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Temperature effects on body size of freshwater crustacean zooplankton from Greenland to the tropics

Havens, K.E.; Motta Pinto- Coelho, R.; Beklioglu, M.; Christoffersen, K.S.; Jeppesen, E.; Lauridsen, T.; Mazumder, A.; Méthot, G.; Pinel Alloul, B.; Tavşanoğlu, U.N.; Erdoğan, S.; Vijverberg, J.

published in

Hydrobiologia
2015

DOI (link to publisher)

[10.1007/s10750-014-2000-8](https://doi.org/10.1007/s10750-014-2000-8)

document version

Peer reviewed version

[Link to publication in KNAW Research Portal](#)

citation for published version (APA)

Havens, K. E., Motta Pinto- Coelho, R., Beklioglu, M., Christoffersen, K. S., Jeppesen, E., Lauridsen, T., Mazumder, A., Méthot, G., Pinel Alloul, B., Tavşanoğlu, U. N., Erdoğan, S., & Vijverberg, J. (2015). Temperature effects on body size of freshwater crustacean zooplankton from Greenland to the tropics. *Hydrobiologia*, 743(1), 27-35. <https://doi.org/10.1007/s10750-014-2000-8>

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1 Accepted by Hydrobiologia: 14/7/014

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3 **Temperature effects on body size of freshwater crustacean zooplankton from**
4 **Greenland to the tropics**

5

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40 **Abstract** The body size of zooplankton has substantive effects on the function of aquatic
41 food webs because size affects the ability of zooplankton to: exploit food resources,
42 effectively clear the water of algae, and serve as a food source for fish. A variety of factors
43 may affect size, and earlier studies indicate that water temperature may be a particularly
44 important variable. Here we tested the hypothesis that the body size of cladocerans,
45 calanoids and cyclopoids declines with increasing water temperature, a response
46 documented in an earlier study that considered only cladoceran zooplankton. We tested
47 the hypothesis by comparing body size data that were available from prior studies of lakes
48 ranging from 6 to 74° latitude and encompassing a temperature range of 2 to 30°C.
49 Cladoceran body size declined with temperature, however, the trend was just marginally
50 significant ($p = 0.01$). The decline in size was significant ($p = 0.05$) for cyclopoids. In both
51 cases, there was considerably more variation around the regression than previously
52 observed suggesting that other variables such as fish predation played an important role in
53 affecting size. Calanoid body size was unrelated to temperature. In contrast with
54 cladocerans and cyclopoids, perhaps calanoid body size is not metabolically constrained by
55 temperature or is differently affected by changes in fish predation occurring with
56 increasing temperature. The unexpected result for calanoids requires further investigation.

57

58 **Keywords** zooplankton size; latitudinal patterns; global comparison

59

60

61 **Introduction**

62 Body size of zooplankton is a highly important attribute because of the influence it has on
63 bioenergetics in aquatic food webs. Body size affects the manner in which the zooplankton
64 interacts with its resources. Large-bodied zooplankton have higher grazing rates, they
65 graze a wider size range of food items, and therefore have greater top-down effects on
66 resources than small-bodied zooplankton (Carpenter & Kitchell, 1988). Likewise body size
67 affects the availability and antipredator responses of zooplankton to both invertebrate and
68 vertebrate predators (Zaret, 1980; Gelinas et al., 2007), and the relationship between
69 phytoplankton biomass and phosphorus in lakes (Mazumder, 1994a; b and see the review
70 by Meerhoff et al., 2012).

71 In warm water lakes the size of zooplankton generally is smaller than of those in cold
72 water lakes. The reasons for this trend have been debated, yet so far, answers are
73 inconclusive. When considered alone and independent of other factors, higher temperature is
74 expected to result in smaller animals because higher temperature shortens generation time
75 (Gillooly, 2000) resulting in smaller adult body size (Geiling & Campbell, 1972; Angilletta &
76 Dunham, 2003). This phenomenon is not restricted to zooplankton. Atkinson (1994)
77 conducted a review and found that >80% of ectothermic species studied in laboratory
78 experiments displayed faster growth and smaller adult size at higher temperatures, and in
79 general, animals in colder climates are larger as adults than conspecifics at colder
80 temperatures (Ashton, 2001).

81 Larger zooplankton also may be more susceptible to thermal stress at high
82 temperatures (Moore et al., 1996). However, changes in temperature also can have indirect
83 effects on the food web, and these could be of greater importance than direct effects in

84 determining zooplankton body size. Hart & Bychek (2011) reviewed the factors affecting
85 body size and concluded that 'direct thermal effects on body size are commonly confounded
86 by other environmental factors that are related directly or indirectly to temperature' and
87 that 'predation undoubtedly has an over-riding influence on body size selection.'

88 One prior study examined the relationship of body size in freshwater cladoceran
89 zooplankton with latitude and temperature (Gillooly & Dodson, 2000) using data from
90 1,100 lakes between 7 and 78° latitude in North, Central and South America. The authors
91 found that temperature alone explained over 90% of variation in cladoceran body size. In
92 that study the authors did not use direct measurements of size. They took species lists from
93 the literature and estimated size based on assumptions including invariant size within
94 species and even distribution of density among species in lakes. This makes our study
95 unique, in being the first to address the relationship between size and temperature with
96 actual measurements of density and biomass of cladocerans, and the first to broaden the
97 assessment to include cyclopoids and calanoids.

98 We obtained crustacean zooplankton data from published studies conducted in
99 Brazil, Canada (British Columbia and Ontario), Ethiopia, Greenland, Turkey and the USA
100 (Alaska and Florida). All datasets had direct measurements of density, and biomasses were
101 calculated from body lengths using published and well-accepted allometric methods. We
102 calculated the mean body size (μg dry weight) of cladocerans, calanoids and cyclopoids in
103 each region by dividing total biomass by total density in each of these major taxonomic
104 groups. We tested the hypothesis that body size of cladocerans, cyclopoids and calanoids
105 declines with temperature across the broad latitudinal gradient of our study lakes.

106

107 **Methods**

108 Study Lakes

109 We used pre-existing data from lakes representing a wide range of nutrient concentrations,
110 six countries and several climactic regions (Fig. 1, Table 1). Late summer samples were
111 used (August-September in Canada, United States and Turkey, and September in
112 Greenland), because only that period of time was sampled in synoptic surveys in Greenland
113 and Turkey and so that data would be comparable in regard to the time of full development
114 of crustaceans and highest fish predation (Jeppesen et al., 1997). In Ethiopia and Brazil,
115 data were taken from the dry season (November to January in Ethiopia, July-August in
116 Brazil), which also are times of high fish predation (Vijverberg et al., 2014). During the
117 rainy season (July-September) in N.E. Africa and in South America, short water residence
118 times flush zooplankton from lakes and reservoirs, making it an unsuitable time for
119 studying zooplankton.

120

121 Sampling Methods

122 Detailed sampling methods are provided in published papers dealing with other aspects of
123 the plankton: for Greenland (Jeppesen et al., 2001); Ontario, Florida and Brazil (Pinto-
124 Coelho et al., 2005); British Columbia (Kainz et al., 2004); and Africa (Vijverberg et al.,
125 2014). Therefore, only brief descriptions of methods are provided here.

126 Sampling methods in all lakes except Turkey collected animals from the entire water
127 column. In Greenland, mid-lake depth-integrated water samples (20-25L) were taken with
128 a Patalas sampler. Of the pooled sample, a 15-20 L subsample was filtered on a 20 µm filter.
129 In Turkey, a 40 L mid-lake integrated water sample through the entire mixed layer was

130 taken with a KC Denmark Water Sampler (3.5 L), and 20 L was filtered through a 20 μm
131 filter. In Ontario, zooplankton was sampled from the entire water column at the deepest
132 site in the lakes by vertical tows with a 53 μm mesh conical plankton net. In British
133 Columbia and Alaska, vertical tows of a 64 μm mesh conical net were taken from 1 m above
134 the sediments to the surface at the deepest location in the lakes. In Florida, Ethiopia and
135 Brazil, single vertical tows of the entire water column were done with conical nets with
136 153, 150 and 90 μm mesh, respectively. In Ethiopia, water column samples were collected
137 from three open-water sites, whereas in Brazil, water column samples were taken from 11
138 sites in Furnas Reservoir and 2 sites in Ibirité Reservoir (Pinto-Coelho et al. 2005).

139 Samples from Alaska, Canada, Florida, Ethiopia and Brazil were preserved in 10%
140 formalin. In Greenland and Turkey, samples were preserved in 4% Lugol's. Crustacean
141 zooplankton was enumerated at 40, 50 or 100x magnification, and 25-50 individuals
142 (where possible) of each species were measured with an ocular micrometer to the nearest
143 25 μm . Standard allometric equations were used to convert body lengths to biomass
144 (Dumont et al., 1975; McCauley, 1984).

145 In a large compilation of data from many different regions, it is optimal if sampling
146 methods are identical. In practice this rarely is possible, but the methods used here were
147 comparable and were adequate to collect a representative sample of crustacean
148 zooplankton, as for the most part, only nauplii and rotifers passed through the nets, even in
149 Florida, where the largest mesh size was used (Havens et al., 1996). Here we examined
150 body size only for adults and copepod copepodids, so loss of those smaller animals was not
151 an issue. While chemical preservation can affect the dry weight of zooplankton (Giguere et
152 al., 2011), we are aware of no literature that examines effects of different chemical

153 preservatives on body lengths, which were used in this study to estimate weight with
154 standard equations.

155 The average body size ($\mu\text{g dry weight animal}^{-1}$) was determined separately for
156 cladocerans, calanoids and cyclopoids, by dividing the total biomass of the group ($\mu\text{g dry}$
157 weight L^{-1}) by the total numeric density (animals L^{-1}). We did not weight the calculations by
158 relative densities of species in each lake, because the individual species measurement and
159 body size data were not available to the authors. Although body lengths might be more
160 relevant to predators than body size in μg , the authors did not have access to the thousands
161 of raw count sheets where body length measurements were recorded.

162 Water temperatures were measured *in situ* and reflect either near-surface
163 temperatures in shallow mixed lakes or the average epilimnetic temperatures in deeper
164 stratified lakes.

165

166 Data Analysis

167 We examined graphically the relationship between the body size of cladocerans, calanoids
168 and cyclopoids and water temperature, and fitted linear regressions to the non-
169 transformed data, using means from each lake region. We did not use data from individual
170 lakes, because the number of data points varied widely among the regions, such that
171 certain lake-rich locations such as Greenland would have largely driven the results. We also
172 did not transform the data because in general, the number of lakes per region was low, and
173 the body size data from the regions were not highly skewed.

174 In the 59 lake dataset from Greenland, 29 of the lakes were free of fish because they
175 freeze solid to the bottom in winter or due to the fact that the lakes today are or in the past

176 have not been connected to the sea, preventing fish colonization. In order to elucidate the
177 importance of fish predation on mean body size of crustacean zooplankton, we compared
178 body sizes of cladocerans, cyclopoids and calanoids between the two groups of Greenland
179 lakes: fishless vs. lakes with fish.

180 We also examined an alternative explanation for body size differences among lake
181 regions; i.e, differences in trophic state. We used linear regression to explore whether there
182 were significant relationships between lake trophic state and the body size of cladocerans
183 and copepods. We used total phosphorus (TP) as a surrogate for trophic state, because it
184 was measured in all of the lakes except for those in Ethiopia. All statistical analyses were
185 done with SYSTAT 13.

186

187 **Results**

188 Across all of the lakes there were 85 species of cladocerans, 18 calanoids and 27
189 cyclopoids (Appendix 1). Only five species of cladocerans occurred in more than four lake
190 regions (*Bosmina longirostris*, *Chydorus sphaericus*, *Diaphanosoma brachyurum*, *Holopedium*
191 *gibberum* and *Polyphemus pediculus*). No species of calanoids or cyclopoids occurred in
192 more than two regions.

193 The mean body size of cladocerans declined with increasing temperature (Fig. 2A).
194 The largest mean size was in Greenland at an average water temperature of 12°C, and
195 smaller animals occurred in Florida at 30°C. There was considerable scatter of data around
196 the mean values, and the linear regression explained just 33% ($p = 0.10$) of the variability
197 in the data, i.e. it was only marginally significant. There were smaller cladocerans in Alaska
198 at 16°C than in Florida at 30°C (one-way ANOVA, $p < 0.05$). Mean body size of cyclopoids

199 also declined with increasing water temperature, there was somewhat less scatter around
200 the means, and a larger amount of overall variation in body size (38%, $p = 0.05$) was
201 explained by temperature than was the case for cladocerans. Largest animals were in the
202 cold lakes in Greenland and smallest animals were in the warm-water lakes in Florida (Fig.
203 2B). There was no significant relationship between the mean body size of calanoids and
204 water temperature (Fig. 2C). It was equally likely to find large and small animals in lakes at
205 high and low water temperatures.

206 Although earlier studies have identified effects of trophic state on zooplankton body
207 size, in particular smaller cladocerans and larger copepods in lakes with higher TP
208 (Jeppesen et al., 2000), in this study body size was not affected by that attribute. There
209 were no significant relationship between body size of any crustacean zooplankton group
210 and TP for the regionally aggregated data (cladocerans: $r^2 = 0.08$, $p > 0.4$; cyclopoids, $r^2 =$
211 0.01 , $p > 0.9$; calanoids, $r^2 = 0.07$, $p > 0.6$).

212 A closer examination of the Greenland data was done by comparing lakes with fish
213 and without fish. The lakes did not differ importantly in trophic state (TP $10 \pm 6 \mu\text{g L}^{-1}$ with
214 fish, $18 \pm 8 \mu\text{g L}^{-1}$ without fish) or water temperature ($12.2 \pm 4^\circ\text{C}$ with fish vs. $11.7 \pm 3^\circ\text{C}$
215 without fish), only in the presence or absence of planktivores. Cladoceran body size was 5-
216 fold higher ($p < 0.001$) in the fishless lakes ($10.9 \pm 3.1 \mu\text{g}$) than in the lakes with fish
217 ($2.2 \pm 1.3 \mu\text{g}$). Body size of cyclopoids was marginally higher ($p < 0.05$) in the fishless lakes
218 ($6.1 \pm 1.4 \mu\text{g}$) than in the lakes with fish ($4.4 \pm 1.5 \mu\text{g}$), and body size of calanoids did not
219 significantly differ between lake types ($1.4 \pm 0.2 \mu\text{g}$ in lakes with fish, vs. $1.6 \pm 0.2 \mu\text{g}$ in
220 fishless lakes).

221

222 Discussion

223 This is the first study to quantify with actual measurements of density and biomass
224 of zooplankton (from 123 lakes including 85 species) whether or not cladocerans become
225 smaller as one moves southward from the Arctic to the tropics. We observed a declining
226 trend in size; however it was just marginally significant at $p = 0.10$. While the trend was
227 weak, in general it was in agreement with that found in an earlier study (Gillooly & Dodson,
228 2000). The greater variability of our results is possibly explained by differences in
229 methodology. While we measured species' densities and biomass, Gillooly and Dodson
230 (2000) worked only with species lists, and they assumed that: (1) in any lake, the density of
231 every species is equal; and (2) across all lakes, the size of any given species does not vary.
232 Because we took a more direct approach that did not require such assumptions, our results
233 provide a more realistic picture of what occurs in lakes, where other factors interact with
234 temperature to influence body size.

235 To illustrate what affect the assumption of invariant species' size can have on the
236 variability of results, we examined the degree of variation in mean body size of dominant
237 cladoceran species between individual lakes, considering two selected regions – one in the
238 subtropics (Florida) and one in the north temperate zone (British Columbia). In Florida,
239 four species accounted for 94% of the total density of cladocerans: *Bosminopsis dietersi*,
240 *Eubosmina tubicen*, *Daphnia lumholtzi* and *Diaphanosoma brachyurum*. Had we assumed
241 invariant body sizes, it would have markedly affected our results, because actual body sizes
242 varied by more than two-fold among the lakes. The actual mean sizes (in μg dry weight,
243 averaged by lake) ranged from 0.7 to 1.2 for *B. dietersi*, from 0.4 to 0.8 for *E. tubicen*, from
244 3.5 to 8.4 for *D. lumholtzi*, and from 0.6 to 1.4 for *D. brachyurum*. In British Columbia, where

245 the mean body size of the cladoceran assemblage was highly variable, four species
246 accounted for 99% of total biomass: *Bosmina longirostris*, *Diaphanosoma brachyurum*,
247 *Holopedium gibberum* and *Daphnia* sp. Again, had we assumed an invariant species' body
248 sizes, it would have considerably affected our results, greatly reducing variation. The actual
249 mean sizes (in μg dry weight, averaged by lake) ranged from 0.8 to 3.7 μg for *B. longirostris*,
250 from 0.8 to 18.9 μg for *D. brachyurum*, from 0.1 to 9.5 μg for *H. gibberum*, and from 0.9 to
251 11.5 μg for *Daphnia* sp.

252 There also is evidence, from our study and others, that a viewpoint (e.g., Crisman,
253 1992) that sub-tropical and tropical lakes contain only small cladocerans is incorrect.
254 Iglesias et al. (2011) found that in warm water lakes in Uruguay (34° latitude), some lakes
255 had small cladocerans while in other lakes they were large and included large *Daphnia*. The
256 difference was due to an absence of visual predation (by zooplanktivorous fish) in the
257 *Daphnia* dominated lakes, not to a difference in water temperature. Further, when fish-free
258 enclosures were placed into the lakes with high fish predation and small cladocerans, large
259 *Daphnia* appeared within two weeks, and they only were eliminated when fish were added
260 to the enclosures.

261 A somewhat stronger relationship occurred between body size and temperature in
262 cyclopoids than in cladocerans. This is consistent with a greater relative control of
263 cyclopoids by temperature than by fish predation or resource composition. Because of their
264 escape swimming behaviors, cyclopoids are less sensitive to fish predation than
265 cladocerans, especially when considering large species such as *Daphnia* (Fernando, 1994;
266 Jeppesen et al., 2001) and because cyclopoids are omnivorous (Adrian & Frost, 1993), they
267 may be less sensitive to changes in phytoplankton composition. Resistance of cyclopoids to

268 increased fish predation is evidenced by results of controlled experimental (eg., Drenner &
269 McComas, 1984) and whole-lake studies (Brooks & Dodson, 1965).

270 An unexpected result was the finding that body size of calanoid copepods did not
271 vary with water temperature. The literature on calanoid response to temperature also is
272 rife with inconsistent results. Some studies document an inverse relationship between
273 adult body size and temperature (Lonsdale & Levinton, 1985; Atkinson, 1994); others
274 indicate more complex effects that depend on species and resource availability (Lin et al.,
275 2013); and some indicate that no relationship exists. For example, Twombly & Tisch (2000)
276 found that in controlled experiments, temperature had no significant effect on mature adult
277 body size of *Boeckella triarticulata* or *Diaptomus leptopus*, and Escribano & McLaren (1992)
278 found no significant effect of temperature on *Calanus glacialis* size. These findings are in
279 contrast to results from the ocean, where there is a well-established relationship between
280 the size of copepods and temperature. In general, marine cold-water calanoids are large
281 and have large lipid deposits, and warm-water calanoids are small and have small lipid
282 deposits (e.g., Hooff & Peterson, 2006; Lee et al., 2006). In lakes, more is known about fish
283 predation on calanoids (and cyclopoids) than about temperature effects. Catching these
284 animals may be challenging because copepods are fast swimmers and therefore have a
285 better chance to escape predation than cladocerans (Drenner & McComas, 1984). Yet this
286 does not explain the difference in relationship between calanoids and cyclopoids with
287 temperature and more research is needed to discern the underlying cause.

288 More evidence regarding the importance of fish predation on the zooplankton came
289 from the analysis of Greenland data from lakes with vs. without fish. Cladocerans, the group
290 most affected by fish predation, were much larger in lakes without fish. Cyclopoids, less

291 affected by fish predation, were only slightly smaller in the presence of fish, and calanoids
292 were unaffected. While we do not have data from the other regions to make such a
293 comparison (Greenland was the only region where we encountered fishless lakes) the
294 results are (a) consistent with the hypothesis that fish predation plays a greater role in
295 regulating body size of cladocerans than copepods, and (b) reinforce the importance, for
296 cladocerans in particular, of measuring body size on a lake-by-lake basis, rather than
297 assuming invariant species' body sizes across all lakes.

298 It is possible that other factors, such as invertebrate predation, also could influence
299 the observed variation in body size in this study, as generally discussed by Hart & Bychek
300 (2011); however, we have no such data to analyze.

301 Another factor not considered in this study, which could influence body size
302 estimates, is diel vertical migration. In lakes with planktivorous fish, it is well established
303 that larger zooplankton migrate to deeper water to avoid predation by sight-feeding fish.
304 We do not expect this factor to largely influence our results, because except for Turkey, all
305 samples encompassed the entire water column. It is possible that in Turkish lakes,
306 especially those with a thermocline and fish predation, the body sizes could be under-
307 estimated. Lacking information on whether or not migration occurred, we cannot test this
308 hypothesis.

309 From our results, it is not clear whether the changes in body size with temperature
310 were driven primarily by a change in species composition or by individual species
311 becoming smaller. Daufresne et al. (2009) found that reduced size in warm waters can be
312 attributed to small species replacing larger ones, smaller individuals within a species being
313 favored over larger ones, or a combination of both. In our analysis, very few species

314 occurred over the entire geographic range (Appendix I), so with just a few exceptions, the
315 changes in body size likely were driven by a change in the taxonomic composition of the
316 communities. However, the authors do not have access to the detailed data from all of the
317 geographic regions to quantify the relative importance of these two factors that could affect
318 average size.

319 It is well-established that temperature affects growth rates and adult size in a wide
320 range of organisms, both from field and laboratory experiments (Atkinson, 1994; Ashton,
321 2001). Yet it also has been established that temperature can have both direct and indirect
322 effects, the latter being mediated by changes in food web structure, including changes in
323 predation pressure. Here we demonstrated that in lakes over a broad latitudinal gradient,
324 cladocerans displayed a marginally significant decrease in body size with water
325 temperature, as documented in an earlier synoptic study. However, in the present study the
326 variation in body size at any given temperature was higher than previously reported, and
327 that it may be attributed to differences in fish predation. Cyclopoids responded to
328 temperature in a similar manner as cladocerans; however, the degree to which
329 temperature explained the variation in size was greater and in line with expectations
330 considering the greater ability of cyclopoids to co-exist with fish predators. Calanoid size
331 did not vary with temperature. It suggests that in contrast with cladocerans and cyclopoids,
332 calanoid body size is not metabolically constrained by higher temperatures. This
333 unexpected result requires further investigation.

334

335

336

338 **Acknowledgements**

339 The authors are grateful to the many field and laboratory support staff who collected and
340 analyzed zooplankton in the study regions. Without their support this paper would not
341 have been possible. The data collection in Florida was supported financially by the South
342 Florida Water Management District. The groups from Aarhus University and METU were
343 supported by the MARS project (Managing Aquatic ecosystems and water Resources under
344 multiple Stress) funded under the 7th EU Framework Programme, Theme 6 (Environment
345 including Climate Change), Contract No.: 603378 (<http://www.mars-project.eu>). The data
346 collection in Turkey was supported by TÜBİTAK-ÇAYDAG (Projects 105Y332 and 110Y12)
347 The Greenland studies was supported by the Research Council for Nature and Universe,
348 Greenland Climate Research Centre and the Danish Agency of the Environment. The data
349 collection in Ethiopia was supported by the National Science Foundation (NSF) project
350 R83-206 and by the Schure-Beijerinck-Popping Fund of the Royal Netherlands Academy of
351 Arts and Sciences (KNAW) project SBP/JK/2004-14. The Canadian studies were supported
352 by the National Science and Engineering Research Council and the Ontario Ministry of
353 Natural Resources. Data collection in Brazil was supported by CNPq (Proc. 521.513/93-6)
354 and FAPEMIG (CBS 1897/96) grants. The work in Florida was done under CRIS Project
355 FLA-FRE-005152 and was supported by the National Sea Grant College Program of the
356 United States Department of Commerce, National Oceanic and Administration, under NOAA
357 Grant NA06OAR-4170014. The authors thank Roger Bachmann for pre-reviewing this
358 paper and providing many valuable comments.

359

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Table 1. Lake regions, latitudes, numbers of lakes and water temperatures at the time of sampling.

Region	Latitude	# Lakes	Temp (°C)
Greenland	66 - 74°N	57	2 - 16
Alaska	55 - 60°N	5	15 - 17
Ontario	49°N	5	17 - 19
British Columbia	49°N	4	19
Turkey	38 - 42°N	32	9 - 17
Florida	28°N	6	30
Brazil	19 - 21°S	4 (13)*	23 - 27
Ethiopia	6 - 13°N	9	19 - 26

*Parenthetical value includes multiple sampling sites in two large dendritic reservoirs

List of Figures

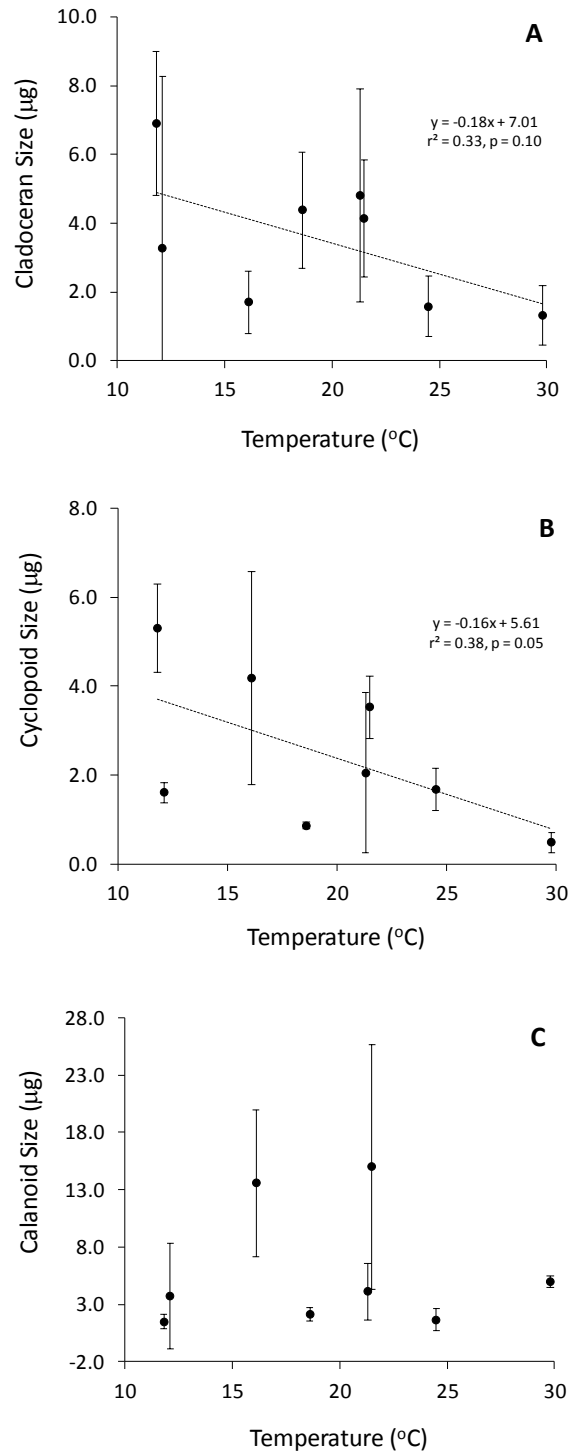
Fig. 1. Map showing the general locations of lakes included in this paper, in: Alaska, Brazil, British Columbia, Ethiopia, Florida, Ontario and Turkey.

Fig. 2. Relationships between the mean size ($\mu\text{g dry weight animal}^{-1}$) of cladocerans (A), cyclopoids (B) and calanoids (C) and water temperature for the eight lake regions. Data are regional means \pm 95% confidence intervals. Linear regressions are shown where there is significance at $p \leq 0.10$.

Fig. 1.



Fig. 2.



Appendix 1. Crustacean zooplankton species in the selected lakes and reservoirs of each geographic region.

A + indicates that the species is present in one or more of the lakes in that geographic region. G = Greenland, A = Alaska, ON = Ontario, BC = British Columbia, T = Turkey, F = Florida, B = Brazil, and E = Ethiopia.

Species	G	A	ON	BC	T	F	B	E
Cladocera								
<i>Acroperus angustatus</i>					+			
<i>Acroperus harpae</i>	+				+	+		
<i>Alona affinis</i>	+				+			
<i>Alona exigua</i>					+			
<i>Alona guttata</i>			+		+	+		
<i>Alona quadrangularis</i>					+			
<i>Alona rectangula</i>	+				+			
<i>Alona sp.</i>			+					
<i>Alonella nana</i>	+							
<i>Alonella excisa</i>	+							
<i>Alonella sp.</i>	+							
<i>Alonopsis</i>	+							
<i>Bosmina hagmanii</i>						+		+
<i>Bosmina (Sinobosmina freyii)</i>			+					
<i>Bosmina longirostris</i>	+	+		+	+	+	+	+
<i>Bosmina (Eubosmina longispina)</i>		+	+					
<i>Bosminopsis deitersi</i>						+	+	
<i>Branchinecta paludosa</i>	+							
<i>Camptocercus rectirostris</i>					+			
<i>Ceriodaphnia cornuta</i>							+	+
<i>Ceriodaphnia dubia</i>					+			
<i>Ceriodaphnia c. righaudi</i>						+	+	
<i>Ceriodaphnia lacustris</i>			+					
<i>Ceriodaphnia laticaudata</i>					+			
<i>Ceriodaphnia megops</i>								
<i>Ceriodaphnia quadrangulata</i>	+				+			
<i>Ceriodaphnia sp.</i>				+			+	
<i>Chydorus sphaericus</i>	+	+	+		+	+		
<i>Chydorus piger</i>			+		+			
<i>Chydorus sp.</i>			+	+				
<i>Daphnia ambigua</i>						+		
<i>Daphnia barbata</i>								+
<i>Daphnia catawba</i>			+					
<i>Daphnia dubia</i>			+					
<i>Daphnia galeata</i>		+			+			
<i>Daphnia hyalina</i>								+
<i>Daphnia gessneri</i>						+		
<i>Daphnia laevis</i>			+				+	
<i>Daphnia longiremis</i>			+					
<i>Daphnia longispina</i>		+			+			
<i>Daphnia lumnoltzi</i>						+		
<i>Daphnia magna</i>					+			+
<i>Daphnia mendotae</i>			+					
<i>Daphnia parvula</i>			+					
<i>Daphnia pulex</i>	+		+		+			
<i>Daphnia retrocurva</i>			+					
<i>Daphnia sp.</i>	+		+	+				
<i>Diaphanosoma birgei</i>			+			+	+	

Appendix 1 (Cont'd).

Species	G	A	ON	BC	T	F	B	E
<i>Diaphanosoma brachyurum</i>			+	+	+	+		
<i>Diaphanosoma brevireme</i>						+		
<i>Diaphanosoma excisum</i>								+
<i>Diaphanosoma fluviatile</i>							+	
<i>Diaphanosoma lacustris</i>								+
<i>Diaphanosoma mongolianum</i>					+			
<i>Diaphanosoma sarsi</i>								+
<i>Diaphanosoma spinulosum</i>							+	
<i>Diaphanosoma sp.</i>			+		+		+	
<i>Echinisca rosea</i>						+		
<i>Eubosmina tubicen</i>						+		
<i>Eurycercus glacialis</i>	+							
<i>Graptolebris testudinaria</i>	+							
<i>Holopedium gibberum</i>	+	+	+	+		+		
<i>Ilyocryptus spinifer</i>						+		
<i>Latona setifera</i>	+							
<i>Leptodora kindtii</i>			+	+		+		
<i>Leydigia leydigi</i>					+			
<i>Macrothrix rosea</i>					+			
<i>Macrothrix sp.</i>	+				+			
<i>Macrothrix hirsuticornis</i>								
<i>Moina branchiate</i>					+			
<i>Moina micrura</i>					+		+	+
<i>Moina minuta</i>							+	
<i>Moina macrocopora</i>					+			
<i>Moina sp.</i>					+			
<i>Ophryoxus gracilis</i>				+				
<i>Pleuroxus aduncus</i>					+			
<i>Pleuroxus striatus</i>						+		
<i>Pleuroxus truncatus</i>					+			
<i>Pleuroxus uncinatus</i>					+			
<i>Pleuroxis sp.</i>					+			
<i>Polyphemus pediculus</i>	+	+		+	+			
<i>Scapholebris mucronata</i>	+							
<i>Sida crystallina</i>						+		
<i>Simocephalus vetulus</i>	+				+			
<i>Simocephalus sp.</i>				+	+			

Calanoida

<i>Argyrodiaptomus furcatus</i>							+	
<i>Epischura lacustris</i>		+	+					
<i>Arctodiaptomus doralis</i>						+		
<i>Diaptomus floridanus</i>						+		
<i>Diaptomus sp.</i>		+						
<i>Leptodiaptomus ashlandi</i>			+					
<i>Leptodiaptomus minutus</i>	+		+					
<i>Leptodiaptomus sicilis</i>			+					

Appendix 1 (Cont'd).

Species	G	A	ON	BC	T	F	B	E
<i>Notodiaptomus iheringi</i>							+	
<i>Notodiaptomus cf. nordestinus</i>							+	
<i>Notodiaptomus cearensis</i>							+	
<i>Notodiaptomus henseni</i>							+	
<i>Notodiaptomus corderoi</i>							+	
<i>Skistodiaptomus oregonensis</i>			+					
<i>Thermodiaptomus galebi lacustris</i>								+
<i>Thermodiaptomus processifer friedae</i>								+
<i>Tropodiaptomus kraepelini</i>								+
Calanoid copepods (not identified)				+	+			
Cyclopoida								
<i>Acanthocyclops carolinus</i>								
<i>Acanthocyclops vernalis</i>			+			+		
<i>Cyclops abyssorum alpinus</i>								
<i>Cyclops</i> sp.	+	+						
<i>Diacyclops bicuspidatus thomasi</i>			+					
<i>Diacyclops navus</i>			+					
<i>Ergasilus</i> sp.		+						
<i>Eucyclops serrulatus</i>			+					
<i>Eucyclops speratus</i>			+					
<i>Megacyclops viridis viridis</i>								+
<i>Mesocyclops aequatorialis similis</i>								+
<i>Mesocyclops brasilianus</i>							+	
<i>Mesocyclops edax</i>			+			+		
<i>Mesocyclops leuckarti</i>			+					
<i>Mesocyclops longisetus</i>							+	
<i>Mesocyclops meridianus</i>							+	
<i>Mesocyclops ogannus</i>							+	
<i>Mesocyclops</i> sp.			+				+	
<i>Metacyclops mendocinus</i>							+	
<i>Orthocyclops modestus</i>			+					
<i>Thermocyclops decipiens</i>							+	
<i>Thermocyclops minutus</i>							+	
<i>Thermocyclops</i> sp.								+
<i>Tropocyclops prasinus</i>			+			+		
<i>Tropocyclops prasinus mexicanus</i>								
<i>Tropocyclops</i> sp.								
Cyclopoid copepods (not identified)				+	+			