Assessing the Spread and Establishment of Prussian Carp (*Carassius gibelio*) in Northern Alberta

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Abstract:

The Prussian carp (*Cassasius gibelio*) is an exceptionally dangerous invasive freshwater fish species. Native to Asia and eastern Europe, it has come to dominate many freshwater bodies across Eurasia through anthropogenic activities, causing extensive ecological damage by outcompeting native taxa and degrading environmental conditions. Within the last two decades, the Prussian carp has been introduced into Alberta, and has since spread into the rivers and lakes of the province. To date, most research relating to Prussian carp in North America has focused exclusively on southern Alberta. My research project aimed to expand research into northern Alberta, specifically the Edmonton region, with the objective to determine if Prussian Carp have spread into northern Alberta. Twelve lakes and ponds in the Edmonton area were surveyed using an underwater drone to collect footage. Four of these sites were further subjected to eDNA analysis. The results of the drone footage picked up a mixture of native and invasive fish species, with two being positive for goldfish. The eDNA analysis picked up neither goldfish or Prussian carp DNA at any of the test sites, likely due to low eDNA concentrations. Overall, these results highlight the need for ecological management to mitigate the spread of invasive fish species in Alberta.

Key Words: Prussian carp, invasive species, anthropogenic introduction, eDNA analysis, northern Alberta

Introduction:

Freshwater ecosystems and their native fauna have become increasingly imperilled throughout the globe (Docherty, 2016, p. 1). Of all the factors that have put said systems in jeopardy, the introduction of invasive species is arguably one of the leading contributors (Dextrase & Mandrak, 2006, p. 15). An invasive species can be described as a non-native species that has been introduced to a new environment. Furthermore, a species can only be considered as truly invasive when they actively cause harm to these native ecosystems and or human health (Docherty, 2016, p. 1). Of the aquatic invasive species that are currently noted, it is the Prussian carp (*Carassius gibelio* Bloch, 1783) (Vasile, 2019, p. 77) that arguably poses the biggest threat.

The Prussian carp was first described by Bloch in 1783 (Vasile, 2019, p. 77) and is currently classified as a freshwater cyprinid fish belonging to the genus *Carassius* (Rylková et al., 2013, p. 13). It is currently regarded as a close relative of the common goldfish (*Carassius auratus* Linnaeus, 1758) (Rylková et al., 2013, pp. 13–14). That said, it should be noted that some researchers would argue that the two taxa should be regarded as two subspecies within one single species because of the high degree of morphological (Docherty, 2016, p. 77) and molecular (Kalous, Bohlen, Rylková and Petrtyl, 2012, p. 14; Rylková et al., 2013, p. 16) similarities between them. In fact, it is extremely common to confuse Prussian carp for goldfish, and vice versa (Docherty, Ruppert, Rudolfsen, Hamann & Poesch, 2017, p. 292).

There are several biological and physiological factors that make the Prussian carp an extremely potent invasive species in any freshwater ecosystem. Firstly, Prussian carp have proven to have a high degree of dietary plasticity, feeding omnivorously on a variety of plankton and invertebrates, and can adjust this feeding behaviour in accordance with the season and type of freshwater environment (ie river versus lake) they occupy (Balik, Karasahin, Özkök, Çubuk & Uysal, 2004, pp. 88–89; Ozdilek & Jones, 2014, pp. 772–773). Prussian carp have also been observed to tolerate extreme conditions, including near-freezing temperatures (Antonova, 2010, pp. 57–60; Docherty, 2016, p. 16), anoxic environments (Lushchak et al., 2000, pp. 104–105), and alkaline habitats with a pH as high as 8.6 (Docherty, 2016, p.16). Additionally, Prussian carp have a unique reproductive strategy known as gynogenesis wherein females can use the sperm of any male cyprinid to ‘trigger’ embryonic development without incorporating their genetic material (Docherty et al., 2017, pp.6,292). The end result is triploid female offspring that are genetically identical to the mother (Liasko et al., 2011, p.318), which mature quickly and can, in turn, produce more triploid females in multiple spawning seasons every year (Şaşı, 2008, p. 91). Finally, the feeding behaviours of Prussian carp, specifically when they forage for food by sucking up sediment, is incredibly destructive, as it degrades environmental conditions by increasing turbidity and decreasing water clarity (Crivelli, 1995, p. 315), making the habitat unlivable for more sensitive native species (Docherty,2016, pp.17-18). Ultimately, the Prussian carp's high adaptability, hardiness, ability to rapidly reproduce and tendency to degrade environmental conditions to make it unlivable for other species is what makes it extraordinarily invasive and dangerous to native ecosystems.

Members of the genus *Carrasius* have an extended history of translocation and introduction in Europe and China, but Prussian carp specifically have only become established across Eurasia over the last century (Rylková et al., 2013, p. 14). For the most part, it is thought that the Prussian carp is originally native to Asia (Vetemaa, Eschbaum, Albert & Saat, 2005, p. 87) and possibly some areas in eastern Europe (Rylková et al., 2013, p. 18). In the present day however, Prussian carp are now established throughout Eurasia (Docherty, 2016, p. 12; Economidis, Dimitriou, Pagoni, Michaloudi & Natsis., 2000, p. 247; Slavík & Bartoš, 2004, p. 246,252). For the most part, the cause of this spread has been anthropogenic (Salaj & Treer, 2018, p. 356; Vetemaa et al., 2005, p. 287), including purposeful introduction by anglers (Docherty et al., 2017, p. 293), escapement from aquaculture (Musil, Jurajda, Adámek, Horky & Slavík, 2010, p. 43) or, given the high degree of morphological similarity with other species, being introduced as a result of being mistaken for another carp species (Docherty, 2016, p.12). Additionally, Prussian Carp have a strong affinity for human-made water bodies, including lakes, ponds and canals, which further enhanced their spread (Docherty et al., 2017, pp. 293-294).

Apart from anthropogenic factors, experimental research conducted by Lovas-Kiss (2020) suggests that migratory waterfowl may also aid in the dispersal of invasive fish species between waterbodies (Lovas-Kiss et al., 2020, pp. 15397–15399). Through experimentation, they found that when a species such as a duck consumed the eggs of Prussian carp, a small proportion of said eggs passed through the digestive tract were expelled from the digestive tract with the feces and hatched into viable fry (Lovas-Kiss et al., 2020, p. 15398). As such, it is suggested that waterfowl may unwittingly spread Prussian carp by consuming eggs from an infested waterbody into one that is not (Lovas-Kiss et al., 2020, p. 15399).

Vectors of dispersal aside, the impact of Prussian carp on Eurasia's freshwater ecosystems has been devastating. When introduced, Prussian carp can and will decrease the number of native taxa as a result of out-competing them (Şaşi, 2008, p.92; Balik et al.,2003, p.90; Docherty, 2016, p.17), reproducing rapidly (Docherty,2016, p.12; Docherty et al., 2017, pp.291-292) and degrading the conditions of their surrounding habitat (Crivelli, 1995, p. 315). Invariably, native freshwater ecosystems are altered, which in turn impacts human economies (Docherty et al., 2017, p.291). Indeed, van der Veer & Nentwig (2015) have gone so far as to classify the Prussian carp as the most destructive invasive fish species in all of Europe (van der Veer & Nentwig, 2015, p. 635).

In the last two decades, Prussian carp have also spread into and become established in North America, specifically the Red Deer, Bow and South Saskatchewan river systems, and Lacombe lake in Alberta, Canada (Docherty et al., 2017, p. 294). Given the distance and separation between Eurasia and North America, the reason behind their arrival in Alberta is clearly anthropogenic (Docherty et al., 2017, p. 294). While the exact means of their introduction remains unclear (Kucher, Stock & Das, 2019, p. 849) Prussian carp were probably unknowingly introduced via aquaculture. Given that aquacultural practices in Alberta rear several carp species, including those that are morphologically similar to Prussian carp, meaning Prussian carp probably arrived in Alberta through shipments of commercially desirable fish (Elgin, Tunna and Jackson, 2014, p. 280). Regardless of how they ended up in North America, Prussian carp have since spread throughout southern Alberta at what is believed to be an eight to elevenfold increase in their range (Docherty et al., 2017, p. 291). Alarmingly, a recent survey conducted by Docherty et al. (2017) has noted three distinct Prussian carp populations in the province, suggesting three distinct instances of Prussian carp introduction, that indicates that just as in Eurasia, human action has been a significant contributor to their spread (Docherty et al., 2017, p. 293).

Despite their comparatively recent arrival to the province, there has already been some indication that Prussian carp have begun to impact Alberta's native species negatively. A recent study conducted by Ruppert et al. (2017) focused on streams associated with the Red Deer watershed before and after invasion. The results indicate that as Prussian carp become established, native fish and benthic invertebrate communities restructure, reducing several native fish species, including the fathead minnow, brook stickleback, lake chub and white sucker (Ruppert et al., 2017, p.10). Similarly, benthic invertebrate communities were observed to become less diverse and abundant with Prussian carp establishment (Ruppert et al, 2017, pp.7,10). Thus, Prussian carp appear to be just as impactful in Alberta as they are in Eurasia.

Given the damage Prussian carp have caused in Eurasia, and continue to cause in North America, establishing where and by what means Prussian carp have spread into Alberta is critical. To date, all research conducted on Prussian carp in Alberta has occurred within the southern region of the province (Docherty et al., 2017, pp. 291-296; Elgin et al., 2014, pp.275-282; Ruppert et al., 2017, pp. 1-14), with virtually no focus on the central and northern areas. My research project sought to gather data about Prussian carp in northern Alberta, specifically within the Edmonton region. Ultimately, my research objective was to determine if Prussian carp have spread into northern Alberta, and if so, by what means.

Materials and Methods:

My methodology was broken down into two components: drone surveillance and environmental DNA (eDNA) analysis. The first and most comprehensive part of my methods involved looking for visual confirmation of Prussian carp using a Trident Underwater Drone within water bodies under investigation. Before any drone footage was collected, I had to establish where precisely to survey. In part, my survey decisions were made based on past data collected by fellow research student Heather Deptford from lakes and ponds in the Edmonton, St. Albert and Strathcona county jurisdictions. While her results did not explicitly suggest that Prussian carp were present in any of her survey sites, she did note several non-native species in two ponds in the Millwoods area, including goldfish (Deptford, 2019, pp. 1–14). As such, I chose to include the same two Millwoods ponds in the new survey. I also decided to revisit several other ponds and lakes where Deptford did not find any invasive fish species but could still be at risk for Prussian carp introduction. These included lakes and ponds that were close to parks with children, places frequented by anglers (Deptford, 2019, pp. 4-5; Docherty et al., 2017, p. 293), and places with a history of translocations. Using Google Earth Pro mapping software, I selected several new lakes and ponds in the north and south Edmonton areas to widen the survey range. Overall, 12 ponds and lakes were surveyed from May to August 2020. Of these twelve survey sites, six had previously been surveyed by Deptford (Deptford, 2019, p. 13), while the other six were surveyed for the first time. Seven were located in the south Edmonton region, three were located in the north Edmonton region, one was located in the St. Albert region, and a final one was located in the Beaumont region (Table 1; Figure 1).

Before surveying the chosen waterbodies, I put the drone through a negative control run by piloting it in a full bathtub. This served as a point of reference for how a waterbody without any fish would look on the drone footage. Following the control run, I took the drone out to the twelve selected sites to collect video footage. When I arrived at each pond or lake, I scouted the area to establish a launch site. I used a site at a boat dock or a bare patch along the shoreline in most cases. For other cases, I had to use chest waders to create a launch site for the drone in deeper water, while In other cases, I used two different launch sites to better access the area I intended to survey. From there, the drone would be activated on land by connecting it to its portable Wi-Fi unit through a yellow tether. Sofar Trident, an application on my mobile phone, was then opened to connect me to the control panel for the drone. The drone was then placed in the water, and the survey began.

I collected video footage through the Sofar Trident application in 5-10 minute increments during surveying, although some video footage could last up to 30 minutes. On average, I would survey a waterbody for approximately an hour and collect between 30 to 40 minutes of footage in total. As my objective was to locate fish, mainly Prussian carp, I piloted the drone in areas that they generally prefer, namely the benthic regions and areas along the shoreline with dense vegetation (Docherty, 2016, p. 14; Vetemaa et al., 2005, p. 290). To ensure that both areas were covered, I developed a 'loop-around' surveying strategy whereby the drone would be launched, sent out into the deeper areas of the pond or lake, and brought back around to survey along shoreline vegetation (Figure 2). In a few cases, I would do the opposite by starting along the shoreline before going into deeper water (Figure 2). Once the surveying was completed, the drone was cleaned off-site with soapy water to sanitize it and prevent any cross-contamination between lakes and ponds. The footage the drone recorded was then downloaded onto a virtual drive. All footage was uploaded into a file linked to the collection date, corresponding to a specific pond or lake the footage was taken from.

The next step of the survey process involved actually watching the collected footage. I would start by watching each video over once at full speed to see any fish-like objects picked up.

If there were, the video would be re-watched in slow motion, and any fish or fish-like objects were noted, regardless if they were invasive or not. Overall, around seven hours of raw footage was collected, and it took around twenty-five hours in total to review and analyze. Once the footage was analyzed, I then attempted to identify the fish captured by the drone by looking for morphological indicators, more specifically scale colour, body and caudal fin shape (Joynt & Sullivan, 2003). While watching the footage, the focus was on finding and identifying Prussian carp and other invasive fish species, namely goldfish. That said, native fish taxa were also identified where possible to gauge the species composition of the survey sites.

The second component for surveying and determining the presence of Prussian carp involved molecular confirmation in the form of environmental DNA (eDNA). Because the DNA of aquatic organisms can remain in the surrounding environment for an extended period of time, it is possible to extract the genetic material from the water and analyze it to determine what kinds of fish species are present (Laramie et al., 2015, p.1). For my purposes, eDNA analysis was used to verify the presence of Prussian carp and goldfish in conjunction with the drone footage. In total, four lakes and ponds were chosen for eDNA analysis. Two were selected based on Deptford's past observations of goldfish in the Millwood's area (Deptford, 2019, p. 13). The remaining two sample locations were chosen due to observations of objects that resembled goldfish on the footage but could not be confidently differentiated from an aquatic invertebrate species.

Water samples for the eDNA analysis were taken between September and October 2020 from Millwoods pond, Millwoods storm water facility, Fountain Lake and Eaux Claires Lake 2, spanning both north and south Edmonton (Figure 3). For each of the waterbodies, I would use two five-gallon buckets to collect two water samples from different parts of the lake or pond to account for the fact that fish activity, and therefore genetic material, may not be evenly distributed (Furlan et al., 2016, p. 641). Once collected, the containers were sealed and taken to one of the biology labs at MacEwan University on the same day for processing. Each water sample was sucked through its own 0.2 μm pore cellulose nitrate filter via a vacuum pump connected to a lab bench. The filters were then folded up and stored in lab-grade ethanol until the eDNA analysis could be completed. I also included one negative and one positive control sample. The negative control sample was created using sterile water, and the positive by using a sample collected from a goldfish tank at the MacEwan University's childcare center. The logic in using these controls was to firstly set a baseline for a filter sample without any genetic material and to secondly gage the ability of the eDNA analysis to detect and differentiate between the eDNA of Prussian carp and a closely related species like goldfish (Kalous et al., 2012, p. 14). Ten filter samples were collected in total, two for the controls and eight for the test samples. Each sample was also assigned a unique number from one to ten before being sent away for the eDNA analysis.

The eDNA analysis itself was conducted by the Molecular Biology Service Unit (MBSU) laboratory at the University of Alberta. In summary, the MBSU lab processed the samples by first extracting any eDNA from the filters (*EDNA Extraction from Filters*, 2015) then used quantitative polymerase chain reaction (qPCR) to amplify any present Cytochrome B gene sequences specific to Prussian carp and goldfish in each of the samples (Rodgers et al., 2019, pp. 1091–1092). The primers used in the qPCR were based on alignments from the research of Halas, Lovejoy and Mandrak (2018) regarding different goldfish haplotypes to ensure that the different variants could be detected.

Results:

Analysis of the drone footage lead to the detection of fish in eight lakes and ponds spanning the entire Edmonton area (Figure 4). Generally speaking, seven of the said lakes and ponds had various fish present that I could not confidently identify to the genus or species level due to poor water visibility. That said, I was still able to identify several native fish tata to the genus and species level in three different lakes and ponds, with brook stickleback (*Clupea inconstans* in Millwoods pond, *Phoxinus* species and brook stickleback in Bearspaw lake, and a salmonid species in St. Albert Lacombe lake (Table 2). In terms of invasive fish species, the footage did not pick up any clear indications of Prussian Carp in any of the lake or ponds that I had surveyed. However, goldfish were successfully identified in Millwoods pond and Kitllitz lake (Table 2). Millwoods pond had previously had goldfish confirmed by Deptford (Deptford, 2019, p. 13), while I had established the presence of goldfish found in Kitllitz lake. Deptford had also previously confirmed goldfish in Millwoods Storm Water Facility (Deptford, 2019, p. 13). However, my own survey only confirmed the presence of brook sticklebacks (Table 2) with no indications of goldfish at all.

The results of the eDNA analysis performed by the MBSU lab detected neither Prussian carp nor goldfish DNA for my negative control sample and only detected goldfish DNA on the positive control sample. For the eight test samples I collected, there was no positive confirmation of either Prussian carp or goldfish DNA for all the sampled water bodies (Table 3). Critically, the results of the eDNA analysis directly oppose the collective finding of Deptford and myself regarding Millwoods pond and Millwoods Storm Water Facility, where goldfish had previously been confirmed (Deptford, 2019, p. 13).

Discussion:

The collective results from the drone footage and eDNA analysis both indicated that Prussian carp specifically were not present in any of the ponds or lakes that I surveyed and sampled from at the time (Tables 2 & 3). However, the video analysis still confirmed the presence of fish in several different waterbodies. The vast majority of the waterbodies with documented fish showed indications of native fish taxa exclusively, including brook stickleback, trout, *Phoxinus* and other unidentified cyprinids (Table 2). The prevalence of these species across the surveyed lakes and ponds suggests that native fish populations still persist in waterbodies around the Edmonton area. Given the fact that these species can face decline when they live in the same habitat as Prussian Carp (Ruppert et al., 2017, p. 11), it can further be argued that the prevalence of native fish is indicative of the lack of Prussian carp overall.

Despite the lack of Prussian carp in the drone footage, I was still able to confirm invasive fish, specifically goldfish, in Millwoods pond and Kitllitz lake. Millwoods pond had already had goldfish previously documented by Deptford (Deptford, 2019, p. 13), while the goldfish in Kitllitz lake were newly confirmed by me. Previously, Deptford had also found goldfish in Millwoods storm water facility. However, my survey of the area only indicated the presence of brook sticklebacks and other unidentified fish species. This discrepancy can be attributed to the fact that I surveyed the pond in May, around the time that brook sticklebacks spawn (Joynt & Sullivan, 2003, p. 136). Deptford surveyed the same pond in November, long after the spawning ends (Deptford, 2019, p. 13; Joynt & Sullivan, 2003, p. 136), resulting in different fish species being observed due to seasonal behaviour. Thus, Millwoods storm water facility can be considered as a positive site for goldfish, making a total of three waterbodies that have confirmed for goldfish in the Edmonton area to date.

When comparing the results from the drone footage against the results of the eDNA analysis, the results seemingly contradict each other. While Deptford (Deptford, 2019) and I had visual confirmation of goldfish in Millwoods pond and Millwoods storm water facility (Table 2), the eDNA analysis did not pick up any molecular evidence of goldfish at either site (Table 3). Therefore, this discrepancy brings the accuracy of the results for the eDNA analysis of the other two test sites into question. With that in mind, conditions relating to the availability of eDNA in the lakes and ponds I sampled from may help explain these conflicting results.

Past research conducted by Takahara, Minamoto and Doi (2013) and Tréguier, Paillisson, Dejean, Valentini, Schlaepfer and Roussel (2014) show that the effectiveness of eDNA analysis to detect invasive species can vary. For Takahara et al. (2013), eDNA effective in successfully detecting the eDNA of invasive bluegill sunfish (*Lepomis macrochirus*) in ponds sampled along the mainland and islands of Japan (Takahara et al., 2013, p. 3). However, Tréguier et al. (2014) found eDNA analysis to be entirely ineffective in detecting the presence of red swamp crayfish (*Procambarus clarkii*) in freshwater ponds in France where they have been present starting in 1981 (Tréguier et al., 2014, p. 872). While these studies deal with different phyla, they still highlight the importance of the abundance and density of the target species in a successful eDNA analysis. Takahara et al. (2013) worked with ponds that had a very high density of bluegill sunfish, so much so that they reported seeing them along the shorelines (Takahara et al., 2013, p. 3). By contrast Tréguier et al. (2014) sampled from ponds that did not immediately show signs of crayfish (Tréguier et al., 2014, p. 876). Because species density correlates with eDNA concentration and availability (Mauvisseau, Burian, Gibson, Brys, Ramsey and Sweet, 2019, p. 7; Roussel, Paillisson, Tréguier and Petit, 2015, p. 824; Schultz & Lance, 2015, p. 13) it is therefore reasonable to expect that waterbodies with a high density of the target species will produce samples with a high enough concentration of eDNA to be detectable.

My own experiences in collecting my eDNA samples align with that of Tréguier et al. (2014). At every lake that I took water samples from, including the two waterbodies confirmed for goldfish, I did not observe any fish activity at the collection points. Furthermore, I collected my samples between September and October when fish activity, namely spawning, dwindles (Joynt & Sullivan, 2003, pp. 58–86). These two factors considered, the negative eDNA results from Millwoods pond and Millwoods storm water facility reflect low fish activity and abundance from the areas I sampled from rather than an absence and loss of goldfish following the surveys done by Deptford and myself. By that same token, the negative results from Fountain lake and Eaux Claires Lake 2 should not be interpreted as absolute proof of a lack of goldfish. Instead, I would suggest that the eDNA sampling strategies of Edmonton ponds and lakes should be changed for the future, including taking more than two samples from each pond and lake and sampling in spring and summer when fish are more active. Doing so would produce results that can more reliably confirm if Prussian carp and goldfish are present or not.

In reviewing the findings of the drone survey footage and the results and caveats of the eDNA analysis, the overarching conclusion reached is that Prussian carp specifically have yet to become established in northern Alberta. However, the results from the drone footage specifically are still a cause for concern. As previously stated, Deptford and I successfully identified three ponds and lakes in the Edmonton area that had goldfish. As with all invasive fish species, goldfish must be first introduced through human vectors (Salaj & Treer, 2018, p. 356; Vetemaa et al., 2005, p. 287). Because the three lakes and ponds with goldfish were all located in urban areas, they may have been introduced purposefully as unwanted pets, via avian transmission from another infected waterbody or a combination thereof (Lovas-Kiss et al., 2020, pp. 15397–15399). Regardless, all three locations now have goldfish due to human activity at some point in time.

In the future, mitigating or even stopping the spread of Prussian carp into northern Alberta will be critical. To date, Alberta's provincial government has taken to educating the public about the dangers of releasing non-native fish, including goldfish and Prussian carp, through public campaigns and pamphlets (Environment and Parks, 2018, pp. 18-21). While this is undoubtedly a step in the right direction, more action by implementing stricter laws and penalties might be necessary, especially when considering that my study still found evidence of goldfish in the Edmonton area. Additionally, waterbodies in the Edmonton area should be continually monitored and studied. This might be done by continuing to survey ponds and lakes in Edmonton with the drone, covering a mixture of old and new survey sites as I did. I would also recommend that the streams and rivers in the Edmonton area, including the North Saskatchewan river, start to be monitored through the use of eDNA analysis and minnow traps. The minnow traps specifically may prove to offer a way to document and locate any present fish species when the drone cannot be used. All these steps will be critical to understand and mitigate the spread of Prussian carp across Alberta and protect native species and ecosystems for future generations.

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Tables and Figures

Table 1. A summary of the lakes and ponds surveyed including the waterbody name, coordinates, if it had ben surveyed before by Deptford and the reason for survey in 2020.

Waterbody Name	Coordinates	Surveyed Before?	Reason for Survey
Millwoods pond	53.455859, -133.436857	Yes	Past Goldfish Sightings by Deptford
Millwoods Storm Water Facility	53.457438, -133.424648	Yes	Past Goldfish Sightings by Deptford
Kiniski Gardens Lake	53.474821, -113.405538	No	Expanding survey range in south Edmonton
Fountain Lake	53.481522, -113.390396	No	Expanding survey range in south Edmonton
Eaux Claires Lake 1	53.623281, -113.477377	No	Expanding survey range into north Edmonton
Eaux Claires Lake 2	53.617336, -113.479012	No	Expanding survey range into north Edmonton
Kitllitz Lake	53.47259, -113.391973	No	Expanding survey range in south Edmonton
Castle Downs Lake	53.616349, -113.514127	No	Expanding survey range into north Edmonton
St. Albert Lacombe Lake	53.637563, -113.654788	Yes	History of carp species being present in lake
Bearspaw Lake	53.443865, -113.505172	Yes	Fish sightings by deptford
Jackie Parker Park	53.484925, -113.42326	Yes	Revisit due to close proximity to golf course
Beaumont Fish Pond	53.484925, -113.42326	Yes	Past reports of goldfish being present

Table 2. Summary of native and non-native fish taxa that were observed across the surveyed lakes and ponds from the drone footage

Waterbody Name	Coordinates	Date Surveyed	Fish Taxa observed	Invasive (Yes/No)
Millwoods pond	53.455859, -133.436857	05/16/2020	Goldfish, unidentified cyprinid species	Yes
Millwoods Storm Water Facility	53.457438, -133.424648	05/27/2020	Brooke sticklebacks, other unidentified fish species	No
Kiniski Gardens Lake	53.474821, -113.405538	06/13/2020	None	No
Fountain Lake	53.481522, -113.390396	06/19/2020	Unidentified fish	No
Eaux Claires Lake 1	53.623281, -113.477377	06/25/2020	None	No
Eaux Claires Lake 2	53.617336, -113.479012	07/4/2020	Unidentified fish species	No
Kitllitz Lake	53.47259, -113.391973	07/6/2020	gold fish, other unidentified fish species	Yes
Castle Downs Lake	53.616349, -113.514127	07/11/2020	Unidentified fish	No
St. Albert Lacombe Lake	53.637563, -113.654788	07/15/2020	Salmonid species	No
Bearspaw Lake	53.443865, -113.505172	07/22/2020	Brook sticklebacks, *Phoxinus* species, unidentified cyprinid species	No
Jackie Parker Park	53.484925, -113.42326	07/25/2020	None	No
Beaumont Fish Pond	53.484925, -113.42326	08/15/2020	None	No

Table 3. Overview of results from the eDNA analysis of four ponds and lakes in the Edmonton area including control samples

Sample location	Sample number (s)	Prussian Carp DNA?	Goldfish DNA?	Notes
Millwoods Town Center Storm Water Facility	1 and 2	No	No	
Millwoods Pond	3 and 4	No	No	
Fountain Lake	5 and 6	No	No	
Eaux Claires Lake 2	7 and 8	No	No	
MacEwan University	9	No	Yes	Positive control from goldfish tank
MacEwan University	10	No	No	Negative control

Figure 1. Distribution of the twelve sites surveyed with the drone from April to August 2020. The twelve survey sited spanned the Edmonton, St. Albert and Beaumont jurisdictions. Six of these sited had previously been surveyed by Deptford (blue) while the remaining six were newly surveyed in the summer and spring of 2020

Figure 2. The drone piloting strategies used for each survey site. To cover both the benthic region and shoreline vegetation, the drone was most commonly sent out into the middle of the survey site before being brought back around to survey along the shore (Path 1). In a few instances, the opposite would be done (Path 2).

Figure 3. Distribution of eDNA sample sites. Four ponds and lakes in total were selected for eDNA analysis to test for goldfish and Prussian Carp DNA. Three of the sample sites were in south Edmonton in the Millwoods area, while one sample site was located in north Edmonton in Eaux Claires.

Figure 4. Distribution of survey sites confirmed for native and invasive fish species. Eight of the 12 ponds surveyed were confirmed as having fish present from the drone footage. The distribution of these sites were fairly even between north and south Edmonton with three sites in the north and five in the south.

Figure 1. Distribution of the twelve sites surveyed with the drone from April to August 2020.

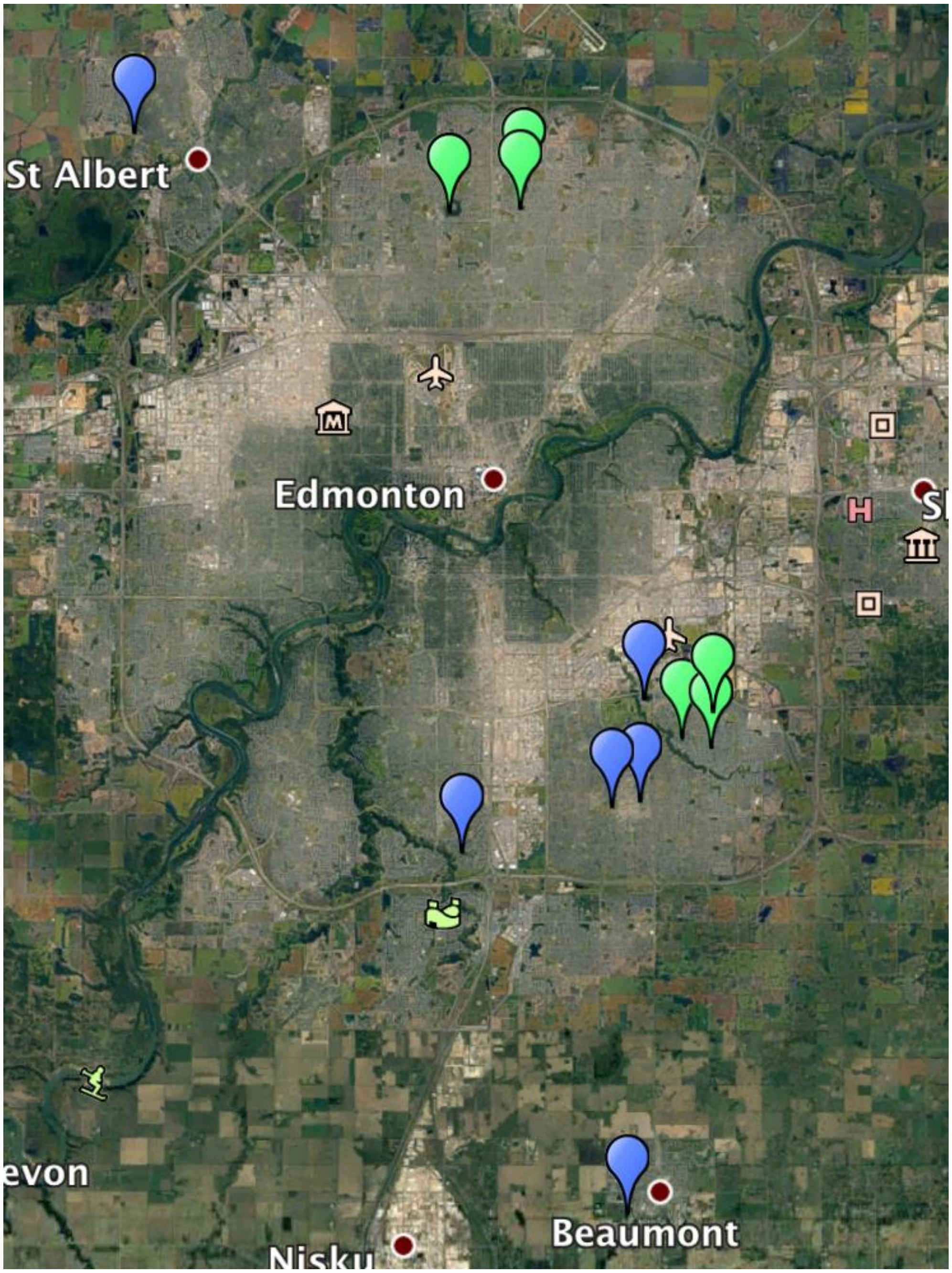

Figure 2. The drone piloting strategies used for each survey site.

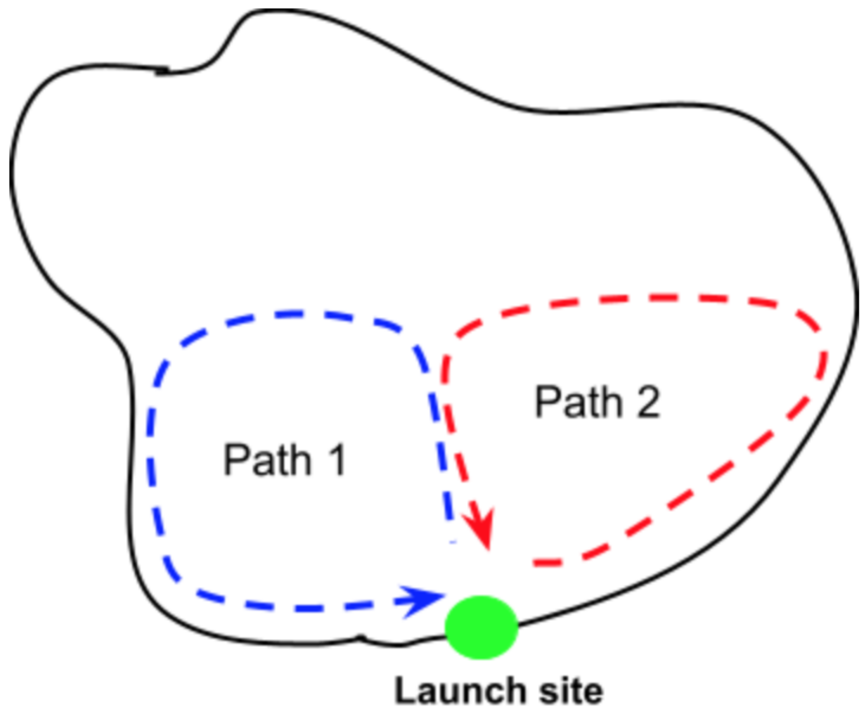

Figure 3. Distribution of eDNA sample sites

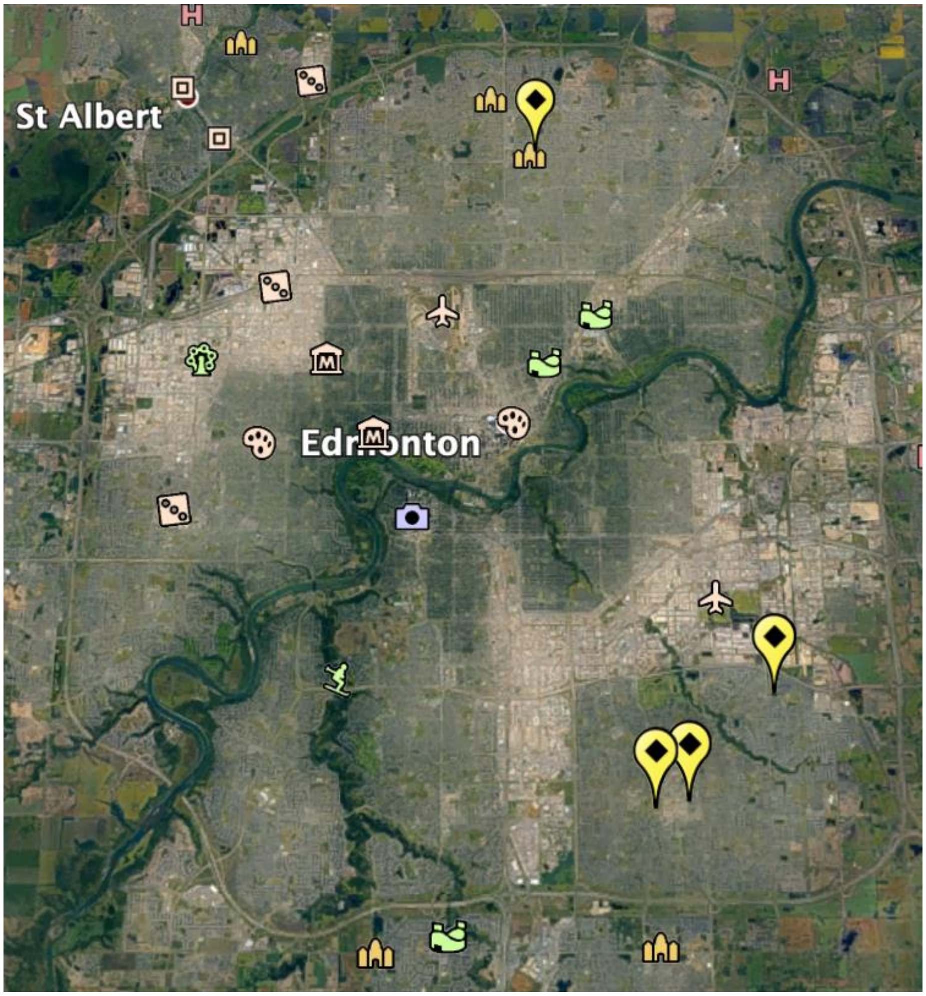

Figure 4. Distribution of survey sites confirmed for native and invasive fish species.