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Online advertisements for crayfish decrease after a provincial ban

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1 Fewer online advertisements for marbled crayfish after banning suggest policy success

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9

10 **Abstract**

11 The parthenogenetic marbled crayfish, *Procambarus virginalis*, is an unwanted species
12 introduced in many countries. There are no established populations in North America to date.
13 Several jurisdictions in the United States and Canada have specifically banned ownership of
14 marbled crayfish, but it is unclear if such bans effectively reduce ownership. The Canadian
15 province of Saskatchewan prohibited marbled crayfish in 2020. We tested whether the
16 introduction of this law affected behaviour by comparing online advertisements for crayfish in
17 Saskatchewan and other Canadian provinces over two years before and after the ban. The
18 number of online advertisements and sellers in Saskatchewan for all crayfish – not just marbled
19 crayfish – was significantly smaller after the ban. No other province showed this pattern. This
20 suggests banning marbled crayfish reduced the online availability of crayfish and may be an
21 example of a successful policy to reduce availability of aquarium pets.

22

23 **Keywords**

24 Marmorkrebs, crayfish, pet trade, aquarium, policy

25

26 **Introduction**

27

28 The aquarium trade is a large, profitable, and little regulated market (Raghavan et al.
29 2013; Voigt 2016) that can drive species introductions (Chucholl 2013; Chucholl and Wendler
30 2016; Yanai et al. 2017; Chan et al. 2019; Lockwood et al. 2019; Olden et al. 2020; Beaury et al.
31 2021). To curb introductions, many jurisdictions attempt to regulate the aquarium trade, typically
32 by banning the possession and / or release of certain categories of organisms (e.g., all members
33 of a species, genus, or other taxonomic category). But it is an open question how effective such
34 policies are (Patoka et al. 2018; Daley 2019). Illegal trade and other activities often continue on
35 online platforms, despite policies of service providers, or laws at the regional or national level
36 (El Bizri et al. 2015; Sy and Lorenzo II 2020; Borges et al. 2021; Cox and Collins 2021;
37 Magalhães et al. 2021; Sung et al. 2021). Laws prohibiting release have never resulted in charges
38 being laid (Azevedo-Santos et al. 2015; Nova Scotia Fisheries and Aquaculture 2015). Here, we
39 use marbled crayfish as a case study to examine the effectiveness of possession bans in reducing
40 the trade of aquarium pets.

41

42 Marbled crayfish, *Procambarus virginalis* Lyko 2017, are an all female, asexually
43 reproducing species (Scholtz et al. 2003) that has no native population. The species separated
44 from sexually reproducing ancestors by polyploidy extremely recently by most evolutionary
45 timescales (Vogt et al. 2015; Martin et al. 2016; Gutekunst et al. 2021). Marbled crayfish were
46 first found in the mid 1990s in the German aquarium trade, with the earliest unambiguous written
47 record in 1995 (Vogt 2018). It took several years for the first technical paper to be published
48 about the species (Scholtz et al. 2003). Since their discovery, marbled crayfish have been
49 released into natural habitats repeatedly, including Madagascar (Jones et al. 2009; Kawai et al.
50 2009; Gutekunst et al. 2018), Europe (Chucholl et al. 2012; Löökkös et al. 2016; Novitsky and
51 Son 2016; Pârvulescu et al. 2017), and Asia (Kawai and Takahata 2010; Fujiie 2017; Charlier
52 2020; Anonymous 2021a). They were introduced with no environmental assessments or other
53 foreknowledge to these jurisdictions. Crayfish introductions can cause multiple problems, such

54 as acting as vectors for crayfish plague (Keller et al. 2014; Francesconi et al. 2021), competing
55 with native crayfish species (Chucholl et al. 2008; Hanshew and Garcia 2012; Sandra and Karlo
56 2012; Hale et al. 2016), changing behaviour of native fish species (Mohammed et al. 2023), or
57 altering food webs (Twardochleb et al. 2013). The overall economic costs of crayfish
58 introductions are generally negative (Twardochleb et al. 2013).

59

60 To date, no populations of marbled crayfish have been found in North America. But
61 surveying online advertisements shows that marbled crayfish are readily available in the
62 aquarium trade in Canada and the United States (Faulkes 2010, 2015). Online advertisements of
63 pets can correlate with risk of introductions (Kikillus et al. 2012), indicating the risk of marbled
64 crayfish being introduced into natural habitats in Canada and the United States is probably high.
65 Some states and provinces in these countries regulate the possession and trade of crayfish
66 generally, and some have regulations that specifically include marbled crayfish (Anonymous
67 2010, 2021b). To our knowledge, in over ten years since marbled crayfish were banned in some
68 jurisdictions in Canada and the United States (Anonymous 2010), only one person has been
69 charged for selling marbled crayfish (United States Department of Justice 2022). Therefore,
70 evidence is needed to show that policy changes have the intended effect of reducing the
71 ownership and trade of marbled crayfish.

72

73 In 2020, the Canadian province of Saskatchewan banned marbled crayfish and rusty
74 crayfish (*Faxonius rusticus*; listed using former genus name *Orconectes* in regulations)
75 (Government of Saskatchewan 2020). Coincidentally, the online trade of crayfish in
76 Saskatchewan had been documented in a previous study (Faulkes 2018). Thus, Saskatchewan's
77 ban provided a "natural experiment" to test the effectiveness of the policy. For this project, we
78 focus on marbled crayfish because it is more widespread in the North American pet trade than *F.*
79 *rusticus* (Faulkes 2015), and is more likely to be identified to the species level in advertisements
80 because its parthenogenetic reproduction is so distinct.

81 If the ban was effective at changing the behaviour of crayfish owners, we predict these
82 three effects are predicts. First, the number of online advertisements for, and sellers of, marbled
83 crayfish should be reduced in Saskatchewan. Second, the number of online advertisements and
84 sellers for marbled crayfish should not decrease in other provinces that did not change their
85 policy. Previously, the provinces of Manitoba, Alberta, and Nova Scotia were picked for
86 comparison to Saskatchewan based on similarities in geography and population (Faulkes 2018).
87 There were existing prohibitions on crayfish in Manitoba (since at least 2006; [https://laws-](https://laws-lois.justice.gc.ca/eng/regulations/sor-87-509/section-16-20060322.html#wb-cont)
88 [lois.justice.gc.ca/eng/regulations/sor-87-509/section-16-20060322.html#wb-cont](https://laws-lois.justice.gc.ca/eng/regulations/sor-87-509/section-16-20060322.html#wb-cont) ;
89 <https://www.gov.mb.ca/stopais/resource/print,index.html>) and Alberta (since at least 2013;
90 [https://open.alberta.ca/dataset/dbf392f4-266f-4947-adc0-fa4bdf4e2c9c/resource/ff5b657a-086f-](https://open.alberta.ca/dataset/dbf392f4-266f-4947-adc0-fa4bdf4e2c9c/resource/ff5b657a-086f-44f5-9c4b-3a14e335d125/download/1838656-2013-alberta-sportfishing-regulations.pdf)
91 [44f5-9c4b-3a14e335d125/download/1838656-2013-alberta-sportfishing-regulations.pdf](https://open.alberta.ca/dataset/dbf392f4-266f-4947-adc0-fa4bdf4e2c9c/resource/ff5b657a-086f-44f5-9c4b-3a14e335d125/download/1838656-2013-alberta-sportfishing-regulations.pdf)). Nova
92 Scotia had no prohibitions on owning crayfish. Third, online advertisements for crayfish other
93 than marbled crayfish should stay at the same level in all provinces.

94

95 **Methods**

96

97 Saskatchewan banned marbled crayfish on 1 April 2020 (Government of Saskatchewan
98 2020). Data collection began on 1 June 2020 and continued until 31 May 2022 (two consecutive
99 years). Data collected from the previous study beginning at the start of 2016 to the end of 2017
100 was used as comparison.

101

102 The methods were similar to those used in a previous study (Faulkes 2018). Alerts for the
103 words “crayfish,” “crawfish,” “crawdad,” and “écrevisse” were created for the Canadian
104 advertising website Kijiji. Information about each advertisement was entered into a spreadsheet
105 and a PDF of the advertisement was saved. For advertisements that were removed before
106 viewing, the take-down notice was saved as a PDF to confirm that there had been an
107 advertisement.

108

109 Previous results (Faulkes 2018) showed that there were fewer advertisements for crayfish
110 from Manitoba than the other three provinces. This might suggest that aquarium keeping in
111 general was not a popular hobby in Manitoba. To test whether this low number of advertisements
112 was specific to crayfish, we searched for advertisements for “snail” (common name for
113 gastropod mollusks), “angelfish” (common name for *Pterophyllum* spp.), and “oscar” (common
114 name for *Astronotus ocellatus*) starting 1 January 2022 and until 31 May 2022 (five months).
115 The advertisements for these control species followed the same methods used for crayfish.

116

117 The number of advertisements for crayfish in general and marbled crayfish specifically
118 were calculated for each month of each province. The identification of marbled crayfish was
119 based on key words found in advertisements that involve traits specific to this species, such as
120 “self-cloning” and “marbled.” Due to the possibility of misidentification, the number of marbled
121 crayfish advertisements may not be accurately represented.

122

123 The population size for the Canadian provinces were taken from the 2016 and 2021
124 census data (Statistics Canada). As the census of population is conducted every five years,
125 quarterly population estimates were used for the years that were not conducted (Statistics
126 Canada). Quarterly population estimates are composed of quarter 1 ranging from January to
127 March, quarter 2 ranging April from June, quarter 3 ranging from July to September, and quarter
128 4 ranging from October to December.

129

130 We used Google Alerts (<https://www.google.com/alerts>) for “marbled crayfish,”
131 “Marmorkrebs,” and “*Procambarus virginialis*” to monitor online news and articles about
132 marbled crayfish.

133

134 Non-parametric statistics were used to compare advertisements and sellers before and
135 after Saskatchewan policy changed, because datasets were not normally distributed (many
136 zeroes).

137

138 **Results**

139

140 When all four provinces are considered at once, online advertisements for crayfish in
141 2016-2017 were extremely similar to those recorded in 2020-2022 (Faulkes 2018). There were
142 287 advertisements for crayfish in 2016-2017 (Faulkes 2018) and 284 in 2020-2022.
143 Advertisements that appeared to be selling marbled crayfish accounted for 24% of
144 advertisements in 2016-2017 (Faulkes 2018) and 26% in 2020-2022. Similar to the previous
145 study (Faulkes 2018), most advertisements in 2020-2022 originated from major cities.

146

147 Online advertisements for marbled crayfish per month per million people declined
148 significantly in Saskatchewan but not in any other province (Figure 1A, Table 1). Alberta
149 significantly increased in the number of advertisements, while Manitoba and Nova Scotia
150 remained unchanged. The same patterns emerged when individual sellers were counted (Figure
151 1B, Table 1).

152

153 Online advertisements for all other crayfish species (Figure 2A, Table 1) also declined
154 significantly in Saskatchewan but not in any other province. The number of advertisements per
155 month per million people did not differ in Alberta or Manitoba and significantly increased in
156 Nova Scotia .

157

158 The number of individual sellers (Figure 2B, Table 1) also dropped in Saskatchewan, did
159 not change in Alberta or Manitoba, and significantly increased in Nova Scotia.

160

161 The lack of advertisements and sellers for crayfish is not due to a general lack of interest
162 in aquariums. The number of advertisements for three other types of pets in the aquarium trade
163 were higher than for crayfish. There were 524 advertisements for snails, 275 for angelfish, and
164 161 for oscars in only five months. Provinces differed significantly in advertisements (Figure 3)
165 for snails (one way ANOVA, $f_{3,16} = 7.89$, $n = 20$, $p = 0.0019$) and angelfish (one way ANOVA,
166 $f_{3,16} = 9.16$, $n = 20$, $p = 0.00$), but not oscars (one-way ANOVA, $f = 1.8$, $df = 3$, $n = 20$,
167 $p = 0.00092$). The patterns of advertisements did not mirror those for crayfish. For example,
168 Manitoba never had the smallest number of advertisements for the other pets, as it did for
169 crayfish.

170

171 During the 2020-2022 study period, there were no media stories captured by Google
172 Alerts about the banning of marbled crayfish in Saskatchewan.

173

174 Discussion

175

176 The number of online advertisements and online sellers for crayfish was smaller in
177 Saskatchewan after marbled crayfish were banned than before the ban. The number of
178 advertisements and sellers did not decline in any other province, and other aquarium pets
179 continued to be advertised in Saskatchewan. These changes are consistent with the hypothesis
180 that banning marbled crayfish changed the behaviour of pet crayfish owners.

181

182 Although the policy targeted marbled crayfish, advertisements for all crayfish species
183 were reduced in the Saskatchewan after the marbled crayfish ban, which was not predicted. One
184 explanation is that this change was driven by policy due to pet owners lacking information. Pet
185 owners may hear that crayfish are banned, but not which species. They may not be able to

186 identify which species they own. Thus, banning one crayfish species may cause pet owners not
187 to advertise other crayfish species.

188

189 An alternative explanation is that the change in online advertisements was not driven by
190 policy, but that crayfish became less popular pets in Saskatchewan independent of any policy
191 changes. Pet ownership can be driven by “social contagion” (fads and crazes) (Herzog 2006;
192 Ghirlanda et al. 2013; Ghirlanda et al. 2014) and fall out of fashion. Because there are relatively
193 few crayfish sellers, changes in the behaviour of just a few individuals could alter the pattern of
194 advertisements for entire provinces, although the stability in number of advertisements over
195 more than five years suggests that this was not the case.

196

197 A limitation of this study is that we were unaware of the ban before it too place, so we
198 have no data from over 20 months before, and two months after, the ban was implemented. We
199 cannot say if advertisements for crayfish declined before legislation was passed in
200 Saskatchewan. That the number of advertisements for crayfish was almost zero when data
201 collection began (two months after the ban) is consistent with the hypothesis these differences
202 were not caused by policy changes. We saw no online news stories about the change in
203 regulation in Saskatchewan media. Indeed, we only became aware of the policy change after it
204 occurred, despite that we are highly motivated to know about such changes.

205

206 Three other groups of common aquarium pets were well represented in online
207 advertisements. Therefore, the low levels of crayfish advertisements in Manitoba and
208 Saskatchewan were not explained by lack of people posting about aquarium-related pets
209 generally.

210

211 The balance of evidence suggests that this policy change was effective. This comparison
212 of multiple jurisdictions before and after a policy change is a stronger model for assessing policy

213 a “before and after” of one jurisdiction (Magalhães and Andrade 2015) or a single survey
 214 comparing jurisdictions that differ in policy (Faulkes 2018). Another province, Ontario, has
 215 banned marbled crayfish after Saskatchewan (Anonymous 2021b). Such regulatory changes can
 216 be used to assess the effectiveness of policies, if there is ongoing surveillance of pet sales.
 217 Surveillance is sometimes recommended (Shivambu et al. 2020) but is difficult to carry out,
 218 because of the number of species in the pet trade, the number of avenues to acquire pets (retail
 219 stores, online advertisements, owner to owner, etc.), and the physical distribution of pet stores.
 220 But assessment of policy is necessary because the ultimate goal of policy is to change human
 221 behaviour on a wide scale. Laws that do not change behaviour are not effective and alternative
 222 methods should be used to cause the desired social change.

223

224 **Conclusions**

225 Legislation prohibiting the ownership of the potentially invasive marbled crayfish was
 226 correlated with a reduced number of online advertisements for this species as an aquarium pet.
 227 The methods here provide a way to assess the effectiveness of new legislation in a simple, non-
 228 intrusive manner. These assessments can help guide policymakers in crafting legislation that
 229 reduces the risk of unwanted introductions through the pet trade.

230

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232 ZF conceived the project and designed the methodology. JX and ZF collected the data, analyzed
 233 the data, and wrote the manuscript.

234

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236

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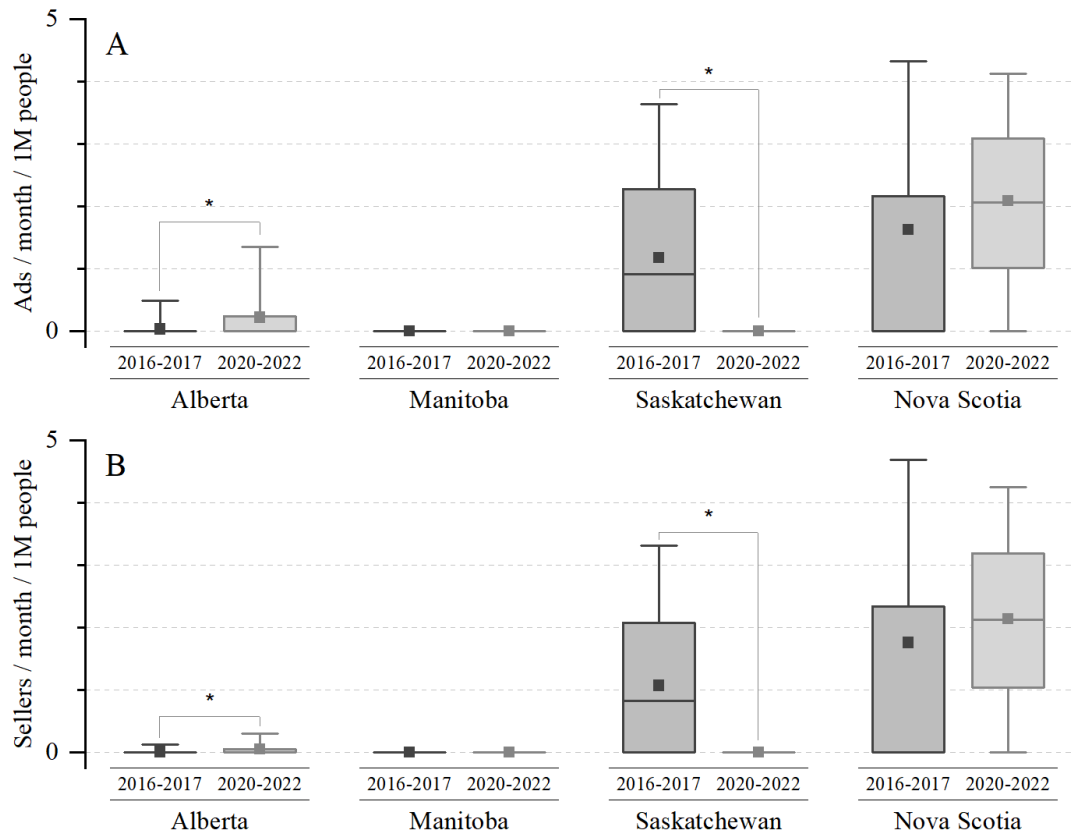
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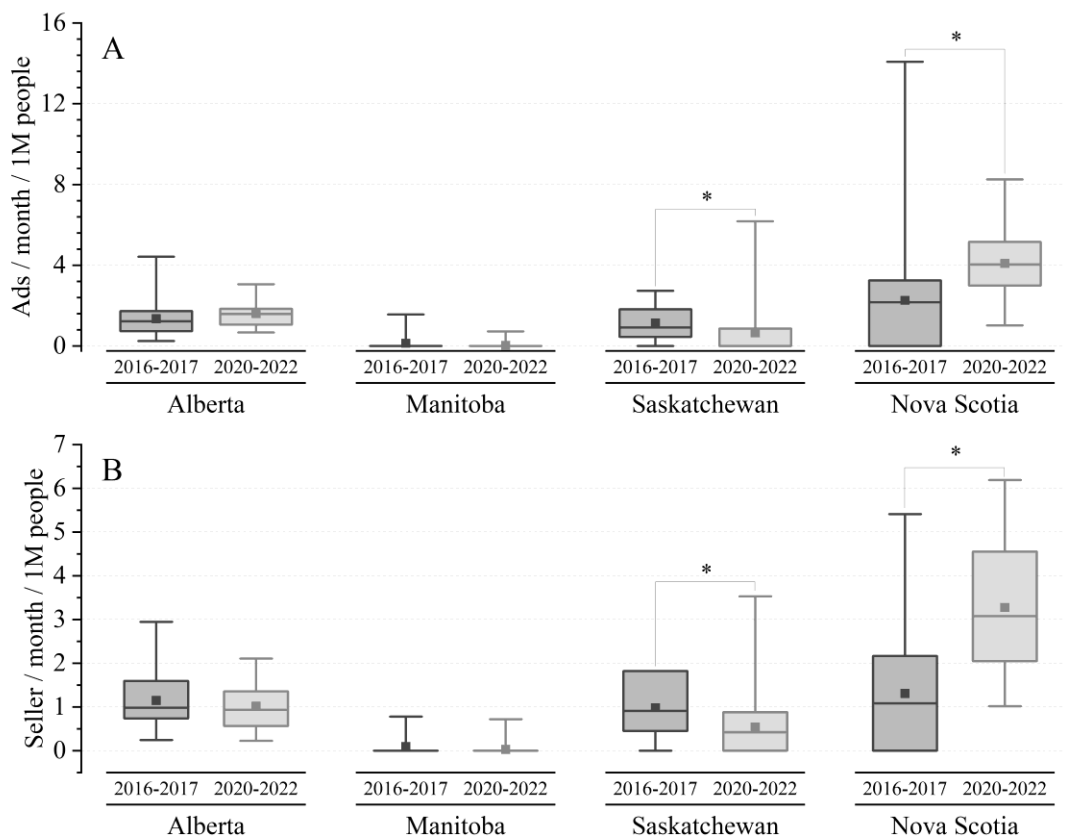
401 Figure 1. Number of (A) advertisements and (B) unique sellers for marbled crayfish. Box = 50%
 402 of data; dividing line = median; dot = mean; whiskers = minimum and maximum; asterisk =
 403 significant difference.



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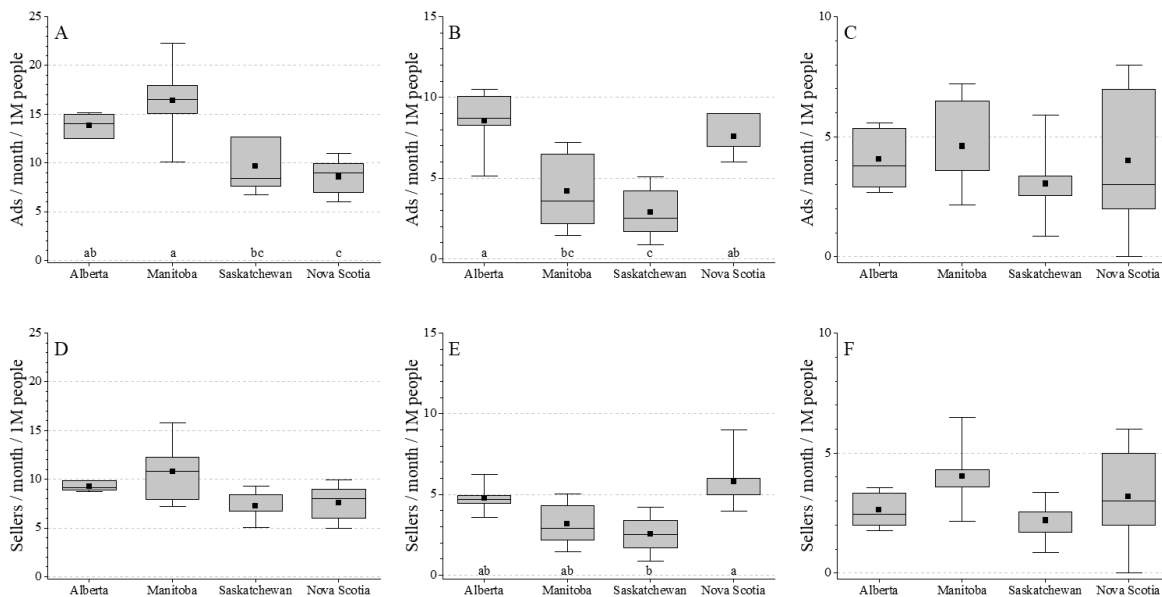
406 Figure 2. Number of (A) advertisements and (B) unique sellers for crayfish species other than
 407 marbled crayfish. Box = 50% of data; dividing line = median; dot = mean; whiskers = minimum
 408 and maximum; asterisk = significant difference.



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411 Figure 3. Number of (A-C) advertisements and (D-F) unique sellers for (A, D) snails, (B, E)
 412 angelfish, and (C, F) oscars. Box = 50% of data; dividing line = median; dot = mean; whiskers =
 413 minimum and maximum. Boxes that do share a letter are significantly different.



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416 Table 1. Statistical comparisons of changes in online advertising for crayfish.

Province	Measure	U score	z score	p value
Saskatchewan	Marbled crayfish advertisements and sellers	108	3.70	0.00022
	All other crayfish advertisements	131	3.23	0.0012
	All other crayfish sellers	126	3.33	0.00086
Alberta	Marbled crayfish advertisements and seller	183	-2.15	0.032
	All other crayfish advertisements	218	-1.43	0.15
	All other crayfish sellers	241	0.96	0.33
Manitoba	Marbled crayfish advertisements and sellers	Identical data	Identical data	Not significant
	All other crayfish advertisements and sellers	262.5	0.52	0.60
Nova Scotia	Marbled crayfish advertisements and sellers	257.5	-0.62	0.55
	All other crayfish advertisements and sellers	124	-3.37	0.00076

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