight cardinal directions (e.g., E–SW means east + southeast + south + southwest).

Plot analysis

Plots were 20 m linear transects. We oriented the 2022 transects on site-specific, randomly selected compass bearings. Transects established during 2004–2012 were permanently marked at the 0 m and 20 m points with iron pins (rebar).
At each plot, we recorded location and elevation using a hand-held GPS unit (Garmin GPSMap 64, Olathe, Kansas, USA); slope aspect and steepness using a compass with built-in clinometer (Ranger sighting compass, Silva, Bromma, Sweden); *Vaccinium* cover in 19, 0.04 m² quadrats placed at 1 m intervals along the transect; and conifer density in four size classes (Table 2). We facilitated visual estimates of Grouseberry cover by dividing the 0.04 m² quadrat frame into 25 equal squares using monofilament line.

We analyzed matched photographs taken in 1978 and 2022. They show the change in forest cover that occurred during a 44-year period (1978–2022) at two locations in the Scoparium site. There, D.H. observed an adult female Grizzly Bear feeding on Grouseberries for five hours (12 September 1978) and three hours (17 October 1978), with feeding observed in both locations on both dates. We took observations and photographs from a mountain slope 200–260 m elevation above the feeding areas, and 700–850 m map distance away. The two feeding areas measured ~6 ha and ~7 ha and were separated at their closest point by ~400 m. We matched the 1978 camera location in 2022 by carrying in the field 20 cm × 30 cm prints of two 1978 photographs. We gridded those portions of the photographs that fell within the two feeding areas as delineated in field notes and site sketches made in 1978, and we scored each intersection of grid lines as either open habitat or coniferous foliage; 3870 and 4404 intersections were scored for Feeding Areas 1 and 2, respectively.

Data analysis

Because conifer infilling is dominated by smaller individuals, particularly in the recent 2001 burn where Trees (>10 cm diameter 1.4 m above the ground [dbh]) were absent in all but one plot, our analyses emphasize Saplings (small conifers between

30 cm and 2 m high) and Staddles (height >2 m but dbh ≤10 cm; Table 2). We do not emphasize Seedlings (height ≤30 cm) given that seedling height asymptotically approaches zero, making counts difficult (and hence potentially inaccurate), particularly where herbs, shrubs, or abundant conifer Staddles and Saplings conceal the ground; furthermore, seedlings are subject to high mortality and thus may or may not contribute to subsequent infilling (Brodersen *et al.* 2019). The densities of Staddles + Saplings measured in 2022 in the 2001 burn did not differ between the 11 permanently marked, original plots and the 34 randomly placed 2022 plots (Mann-Whitney-Wilcoxon $U = 130$, $P = 0.13$), and these two 2022 samples were combined ($n = 45$) for some analyses. Data often had many zero observations and did not follow a normal distribution (Shapiro-Wilk normality test, $W = 0.78$, $P < 0.01$); we thus used nonparametric tests. We conducted the tests in R version 4.2.2 (R Core Team 2022). Values reported are means ± SD.

Results

Grouseberry cover in our plots was $39 \pm 21\%$ (range 2–86%, $n = 85$). This high cover reflects our method of selecting study sites in Grouseberry habitat (Pengelly and Hamer 2014). In the 2001 prescribed burn, Grouseberry cover was $29 \pm 17\%$ (range 2–75%, $n = 45$). We selected 11 original plots in this burn where *Vaccinium* cover was high (mean cover in 2022, 49%), but we randomly placed the 34 burn plots added in 2022 and they had lower Grouseberry cover (23%). Grouseberry cover in the mature forests adjacent to the 2001 burns was $59 \pm 15\%$ (range 36–86%, $n = 11$).

Spruce made up most of the conifers (55%) in the 85 plots and dominated the Tree (54%), Sapling (49%), and Seedling (72%) size classes. Subalpine Fir made up 34% of all conifers, Lodgepole Pine made up 11%, and Subalpine Larch <1%. Lodgepole Pine made up 66% of the Staddles in the prescribed burns 21 years post-fire (Figure 2) but otherwise was a relatively minor component in the spruce-fir forests of the cooler, upper subalpine sites (Figure 3). Subalpine

TABLE 2. Plot sizes used to measure conifer densities in four size categories at Grouseberry (*Vaccinium scoparium*) plots in Banff National Park, Alberta.

Size category	Height (m)	Diameter* (m)	Plot radius† (m)	Plot area (m ²)
Trees	>2	>0.1	5.64	100
Staddles	>2	≤0.1	4	50
Saplings	>0.3, ≤2	—	3	28
Seedlings	≤0.3	—	3	28

*Conifer diameter was measured 1.4 m above the ground.
†Density plots were centred at the 10 m mark of 20 m transects (all four plot sizes were nested at the same centre point).



FIGURE 2. Plot T10 in 2001 burn, photographed in 2022. Plot T10 tallied 153 Staddles/100 m² (all Lodgepole Pine [*Pinus contorta*]) and 92 Saplings/100 m² (42% Engelmann Spruce [*Picea engelmannii*], 42% Lodgepole Pine, and 17% Subalpine Fir [*Abies lasiocarpa*]); Grouseberry (*Vaccinium scoparium*) cover was 19%. The person in the photo is D. Hamer. Photo: D. Hamer.

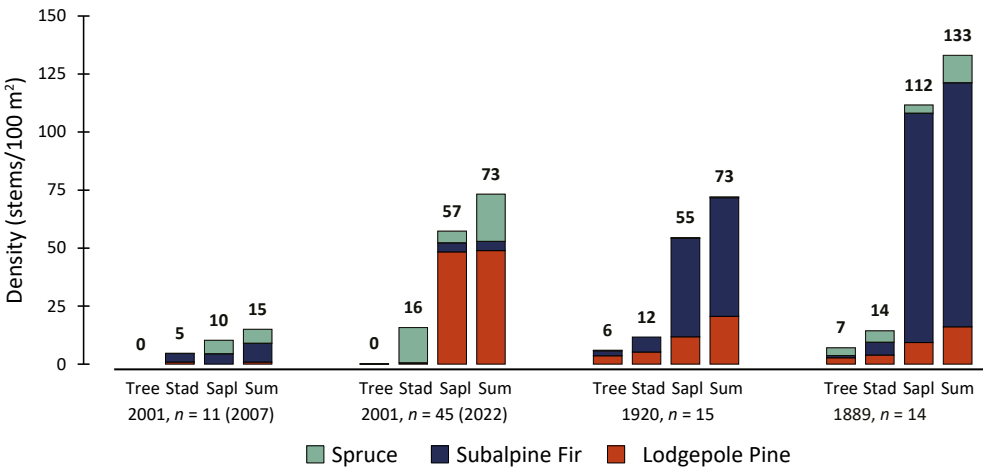


FIGURE 3. Densities (stems/100 m²) of Trees (diameter 1.4 m above the ground >10 cm), Staddles (diameter 1.4 m above the ground ≤10 cm, height >2 m), and Saplings (30 cm < height ≤2 m) in the 2001 Wigmore prescribed burn 6–7 years post-fire (2007–2008) and 21 years post-fire (2022), and in the 1920 Allenby burn and 1889 Scoparium burn. Spruce = Engelmann Spruce (*Picea engelmannii*). Subalpine Fir (*Abies lasiocarpa*). Lodgepole Pine (*Pinus contorta*). Stad = Staddle; Sapl = Sapling.

Fir, considered a very shade tolerant and often late-successional species (Varga and Klinka 2001), dominated in the two older burns 102 and 133 years post-fire (Figure 3).

The density of conifer ingrowth in mature forest at the Wigmore sites (where Pengelly and Hamer [2014] placed matched plots adjacent to the 2001 burns in multi-aged, old forest originating from fires

that occurred from ~1800 to 1868 [Hamer and Herero 1987a]) provides a baseline for intermediate-sized conifers present in mature, closed forest in the study area, namely, 22 ± 38 Staddles + Saplings/100 m² (range 2–134 stems/100 m², $n = 11$). Higher conifer density occurred in plots >70 years post-fire, i.e., the Scoparium and Allenby sites: 91 ± 185 Staddles + Saplings/100 m² (range 7–1040 stems/100 m², $n =$

29), given that these two sites were in regenerating post-fire communities (see Methods) with abundant post-fire conifer infilling (Figure 4).

Conifer density in the 2001 Wigmore burns increased rapidly post-fire (Figure 3). The mean density of Staddles + Saplings in the 2001 prescribed burn increased from 15 ± 18 stems/100 m² in 2007–2008 (six to seven years post-fire; $n = 11$) to $73 \pm$

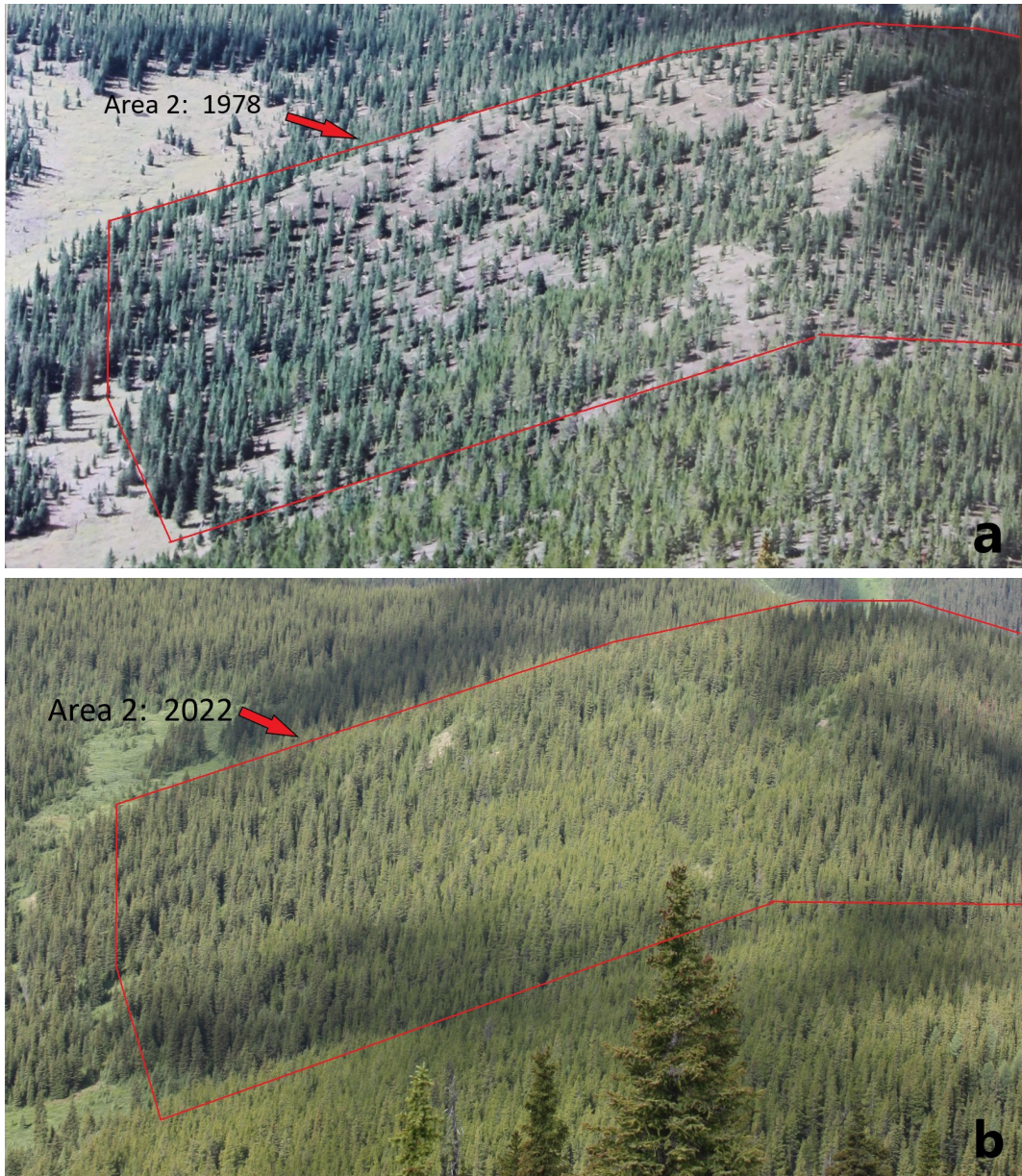


FIGURE 4. Matched photographs of Feeding Area 2, Scoparium site. a. Photograph taken on 12 September 1978, 89 years post-fire. b. Photograph taken on 22 July 2022, 133 years post-fire. Photos: D. Hamer.

67 stems/100 m² in 2022 (21 years post-fire; $n = 45$). The density of conifer infilling (Staddles + Saplings) differed among the four post-fire ages that we studied, i.e., the 2001 burn six to seven years post-fire, the 2001 burn 21 years post-fire, the 1920 burn 102 years post-fire, and the 1889 burn 133 years post-fire (Kruskal-Wallis test, $H = 17.5$, $P < 0.001$). Staddle + Sapling density did not differ among the three older post-fire samples but was lower in the 2001 burn six to seven years post-fire (Dunn multiple comparison test, adjusted $P < 0.004$). We excluded Trees from this analysis because they were essentially absent in the 2001 burn, both six to seven years post-fire and 21 years post-fire.

In 2022, living Trees (i.e., excluding fire-killed snags) occurred in just one plot in the 2001 burn. Mean Tree densities in the 1920 and 1889 burns (Figure 3) and in the old-growth forests adjacent to the 2001 burn (8.8 trees/100 m²) ranged from 6 to 9 stems/100 m² and did not differ among the three sites (Kruskal-Wallis $H = 0.69$, $P = 0.71$).

Our index of conifer foliage at the Scoparium Grizzly Bear feeding areas, as measured from matched, oblique photographs, increased by 54% during the 44 years from 1978 (89 years post-fire) to 2022 (133 years post-fire). In Feeding Area 1, the portion of grid intersections scoring conifer foliage increased from 58% to 96% from 1978 to 2022 (a 65% increase), and in Feeding Area 2, conifer intersections increased from 69% to 98% (a 42% increase; Figure 4).

Discussion

Conifer regeneration in the Wigmore 2001 prescribed burns increased rapidly following fire. Twenty-one years post-fire, the density of intermediate-sized conifers (height >0.3 m, diameter ≤ 10 cm, i.e., Saplings + Staddles) at Wigmore was similar to the density we recorded in the older 1920 Allenby and 1889 Scoparium burns (Figure 3). Some notable differences were evident, however. Because the 2001 fire was stand-replacing, a Tree component was still absent at Wigmore in 2022 (i.e., the diameters of the young conifers were <10 cm). The species composition of the intermediate-sized conifers also differed (mostly spruce in the 2001 burn, mostly Subalpine Fir in the two older burns). Finally, the 1889 site had twice the density of Saplings compared to the other two sites. However, statistically the three older burns had an equivalent density of intermediate-sized conifers. All three sites thus had the potential for further development of a conifer overstorey, as illustrated in Figure 4 for the 1889 burn.

Although conifer regrowth in the Wigmore prescribed burns was substantial by 21 years post-fire (Figure 2), regrowth was delayed for several decades

at the 1889 Scoparium burn (Figure 4a). The rate at which conifer ingrowth occurs is variable, with multiple explanations, from fire season and severity, to site characteristics, including the composition and age of the pre-fire community, to weather both pre- and post-fire (Little *et al.* 1994; Gill *et al.* 2021). This lag in recruitment following the 1889 fire may, in part, explain why our results indicated a comparable amount of conifer regeneration between the 133-year-old 1889 burn and the 21-year-old 2001 burn. Regardless of cause, what is important to managers is that conifer ingrowth intercepts solar radiation and shades the understorey, and this shading can substantially reduce fruit production in shrubby understorey berry-producing species (citations in Introduction). In the Wigmore sites, Grouseberry produced 7.0 times more fruit per square metre of *Vaccinium* cover in the prescribed burns than in the adjacent mature forests (Pengelly and Hamer 2014), even though Grouseberry vegetative growth was prolific under the forest canopy, with double the cover of that found in the adjacent burns.

The highest Grouseberry fruit densities recorded in the 10 study sites, 2480 and 1790 Grouseberry fruits/m² of *Vaccinium* cover, were at the Wigmore East burn (Figure 3 in Pengelly and Hamer 2014). Although Grouseberry produces the smallest of Alberta's *Vaccinium* fruits, this superabundance of fruits (in some years) ensures that Grouseberries are an important food for Grizzly Bears. In 2021, we found eight bear scats containing Grouseberries in the Wigmore burns in just two person-hours of searching (D.H. unpubl. data), twice the number found in the 1978 Scoparium feeding areas described earlier (see Methods). Because American Black Bear (*Ursus americanus*) do not occur in the Front Ranges study area (Hamer and Herrero 1987a), these scats are attributable to Grizzly Bears.

At the Wigmore sites, plots in mature forests adjacent to the 2001 burn had a mean of nine Trees/100 m², whereas in the 2001 burn 21 years post-fire, mean densities of 16 Staddles/100 m² and 57 Saplings/100 m² were recorded, indicating high potential for conifers to re-create closed-canopy forest. Conifer infilling is also restoring the forest canopy in the older 1920 and 1889 burns. A longer growing season near treeline, resulting from less snow and earlier spring melt, may accelerate infilling in the upper subalpine (Brodersen *et al.* 2019; Kummel *et al.* 2021). At the same time, the Canadian Rocky Mountain national parks are experiencing smaller amounts of forests burned, and hence much longer fire cycles have been recorded since the 1930s (White 1985). This reduction in fire activity is attributed to fire protection since the 1930s and not to climatic change; analysis

has shown no significant changes in fire climate in the mountain national parks since the 1930s (White 1985; Wierzchowski *et al.* 2002). Banff weather station data (1890 to present) indicate warmer, drier winters starting in the 1970s, with, however, no obvious trends during the fire season (M. Heathcott unpubl. analysis). At the same time, fire exclusion allows conifer regeneration to persist and hence reforest open habitat (Greene 2021). Furthermore, a multi-century analysis of fire-scarred trees by Parks *et al.* (2025) has shown that, despite increasing area burned in recent decades, a widespread fire deficit persists across a range of North American forest types and the current fire regime of high areas burned is not unprecedented.

Because of the longer fire cycles in the upper subalpine forests of Banff National Park, the use of prescribed fire is warranted to maintain Grouseberry fruit production for Grizzly Bears and other species. Prescribed fire to maintain these ephemeral open habitats ideally will be consistent with historical frequency and severity, as determined by a fire history study (Greene 2021). Our study found that easterly aspect fire produced the highest density of Grouseberry fruits, similar to previous work on Buffaloberry (*Shepherdia canadensis* [L.] Nuttall), where the greatest fruit production was recorded on northeast aspects (Hamer 1996). However, many factors affect fruit production, including precipitation, drought, degree days of growing, and weather during pollination. A wide variety of burns of different ages on different aspects and elevations is needed to provide food security for Grizzly Bears and many other species.

Management implications

Vaccinium fruits are an important energy source for many populations of Grizzly Bears, a species of Special Concern in Canada (SARA Registry 2025). McLellan (2011, 2015) concluded that the high density of Grizzly Bears in his southeastern British Columbia study area was largely attributable to wildfires of the 1920s and 1930s, which created major shrub fields covering 5–12 km² where Tall Huckleberry, the main Grizzly Bear food in his study area during summer hyperphagia, was abundant. Like the upper subalpine location of our Grouseberry study sites, Tall Huckleberry fruits in McLellan's (2015) study area were produced almost exclusively in higher-elevation areas away from the concentration of human activity in valley bottoms where the risk of Grizzly Bear mortality from hunting and other human activities was higher. These circumstances permitted the Grizzly Bear population to expand despite industrial development in the study area (McLellan 2015).

In Banff National Park, it may be difficult for managers to apply prescribed fire to achieve management

goals. In 24 years of weather data from the Front Ranges of Banff National Park (1980–2003), only three springs and four autumns had burn windows exceeding three days (I.P. unpubl. data). Managers also have the option of allowing natural-ignition wild-fire to burn in upper subalpine forests (above 2000 m). But this is a high-risk option, as was discovered in Yellowstone National Park, where 36% of the park burned in 1988 after managers allowed 18 lightning strikes to continue burning (Turner *et al.* 2003), and in Glacier National Park, Montana, where the lightning-caused Canyon Creek fire in 1988, which authorities similarly did not suppress under a let-burn policy, later experienced “a rare catastrophic run” and burned 400 km², including many agricultural resources (Tall Timbers 1989).

In the Rocky Mountain national and provincial parks, few areas exist where managers permit lightning-caused fires to burn unhindered. In addition, analysis has shown that both lightning and lightning-caused fires are rare events in most of Banff and Jasper national parks compared to forests west of the Continental Divide in British Columbia (Wierzchowski *et al.* 2002). Because of both fire suppression by managers and a paucity of lightning-caused ignition, no lightning-ignited fire >10 ha has occurred in the last century in our study area (White 1985; I.P. pers. obs.). We conclude that although many opportunities exist to light fires like the 2001 Wigmore prescribed burn in our study area, the chance of a lightning fire occurring remains small. Enhanced fruit production for wildlife in Banff National Park will likely result when managers use prescribed fire to create openings in the forest canopy for Grouseberry and other *Vaccinium* species, Buffaloberry, and other fruiting shrubs important to wildlife (Hamer and Herrero 1987b; Hamer 1996; Pengelly and Hamer 2014; McLellan 2018).

Author Contributions

Writing: D.H.; Review: D.H. and I.P.; Conceptualization and Field Investigation: D.H. and I.P.

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Literature Cited

- Achuff, P.L.** 1982. Vegetation: introduction and methods. Pages 71–75 in *Ecological (Biophysical) Land Classification of Banff and Jasper National Parks. Volume II: Soil and Vegetation Resources*. Edited by W.D. Holland and G.M. Coen. Alberta Institute of Pedology, Publication SS-82-44, Edmonton, Alberta, Canada.
- Brodersen, C.R., M.J. Germino, D.M. Johnson, K. Reinhardt, W.K. Smith, L.M. Resler, M.Y. Bader, A. Sala, L.M. Kueppers, G. Broll, D.M. Cairns, F.K. Holtmeier, and G. Wieser.** 2019. Seedling survival at timberline is critical to conifer mountain forest elevation and extent. *Frontiers in Forests and Global Change* 2: 9. <https://doi.org/10.3389/ffgc.2019.00009>
- Ciarniello, L.M., M.S. Boyce, D.C. Heard, and D.R. Seip.** 2007. Components of Grizzly Bear habitat selection: density, habitats, roads, and mortality risk. *Journal of Wildlife Management* 71: 1446–1457. <https://doi.org/10.2193/2006-229>
- Gill, N.S., T.J. Hoecker, and M.G. Turner.** 2021. The propagule doesn't fall far from the tree, especially after short-interval, high-severity fire. *Ecology* 102: e03194. <https://doi.org/10.1002/ecy.3194>
- Greene, G.A.** 2021. Fire-resilient ecosystems: fire exclusion and selective harvesting degrade dry forests in British Columbia. Ph.D. thesis, University of British Columbia, Vancouver, British Columbia, Canada. <https://doi.org/10.14288/1.0398455>
- Hamer, D.** 1996. Buffaloberry (*Shepherdia canadensis* (L.) Nutt.) fruit production in fire-successional bear feeding sites. *Journal of Range Management* 49: 520–529. <https://doi.org/10.2307/4002293>
- Hamer, D., and S. Herrero.** 1987a. Grizzly Bear food and habitat in the Front Ranges of Banff National Park, Alberta. *International Conference on Bear Research and Management* 7: 199–213. <https://doi.org/10.2307/3872626>
- Hamer, D., and S. Herrero.** 1987b. Wildfire's influence on Grizzly Bear feeding ecology in Banff National Park, Alberta. *International Conference on Bear Research and Management* 7: 179–186. <https://doi.org/10.2307/3872624>
- Hamer, D., S. Herrero, and K. Brady.** 1991. Food and habitat used by Grizzly Bears, *Ursus arctos*, along the continental divide in Waterton Lakes National Park, Alberta. *Canadian Field-Naturalist* 105: 325–329. <https://doi.org/10.5962/p.358039>
- Hamer, J.D.W.** 1974. Distribution, abundance, and management implications of the Grizzly Bear and mountain caribou in the Mountain Creek watershed of Glacier National Park, British Columbia. M.Sc. thesis, University of Calgary, Calgary, Alberta, Canada.
- Hamer, J.D.W.** 1985. Feeding ecology of Grizzly Bears in the Cascade and Panther valleys of Banff National Park, Alberta. Ph.D. thesis, University of Calgary, Calgary, Alberta, Canada.
- Janz, B., and D. Storr.** 1977. The climate of the contiguous mountain parks. Department of the Environment, Atmospheric Environment Service Project Report No. 30, Toronto, Ontario, Canada.
- Kummel, M., A. McGarigal, M. Kummel, C. Earnest, and M. Feiden.** 2021. Tree establishment and growth drive treeline advance and change treeline form on Pikes Peak (Colorado) in response to recent anthropogenic warming. *Canadian Journal of Forest Research* 51: 1458–1471. <https://doi.org/10.1139/cjfr-2019-0358>
- Little, R.L., D.L. Peterson, and L.L. Conquest.** 1994. Regeneration of Subalpine Fir (*Abies lasiocarpa*) following fire: effects of climate and other factors. *Canadian Journal of Forest Research* 24: 934–944. <https://doi.org/10.1139/x94-123>
- Martin, P.** 1983. Factors influencing Globe Huckleberry fruit production in northwestern Montana. *International Conference on Bear Research and Management* 5: 159–165. <https://doi.org/10.2307/3872533>
- McLellan, B.N.** 2011. Implications of a high-energy and low-protein diet on the body composition, fitness, and competitive abilities of Black (*Ursus americanus*) and Grizzly (*Ursus arctos*) Bears. *Canadian Journal of Zoology* 89: 546–558. <https://doi.org/10.1139/z11-026>
- McLellan, B.N.** 2015. Some mechanisms underlying variation in vital rates of Grizzly Bears on a multiple use landscape. *Journal of Wildlife Management* 79: 749–765. <https://doi.org/10.1002/jwmg.896>
- McLellan, C.R.** 2018. Food availability and Grizzly Bear (*Ursus arctos*) selection of post-fire and thinned forests in the mountain national parks of Canada. M.Sc. thesis, University of Alberta, Edmonton, Alberta, Canada.
- McLellan, B.N., and F.W. Hovey.** 1995. The diet of Grizzly Bears in the Flathead River drainage of southeastern British Columbia. *Canadian Journal of Zoology* 73: 704–712. <https://doi.org/10.1139/z95-082>
- Mundy, K.R.D., and D.R. Flook.** 1973. Background for managing Grizzly Bears in the national parks of Canada. *Canadian Wildlife Service Report Series* No. 22.
- Munro, R.H.M., S.E. Nielsen, M.H. Price, G.B. Stenhouse, and M.S. Boyce.** 2006. Seasonal and diel patterns of Grizzly Bear diet and activity in west-central Alberta. *Journal of Mammalogy* 87: 1112–1121. <https://doi.org/10.1644/05-mamm-a-410r3.1>
- Nielsen, S.E., R.H.M. Munro, E.L. Bainbridge, G.B. Stenhouse, and M.S. Boyce.** 2004. Grizzly Bears and forestry II. Distribution of Grizzly Bear foods in clearcuts of west-central Alberta, Canada. *Forest Ecology and Management* 199: 67–82. <https://doi.org/10.1016/j.foreco.2004.04.015>
- Parks, S.A., C.H. Guiterman, E.Q. Margolis, M. Loneragan, E. Whitman, J.T. Abatzoglou, D.A. Falk, J.D. Johnston, L.D. Daniels, C.W. Lafon, R.A. Loehman, K.F. Kipfmüller, C.E. Naficy, M.-A. Parisien, J. Portier, M.C. Stambaugh, A.P. Williams, A.P. Wion, and L.L. Yocom.** 2025. A fire deficit persists across diverse North American forests despite recent increases in area burned. *Nature Communications* 16: 1493. <https://doi.org/10.1038/s41467-025-56333-8>
- Pengelly, I., and D. Hamer.** 2014. Grouseberry (*Vaccinium*

scoparium Leiberg ex Coville) fruit production in forest openings in Banff National Park, Alberta. Canadian Field-Naturalist 128: 400–407. <https://doi.org/10.22621/cfn.v128i4.1635>

R Core Team. 2022. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

SARA (*Species at Risk Act*) Registry. 2025. Species summary: Grizzly Bear (*Ursus arctos*), Western population. Government of Canada, Ottawa, Ontario, Canada. Accessed 15 September 2025. <https://species-registry.canada.ca/index-en.html#/species/1195-863>

Szczawinski, A.F. 1962. The Heather Family (Ericaceae) of British Columbia. Handbook no. 19. British Columbia Provincial Museum, Victoria, British Columbia, Canada.

Tall Timbers. 1989. E.V. Komerek fire ecology database: the 1988 Canyon Creek Fire. Accessed 5 January 2024. <https://www.frames.gov/catalog/29953>.

Turner, M.G., W.H. Romme, and D.B. Tinker. 2003. Surprises and lessons from the 1988 Yellowstone fires. *Frontiers in Ecology and the Environment* 1: 351–358. [https://doi.org/10.1890/1540-9295\(2003\)001\[0351:salft](https://doi.org/10.1890/1540-9295(2003)001[0351:salft)

[y\]2.0.co;2](https://doi.org/10.1890/1540-9295(2003)001[0351:salft)

Vander Kloet, S.P., and T.A. Dickinson. 1999. The taxonomy of *Vaccinium* section *Myrtilus* (Ericaceae). *Brittonia* 51: 231–254. <https://doi.org/10.2307/2666632>

Varga, P., and K. Klinka. 2001. Structure of high-elevation, old-growth stands in west-central British Columbia. *Canadian Journal of Forest Research* 31: 2098–2106. <https://doi.org/10.1139/x01-148>

Welch, C.A., J. Keay, K.C. Kendall, and C.T. Robbins. 1997. Constraints on frugivory by bears. *Ecology* 78: 1105–1119. [https://doi.org/10.1890/0012-9658\(1997\)078\[1105:cofbb\]2.0.co;2](https://doi.org/10.1890/0012-9658(1997)078[1105:cofbb]2.0.co;2)

White, C. 1985. Wildland fires in Banff National Park, 1880–1980. Occasional Paper No. 3. National Parks Branch, Environment Canada, Ottawa, Ontario.

Wierzchowski, J., A.M. Heathcott, and M.D. Flannigan. 2002. Lightning and lightning fire, central cordillera, Canada. *International Journal of Wildland Fire* 11: 41–51. <https://doi.org/10.1071/wf01048>

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SUPPLEMENTARY MATERIALS:

- TABLE S1.** Universal Transverse Mercator (UTM) coordinates of Sites 1–10.
- TABLE S2.** Conifer densities (stems/100 m²) by site age (years post-fire), species, and conifer size class at 85 Grouseberry (*Vaccinium scoparium*) plots in Banff National Park, Alberta.

A baseline study of the fishes in the north-flowing section of the Rideau River-Canal system, Ontario, 1998–2000

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Abstract

Since 1883, 64 fish species belonging to 22 families have been reported from the north-flowing section of the Rideau River-Canal system, Ontario, Canada. Six of these species are non-native, two of which have become established with the remaining four no longer present. A total of 34 species belonging to 11 families were collected in the mainstem north-flowing section of the Rideau River and five of its tributaries during our 1998–2000 study. The fish community along the Rideau River mainstem at sites with adjacent urban land use was distinguishable from sites that were adjacent to agricultural–forested areas. The urban sites cluster was characterized by an abundance of Rock Bass (*Ambloplites rupestris*) and a low abundance of Bluegill (*Lepomis macrochirus*), Pumpkinseed (*Lepomis gibbosus*), Yellow Perch (*Perca flavescens*), Brown Bullhead (*Ameiurus nebulosus*), and White Sucker (*Catostomus commersonii*). The two mixed agricultural–forested site clusters combined were characterized by an abundance of Black Crappie (*Pomoxis nigromaculatus*), Largemouth Bass (*Micropterus nigricans*), Bluegill, Pumpkinseed, Yellow Perch, and Brown Bullhead. Our study is a baseline of the fish community in the Rideau River watershed at the end of the 20th century, with which to compare as the impacts of climate and land use changes continue.

Key words: Rideau River; fishes; land use; species richness; abundance

Introduction

The Rideau River-Canal system is a 202-km long regulated waterway constructed in 1826–1832, linking the Ottawa River at Ottawa in the north to Lake Ontario and the St. Lawrence River at Kingston in the south via 47 locks (Watson 2024). This engineering feat united the north-flowing Rideau River, which empties into the Ottawa River, and the south-flowing Cataraqui River, which empties into Lake Ontario. Prior to the construction of the Rideau River-Canal system, the natural outlet of the Rideau River was the 15 m Rideau Falls, an impassable barrier to the upstream movement of fishes from the Ottawa River to the Rideau River. In theory, the intermittent locks constructed along the entire length of the waterway allows the movement of fishes into the Rideau system from both the Ottawa River and the St. Lawrence River/Lake Ontario. Regulated waterways are well known for impacting the ichthyofauna (Jungwirth *et al.* 2000; Nunn and Cowx 2012; Birnie-Gauvin *et al.*

2017). Locks can serve as a conduit for invasive fish movement (Bergman *et al.* 2022) and yearly water drawdown can reduce fish overwintering habitat, perhaps by creating shallow-water barriers that decrease connectivity (Bergman *et al.* 2023). The waterway became a National Historic Site of Canada in 1925, a Canadian Heritage River in 2000, and a UNESCO World Heritage Site in 2007 (Watson 2024).

Our study constituted the fish component of the Rideau River Biodiversity Project (Phelps 2001; Johnson *et al.* 2003). We 1. compare the historical ichthyofauna (1883–1997) of the north-flowing section of the Rideau River-Canal system to that we collected from 1998 to 2000; 2. determine if there were differences in fish abundance from sites with different adjacent land uses (i.e., urban, agricultural, forested); 3. compare the ichthyofauna of the mainstem north-flowing section of the Rideau River with that of five of its tributaries; and 4. establish a baseline with which to compare future fish community studies.

Methods

Thirty-five sites were sampled along the Rideau River and five of its tributaries in the summers of 1998–2000 (Tables 1 and 2). Fourteen sites with an associate land-use category were sampled along the mainstem Rideau River, upstream to downstream, from Smiths Falls (river km [rkm] 97) to Rideau Falls, Ottawa (rkm 0) from mid-July to mid-September 1998 and then again in August–September 2000 using a variety of methods (Table 1, Figure 1). Site numbers run roughly downstream to upstream, from 1 to 14 following Phelps (2001). The land use adjacent to these sites was visually determined in the field to be agricultural, forested, or urban; there were five agricultural and four forested sites from Smiths Falls to Rideau Glen and five urban sites downstream of Black Rapids to Rideau Falls (Table 1). Note that the urban sites were in the downstream part of our study area while the agricultural-forested sites were in the upstream part. Six additional sites were sampled between Smiths Falls and Manotick in 2000 (Table 1). Five tributaries to the Rideau River in this 97-km segment were each sampled at three sites: as close to their source as it was possible to navigate, their confluence with the Rideau, and about midway between these two. Jock River, Stevens Creek, and Kemptville Creek were sampled during the last two weeks of July 1999 while Cranberry Creek and Mosquito Creek were sampled during August–September 2000 (Table 2; Figure 1).

Fishes were identified to species using Scott and Crossman (1973), McAllister and Coad (1974), Bernatchez and Giroux (1991), and Coad (2001). We followed Page *et al.* (2023) as the most current fish nomenclature. Fork or total length (mm), depending on the species, and weight (g) were measured on each captured fish. Most fishes were then released at the site of capture, but those that could not be identified in the field were brought to the lab.

We recorded the following habitat characteristics at each site: water depth, water temperature, and water clarity; percent cover of each substrate type, bank height, percent cover of overhanging vegetation, percent total cover, and percent cover of individual deep aquatic (i.e., 7 m from shoreline) and riparian (i.e., shallow) vegetation also were recorded in 1998. No water physicochemistry or water quality parameters were measured except for temperature and clarity. Substrate was visually estimated at three plots 1 m from the shoreline (i.e., shallow areas) and at three plots 7 m from the shoreline (i.e., deep areas) and averaged. The substrate was classified according to Meador *et al.* (1993) and plant species were identified using Newmaster *et al.* (1997). Seven plant species were common to both shallow and deep areas:

American Eelgrass (*Vallisneria americana* Michaux), Eurasian Water-milfoil (*Myriophyllum spicatum* L.), pondweed (*Potamogeton* L.), Fragrant Water-lily (*Nymphaea odorata* Aiton), Variegated Pond-lily (*Nuphar variegata* Engelmann ex Durand), duckweed (*Lemna* L.), and elodea (*Elodea* Michaux). Various species of algae were only found in shallow areas and Common Hornwort (*Ceratophyllum demersum* L.) was only found in deep areas. Fish species richness (i.e., number of species), abundance for each species, and catch-per-unit effort for each species were recorded at each sampling site. Catch-per-unit effort for each species was calculated at each site by summing the number of individuals captured and dividing by the number of collecting gear used.

Cluster analyses were performed using SYSTAT v5 (SYSTAT 1992); the Visual Basic Application in Microsoft Excel 97 was used to create a Visual Basic Macro to perform the nonparametric Mantel tests. Because urban sites were sequentially distributed downstream while agricultural and forested sites were randomly arranged upstream, Mantel tests were performed between the geographic distance of the 14 sites sampled along the river in 1998 and the abundance of fishes and habitat characteristics at those sites to determine whether these were correlated. A cluster analysis using Pearson distance and Ward joining algorithm was performed between land-use type and habitat characteristics at the 14 sites sampled in 1998 to assess whether these were correlated. Mantel tests were performed between habitat characteristics and fish species richness and abundance at the same sites to assess if these were correlated. A cluster analysis using Pearson distance and Ward joining algorithm was performed between land-use type and abundance of fishes at the same sites to assess if these were correlated.

Results

In 1998, 6904 fishes (6394 individuals, excluding young-of-the-year centrarchids; Table 3) were captured along the length of the mainstem Rideau River between Smiths Falls and Ottawa (Figure 1). Two individuals were first records for the mainstem Rideau River (Table 4): a Tadpole Madtom (*Noturus gyrinus*, collected 28 August upstream from the Catchall at buoy N211 [site 12], although this species was collected as early as 1976 in Kemptville Creek [Phelps *et al.* 2000a]), and a Freshwater Drum (*Aplodinotus grunniens*) collected 27 July west of Bank Street Bridge [site 3] (Phelps *et al.* 2000b). Only one individual each of Emerald Shiner (*Notropis atherinoides*) and Mottled Sculpin (*Cottus bairdii*) was collected (Table 3), despite intensive effort with a wide array of collection gear; this may be an indication of

TABLE 1. Sites along the Rideau River mainstem sampled for ichthyofauna in 1998 and 2000 and their adjacent land uses. Sites are located as indicated in Figure 1. The N values refer to buoys. Land use was not identified for sites 15–20 because they were not part of the analyses that examined the relationship between land use and biological parameters. See table footnotes for sampling gear used.

Site	Location	Latitude (°N)	Longitude (°W)	Land use	Dates sampled in 1998*	Dates sampled in 2000†
1	Former Ottawa City Hall	45.4379	75.6922	Urban	20, 23, 31 July	10 September
2	South of Saint Patrick Street Bridge	45.4364	75.6754	Urban	20, 22, 31 July	10 September
3	West of Bank Street Bridge	45.3867	75.6858	Urban	27, 30 July, 20 August	10 September
4	West of Bronson Street Bridge	45.3829	75.6914	Urban	27–29, 31 July	10 September
5	Downstream of Black Rapids	45.3283	75.7003	Urban	3, 5, 21 August	10 September
6	Rideau Glen, upstream of N44	45.3025	75.6975	Agricultural	5, 7, 21 August	10 September
7	Across from Rideau River Provincial Park	45.0539	75.6697	Forested	10, 13–14, 27 August	3 September
8	N207, downstream from the Catchall	45.0125	75.7331	Forested	13, 27 August	3 September
9	N337, upstream from bird sanctuary	44.8962	75.8786	Forested	17, 19, 24 August	3 September
10	N320, bird sanctuary	44.9111	75.8666	Forested	19, 24 August	3 September
11	N183, upstream of Libby Island	45.0206	75.7173	Agricultural	27–28 August, 10 September	3 September
12	N211, upstream from the Catchall	45.0098	75.7419	Agricultural	28 August, 3, 8–9, 14 September	3 September
13	Upstream of N250	44.9729	75.8124	Agricultural	1, 4, 15 September	4 September
14	N253, upstream from Rideau Creek confluence	44.9895	75.7706	Agricultural	31 July, 1, 8, 17 September	4 September
15	Upstream of Manotick Bridge	45.2318	75.6758	—	—	19 August
16	Upstream of Hurst Marina, Manotick	45.1595	75.6350	—	—	19–20 August
17	N140, McGahey's Bend	45.0947	75.6237	—	—	20 August
18	Across from Baxter Conservation Area	45.0991	75.6200	—	—	21 August
19	1.7 km east of Kilmarnock Island	44.8693	75.9000	—	—	21, 23–24 August
20	Kilmarnock, 500 m downstream of boat ramp	44.8853	75.8796	—	—	21 August

*Collecting gear used at each site in 1998: one of two trap nets (1.83 m³ box with a multifilament stretched mesh size of 6.4 cm and a 25 m × 1.83 m lead and a 1.20 m³ box with a multifilament stretched mesh size of 6.4 cm and a 15 m × 1.20 m lead); a hoop/fyke net (9.1 m × 0.9 m lead, mesh size 6 mm, and rings 76 cm in diameter) set perpendicular to the current for 24 h; one unbaited minnow trap 44.5 cm long, 23 cm in diameter, with a 1.1 cm opening set for 24 h; two passes (three at sites 4–6, four at site 14) of a 30-m seine net with mesh size 6 mm and bag weighted down with chain to prevent rolling, operated from a boat in deeper water or by two people in wadeable water; and a backpack DC electrofisher (Model 12-A, Smith-Root Inc., Vancouver, Washington, USA) operated for 1200 s, used in conjunction with fine mesh dipnets.

†Two unbaited minnow traps were used to resample the 1998 sites in 2000. Two boat-operated 30 m seine hauls (four at site 16, none at site 18), three unbaited minnow traps (none at sites 15–17, two at site 19, one at site 20) and 1200 s of electrofishing (none at sites 15–17, 20) were used at the six additional sites sampled only in 2000.

the rarity of the above four species in the mainstem. The most ubiquitous species were members of Centrarchidae, with Pumpkinseed (*Lepomis gibbosus*) and Rock Bass (*Ambloplites rupestris*) found at all 14 sites and Bluegill (*Lepomis macrochirus*) and Black Crappie (*Pomoxis nigromaculatus*) found at 13 sites (Table 3). These sites were adjacent to all three types of land uses (urban, agricultural, and forested; Table

1). These four species accounted for 46.81% of fishes collected (Table 3).

Species richness (presence/absence) and relative abundance (catch-per-unit effort) of fishes and the habitat characteristics for each site were plotted against the distance (in rkm) of each site away from the confluence of the Rideau and Ottawa Rivers, to determine if a longitudinal continuum existed along the length

TABLE 2. Ichthyofauna sampling sites along tributaries to the Rideau River, 1999 and 2000. See table footnotes for sampling gear used.

Site	Tributary	Location	Latitude (°N)	Longitude (°W)	Dates sampled in 1999*	Dates sampled in 2000†
JR1	Jock River	Confluence with Rideau River	45.2608	75.7069	22 July	—
JR2	Jock River	Bow of Jock River Park	45.2536	75.8075	27 July	—
JR3	Jock River	Richmond	45.1872	75.8333	27 July	—
SC1	Stevens Creek	Confluence with Rideau River	45.1472	75.6444	28 July	—
SC2	Stevens Creek	North Gower	45.1299	75.7138	30 July	—
SC3	Stevens Creek	At Hwy 4	45.1398	75.7268	30 July	—
KC1	Kemptville Creek	Confluence with Rideau River	45.0569	75.6554	21 July	—
KC2	Kemptville Creek	Midway between Kemptville and confluence	45.0455	75.6532	20 July	—
KC3	Kemptville Creek	Kemptville	45.0200	75.6408	19 July	—
CC1	Cranberry Creek	Confluence with Rideau River	45.1383	75.6411	—	30 August
CC2	Cranberry Creek	Midway between confluence and source	45.1196	75.6671	—	30 August
CC3	Cranberry Creek	Source	45.0747	75.7369	—	30 August
MC1	Mosquito Creek	Confluence with Rideau River	45.2894	75.6963	—	28 August
MC2	Mosquito Creek	Midway between confluence and source	45.2683	75.6458	—	28–29 August
MC3	Mosquito Creek	Source	45.2681	75.5979	—	29 August, 23–24 September

*Two passes of a 10 m seine net (one pass at KC2, three at KC3; mesh size not recorded), eight unbaited minnow traps set for 24 h, and 1200 s of electrofishing (2400 s at KC2) were used at each site in the Jock River, Stevens Creek, and Kemptville Creek in 1999.

†Two passes of a handheld seine net (none at CC2, CC3, three passes at MC2; mesh size not recorded), three unbaited minnow traps set for 24 h, and 1200 s of electrofishing were used (none at CC2, CC3, MC1, MC2) at each site in Cranberry Creek and Mosquito Creek in 2000.

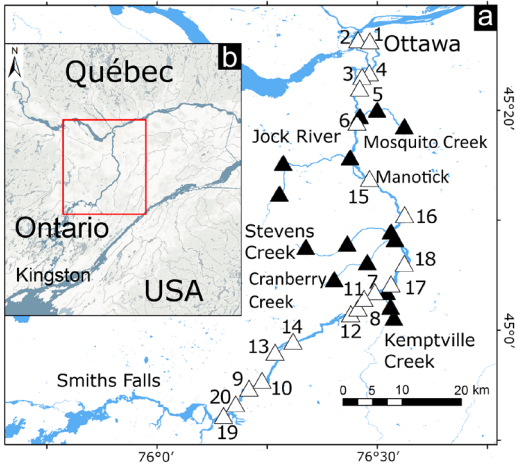


FIGURE 1. a. North-flowing section of the Rideau River-Canal system between Smiths Falls and Ottawa, Ontario, Canada with b. showing context in southeastern Ontario. Sampling sites (1998–2000) are indicated by the numbered open triangles (mainstem) and closed triangles (tributaries). See Tables 1 and 2 for site details.

of the Rideau River (i.e., if there was an increasing or decreasing trend downstream to upstream or if distance from the river’s confluence plays a role in structuring the fish community). The Mantel tests indicated statistically significant positive correlations between the geographic distance from the confluence of the Rideau and Ottawa Rivers to each of the 14 sites sampled and the abundance of piscivorous ($Z = 5025, P = 0.002 < \alpha = 0.006$) and insectivorous ($Z = 17\,590, P < 0.001 < \alpha = 0.006$) fishes. Piscivorous species were Northern Pike (*Esox lucius*), Rock Bass, Smallmouth Bass (*Micropterus dolomieu*), Largemouth Bass (*Micropterus nigricans*), Black Crappie, and Walleye (*Sander vitreus*). Insectivorous species were White Sucker (*Catostomus commersonii*), Silver Redhorse (*Moxostoma anisurum*), Greater Redhorse (*Moxostoma valenciennesi*), Brown Bullhead (*Ameiurus nebulosus*), Pumpkinseed, Bluegill, and Yellow Perch (*Perca flavescens*). Note that Yellow Perch was grouped with the insectivorous fishes because 91% of individuals collected were <15 cm total length.

There were no significant statistical relationships

TABLE 3. Abundance, percent composition, and sampling sites in the mainstem Rideau River, Ontario from which 30 fish species were captured (6394 individuals, excluding young-of-the-year centrarchids), mid-July to mid-September 1998.

Species	Number of individuals	%	Number of sites	List of sites
Pumpkinseed (<i>Lepomis gibbosus</i>)	1149	17.97	14	1–14
Bluegill (<i>Lepomis macrochirus</i>)	952	14.89	13	2–14
Yellow Perch (<i>Perca flavescens</i>)	840	13.14	12	2, 4–14
Common Shiner (<i>Luxilus cornutus</i>)	717	11.21	3	4, 6–7
Rock Bass (<i>Ambloplites rupestris</i>)	553	8.65	14	1–14
Black Crappie (<i>Pomoxis nigromaculatus</i>)	339	5.30	13	2–14
Logperch (<i>Percina caprodes</i>)	303	4.74	9	1, 3, 5–9, 13–14
Banded Killifish (<i>Fundulus diaphanus</i>)	283	4.43	11	2–4, 7–14
Golden Shiner (<i>Notemigonus crysoleucas</i>)	244	3.82	10	2–6, 8–9, 11–12, 14
Bluntnose Minnow (<i>Pimephales notatus</i>)	162	2.53	7	7–9, 11–14
Largemouth Bass (<i>Micropterus nigricans</i>)	161	2.52	10	4, 6–14
Smallmouth Bass (<i>Micropterus dolomieu</i>)	141	2.20	11	1–7, 11–14
Brook Silverside (<i>Labidesthes sicculus</i>)	134	2.10	7	5–8, 10–11, 13
Blacknose Shiner (<i>Notropis heterolepis</i>)	106	1.66	8	7–14
Spottail Shiner (<i>Hudsonius hudsonius</i>)	82	1.28	5	2, 5–7, 12
Brown Bullhead (<i>Ameiurus nebulosus</i>)	76	1.19	9	2, 6–13
Tessellated Darter (<i>Etheostoma olmstedii</i>)	54	0.84	11	1–2, 5–12, 14
Common Carp (<i>Cyprinus carpio</i>)	26	0.41	8	3, 6–8, 11–14
Northern Pike (<i>Esox lucius</i>)	22	0.34	11	1, 3–6, 8, 10–14
Greater Redhorse (<i>Moxostoma valenciennesi</i>)	11	0.17	3	6, 12–13
Blackchin Shiner (<i>Miniellus heterodon</i>)	10	0.16	2	2, 6
Silver Redhorse (<i>Moxostoma anisurum</i>)	9	0.14	4	3, 5–6, 14
Fallfish (<i>Semotilus corporalis</i>)	7	0.11	4	5–6, 8, 12
Walleye (<i>Sander vitreus</i>)	4	0.06	4	5–7, 12
White Sucker (<i>Catostomus commersonii</i>)	3	0.05	3	5, 11–12
Muskellunge (<i>Esox masquinongy</i>)	2	0.03	2	4, 8
Mottled Sculpin (<i>Cottus bairdii</i>)	1	0.02	1	3
Tadpole Madtom (<i>Noturus gyrinus</i>)	1	0.02	1	12
Freshwater Drum (<i>Aplodinotus grunniens</i>)	1	0.02	1	3
Emerald Shiner (<i>Notropis atherinoides</i>)	1	0.02	1	6
Totals	6394	100.02		

between geographic distance and the abundance of small-bodied fishes or all fishes combined, nor with any of the habitat characteristics we measured. Small-bodied fishes were Common Shiner (*Luxilus cornutus*), Golden Shiner (*Notemigonus crysoleucas*), Blacknose Shiner (*Notropis heterolepis*), Spottail Shiner (*Hudsonius hudsonius*), Bluntnose Minnow (*Pimephales notatus*), Fallfish (*Semotilus corporalis*), Brook Silverside (*Labidesthes sicculus*), Banded Killifish (*Fundulus diaphanus*), Tessellated Darter (*Etheostoma olmstedii*), and Logperch (*Percina caprodes*).

Habitat characteristics were water depth, percent coverage of shallow and deep aquatic plants, overhanging vegetation, and substrate.

Sites deemed the best along the Rideau River were those with the highest species richness and abundance of fishes. Site 5 (Figure 1), downstream of Black Rapids, was the best urban site (Table 1, Figure 2). Sixteen species belonging to six families were captured at this site: five centrarchids, four percids, three leuciscids, two catostomids, one esocid, and one atherinopsid (Table 3). The best agricultural site was site 6, Rideau

TABLE 4. Fish species collected during our study (1998–2000) and reported in the north-flowing section of the Rideau River system according to literature records (1883–1997, with year of first documented collection in brackets)*. The tributaries we sampled were Jock River, Stevens Creek, Kemptville Creek, Cranberry Creek, and Mosquito Creek, the first three in 1999 and the last two in 2000 (Table 2).

Family	Species	1998–2000		1883–1997
		Rideau River mainstem	Tributaries	
Petromyzontidae	Silver lamprey (<i>Ichthyomyzon unicuspis</i>)			+ (1883)
Lepisosteidae	Longnose Gar (<i>Lepisosteus osseus</i>)			+ (1893)
Anguillidae	American Eel (<i>Anguilla rostrata</i>)			+ (1996)
Alosidae	Alewife (<i>Alosa pseudoharengus</i>)			+ (1982)
Cyprinidae	Common Carp (<i>Cyprinus carpio</i>)	+		+ (1957)
Leuciscidae	Northern Redbelly Dace (<i>Chrosomus eos</i>)			+ (1937)
	Finescale Dace (<i>Chrosomus neogaeus</i>)			+ (1974)
	Brassy Minnow (<i>Hybognathus hankinsoni</i>)		+	+ (1974)
	Eastern Silvery Minnow (<i>Hybognathus regius</i>)			+ (1962)
	Common Shiner (<i>Luxilus cornutus</i>)	+	+	+ (1937)
	Northern Pearl Dace (<i>Margariscus nachtriebi</i>)			+ (1937)
	Golden Shiner (<i>Notemigonus crysoleucas</i>)	+	+	+ (1937)
	Emerald Shiner (<i>Notropis atherinoides</i>)	+		+ (1974)
	Blackchin Shiner (<i>Miniellus heterodon</i>)	+	+	+ (1937)
	Blacknose Shiner (<i>Notropis heterolepis</i>)	+	+	+ (1937)
	Spottail Shiner (<i>Hudsonius hudsonius</i>)	+	+	+ (1937)
	Rosyface Shiner (<i>Notropis rubellus</i>)		+	+ (1883)
	Sand Shiner (<i>Miniellus stramineus</i>)			+ (1987)
	Mimic Shiner (<i>Paranotropis volucellus</i>)		+	+ (1974)
	Bluntnose Minnow (<i>Pimephales notatus</i>)	+	+	+ (1937)
	Fathead Minnow (<i>Pimephales promelas</i>)			+ (1937)
	Longnose Dace (<i>Rhinichthys cataractae</i>)			+ (1937)
	Creek Chub (<i>Semotilus atromaculatus</i>)			+ (1937)
	Fallfish (<i>Semotilus corporalis</i>)	+	+	+ (1937)
Catostomidae	White Sucker (<i>Catostomus commersonii</i>)	+	+	+ (1883)
	Lake Chubsucker (<i>Erimyzon sucetta</i>)			+ (1883)
	Silver Redhorse (<i>Moxostoma anisurum</i>)	+	+	+ (1937)
	Shorthead Redhorse (<i>Moxostoma macrolepidotum</i>)			+ (1937)
	Greater Redhorse (<i>Moxostoma valenciennesi</i>)	+		+ (1974)
Ictaluridae	Yellow Bullhead (<i>Ameiurus natalis</i>)			+ (1974)
	Brown Bullhead (<i>Ameiurus nebulosus</i>)	+	+	+ (1906)
	Channel Catfish (<i>Ictalurus punctatus</i>)			+ (1995)
	Stonecat (<i>Noturus flavus</i>)			+ (1974)
	Tadpole Madtom (<i>Noturus gyrinus</i>)	+	+	
Salmonidae	Rainbow Trout (<i>Oncorhynchus mykiss</i>)			+ (1935)
	Brown Trout (<i>Salmo trutta</i>)			+ (1935)
Esocidae	Northern Pike (<i>Esox lucius</i>)	+	+	+ (1937)
	Muskellunge (<i>Esox masquinongy</i>)	+	+	+ (1883)
	Central Mudminnow (<i>Umbra limi</i>)	+	+	+ (1883)
Percopsidae	Trout-perch (<i>Percopsis omiscomaycus</i>)			+ (1937)
Gadidae	Burbot (<i>Lota lota</i>)			+ (1906)
Atherinopsidae	Brook Silverside (<i>Labidesthes sicculus</i>)	+	+	+ (1937)
Gasterosteidae	Brook Stickleback (<i>Culaea inconstans</i>)			+ (1937)
Fundulidae	Banded Killifish (<i>Fundulus diaphanus</i>)	+	+	+ (1974)

TABLE 4. Continued.

Family	Species	1998–2000		1883–1997
		Rideau River mainstem	Tributaries	
Cottidae	Mottled Sculpin (<i>Cottus bairdii</i>)	+		+ (1974)
Centrarchidae	Rock Bass (<i>Ambloplites rupestris</i>)	+	+	+ (1906)
	Pumpkinseed (<i>Lepomis gibbosus</i>)	+	+	+ (1937)
	Bluegill (<i>Lepomis macrochirus</i>)	+	+	+ (1937)
	Smallmouth Bass (<i>Micropterus dolomieu</i>)	+	+	+ (1883)
	Largemouth Bass (<i>Micropterus nigricans</i>)	+	+	+ (1883)
	Black Crappie (<i>Pomoxis nigromaculatus</i>)	+	+	+ (1906)
	Iowa Darter (<i>Etheostoma exile</i>)			+ (1974)
Percidae	Johnny Darter (<i>Etheostoma nigrum</i>)			+ (1937)
	Tessellated Darter (<i>Etheostoma olmstedii</i>)	+	+	+ (1974)
	Yellow Perch (<i>Perca flavescens</i>)	+	+	+ (1937)
	Logperch (<i>Percina caprodes</i>)	+	+	+ (1883)
	Sauger (<i>Sander canadensis</i>)			+ (1883)
	Walleye (<i>Sander vitreus</i>)	+	+	+ (1883)
Sciaenidae	Freshwater Drum (<i>Aplodinotus grunniens</i>)	+		

*Sources: Small (1883, 1893); Halkett (1906); Prince *et al.* (1906); Dymond (1939); McAllister and Coad (1974); Coad (1983, 1987); Settingington (2004).

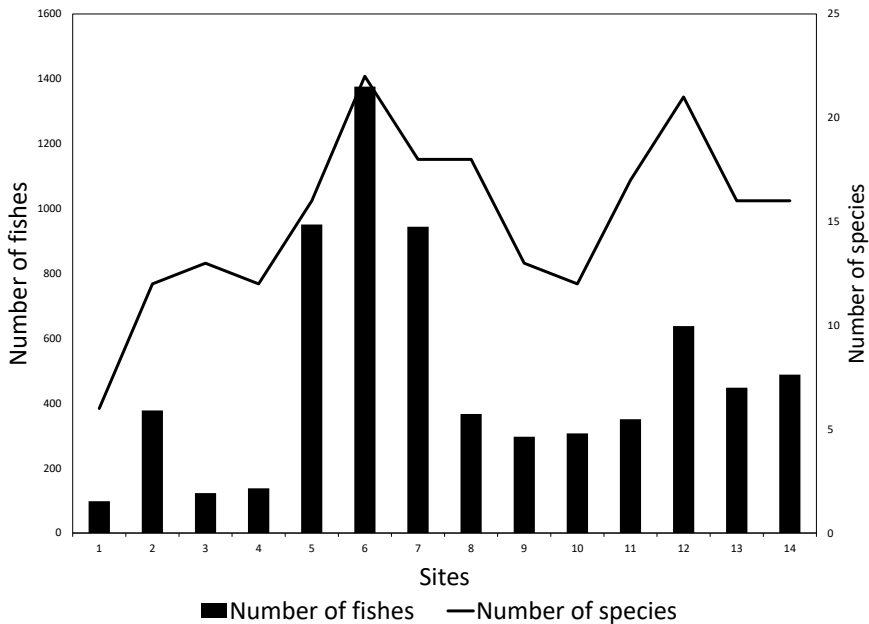


FIGURE 2. Number of fishes captured per site (left axis) and number of fish species captured per site (right axis) along the mainstem Rideau River from mid-July to mid-September 1998.

Glen, in the Black Rapids to Long Island reach of the river (Table 1, Figure 2). Twenty-two species belonging to eight families were captured at this site: six leuciscids, six centrarchids, four percids, two catostomids, one cyprinid, one ictalurid, one esocid, and one atherinopsid (Table 3). The best forested site was site 7, across from Rideau River Provincial Park (Table 1, Figure 2). Eighteen species belonging to seven families were captured at this site: six centrarchids, four leuciscids, four percids, one cyprinid, one ictalurid,

one atherinopsid, and one fundulid (Table 3).

In 1999, 2098 fishes were captured from three tributaries to the Rideau River: 1097 in the Jock River, 747 in Kemptville Creek, and 254 in Stevens Creek. A tiny individual of salamander, Mudpuppy (*Necturus maculosus*) was also collected in a minnow trap in Kemptville Creek, at Kemptville, on 19 July 1999. Three fish species were captured in these tributaries that were not captured in the mainstem Rideau River in 1998 (Table 4): Rosyface Shiner (*Notropis rubellus*) in all three tributaries, Central Mudminnow (*Umbra limi*) in Kemptville Creek and Stevens Creek, and Mimic Shiner (*Paranotropis volucellus*) in Jock River.

In 2000, 1596 fishes were captured from two tributaries to the Rideau River (806 in Cranberry Creek and 790 in Mosquito Creek), 4118 fishes were captured at the six new sites on the Rideau River mainstem between Smiths Falls and Manotick, and 73 fishes were captured at the 14 sites along the Rideau River mainstem that were sampled in 1998. Brassy Minnow (*Hybognathus hankinsoni*) was captured in both these tributaries but was not captured in the mainstem Rideau River in 1998 and 2000 (Table 4) or in the three tributaries (Jock River, Kemptville Creek, and Stevens Creek) sampled in 1999. Central Mudminnow was captured at one of the new mainstem sites (site 20 [Table 1]) and in Cranberry Creek (Table 4) but was not captured in the original 14 sites on the mainstem Rideau River in 1998 or 2000.

Over the three years of our study (1998–2000), 14777 fishes comprising 34 species belonging to 11 families were collected and the great majority released in the mainstem Rideau River and five of its tributaries, but only 26 species (76%) were collected from both the mainstem and tributaries (Table 4). Five species (Common Carp [*Cyprinus carpio*], Emerald Shiner, Greater Redhorse, Mottled Sculpin, and Freshwater Drum) were collected only in the mainstem Rideau River and three species (Brassy Minnow, Rosyface Shiner, and Mimic Shiner) were collected only in one or more of the tributaries surveyed (Table 4).

Supplementary files containing the raw data of habitat characteristics recorded during the 1998 field season (Table S1) and the raw data for the fishes collected during the 1998–2000 field seasons are provided (Tables S2, S3, and S4).

Cluster analysis showed that aquatic habitat characteristics (i.e., abundance of shallow and deep aquatic plants, and substrate type) were correlated with adjacent land-use type. Urban sites clustered separately from agricultural sites, while forested sites were distributed in either cluster (Figure 3). Forested sites possess a mixture of habitat characteristics (i.e.,

abundance of shallow and deep aquatic plants, and substrate type) that align them either with urban or agricultural sites. Thus, forested sites as a whole cannot be separated from other land-use types (i.e., agricultural, urban) based on those characteristics. The urban cluster (A in Figure 3) was characterized by an abundance of American Eelgrass in deep areas, algae in shallow areas, and a primarily sand substrate. The agricultural cluster (B in Figure 3) was characterized by a mixture of American Eelgrass and Variegated Pond-lily and Fragrant Water-lily in deep areas, and a substrate with large woody debris overlying primarily clay, sand, and detritus. The other five habitat characteristics recorded (i.e., water depth, water temperature, water clarity, bank height, and percent cover of overhanging vegetation) did not show significant differences among the three land-use types.

We conducted an in-depth examination of the relationship between land-use type and various aquatic characteristics (i.e., abundance of shallow and deep aquatic plants, substrate type, abundance of all fish species, and abundance of piscivorous and insectivorous fishes separately) at the 14 sites sampled in 1998. The results, detailed below, showed that the five urban sites constituted a single cluster (Figure 4, cluster A and Figure 5, cluster A), although two forested sites were found within the urban group (Figure 4, cluster A), and neither the five agricultural nor the four forested sites could be separated from each other (Figure 4, cluster B and Figure 5, clusters B and C). Therefore, the latter two land-use types were treated as a single grouping with regards to piscivorous and insectivorous fish abundance.

Mantel tests showed statistically significant positive correlations between the fish abundance and the species richness ($Z = 510$, $P < 0.001 < \alpha = 0.003$) and abundance ($Z = 112$, $P < 0.001 < \alpha = 0.004$) of deep aquatic plants and the different substrate types ($Z = 520$, $P = 0.001 < \alpha = 0.003$). No significant correlation existed between habitat characteristics and the species richness of fishes.

The fish abundance data were further broken down into four functional subgroups (i.e., piscivores, insectivores, small-bodied fishes, and young-of-the-year). Mantel tests showed statistically significant positive correlations between the abundance of insectivorous fishes and the species richness ($Z = 322$, $P < 0.001 < \alpha = 0.003$) and abundance ($Z = 83$, P and $\alpha = 0.004$) of deep aquatic plants and the different types ($Z = 350$, $P < 0.001 < \alpha = 0.003$) and abundance of substrates ($Z = 138$, $P < 0.001 < \alpha = 0.004$). The abundance of small-bodied fishes (adult total length < 20 cm, see above for full list of species) also showed statistically significant positive correlations with the species richness ($Z = 491$, $P < 0.001 < \alpha = 0.003$) and abundance (Z

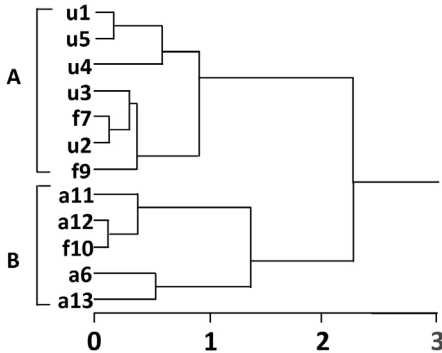


FIGURE 3. Clustering tree of ichthyofaunal sampling sites 1–14 along the Rideau River in 1998 (see Table 1 and Figure 1 for locations) according to the relative abundance of deep and shallow aquatic vegetation and substrate type using Pearson distance and Ward joining algorithm. Sites 8 and 14 were removed from the data set because no shallow aquatic vegetation was present at these sites. Group A consists of all urban (symbol u) and two forested (symbol f) sites clustered at a distance of 0.901. Group B consists of four agricultural (symbol a) sites and one forested site clustered at 1.367.

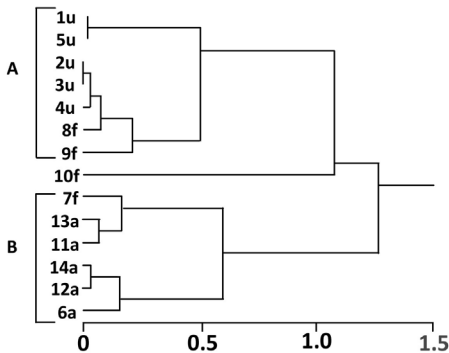


FIGURE 4. Clustering tree of ichthyofaunal sampling sites 1–14 along the Rideau River in 1998 (see Table 1 and Figure 1 for locations) according to the relative abundance of piscivorous fish species present at three or more sites using Pearson distance and complete joining algorithm. Young-of-the-year were removed from the data. Group A consists of all urban (symbol u) sites and two forested (symbol f) sites clustered at a distance of 0.492. Group B consists of all agricultural (symbol a) and one forested site clustered at 0.593.

= 142, $P < 0.001 < \alpha = 0.003$) of deep aquatic plants such as American Eelgrass, Variegated Pond-lily, and pondweed spp., and the different types ($Z = 520$, $P = 0.001 < \alpha = 0.004$) and abundance of the following substrates: bedrock, boulders, rubble, gravel, sand, clay, detritus, and large woody debris ($Z = 229$, $P < 0.001 < \alpha = 0.004$).

Cluster analyses showed that the fish community was correlated with adjacent land-use type. Three cluster analyses examining the abundance of all fish

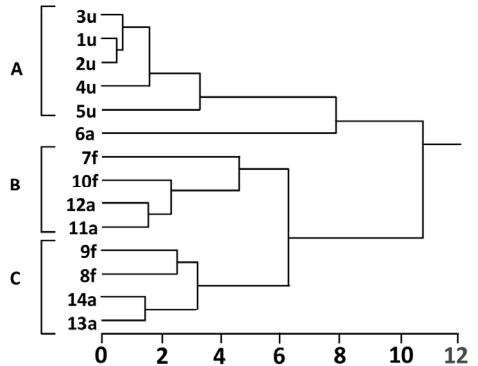


FIGURE 5. Clustering tree of ichthyofaunal sampling sites 1–14 along the Rideau River in 1998 (see Table 1 and Figure 1 for locations) according to the relative abundance of insectivorous fish species present at three or more sites using Euclidean distance and complete joining algorithm. Young-of-the-year were removed from the data. Group A consists of all urban (symbol u) sites clustered at a distance of 3.62. Groups B and C each consist of two agricultural (symbol a) sites and two forested (symbol f) sites clustered at 4.616 and 3.198, respectively.

species, as well as two functional subgroups (i.e., piscivores or insectivores) versus land-use type were conducted. The cluster analysis involving all fish species showed that urban sites clustered together, while agricultural and forested sites formed another cluster when using Pearson distance and Ward joining algorithm (results not shown). The cluster analyses examining the subgroups separately showed that the abundance of piscivores produced an urban cluster (A in Figure 4) using Pearson distance and complete joining algorithm characterized by an abundance of Rock Bass, and a combined agricultural-forested cluster (B in Figure 4) characterized by an abundance of Black Crappie and Largemouth Bass. Similarly, the abundance of insectivores produced an urban cluster (A in Figure 5) using Euclidean distance and complete joining algorithm characterized by a low abundance of Bluegill, Pumpkinseed, Yellow Perch, Brown Bullhead, and White Sucker, and two mixed agricultural-forested clusters (B and C in Figure 5) characterized by an abundance of those species minus White Sucker.

Discussion

Temporal changes to fish species richness

In the 114 years between 1883 and 1997, 57 species of fishes belonging to 18 families were recorded from the north-flowing section of the Rideau River-Canal system (Small 1883, 1893; Prince *et al.* 1906; Halkett 1906, 1908; Dymond 1939; McAllister and Coad 1974; Coad 1983, 1987; Settingington 2004 in

part; see full details below). Despite intensive and extensive sampling effort from mid-July to mid-September during our three-year study (1998–2000) using a wide variety of sampling gear, only 32 (56%) of these previously recorded species belonging to 10 families were captured (Table 4). The eight missing families, represented by one, or in one case two, species, are Petromyzontidae, Lepisosteidae, Anguillidae, Alosidae, Salmonidae, Percopsidae, Gadidae, and Gasterosteidae (Table 4). No scar or wound that would be associated with the attachment and feeding of an adult Silver Lamprey (*Ichthyomyzon unicuspis*; Petromyzontidae) was observed on any of the fishes we collected. Because it was only recorded once by Small (1883), Silver Lamprey is probably no longer present in the system. Likewise, Longnose Gar (*Lepisosteus osseus*; Lepisosteidae) and Burbot (*Lota lota*; Gadidae) were only reported once, by Small (1883) and Halkett (1906), respectively, and are probably no longer present. Two salmonids, Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta*) were the result of introductions in 1935–1937 (Dymond 1939) and never became established.

By contrast, two additional species, Tadpole Madtom and Freshwater Drum, the latter belonging to a previously undocumented family Sciaenidae, were recorded for the first time during the 1998–2000 study (Phelps *et al.* 2000a,b). Although Tadpole Madtom was first documented as being collected in 1976 (Table 4) based on Canadian Museum of Nature collections, it was first reported in the scientific literature by Phelps *et al.* (2000a).

Our being contacted by members of the public during our study resulted in the addition of two species and families for the Rideau River system, collected in downtown Ottawa. A photograph of a Pacu or Piranha (Serrasalminidae) collected along the eastern shoreline of Dow's Lake was taken in 1994 and an Oscar (*Astronotus ocellatus*; Cichlidae) was collected in 1999 near Landsdowne Park. These two new records from the Rideau Canal were reported by Renaud and Phelps (1999, 2001) and were probably the result of aquarium dumping.

New additions to the Rideau River system have been reported since our study ended. Coad and Alfonso (2005) reported Hornyhead Chub (*Nocomis biguttatus*; Leuciscidae) from the Jock River and its tributary, Kings Creek, both collected 25 June 2004.

COSEWIC (2013) reported Bridle Shiner (*Notropis bifrenatus*; Leuciscidae) at four sites along Cranberry Creek and the Rideau Valley Conservation Authority (2012) collected this species in Stevens Creek. Bridle Shiner's Special Concern status was confirmed in 2013 (COSEWIC 2013) and it is listed as Special Concern under the Canadian *Species*

at Risk Act (SARA Registry 2023a).

The presence of the invasive Round Goby (*Neogobius melanostomus*; Gobiidae) was first reported by Bergman and Cooke (2019) in Edmonds Lockstation, downstream of Smiths Falls during water draw-down in 2018. They captured 45 individuals from 9 to 18 July 2019 in the vicinity of Edmonds Dam using backpack electrofishing and tagged them with acoustic transmitters to follow their movement (Bergman *et al.* 2022). An additional 14 specimens of Round Goby were collected 17–25 July 2019 and deposited as vouchers at the Canadian Museum of Nature (Bergman *et al.* 2022: catalogue number CMNFI 2019–0107.1.). More recently, N.R.A. and Sarah E. Steele (Canadian Museum of Nature) captured six individuals on 28 September 2023 at Kilmarnock using an electrofisher. This non-native, invasive species has probably become established.

The new total for the north-flowing section of the Rideau River-Canal system is therefore 64 fish species belonging to 22 families. Bergman *et al.* (2021) incorrectly reported 107 fish species for the Rideau Canal based on Coad (2011). However, Coad (2011) was referring to the National Capital Region and surrounding areas, which encompasses numerous river systems, including the Rideau.

The human population of the city of Ottawa has increased significantly during the period from 1883 to 2021. In 1901 there were 101 102 inhabitants, more than doubling to 206 367 in 1941, again more than doubling to 471 931 in 1971, almost doubling to 934 243 in 2016, and finally reaching 1 017 449 in 2021 (Wikipedia 2024). As early as 1918 there was concern about contamination of the Rideau River in Ottawa South because pipes would discharge domestic sewage directly into the river (A.K.C. 1918). The continued increase of the human population in municipalities along the Rideau River, with all of the associated stressors on the aquatic environment that this entails, is expected to change the fish community in the future.

Historical (1883–1997) ichthyofauna collections from the Rideau River

Although Van Cortlandt (1859) produced a list of the fishes of the Ottawa Valley that probably included fishes from the north-flowing section of the Rideau River-Canal system, the precise collection locality was not indicated, and, therefore, Small (1883) was the first to compile a list of fishes from the north-flowing section of the Rideau River-Canal system. Small's (1883) list included these 11 species: *Ichthyomyzon argenteus* (see below), Rosyface Shiner (under the genus *Mimilus*, a junior synonym), White Sucker, Lake Chubsucker (*Erimyzon sucetta*), Muskellunge (*Esox masquinongy* as *Esox nobilior*, a

junior synonym), Central Mudminnow, Smallmouth Bass, Largemouth Bass (as *Micropterus salmoides*, a species restricted to southeastern USA; see Kim *et al.* 2022), Logperch, Sauger (*Sander canadensis*), and Walleye both under the genus *Stizostedion*, a junior synonym.

Small (1883: 47) described *I. argenteus* as having parasitic habits, stating that unidentified “dead fish are frequently found with circular wounds on their sides, giving evidence of the cause of death”. *Ichthyomyzon argenteus* is based on *Petromyzon argenteus*, a preoccupied name that was replaced by *Petromyzon bdelium* and later transferred to the genus *Ichthyomyzon*. However, Ohio Lamprey (*Ichthyomyzon bdelium*) does not occur in Canada (Renaud *et al.* 2009) and the only two parasitic lamprey species occurring in the National Capital Region, Chestnut Lamprey (*Ichthyomyzon castaneus*) and Silver Lamprey, are presently restricted to the Ottawa River system (Renaud and de Ville 2000; Renaud 2002). Hubbs and Trautman (1937: 53) stated that the lamprey reported by Small (1883) from the Rideau River system is Silver Lamprey, the “identification based on locality, with more or less evidence of a circumstantial, confirmatory nature”.

Small (1883: 40) stated that Rosyface Shiner was found in “shallow water below locks” and we assumed that the locks were those of the Rideau River-Canal system. According to Dymond (1939), the record of Lake Chubsucker, a catostomid reported by Small (1883) is a probable misidentification of Creek Chub (*Semotilus atromaculatus*), a leuciscid. Additionally, COSEWIC (2008) stated that the disjunct record of Lake Chubsucker by Small (1883), from others in southern Ontario, indicates that it is probably erroneous, but did not provide an alternative identification. However, according to COSEWIC (2008), Lake Chubsucker, assessed and listed as Endangered (SARA Registry 2023b), exhibits a disjunct distribution across its range. Furthermore, Dymond (1939) showed that the disjunct nature of a record is not in of itself evidence of an error. As a case in point, the record by Small (1883) of another catostomid, Quillback (*Carpiodes cyprinus*), in the Ottawa area, was considered an error because at the time the species was only known in Ontario from Lake Erie, until Dymond (1939) collected a specimen from Green’s Creek, a tributary to the Ottawa River. Therefore, we accept the record of Lake Chubsucker by Small (1883). Small (1893) reported that a small Longnose Gar was taken in a scoop net at the foot of the locks in Ottawa (undoubtedly those of the north-flowing section of the Rideau River-Canal system) and kept by him in an aquarium for several weeks.

Halkett (1906, 1908) reported on the fishes at the

Canadian Fisheries Museum, a repository that existed in Ottawa from 1884 to 1918 (Knight 2014). Only three fish species from the Rideau River-Canal system up to Smiths Falls were in this museum: Brown Bullhead, Rock Bass, and Black Crappie (as *Pomoxis sparoides*, a questionable synonym). However, Prince *et al.* (1906), in their report on the fish collection of the museum, that included Halkett as a co-author, omitted Black Crappie and added Burbot (as *Lota maculosa*, a junior synonym) to the list of fishes in the aforementioned area.

Dymond (1939) recorded the following 34 species from the north-flowing section of the Rideau River-Canal system, principally, if not entirely, collected by seining during August 1937: Northern Redbelly Dace (*Chrosomus eos*), Common Shiner (under the genus *Notropis*), Northern Pearl Dace (*Margariscus nachtriebi*; as *Margariscus margarita nachtriebi*), Golden Shiner, Blackchin Shiner (*Minniellus heterodon*, under the genus *Notropis*), Blacknose Shiner, Spottail Shiner (under the genus *Notropis*), Bluntnose Minnow (under the genus *Hyborhynchus*, a junior synonym), Fathead Minnow (*Pimephales promelas*), Longnose Dace (*Rhinichthys cataractae*), Creek Chub, Fallfish (under the genus *Leucosomus*), White Sucker, Silver Redhorse, Shorthead Redhorse (*Moxostoma macrolepidotum* as *Moxostoma lesueurii*, a junior synonym), Brown Bullhead, introduced Rainbow Trout (as *Salmo gairdneri*, a misspelled junior synonym), introduced Brown Trout (as *Salmo fario*, a junior synonym), Northern Pike, Muskellunge, Central Mudminnow, Trout-perch (*Percopsis omiscomaycus*), Brook Silverside, Brook Stickleback (*Culaea inconstans*, under the genus *Eucalia*, a preoccupied name), Slimy Sculpin (*Cottus cognatus*, but see below), Rock Bass, Pumpkinseed (under the genus *Eupomotis*, a junior synonym), Bluegill (under the genus *Helioperca*, a junior synonym), Largemouth Bass (as *Aplites salmoides*, a species restricted to southeastern USA), Black Crappie (as *Pomoxis sparoides*), Johnny Darter (*Etheostoma nigrum*, under the genus *Boleosoma*, a junior synonym), Yellow Perch, Logperch, and Walleye (under the genus *Stizostedion*). According to Dymond (1939: 40), Slimy Sculpin was collected “... from a spring creek near Ellwood station, south of Ottawa”. Sawmill Creek runs through Ellwood neighbourhood, a former railway point situated in the south end of Ottawa, where it enters the Rideau River at Billings Bridge. However, McAllister and Coad (1974) mention only Mottled Sculpin in the Rideau River-Canal system, and furthermore, report the finding on 25 May of an eyed egg mass of this species from Sawmill Creek. Accordingly, McAllister and Coad (1974: 20) deleted “*C. cognatus* from the regional list until a validly identified specimen is

collected”.

McAllister and Coad (1974) reported the following 44 species in the Rideau River-Canal system within a 48.2 km radius of the Peace Tower on Parliament Hill, in Ottawa, reaching at least as far south as Kemptville: Northern Redbelly Dace, Finescale Dace (*Chrosomus neogaeus*), introduced Common Carp, Brassy Minnow, Mississippi Silvery Minnow (*Hybognathus nuchalis*, this species is restricted to central and southern USA and Eastern Silvery Minnow [*Hybognathus regius*] is the correct name for the species found on the Atlantic slope of Canada and USA), Common Shiner (under the genus *Notropis*), Northern Pearl Dace (as Allegheny Pearl Dace [*Semotilus margarita*], a misidentified species with a distribution restricted to the USA), Golden Shiner, Emerald Shiner, Blackchin Shiner (under the genus *Notropis*), Spottail Shiner (under the genus *Notropis*), Rosyface Shiner, Mimic Shiner (under the genus *Notropis*), Bluntnose Minnow, Fathead Minnow, Longnose Dace, Creek Chub, Fallfish, White Sucker, Silver Redhorse, Shorthead Redhorse, Greater Redhorse, Yellow Bullhead (*Ameiurus natalis*), Brown Bullhead (both bullhead under the genus *Ictalurus*), Stonecat (*Noturus flavus*), Northern Pike, Central Mudminnow, Trout-perch, Brook Silverside, Brook Stickleback, Banded Killifish, Mottled Sculpin, Rock Bass, Pumpkinseed, Bluegill, Smallmouth Bass (misspelled *dolomieu*), Largemouth Bass (as *Micropterus salmoides*), Black Crappie, Iowa Darter (*Etheostoma exile*), Johnny Darter, Tessellated Darter, Yellow Perch, Logperch, and Walleye (under the genus *Stizostedion*). McAllister and Coad (1974) used a variety of sources to map the fish distributions, but we included only those species that were collected by National Museum (now Canadian Museum of Nature) and University of Ottawa personnel and excluded those from the Royal Ontario Museum and the literature because the latter were already reported elsewhere (i.e., Small 1883; Halkett 1906; Dymond 1939).

Coad (1983) reported Alewife (*Alosa pseudoharengus*; Alosidae) in the Rideau Canal from immediately below the locks at Hog's Back Road, in Ottawa and Coad (1987) reported Sand Shiner (*Minicellus stramineus*, under the genus *Notropis*; Leuciscidae) from the Jock River at Jockvale.

Settingington (2004) compiled the results of a six-year fisheries assessment (1995–2000) conducted by the City of Ottawa and the Ontario Ministry of Natural Resources for the following six reaches of the Rideau River: Ottawa, Mooney's Bay, Eccolands, Long, Andrews ville, and Kilmarnock. The list of fishes collected included 39 species over that period, but five species were only collected in 1995–1997 (American Eel [*Anguilla rostrata*], Mimic Shiner,

Shorthead Redhorse, Channel Catfish [*Ictalurus punctatus*], and Tessellated Darter) and five were only collected in 1998–2000 (Emerald Shiner, Fallfish, Yellow Bullhead, Tadpole Madtom, and Central Mudminnow). American Eel (in 1996) and Channel Catfish (in 1995), both collected in the Mooney's Bay reach, were new records for the north-flowing section of the Rideau River-Canal system (Table 4). Note that American Eel was assessed as Threatened by COSEWIC (2012) but has yet to be added to the species-at-risk list (SARA Registry 2023c). The remaining 29 species were collected during both periods: Alewife, Common Carp, Eastern Silvery Minnow, Common Shiner, Golden Shiner, Blackchin Shiner (under the genus *Notropis*), Blacknose Shiner, Spottail Shiner (under the genus *Notropis*), Bluntnose Minnow, White Sucker, Silver Redhorse, Greater Redhorse, Brown Bullhead, Northern Pike, Muskellunge, Brook Silverside, Brook Stickleback, Banded Killifish, Mottled Sculpin, Rock Bass, Pumpkinseed, Bluegill, Smallmouth Bass, Largemouth Bass (as *Micropterus salmoides*), Black Crappie, Johnny Darter, Yellow Perch, Logperch, and Walleye.

Non-native species

There are other non-native species reported from our study area, besides Round Goby and the single Pacu (or Piranha) and Oscar, previously discussed. According to Dymond (1939), six adults each of Brown Trout and Rainbow Trout were released yearly in the Rideau River Canal above Hog's Back Falls (officially known as Prince of Wales Falls) in 1935, 1936, and 1937, and 1600 yearling Brown Trout were planted in the Rideau River Canal below Hog's Back Falls in the early autumn of 1937. Neither species have become established. The earliest record of Common Carp in the system is 1957 (McAllister and Coad 1974) and the species is well established having been collected ever since. Therefore, only two of six non-native species (Common Carp and Round Goby) have become established.

Stocking of native fishes

A number of species have been stocked in the north-flowing section of the Rideau River-Canal system for the purpose of improving recreational fishing including fishing derbies. Muskellunge fry, Smallmouth Bass and Largemouth Bass fingerlings and adults, and Walleye eggs were stocked annually during the 1940s in the Rideau and Jock Rivers according to newspaper articles in *The Ottawa Citizen* (Phelps 2001). These four species have been recorded in the system since the 1880s (Small 1883).

Management recommendations

Our data on the fish community composition, abundance, species richness, and associated habitat

characteristics are important for resource management. An understanding of the association between the fish community and land use will enable resource managers to prioritize certain areas for conservation to maintain a diverse and abundant fish community. Moreover, a more in-depth knowledge of the entire fish community will lead to a fuller understanding of the economically and recreationally important sport-fish species (Northern Pike and Muskellunge) for which the Rideau River is reputed (Pankhurst *et al.* 2016). Trophy Muskellunge have long been known to occur in the north-flowing section of the Rideau River system. Bebee (2007) documented the capture between 1891 and 1967 of 24 specimens over 11.3 kg (25 lbs), mostly from the Long Reach (i.e., Burritts Rapids to Manotick), except for one taken at Hog's Back. The record was 26.3 kg (58 lbs) in 1902 from the Long Reach.

The dispersal of Round Goby downstream of Edmonds Lockstation may pose a threat to the Logperch population. Bergstrom and Mensinger (2009) demonstrated through laboratory experiments that Round Goby outcompetes Logperch for food (i.e., amphipods) at a water temperature of $15 \pm 1^\circ\text{C}$. While Logperch showed a statistically significant decrease in wet weight, Round Goby showed a significant increase in wet weight. One competitive advantage that Round Goby has over Logperch is that the former is active at night, while the latter is not (Bergstrom and Mensinger 2009). Two other fish species in the Rideau system that may be negatively impacted by Round Goby are Johnny Darter (Lauer *et al.* 2004) and Mottled Sculpin (Dubs and Corkum 1996). Therefore, there needs to be ongoing monitoring of the dispersal of Round Goby. Finally, Bergman *et al.* (2021) have warned of potential invasion of the Rideau River-Canal system by Asian carps (i.e., Grass Carp [*Ctenopharyngodon idella*], Bighead Carp [*Hypophthalmichthys nobilis*], Silver Carp [*Hypophthalmichthys molitrix*], and Black Carp [*Mylopharyngodon piceus*]), species well documented to negatively impact native ecosystems. Our study documents the composition of the north-flowing section of the Rideau River-Canal system ichthyofauna prior to any such invasion.

Author Contributions

Writing – Original Draft: C.B.R. and A.P.; Writing – Review & Editing: C.B.R., N.R.A., and A.P.; Conceptualization: A.P.; Supervision: C.B.R.; Investigation: A.P., N.R.A., and C.B.R.; Methodology: A.P.; Formal Analysis: A.P.; Visualization: N.R.A.; Funding Acquisition: C.B.R. and N.R.A.

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Literature Cited

- A.K.C. 1918. Rideau River contamination. Letter to the editor, *The Ottawa Citizen*, 29 May [reprinted in the 30 September 1999 issue, p. E5].
- Bebee, E. 2007. Fish Tales: the Lure and the Lore of the Rideau. Ed Bebee & The Friends of the Rideau, Smiths Falls, Ontario, Canada.
- Bergman, J.N., C. Beaudoin, I. Mistry, A. Turcotte, C. Vis, V. Minelga, K. Neigel, H.-Y. Lin, J.R. Bennett, N. Young, C. Rennie, L.L. Trotter, A.E.I. Abrams, P. Beaupre, D. Glassman, G. Blouin-Demers, D. Garant, L. Donaldson, J.C. Vermaire, J.P. Smol, and S.J. Cooke. 2021. Historical, contemporary, and future perspectives on a coupled social-ecological system in a changing world: Canada's historic Rideau Canal. *Environmental Reviews* 30: 72–87. <https://doi.org/10.1139/er-2021-0026>
- Bergman, J.N., and S.J. Cooke. 2019. Tracking fish in the Rideau Canal Waterway. Accessed 1 September 2021. <https://muskiecanada.ca/en/tracking-fish-in-the-rideau-canal-waterway/>.
- Bergman, J.N., K.L. Neigel, S.J. Landsman, D. Glassman, L. LaRochelle, J.R. Bennett, C.D. Rennie, J.C. Vermaire, and S.J. Cooke. 2023. Multi-year evaluation of Muskellunge (*Esox masquinongy*) spatial ecology during winter drawdowns in a regulated, urban waterway in Canada. *Hydrobiologia* 850: 417–439. <https://doi.org/10.1007/s10750-022-05085-3>
- Bergman, J.N., G.D. Raby, K.L. Neigel, C.D. Rennie, S. Balshine, J.R. Bennett, A.T. Fisk, and S.J. Cooke. 2022. Tracking the early stages of an invasion with biotelemetry: behaviour of Round Goby (*Neogobius melanostomus*) in Canada's historic Rideau Canal. *Biological Invasions* 24: 1149–1173. <https://doi.org/10.1007/s10530-021-02705-2>
- Bergstrom, M.A., and A.F. Mensinger. 2009. Interspecific resource competition between the invasive Round Goby and three native species: Logperch, Slimy Sculpin, and Spoonhead Sculpin. *Transactions of the American Fisheries Society* 138: 1009–1017. <https://doi.org/10.1577/T08-095.1>

- Bernatchez, L., et M. Giroux. 1991. Guide des poissons d'eau douce du Québec et leur distribution dans l'est du Canada. Éditions Broquet Inc., La Prairie, Québec, Canada.
- Birnie-Gauvin, K., K. Aarestrup, T.M.O. Riis, N. Jepsen, and A. Koed. 2017. Shining a light on the loss of rheophilic fish habitat in lowland rivers as a forgotten consequence of barriers, and its implications for management. *Aquatic Conservation: Marine and Freshwater Ecosystems* 27: 1345–1349. <https://doi.org/10.1002/aqc.2795>
- Coad, B.W. 1983. The Alewife, *Alosa pseudoharengus* (Wilson) a fish new to the National Capital Region (Osteichthyes: Clupeidae). *Trail & Landscape* 17: 256–258. Accessed 28 May 2025. <https://www.biodiversitylibrary.org/page/58436498>.
- Coad, B.W. 1987. Checklist of the fishes of the Ottawa District. *Trail & Landscape* 21: 40–60. Accessed 28 May 2025. <https://www.biodiversitylibrary.org/page/50324666>.
- Coad, B.W. 2001. Keys to the fishes of the National Capital Region. *Trail & Landscape* 35: 133–166. Accessed 28 May 2025. <https://www.biodiversitylibrary.org/page/58934389>.
- Coad, B.W. 2011. Biodiversity of fishes in Canada's National Capital Region. *Acta Ichthyologica et Piscatoria* 41: 89–94. <https://doi.org/10.3750/aip2011.41.2.03>
- Coad, B.W., and N. Alfonso. 2005. The Hornyhead Chub, *Nocomis biguttatus*, a fish new to the National Capital Region (Actinopterygii: Cyprinidae). *Trail & Landscape* 39: 68–72. Accessed 28 May 2025. <https://www.biodiversitylibrary.org/page/59024079>.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2008. COSEWIC assessment and update status report on the Lake Chubsucker *Erimyzon sucetta* in Canada. COSEWIC, Ottawa, Ontario, Canada.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2012. COSEWIC assessment and status report on the American Eel *Anguilla rostrata* in Canada. COSEWIC, Ottawa, Ontario, Canada.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2013. COSEWIC assessment and status report on the Bridle Shiner *Notropis bifrenatus* in Canada. COSEWIC, Ottawa, Ontario, Canada.
- Dubs, D.O.L., and L.D. Corkum. 1996. Behavioral interactions between Round Gobies (*Neogobius melanostomus*) and Mottled Sculpins (*Cottus bairdi*). *Journal of Great Lakes Research* 22: 838–844. [https://doi.org/10.1016/S0380-1330\(96\)71005-5](https://doi.org/10.1016/S0380-1330(96)71005-5)
- Dymond, J.R. 1939. The fishes of the Ottawa region. Contributions of the Royal Ontario Museum of Zoology 15: 1–43.
- Halkett, A. 1906. Report of the Canadian Fisheries Museum. Thirty-eight annual report of the Department of Marine and Fisheries. 1905. Fisheries. Sessional Paper no. 22, Appendix no. 14: 362–370.
- Halkett, A. 1908. Report of the Canadian Fisheries Museum. Fortieth annual report of the Department of Marine and Fisheries. 1907. Fisheries. Sessional Paper no. 22, Appendix no. 14: 321–349.
- Hubbs, C.L., and M.B. Trautman. 1937. A revision of the lamprey genus *Ichthyomyzon*. Miscellaneous Publications of the Museum of Zoology, University of Michigan no. 35: 7–109 + 2 pls. Accessed 28 May 2025. <https://hdl.handle.net/2027.42/56280>.
- Johnson, M.C., M. Poulin, and M. Graham. 2003. Towards an integrated approach to the conservation and sustainable use of biodiversity: lessons learned from the Rideau River Biodiversity Project. *Human Ecology Review* 10: 40–55.
- Jungwirth, M., S. Muhar, and S. Schmutz. 2000. Fundamentals of fish ecological integrity and their relation to the extended serial discontinuity concept. *Hydrobiologia* 422: 85–97. <https://doi.org/10.1023/a:1017045527233>
- Kim, D., A.T. Taylor, and T.J. Near. 2022. Phylogenomics and species delimitation of the economically important Black Basses (*Micropterus*). *Scientific Reports* 12: 9113. <https://doi.org/10.1038/s41598-022-11743-2>
- Knight, W. 2014. Modeling authority at the Canadian Fisheries Museum, 1884–1918. Ph.D. thesis, Carleton University, Ottawa, Ontario, Canada. <https://doi.org/10.22215/etd/2014-10271>
- Lauer, T.E., P.J. Allen, and T.S. McComish. 2004. Changes in Mottled Sculpin and Johnny Darter trawl catches after the appearance of Round Gobies in the Indiana waters of Lake Michigan. *Transactions of the American Fisheries Society* 133: 185–189. <https://doi.org/10.1577/t02-123>
- McAllister, D.E., and B.W. Coad. 1974. Fishes of Canada's National Capital Region. Fisheries Research Board of Canada Miscellaneous Special Publication 24: 1–200.
- Meador, M.R., C.R. Hupp, T.F. Cuffney, and M.E. Gurtz. 1993. Methods for characterizing stream habitat as part of the national water-quality assessment program. U.S. Geological Survey. Open-File Report 93-408, Raleigh, North Carolina, USA.
- Newmaster, S.G., A.G. Harris, and L.J. Kershaw. 1997. Wetland Plants of Ontario. Lone Pine Publishing, Edmonton, Alberta, Canada.
- Nunn, A.D., and I.G. Cowx. 2012. Restoring river connectivity: prioritizing passage improvements for diadromous fishes and lampreys. *AMBIO* 41: 402–409. <https://doi.org/10.1007/s13280-012-0281-6>
- Page, L.M., K.E. Bemis, T.E. Dowling, H. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, K.E. Hartel, R.N. Lea, N.E. Mandrak, M.A. Neighbors, J.J. Schmitter-Soto, and H.J. Walker, Jr. 2023. Common and scientific names of fishes from the United States, Canada, and Mexico, 8th edition. American Fisheries Society, Special Pub-

- lication 37, Bethesda, Maryland, USA. <https://doi.org/10.47886/9781934874691>
- Pankhurst, K., J.D. Midwood, H. Wachelka, and S.J. Cooke.** 2016. Comparative spatial ecology of sympatric adult Muskellunge and Northern Pike during a one-year period in an urban reach of the Rideau River, Canada. *Environmental Biology of Fishes* 99: 409–421. <https://doi.org/10.1007/s10641-016-0482-0>
- Phelps, A.M.** 2001. Investigating the fish community of the Rideau River, Ontario, with respect to historical changes and current land-use practices. M.Sc. thesis, University of Ottawa, Ottawa, Ontario, Canada. <https://doi.org/10.20381/ruor-7593>
- Phelps, A., F. Chapleau, and C.B. Renaud.** 2000a. The Tadpole Madtom, *Noturus gyrinus*, a rarely seen fish of the Rideau River System, Ontario. *Trail & Landscape* 34: 30–34. Accessed 28 May 2025. <https://www.biodiversitylibrary.org/page/58783918>
- Phelps, A., C.B. Renaud, and F. Chapleau.** 2000b. First record of a Freshwater Drum, *Aplodinotus grunniens*, in the Rideau River, Ottawa, Ontario. *Canadian Field-Naturalist* 114: 121–125. <https://doi.org/10.5962/p.363921>
- Prince, E.E., A. Halkett, W.S. Odell, and E.E. Lemieux.** 1906. Zoological Report – 1905–6. *Ottawa Naturalist* 20: 56–61. Accessed 22 December 2023. <https://www.biodiversitylibrary.org/page/1839413>
- Renaud, C.B.** 2002. The Muskellunge, *Esox masquinongy*, as a host for the Silver Lamprey, *Ichthyomyzon unicuspis*, in the Ottawa River, Ontario/Québec. *Canadian Field-Naturalist* 116: 433–440. <https://doi.org/10.5962/p.363482>
- Renaud, C.B., and N. de Ville.** 2000. Three records of the Chestnut Lamprey, *Ichthyomyzon castaneus*, new to Québec. *Canadian Field-Naturalist* 114: 333–335. <https://doi.org/10.5962/p.363978>
- Renaud, C.B., M.F. Docker, and N.E. Mandrak.** 2009. Taxonomy, distribution, and conservation of lampreys in Canada. Pages 293–309 in *Biology, Management, and Conservation of Lampreys in North America*. Edited by L.R. Brown, S.D. Chase, M.G. Mesa, R.J. Beamish, and P.B. Moyle. American Fisheries Society Symposium 72, Bethesda, Maryland, USA.
- Renaud, C.B., and A. Phelps.** 1999. Oscar-winning catch. *Trail & Landscape* 33: 178–180. Accessed 28 May 2025. <https://www.biodiversitylibrary.org/page/58790406>
- Renaud, C.B., and A. Phelps.** 2001. A Pacu/Piranha in the Rideau Canal. *Trail & Landscape* 35: 86–89. Accessed 28 May 2025. <https://www.biodiversitylibrary.org/page/58894712>
- Rideau Valley Conservation Authority.** 2012. Stevens Creek catchment – Lower Rideau River sub-watershed report 2012. Accessed 31 July 2025. <https://watersheds.rvca.ca/files/971/2012/270/Stevens-Creek-Catchment-Report.pdf>
- SARA (Species at Risk Act) Registry.** 2023a. Species summary: Bridle Shiner (*Notropis bifrenatus*). Government of Canada, Ottawa, Ontario, Canada. Accessed 12 July 2024. <https://species-registry.canada.ca/index-en.html#/species/546-69>
- SARA (Species at Risk Act) Registry.** 2023b. Species summary: Lake Chubsucker (*Erimyzon sucetta*). Government of Canada, Ottawa, Ontario, Canada. Accessed 12 July 2024. <https://species-registry.canada.ca/index-en.html#/species/101-63>
- SARA (Species at Risk Act) Registry.** 2023c. Species summary: American Eel (*Anguilla rostrata*). Government of Canada, Ottawa, Ontario, Canada. Accessed 12 July 2024. <https://species-registry.canada.ca/index-en.html#/species/891-632>
- Scott, W.B., and E.J. Crossman.** 1973. Freshwater fishes of Canada. *Bulletin of the Fisheries Research Board of Canada* 184: 1–966.
- Settingington, L.** 2004. Rideau River fisheries assessment summary report 1995–2000 - Index netting, nursery habitat inventory, contaminant analysis, and fall drawdown monitoring. City of Ottawa, Environmental Programs and Technical Support Division and Ontario Ministry of Natural Resources, Kemptville, Ontario, Canada.
- Small, H.B.** 1883. Fishes of the Ottawa district. *Ottawa Field-Naturalists' Club Transactions* 4: 31–49. Accessed 22 December 2023. <https://www.biodiversitylibrary.org/page/12933926>
- Small, H.B.** 1893. My aquarium. *Ottawa Naturalist* 7: 33–48. Accessed 22 December 2023. <https://www.biodiversitylibrary.org/page/30103307>
- SYSTAT.** 1992. SYSTAT for Windows: Statistics, Version 5 Edition. Evanston, Illinois, USA.
- Van Cortland [Cortlandt], E.** 1859. An enumeration of the principal mammals, birds, reptiles and fishes of the Ottawa Valley. *Farmer's Journal and Transactions of the Lower Canada Board of Agriculture* 11: 198–200.
- Watson, K.W.** 2024. History of the Rideau Canal. Rideau Canal National Historic Site World Heritage Site. Accessed 11 July 2024. <https://www.rideau-info.com/canal/history/hist-canal.html>
- Wikipedia.** 2024. Ottawa. Wikipedia, the free encyclopedia. Accessed 8 August 2024. <https://en.wikipedia.org/wiki/Ottawa>

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SUPPLEMENTARY MATERIALS:

TABLE S1. Habitat characteristics of 14 sites along the Rideau River in 1998. a. Type and percent substrate type, b. Description of substrate classification based on particle size. c. Summary of type and percent vegetation cover in deep and shallow water.

TABLE S2. Gear type and fishes collected at sites in the mainstem Rideau River, Ontario between Smiths Falls and Ottawa mid-July to mid-September 1998.

TABLE S3. Gear type and fishes collected at sites in the tributaries of the Rideau River, Ontario in 1999.

TABLE S4. Gear type and fishes collected at sites in the mainstem Rideau River and in the tributaries of the Rideau River, Ontario in 2000.

The Canadian Field-Naturalist

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 United States Dollars, EUR Euros, AUD Australian Dollars, GBP British Pounds.

BOTANY

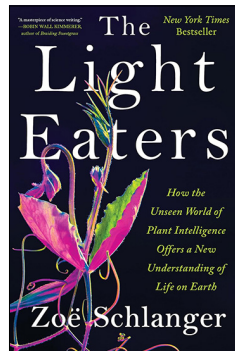
The Light Eaters: How the Unseen World of Plant Intelligence Offers a New Understanding of Life on Earth

By Zoë Schlanger. 2024. HarperCollins. 304 pages, 36.99 CAD, Hardcover, 24.99 CAD, Paper, 11.99 CAD, E-book.

As the culmination of years of interviews and study, *The Light Eaters* is at once a celebration of plant science and an investigation into our collective understanding of our vegetal neighbours.

Chapter 1 describes how Schlanger fell into plant research and her discovery of botany as a fascinating, living science. It also introduces the villain in the plant intelligence story: 1973's *The Secret Life of Plants* (Harper & Row) by Peter Tompkins and Christopher Bird, a disastrous pseudo-scientific bestseller that made the topic anathema for decades.

Chapter 2, How Science Changes its Mind, outlines the history of scientific thinking (and disagreement) about plants, animals, and consciousness. The subsequent nine chapters each address different elements of the plant intelligence question. For example, Chapter 3 explores research in plant communication (including studies of tobacco and sagebrush) that suggests differences in how individual plants respond to chemical cues sent by other plants of the same species. This is expanded upon in Chapter 5, An Ear to the Ground, which explores the developing field of phytocoustics—how plants respond to sound/vibrations. In some cases, plants have developed to amplify or interact with sound to their pollination advantage, as



seems to be the case with bat echolocation and *Marcgravia evenia* flowers (p. 102).

The Light Eaters presents plants as neither miniature humans nor automatons, but instead as active beings inextricably connected to their environments, eluding our attempts to fit them into neat and tidy boxes. Take, for example, the plant species *Boquila trifoliolata*, a South American climbing vine. Dr. Ernesto Gianoli and (then undergraduate student) Dr. Fernando Carrasco-Urra discovered it behaving strangely—it can mimic the leaf shape, gloss, dentition, venation, and colour of diverse plants near it, even mimicking the leaves of different plant species in different areas of a single *B. trifoliolata* individual. In subsequent observations, *B. trifoliolata* has been shown to also mimic plants from different continents, dispelling any possible co-evolutionary explanations for its behaviour. This extreme plasticity, varying within and across individuals, is beyond our current understanding of plants. How can the same species mimic the leaves of an introduced *Ranunculus repens*, create a spiny leaf tip to emulate *Rhaphithamnus spinosus*, and change its form to mimic a fern?

Schlanger's curiosity and openness to new ideas shines through in her writing. Her own developing viewpoint is not concealed but neither is it the dominant narrative presented; in true scientific fashion, she includes and considers conflicting perspectives. In an excellent example of popular science writing, Schlanger names the scientists and humanizes the work—what the researchers were thinking and their

reactions. As a curious explorer of the science, Schlanger is a stand-in for the reader while also acting as a translator. She grounds complex research methods and results in easy-to-understand language and demystifies the process of science, how scientists approach questions and design studies to explore them.

The Light Eaters is a fascinating exploration of modern plant science written for a general audience that may not otherwise have access to this world. More broadly, it is also a thoughtful critique of the

current Western scientific approach, acknowledging both the positives and negatives of an approach that is highly skeptical of (and at times resistant to) new ideas. There is plenty in *The Light Eaters* to follow-up on for those so inclined, and, as a thoroughly thought-provoking read, I recommend this book without reservation.

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CONSERVATION AND CLIMATE CHANGE

Wetland Restoration for Endangered Species Recovery: a Multidisciplinary Case Study of Big Meadow Bog, Brier Island, Nova Scotia

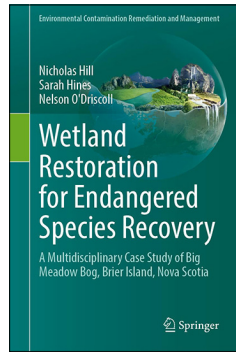
Edited by Nicholas M. Hill, Sarah Hines, and Nelson J. O'Driscoll. 2025. Springer Cham. 353 pages, 95 colour illustrations, and 22 black and white illustrations, 291.95 CAD, Hardcover. Also available as an E-book.

For information about this book and its accessibility go to <https://link.springer.com/book/10.1007/978-3-031-71344-6> (a preview is also available on Google Books). It is organized into two primary sections: Section I overviews the restoration work to characterize the biogeochemistry of the bog and the ecological interactions, and Section II examines the post-restoration temporal and spatial changes in the bog and the need for continued monitoring and intervention. The book has 17 chapters, eight in Section I and nine in Section II.

There is substantial variation in the quality of the chapters, but all are useful in providing a helpful list of references as well as some useful, and sometimes novel, perspectives. Overall, the work is an extremely significant conservation achievement.

Chapter 1, Introduction, suggests that a common problem of conservation is the lack of evidence and other knowledge to direct and guide recovery and restoration actions. This book summarizes diverse work and conservation activities that support the recovery of the Endangered (SARA Registry 2025) plant Eastern Mountain Avens (*Geum peckii*). The key factor is the will and interest of researchers, governmental and non-governmental conservation practitioners, and the local community on Brier Island, Nova Scotia. The introduction contains an important overview of the rationale for the restoration project and an outline of the concepts of adaptive management, which shapes the rest of the project and the structure of the book (p. 9, Figure 1.1). In an adaptive management approach, collaborators work cyclically through five steps: (1) concept development, (2) planning and monitoring, (3) implementing actions and monitoring, (4) analyzing and adapting, and (5) sharing what is learned. Information is centred on two main, closely related subjects: *G. peckii* and its major habitat in Big Meadow Bog on Brier Island.

At this point some background may be helpful. Eastern Mountain Avens has been referred to as “a sentinel species for conservation in Canada and globally” (p. 323). It is an attractive plant that can grow up to 0.5 m tall with large yellow flowers with deep



orange centres, and it has a story. It is believed to be an ice age relict that may have been common in the glacial parkland below the fluctuating front of the Wisconsin Glacier. This huge mass of mile-deep ice covered most of Canada, extending into the northern United States, more than 10 000 years ago, and for 100 000 years before that. This parkland was a special environment without a definite modern analogue. It had a remarkable combination of elements including Eastern Chipmunks, Thirteen-lined Ground Squirrels from the western prairies, and lemmings now found in the far northern tundra. It was cool and often foggy. As the ice continued to melt, and the new boreal forest extended northward, the environment changed, and the Eastern Mountain Avens populations moved to a higher elevation into a similar bioclimatic zone in the White Mountains of New Hampshire. Probably at the same time, populations of *G. peckii* also moved to parts of the newly exposed coastline of Nova Scotia. Some of the first land in Nova Scotia to appear during deglaciation was Brier Island, which may have been much bigger then. The sea level was lower because a lot of water was still tied up in the continental glacier. The parkland flora moved north following the receding ice, but the climate rapidly changed. Continued warming and the difficulty colonizing a new environment to which they were not adapted resulted in some plants dying out (Courtin *et al.* 2025). Others moved north, but some became isolated in special environments that resembled the parkland. These were mostly cool places but with relatively moderate temperatures. Eastern Mountain Avens in Nova Scotia moved to the cool shoreline of the Bay of Fundy where it currently occurs on Digby Neck and Brier Island. The Minas Basin–Bay of Fundy shoreline region is one of two regions in Nova Scotia where Arctic-alpine plants are isolated and/or disjunct from more extensive cold environments in the north and west (Hounsell and Smith 1966).

The largest populations of *G. peckii* in Canada are in Big Meadow Bog on Brier Island. Drainage of the bog by ditching in 1958 lowered the water table replacing open habitat with thickets and leading to colonization by thousands of Herring Gulls (*Larus argentatus*). The gulls also eliminated habitat by trampling and changing the plant community through fertilization. There was a substantial decline in the population of Eastern Mountain Avens. A series of status reports (see Chapter 1) resulted in the plant

being listed as Endangered. The most recent of these indicates that fewer than 9000 plants remain localized within an area of 17 km², with less than 1 km² occupied by the plants, and there has been a 64% decline (COSEWIC 2010). The restoration of the habitat in Big Meadow Bog was a natural result of increasing attention and support. It was Species at Risk legislation that made it possible.

Chapter 2, Big Meadow Bog: a Lost Backyard, outlines the additional major conservation achievement of a protected landscape. Big Meadow Bog served as a common ground for Indigenous Peoples and early European settlers. Here they harvested medicinal plants, berries, and game. This ended in 1958 when it was ditched, dried, and isolated by woody growth. The bog was left ditched for 55 years with barriers of woody vegetation developing on the dry peat and isolating it from local communities. A past Chief of L'sitkuk (Bear River First Nation, which included the first people of the Bay of Fundy region), noted: "We have a responsibility to look after the lands and waters as we will only be as healthy as nature around us" (p. 13). The restoration effort (for the bog and *G. peckii*) and the boardwalk have reconnected local people with the bog, thus renewing appreciation and pride in their immediate natural landscape. This contribution to the community and to the protection of extensive biodiversity started in 1993 with the Nature Conservancy of Canada acquiring and designating the more than 4 km² Brier Island Nature Reserve (p. 6). It includes one quarter of the island area, 17% of the total population of *G. peckii*, and critical components of the Brier Island ecosystem.

Chapter 3, Genetic Variation, Clonal Structure, and Mating System of the Imperiled Eastern Mountain Avens (*Geum peckii*) and Its Separation from Spreading Avens (*G. radiatum*), has to do with genetic variation and taxonomy. *Geum peckii* from Nova Scotia and New Hampshire and *Geum radiatum* from the southern Appalachians are supported as separate species based largely on recent molecular evidence (COSEWIC 2010). Nova Scotian *G. peckii* is genetically uniform compared to the New Hampshire population, which has a genetic structure at a scale of 10 km. Ramets of Nova Scotian plants found more than 1 m apart are unlikely to be members of the same clone. *Geum peckii* has a mixed mating system with partial outcrossing and partial self-pollination. The Nova Scotian plants have a very high inbreeding depression but ample genetic variation indicating the importance of maintaining a suitable environment for management and recovery. This study has advantages over previous information based on RAPD (Random Amplified Polymorphic DNA) markers (Paterson and Snyder 1999).

In Chapter 4, Ecology and Conservation of the Eastern Mountain Avens in Nova Scotia, *G. peckii* is found to be a plant of naturally stressed wetland habitats where interspecific competition from shrubs is low. This chapter is very valuable in presenting a great deal of biological information resulting from discussions of: (1) range and habitat; (2) transplantation experiments relating to shrub encroachment and the water table; (3) regenerative biology including pollination, germination, and dispersal; (4) population dynamics; and (5) ecological interventions including shrub removal and facilitating seed germination and growth. It is concluded that without intervention the plant could be eliminated from Canada. An interesting paragraph at the end of the conclusion counters John Harper's argument that conservation is an idea based on nostalgia (Harper was the pioneer of plant population biology; pp. 92–93).

Chapter 5, Climate Change on Brier Island: Prospects for Long-Term Survival of *Geum peckii*, is an exemplary and very relevant chapter based on extensive data and clever analysis. It goes beyond the general subject matter containing (for example) graphs showing climate warming in Nova Scotia with the 1997 and 1998 step change (Figures 5.1 and 5.2). Climate change on Brier Island since the 1960s, following declines of *G. peckii*, is evaluated. The island has warmed 2°C since the 1990s. Brier Island has experienced more climate warming than other parts of Nova Scotia and now has the warmest temperature regime in Atlantic Canada. It is speculated that the warming climate, to which this Arctic-alpine plant may not be well adapted, will limit its general performance, but it may also cause more vigorous shrub growth that would displace *G. peckii*. Climate change is considered a serious threat that will also eliminate populations of *G. peckii* by rising sea levels and more severe storms. The high winds and upwelling of deep, cool water in the Bay of Fundy, which has helped to maintain cool conditions on Brier Island, may be changing along with the general oceanic warming. There is evidence from cultivation that *G. peckii* has a broader climatic tolerance than the zones in which it occurs, and that its restriction to cooler locations is mediated by some other factor such as competition or predation (COSEWIC 2010: 18). This makes climate change seem a little less threatening, but is *G. peckii* likely to survive without being looked after (cultivated) in gardens (which are watered)? The plant may need a foggy, moist, and disturbed habitat. Many plants that can survive in cultivation may not survive in a nearby natural habitat. The ease of cultivation is an important management consideration, but perhaps not a good reason to downgrade the threat of climate change. The stronger evidence for a lack of impact of

increasing temperature may be that *G. peckii* survived the warmer temperatures of the postglacial hypsithermal interval, but data to support this have not been critically reviewed.

Chapter 6, Geological History and Ecosystems Evolution at Big Meadow Bog, Brier Island, Nova Scotia, provides some useful information, but the conclusion may benefit from additional work. For example, the comparison with a wide-ranging turtle (p. 130) does not seem informative. Late Holocene environmental change including dry periods with forest cover that were open bog during wetter periods are an interesting revelation. Perhaps the plants have a degree of resilience on a very local scale and can move over the landscape (assisted by unusually high winds; p. 114). It may be possible to discover more precisely the sites occupied by *G. peckii* in the past using macrofossils (seeds, etc.) preserved in dated peat layers (e.g., Landry and Cwynar 2005). The difficulty with this idea is that the seeds of *G. peckii* may be scarce and short-lived (p. 82).

Chapter 7, Pre and Post Restoration Hydrology of Big Meadow Bog, indicates that the restoration was successful in raising water levels overall, but parts of bog had poor water level recovery. It is important to consider that the rise in water level in some areas was not beneficial to *G. peckii* because it led to an increase in Sweet Gale shrubs from 5 to 85% cover (p. 85).

Chapter 8, Differences in Shallow Groundwater Dynamics Between Disturbed and Undisturbed Peatlands on Brier Island, Nova Scotia: Implications for Persistence of *Geum peckii* in Big Meadow Bog, provides some foundation for understanding the hydrologic niche of *G. peckii*. There has always been a general agreement that a return to the original (preditching) hydrology of Big Meadow Bog would benefit the plant.

Chapter 9, Greenhouse Gas Emissions from Big Meadow Bog: Influence of Gull-Derived Phosphate as a Biogeochemical Driver, reports that the long-term goal of reducing gull numbers could return Big Meadow Bog to a carbon sink, but in the short-term greenhouse gas emissions (CO_2 , CH_4 , N_2O) have been exacerbated by the changing hydrology and eutrophication.

Chapter 10, Restoration of Wetland Hydrology at Big Meadow Bog, is well grounded with scientific information from other studies, e.g., from the extensive work done on peatland restoration in Yorkshire, England. The restoration design was implemented for Big Meadow Bog from 2016 to 2018. It included blocking ditches with regularly spaced dams, re-profiling ditch edges, and woody plant removal. It was followed by an assessment of effectiveness in 2023,

which indicated that ditch-blocking structures were mostly functioning well.

Chapter 11, Baseline and 3-Year Post-restoration Bird Communities at Big Meadow Bog, Brier Island, Nova Scotia, indicates that much longer post-restoration periods are needed before restoration will be complete. Herring Gull abundance is associated with major deterioration of the breeding bird community in northeastern Big Meadow Bog, and it "is likely to take several decades" to repair the damage (p. 241).

Chapter 12, Effects of Avian Biotransport of Industrial Wastes to a Bog Ecosystem, reports that over 3000 Herring Gulls, using the bog as one of the largest nesting sites in the Maritimes, bring nutrients to the ecosystem. The gulls are largely subsidized by human activity (fish processing plants and American Mink farms, etc.) where they scavenge waste and carcasses.

Chapter 13, A Multi-Year Study of Methylmercury and Nutrient Export in Surface Water from Big Meadow Bog, Brier Island, Nova Scotia, notes that water table restoration in 2013 resulted in increased outflow of methylmercury, but it declined thereafter to a stable state of lower levels.

Chapter 14, Foliar Endophytic Fungi from *Geum peckii* in Canada, provides the first survey of this group in Eastern Mountain Avens including important new information. Although the results, along with additional study, may be helpful to conservation, the extent is unclear.

Chapter 15, *Ex Situ* Conservation of the Globally Imperiled Eastern Mountain Avens (*Geum peckii*) in Nova Scotia, Canada, indicates that Eastern Mountain Avens was successfully retrieved from seedbank storage, propagated by tissue culture, and returned to a natural habitat. It was confirmed for the first time that *G. peckii* grows in association with arbuscular mycorrhizal fungi and can be inoculated with these fungi. This was the first time in Nova Scotia that an endangered plant species was successfully retrieved from seedbank storage. This chapter is a very helpful outline of *ex situ* conservation methods. Thousands of *G. peckii* seeds are stored long term in the Acadia Seed Bank, with thousands more to be collected routinely and sustainably in the future. This work illustrates the value of seed banks and of tissue culture techniques to the conservation of biodiversity.

Chapter 16, Managing Gull Numbers: History and Challenges, begins with a review of general problems with gulls. The experiments with preventing gulls from nesting near Eastern Mountain Avens are discussed. The use of bamboo poles and egg removal was not effective.

Chapter 17, Summary and Conclusions, includes a helpful summary of the conclusions of each chapter

(pp. 345–349). In many situations we look past landscape disturbances and threats to find alternative sites for conservation. In this case an endangered species was threatened by wetland alteration, and people chose to fix the problem with a concerted conservation effort. Restoration and recovery are relatively new sciences developing from ecology, and there is much still to learn, making this book a valuable case study. The specific problems that remain to be resolved with Nova Scotian *G. peckii* and Big Meadow Bog are outlined here, providing valuable directions for future conservation efforts.

This is a long book with diverse conservation and restoration subjects, all of which are of some interest. Two important questions are:

- 1) What is missing from one of the most complete and extensive research efforts to protect an endangered plant in Canada?
- 2) What is next?

Regarding the first question, I noticed the following, which I do not consider definitely limiting to the conservation effort in this case:

- a) Information on pollination and dispersal has not been studied in a sufficiently detailed manner.
- b) Mathematical methods of determining survival likelihood have not been used.
- c) Habitat diversity deserves more consideration. Where was *G. peckii* before the bog developed 700 or 1700 years ago (pp. 18, 58), or even when the freshwater peatland developed 2500 years ago (p. 18)? Presumably the plant was present in some of its other habitats including successional sheep pasture (8% of current occurrences; pp. 58, 61, 90, 346, etc.), perhaps previously grazed and disturbed by other mammals, or burned areas (where populations were increased by fire). Over several thousand years in Nova Scotia, it may have benefited from natural fire, disturbance by mammals, and later activities of Indigenous Peoples including the use of fire.
- d) Fire, although associated with increasing populations of *G. peckii* (p. 89), was not used in restoration experiments.
- e) The disturbance requirement may have been under-emphasized despite the presence of seedlings in ATV trails, deer paths (pp. 80, 81), and sheep pastures. Over many thousands of years, Eastern Mountain Avens evolved in the cool, highly disturbed environment of fluctuating ice lobes, erosion, deposition, and megafauna (mastodons, mammoths, various Muskoxen, various very large ground sloths, giant beavers, horses, Stag Moose, Caribou, tapirs, etc.) that may have had much more impact on the landscape than

ATVs of today. When the climate rapidly changed, the megafauna and many other plants died out (Courtin *et al.* 2025), but *G. peckii* remained. This may help to develop a realistic view of the evolutionary ecology of this fascinating plant.

Regarding question two, there are a few important future actions:

- a) The gulls need to be reduced in number and moved. An obvious solution is the enforcement of some of the regulations having to do with the dumping of organic waste on the landscape. There are a number of actions that may not have been tested adequately yet, such as noisemakers and regular disturbance at key times.
- b) Everyone seems to agree that *ex situ* conservation methods are an essential insurance for plant survival. It is probably a good time to cross provincial boundaries, cooperate with Newfoundland and Labrador, and establish *ex situ* plantings on coastal streamsides north of Bellburns and on Belle Isle.
- c) Should consideration be given to improving the genetic variation in the Canadian population by introducing plants from the White Mountains?
- d) Without continuing interventions this species may be lost from Canada. It is time now for a new plan.

Reading and writing is not that difficult, certainly not as difficult as it is to indulge in endless meetings and communications, extensive data gathering and analysis, to create hundreds of proposals and plans, and to carry out the heavy work of restoration. This has been a very big job, but it has also been very successful. Many hundreds of people, from Nova Scotia and beyond, have been involved. In particular, the people of Nova Scotia—including Indigenous Peoples, local community members, researchers, consultants, and government employees, who worked together to protect Eastern Mountain Avens and restore Big Meadow Bog—deserve our admiration and sincere appreciation. Dr. Nicholas M. Hill, adjunct professor at St. Francis Xavier University and Acadia University, played a major role.

Literature Cited

- COSEWIC (Committee on the Status of Endangered Wildlife in Canada).** 2010. COSEWIC assessment and status report on the Eastern Mountain Avens *Geum peckii* in Canada. COSEWIC, Ottawa, Ontario, Canada.
- Courtin, J., K.R. Stoof-Leichsenring, S. Lisovski, Y. Liu, I.G. Alsos, B.K. Biskaborn, B. Diekmann, M. Melles, B. Wagner, L. Pestryakova, J. Russell, Y. Huang, and U. Herzschuh.** 2025. Potential plant extinctions with the loss of the Pleistocene mammoth steppe. *Nature Communications* 16: 645. <https://doi.org/10.1038/s41467-024-55542-x>

- Hounsell, R.W., and E.C. Smith.** 1966. Contributions to the flora of Nova Scotia VIII. Distribution of Arctic-alpine and boreal disjuncts. *Rhodora* 68: 409–419. Accessed 6 August 2025. <https://www.biodiversitylibrary.org/page/632489>.
- Landry, M., and L.C. Cwynar.** 2005. History of the endangered Thread-leaved Sundew (*Drosera filiformis*) in southern Nova Scotia. *Canadian Journal of Botany* 83: 14–21. <https://doi.org/10.1139/b04-137>
- Paterson, I.G., and M. Snyder.** 1999. Genetic evidence supporting the taxonomy of *Geum peckii* (Rosaceae) and *G. radiatum* as separate species. *Rhodora* 101: 325–340.
- SARA (*Species at Risk Act*) Public Registry.** 2025. Species summary: Eastern Mountain Avens (*Geum peckii*). Government of Canada, Ottawa, Ontario, Canada. Accessed 6 August 2025. <https://species-registry.canada.ca/index-en.html#/species/184-143>.

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ENTOMOLOGY

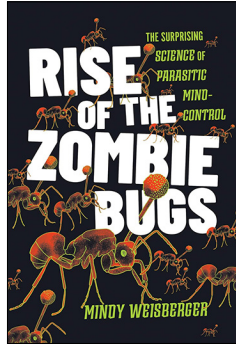
Rise of the Zombie Bugs: the Surprising Science of Parasitic Mind-Control

By Mindy Weisberger. 2025. Johns Hopkins University Press. 296 pages and 13 black and white illustrations, 38.95 CAD, Hardcover. Also available as an E-book.

Most scientists are good writers; it's part of their work. Few are great writers. In addition to writing up their research as reports (so-called 'papers'), some write books as well. These are often well written, and sometimes they're great.

In contrast, there are, by profession, great writers; not all of them can interpret science correctly, though. Mindy Weisberger is one of the savvy writers who does interpret science well, and reading her book instilled a pleasure like working with a perfectly sharpened knife in the kitchen. Weisberger knows how to use the scientific literature and makes frequent references to studies, even telling the reader the nationalities and universities of the researchers. I don't know why, but I found those inclusions satisfying. Perhaps because it suggests that parasites are of worldwide interest and not just restricted to one post-retirement, unshaven, so-called 'evil scientist' in a windowless basement lab somewhere.

Zombies are cool right now and have been for some time. You'll find them in movies, TV shows, and video games. Weisberger takes advantage of this popularity by starting each chapter with a quote from zombie culture and conservatively sprinkling the text with references, too. Chapter 1, though, has many references and uses them to frame the (nearly) mythical human zombie as a precursor to the rest of the book. Fittingly, the book ends with some rare cases of parasites affecting human behaviour (e.g., toxoplasmosis). Omitting



this would have been dreadfully anticlimactic.

The meat of the book is about the insects, fungi, and viruses that find their way into living insects (sometimes other invertebrates, too) and how the parasitoids then control the behaviour of their hosts with the universal goal to procreate. Did you catch my use of the word 'parasitoid'? Weisberger uses 'parasite' instead, and that's not quite correct. A parasite (e.g., Head Lice in humans) rarely kills its host. It would be detrimental to kill your host if it's providing you and your offspring with shelter and food. A parasitoid lives long term on or in its host (resembling what a parasite does) but is eventually responsible for the host's death (although not before completing its own life cycle). This is a small error (one of only a few) and should be insignificant to most readers.

Each humorously titled chapter (e.g., Zombifying Viruses: the Attack of the Ooze) deals with one (or a few related) zombie-inducing scenarios. The themes of the chapters are how parasitoids get into their hosts, manipulate their hosts without killing them (for the time being), feed, and reproduce. Most of the book's examples are of insects being used as hosts, although spiders, millipedes, snails, and, finally, humans get zombified, too.

The only small downside in this book are the low-quality photographs. I assume the originals are fine and that the low contrast images are a result of the printing process used. They do add to the content of the book but could have been so much better.

Overall, a great read.

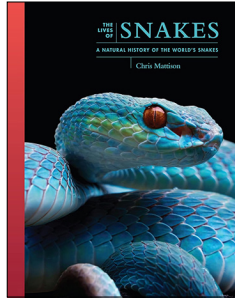
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HERPETOLOGY

The Lives of Snakes: a Natural History of the World's Snakes

By Chris Mattison. 2025. Princeton University Press. 288 pages and 150 colour illustrations, 48.00 CAD, Hardcover, 39.99 CAD, E-book.

First of all, *The Lives of Snakes* is a beautiful book, artfully designed and filled with photographs that range in quality from very good to amazing. While not a coffee-table book, it is still a book that one can flip through casually to enjoy the photos and short species accounts.



The Lives of Snakes consists of an introduction and six chapters, each dealing with a specific topic along with some species accounts that highlight aspects of that chapter. The introduction covers subjects such as taxonomy, species diversity, and the global distribution of snakes. The chapters are: Form and Function, Dealing with the Environment, Reproduction, Diet and Feeding, Enemies and Defense, and Snakes and Humans. Each chapter consists of a variety of topics; most topics are laid out in two-page spreads, but a few are longer. Each topic has a title in large font, a single paragraph in bold, several paragraphs in regular print, and a few photos to illustrate its point. For example, in the chapter Dealing with the Environment, topics include temperature and water balance, thermoregulation, and snakes in deserts. These sections are usually a basic introduction to the subject matter given there is not much room in a two-page spread to provide in-depth information, especially with photos taking up almost half the space.

The species accounts within each chapter are a highlight of the book. Each account is presented as a two-page spread with one page consisting of a photo of the snake. In addition, each account includes a world map showing the distribution of each species, a text box with some basic information (scientific name,

family, typical length, egg-laying or not, and habitat), and a few paragraphs that take up roughly half a page and highlight a feature or two of the species.

Overall, this is a wonderful book for anyone interested in snakes. Many of the accounts profiled species I am familiar with, but others profiled unusual species I had not heard of before. The text is somewhat basic, so those with a fair amount of snake knowledge will already be familiar with much of the information in the book.

I have a few minor critiques. As mentioned before, each species account features a world map showing its global distribution. Yet, even for wide-ranging species, over half of the world map is unoccupied. For species with limited distributions, the reader has to look closely to see where the snake occurs. It would have been better to provide more detailed maps of particular regions in this case. The book has almost nothing on hibernation/brumation aside from a brief mention that in some areas snakes may be “inactive during the winter” (p. 90). In many parts of the world, including Canada, the winter environment can limit the range of species and affect survival of individual snakes. A section on overwintering conditions and the stresses these conditions place on snakes should have been included. Occasionally, the author makes a broad statement that is not always correct, e.g., “Lizards occur everywhere that snakes do” (p. 167). Such a statement is true in many places, but it is certainly not true in Canada. There are no native lizard species east of Ontario, but native snakes occur in Quebec, New Brunswick, Nova Scotia, and Prince Edward Island. Despite these minor issues, I would still recommend this book for any naturalist interested in snakes.

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ORNITHOLOGY

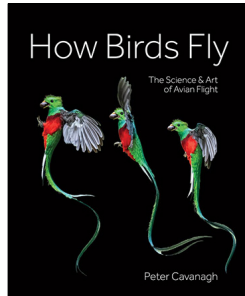
How Birds Fly: the Science and Art of Avian Flight

By Peter Cavanagh. 2024. Firefly Books. 336 pages and 350 colour photos and illustrations, 49.95 CAD, Hardcover.

This book is a masterpiece. Well-written and superbly illustrated, it explains the current scientific understanding behind how (and why) birds fly. It is also a wonderful celebration of birds. The author's credentials shine throughout the book; Cavanagh is a retired professor of human biomechanics, a distinguished scientist, a world-class bird photographer, and an experienced pilot of small planes. His writing evokes some laugh-out-loud moments. The quality of the book's production is remarkable. It includes breathtaking and well-chosen large photographs of birds in flight that were selected from the author's many images of birds from every continent. The quality and variety of the other illustrations and diagrams—which include examples of figures from in-depth scientific studies of flight—are uniformly exceptional and informative. I liked the digital artistic representations of theropod dinosaurs at different stages of evolution; a modern birdwatcher would have felt quite at home 100 million years ago.

The extraordinary nature and variety of bird flight is on full display in this stunning tour de force. No flying bird will ever look quite the same to me. Although scientists have figured out so much about the secrets of bird flight, there is clearly a lot more to discover with the application of technologies, including high-speed photography and other novel photographic techniques, wind tunnels, computer-assisted modeling, and electronic tracking of body sensors in birds. Bird flight has many surprises, but there are many more to come.

Thirteen chapters cover topics such as: the changes in anatomy that supported the evolution of flight in birds; the extraordinary nature and diversity of feathers; the uses of different types of muscles; the aerodynamics of takeoff, landing, gliding, soaring, flapping, in-flight maneuvering, and hovering; formation flying and flocking; and migration. There is also a discussion of selected flight specialists such as albatrosses, hummingbirds, owls, and swifts. What struck me most was the diversity of bird flight and the numerous adaptations to the different types of flight by so many birds. In asking "How do birds fly?", one should not expect a simple one-size-fits-all answer. There are no standard methods for flying because all anatomies and adaptations require



different strategies. For example, birds continuously change the size, shape, warping, and camber of their wings to adjust, often with subtle fine-tuning, to different atmospheric conditions and flying speeds. As first recognised by Charles Darwin in the finches of the Galápagos Islands, birds can evolve surprisingly quickly, leading to their extraordinary diversity, including that of flight. Bird evolution and adaptation are constant themes of the book, but the adaptations discussed are not just anatomical; they are also physiological, biochemical, and neurological. There is so much more to birds than what we see.

As a bird carver, this reviewer was forcefully reminded that the primary wing feathers are anatomically the 'hand wing' and the secondary feathers are the 'arm wing'. The primary feathers provide the propulsive thrust (and lift) required for movement, whereas the secondaries attached to the ulna are more for maintaining lift and gliding. The emargination (notching) of the terminal primary feathers is critical to producing lift in birds. The tertiary feathers (tertials), between the secondaries and the body, presumably originated from the humerus. These major feather groups control the aerodynamics of flight through their positioning. I hadn't realized the importance of the flexibility of the wrist between the hand and arm wings, which can act quite independently, as can both wings. The alula feathers, originating from the thumb, are an important part of bird flight (especially in some species), acting as a leading-edge vortex generator to produce a novel form of lift. For carvers, they are a minor detail, but not for birds. All flight feathers, whether main or minor (the various coverts), are movable and integrated into the dynamics of flight. *How Birds Fly* shows these details in breathtaking photographs. (I loved the photos of Red Kite and Northern Gannet flying upside down.) The magic, of course, is how this is all integrated by a bird into its needs for successful flight, including takeoff and landing (moments that many people who have flown in airplanes will always find a bit scary), because this is all carried out instinctively.

The complex aerodynamics of the different types of bird flight is skillfully discussed and illustrated. Cavanagh often compares bird flight to that of airplanes, which uniformly come out as a very poor second to birds. The author walks us gently through the application of Newtonian mechanics to explain the complex aerodynamics of flight.

There is a spectacular photograph of the air vortices generated by Northern Goshawk's wing and

tail tips, which provide some of the lift required for flight. The role of the bird's tail in flight is still not well understood. Although relatively small compared to the wing, the tail likely has an outsized influence on flight because of its distance from a bird's centre of gravity. Bird carvers tend to carve tails narrowly, with closely overlapping feathers, which not only is technically quite difficult but also does not give the tail the attention it deserves.

In a chapter called Bioinspired Flight, Cavanagh discusses the potential applications of what has been learned about the variety of bird flight. For example, there is evidence that the dark colours on the upper surface of the wings of some birds (including the black tips of some flight feathers) increase

the temperature of the boundary air around the wing by absorbing sunlight and thus improving flight lift. Perhaps one day the upper surface of aircraft wings will be painted black. By contrast, Great Snipe avoid solar-induced overheating (which adds to the heat from their own muscles) in their more than three days of non-stop migration from Sweden to Sub-Saharan Africa by climbing during the day to over 5000 m, where temperatures are around -20°C .

Congratulations to Peter Cavanagh and his publisher for such a wonderful and important book.

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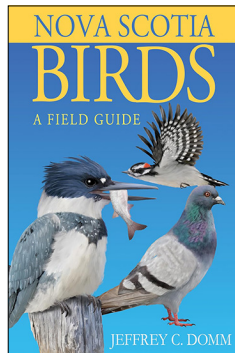
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Nova Scotia Birds: a Field Guide. Third Edition

By Jeffrey C. Domm. 2024. Formac Publishing Company Limited. 224 pages, 27.95 CAD, Paper.

The newest edition of this field guide (previous editions published in 2005 and 2012 were titled the *Formac Field Guide to Nova Scotia Birds*) is written and illustrated by Jeffrey Domm, a well-known and prolific nature illustrator, artist, and writer based in Belnan, Nova Scotia. It is a treat to have a Nova Scotia-specific bird guide, and this book is noticeably lighter than its competitor on my shelf, *Birds of Eastern Canada, Second Edition* (DK, 2019). This makes it a less begrudging inclusion in a backpack already packed full of water, snacks, and warm layers (a necessary addition for any Nova Scotian sojourn, as Domm notes in the introduction). Following a brief introduction and guide overview, Domm provides a map and short description of 46 Nova Scotia birding hot spots. Starting with sea-shore and water birds, each of the subsequent pages is devoted to one species.

The main section of each species page contains the common name, Latin name, illustration(s), physical description (including sex and seasonal differences), voice, diet, an illustration of the flight pattern with corresponding text, and lookalikes—one to two species that may be confused for one another. I appreciate that the flight pattern consists of illustrations instead of a line diagram, as I find the illustrations more intuitive, especially for birds that glide. Some species have an additional Did You Know? section,



which provides interesting facts. This would have been a good place to include the Mi'kmaq names that are species-specific, for example Blue Jay, American Crow, and Blue-winged Teal.

The outer edge of each page features a panel that depicts the size of the species compared to the book, an illustration of the bird in flight, a wheel of the year showing which months are best for seeing the species, and descriptions of its feeding behaviour and habitat. These last two sections merit special mention. Feeding behaviour is only included for water birds; icons depicting the species' primary feeding technique(s) are included for each bird. This is extremely helpful for beginner birders, for whom it's useful to know, for example, that while Common Eider tip upside down in the water to feed, Bufflehead dive from the surface of the water. Nine habitats are represented by small diagrams: cliff/embankment, dead tree, meadow, shrub, marsh, wetland, soaring overhead (used for birds of prey that would typically be seen overhead), needle tree, and leafy tree. On each page, a small bird icon indicates the location(s) where a species is likely to be found; it is a simple yet effective way to communicate this information, in contrast to burying it in the text as other guides do. The guide finishes with an illustrated Quick Reference Index (pp. 219–221) and an Index of Bird Names.

The guide contains information for 200 bird species. For practicality's sake, one cannot expect all bird species to be included, but I was disappointed to note the absence of Ruddy Duck, all egrets, and all herons except Great Blue Heron. However, Domm has created illustrations for many species that lack their own entry proper. For example, the Great Blue

Heron entry (p. 67) includes a small (~2 cm tall) image of both Sandhill Crane and Green Heron under the lookalikes section, but neither of these species is profiled in the book. Other birds that appear solely in the lookalikes section of other species include Horned Grebe, Redhead Duck, Gadwall, Black-crowned Night-heron, and Pine Warbler.

Some species include illustrations for male/female, winter/summer, and breeding/non-breeding identification, but for others it would have been helpful to include fall (in the case of warblers) or winter plumage illustrations to support the text. For example, Red-throated Loon has both summer and winter plumage shown in this guide, but Common Loon is depicted only in summer plumage (p. 40). For novice birders, the winter plumage of Red-throated Loon on the verso (p. 41), which looks very similar to Common Loon in winter plumage, may lead to confusion.

This guide's art is predictably excellent. While some readers might miss having callout annotations that highlight key identifying features, the description text is well written and clear. The guide lacks a 'parts of a bird' diagram, and a future edition, if it sought to be more beginner friendly, would benefit from a short glossary to define terms such as 'barring'. That being said, my main complaint is that I want more of this book—more species, more plumage variation—but this guide is not designed to be comprehensive. I would recommend *Nova Scotia Birds* to both tourists and residents alike; it contains many of the most common birds in the province as well as notable species that will be of interest to visitors, such as Harlequin Duck. This edition, with its all-new art, is a great little guide, and I continue to want Jeff's art on all my walls.

HEATHER CRAY
Halifax, NS, Canada

The Canadian Field-Naturalist

NEW TITLES

Prepared by Jessica Sims

If you are interested in reviewing a book on this list, please contact Jessica Sims (bookrevieweditor@canadianfieldnaturalist.ca). This list covers a range of upcoming and new releases in field biology, ecology, and natural history. We also welcome your suggestions for new titles and offers to review unlisted books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, or books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Please note: Books marked with a * have already been assigned to a *Canadian Field-Naturalist* reviewer. All other books are available for review and review copies of books marked with a † have been explicitly offered by publishers.

Currency Codes: CAD Canadian Dollars, AUD Australian Dollars, USD United States Dollars, EUR Euros, GBP British Pounds.

BIOLOGY

The Arrogant Ape: the Myth of Human Exceptionalism and Why It Matters. By Christine Webb. 2025. Avery. 336 pages, 42.00 CAD, Hardcover, 18.99 CAD, E-book.

†**To Have or To Hold: Nature's Hidden Relationships.** By Sophie Pavelle. 2025. Bloomsbury. 336 pages, 40.00 CAD, Hardcover, 22.99 CAD, E-book.

Life History Evolution: Traits, Interactions, and Applications. Edited by Michal Segoli and Eric Wajnberg. 2025. Wiley. 496 pages, 132.00 CAD, Hardcover. Also available as an E-book.

The Ocean's Menagerie: How Earth's Strangest Creatures Reshape the Rules of Life. By Drew Harvell. 2025. Penguin Publishing Group. 288 pages, 42.00 CAD, Hardcover, 18.99 CAD, E-book.

The Radiant Sea: Color and Light in the Underwater World. By Steven Haddock and Sönke Johnsen. Foreword by Helen Scales. 2025. Abrams Books. 224 pages and 100 colour photos, 69.00 CAD, Hardcover. Also available as an E-book.

Understanding the Tree of Life. Understanding Life Series. By Kevin Omland. 2025. Cambridge University Press. 150 pages, 22.95 CAD, Paper.

Are Viruses Alive? Mind-Altering Stories about Life and Evolution. By Noga Wies. 2025. Pelagic Publishing. 168 pages, 35.00 CAD, Hardcover, 23.00 CAD, Paper.

BOTANY

Cannabis: a Global History. By Bradley J. Bourgerdi. 2025. Reaktion Books. Distributed by University of Chicago Press. 168 pages, 53 colour plates, and 65 halftones, 25.95 CAD, Hardcover. Also available as an E-book.

The History Trees: Extraordinary Tales of Trees through Time. By Colin Salter. 2025. Pavilion Books. 224 pages, 37.00 CAD, Hardcover. Also available as an E-book.

Kew Pocketbooks: Tropical Plants. By Brie Langley. 2025. Royal Botanic Gardens, Kew. Distributed by University of Chicago Press. 96 pages and 40 colour plates, 19.50 CAD, Hardcover.

Take to the Trees: a Story of Hope, Science, and Self-Discovery in America's Imperiled Forests. By Marguerite Holloway. 2025. W.W. Norton. 272 pages, 38.99 CAD, Hardcover, 29.99 CAD, E-book.

CONSERVATION AND CLIMATE CHANGE

Canadian Ecopolitics. By Rosalind Warner, Peter J. Stoett, and Will Greaves. 2025. University of Toronto Press. 360 pages, 115.00 CAD, Hardcover, 61.95 CAD, Paper. Also available as an E-book.

Climate Changed: Models and the Built World. Edited by Mara Freilich, Irmak Turan, Jessica Varner, and Lizzie Yarina. 2025. Columbia University Press. 248 pages, 156.00 CAD, Hardcover, 39.00 CAD, Paper. Also available as an E-book.

Debating Disaster Risk: Ethical Dilemmas in the Era of Climate Change. Edited by Gonzalo Lizarralde, Lisa Bornstein, and Tapan Dhar. 2025. Columbia University Press. 376 pages, 182.00 CAD, Hardcover, 46.00 CAD, Paper. Also available as an E-book.

Existential Politics: Why Global Climate Institutions are Failing and How to Fix Them. By Jessica F. Green. 2025. Princeton University Press. 224 pages, 129.00 CAD, Hardcover, 41.00 CAD, Paper. Also available as an E-book.

Extracting the Future: Lithium in an Era of Energy Transition. By Mark Goodale. 2025. University of California Press. 304 pages and 26 black and white illustrations, 119.00 CAD, Hardcover, 37.95 CAD, Paper. Also available as an E-book.

Habitat: the Fundamental Unit for Understanding and Conserving Nature. By Roger L.H. Dennis and Simone Fattorini. 2025. CABI Publishing. 504 pages, 305.50 CAD, Hardcover.

Here Comes the Sun: a Last Chance for the Climate and a Fresh Chance for Civilization. By Bill McKibben. 2025. W.W. Norton. 224 pages, 39.99 CAD, Hardcover, 30.99 CAD, E-book.

The Hype about Hydrogen: False Promises and Real Solutions in the Race to Save the Climate. Edition, Revised and Updated. By Joseph J. Romm. 2025. Island Press. 240 pages, 43.95 CAD, Paper. Also available as an E-book.

Narrating the Multispecies World: Stories in Times of Crises, Loss, and Hope. Edited by Michaela Fenske. 2025. transcript publishing. 336 pages, 72.00 CAD, Paper.

Regulating International Trade in Wildlife: 50 Years of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. By David H.W. Morgan. 2025. CRC Press. 192 pages, 32 black and white illustrations, and 16 tables, 355.50 CAD, Hardcover, 88.95 CAD, Paper.

Science in Resistance: the Scientist Rebellion for Climate Justice. By Fernando Racimo. 2025. University of California Press. 312 pages and 20 black and white illustrations, 119.00 CAD, Hardcover, 31.95 CAD, Paper. Also available as an E-book.

Slow Down or Die: the Economics of Degrowth. By Timothée Parrique. Translated by Claire Benoit. 2025. Europa Editions. 288 pages, 29.50 CAD, Paper.

The Story of CO₂ is the Story of Everything: How Carbon Dioxide Made Our World. By Peter Bran-

nen. 2025. HarperCollins. 512 pages, 43.50 CAD, Hardcover.

Synoptic Paleoclimatology: the Weather Regime Approach from the Tropics to the Poles. By Ian D. Goodwin. 2025. Cambridge University Press. 764 pages, 91.95 CAD, Hardcover.

***Wetland Restoration for Endangered Species Recovery: a Multidisciplinary Case Study of Big Meadow Bog, Brier Island, Nova Scotia.** Edited by Nicholas M. Hill, Sarah Hines, and Nelson J. O'Driscoll. 2025. Springer Cham. 353 pages, 95 colour illustrations, and 22 black and white illustrations, 291.95 CAD, Hardcover. Also available as an E-book.

ECOLOGY

Carbon: the Book of Life. By Paul Hawken. 2025. Penguin Publishing Group. 256 pages, 37.99 CAD, Hardcover, 16.99 CAD, E-book.

The Great Tree Story: How Forests Shaped Our World. By Levison Wood. 2025. Gaia Books. 311 pages, 25.00 GBP, Hardcover.

The Nature of Pandemics: Why Protecting Biodiversity is Key to Human Survival. By Jake Robinson. 2025. Pelagic Publishing. 336 pages, 38.00 CAD, Hardcover.

The Ocean Book: the Stories, Science, and History of Oceans. DK Nature Books. By DK. 2025. DK. 320 pages, colour photos, colour illustrations, and black and white illustrations, 54.00 CAD, Hardcover, 19.99 CAD, E-book.

ENTOMOLOGY

Insect Pathology. Third Edition. Edited by Nemat Keyhani and Brian Lovett. 2025. Academic Press. 500 pages, 296.50 CAD, Hardcover, 155.99 CAD, Paper.

The Riverfly Handbook. By Craig Macadam. 2025. Amateur Entomologists' Society. 135 pages, 66 colour and black and white photos, and colour illustrations, 22.99 GBP, Paper.

HERPETOLOGY

†**Maine Amphibians and Reptiles. Third Edition.** Edited by Malcolm L. Hunter Jr., Trevor B. Persons, Aram J.K. Calhoun, Phillip G. de Maynadier, and Derek T. Yorks. 2025. University of Maine Press. 448 pages, 32.00 USD, Paper.

ORNITHOLOGY

Birds of New England: a Timber Press Field Guide. By Zach Adams. 2025. Timber Press. 528 pages and 900+ photos, 39.99 CAD, Paper, 26.99 CAD, E-book.

Birds of Prey of the Northeast: Field Guide. By Stan Tekiela. 2025. Adventure Publications. 168 pages, 22.95 CAD, Paper. Also available as an E-book.

***Crossbills and Conifers: One Million Years of Adaptation and Coevolution.** By Craig Benkman. 2025. Pelagic Publishing. 224 pages and colour illustrations, 124.00 CAD, Hardcover, 57.00 CAD, Paper. Also available as an E-book.

The Merlin: the Ecology of a Magical Raptor. By Frank Rennie. 2025. Pelagic Publishing. 216 pages, 57.00 CAD, Paper.

National Geographic Field Guide to the Birds of the United States and Canada. Eighth Edition. By Ted Floyd. 2025. Disney Publishing Group. 592 pages, 44.00 CAD, Paper.

Nature Needs You: the Fight to Save Our Swifts. The Wainwright Prize Longlist 2025 for Conservation Writing. By Hannah Bourne-Taylor. 2025. Elliott & Thompson. 320 pages, 16.99 GBP, Hardcover. Also available as an E-book.

We Should All Be Birds: a Memoir. By Brian Buckbee with Carol Ann Fitzgerald. 2025. Tin House Books. 256 pages, 38.99 CAD, Hardcover, 15.99 CAD, E-book.

A Year of Tropical Birdsong: 52 Stories of Tropical Songbirds. By Dominic Couzens. Illustrations by Madeleine Floyd. 2025. Rizzoli. 224 pages and 52 colour illustrations, 37.95 CAD, Hardcover. Also available as an E-book.

ZOOLOGY

Bats and Ladders: Stories from the Real World of Bat Conservation. By George Bemment. 2025. Pelagic Publishing. 168 pages and colour illustrations, 37.00 CAD, Hardcover, 29.00 CAD, Paper.

Bringing Up Beaver: Two Orphaned Beaver Kits, Their Humans, and Our Journey Back to the Wild. By John Aberth. 2025. Pegasus Books. 208 pages and 16 colour photos, 37.95 CAD, Hardcover, 25.99 CAD, E-book.

For the Love of Bears. By Chris Tarrant. 2025. Great Northern Books. 176 pages and colour photos, 25.00 GBP, Hardcover.

Sharks: Ocean Travellers. By Michael Bright. 2025. Cornell University Press. 288 pages and 113 illustrations, 40.95 CAD, Hardcover.

OTHER

California National Parks: Yosemite, Kings Canyon, Sequoia, and Pinnacles. By Jonathan G. Way. 2025. Self-published. 638 pages and colour photos, Open Access URL (but please consider a 10.00 USD donation) at <https://www.easterncoyoteresearch.com/downloads/CaliforniaNationalParks.pdf>.

The California Naturalist Handbook. Second Edition. By Greg de Nevers, Deborah Edelman, and Adina Merenlender. 2025. University of California Press. 320 pages, 72 colour figures, and eight maps, 43.95 CAD, Paper. Also available as an E-book.

Citizen Science in Biology: the History and Development of Public Participation in Science. By Wilson Wall and David Morgan. 2025. Pelagic Publishing. 248 pages, 86.00 CAD, Hardcover.

A Field Guide to Ice: the Only Guide to Land Ice and Sea Ice in All Its Forms. By James H.C. Fenton. 2025. Self-published. 36 pages and colour photos, 5.00 GBP, Paper.

Fuji: a Mountain in the Making. By Andrew W. Bernstein. 2025. Princeton University Press. 352 pages, 15 colour illustrations, 54 black and white illustrations, and nine maps, 48.00 CAD, Hardcover. Also available as an E-book.

The Hidden Seasons: a Calendar of Nature's Clues. By Tristan Gooley. 2025. The Experiment. 384 pages, 33.95 CAD, Hardcover, 23.99 CAD, E-book.

The Hundred Years' Trial: Law, Evolution, and the Long Shadow of *Scopes v. Tennessee*. By Alexander Gouzoules and Harold Gouzoules. 2025. Johns Hopkins University Press. 352 pages and 14 black and white illustrations, 42.95 CAD, Hardcover, 36.99 CAD, E-book.

Maple Syrup: a Short History of Canada's Sweetest Obsession. By Peter Kuitenbrouwer. 2025. Doubleday Canada. 328 pages, 36.95 CAD, Hardcover, 16.99 CAD, E-book.

Meltdown: the Making and Breaking of a Field Scientist. By Sarah Boon. 2025. University of Alberta Press. 312 pages, 27.99 CAD, Paper. Also available as an E-book.

Mushrooms of Alaska: a Timber Press Field Guide. By Steve Trudell, Noah Siegel, and Kate Mo-

hatt. 2025. Timber Press. 572 pages and colour photos, 39.99 CAD, Paper, 26.99 CAD, E-book.

Nature at Night: Discover the Hidden World that Comes Alive After Dark. By Charles Hood. 2025. Timber Press. 320 pages and 240+ colour photos, 39.00 CAD, Hardcover, 26.99 CAD, E-book.

†**The Pale Blue Data Point: an Earth-Based Perspective on the Search for Alien Life.** By Jon Willis. 2025. University of Chicago Press. 256 pages, 10 colour plates, and 10 halftones, 33.95 CAD, Hardcover. Also available as an E-book.

Pan-Species Listing: How to Become a Super-Naturalist. By Graeme Lyons. 2025. Pelagic Publishing. 288 pages, 48.00 CAD, Paper.

The RAVEN Essays: Indigenous Environmental Justice, Education and Self-Determination. Edited by John Borrows, Dawn Hoogeveen, Max Ritts, and Sue Smitten. 2025. University of Toronto Press. 288 pages, 95.00 CAD, Hardcover, 34.95 CAD, Paper. Also available as an E-book.

Spirit of the Rainforest: How Indigenous Wisdom and Scientific Curiosity Reconnects Us to the Natural World. By Rosa Vasquez Espinoza. 2025. Octo-

pus Books. 336 pages, 34.99 CAD, Hardcover, 21.99 CAD, E-book.

Spring is the Only Season: How It Works, What It Does and Why It Matters. By Simon Barnes. 2025. Bloomsbury Publishing. 448 pages, 25.31 CAD, E-book.

Strata: Stories from Deep Time. By Laura Poppick. 2025. W.W. Norton. 288 pages, 39.99 CAD, Hardcover. Also available as an E-book.

Swimming Holes and Beaches of Southwestern British Columbia including the Gulf Islands and Vancouver Island. By Alex McKeen and George Harwood Smith. 2025. Greystone Books. 272 pages, 29.95 CAD, Paper.

True Nature: the Pilgrimage of Peter Matthiessen. By Lance Richardson. 2025. Pantheon. 736 pages, 54.00 CAD, Hardcover, 18.99 CAD, E-book.

We Dig Ammonites: Fact, Folklore, and History. By Jodi Summers. 2025. Columbia University Press. 416 Pages, 78.00 CAD, Hardcover. Also available as an E-book.

Wildlife Photographer of the Year: Portfolio 35. Edited by Keith Wilson. 2025. Natural History Museum, London. 160 pages, 64.99 CAD, Hardcover.

The Canadian Field-Naturalist

News and Comment

Compiled by Amanda E. Martin

Upcoming Meetings and Workshops

Society for Integrative and Comparative Biology Annual Meeting

The annual meeting of the Society for Integrative and Comparative Biology to be held 3–7 January 2026 at the Oregon Convention Center, Portland, Oregon.

Registration is currently open. More information is available at <https://www.xcdsystem.com/sicb/program/ddC9FQp/index.cfm?pgid=2708>.

The Stewardship Network Conference

The 19th Stewardship Network Conference to be held 22–23 January 2026 at the Kellogg Hotel & Conference Center, East Lansing, Michigan. Registration

is currently open. More information is available at <https://conference.stewardshipnetwork.org/>.

Midwest Fish & Wildlife Conference

The 86th Midwest Fish & Wildlife Conference to be held 25–28 January 2026 at the Grand Wayne Convention Center, Fort Wayne, Indiana. Registration

is currently open. More information is available at <https://www.midwestfw.org/>.

Society for Range Management Annual Meeting

The annual meeting of the Society for Range Management to be held 7–11 February 2026 at the Portola Hotel & Spa at Monterey Bay and Monterey Marriott, Monterey, California. The theme of the conference is:

“‘Herd ‘round the World’: Celebrating Global Rangelands and Pastoralism’. Registration is currently open. More information is available at <https://rangelands.org/annual-meeting-2026/>.

Wetland Science Conference

The Wisconsin Wetland Association’s Wetland Science Conference to be held 24–26 February 2026 at the Ho-Chunk Hotel & Convention Center, Baraboo,

Wisconsin. More information is available at <https://conference.wisconsinwetlands.org/>.

National Native Seed Conference

The National Native Seed Conference to be held as an online meeting, 25–26 February 2026. The theme of the conference is: ‘Seeds for Change: Building

Resilient Native Seed Infrastructure’. Registration is currently open. More information is available at <https://appliedeco.org/npsc26/>.

Alberta Chapter of The Wildlife Society Conference

The annual conference of the Alberta Chapter of The Wildlife Society to be held 26 February–1 March 2026 at the Banff Park Lodge Resort Hotel & Conference Centre, Banff, Alberta. The theme of the

conference is: ‘Working Together: Science and Management’. Registration is currently open. More information is available at <https://www.actws.ca/conference/>.

Entomological Society of America, Southeastern Branch Meeting

The annual meeting of the Southeastern Branch of the Entomological Society of America to be held 8–11 March 2026 at the Omni Hilton Head Oceanfront

Resort, Hilton Head, South Carolina. The theme of the meeting is: ‘A Century of Innovations Addressing Global Challenges in a Hyperconnected World’.

Registration is currently open. More information is available at <https://www.entsoc.org/membership/branches/southeastern/meeting>.

Entomological Society of America, Eastern Branch Meeting

The annual meeting of the Eastern Branch of the Entomological Society of America to be held 14–17 March 2026 at the Saratoga Hilton, Saratoga Springs, New York. The theme of the meeting is: ‘Entomology

Storytime’. Registration is currently open. More information is available at <https://www.entsoc.org/membership/branches/eastern/meeting>.

Eastern Bird Banding Association Annual Meeting

The 103rd annual meeting of the Eastern Bird Banding Association to be held 20–22 March 2026 at the Antiochian Village, Pennsylvania. More information

is available at <https://easternbirdbanding.org/annualmeeting2026>.

Entomological Society of America, Southwestern Branch Meeting

The annual meeting of the Southwestern Branch of the Entomological Society of America to be held 29 March–1 April 2026 at the Embassy Suites by Hilton Amarillo Downtown, Amarillo, Texas. Registration

is currently open. More information is available at <https://www.entsoc.org/membership/branches/southwestern/meeting>.

***The Canadian Field-Naturalist* moves to full-colour printing and continuous online posting**

Advances have been made in digital printing as a replacement for offset printing. Offset printing uses plates to transfer an image, including text, to a rubber surface onto which a sheet of paper is rolled. It is best suited for large print runs. Digital printing is similar to laser printing in that it uses toner or liquid ink to transfer the image to paper, but it is less wasteful than offset printing and is better and more cost effective for smaller print runs. Because of COVID-19 supply-chain issues, *The Canadian Field-Naturalist* (CFN) tried digital printing, with limited success; see 135(4) and 136(1). Recently Gilmore Printer Services, Ottawa, which prints CFN, upgraded their digital printer. Recent results using digital printing were equivalent to offset printing; see 138(2) and 138(3). As such, CFN has moved to digital printing. One additional advantage for digital over offset printing is that CFN can now be printed fully in colour. Previously, while the online version was in colour, there was an additional cost to print in colour for those authors wishing and able to pay for colour. This additional charge has now been eliminated. And, we no longer have to produce two versions of the journal: one full-colour for posting online and the other for printing, some of which could be in colour.

Another recent change is that manuscripts for articles and notes will be posted online as soon as they are finalized and we have received author order and copyright transfer forms. Previously we waited until all the content of an issue was ready before online posting. The continuous, online-posted, latest issue will be labelled “In Progress” when we are still adding content and it is not yet complete. Content in the “In Progress” issue will be fully citable, with a year, volume, issue, page numbers, and a DOI assigned when they are published. As always, the latest issue can be viewed at <https://www.canadianfieldnaturalist.ca/index.php/cfn/issue/view/111>.

Lastly, while content will continue to be posted online, now immediately as it is finalized, the publication date for each issue of CFN remains the mailing date of the printed copy, which occurs several weeks after a full issue is posted online and the print-galley proofs have been reviewed and any required corrections made. The publication date remains extremely important when new species are formally described and named as outlined in international codes for nomenclature of flora and fauna.

CFN PRODUCTION TEAM

In Memoriam: Gerald “Gerry” L. Mackie (20 July 1942–4 November 2025)

On the morning of the second day of the biennial hybrid Canadian Freshwater Mollusc Research Meeting (CFMRM), attendees learned of the death of Dr. Gerry Mackie the previous day. Gerry was an inaugural Co-chair of the Mollusc Species Specialist Subcommittee (SSC) of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) along with Dr. Theresa (Aniskowicz) Fowler (Sheppard and Lepitzki 2022) the year after the combined Lepidoptera/Mollusc SSC was formed in 1994. He continued as Co-chair from 1995 through 2006 and saw the creation of the separate Mollusc SSC in 2000. I had the pleasure of being a member of the SSC under the leadership of Gerry at the end of his first stint and then as a fellow Co-chair with him during his second, four-year term as Co-chair from 2011 to 2014. Many of the attendees at the meeting remembered and honoured Gerry’s tutelage on Ontario’s freshwater mussels. Others referred to his body of work he

amassed during his tenure as professor at the University of Guelph (1974–2003), or after he retired from academia and continued to work as an environmental consultant. In addition to mussels, he was an expert on the small fingernail clams and took great pleasure in digging through the wet mud (Figure 1). He was not averse to looking in leaf litter for small terrestrial gastropods (Figure 2)—a true malacologist. At least one of his numerous publications is found in *The Canadian Field Naturalist* (Metcalf-Smith *et al.* 1998).

A short write-up on Gerry’s malacological legacy is planned to be included in the proceedings of the CFMRM, which will be published as a Canadian Technical Report of Fisheries and Aquatic Sciences, as well as longer, full tributes. In the meantime, his obituary from his family can be found at <https://www.guelphtoday.com/obituaries/mackie-dr-gerald-11453641>.



FIGURE 1. Dr. Gerry Mackie (right foreground) searching through the bottom mud downstream of a small beaver dam, south of Hay River, Northwest Territories, 10 September 2013. Dr. Joe Carney is in the background looking for freshwater mussels. Photo: D.A.W. Lepitzki.



FIGURE 2. Dr. Gerry Macke (right) searching through leaf litter at Twin Falls Gorge Park, Northwest Territories, 10 September 2013. Robert Forsyth, layout person for *The Canadian Field-Naturalist*, is on the left. Photo: D.A.W. Lepitzki.

Literature Cited

- Metcalf-Smith, J.L., S.K. Staton, G.L. Mackie, and N.M. Lane.** 1998. Selection of candidate species of freshwater mussels (Bivalvia: Unionidae) to be considered for national status designation by COSEWIC. *Canadian Field-Naturalist* 112: 425–440. <https://doi.org/10.5962/p.358445>
- Sheppard, S., and D.A.W. Lepitzki.** 2022. In memoriam: Theresa (Aniskowicz) Fowler (27 March 1948–13 May 2022). *Canadian Field-Naturalist* 136: 81–82. <https://doi.org/10.22621/cfn.v136i1.3029>

D.A.W. LEPITZKI
CFN Editor-in-Chief
COSEWIC member, 2009 to present

The Canadian Field-Naturalist

Editors' Report for Volume 137 (2023)

Issues 1 and 2 of volume 137 for the year 2023 were combined as a Special Issue honouring Donald F. McAlpine's contributions to the natural history of the Canadian Maritimes. As such, there are only three mailing dates for volume 137 of *The Canadian Field-Naturalist* (CFN): 7 February, 27 June, and 18 December 2024; online posting dates are approximately four weeks before the mailing dates: 9 January, 31 May, and 23 October 2024, respectively. The time differential is because the print proofs need to be produced and then couriered from and back to the printer after they are checked by the *Editor-in-Chief* (EiC) before printing and then shipped to the mailer. The Canada Post strike from mid-November to mid-December 2024 resulted in a longer than typical difference between the online and mailing dates for 137(4). In comparison, the mailing and online posting dates of the four issues in volume 136 ranged from 8 September 2022 to 17 July 2023 and 5 August 2022 to 22 June 2023, respectively.

Summaries of the distribution of paid subscribers to CFN for volume 137 are shown in Table 1, and are compared to volume 136. This list does not include free copies distributed to Honorary Ottawa Field-Naturalists' Club (OFNC) members or online access, which is included in OFNC membership dues and those provided to *Associate Editors* (AE). Institutional subscribers potentially represent many thousands of users. The overall decline in subscribers continued with a net loss of seven for volume 137 compared to volume 136. The decline in institutional subscribers continued (–8) and individual subscribers fell (–4), while there was a small increase in OFNC members who paid for the print copy of CFN (+5).

There was no change in the number of articles published in volume 137 ($n = 21$) compared to the number published in volume 136 while the number of notes decreased by eight, resulting in eight fewer manuscripts published in volume 137 ($n = 30$) in comparison to volume 136 (Table 2). Mammals and plants were the most popular subjects followed by 'others', birds, and amphibians and reptiles (Table 2). Three of the five manuscripts in the 'other' category were in the double Special Issue and on organisms that fit poorly in our typical subject categories: fungi, lichens, and slime moulds. A couple more book reviews ($n = 23$) and nearly 140 additional new titles ($n = 501$) were published in volume 137 in comparison to volume 136 (Table 3) under the more-thanable editorial eye of *Book Review Editor* Jessica Sims. The total number of pages published in volume 137 decreased by five in comparison to volume 136 (Table 4) with more pages of articles (+58) and Book Reviews/New Titles (+7) but fewer pages of notes (–37), tributes (–18), and News and Comment (–9) published. Once again, there were no thematic collections (editor-selected compilations of previously published contributions in both CFN and the regional OFNC publication, *Trail & Landscape*, on a central theme with internet links to each article) nor additional articles on Greatest Canadian Field Naturalists, the latter of which were included in News and Comment in volume 131 (for 2017). *Guest Editors* Graham Forbes and Stephen Clayden provided a 12 page Foreword and Notes on the natural history of Don McAlpine for the special double issue.

The number of manuscripts submitted or enquiries about potential submissions was the same in

TABLE 1. The volume 137 (136) circulation of *The Canadian Field-Naturalist*. Compiled by Eleanor Zurbrigg from the subscription list for 137(4). This list does not include copies distributed to Honorary Members or online access which is included in OFNC membership dues.

Subscriber type	Canada	USA	Other	Total
OFNC Members	40 (35)	0 (0)	0 (0)	40 (35)
Subscriptions:				
Individual	25 (26)	9 (12)	0 (0)	34 (38)
Institutional	55 (57)	69 (74)	11 (12)	135 (143)
Total	120 (118)	78 (86)	11 (12)	209 (216)

TABLE 2. Number of research articles and notes published in *The Canadian Field-Naturalist*, volume 137 (volume 136), by major field of study, not including the two Special Issue introductions.

Subject	Articles	Notes	Total
Mammals	3 (7)	3 (5)	6 (12)
Birds	3 (5)	1 (4)	4 (9)
Amphibians and Reptiles	4 (5)	0 (2)	4 (7)
Fishes	1 (0)	0 (2)	1 (2)
Plants	3 (2)	3 (3)	6 (5)
Insects	0 (0)	2 (1)	2 (1)
Non-insect invertebrates	2 (1)	0 (0)	0 (1)
Other	5 (1)	0 (0)	5 (1)
Total	21 (21)	9 (17)	30 (38)

TABLE 3. Number of reviews and new titles published in the Book Review section of *The Canadian Field-Naturalist*, volume 137 (volume 136), by topic.

	Reviews	New Titles
Zoology*	10 (11)	171 (106)
Botany	3 (2)	56 (36)
Miscellaneous†	10 (8)	274 (216)
Total	23 (21)	501 (358)

*Includes Entomology, Herpetology, Ornithology, and Zoology.
†Includes Biology, Conservation and Climate Change, Ecology, and Other.

2023 as it was in 2022 ($n = 47$; Table 5). Over the past seven years, the percent of submissions not declined ranged from 80 to 91%. Four of the seven submitted manuscripts that were declined in 2023 did not have any formal peer review beyond that of the EiC and assigned AE; two of these four were declined because the authors did not have government or university research or collecting permits. See the Legal Issues, Ethical Conduct section of the CFN online Instructions to Authors at <https://www.canadianfieldnaturalist.ca/public/journals/1/CFN-author-instructions20Sept2019.pdf>. Three others were declined after formal peer-review.

Dwayne Lepitzki, EiC, initially reviewed the appropriateness of a submission and assigned an AE after William Halliday, *Online Journal Manager and Webmaster*, determined the completeness of the submission. Dwayne then reviewed the recommendation from the AE and reviewers and decided if and when the submitted and subsequently revised manuscript was accepted for publication. A *Copy Editor* (Sandra Garland or John Wilmshurst) was then assigned and once their work was reviewed by Dwayne and the authors, the manuscript was sent for layout and typesetting. *Assistant Editor* Amanda Martin edited content, proofread galleys (as did Dwayne), and sent and received author order and transfer of copyright forms; she also prepared the News and Comment. Robert Forsyth typeset galleys, provided corrections for page proofs, and created pdfs for online posting

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist*, volume 137 (136), by issue. Note that because issues 1 and 2 of volume 137 were combined, the number of pages is shown in the issue 2 column.

	Issue				Total
	1	2	3	4	
Special Issue introduction		12 (–)			12 (–)
Editorials/Editors’ Report	– (0)	0 (3)	0 (0)	4 (0)	4 (3)
Articles	– (22)	132 (56)	56 (54)	67 (65)	255 (197)
Notes	– (26)	5 (21)	31 (26)	7 (7)	43 (80)
Thematic Collections	– (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tributes	– (21)	0 (0)	12 (9)	0 (0)	12 (30)
Book Reviews and New Titles	– (9)	23 (12)	17 (13)	17 (16)	57 (50)
News and Comment*	– (4)	3 (7)	2 (3)	2 (2)	7 (16)
Reports†	– (16)	10 (0)	0 (0)	0 (0)	10 (16)
Errata	– (0)	0 (0)	0 (3)	0 (0)	0 (3)
Blank page‡	– (2)	0 (1)	0 (1)	1 (0)	1 (4)
Index	– (–)	– (–)	– (–)	6 (6)	6 (6)
Total	– (100)	188 (100)	118 (109)	104 (96)	410 (405)

*Includes the James Fletcher Award for best paper published in the volume.
†Includes Annual Business Meeting Minutes, Annual Committee Reports, and OFNC Awards; Financial Statements are only available online beginning with 132.
‡Necessary to begin each issue with an odd numbered page.

TABLE 5. Annual number of submissions and inquiries about submissions to *The Canadian Field-Naturalist* from 2017 to 2023 and percent submissions accepted and/or undergoing revision or further review. Some of the enquiries result in later formal submissions. Note the year of submission does not equate with the year of publication given the time required for peer-review, revisions, and publication.

Year	2017	2018	2019	2020	2021	2022	2023
Number of submissions and enquiries	57*	67†	49	63	46	47‡	47
% submissions not declined and undergoing revision and further review§	90%	83%	85%	80%	89%	91%	85%

*Includes 10 for the Special Issues 132(1) and 132(2) honouring Dr. Francis Cook.

†Includes 13 for the Special Issues 132(1) and 132(2) honouring Dr. Francis Cook.

‡Includes 11 for the Special Double Issue for 2023, volume 137(1–2).

§Not all of these submissions may be revised by the authors and resubmitted or eventually accepted and published.

and printing. Jessica Sims requested books for review, selected reviewers, edited submitted reviews, and prepared the list of new titles. Ken Young sent page charge invoices to authors and tracked the budget while Eleanor Zurbrigg managed subscriptions and mailed printed copies. William Halliday provided digital content to subscribers; posted tables of contents, abstracts, and pdfs on the CFN website; and prepared the Index. Our AEs managed manuscripts, provided reviews and recommendations, and guided authors through the revisions process. Dave Seburn, our *Map Editor*, reviewed and provided suggestions for all the maps. The Publication Committee, chaired by Jeff Saarela and consisting of Annie Bélair, Carolyn Callaghan, Paul Catling, William Halliday, Dwayne Lepitzki, Amanda Martin, Karen McLachlan Hamilton, Ken Young, and Eleanor Zurbrigg effectively guided the operation of the journal. We are indebted to our very dedicated team.

The following AEs voluntarily managed, assessed, and reviewed the 30 manuscripts published in volume 137 (Table 2) or the seven others submitted in 2023 that were declined: R. Brooks, University of Guelph, emeritus, Weymouth NS (1 manuscript published—Ron died in December 2023); P.M. Catling, Agriculture and Agri-Food Canada, retired, Ottawa ON (3—stepped down as AE in October 2023); S. Clayden, New Brunswick Museum (1 as *Guest Editor*); J. Foote, Algoma University, Sault St. Marie ON (1 + 1 declined); G. Forbes, University of New Brunswick, Fredericton NB (9, including as *Guest Editor*); W. Halliday, Wildlife Conservation Society Canada, Whitehorse YT and University of Victoria, Victoria BC (3 + 1 declined); K. Ilves, Canadian Museum of Nature, Ottawa ON (1 + 2 declined); T. Jung, Yukon Government, Whitehorse YT (1 + 1 declined); D. Lepitzki, Banff AB (1 declined); B. Patterson, Ontario Ministry of Natural Resources and Forestry, Peterborough ON (1); J.M. Saarela, Canadian Museum of Nature, Ottawa ON (5); J. Skevington, Agriculture and Agri-food Canada, Ottawa ON (1); and D. Tozer, Birds Canada, Port

Rowan ON (3 + 1 declined). Thomas Onuferko, Canadian Museum of Nature, Ottawa ON, joined as an AE in 2023 with expertise in insects.

As with many other journals, AEs are at times having difficulty finding suitable reviewers; without dedicated AEs and reviewers there would be no journal. As such, a heart-felt thanks and gratitude is extended to the following who voluntarily reviewed manuscripts published in volume 137 (number of manuscripts reviewed >1 in parentheses) or submitted in 2023: Michael Akresh, Antioch University New England; Noel Alfonso, Canadian Museum of Nature (retired); Bernard Angers, University of Montreal; John Atwood, Missouri Botanical Garden; Fred Beaulieu, Agriculture and Agri-Food Canada; Alain Belliveau, Acadia University; Kristin Bianchini, Environment and Climate Change Canada; Rudy Boonstra, University of Toronto; Sam Brinker, Ontario Natural Heritage Information Centre; Daniel Brunton, Ottawa ON; Suzanne Carriere, Government of Northwest Territories (retired); Kira Cassidy, US National Park Service; Pete Cott, University of Alberta; Jennifer Doubt, Canadian Museum of Nature; Andrew Edelman, University of Georgia; Keith Egger, University of Northern British Columbia; Laura Feyrer, Fisheries and Oceans Canada; Scott Gillingwater, Upper Thames River Conservation Authority; Steve Grasby, Geological Survey of Canada; David Green, McGill University; Sybille Haessler, University of Northern British Columbia; Jim Harding, Michigan State University Museum; Tom Herman, Acadia University; Sascha Hooker, University of St. Andrews; Donna Hurlburt, Government of Nova Scotia; Leonard Hutchinson, Lakehead University; Morgan Jackson, McGill University; Colin Jones, Ontario Ministry of Natural Resources and Forestry; Tom Jung, Government of Yukon; John Koprowski, University of Wyoming; Jolene Laverty, Government of Nova Scotia; James Lendemer, New York Botanical Garden; Dwayne Lepitzki, Banff AB; Etienne Leveille-Bourret, Université de Montréal; Chantel Markle, University of

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of Nature; Steven Stephenson, University of Arkansas; Dan Strickland, Chief Algonquin Provincial Park Naturalist (retired); Richard P. Thiel, Tomah WI; R. Greg Thorn, University of Western Ontario; James C. Trager, Missouri Botanical Garden; Jana Vamosi, University of Calgary; Will Van Hemessen, University of Western Ontario; Jonathan G. Way, Eastern Coyote/Coywolf Research; Tyler Wheeldon, Ontario Ministry of Natural Resources and Forestry.

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DWAYNE A.W. LEPITZKI, *Editor-in-Chief*
AMANDA E. MARTIN, *Assistant Editor*

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