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The occurrence of introduced rosy red minnows (*Pimephales promelas*) in Alberta, Canada

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Abstract

Rosy red minnows are a golden morph of Fathead Minnow (*Pimephales promelas*) commonly sold in pet shops and used, in some jurisdictions, as baitfish. They have formed several naturalized populations in British Columbia, where they are considered a priority conservation concern. The Government of Alberta had noted two occurrences of rosy red minnows in 2016 and 2017, but their identification could not be independently confirmed without photographic or physical vouchers. Based on our own collections, Royal Alberta Museum specimens, community science initiatives, and enquiries to other field researchers, we report that rosy red minnows have been present in Alberta earlier than previously thought, are likely breeding in Alberta, and have a widespread distribution from Fort McMurray to Lethbridge. Given that Alberta has native populations of wild-type Fathead Minnow, the impacts of rosy red minnows on native populations requires immediate attention.

Key words: Invasive species; aquatic invasions; freshwater; baitfish

Introduction

The spread of invasive species is likely a major contributor to biodiversity loss worldwide (WWF 2020). Freshwater habitats that would otherwise be strongly resistant to invasions have experienced substantial degradation from human activities, potentially exacerbating the threat of invasive fishes (Dudgeon *et al.* 2006). Invasive species cost the government of Alberta, Canada, an estimated $2.1 billion annually (McClay *et al.* 2004; AISC 2022), yet the ecological costs of aquatic invasions are poorly understood, and may be complex. For example, the release of aquarium fish into Banff Hot Springs has been implicated in the extinction of Banff Longnose Dace (*Rhinichthys cataractae smithi*; Renaud and McAllister 1988), while introduced Whirling Disease (*Myxobolus cerebralis*) has impacted local salmonid populations (AEP 2018; James *et al.* 2021). The current spread of Prussian Carp (*Carassius gibelio*) throughout southern Alberta has had potentially negative impacts on native fish biodiversity (Docherty 2016; Docherty *et al.* 2017), but may also provide a novel, important food source for wetland birds. Invasive success is complex but likely requires, among other factors, the repeated introduction of a species into an area (Drury *et al.* 2007). However, because successful introductions begin with small population sizes, species in the early stages of invasion are difficult to detect; by the time they are detected, the species may have spread so far and increased in abundance so much that prevention is no longer feasible (e.g., Prussian Carp in Alberta; Docherty *et al.* 2017). Given the many unknowns about the threat of aquatic invaders in Alberta, the early detection of potentially invasive aquatic species is vital to ensure the future flourishing of local fishes.

One of Canada's newest invasive species is rosy red minnow, reported to be a colour variant of Fathead Minnow (*Pimephales promelas*; Government of Alberta 2023). First discovered in an aquaculture facility in Arkansas, USA in the early 1980s, the rosy red minnow (known commonly as rosy reds) combined the hardiness of Fathead Minnow with the beauty of Goldfish (*Carassius auratus*; Sutton 2018), making it an attractive option for live bait. Captive breeding of rosy red proved to be highly successful with aquarium enthusiasts and recreational anglers alike; rosy reds are now sold in pet stores and bait shops worldwide. In Alberta, rosy reds are sold as pet or feeder fish. Although the use of live baitfish is banned in Alberta, all members of Leuciscidae, including Fathead Minnow, are permitted for use as dead bait in

some locations (Government of Alberta 2024). The rosy red's ability to withstand poor water quality conditions, as well as its flexible feeding strategies, make it a prime candidate for an aquatic invasion (Godard *et al.* 2013), and indeed both the so-called "normal colour" or wild-type Fathead Minnow and its rosy red counterparts have formed self-sustaining populations in Belgium (Verreycken *et al.* 2007), Britain (Godard *et al.* 2013), Germany (Dümpelmann and Freyhof 2015), and, in Canada, the provinces of Ontario (Funnell *et al.* 2009) and British Columbia (CCIS 2020).

Where they have invaded, rosy reds have been reported to act as vectors for pathogens and parasites (Michel *et al.* 1986; Iwanowicz and Goodwin 2002; McCann 2012), are suspected to compete with native fishes (ISCBC 2023), and may facilitate the invasion of other aquatic species (Docherty *et al.* 2017). Unlike British Columbia, Alberta has native Fathead Minnow populations that could be negatively impacted by rosy reds, especially if there is interbreeding. Mitigating the spread of rosy reds in the wild is therefore crucial for protecting Alberta's aquatic ecosystems. Identification of rosy reds is complicated by the possibility that related Bullhead Minnow (*Pimephales vigilax*), which is not native to Alberta, may also be sold as rosy red variants (Hubbs *et al.* 2004; Nico and Sturtevant 2024).

The Government of Alberta first documented the presence of rosy reds in a stormwater pond in Calgary in 2016 and Bolloque Creek, north of Edmonton, in 2017 (AEP 2021). These appeared to be isolated incidents, but there was no apparent follow-up in those locations and no samples were collected and vouchered for verification. Based on our own vouchered materials and photographic evidence from other sources, we report that (1) rosy reds appeared in the wild as early as 2011 in Alberta; (2) they have been observed in reproductive condition with nest-guarding behaviours; (3) Alberta's rosy reds are morphologically similar to Fathead Minnows as opposed to the related, non-native Bullhead Minnow; and (4) rosy red minnow distribution is widespread, from north of Edmonton and south to Lethbridge, with the 2022–2023 period showing a marked increase in sightings. Whether rosy reds are being consistently released into waterbodies, or if they have now become established, requires further investigation, as does the consequences of potential interbreeding with native wild-type Fathead Minnow.

Methods

On 28 May 2022, several rosy reds were captured by dip netting in Whitemud Creek, Edmonton (see Table 1 for coordinates). In July 2022, a single rosy red was observed off a pedestrian bridge spanning Fish Creek in Fish Creek Provincial Park, Calgary by M.R.J.M.'s six-year-old son. A similar, if not the same, fish was captured and photographed 30 m upstream on 22 August 2022, but was released. It was observed in the same location again several weeks later and was finally captured and euthanized with clove oil on 24 September 2022. Despite studies suggesting high predation of rosy reds in the wild (Dümpelmann and Freyhof 2015), this individual appeared healthy. It was captured schooling with juvenile White Sucker (*Catostomus commersonii*). Rosy reds from both locations (Table 1, Figure 1) were preserved in 70% ethanol (no separate tissue samples were vouchered) and sent to the Royal Alberta Museum (RAM), where they joined eight additional rosy reds that had been sent to the RAM in 2018 as part of a case involving the illegal release of baitfish (location unknown).

Nine of the 10 vouchered specimens (vouchers L18.7.1–L18.7.8, L22.2.1, L22.3.1; Table 1) were phenotyped according to Scott and Crossman (1973), Smith and Lamb (1976), Page and Burr (2011), and Hendrickson and Cohen (2022) to determine species identification (voucher L.18.7.9 was in poor shape and was excluded from analysis). They were scored for anal fin ray counts, dorsal fin ray counts, lateral line scale counts, herring bone line presence/absence, lateral line completeness, and peritoneum colour. All four species of *Pimephales* typically have seven anal fin rays. Fathead Minnow is distinguished by 8–9 dorsal fin rays; 39–54 lateral line scales; herringbone lines present along upper side; usually incomplete lateral line; and a mostly black peritoneum. Bullhead Minnow typically has eight dorsal fin rays, 37–45 lateral line scales, no herringbone lines, complete lateral line, and a silvery peritoneum with black specks.

Additional records of rosy reds were found by emailing government biologists, Trout Unlimited Canada staff, environmental consultants, and by searching iNaturalist using the Fishes of Alberta project page; members of the public also reported directly to the School of Fish (https://www.schooloffishid.com) with their discoveries. All 68 781 records of Fathead Minnow were downloaded from the Fish and Wildlife Internet Mapping Tool (FWIMT) and all comments were searched for mentions of "rosy", "rosey", "golden", "gold", "pink", or "invasive" Fathead Minnow. Two additional records were found this way, along with three possible records with ambiguous comments. The scientists who made the ambiguous comments were contacted over email; two responded that their comments did not refer to rosy reds and the third was unreachable. This last is included as a footnote to Table 1 but is not included in our results.

TABLE 1. Known occurrence of rosy red minnows (*Pimephales promelas*) in Alberta, Canada. All vouchered specimens are at the Royal Alberta Museum in Edmonton, Alberta, preserved in 70% ethanol. Photographs not found on iNaturalist are either published in this paper or held by the authors. FWMIT = Fish and Wildlife Internet Mapping Tool.

No.	Date collected	Location*	Latitude, longitude	Collected by	Documentation
1	30 Sept. 2011	Western Headworks Canal, Calgary	51.045°N, 114.010°W	L. Peterson, Trout Unlimited Canada	Photographed
2	Aug. 2012	Clearwater River, Fort McMurray	56.716°N, 111.339°W	T. Hancock, Fisheries and Oceans Canada (DFO)	Written record
3	6 June 2013	Irvine Creek, north of Beaumont	53.378°N, 113.419°W	S.D., School of Fish	Photographed, FWMIT
4	12 Sept. 2015	Dog Creek, Spruce Grove	53.568°N, 113.915°W	D. Wenckowski (EnviroMak Inc. 2015)	Photographed, FWMIT
5	16 Aug. 2016	Silverado Stormwater Drainage Pond, Calgary	50.883°N, 114.072°W	Alberta Environment and Parks (AEP)	Written record
6	17 Aug. 2016	McLaughlin Pond, Spruce Grove	53.551°N, 113.928°W	B. Tether and K. Thompson (EnviroMak Inc. 2016)	FWMIT
7	04 May 2017	Bolloque Creek	54.500°N, 113.681°W	AEP	Written record
8	29 Sept. 2017	Southwest of Three Hills	51.650°N, 113.066°W	J. Card	Written record
9	2018	Central Alberta	Unknown	AEP—involved in illegal release case	Vouchered (L18.7.1–L18.7.9)
10	12 Sept. 2019	Anders on the Lake, Red Deer	52.241°N, 113.786°W	Advisian (Advisian 2019)	FWMIT
11	13 May 2021	Country Hills, Calgary	51.156°N, 114.056°W	super_eng_chick	Photographed (iNaturalist)
12	28 May 2022	Whitemud Creek, Edmonton	53.448°N, 113.546°W	S.D.	Photographed, vouchered (L22.2.1)
13	24 Sept. 2022	Fish Creek Park, Calgary	50.926°N, 114.110°W	mrjmorris	Photographed (iNaturalist) Vouchered (L22.3.1)
14	2 Oct. 2022	Dale Hodges Park, Calgary	51.086°N, 114.169°W	quinnbirds	Photographed (iNaturalist)
15	29 Apr. 2023	Sunridge Park, Lethbridge	49.653°N, 112.877°W	charlie_myles	Photographed (iNaturalist)
16	5 May 2023	Nose Creek, north of Balzac	51.228°N, 113.999°W	D. Gastle, Triton Environmental Consultants	Photographed
17	12 June 2023	Mill Creek, Edmonton	53.527°N, 113.477°W	yegbio	Photographed (iNaturalist)
18	05 Aug. 2023	Unnamed wetland, Edmonton	53.496°N, 113.398°W	ryrudy	Photographed (iNaturalist)
19	31 Aug. 2023	Mill Creek Ravine South, Edmonton	53.514°N, 113.471°W	mumbum	Photographed (iNaturalist)
20	02 Oct. 2023	Western Headworks Canal, Calgary	51.045°N, 114.010°W	mrjmorris	Photographed (iNaturalist)

*28 August 2020, FWIMT reports, in an unnamed pond NE of Trochu, 51.835°N, 113.185°W, that numerous Fathead Minnow were collected and disposed of as an "invasive species", but not all Fathead Minnow collected at that location received such a comment. It is uncertain if the "invasive" Fathead Minnow refer to rosy reds, but it does not seem likely (Ghostpine Environmental Services Ltd. 2020).

Results

Descriptions of vouchers

Vouchered specimens were orange-red when captured (Figure 1), but colour was lost during preservation, giving fish a pale preserved colour in contrast to the dusky-coloured native Fathead Minnow. Standard length was on average 57.6 mm (range 35–74 mm, n = 10). The first dorsal fin ray was a half-ray and the anal fin had seven rays, as typical of *Pimephales*. Specimens had 8–9 dorsal fin rays, 45–47 lateral line scales, herringbone patterns present along the upper

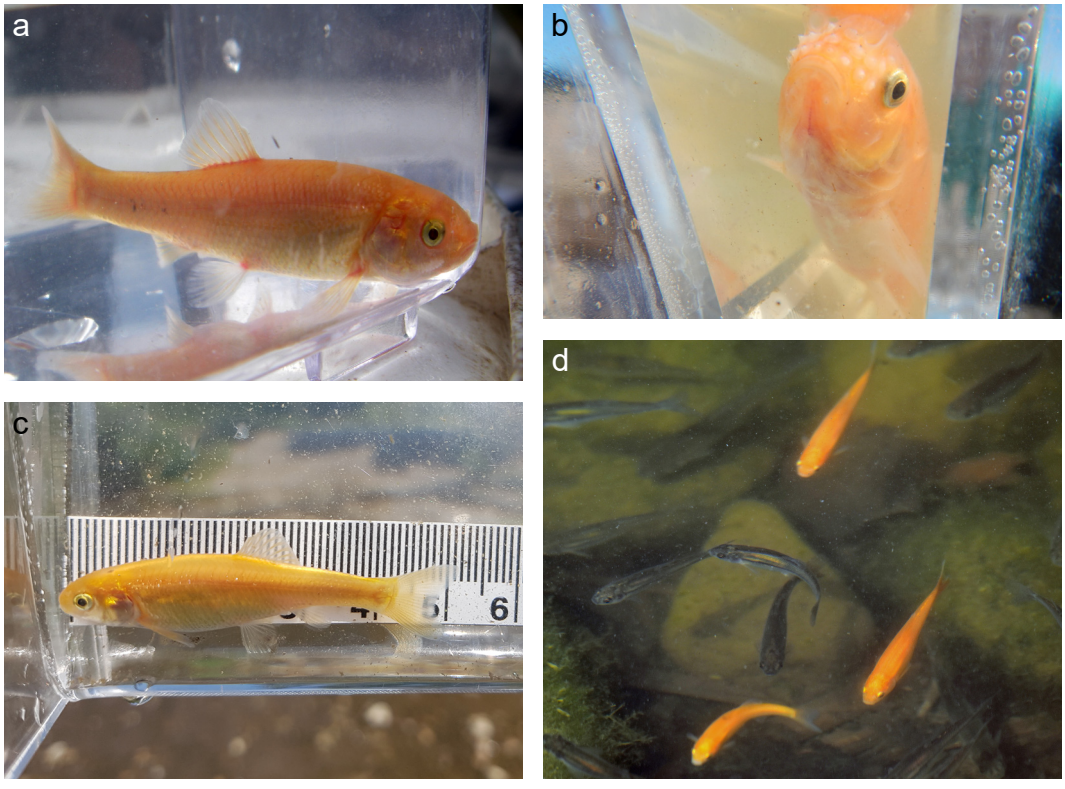

FIGURE 1. Rosy red minnow (*Pimephales promelas*) observed in Alberta. a. First known record of a rosy red in Alberta, from the Western Bow River Headworks Canal, Calgary, 2011 (no. 1, Table 1). b. Male with breeding tubercles, from Irvine Creek, north of Beaumont, 2013 (no. 3, Table 1). c. A single rosy red from Fish Creek Park, Calgary, 2022 (no. 13, Table 1). d. Rosy reds swimming alongside wild-type Fathead Minnows, Sunridge Park, Lethbridge, 2023 (no. 15, Table 1). Photo a: L. Peterson. Photo b: S. Derlukewich. Photo c: M. Morris. Photo d: C. Myles (charlie_myles 2023), Attribution-Non Commercial 4.0 International (CC BY-NC 4.0), photograph cropped.

side, and an incomplete or nearly (but never fully) complete lateral line. The peritoneum was inspected in a single sample and was mostly black.

Other records

Including the three vouchered records described above, we found a total of 20 records of rosy reds in the province—with four new records added as this paper was under review. The Government of Alberta had records of rosy reds from 2016 and 2017, but without documentary evidence (AEP 2021). Trout Unlimited Canada staff responded to our enquiries with what is now the earliest discovery of rosy reds in the province, having photographed a sample from Calgary in 2011 (Figure 1); the Trout Unlimited annual fish rescue turned up another individual at the same location in October of 2023 (mrjmorris 2023). Our own records included a photograph of a male in breeding condition north of Beaumont from 2013 (Figure 1b). Inquiries to biologists turned up several additional records, including our most northern record in Fort McMurray. Searching iNaturalist returned additional reports: Edmonton records from 2023 (mumbum 2023; ryrudy 2023), Calgary records from 2021 (super_eng_chick 2021) and 2022 (quinnbirds 2022), and a Lethbridge record from 2023 (charlie_myles 2023). In short, there are now 20 reports of rosy red minnows from Alberta, nine of which extended from Edmonton to Lethbridge between May of 2022 and October of 2023 (Table 1). These 20 records encompass three major river basins and seven sub-basins (Athabasca River Basin: Upper Central Athabasca, Lower Central Athabasca; North Saskatchewan River Basin: Upper North Saskatchewan, Central North Saskatchewan; South Saskatchewan River Basin: Red Deer, Bow, Upper South Saskatchewan; Figure 2) and the major urban centres of Fort McMurray, Edmonton, Red Deer, Calgary, and Lethbridge.

Discussion

Here we report the first vouchered and photographic evidence of rosy red minnows in Alberta,

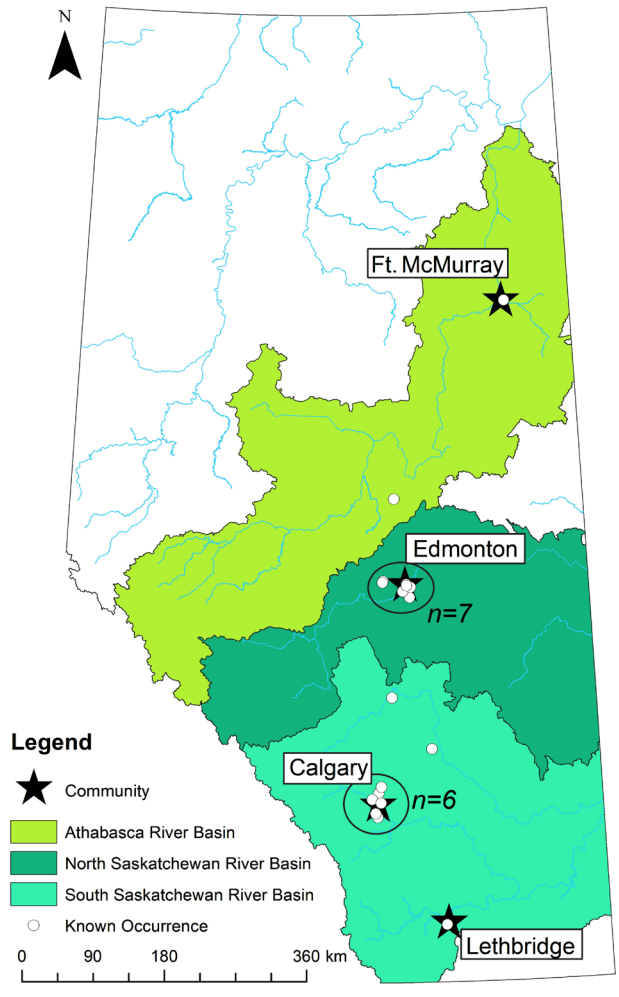

FIGURE 2. Known occurrences (white circles with black outlines) of rosy red minnow (*Pimephales promelas*) in Alberta, Canada, and their drainage basins: Athabasca; North Saskatchewan; and South Saskatchewan. Map generated by S. Derlukewich and J. Reilly, ArcGIS (ESRI, Redlands, California, USA).

Canada, from as early as 2011. Although there is not yet evidence for reproduction in the wild, a male found in 2013 was in breeding condition and exhibited nest-guarding behaviours (Figure 1b). In British Columbia, where self-sustaining populations are known, there are no native Fathead Minnow to interbreed with; such is not the case in Alberta.

Rosy reds purchased in Wisconsin in 1995 keyed out morphologically as the related Bullhead Minnow (Muller 2000). Hubbs *et al.* (2004) suggested that rosy red forms of Bullhead Minnow may be sold in shops along the Great Lakes. If true, the rosy reds in Alberta could constitute not only a new morphotype of fish for the province, but also a new species record. However, our vouchered specimens were most consistent with Fathead Minnow identification, at or exceeding the highest known count of 45 scales in Bullhead Minnow, having incomplete lateral lines, herringbone lines along the side, and mostly black peritoneum (Page and Burr 2011; Hendrickson and Cohen 2022).

The genetic cause of the rosy red mutation does not appear to be characterized in Fathead Minnow, nor is it clear how frequently it may spontaneously appear in the wild. Given that it appeared on at least two farms in Arkansas in the 1980s (Sutton 2018), it is possible this mutation could occur in the wild at a certain rate.

However, it seems unlikely that such forms are spontaneously occurring in Alberta, based on several lines of evidence: (1) Scott and Crossman (1973), Nelson and Paetz (1992), and Joynt and Sullivan (2003) do not mention seeing such forms among the many native Fathead Minnow individuals that have been sampled in Alberta and across Canada; (2) the RAM collection contains 10 916 preserved Alberta-caught Fathead Minnow, but there are no notes of rosy reds in the collection prior to 2018 (anecdotally, some of the oldest, palest preserved specimens in the collection were still more pigmented than recently-preserved rosy reds; sometimes extremely pale, almost pigmentless, specimens are found in museums having been collected from turbid waters or having been exposed to too much ultraviolet light over long time periods while in preservative); (3) the 2018 rosy reds found in the RAM collection were part of an investigation into released baitfish, suggesting at least some of Alberta's rosy reds are not native; (4) mutation rates should not change over time, so observations should be fairly consistent across years—yet most observations have occurred during 2022–2023; and (5) the occurrence of rosy reds near or within major urban centres that have pet stores suggest these are released fish. Although not definitive, such lines of evidence are suggestive of the introduced origin of these fish; genetic comparisons between wild-caught rosy reds and their conspecific wild-type Fathead Minnow could help address this issue.

The ecological implications of rosy red invasions are unclear. In British Columbia, where Fathead Minnow is not native, there is fear about the transfer of disease to native salmonids (CCIS 2020). Fathead Minnow is known to be susceptible to infections by *Yersinia ruckeri*; authors of a study on invasive Fathead Minnow in Europe (likely the normal colour variety, but the record is unclear) speculated that a sudden, unexplained outbreak of Enteric Redmouth Disease in salmonids in 1981 could have been caused by the shipment of infected Fathead Minnow from Arkansas and Missouri in 1979 (Michel *et al.* 1986). More recently, native Fathead Minnow from Manitoba have been found to carry the introduced Asian Fish Tapeworm (*Bothriocephalus acheilognathi*; Choudhury *et al.* 2006), while novel pathogens have been discovered in rosy reds in Arkansas baitfish farms (Iwanowicz and Goodwin 2002).

In Alberta, where salmonids have adapted to local Fathead Minnow populations, the threat of disease transfer is possibly lower, although captive-bred rosy reds could potentially bring new diseases into the province (McCann 2012). Ecologically, rosy reds released into ponds that lack native Fathead Minnow could reduce invertebrate abundance and taxon biodiversity, as has been documented for native Fathead Minnow in prairie ponds (Hanson and Riggs 1995). Introductions into ponds without local leuciscids could also permit the spread of gynogenetic Prussian Carp, which can use Fathead Minnow sperm to initiate embryogenesis (Docherty *et al.* 2017). Perhaps most strikingly, there appears to be nothing known about the possible introgression of rosy reds with wild Fathead Minnow. Reproductive success could be enhanced in introgressed minnows given the high fecundity of rosy reds (Clement and Stone 2003), but could also be reduced through outbreeding depression (for instance, rosy reds are known to have worse body condition than their wild counterparts when raised under similar conditions; Ludwig 1995) or increased predation by avian predators on rosy-coloured young (speculated in Dümpelmann and Freyhof 2015).

If Fathead Minnow are locally adapted to their environments (Klymus *et al.* 2022), and rosy reds are aquaculture products originally sourced from the United States, then rosy red introgression could introduce both the causative colour morph allele into Alberta's Fathead Minnow, as well as break up locally adapted gene complexes (e.g., as happened with wild and farmed Atlantic Salmon [*Salmo salar*]; Morris *et al.* 2010; Harvey *et al.* 2016). Indeed, aquaculture-reared Fathead Minnow show signs of adaptation to constant environments, including increased food consumption and lower thermal plasticity when compared to wild conspecifics (Hirakawa and Salinas 2020). If rosy reds similarly differ from wild Fathead Minnow, interbreeding could introduce non-adaptive genetic materials into wild populations.

Given how little is known about rosy red minnows, the precautionary approach is best—report and eliminate rosy reds when captured. We would urge the banning of rosy reds as baitfish, as the Government of Alberta has already done for Goldfish and species of carp (Government of Alberta 2024). Studies on the genetics of rosy red minnows and the possibility and consequences of interbreeding with local Fathead Minnow populations are sorely needed.

Author Contributions

Writing – Original Draft: M.R.J.M. and S.D.; Writing – Review & Editing: M.R.J.M., S.D., and S.M.; Conceptualization: M.R.J.M.; Investigation: M.R.J.M., S.D., and S.M.; Methodology: M.R.J.M., S.D., and S.M.; Funding Acquisition: S.M.

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