**Integrating taxonomic and trait analyses to assess the
impact of damming on
fish communities in a northern cold region river**

Journal:	<i>Canadian Journal of Fisheries and Aquatic Sciences</i>
Manuscript ID	cjfas-2016-0074.R2
Manuscript Type:	Article
Date Submitted by the Author:	14-Jul-2016
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Keyword:	biomonitoring, DAMS < Environment/Habitat, functional diversity, taxonomic diversity, trait-approach

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Abstract

Dams are considered one of the most important threats to freshwater ecosystems. To date assessments of the impact of riverine impoundments are based primarily on taxonomic approaches where little can be inferred about functional ecological change. We assessed the impact of damming in a cold region river fish community in Alberta, Canada by integrating taxonomic and trait-based approaches over time (before, during the first 5 years, and after 5 years of dam construction), considering the longitudinal habitat and environmental change created by reservoir formation (downstream, reservoir and upstream). Integrating both approaches was found to be informative as alterations to taxonomic composition in fish communities provided initial clues to a functional response in a spatio-temporal context. Biomonitoring should therefore explicitly consider longitudinal spatial gradients in the design, implementation and evaluation of management actions. Understanding the underlying environmental causes of why the combination of some traits are connected to the risk of species loss or a decline in their distribution is an important step towards the development of better conservation and mitigation strategies.

Key-words: biomonitoring, dams, functional diversity, taxonomic diversity, trait-approach

51 **Introduction**

52

53 Historically, dams, and the reservoirs they create, have been viewed as a benefit to
54 society (Baxter 1977, Nilsson et al. 2005). However, in the last decade, a wide range of
55 studies have demonstrated that dams cause considerable ecological damage by creating
56 impassible barriers to fish migrations, habitat degradation and changes to water quality
57 (Olden and Naiman 2010, Poff and Zimmerman 2010, Liermann et al. 2012, Webb et al.
58 2013). Changes to the disturbance regime of natural rivers are linked to the losses of
59 native species if they lack specific biotic adaptations to the new environment (Mims and
60 Olden 2013).

61

62 It is assumed that in the face of environmental change, species that display similar
63 niches with respect to multiple environmental factors respond in similar fashion
64 (Southwood 1977, Henle et al. 2004). Advances in the application of species traits to
65 analyze the functional structure of communities have provided an alternative approach
66 to assess the consequences of multiple disturbances (Mouillot et al. 2013). In the
67 common biomonitoring practice, the taxonomic composition of communities is
68 employed as an indicator of ecological change, offering limited inference about
69 functional change. From a conservation perspective, organisms with particular life-
70 history adaptations could be affected by flow-regime modifications caused by damming
71 that redistribute extreme flow events to different times of the year (Lytle and Poff
72 2004). For example, resident salmonids Bull Trout (*Salvelinus confluentus*) and
73 Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) have seasonal and life-stage
74 specific habitat requirements that can be altered by modifications to natural flow regime
75 and consequently dams can be detrimental to their populations (Muhlfeld et al. 2012).

76 Mims and Olden (2012) have linked the three dimensions of flow (variability,
77 predictability and seasonality) to the life-history of fish communities from free-flowing
78 rivers of the United States. Recently, Mims and Olden (2013) have shown that life-
79 history composition of freshwater fish assemblages that are built over millennia upon
80 particular habitat templates, are significantly altered downstream of dams within a few
81 decades. These changes are directional and indicate a filtering by dams for some life-
82 histories (i.e., equilibrium strategists) and against other life histories (i.e., opportunists).
83 Traits can be therefore potentially be used as an analytical tool to predict biotic
84 responses to flow regulation, broadening the understanding of the ecological impacts of
85 dams (Mims and Olden 2013).

86

87 The Oldman River is a cold region system (UNESCO, 2011) that is part of the Lower
88 South Saskatchewan River Basin located in the southern part of Alberta, Canada
89 (Mitchell 2001). The average winter temperature ranges from -12.5°C and -8°C and
90 average summer temperatures are between 14°C and 16°C (Saskatchewan Environment
91 and Resource Management 1995). Owing to a highly variable flow pattern and time
92 distribution of runoff from the mountainous part of the watershed, reservoirs have been
93 built along the Oldman River since the 1950s to regulate the flow and to store water for
94 irrigation (Rock and Mayer 2006). The effects of damming on downstream fish
95 assemblages remain largely unknown. The main objective of this study was to analyze
96 how fish assemblages from the Oldman River were affected by the construction of the
97 Oldman dam in the short-term (< 5 years after dam closure) and longer term (> 5 years
98 after dam operations startup), considering the longitudinal gradient in fish assemblages
99 that were differentially affected by habitat change downstream of the dam, in the
100 reservoir and upstream of the reservoir. Specifically, fish assemblages were compared

101 before and after dam operations by two different approaches: (i) traditional taxonomic
102 analyses and (ii) trait-based functional analyses.

103

104 **Methods**

105 *Study area*

106 The western portion of the Oldman River watershed consists of fescue grasslands while
107 the central and eastern portions consist of dryer mixed grass areas and some native
108 prairie vegetation (Byrne et al., 2006). About 33% of the watersheds' land cover is
109 agricultural, 29% is forested and 17% is native vegetation (Byrne et al., 2006). The
110 study area is located in the portion of the watershed which includes the mountains
111 (upstream from Oldman River dam) and foothills (reservoir and downstream locations)
112 sub-basins. The topography of the former area has limited intensive agriculture and
113 large municipalities, while the latter is characterized by highly productive grasslands
114 (Willms and Chanasyk, 2006). The Oldman River headwaters occur in a glacial
115 montane ecoregion in the Livingstone Range of the Rocky Mountains where coniferous
116 trees are dominant (Romanuk et al., 2006). Over 70% of the water supply in the Oldman
117 Basin is derived from the annual snowpack (Byrne et al., 2006). The Oldman River has
118 a total length of 362 km, a drainage area of 26,700 km² and its mean discharge is 95
119 m³/s (Mitchell 2001). The Oldman dam was completed in 1991 to supply water for
120 irrigation (Mitchell 2001). The reservoir is located about 10 km north of Pincher Creek
121 and 10 km west of Brocket (Figure 1) and is located in the semi-arid grasslands near the
122 foothills of the Rocky Mountains. The reservoir inundates 12 km of the mainstream
123 Oldman River and 5 km of the north fork of the Oldman River; 12 km of the Castle
124 River; and 7.5 km of the Crowsnest River. The dam face has a maximum height of 76 m

above the original riverbed; the crest is 1200 m in length and the maximum depth of the reservoir is 68.6 m (Mitchell 2001).

Fish surveys

Surveys sites were chosen within the Oldman River and the Crowsnest River, in the reaches affected by the construction of the Oldman Dam. Sampling sites were obtained from the Fisheries and Wildlife Management Information System (FWMIS) available from the Government of Alberta's Fisheries and Wildlife database (Sustainable Resource Development Alberta 2015). In order to assess the impact of damming in fish assemblages four different areas were defined with reference to the location of the dam: *Downstream*: an area that included 20 km immediately downstream of the dam face (**D1**); a second downstream reach 50-70 km below the dam face, covering another stretch of 20 km (**D2**); *Upstream*: the first 20 km upstream from the reservoir along the Oldman River (**U1**) and the first 20 km upstream from the reservoir along the Crowsnest River (**U2**) that were combined to provide a more robust statistical analysis (**U**); *Reservoir*: included all the area of the reservoir (**R**) (Figure 1). Only sites sampled by electrofishing (backpack and boat) were considered, with the exception of the Reservoir where samples from gill nets were also included, as it was the only method applied after dam closure. Only intermediate and adults individuals were included in the analysis. In order to assess the impact of dam closure with respect to time, data were classified accordingly to 3 time periods: before dam closure (**before**); during the initial period of potentially high productivity and environmental instability (Agostinho et al. 2008) considered as the first 5 years after dam closure (**< 5 yrs**); and after 5 years of dam closure (**> 5 yrs**) (Table 1). Because there were gaps on the information and

149 differences in sampling methods, we have used relative abundances on untransformed
150 data.

151

152 *Flow data*

153 Pre- and post-impoundment daily flow records were obtained from the Water Survey of
154 Canada webpage (Water Survey of Canada 2015) using hydrometric gauging stations
155 for 2 locations: *Downstream* - Gauge station (GS1) 05AA024; Upstream – Gauge
156 station (GS2) 05AA008 (Figure 1).

157

158 *Traits and trait categories*

159

160 Fish traits were obtained from a comprehensive database for freshwater fishes of the
161 United States and Canada synthesized from various literature, agency, and expert
162 accounts (Scott and Crossman 1973, Balon 1981, Coker et al. 2001, Mims et al. 2010,
163 Froese and Pauly 2015). Shape-factor and swimming factor were classified according to
164 (Poff and Allan 1995). Conservation Status was based on the List of Endangered and
165 Threatened species currently listed under Alberta's Wildlife Act and other species were
166 assessed by the Endangered Species Conservation Committee (ESCC) and its Scientific
167 Subcommittee (SSC). A total of sixteen trait-classes were defined, represented by fifty-
168 two categories, including behavioral, life-history, ecological and socio-economic
169 aspects (Table 2).

170

171 Where species traits were unknown, classification was based on congeneric taxa
172 (Supplementary material, Table S1). All species traits were expressed as binary factors
173 (i.e. 1/0), except life-history traits and morphology, which were expressed as continuous

174 variables. Taking this approach circumvented the problem of arbitrary weighting of
175 particular parameters by keeping weights identical (Ernst et al. 2006).

176

177 **Data analysis**

178

179 *Taxonomic analyses*

180 Initial taxonomic analyses were performed by hierarchical cluster analysis on the
181 relative abundances of fish species for each study location using a Manhattan distance
182 and the complete linkage methods to discriminate groups (Kaufman and Rousseeuw
183 2005) based on the three time periods previously defined: before, < 5 yrs and > 5 yrs.
184 For parametric analyses, normality and homogeneity of variances were tested by
185 Shapiro–Wilk W-statistic and Levene’s test, respectively. A Permutational Multivariate
186 Analyses of Variance (PERMANOVA; bi-factorial) (McCune et al. 2002) was used to
187 test for differences in fish communities between time periods and between locations.
188 Species richness (S, total number of fish species in each sample) and species diversity
189 (H, Shannon entropy) were calculated for each sampling site. For each location
190 (Downstream- D1 and D2; Reservoir and Upstream) time period differences in the
191 variables were analyzed using the Kruskal–Wallis test and the subsequent *post hoc*
192 Nemenyi test for pairwise samples. To analyze how communities varied in the same
193 location between the different time periods, a test of dissimilarities percent (SIMPER;
194 Clarke and Warwick 2001) was applied to determine which fish species contributed the
195 most to the differences observed between the groups.

196

197 *Traits analysis*

198 Testing for independence or redundancy of traits prior to the calculation of functional
199 diversity metrics was performed using Pearson's correlation coefficient. This allowed
200 for the identification of significantly autocorrelated traits that were subsequently
201 removed from analyses to avoid under or overestimation of functional diversity
202 (Petchey and Gaston 2006). A threshold of 0.7 was applied for exclusions, (after
203 Dormann et al. 2013). A Permutational Multivariate Analyses of Variance
204 (PERMANOVA; bi-factorial; McCune et al. 2002) was used to test for differences in
205 the functional structure of fish communities between time periods and between
206 locations.

207

208 To analyze which traits were more closely correlated to the response of fish
209 communities to dam closure in each location (Downstream - D1 and D2; Reservoir and
210 Upstream), multinomial logistic regression was performed using time periods (before,
211 < 5 yrs and > 5 yrs) as the response variable and species traits and flow as covariates.
212 Analysis of aggregations of species traits offers some advantages compared to analyses
213 of individual taxa. Metrics aggregate data into a smaller number of categories,
214 simplifying selection of an appropriate reference category that has ecological or
215 management significance when compared to other categories (Qian et al. 2012). Metric
216 categories often have direct ecological significance (e.g., tolerance or functional
217 groups) that arises from traits associated with the taxon. The selection of the best
218 model for each location was made by a stepwise routine based on the Akaike's
219 information criterion (AIC) and Deviance (Komori et al. 2015). From the selected
220 models a hierarchical clustering analysis was performed using Manhattan distance and
221 the complete linkage method to discriminate groups (Kaufman and Rousseeuw 2005)

222 based on the choice of the first 10 selected traits with the higher coefficient values in
223 the models.

224

225 Statistics were computed using R version 3.1.2 (R. Development Core Team 2012).
226 Kruskal–Wallis tests and the Stepwise routines were performed using the STATS
227 package; *post hoc* Nemenyi-test was performed using the PMCMR package (Pohlert
228 2014). The maximum likelihood estimator of the multinomial regression model was
229 implemented with the function multinom using the R package nnet in the VR bundle
230 (Venables and Ripley 2002).

231

232 **Results**

233

234 *Flow*

235 As anticipated, the natural flow regime was modified by the construction of Oldman
236 Dam Downstream, where river regulation was associated with a reduction in monthly
237 flow variability (Figure 2). There was also an observed change in peak flows from
238 October to November and an increase in the variability and intensity of July flows. A
239 shift from May to June of the most intense spring runoff peak flow was also observed.
240 Upstream changes were found during the time periods considered, with an increase in
241 intensity and variability of June and October flows and the suppression of the October
242 peak flow after 5 years of dam operational commissioning (Figure 2).

243

244 *Taxonomic analysis*

245 A total of 5541 individuals representing 25 fish species and 11 families were recorded.
246 The hierarchical clustering analysis showed that the effect of dam closure was stronger

247 than seasonality as it distinguished 3 groups according to the time periods defined
248 (before, < 5 yrs and > 5 yrs) for all locations with the exception of Upstream (where
249 because of a lack of data for < 5 yrs, only two groups were formed: before and > 5 yrs),
250 and no clear groups according to seasons. Fish assemblages were significantly different
251 between locations ($F_{3,6} = 19.11$, $R^2 = 0.27$, $p < 0.001$) and time periods ($F_{2,6} = 5.01$, R^2
252 $= 0.05$, $p < 0.001$). No significant interaction was found between locations and time
253 periods ($F_{5,6} = 1.35$, $R^2 = 0.03$, $p = 0.09$). There was no significant difference for the
254 mean Species richness (S) and Shannon entropy (H') between time periods in all the
255 locations (Figure 3; Supplementary material, Table S2).

256

257 The results of SIMPER analysis that compared the three groups defined by the cluster
258 analysis in each location showed the most significant overall dissimilarities occurred
259 between < 5yrs. and > 5 yrs. for all locations, with the exception of Upstream (Table 3).
260 The differences between the three groups that constituted the time periods analyzed
261 were explained mostly by the decrease in the relative abundance of Mountain Whitefish
262 (*Prosopium williamsoni*) in Downstream areas (D1 and D1) and in the Upstream stretch
263 (Table 4). In the Reservoir, Mountain Whitefish decreased during the < 5yrs. period and
264 increased > 5 yrs. while the relative abundance of Rainbow Trout (*Oncorhynchus*
265 *mykiss*) increased in D1, it decreased in D2 and was absent in the Reservoir after > 5
266 yrs. Longnose dace (*Rhinichthys cataractae*), was absent before the initiation of dam
267 operations in D1 and Upstream was one of the species that increased the most in relative
268 abundance of all locations. Also, the relative abundance of the Bull Trout (*Salvelinus*
269 *confluentus*) consistently decreased in all locations after dam closure and was
270 completely absent in the Reservoir after > 5yrs.

271

272 *Trait analysis*

273 The results from the correlation matrix indicated that 17 trait categories had a strong
274 correlation (Spearman Correlation $r_s > 0.7$). Consequently for subsequent analyses the
275 following highly correlated traits were eliminated: Origin - *introduced*, Conservation
276 status - *not at risk*, Migration - *resident*, Habitat preference – *benthopelagic*, Flow
277 preference – *generalist*, Spawning habitat – *generalist*, Reproductive timing – *winter*,
278 Nest – *open substratum*, Parental care – *no*, Feeding diet - *planktonic*, Life-history –
279 *lifespan* and *age at first maturity*, Adhesive eggs – *no*, Tolerance – *medium* and *high*.

280

281 The functional structure of fish communities were significantly different between
282 locations ($F_{3, 219} = 329.46$, $R^2 = 0.64$, $p < 0.001$) and time periods ($F_{2, 219} = 29.46$, $R^2 =$
283 0.13 , $p < 0.001$). The interaction between locations and time periods was also
284 significant ($F_{5, 21} = 15.15$, $R^2 = 0.05$, $p < 0.01$). Results from the multinomial regression
285 analyses indicated that for each location, there was a distinct combination of traits that
286 explained the changes that occurred between the time periods. For Downstream – D1,
287 the model selected 27 variables (Residual Deviance = 105.40; AIC = 153.40;
288 Supplementary material, Table S3 - A). For Downstream – D2 the model selected 31
289 variables (Residual Deviance = 211.74; AIC = 303.74; Supplementary material, Table
290 S3 - B). For the Reservoir the model selected 21 variables (Residual Deviance = 65.141;
291 AIC = 97.141; Supplementary material, Table S3 - C). For Upstream the model selected
292 29 variable (Residual Deviance: 41.328; AIC: 69.328; Supplementary material, Table
293 S3 - D). The 10 traits categories having the highest coefficient values were chosen for
294 the subsequent hierarchical clustering analysis (HCA) in each location (Table 5). The
295 results from HCA showed that the combination of traits was related to the formation of
296 different groups based on the time periods defined. When organized by season, no clear
297 groups formed, indicating that despite seasonal changes, time periods were more

298 strongly related to the formation of new communities. For all locations there was a clear
299 separations of time periods (before, < 5 yrs and > 5 yrs), indicating that the choice of
300 trait combinations were most strongly related to the new functional structure of
301 communities after dam closure. For the Reservoir, the most significant trait categories
302 that separated communities before and after dam closure were related to reproductive
303 requirements such as lotic flow for spawning and habitats favorable for nest building, as
304 well as parental care (Table 5). Also, water temperature (thermal preference – cold)
305 appeared to have an important role together with habitat preference (benthic) and
306 migratory behavior. Upstream, feeding diet (invertivore), migratory behavior, water
307 temperature (thermal preference – cold) were identified as relevant traits. Downstream,
308 for both areas (D1 and D2) reproduction types demonstrated a high relevance in
309 separating the groups (e.g.: lithophils - gravel/sand and lithophils - rock and gravel,
310 ariadnophils and speleophils for D1; and phytophils and psammophils for D2). In the
311 area closest to the dam face (D1) water temperature (thermal preference – cold) was the
312 most relevant trait. D2 was also related to reproductive traits (adhesive eggs and lotic
313 spawning habitat). Low tolerance appeared to be associated with Downstream - D2 and
314 Upstream (Table 5).

315

316 Discussion

317

318 This study responds to the recent necessity for complementing taxonomic and
319 functional analyses to characterize community response to environmental changes (Díaz
320 et al. 2007, Suding et al. 2008, Baraloto et al. 2012). Construction and operations of the
321 dam in the Oldman River system did not have a direct effect on overall taxonomic
322 diversity (mean Species richness and Shannon entropy) of fish in the system, but there

323 was a significant change in the relative abundances of species with contrasting
324 functional strategies. Most importantly, different changes were observed in a spatial-
325 temporal context, indicating that the longitudinal gradient formed after dam
326 construction (from Upstream to Downstream of the dam) played a key role in
327 determining which species-trait combinations showed greater responses to habitat
328 alterations.

329

330 Damming impacted the natural river flow with the loss of spring high flows and lower
331 winter flows. River temperature was altered with delayed spring-summer warming and
332 autumn cooling (Golder Associates Ltd. 2003). The large error bars after 5 years of dam
333 closure in upstream and downstream flow variations are associated with the year of
334 2005 and indicate an exceptional heavy rain event that struck the headwater tributaries
335 of the Saskatchewan River Basin in June of that year (Shook, 2015).

336

337 Although flow variation did not show a high coefficient value in any of the fitted
338 regression models, flow alterations as a consequence of dam operations have a direct
339 influence on water temperature (Olden and Naiman 2010). The Oldman Reservoir has
340 caused substantial changes in the downstream temperature regime relative to pre-
341 impoundment temperatures (Hazewinkel and Saffran 2007). Specifically, there was a
342 sharp temperature increase that coincided with the operation of the spillway and was
343 caused by the release of relatively warm epilimnetic water over the crest of the Oldman
344 River Dam during winter months. The greatest difference between post-impoundment
345 temperatures and pre-impoundment temperatures occurs during mid-June through late-
346 August, when the river directly downstream of the reservoir is substantially cooler than
347 observed under historical conditions prior to dam construction (Figure 4). In September,

there is a reversal of the cooling effect, such that river temperatures downstream of the reservoir are on average 2.3°C warmer than under historic conditions (Figure 4; Hazewinkel and Saffran 2007). These alterations are a strong indication that thermal preference is an important trait to be considered and studies have shown a link between water temperature alterations and a detrimental effect to freshwater fish (Olden and Kennard 2010, Olden and Naiman 2010). The trait preference for cold water showed a very high relevance Downstream close to the dam face. The cold water Mountain Whitefish and Bull Trout were among the main species responsible for the separation of groups in the taxonomic analysis. Their relative abundance decreased in all locations. This result supports the tenant that water temperature increases below the dam during cold months has had an influence in the functional response of communities. Upstream, however, other natural factors might be involved in a change of water temperature, such as the regional climate change as predicted by Schindler and Donahue (2006) and Shepherd et al. (2010) that might have resulted in an alteration of the natural river flow in the last decade (Figure 2). At the Downstream D1, after thermal preference, the combination of the most relevant traits were related to reproductive habitat requirements, demonstrating that dam operations and flow modifications may favor selection of fish with a reproductive preference for stable conditions, such as brood hidens, substrate choosers and lotic spawning habitats (McManamay and Frimpong 2015; e.g.: Longnose Dace, Longnose Sucker (*Catostomus catostomus*) and Rainbow Trout). Interestingly, further away downstream from the direct influence of the dam (D2), the trait of adhesive eggs was relevant, characteristic of the Longnose Sucker and the Longnose Dace, species that increased in relative abundance after dam closure.

372 The results from this study are generally in accordance to Mims and Olden (2013) and
373 McManamay and Frimpong (2015) who documented an increase in the proportion of
374 equilibrium strategists that followed hydrologic changes induced by dam regulation. In
375 the Reservoir, traits related to reproductive requirements (e.g., lotic spawning habitat,
376 nest building and parental care) as well as thermal preference, migration, lentic flow
377 preference and pelagic habitats were more relevant. This is in accordance to the findings
378 of Agostinho et al. (2008) who showed that the formation of a reservoir created a habitat
379 with a larger volume of lentic water. Consequently there was an observed increase in
380 pelagic species, adapted to lentic flow and a degradation of the environmental
381 conditions that allow parental care associated with benthic habitats that are inaccessible
382 or degraded by reservoir formation. Migratory species are also affected by the barrier
383 imposed by the dam. For example, the Westslope Cutthroat Trout and the Bull Trout
384 nearly disappeared from the reservoir area after > 5 yrs. of dam closure. Both require
385 lotic habitats to spawn, both are nest builders and migratory species. Also, these species
386 require the coldest water temperatures of any native salmonid; they require clean
387 substrates for spawning and rearing and connections between river, lake and headwater
388 streams that support annual spawning and feeding migrations (Liknes and Graham,
389 1988; Fraley and Shepard, 1989). In contrast, the White Sucker (*Catostomus*
390 *commersoni*) increased in relative abundance, likely linked to its generalist traits for
391 reproductive requirements (e.g., no spawning flow preference, open substratum and no
392 parental care). Longnose dace also increased after dam closure, especially at the
393 Reservoir and Upstream stretches. This species is non-migratory and is tolerant to a
394 wide range of flows (Cooper, 1980).

395

396 Functional adaptation (e.g., life history and behavioral) appear to play an important role
397 in the adaptation of certain species to the new environmental conditions after damming
398 and new flow scenarios (Lytle and Poff 2004). Life-history strategies, the seasonal
399 timing of flow events, water temperature and type of substrate are key traits to
400 adaptation potential. Life-history adaptations involve the synchronization of a life-stage
401 to long-term flow regime dynamics, rather than an immediate response to individual
402 flow events and are particularly important for organisms with complex or migratory life
403 cycle (Lytle and Poff 2004).

404

405 Changes in Upstream fish communities were unexpected, nevertheless studies have
406 demonstrated that large migratory species seek to avoid the impounded region in their
407 reproductive period, moving toward upstream areas (Antonio et al. 2007). Changes in
408 water temperature, probably related to regional climatic alterations in the head-water
409 areas of the Oldman basin appears to be relevant in the response of fish communities
410 after > 5 years. Upstream and Downstream areas showed variation in flow after > 5
411 years of dam closure, which indicates that a more general event could also contribute to
412 explaining the changes observed in fish communities, in addition to dam construction.
413 However, further hydro-climatic studies with a minimum of 20 years of flow records
414 are necessary to assess this possibility and to fully understand the implications and
415 potentially confounding effects from flow alterations in Reservoir and Downstream
416 from the dam.

417

418 Despite the fact that these results are difficult to extrapolate to other systems, as they are
419 based in one system alone, they show that this novel approach (using taxonomic and
420 trait metrics) can be very useful to the establishment of long term monitoring programs

421 as it provides a broader knowledge of fish community response to environmental
422 change, regardless of the driver. Taxonomical and functional analyses are
423 complementary and should be used to detect changes in particular species and/or traits
424 and their impacts on ecosystem processes that might followed (Lavorel and Garnier
425 2002, Bellwood et al. 2006). The ultimate impact of disturbance on community
426 composition depends not only on initial changes in community composition but also on
427 changes in their functional structure that will determine their reproductive success and
428 remain event in subsequent generations (Shea et al. 2002, Haddad et al. 2008). While
429 examples of ecological consequences to drastic hydrologic alterations are more common
430 (Poff et al. 2010), little empirical evidence is available for assessing ecological
431 responses to small or moderate hydrologic changes. Thus, understanding how natural
432 hydrology structures biotic communities in river systems provides a reference
433 framework to make future projections under a range of hydrologically altered scenarios.
434 In addition, more local-level analyses that consider the multidimensional nature of
435 hydrologic disturbances, such as water quality and temperature are needed to make
436 more accurate localized predictions.

437

438 This study demonstrates that integrating taxonomic and functional analyses to assess the
439 impact of river impoundment on fish community structure and function is more
440 informative than considering one approach alone. Alterations to taxonomic composition
441 in fish communities give initial clues to a functional response in a temporal-spatial
442 context. Using a suite of multivariate approaches allowed a reduction in the possible
443 trait combinations that were most significant in discriminating changes in fish
444 communities after dam closure. The longitudinal environmental gradient created by the
445 dam was shown to be important in determining which species and functional groups are

subsequently formed in the respective new habitat types created. This spatial effect is important to consider when planning adaptive management strategies and related biomonitoring programs. Further studies are necessary to develop an improved mechanistic understanding of how riverine impoundments affect the structural and functional diversity of fish communities in a spatial and temporal context. This step has to be made by determining species–environment relationships more effectively, taking into consideration linkages and interactions among traits and the fact that they are context-depend (Verberk et al. 2013). Understanding the underlying causes of why the combination of some traits are connected to the risk of extinction or a decline in distributions is an important step towards better conservation and mitigation strategies. Limitations of data availability and data quality in this study highlights the need to establish long-term biomonitoring programs that utilize standardized quantitative sampling procedures, are appropriately integrated with associated water quality/quantity and hydro-climatic monitoring programs, and have well defined quality assurance and control protocols. The ability to have open access to all data sources is also paramount.

Acknowledgements

This study was supported by National Foundation for Science and Technology (FCT) with a grant to ACL (SFRH/BD/51408/2011) and CESAM funding (UID/AMB/50017/2013). The authors would like to thank the anonymous reviewers for valuable comments and suggestions on the manuscript.

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674 Table 1 - Description of the sampling points, date and survey type of for each location
675 (Reservoir, Downstream - D1 and D2 and Upstream - U1 and U2).

Location	Period after dam construction	Year	Month	Season	Sampling points	Survey type
Reservoir	Before	1985	May	Spring	2	Electrofishing
			October	Autumn		
		1986	March	Spring	3	
			October	Autumn		
	< 5 yrs	1995	May	Spring	5	Gill Net
			October	Autumn		
		1996	May	Spring	5	
			October	Autumn		
	> 5 yrs	2006	May	Spring	5	
			October	Autumn		
			June	Spring/Summer		
Downstream (D1)	Before	1985	October	Autumn	3	
		1986	March	Spring	3	
	< 5 yrs	1994	May	Spring	3	

Location	Period after dam construction	Year	Month	Season	Sampling points	Survey type	
Downstream (D2)		1995	June	Spring/Summer	7	Electrofishing	
			May	Spring			
			October	Autumn			
		1996	June	Spring/Summer	7		
			May	Spring			
			October	Autumn			
	> 5 yrs	2005	June	Spring/Summer	5		
			May	Spring			
			October	Autumn			
		2006	May	Spring	5		
	Upstream (U1)	Before	1983	March	Spring		3
				June	Spring/Summer		
1985			May	Spring	3		
			June	Spring/Summer			
< 5 yrs			1995	June	Spring/Summer	7	
				May	Spring		
		October		Autumn			
		1996	June	Spring/Summer	5		
			May	Spring			
			October	Autumn			
> 5 yrs		1999	June	Spring/Summer	2		
			September	Autumn			
		2004	October	Autumn	5		
			2005	May		Spring	
	June	Autumn					
Upstream (U2)	Before	1985	May	Spring	3		
			October	Autumn			
		1986	March	Spring	7		
			2004	October		Autumn	
		> 5 yrs	2005	March	Spring		
			2006	September	Autumn		
Upstream (U2)	> 5 yrs	1984	April	Spring	3		
			May	Spring			
		1985	September	Autumn	3		
			October	Autumn			
		2007	May	Spring	3		
			October	Autumn			

Location	Period after dam construction	Year	Month	Season	Sampling points	Survey type
			May	Spring		
		2009	June	Spring/Summer	2	
			September	Autumn		

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677 Table 2 - Description of the sixteen trait classes used to characterize fish species.

Trait	Trait category/range	Description
<i>Origin</i>	Native	naturally occur in the Oldman River Basin
	Introduced	not originally from the Oldman River Basin and introduced intentionally or accidentally
<i>Conservation Status</i>	Not at risk;	
	Endangered+Special+Concern+Threatened	
<i>Migration</i>	Sedentary/Resident	not migrants
	Potamodromous	migrations occur wholly within fresh water
<i>Habitat use</i>	Benthic	occur mainly close to the substrate
	Pelagic	occur mainly in the pelagic area of the river
	Benthopelagic	live and feed near the bottom as well as in midwaters or near the surface
<i>Flow preference</i>	Lentic	Prefer lentic flow
	Generalist	Occur in both lentic and lotic flows
<i>Feeding diet</i> Based on a predominance of more than 50% of a food item	Invertivore	predominance of immature and adult insects forms
	Piscivore	predominance of fish including blood, scale and body parts
	Planktivore	predominance of planktonic microcystaceans
	Omnivore	similar proportions of animal and vegetal items
<i>Reproduction</i>		pelagic spawners
	Pelagophils	rock-gravel spawners with benthic larvae
	Lithophils (rock-gravel)	gravel-sand spawners with benthic larvae
	Lithophils (gravel-sand)	aquatic plants or flooded vegetation spawners
	Phytophils	sand spawners
	Psammophils	gravel-sand spawners with pelagic larvae
	Lithopelagophils	

Trait	Trait category/range		Description
	Ariadnophils		glue making spawners and male guarding eggs in nests
	Speleophils		cavity nesters
Reproductive timing	Winter; Autumn; Spring; Summer		
Spawning habitat	Lentic; Lotic; Generalist		
Nesting	Open spawners; Nest spawners	substratum	
Parental Care	Yes No		care for eggs and larvae do not display this behavior
Life-history			
MAXBL(cm)	8.7 – 241.4		Continuous variables
Age 1st mat (years)	1 - 20		
Lifespan (years)	3 – 155		
Fractional spawner	yes; no		Binary variables (0,1)
Adhesive eggs	yes; no		
Thermal preference			
Preferred temperatures determined for adult fish in laboratory experiments were used when available	Warm Cool Cold	> 25°C 19-25°C < 19°C	
Morphology			
Shape factor	4.17 – 13.37		ratio of total body length to maximum body depth
Swimming factor	0.5 – 0.62		ratio of minimum depth of the caudal peduncles to the maximum caudal fin depth
Tolerance			
General tolerance to pollution, turbidity; dissolved oxygen concentration	High; Medium; Low		

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680 Table 3 – Results from the SIMPER analysis of the total number of species that

681 accounted for 90% of the dissimilarity between the time periods: Before vs. < 5yrs;

Before vs. > 5yrs and < 5yrs vs. > 5yrs and their overall dissimilarity in respective locations (Downstream – D1 and D2, Reservoir, and Upstream).

	Before vs. < 5yrs		Before vs. >5yrs		< 5yrs vs. > 5yrs	
	species (n)	overall dissimilarity (%)	species (n)	overall dissimilarity (%)	species (n)	overall dissimilarity (%)
Downstream (D1)	11	0.65	11	0.66	11	0.77
Downstream (D2)	19	0.72	9	0.73	19	0.77
Reservoir	8	0.78	7	0.80	8	0.82
Upstream	-	-	14	0.80	-	-

Table 4 – Results from the SIMPER analysis of dissimilarity for the species contributing most to the differences between the three time periods (Before, < 5 yrs and > 5 yrs) in respective locations (Downstream D1 and D2, Reservoir and Upstream). Fish species contributing most to the dissimilarity between time periods are shown together with their average relative abundance (av.) and percentage contribution in dissimilarity (%).

Downstream (D1)				Downstream (D2)				Reservoir				Upstream			
Before vs. < 5yrs															
	av. B	av. <5yrs	%		av. B	av. <5yrs	%		av. B	av.<5yrs	%		av. B	av. A1	%
<i>P. williamsoni</i>	55.14	38.66	0.21	<i>P. williamsoni</i>	55.14	26.63	0.20	<i>P. williamsoni</i>	34.80	26.39	0.19	-	-	-	-
<i>O. mykiss</i>	20.14	21.11	0.13	<i>O. mykiss</i>	20.14	11.78	0.11	<i>R. cataractae</i>	14.27	25.0	0.16	-	-	-	-
<i>S. confluentus</i>	14.73	5.51	0.09	<i>R. cataractae</i>	0.0	18.0	0.09	<i>O.mykiss</i>	24.80	9.72	0.13	-	-	-	-
<i>R. cataractae</i>	0.0	12.06	0.06	<i>S. confluentus</i>	14.73	3.77	0.08	<i>S. confluentus</i>	23.27	4.17	0.12	-	-	-	-
<i>L. lota</i>	10.0	1.72	0.06	<i>C. commersoni</i>	0.0	12.28	0.061	<i>C. inconstans</i>	0.0	16.67	0.08	-	-	-	-
Before vs. > 5yrs															
	av. B	av. >5yrs	%		av. B	av. >5yrs	%		av. B	av. >5yrs	%		av. B	av. >5yrs	%
<i>P. williamsoni</i>	55.14	18.33	0.19	<i>P. williamsoni</i>	55.14	34.40	0.22	<i>P. williamsoni</i>	34.80	50.0	0.23	<i>P. williamsoni</i>	55.03	5.87	0.26
<i>O. mykiss</i>	20.14	26.90	0.09	<i>O. mykiss</i>	20.14	13.53	0.12	<i>C. commersoni</i>	0.0	33.33	0.17	<i>R. cataractae</i>	0.0	42.71	0.21
<i>R. cataractae</i>	0.0	15.87	0.08	<i>R. cataractae</i>	0.0	17.50	0.09	<i>O.mykiss</i>	24.80	0.0	0.12	<i>O.mykiss</i>	32.84	21.82	0.17
<i>S. confluentus</i>	14.73	3.57	0.07	<i>C. catostomus</i>	0.0	14.73	0.07	<i>S. confluentus</i>	23.26	0.0	0.11	<i>C. catostomus</i>	0.0	10.69	0.05
<i>C. catostomus</i>	0.0	14.08	0.07	<i>S. confluentus</i>	14.73	0.08	0.07	<i>C. catostomus</i>	0.0	16.67	0.083	<i>C. commersoni</i>	0.0	8.86	0.04
< 5yrs vs. > 5yrs															
	av. <5yrs	av.>5yrs	%		av.<5yrs	av.>5yrs	%		av.<5yrs	av.>5yrs	%		av.<5yrs	av.>5yrs	%
<i>P. williamsoni</i>	38.66	18.33	0.19	<i>P. williamsoni</i>	26.63	34.40	0.20	<i>P. williamsoni</i>	26.39	50.0	0.23	-	-	-	-
<i>O. mykiss</i>	21.11	26.90	0.16	<i>R. cataractae</i>	18.0	17.50	0.14	<i>C. commersoni</i>	4.17	33.33	0.17	-	-	-	-
<i>R. cataractae</i>	12.07	15.87	0.12	<i>O. mykiss</i>	11.78	13.53	0.11	<i>R. cataractae</i>	25.0	0.0	0.13	-	-	-	-

<i>C. catostomus</i>	5.86	14.05	0.08	<i>C. commersoni</i>	12.28	14.33	0.11	<i>C. catostomus</i>	5.56	16.68	0.09	-	-	-	-
<i>C. commersoni</i>	9.89	4.44	0.06	<i>C. catostomus</i>	11.21	14.74	0.09	<i>C. inconstans</i>	16.68	0.0	0.08	-	-	-	-

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Table 5 – Results from the multinomial regression model with a combination of the 10 species traits categories with the higher coefficient values for each location (Downstream – D1 and D2, Reservoir, and Upstream).

Downstream (D1)		Downstream (D2)		Reservoir		Upstream	
Variable	Coeff. value	Variable	Coeff. value	Variable	Coeff. value	Variable	Coeff. value
therm_pref_cold	9.45; 7.04	rep_phytophils	-33.35; -12.92	spaw_hab_lotic	-16.52; -8.77	feed_invertrivore	-5.04
rep_lithophils (g/s)	7.38; 1.19	rep_psammophils	28.05; -30.06	them_pref_cold	-12.36; -7.69	migr_potomod	-4.25
rep_lithophil (r/g)	-6.67; -3.10	feed_omnivore	22.95; -9.0	nest_spawner	-8.32; -6.28	thema_pref_cold	4.11
feed_generalist	6.80; -3.16	rep_ariadnophils	21.99; -0.69	habitat_benthic	-6.99; -7.74	feed_omnivore	3.40
spaw_hab_lentic	-6.28; -3.16	adhesive_eggs	21.66; -21.17	feed_hab_general	-4.20; 4.83	not_fract_spawner	-3.06
rep_ariadnophils	-6.29; -3.16	spaw_hab_lotic	-20.97; -41.67	feed_hab_pelagic	-4.12; 11.30	orign_native	-2.79
rep_speleophils	5.98; 1.06	rep_lithophil (r/g)	19.91; 46.22	migr_potomod	-3.51; -1.99	rep_speleophils	2.32
habitat_pelagic	5.55; 1.19	rep_litho-pelagophils	-19.55; 3.91	feed_omnivore	-4.04; -1.41	parental care	2.32
feed_habitat_benthic	4.85; -1.73	tolerance_low	-15.95; -3.07	parental care	-2.96; -6.33	tolerance_low	-2.05
feed_omnivore	-4.68; 1.94	nest_spawner	14.18; 32.37	flow_lentic	2.03; 1.85	habitat_benthic	-1.83

Figure Captions

Figure 1 – Location of the study area: a – Canada, b – Alberta; c – Oldman River. Sampling sites locations: Downstream (**D1** and **D2**); Reservoir (**R**) and Upstream (**U**): (**U1** and **U2**). Gauge station 05AA024 (**GS1**); Gauge station 05AA008 (**GS2**).

Figure 2 - Mean monthly discharge (m^3/s) and standard deviation for Oldman River before (1983 to 1986), during the first 5 years (1994 to 1998) and after 5 years (1999 to 2010) of dam closure, in the locations Downstream and Upstream.

Figure 3 - Box-plots of species richness (S) and diversity (Shannon entropy) between locations (Downstream - D1 and D2, Reservoir – R and Upstream - U) and time periods (before, < 5 yrs and > 5 yrs).

Figure 4 – Daily average water temperature in the Oldman River near Brocket (approx. 100 m downstream from the dam) in the periods before dam closure (1985, 1988-1990), transition (1991-1992) and post-dam closure (1993-2001). Adapted from Hazewinkel and Saffran (2007).

Figure 1 – Location of the study area: a – Canada, b – Alberta; c – Oldman River. Sampling sites locations: Downstream (D1 and D2); Reservoir (R) and Upstream (U): (U1 and U2). Gauge station 05AA024 (GS1); Gauge station 05AA008 (GS2).

182x156mm (300 x 300 DPI)

Mean monthly discharge (m³/s) and standard deviation for Oldman River before (1983 to 1986), during the first 5 years (1994 to 1998) and after 5 years (1999 to 2010) of dam closure, in the locations Downstream and Upstream.

250x328mm (300 x 300 DPI)

Box-plots of species richness (S) and diversity (Shannon entropy) between locations (Downstream - D1 and D2, Reservoir - R and Upstream - U) and time periods (before, < 5 yrs and > 5 yrs).

110x141mm (300 x 300 DPI)

Daily average water temperature in the Oldman River near Brocket (aprox. 100 m downstream from the dam) in the periods before dam closure (1985, 1988-1990), transition (1991-1992) and post-dam closure (1993-2001). Adapted from Hazewinkel and Saffran (2007).

93x62mm (300 x 300 DPI)

Supplementary Information

Table S1 – Species classification into trait categories.

pecies	Common name	Origin	Conser Statuts	Migration	Habitat pref.	Flow pref.	Feeding habitat	Spawning habitat	Reprod.	Reprod. timming	Nesting	Parental care	Themral pref.	Feeding diet	Life History				Body morphology			Tol.
															MAX BL	Age at 1st mat	Lifespan	Fract. Spaw.	Adhes. eggs	Shape factor	Swim. factor	
<i>Acipenser fulvescens</i>	Lake sturgeon	native	at risk	Potamodromous	benthic	generalist	benthic	generalist	Litho-pelagophils	spring	Open substrat. spawner	No	cold water	invertivore	170	20	154	no	yes	13.365	0.62	medium
<i>Catostomus catostomus</i>	Longnose sucker	native	not at risk	Potamodromous	benthic	generalist	benthic	lotic	Lithophils (rock-gravel)	spring	Open substrat. spawner	No	cool water	invertivore	52.1	6	24	no	yes	5.552	0.388	low
<i>Catostomus commersoni</i>	White sucker	native	not at risk	Potamodromous	benthic	generalist	benthic	generalist	Lithophils (rock-gravel)	spring	Open substrat. spawner	No	cool water	invertivore	52.6	4	15	no	no	5.222	0.405	low
<i>Catostomus platyrhynchus</i>	Mountain sucker	native	not at risk	Potamodromous	pelagic	generalist	benthic	lotic	Lithophils (rock-gravel)	spring	Open substrat. spawner	No	cool water	invertivore	19.6	4	9	yes	yes	4.947	0.459	medium
<i>Castomus sp.</i>	Sucker	native	not at risk	Potamodromous	benthic	generalist	benthic	lotic	Lithophils (rock-gravel)	spring	Open substrat. spawners	No	cool water	invertivore	41.4	4.7	16	yes	yes	5.522	0.405	medium
<i>Moxostoma macrolepidotum</i>	Shorthead redhorse	native	not at risk	Sedentary /Resident	benthic	generalist	benthic	lotic	Lithophils (gravel-sand)	spring	Open substrat. spawners	No	warm water	invertivore	59.4	3	14	yes	yes	5.222	0.405	medium
<i>Cottus ricei</i>	Spoonhead sculpin	native	not at risk	Sedentary /Resident	benthic	generalist	benthic	generalist	Speleophils	spring	Nest-spawners	Yes	cold water	invertivore	13.5	2	6	no	yes	7.571	0.456	low
<i>Couesius plumbeus</i>	Lake chub	native	not at risk	Sedentary /Resident	benthopel	lentic	benthic	lotic	Lithophils (rock-gravel)	summer	Open substrat. spawners	No	cold water	invertivore	16.6	3	5	no	no	4.383	0.372	low
<i>Notropis atherinoides</i>	Emerald shiner	native	not at risk	Sedentary /Resident	benthopel	generalist	pelagic	generalist	Pelagophils	spring	Open substrat. spawners	No	cool water	planktivore	11	1	4	no	no	5.146	0.37	high
<i>Notropis hudsonius</i>	Spottail shiner	native	not at risk	Sedentary /Resident	benthopel	generalist	generalist	generalist	Litho-pelagophils	autumn	Open substrat. spawners	Yes	cool water	invertivore	10	1	4	no	no	4.585	0.382	low
<i>Pimephales promelas</i>	Fathead minnow	native	not at risk	Sedentary /Resident	benthopel	lentic	benthic	lotic	Speleophils	summer	Nest-spawners	Yes	warm water	omnivore	9.3	1	4	yes	yes	4.585	0.382	low
<i>Rhinichthys cataractae</i>	Longnose dace	native	not at risk	Sedentary /Resident	benthic	generalist	benthic	lotic	Lithophils (rock-gravel)	summer	Open substrat. spawners	No	cool water	invertivore	12.6	2	5	yes	yes	4.837	0.333	medium
<i>Semotilus margarita</i>	Pearl dace	native	not at risk	Sedentary /Resident	benthopel	lentic	benthic	lotic	Lithophils (gravel-sand)	summer	Open substrat. spawners	No	cool water	invertivore	15.3	2	4	yes	no	5.146	0.37	low
<i>Esox lucius</i>	Northern pike	native	not at risk	Potamodromous	benthopel	generalist	pelagic	lentic	Phytophils	spring	Open substrat. spawners	No	cool water	piscivore	122	3	12	no	yes	5.968	0.35	medium
<i>Culaea inconstans</i>	Brook stickleback	native	not at risk	Potamodromous	benthopel	generalist	generalist	lentic	Ariadnophils	spring	Nest-spawners	Yes	cool water	omnivore	8.7	1	3	yes	yes	6.8	0.227	medium
<i>Hiodon tergisus</i>	Mooney	native	not at risk	Potamodromous	pelagic	lentic	pelagic	lotic	Litho-pelagophils	spring	Open substrat. spawners	No	warm water	invertivore	31.3	5	8	yes	no	6.068	0.5	medium
<i>Lota lota</i>	Burbot	native	not at risk	Potamodromous	pelagic	lentic	generalist	generalist	Psammophils	winter	Open substrat.	No	cool water	piscivore	100	3	13	yes	no	4.17	0.367	low

pecies	Common name	Origin	Conser	Migration	Habitat pref.	Flow pref.	Feeding habitat	Spawning habitat	Reprod	Reprod. timing	Nesting spawners	Parental care	Thermal pref.	Feeding diet	Life History				Body morphology		Tol.	
<i>Sander vitreus</i>	Walleye	native	not at risk	Potamodromous	benthopel	lentic	pelagic	generalist	Litho-pelagophils	spring	Open substrat. spawners	No	cool water	piscivore	70	5	20	yes	yes	5.552	0.338	medium
<i>Percopsis omiscomaycus</i>	Trout-perch	native	not at risk	Sedentary /Resident	benthopel	generalist	benthic	generalist	Lithophils (rock-gravel)	spring	Open substrat. spawners	No	cool water	invertivore	11.9	2	4	no	yes	4.585	0.382	low
<i>Coregonus clupeaformis</i>	Lake whitefish	native	not at risk	Potamodromous	benthic	lentic	benthic	lentic	Lithophils (rock-gravel)	autumn	Open substrat. spawners	No	cold water	invertivore	63	4	28	yes	yes	7.121	0.343	medium
<i>Oncorhynchus clarki lewisi</i>	Westslope Cutthroat Trout	native	not at risk	Potamodromous	benthopel	generalist	generalist	lotic	Lithophils (rock-gravel)	spring	Nest-spawners	No	cold water	invertivore	30	3	10	yes	no	5.076	0.435	medium
<i>Oncorhynchus mykiss</i>	Rainbow trout	introd.	not at risk	Potamodromous	benthopel	generalist	generalist	lotic	Lithophils (rock-gravel)	spring	Nest-spawners	No	cold water	invertivore	87.5	4	8	yes	no	5.105	0.437	low
<i>Prosopium williamsi</i>	Mountain whitefish	native	not at risk	Potamodromous	benthopel	generalist	benthic	lotic	Lithophils (rock-gravel)	spring	Open substrat. spawners	No	cold water	omnivore	58.5	3	18	yes	no	5.057	0.329	medium
<i>Salmo trutta</i>	Brown trout	introd.	not at risk	Potamodromous	benthopel	generalist	pelagic	lotic	Lithophils (rock-gravel)	spring	Nest-spawners	No	cold water	invertivore	87	3	18	no	yes	5.611	0.368	medium
<i>Salvelinus confluentus</i>	Bull trout	native	at risk	Potamodromous	benthopel	generalist	pelagic	lotic	Lithophils (rock-gravel)	spring	Nest-spawners	No	cold water	piscivore	86	5	19	no	no	5.854	0.309	medium

Table S2 – Results from the Kruskal-Wallis test and *post hoc* pairwise test for multiple comparisons of mean rank sums (Nemenyi-test) for Species richness (S) and Shannon entropy (H') between time periods (before, < 5 yrs, > 5 yrs) in respective locations (Downstream – D1 and D2, Reservoir - R, and Upstream - U). Significant p-values are indicated in bold.

Species richness (S)				Shannon entropy (H')		
Location	Kruskal-Wallis	time	Nemenyi test	Kruskal-Wallis	time	Nemenyi test
D1	H = 8.57	before vs. < 5yrs	0.15	H = 7.42	before vs. < 5yrs	0.22
	p-value = 0.014	before vs. > 5yrs	0.84	p-value = 0.02	before vs. > 5yrs	0.91
		< 5yrs vs. > 5yrs	0.07		< 5yrs vs. > 5yrs	0.08
	H = 4.46	before vs. < 5yrs	0.48	H = 4.04	before vs. < 5yrs	0.64
D2	p-value = 0.11	before vs. > 5yrs	0.22	p-value = 0.13	before vs. > 5yrs	0.31
		< 5yrs vs. > 5yrs	0.26		< 5yrs vs. > 5yrs	0.22
	H = 0.56	before vs. < 5yrs	0.87	H = 0.60	before vs. < 5yrs	0.98
R	p-value = 0.76	before vs. > 5yrs	0.89	p-value = 0.74	before vs. > 5yrs	0.85
		< 5yrs vs. > 5yrs	0.71		< 5yrs vs. > 5yrs	0.77
U	H = 3.27	-	-	H = 2.65	-	-
	p-value = 0.07	-	-	p-value = 0.10	-	-

Table S3 – Results from the multinomial regression model with all selected species traits categories and their coefficient values for each location (Downstream – D1 and D2, Reservoir, and Upstream).

A - Downstream D1
(Intercept) + flow (-0.01, -0.031) + orign_native (-2.721, -5.201) + cv_at_risk (0.541, -0.29) + mig_potomad (-0.37, -2.83) + hab_pelagic (5.55, 1.18) + hab_benthic (1.170, -7.25) + flow_lentic (-1.83, -0.002) + feed_benthic (4.85, -1.73) + feed_pelagic (0.54, -0.29), feed_gener (-6.79, -1.98), spaw_lentic (-6.28, -3.16), spaw_lotic (0.60, 1.78), rep_spel (5.98, 1.05), rep_litho_rg (-6.65, -3.10), rep_litho_gs (7.38, 1.18), rep_psam (-1.83, -0.002), rep_ariad (-6.28, -3.16), repT_spring (2.13, -2.554334), nest_spaw (1.56, -1.22), pc_yes (-0.29, -1.22), themal_cold (9.45, 7.04), repT_spring (2.13, -2.55), nest_spaw (1.56, -1.22), pc_yes (-0.29, -2.10), themal_cold (9.45, 7.04), feed_invert (4.56, -5.66), feed_psiciv (-1.28, -0.29), feed_onmiv (-4.67, 1.94)
B - Downstream D2
(Intercept) + flow (0.17, 0.36), orign_native (-3.79, 10.52), mig_potomad (1.68, -14.716), hab_pelagic (-0.002, -43.88), hab_benthic (18.90, 4.90), flow_lentic (20.53, 19.38), feed_benthic (5.14, 11.13), feed_pelagic (-3.61, -6.13), feed_gener (-2.11, -3.19) + spaw_lentic (-3.35, 12.25) + spaw_lotic (-20.97, -41.66), rep_spel (-9.18, -2.01) + rep_litho_rg (19.91, 46.21) + rep_litho_gs (-3.17, -0.70), rep_litho_pela (-19.549, 3.91), rep_psam (28.04, -30.06) + rep_ariad (21.99, -0.69) + rep_phyto (-33.34, -12.92), repT_spring (-10.81, -10.81) + repT_summer (-14.59, 1.10) + repT_autumn (-0.2, 12.35) + nest_spaw (14.18, 32.37) + pc_yes (4.79, -16.23) + themal_cold (5.54, 2.18) + thermal_warm (16.94, 40.26), feed_invert (-4.38, -10.39), feed_psiciv (-13.86, 23.12) + feed_onmiv (22.95, -8.99), MAXBL (0.062, -0.05) fc_no (10.99, -21.08), adEggs_yes (21.66, -21.17), shape_factor (-4.52, -2.18), swim_factor (-7.69, -0.259846), swim_factor (-7.69, -0.25), tol_low (-15.95, -3.07)
C - Reservoir
(Intercept) + orign_native (-1.68, 0.59) + cv_at_risk (1.40, 3.08) + mig_potomad (-3.51, -1.99) + hab_pelagic (-2.03, 1.85) + hab_benthic (6.99, 7.74) + flow_lentic (-2.03, 1.85) + feed_benthic (2.96, 6.33) + feed_pelagic (-4.12, -11.30) + feed_gener (-4.20, 4.83) + spaw_lotic (-16.52, 8.77) + rep_litho_rg (-5.36, 0.05) + rep_psam (-2.03, 1.85) + repT_spring (-5.36, 0.05) + repT_summer (-4.10, -0.32) + nest_spaw (-8.32, -6.28) + themal_cold (-12.36, -7.69) + thermal_warm + feed_invert (-4.40, 0.05) + feed_psiciv (-0.63, 4.93) + feed_onmiv (-4.04, -1.41) + MAXBL (0.37, 0.46)
D - Upstream
(Intercept) + flow (-0.58) + orign_native (-2.79) + cv_at_risk (-0.08) + mig_potomad (-4.25) + hab_pelagic (-1.81) + hab_benthic (-1.83) + flow_lentic (-1.09) + feed_benthic (0.11) + feed_pelagic (0.18) + feed_gener (-1.52) + spaw_lotic (-0.56) + rep_spel (2.32) + rep_litho_rg (-1.75) + rep_litho_gs (-1.70) + rep_psam (-0.11) + repT_spring (-1.20) + repT_summer (1.63) + nest_spaw (1.09) + pc_yes (2.32) + themal_cold (4.11) + feed_invert (-5.04) + feed_psiciv (-0.19) + feed_onmiv (3.40) + MAXBL (0.23) + fc_no (-3.06) + adEggs_yes (0.86) + shape_factor (-1.31) + swim_factor (-0.84) + tol_low (-2.05)

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