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Underwater faunal assemblages: radiocarbon dates and late Quaternary vertebrates from Cold Lake,
Alberta and Saskatchewan, Canada

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Draft

14 **Abstract**

15

16 Late Quaternary faunal remains from three underwater settings in Cold Lake, Alberta and
17 Saskatchewan, Canada, include at least 13 vertebrate taxa consistent with assemblages that post-date the
18 Last Glacial Maximum (LGM). Seven new radiocarbon dates range from 10350 ± 40 yr BP to 161 ± 23 yr
19 BP and provide insight into the post-LGM biotic history of east-central Alberta and west-central
20 Saskatchewan. The presence of an essentially modern large mammal biota is suggested for the mid-
21 Holocene, and possibly earlier, if the absence of extinct or extirpated taxa in association with Late
22 Pleistocene *Bison* at the AB-SK site is meaningful. Taphonomically, some of the remains suggest
23 deposition in open environments during the Holocene, possibly when lake levels were lower. The
24 recovery of late Quaternary faunal remains from a present-day lacustrine setting is novel, and suggests
25 that similar records may occur in other lakes in western Canada, including those in areas with scarce
26 Quaternary vertebrate records.

27

28 Key Words: Pleistocene, Holocene, Carnivora, Artiodactyla

29 **Introduction**

30

31 Late Quaternary palaeontological records are rare in some regions of western Canada,
32 particularly in the present-day boreal forest, where ecological conditions hamper the discovery of fossil
33 localities. Effective reconnaissance and identification of Quaternary palaeontological sites in the region
34 is challenging due to dense vegetation, moist sediments, and acidic soils that are not conducive for
35 preservation of bone. The few Quaternary fossil records presently known from east-central and
36 northeastern Alberta (e.g., Burns and Young 2017, Jass and Barrón-Ortiz 2017) are typically associated
37 with massive ground disturbance related to the development of infrastructure (e.g., highways, mining,
38 etc.). Although fluvial gravels occur regionally and represent a possible source of additional Quaternary
39 vertebrate remains, they have not yet proven to be as regionally productive as elsewhere in Alberta (e.g.,
40 Jass et al. 2011, Jass and Barrón-Ortiz 2017). Here we present new specimens, new radiocarbon data for
41 five taxa (*Alces alces*, *Bison* sp., *Canis lupus*, *Cervus elaphus*, and *Odocoileus* sp.), and discuss late
42 Quaternary vertebrate records from Cold Lake, a large lake situated along the southern margin of the
43 present-day boreal forest in Alberta and Saskatchewan. We utilize those radiocarbon data and
44 contemporaneous palaeoenvironmental records from the literature to discuss the age, taphonomic origin,
45 and broader significance of the assemblages.

46 Faunal remains from Cold Lake were first brought to our attention in 2012 by Charles "Red"
47 Ehrich, a resident of the town of Cold Lake and an avid scuba diver. Red contacted one of us (CNJ) with
48 questions about two bison skulls that he collected from the lake while diving. The size and morphology
49 of one of the skulls piqued our interest, in part due to the paucity of information concerning late
50 Quaternary vertebrates of the area, but also because of the novel depositional setting as a potential
51 source of palaeontological remains.

52

53 **Setting and context**

54 Cold Lake is a large lake (59.3 km²) that straddles the border between eastern Alberta and
55 western Saskatchewan (Fig. 1). The lake bottom is uneven with several deep basins, reaching a
56 maximum depth of more than 90 m (Bradford 1990a). Portions of the northern lake margin, near Murray
57 Island, are less than 10 m in depth (Fig. 1).

58 The lake is situated between the Central Mixedwood natural sub-region to the north and the Dry
59 Mixedwood natural sub-region to the south (Downing and Pettapiece 2006). Both are characterized by
60 abundant trembling aspen (*Populus tremuloides*) with white spruce (*Picea glauca*). Jack pine (*Pinus*
61 *banksiana*) occurs on drier sites, with black spruce (*Picea mariana*) and tamarack (*Larix laricina*) in
62 more northern and wetter low-lying areas (Downing and Pettapiece 2006). The northern margins of the
63 Central Parkland sub-region and grasslands are about 90 km and 250 km south of the lake, respectively
64 (Downing and Pettapiece 2006).

65 The region surrounding the lake is of considerable geologic interest due to resource potential,
66 notably bitumen production from oil sands (Hein et al. 2007; Government of Alberta 2012). However,
67 little is known about the geomorphologic evolution of the area in post-Last Glacial Maximum (LGM)
68 time. Geologically, the lake is situated within Quaternary formations ranging from pre-glacial Empress
69 Formation sediments at the base, to younger, alternating series of glacial tills and finer grained units
70 along the lateral margins of the lake (Parks et al. 2005). Cretaceous bedrock underlies the Quaternary
71 strata (Parks et al. 2005).

72 The lake was probably formed as part of deglacial processes related to the retreat of the
73 Laurentide Ice Sheet. Ice retreat maps (Dyke 2005) suggest that the lake could have existed by

74 approximately 11,000 yr BP (approximately 13,000 Cal yr BP). The Upper Pleistocene Grand Centre
75 Formation, deposited during the LGM, crops out near the upper margins of the lake (Fenton et al. 1994).

76 Archaeologically, the Cold Lake region is not especially well known, but the record does provide
77 some insight into potential maximum ages that may be represented at post-LGM vertebrate localities.
78 On the Alberta side of the lake approximately forty archaeological sites are recorded, mostly on the
79 southern and northwestern shores. Twice as many have been recorded west of Cold Lake, mostly on the
80 shores of small lakes and rivers. Of sites recorded to date, the most important in terms of continuous
81 occupation of the region is the Duckett site (GdOo-16).

82 The Duckett site is situated on the northeast corner of Ethel Lake, a small oval lake located five
83 kilometres west of Cold Lake. The site yielded a nearly entire sequence of Holocene-age artifacts
84 documenting fairly continuous occupation beginning shortly after deglaciation and continuing until late
85 Pre-contact times (McCullough Consulting Ltd. 1981; Fedirchuk and McCullough 1986). No
86 radiocarbon dates were obtained; however, based on projectile point typology the site was first occupied
87 by people who made Clovis-like fluted points, indicating an early occupation dating between 12,000 to
88 13,000 Cal yr BP (Ives 2006).

89 Cold Lake itself has not been investigated for palaeoecological or palaeolimnological records.
90 However, a basal radiocarbon date of $11,830 \pm 330$ yr BP (AECV-411C; 14896 to 13063 cal yr BP)
91 from a core recovered from Moore Lake, located approximately 15 km west of Cold Lake, helps date
92 Late Pleistocene deglaciation and the early establishment of regional vegetation (Hickman and
93 Schweger 1996). Moore Lake is smaller (9.28 km^2) than Cold Lake and has a small catchment area
94 (Bradford 1990b), making it potentially more sensitive to regional climate changes (cf. Campbell et al.
95 1994). The earliest pollen zone in the Moore Lake record is characterized by pollen from open-ground
96 taxa, such as *Artemisia* (sage), Cyperaceae (sedge), and Gramineae (now Poaceae, grass), possibly

97 representing the presence of pioneering vegetation while stagnant ice was still present (Hickman and
98 Schweger 1996). This was followed by a short-lived zone (*ca.* 11,300 – *ca.* 9,900 ^{14}C yr BP) dominated
99 by *Betula* (birch) and then *Picea* (spruce) pollen, recording the early boreal forest (Hickman and
100 Schweger 1996). This sequence is widespread in pollen records from central and southern Alberta,
101 southern Saskatchewan and adjacent areas of the northern US, where white spruce (*Picea glauca*)
102 appears to have dispersed rapidly northwards during deglaciation, forming a belt of coniferous forest not
103 far from the retreating Laurentide Ice Sheet margin (Ritchie and MacDonald 1986; Beaudoin and
104 Oetelaar 2003; Yansa 2006).

105 Between about 9900 and 8800 ^{14}C yr BP, rapid vegetation change occurred, with an open mixed
106 forest of birch and spruce being present in the region (Hickman and Schweger 1996). Between about
107 8800 to 6200 ^{14}C yr BP the record shows an increase in non-arboreal pollen, reduced spruce pollen, and
108 greater presence of *Populus* (poplar) pollen (Hickman and Schweger 1996). This evidence and dating
109 correlates to an interval of maximum warmth and dryness in the Holocene (Renssen et al. 2012). The
110 pollen assemblage reflects an expansion of grasslands or open parkland vegetation (Hickman and
111 Schweger 1996). Pollen of *Ruppia* (widgeon grass), an aquatic plant tolerant of high salinity (Kantrud
112 1991), also occurs in this zone, signaling a change in the hydrochemistry of Moore Lake.

113 Boreal forest returned to the area between 6200 and approximately 2200 ^{14}C yr BP, as indicated
114 by increased, though variable, presence of arboreal pollen and a decrease in non-arboreal pollen
115 (Hickman and Schweger 1996). Notably, *Pinus* (pine) pollen is present throughout this zone at close to
116 present-day values. This is probably pollen from jack pine, and indicates the establishment of boreal
117 forest with a similar composition to that of today. The last two thousand years were marked by variable
118 pollen assemblages, with occasional peaks in non-arboreal pollen.

119 The Moore Lake palaeoecological record shows that there have been productive landscapes in
120 the vicinity of Cold Lake since the Late Pleistocene, although the floristic composition and character of
121 the vegetation has varied. Of particular note is the probable expansion of the parkland and grassland
122 ecoregions to the north during the early mid-Holocene, indicating a considerable latitudinal shift in
123 vegetation communities. A similar pattern is found in the nearby Lofty Lake record (Lichti-Federovich
124 1970), where evidence suggests an approximate 150-km northward expansion of grassland in the mid-
125 Holocene (Vance et al. 1995).

126

127 **Materials and Methods**

128

129 Skeletal remains reported here come from three general areas of Cold Lake: a site situated along
130 the Alberta-Saskatchewan border (AB-SK site); French Bay on the Alberta side; and a broad area north
131 of Murray Island on the Saskatchewan side (Fig. 1). The remains were collected intermittently by “Red”
132 Ehrich during scuba dives into those regions of the lake. Remains were recovered from the lake bottom
133 between 2.4 m to 10 m below the surface of the water in littoral and near-shore areas. All specimens
134 were visible from the surface of the lake bottom and were not excavated or buried by sediment. Detailed
135 GPS coordinates were collected for each series of specimens recovered, and specimens were collected
136 from the surface of the lake bottom at varying depths. Specific collection locality data are on file at the
137 Royal Alberta Museum and are available upon request. Sample sizes reported here are as follows: AB-
138 SK site, n = 3; French Bay, n = 14; Murray Island site, n = 193. Three of the collected specimens
139 (P14.9.11, P14.9.58, and P15.9.31) are wood fragments that superficially resembled long bone
140 fragments, and are not discussed below. We emphasize that this study includes only specimens
141 accessioned into collections at the Royal Alberta Museum (Edmonton, Alberta, Canada) from 2012 to

October, 2016. Reference to individual specimens outside of the context of this paper should include the museum acronym (e.g., RAM P13.1.1). Collection of specimens is on-going, but intermittent.

Ten specimens representing six taxa (*Alces alces*, *Bison* sp., *Canis lupus*, *Cervus elaphus*, *Odocoileus* sp, and *Ursus* sp.) were sampled for AMS radiocarbon dating on bone collagen (Table 1). Our selections were influenced by costs for radiometric dating, sample sizes from each locality, and the conservation treatment status of individual specimens. Because of lower sample sizes, only single specimens were radiocarbon dated from the AB-SK site (*Bison* sp.) and French Bay (*Cervus elaphus*), whereas eight specimens from the Murray Island site were sampled (*Alces alces*, *Bison* sp., *Canis lupus*, *Cervus elaphus*, *Odocoileus* sp., *Ursus* sp.: Table 1). Each specimen was sampled with a Dremel rotary tool and a clean cutting wheel at the Royal Alberta Museum. Four of the samples (P13.1.1, P13.2.6, P14.9.1, P15.9.1) were submitted to Beta Analytic, Inc. (Miami, Florida, USA), and six samples (P13.3.7, P15.9.60, P15.9.72, P15.9.73, P15.9.86, P15.9.88) were submitted to the A. E. Lalonde AMS Laboratory at the University of Ottawa, Ontario. All pretreatment and analytical procedures followed established protocols of those individual laboratories. Detailed radiocarbon reports are on file at the Royal Alberta Museum.

Criteria for specimen identification are outlined below in the Systematic Palaeontology section. For identifications, we utilized reference material from zooarchaeological and mammalogy collections at the Royal Alberta Museum and descriptions from the literature (e.g., Brown and Gustafson 1979; Elbroch 2006).

Results

165 **Radiocarbon dating**

166

167 The results of radiocarbon dating are summarized in Table 1. Seven of the ten specimens
168 retained enough collagen to permit analysis. A partial skull (P14.9.1) and a vertebra (P15.9.88) of *Bison*
169 sp. and a femur fragment (P13.3.7) of *Ursus* sp. from the Murray Island area failed to produce sufficient
170 collagen for analysis.

171 The range of dates spans the terminal Pleistocene to the late Holocene, which is unsurprising
172 given the presence of Laurentide ice over this region during the LGM. The oldest remains are
173 represented by a skull of *Bison* from the AB-SK site, dating to 10350±350 yr BP. Other remains range
174 from the mid-Holocene (P15.9.60, *Canis lupus*, 6113±28 yr BP) to historic times (P15.9.73, *Alces alces*,
175 161±23 yr BP). The distribution of those dates highlights the importance of direct dating of recovered
176 specimens, especially for interpreting the assemblage from the Murray Island area.

177

178 **Systematic palaeontology**

179

180 Given the results of radiocarbon dating, we invoked a degree of temporal and geographic
181 parsimony in the identification of individual specimens. Direct comparisons with modern reference
182 material representing the extant biota of Alberta and Saskatchewan were a significant part of the
183 identification process. Rather than re-stating published criteria for identification (e.g., Brown and
184 Gustafson 1979) we restrict our descriptions to novel observations of specimens (e.g., morphometric
185 data, elk vs. moose).

186

187 Actinopterygii Klein, 1885

Actinopterygii indeterminate

REFERRED SPECIMENS: **Murray Island area**—P15.9.55, vertebra; P15.9.56, vertebra. None figured.

DESCRIPTION: Vertebrae are amphicoelous and compare favorably with vertebrae from large, freshwater fish.

DISCUSSION: We did not attempt to identify the remains beyond the taxonomic level presented here, and we are unsure of the contemporaneity of these remains with others from the Murray Island area.

Twenty-four species of fish are reported to inhabit Cold Lake (Bradford 1990a).

Aves Linnaeus, 1758

Anseriformes Wagler, 1831

Anatidae Vigors, 1825

Cygnus Bechstein, 1803

Cygnus columbianus (Ord, 1815)

Cygnus columbianus bewickii Yarrell, 1830

REFERRED SPECIMENS: **Murray Island area**—P15.9.32, coracoid; P15.9.33, partial humerus. None figured.

210 DESCRIPTION: The coracoid and humerus were compared with the same elements from several birds
211 with size-equivalent bones (e.g., *Aquila chrysaetos*, *Ardea herodias*, *Grus canadensis*, *Cygnus*
212 *columbianus columbianus*, *C. buccinator*). The morphologies of both bones compare favorably with the
213 genus *Cygnus*. Within that genus comparative specimens of *C. buccinator* consistently are too large and
214 those of *C. c. columbianus* are too small. Comparative specimens of *Cygnus c. bewickii* best match the
215 size and morphology of the Murray Island coracoid and humerus.

216
217 DISCUSSION: Tundra swans do not nest or winter near Cold Lake, but the region lies within their
218 migratory pathway (Sibley 2014). Tundra swans are uncommon in the Quaternary fossil record of
219 Canada (see Harington 2003).

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222 Pelecaniformes Sharpe, 1891
223 Pelecanidae Rafinesque, 1815
224 *Pelecanus* Linnaeus, 1758
225 *Pelecanus erythrorhynchos* Gmelin, 1789

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227 REFERRED SPECIMENS: **AB-SK Border Site**—P15.9.29, partial humerus. Not figured.

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229 DESCRIPTION: The large size of the element, the profile, curvature and distal, anterior features of the
230 anterior portion of the distal end of the humerus compare most favorably to *Pelecanus erythrorhynchos*.
231 A small, circular hole is located at midline on the distal end of the shaft. From comparison to other
232 pelican remains with similar holes, we interpret the opening as resulting from a gunshot wound.

233
234 DISCUSSION: The inferred gunshot wound narrows the potential age range of the specimen to the last few
235 hundred years of geologic time, when firearms became prevalent in western Canada. Cold Lake is
236 situated in the present-day breeding range for white pelicans (Sibley 2014). Pelicans are not listed in
237 summaries of Quaternary localities from Canada (Harington 2003).

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240 Mammalia Linnaeus, 1758

241 Rodentia Bowdich, 1821

242 Castoridae Hemprich, 1820

243 *Castor* Linnaeus, 1758

244 *Castor canadensis* Kuhl, 1820

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246 REFERRED SPECIMENS: **Murray Island area**—P15.9.75, skull fragment with left I1, P4–M2, right P4–
247 M1 (Fig. 2a); P13.3.37, lumbar vertebra.

248

249 DESCRIPTION: The skull fragment and teeth conform to the morphology of *Castor canadensis*. Teeth are
250 hypsodont and square in occlusal outline, with characteristic enamel infoldings. The infraorbital foramen
251 is small as in *C. canadensis* vs. *Erethizon dorsatum*.

252 The caudal vertebra has enlarged, flaring and laterally projecting transverse processes. The
253 spinous process is relatively short and is situated posteriorly on the neural arch. The vertebral body is
254 circular and does not demonstrate the dorsal indentation that is present in some other semi-aquatic taxa
255 (e.g., *Lontra canadensis*).

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DISCUSSION: Beavers occur throughout Alberta in association with permanent water and access to trees (Smith 1993). There are surprisingly few records of beavers in palaeontological contexts in Alberta and Saskatchewan and radiocarbon records are primarily restricted to associated vegetation (Harington 2003).

Cricetidae Fischer, 1817
Ondatra Link, 1795
Ondatra zibethicus (Linnaeus, 1766)

REFERRED SPECIMENS: **Murray Island area**—P13.3.34, partial skull with right I1, M1–M2, left I1, M1 (Fig. 2b).

DESCRIPTION: The single identified specimen has heavy and wide-spread zygomatic arches, a slender rostrum, a sharp crest along the midline of the frontal bones, long and thin incisive foramina, and distinct, rooted teeth consisting of sharp infoldings of enamel that form a series of alternating enamel triangles.

DISCUSSION: *Ondatra zibethicus* occurs throughout Alberta in association with permanent water bodies (Smith 1993). Late Quaternary records are known from elsewhere in Canada (see Harington 2003).

Carnivora Bowdich, 1821

280 Canidae Fischer de Waldheim, 1817

281 *Canis* Linnaeus, 1758

282 *Canis lupus* Linnaeus, 1758

283

284 REFERRED SPECIMENS: **Murray Island area**—P15.9.60, right tibia (proximal portion, Fig. 2c).

285

286 DESCRIPTION: The single specimen identified as *Canis lupus* matches comparative specimens in size and
287 morphology. Because of the large size and the possibility that domesticated dogs might be represented in
288 the Cold Lake assemblage (see below) the morphology of the specimen was also compared to a
289 reference collection of Siberian huskies housed in the mammalogy collections at the Royal Alberta
290 Museum. As compared to the husky sample, the tibial crest tuberosity projects anteriorly farther and has
291 greater length distally as in wolves. The muscular sulcus is shallower and wider in *C. lupus* and the
292 lateral condylar surface extends farther posteriorly to create a deeper V-shaped notch in the posterior
293 edge of the proximal surface than is present in *C. l. familiaris*. The central edges of the condylar surfaces
294 peak at a greater height in *C. lupus* and there is a more defined valley between them than in *C. l.*
295 *familiaris*.

296

297 DISCUSSION: *Canis lupus* and/or *C. latrans* are known from Holocene palaeontological deposits in
298 Alberta (e.g., Burns 1989; Ralrick 2007), and domesticated dogs are known in Alberta's archaeological
299 record (e.g., Brink et al. 1984; Wright et al. 1985; Bartholdy et al. 2017).

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302 *Canis* sp.

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REFERRED SPECIMENS: **Murray Island area**—P15.9.61, partial right tibia. Not figured.

DESCRIPTION: The single tibia conforms to the general morphology of *Canis*, but is intermediate in size between comparative specimens of *C. lupus* and *C. latrans*. The specimen could represent *C. lupus familiaris*, but comparison to a broader sample would be needed to substantiate that identification.

DISCUSSION: Associated radiocarbon ages for other sampled specimens from the Murray Island area span the mid- to late Holocene, when domesticated dogs are known from elsewhere in Alberta (e.g., Brink et al. 1984; Wright et al. 1985; Bartholdy et al. 2017). This raises the possibility that *Canis lupus familiaris* could be represented in the assemblage from Cold Lake.

cf. *Canis* sp.

REFERRED SPECIMENS: **Murray Island area**—P15.9.62, partial left tibia (diaphysis). Not figured.

DESCRIPTION: The size and form of the specimen (P15.9.62) is consistent with *Canis*, but the incomplete nature of the specimen leaves a degree of uncertainty.

Ursidae Fischer de Waldheim, 1817
Ursus Linnaeus, 1758

Ursus sp.

REFERRED SPECIMENS: **Murray Island area**—P13.3.7, right femur fragment (proximal epiphysis, Fig. 2d).

DESCRIPTION: The single specimen identified as *Ursus* sp. (Fig. 2d) was originally thought to be from an artiodactyl, but examination of the shape of the femoral head suggests the specimen is more consistent with assignment to *Ursus*. Unlike comparative artiodactyl specimens, in which the proximal epiphysis includes bone extending laterally onto the proximal surface of the diaphysis, this specimen has a femoral head that is distinctly separated by the neck as in carnivores. The overall structure, including the position of the fovea capitis femoris is consistent with comparative specimens of *Ursus arctos*. Barring recovery of additional material for comparison with other ursids, we conservatively refer the specimen to *Ursus* sp.

DISCUSSION: Cold Lake is situated within the present-day distribution of black bear (*Ursus americanus*) and within the known, historical distribution of grizzly bear (*Ursus arctos*; Banfield 1974). *Ursus* is uncommon in palaeontological and archaeological contexts in parts of western Canada (Burns 2010).

Mustelidae Fischer de Waldheim, 1817

Lontra Gray, 1843

Lontra canadensis (Schreber, 1777)

348 REFERRED SPECIMENS: **Murray Island area**—P13.3.33, skull with right I3, C1, P4, left P2, P4–M1 (Fig.
349 2e); P14.9.66, atlas; P15.9.54, thoracic vertebra.

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351 DESCRIPTION: The dental formula is 3-1-4-1. The cranium is flattened with a long, wide braincase,
352 lacking the well-developed sagittal crest seen in carnivorans of comparable size (e.g., *Gulo gulo*). Other
353 characters include widespread and slender zygomatic arches that converge anteriorly, large and oval
354 infraorbital foramina, and a short and broad rostrum. The left carnassial displays a distinctive marked
355 blade and broad, shelf-like protocone. The left M1 retains a distinctive rectangular occlusal outline
356 characteristic of *Lontra canadensis*.

357 Post-cranial elements were identified based on comparisons with modern skeletal material. The
358 atlas preserves the ventral tubercle, a distinct and posteriorly projecting prominence. There is a single
359 foramen present on each side of the ventral wing surface and a pronounced groove that separates the
360 anterior articular surface from the antero-lateral margin of the wing. Dorsally, there is a single bilateral
361 foramen present posterior to the anterior articular surface. The wings are not rounded, but instead are
362 rectangular in shape and project laterally from the midline. In addition, the antero-ventral margin forms
363 a wide V-shape.

364 The thoracic vertebra has a greater antero-posterior dimension, as opposed to the greater dorso-
365 ventral height that is present in some semi-aquatic taxa (e.g., *Castor canadensis*) in the thoracic region
366 of the vertebral column. The vertebral body demonstrates an indentation dorsally and is rounded
367 ventrally. The spinous process is relatively short and has a squared, flat dorsal surface. The transverse
368 processes are very small and the anterior zygapophyses extend well beyond the surface of the centrum.
369 Collectively, these features are comparable to characters of the vertebrae preserved in modern specimens
370 of *Lontra canadensis*.

371

DISCUSSION: Otters are uncommon in Quaternary palaeontological contexts in parts of western Canada (see summary data in Harington 2003). Cold Lake is situated at the southern distributional margin for extant populations of otters (Smith 1993).

Neovison Baryshnikov and Abramov, 1997

Neovison vison (Schreber), 1777

REFERRED SPECIMENS: **Murray Island area**—P15.9.82, skull with right P4, left P2, P4 (Fig. 2f); P15.9.83, skull with right P2–M1, left P2–M1.

DESCRIPTION: Both skulls have a 3-1-3-1 dental formula. Skulls are similar in size to both *Neovison vison* and *Mustela nigripes* based on comparisons with modern specimens housed in collections at the Royal Alberta Museum. Features of the skull that differentiate *N. vison* and *M. nigripes* include the shape of the frontals in profile, the position and size of the protocone on the M1, and the size of the infraorbital foramen (Owen et al. 2000). As in *N. vison*, both referred specimens have flattened frontals (in profile), a large protocone connected to the body of the P4 by a long neck, and large infraorbital foramina.

DISCUSSION: *Neovison vison* occurs throughout Alberta today and is sympatric with several smaller mustelids (Smith 1993). Quaternary records of *N. vison* are known from western Canada but are sparse (see Harington 2003 for summary).

396 Artiodactyla Owen, 1848

397 Bovidae Gray, 1821

398 *Bison* Hamilton Smith, 1827

399 *Bison* sp.

400

401 REFERRED SPECIMENS: **AB-SK border site**—P13.1.1, cranium with horn cores (Fig. 3a); P15.9.24, left
402 astragalus. **Murray Island area**—P14.9.1, partial braincase and horn core (Fig. 3b); P15.9.21, partial
403 braincase; P15.9.68, skull/horncore fragment; P15.9.71, occipital/basioccipital; P13.3.22, skull
404 fragment; P13.3.24, skull fragment; P15.9.69, skull fragment; P13.3.25, partial right premaxilla and
405 maxilla; P15.9.78, right M2; P15.9.80, right M3; P15.9.77, upper molar fragment; P13.3.1, atlas;
406 P13.3.2, partial atlas; P15.9.11, atlas fragment; P14.9.21, axis; P14.9.48, axis; P14.9.60, axis; P14.9.2,
407 cervical vertebra; P14.9.32, cervical vertebra; P14.9.34 , cervical vertebra; P14.9.62, cervical vertebra;
408 P15.9.23, cervical vertebra; P15.9.50, cervical vertebra; P15.9.86, cervical vertebra; P13.3.8, thoracic
409 vertebra; P13.3.41, thoracic vertebra; P13.3.42, thoracic vertebra; P13.3.43, thoracic vertebra; P13.3.44,
410 thoracic vertebra; P14.9.6, thoracic vertebra; P14.9.7, thoracic vertebra; P14.9.28, thoracic vertebra;
411 P14.9.30, thoracic vertebra; P14.9.35, thoracic vertebra; P14.9.36, thoracic vertebra; P14.9.40, thoracic
412 vertebra; P14.9.41, thoracic vertebra; P14.9.45, thoracic vertebra; P14.9.49, thoracic vertebra; P14.9.50,
413 thoracic vertebra; P14.9.55, thoracic vertebra; P14.9.59, thoracic vertebra; P14.9.61, thoracic vertebra;
414 P15.9.52, thoracic vertebra; P15.9.88, thoracic vertebra (spinous process);P13.3.4, lumbar vertebra;
415 P13.3.6, lumbar vertebra; P14.9.13, lumbar vertebra; P14.9.27, lumbar vertebra; P14.9.42, lumbar
416 vertebra; P14.9.43, lumbar vertebra; P14.9.46, lumbar vertebra; P15.9.7, lumbar vertebra; P15.9.18,
417 sacrum; P14.9.14, partial left innominate; P13.3.10, partial left pubis; P13.3.30, innominate fragment;
418 P14.9.63, innominate fragment; P14.9.47, partial left ilium; P15.9.15, left scapula; P14.9.56, partial right

humerus (incomplete distal portion); P15.9.19, left humerus (Fig. 4a, b); P14.9.8, right radius; P14.9.52, right radius; P15.9.16, radius; P13.3.14, left unciform; P15.9.43, left unciform; P15.9.41, left lunar; P15.9.42, right lunar; P15.9.3, right metacarpal (Fig. 3c); P14.9.25, partial right femur (distal epiphysis); P14.9.39, partial right femur (missing distal end); P14.9.4, left tibia; P15.9.44, left naviculo-cuboid; P15.9.26, right astragalus; P15.9.12, partial right metatarsal (missing distal end); P14.9.65, first phalanx (juvenile); P15.9.47, first phalanx; P15.9.48, first phalanx; P15.9.49, first phalanx; P13.3.13, second phalanx; P13.3.17, third phalanx; P15.9.34, third phalanx; P15.9.35, third phalanx; P15.9.36, third phalanx; P15.9.37, third phalanx; P15.9.38, partial third phalanx (proximal portion); P15.9.39, partial third phalanx (proximal portion). **French Bay**—P13.2.9, partial left dentary with m2–m3; P13.2.10, partial left dentary with p3, m1–m3; P13.2.1, partial femur.

DESCRIPTION: P13.1.1 is a massive, flattened and broad cranium with large and laterally-projected horn cores (Fig. 3a), unlike the vertical and posterior curvature of horn cores in *Bison bison*. Measurements of the specimen are consistent with specimens referred to *B. antiquus* (Table 2). In all measurements, the skull falls within ranges identified for male *B. antiquus* (McDonald 1981), whereas at least one measurement falls outside reported ranges for *B. occidentalis*, *B. bison bison*, and *B. b. athabasca* (Table 2).

P14.9.1 is a partial braincase and horn core (Fig. 3b), and is more diminutive than P13.1.1. Nevertheless, the former specimen falls within published ranges for male bison referred to *B. antiquus* and *B. occidentalis* (Table 2), and has fewer features that overlap in size with extant *B. b. bison* or *B. b. athabasca*. An attempt to radiocarbon date this specimen failed due to insufficient collagen. Based on the smaller size of the specimen, we hypothesize the age of P14.9.1 is geologically younger than P13.1.1. However, we acknowledge that the preservation of the specimens does not permit a tip-to-tip

horn core measurement, which is perhaps the most useful in terms of estimating the geologic age of post-LGM forms (Wilson 1980).

Postcranial remains assigned to bison were compared directly with modern reference specimens of bison, elk, moose, and horse. The single, complete bison metacarpal (P15.9.3, Fig. 3c) is well-preserved, thus permitting collection of morphometric data. Measurements (in mm) are as follows: greatest length = 222.39; greatest breadth of the proximal end = 81.74; greatest depth of the proximal end = 46.12; mid-shaft width = 52.51; distal breadth = 33.58; smallest circumference of the diaphysis = 141.00; smallest depth of the diaphysis = 29.61; mid-shaft breadth = 33.56; greatest breadth of the distal end = 83.04. Because the sample size is $n = 1$, we hesitate to discuss the possible taxonomic implications, other than to say that the specimen is consistent with sizes reported for *Bison b. athabasca* (van Zyll de Jong 1986).

Astragali (none figured) exhibit a range of sizes, possibly reflecting sexual dimorphism. P15.9.26 from the Murray Island area has a medio-lateral width of 43.18 mm and a maximum proximo-distal length of 70.07 mm. P15.9.24 from the AB-SK border site has a medio-lateral width of 59.01 mm and a maximum proximo-distal height of 87.97 mm. We examined modern comparative specimens of bison comparable in size to both astragali, but we note that P15.9.24 comes from the same area where a large bison cranium was recovered, consistent in morphology with other records assigned to *Bison antiquus*.

DISCUSSION: Remains of *Bison* are ubiquitous in post-Late Glacial Maximum deposits in western Canada including both archaeological and non-archaeological settings (e.g., Brink 2008; Wilson et al. 2008; Jass et al. 2011; Heintzman et al. 2016). In that context, remains of *Bison* would be expected in the Cold Lake region. However, the early post-LGM record from the AB-SK border site is notable because it represents an early record from east-central Alberta where faunal records are simply not as abundant as in other regions of western Canada.

Collectively, the records of *Bison* from Cold Lake all occur immediately south of a hypothesized boundary separating extant populations of *Bison b. athabasca* and *B. b. bison* (van Zyll de Jong 1986). Specimens of *Bison* from Cold Lake may eventually permit further evaluation of that boundary over time, assuming ancient DNA can be extracted from the specimens.

Several of the long bone specimens of *Bison* reported here from the Murray Island area preserve evidence of carnivore gnawing (e.g., P14.9.39, P14.9.56, P15.9.12, P15.9.19). Two humeri are notable in having proximal ends that were heavily chewed or completely removed by chewing (e.g., P15.9.19, Fig. 4a, b). The proximal end of the humerus has significant stores of bone fat and carnivores are known to preferentially target elements with high bone fat content (Brink 1997).

Cervidae Goldfuss, 1820

Cervus Linnaeus, 1758

Cervus elaphus Linnaeus, 1758

REFERRED SPECIMENS: **Murray Island area**—P15.9.1, partial cranium with right pedicle (Fig. 3d); P15.9.66, partial cranium; P15.9.79, right M2; P15.9.81, right m2; P15.9.10, axis; P14.9.31, cervical vertebra; P15.9.5, cervical vertebra; P15.9.6, cervical vertebra; P15.9.9, cervical vertebra; P15.9.84, cervical vertebra; P15.9.85 lumbar vertebra; P14.9.22, right scapula (proximal portion); P15.9.14, partial right scapula; P15.9.2, left humerus (juvenile); P15.9.20, left tibia; P14.9.54, right metatarsal (unfused distally); P14.9.9, first phalanx. **French Bay**—P15.3.1, antler fragment and pedicle; P15.3.2, antler fragment and pedicle; P13.2.7, partial right scapula; P13.2.8, partial left scapula; P13.2.2, partial right

humerus (lateral portion); P13.2.4, partial right radius and fused ulna fragment; P13.2.6, partial left metacarpal (anterior portion); P13.2.3, partial right tibia.

DESCRIPTION: P15.3.1, P15.3.2, and P15.9.1 have pedicles/antler fragments most consistent with elk (e.g., Fig. 3d). The pedicles of modern specimens of *Cervus elaphus* sit higher on the skull vault than the laterally projecting pedicles of *Alces alces*, and they are positioned closer together than in *A. alces*. In the reported specimens, the pedicle emanates more dorsally from the skull fragments, whereas the pedicle would emanate more laterally if the specimens were *A. alces*. The antlers exhibit evidence of branching near the pedicle. P15.3.1 and P15.3.2 were found together and from their similarity in appearance it is possible that these specimens came from the same individual. Other cranial specimens (e.g., P15.9.66) exhibit only a shallow depression between the supraorbital foramina as in elk, whereas in moose this depression is pronounced.

Isolated teeth (P15.9.79, P15.9.81, neither figured) are identified as *Cervus elaphus* based on the large size of the teeth and the relatively low crowns in comparison with other ruminants. In addition, the crown narrows markedly above a well-developed cingulum bulge and there is a reduced accessory cusp on the buccal side of the lower molar and the lingual side of the upper molar.

The partial radius/ulna (P13.2.4, not figured) has a long and slender morphology and a broad depression at the anterior border near the lateral glenoid cavity. This depression is present as a notch in *Bison* sp. The styloid process of the ulna is unfused as in *Cervus elaphus* (Brown and Gustafson 1979), and the lateral-most, carpal articular facet forms a wide surface, unlike the acute surface present in comparative *Alces alces*.

The partial metacarpal (P13.2.6, not figured) is assigned to *Cervus elaphus* based on the size and length of the element. In comparative *Alces alces*, the distal end is wider and the ridges on the condyles

are less defined than in *C. elaphus*. In addition, the groove running the length of the anterior surface is more pronounced in *A. alces* and the intercondylar margins do not converge to the extent that they do in *C. elaphus*.

Tibiae are elongate, approaching the size of moose. However, the shape and form of the muscular sulcus is more open than in comparative specimens of *Alces alces*, and the proximo-anterior portion of the epiphysis is less robust in both fossil and comparative specimens of moose.

The metatarsal (P14.9.54, not figured) is long and robust, but less so than comparative *Alces*. In both the specimen and comparative metatarsals of *Cervus elaphus*, an elongated facet on the posterior portion of the proximal end terminates medially adjacent to a smaller oval-shaped facet. In *Alces alces*, the elongate facet continues farther medially across the posterior portion of the proximal metatarsal.

DISCUSSION: Elk, like moose, are known only from the Holocene record of Alberta (e.g., Burns 1986) and are probably a recent immigrant to North America (Burns 2010; Meiri et al. 2013). Although the specimens reported here do not clarify current interpretations of population dynamics based on historic elk records (e.g., Speller et al. 2014), they may present the opportunity for additional testing, assuming any preserve ancient DNA. Some elements (e.g., P15.9.2, P13.2.5, neither figured) exhibit evidence of carnivore gnawing.

Odocoileus Rafinesque, 1832

Odocoileus sp.

REFERRED SPECIMENS: **Murray Island area**—P14.9.64, partial mandible with dp2–m2; P15.9.72, partial, edentulous mandible; P15.9.53, 7th (?) cervical vertebra; P15.9.58, thoracic vertebra; P15.9.51,

535 lumbar vertebra; P15.9.59, partial left scapula (juvenile); P15.9.63, left humerus fragment (proximal
536 portion); P15.9.64, partial right humerus; P13.3.11, partial right innominate; P14.9.3, right metatarsal
537 (Fig. 3e); P15.9.46, right calcaneum.

538
539 DESCRIPTION: All specimens are too small to be *Cervus elaphus* or *Alces alces*. Instead, their
540 morphology is consistent with *Odocoileus* based on direct comparisons with modern reference material.
541 The single specimen with dentition (P14.9.64, not figured) is characterized by brachyodont teeth with
542 the characteristic cingulum of cervids. In some instances (e.g., P14.9.3, Fig. 3e), the skeletal elements
543 are more consistent with *O. hemionus*, but in the absence of a broad study of variation we conservatively
544 refer those elements to *Odocoileus* sp. Measurements (in mm) of the metatarsal (P14.9.3) are as follows:
545 greatest length = 272.62; greatest breadth of the proximal end = 31.75; greatest depth of the proximal
546 end = 35.79; smallest breadth of the diaphysis = 19.10; smallest depth of the diaphysis = 17.13; greatest
547 breadth of the distal end = 37.74; and distal breadth = 17.75.

548
549
550 *Alces* Gray, 1821

551 *Alces alces* (Linnaeus, 1758)

552
553 REFERRED SPECIMENS: **Murray Island area**—P15.9.22, basioccipital and occipital condyles; P15.9.27,
554 skull fragment/petrosal; P15.9.73, partial right dentary with dp4, p3–m2 (Fig. 3f); P15.9.17, partial left
555 radius (proximal portion); P15.9.45, right calcaneum.

556
557 DESCRIPTION: The basioccipital and occipital condyles (P15.9.22, not figured) are identified as *Alces*
558 *alces* based on greater antero-posterior length of the occipital condyles in comparison with *Cervus*

elaphus. Additionally, at the midline, a pronounced channel separates the occipital condyles. In *C. elaphus* and *Bison* sp. this is a shallow separation, rather than a pronounced channel. This groove continues anteriorly and develops into a narrow ridge at midline anterior to the bilateral eminences that are anterior to the condyles. This ridge is not present in comparative *C. elaphus* or *Bison* sp. and the body of the basioccipital is also narrower than in comparative *C. elaphus* or *Bison* sp. An additional skull fragment (P15.9.27, not figured) exhibits similar preservation and is likely from the same individual.

The partial dentary (P15.9.73, Fig. 3f) includes the dp4 and evidence of eruption of the p3 and p4, indicating that the specimen is from a juvenile. The large size of the permanent teeth, the low crowns, the prominent cingulum bulge, the significant accessory cusp on the buccal side, and the pronounced, jutting crests of the paraconid and metaconid are consistent with *Alces alces*. The mandible itself is markedly larger and longer than that of juvenile *Cervus elaphus*. The coronoid process is flatter and longer than in *C. elaphus* and the mandibular body of the tooth row is more robust in order to accommodate the large size of the teeth.

DISCUSSION: Moose remains from Cold Lake are rare compared to bison and elk, and are generally uncommon as fossils or sub-fossils in western Canada south of Beringia (Burns 2010). Limited direct radiocarbon data on moose are available for western Canada (e.g., Harington 2003).

Cervidae indeterminate

REFERRED SPECIMENS: **Murray Island area**—P14.9.18, antler fragment (cf. *Cervus*); P15.9.13, antler fragment (cf. *Cervus*); P15.9.65, antler fragment (cf. *Odocoileus*); P15.9.67, antler fragment; P15.9.74,

582 dentary fragment (*Cervus* or *Alces*); P14.9.19, partial thoracic vertebra (*Cervus* or *Alces*); P14.9.33,
583 thoracic vertebra (*Cervus* or *Alces*); P15.9.4, thoracic vertebra (*Cervus* or *Alces*); P15.9.8, lumbar
584 vertebra (*Cervus* or *Alces*); P14.9.38, right femur (juvenile; cf. *Cervus*). **French Bay**—P13.2.11,
585 thoracic vertebra (*Cervus* or *Alces*); P13.2.12, thoracic vertebra (*Cervus* or *Alces*). None figured.

586
587 REMARKS: Specimens are incomplete, fragmentary, poorly preserved, or represent immature individuals,
588 but exhibit general similarities to cervids. Identifications in parentheses (above) reflect a tentative
589 taxonomic assignment based on general size or similarity. Barring further analysis (e.g., aDNA, protein
590 analysis) our more conservative identification of Cervidae indeterminate should be considered more
591 appropriate for subsequent studies (e.g., radiocarbon dating, isotopic analysis).

592
593
594 Artiodactyla indeterminate

595
596 REFERRED SPECIMENS: **Murray Island area**—P14.9.17, basicranial fragment; P13.3.35, atlas (ventral
597 portion); P13.3.55, atlas (ventral portion); P13.3.5, cervical vertebra (cf. *Bison* sp.); P14.9.12, cervical
598 vertebra (cf. *Bison* sp.); P13.3.9, thoracic vertebra (centrum: cf. *Bison* sp.); P14.9.5, thoracic vertebra
599 (cf. *Bison* sp.); P15.9.87, thoracic vertebra (cf. *Bison* sp.); P13.3.40, lumbar vertebra (centrum; cf. *Bison*
600 sp.); P13.3.39, caudal vertebra (cf. *Bison* sp.); P15.9.57, caudal vertebra (cf. *Bison* sp.); P13.3.28,
601 vertebra fragment; P13.3.36, vertebra fragment (zygapophysis); P13.3.38, vertebra fragment (transverse
602 process); P14.9.26, vertebra fragment; P14.9.57, vertebra fragment (spinous process); P13.3.3, rib (cf.
603 *Bison* sp.); P14.9.23, rib (cf. *Bison* sp.); P14.9.44, rib; P14.9.51, rib (cf. *Bison* sp.); P15.9.76, proximal
604 rib body; P13.3.18, right humerus fragment (distal portion); P13.3.21, humerus fragment (proximal

portion); P14.9.20, partial left ilium (juvenile); P13.3.20, partial right femur (diaphysis, juvenile?); P14.9.15, partial right femur (diaphysis, juvenile); P14.9.16, partial femur (diaphysis); P14.9.24, partial left femur (Fig. 4c); P15.9.30, long bone shaft; P15.9.25, partial calcaneus; P15.9.40, partial right astragalus; P14.9.10, partial naviculo-cuboid; P13.3.12, metapodial fragment (distal portion); P13.3.15, metatarsal (distal portion); P13.3.19, metapodial (distal portion). **French Bay**—P13.2.5, right humerus fragment (medial portion). None figured.

REMARKS: Specimens are incomplete, fragmentary, poorly preserved, or represent immature individuals, and we could not reliably distinguish the elements among *Bison*, *Alces*, or *Cervus*. Other remarks are similar to our Cervidae indeterminate account (see above). Artiodactyla indeterminate is the most appropriate identification for use in subsequent studies.

Mammalia indeterminate:

REFERRED SPECIMENS: **Murray Island area**—P13.3.16, bone fragment; P13.3.23, bone fragment; P13.3.26, bone fragment; P13.3.27, bone fragment; P13.3.29, bone fragment; P13.3.31, bone fragment; P13.3.32, bone fragment; P15.9.70, bone fragment. None figured.

REMARKS: All referred specimens are structurally similar to mammalian bone, but do not preserve features that permit further identification.

628 Discussion

629

630 Vertebrate remains reported here are from three distinct areas of Cold Lake, and radiocarbon
631 dating of selected specimens indicates that some age disparity exists between and within localities
632 (Table 1). The AB-SK border site produced the fewest remains, but includes a cranium from a Late
633 Pleistocene *Bison* radiocarbon dated to 10350 ± 40 yr BP (Cal BP 12392 to 12025). The age is consistent
634 with the Quaternary record of western Canada as a whole, where early post-LGM records of bison are
635 widely reported in the literature (e.g., Wilson et al. 2008; Heintzman et al. 2016), and the record
636 provides insight into the sparse faunal history of east-central Alberta and west-central Saskatchewan.

637 Reconstructions of Laurentide ice sheet recession and subsequent landscape revegetation indicate
638 habitable landscapes in the vicinity of Cold Lake by 11,000 yr BP (approximately 13,000 Cal yr BP),
639 with the ice persisting in portions of far northeastern Alberta (Dyke 2005). Pollen records and
640 radiocarbon data from Moore Lake suggest the possibility of habitable landscapes even earlier (Hickman
641 and Schweger 1996). By 10,000 yr BP (approximately 11,500 Cal yr BP), boreal parkland and early
642 boreal forest occupy much of eastern Alberta (Beaudoin and Oetelaar 2003; Dyke 2005). Notably, this
643 early boreal forest lacked certain key species (e.g., jack pine, *Pinus banksiana*), that characterize broad
644 areas in the region today (see Vance et al. 1995). *Bison* sp. from the AB-SK border site dates to a
645 timeframe when open spruce-birch forest was likely present in the region (Hickman and Schweger
646 1996). A time equivalent pollen zone (L2) from nearby Lofty Lake is dominated by up to 50% spruce
647 pollen, with significant amounts (around 10%) of poplar pollen and some buffaloberry (*Shepherdia*
648 *canadensis*) pollen, also reflecting the establishment of spruce forest (Lichti-Federovich 1970). This
649 early forest was probably more open than the present-day boreal forest (Lichti-Federovich 1970;
650 Hickman and Schweger 1996). In that context, the presence of *Bison* provides further indication of well-

established biomes that supported large grazing ungulates in the vicinity of Cold Lake, shortly after the recession of Laurentide ice. Clearly, populations of *Bison* were able to move rapidly into these newly deglaciated and vegetated landscapes.

Conversely, the only non-*Bison* specimen recovered from the AB-SK site is a partial humerus identified as an American white pelican (*Pelecanus erythrorhynchos*). The specimen has a small circular opening consistent with a wound associated with gunfire, suggesting very recent or historic origin. Therefore, the AB-SK border site contains both the oldest and likely the youngest remains reported here.

The Murray Island area has the greatest sample size reported here and produced the richest assemblage of mammals ($n \geq 12$ taxa). Large mammalian herbivore remains include specimens of *Bison* sp., *Alces alces*, *Cervus elaphus*, and *Odocoileus* sp. Carnivorans include *Ursus* sp., *Canis lupus*, *Canis* sp., *Lontra canadensis*, and *Neovison vison*. Rodents include *Castor canadensis* and *Ondatra zibethicus*. Non-mammalian remains include fish (Actinopterygii) vertebrae and a coracoid and humerus of tundra swan (*Cygnus columbianus bewickii*).

All mammalian taxa reported from the Murray Island area occur at or close to the proximity of Cold Lake today (see Smith 1993). We re-emphasize that the record of *Ursus* could represent *Ursus arctos*, and in that scenario would represent a notable record highlighting the broader distribution of grizzly bears in the past. Unfortunately, an attempt to directly date the single specimen of *Ursus* sp. was unsuccessful.

Radiocarbon dates on individual specimens of *Bison* sp. (4833 ± 26 yr BP), *Canis lupus* (6113 ± 28 yr BP), and *Cervus elaphus* (4310 ± 30 yr BP) indicate a mid-Holocene age for at least some remains from the Murray Island area. Younger dates on remains of *Alces alces* (161 ± 23 yr BP) and *Odocoileus* sp. (364 ± 23 yr BP) from Murray Island highlight the importance of direct dating of individual specimens and taxa for interpretive purposes. A partial bison skull (P14.9.1) from the Murray Island area failed to

674 produce a radiocarbon age due to insufficient collagen, but has morphometric features that suggest the
675 specimen is not of recent or historic origin (Fig. 3b; Table 2). *Bison* sp. and *Cervus elaphus* occur at
676 French Bay, and radiocarbon dating of the latter resulted in a late Holocene age assignment (800 ± 30 yr
677 BP).

678 The distribution of radiocarbon data ($n = 7$) is broad, ranging from the Late Pleistocene to late
679 Holocene. A remarkable feature of these assemblages is that all recovered remains were visible on the
680 bottom of the lake and did not require excavation or removal of sediment for collection, despite their
681 disparate ages. For context, Late Pleistocene levels are at about 9 m in depth in the sediment core from
682 Moore Lake (Hickman and Schweger 1996) and at about 6 m in depth in the Lofty Lake record (Lichti-
683 Federovich 1970), indicating sedimentation rates in excess of 0.5 m per millennium in deep lake basins.

684 The apparent absence of sediment accumulation or burial of older faunal remains is surprising
685 and suggests a complex post-depositional history that led to the exposure of elements of disparate age
686 within a given locality area. Sediment may have been deposited and subsequently removed by erosion
687 (see below) or the bottom may have remained free of sediment accumulation, possibly by sediment
688 resuspension and redistribution (as in sediment focusing; see discussion in Beaudoin and Reasoner
689 1992). Winter ice dynamics, including scouring or ice push, in near-shore areas offer another possible
690 explanation. Further investigation would be required to evaluate sedimentation processes and regimes in
691 Cold Lake.

692 Notably, there is no clear damage on the faunal remains that would be expected with fluvial
693 transport (e.g., rounded, weathered edges; pitting; etc.), and no major drainages occur in close proximity
694 to the localities (Fig. 1). A small drainage is present on the southeast side of French Bay (Bradford
695 1990a), but remains from French Bay show no evidence of fluvial transport. Therefore, we interpret the
696 remains as being of local origin, rather than being redeposited from elsewhere.

Animals may either die on lake ice or become trapped after inadvertently breaking through ice during unstable conditions (Weigelt 1989). In Alberta, there are records of bison falling through thin ice and drowning (e.g., Reynolds et al. 2003) and this situation may apply to ancient bison remains from lacustrine deposits from elsewhere in Alberta (Crossingham 1988). Limbs of a large ungulate were observed sticking down through the ice into Cold Lake during a winter dive (Charles Ehrich, pers. comm.), suggesting that at least some of the remains reported here accumulated as a result of animals being trapped by lake ice. That scenario seems especially likely for remains dating to the late Holocene and historic times (e.g., *Odocoileus* sp., P15.9.72; *Alces alces*, P15.9.73), when lake levels were likely similar to present-day levels.

For some other remains from the Murray Island site, we propose an alternative taphonomic hypothesis. Direct dates on *Bison* sp., *Canis lupus*, and *Cervus elephus* indicate a range of mid-Holocene ages. Analysis of pollen records across western Canada indicates an interval of higher salinity and lower lake levels at or near that time (Ritchie and Harrison 1993). Estimates of exactly how much lake levels might have fallen are generally not available. At Moore Lake, the diatom record indicated higher fluctuating salinity between about 10,000 and 4,500 ^{14}C yr BP (Hickman and Schweger 1996). Diatom and algal pigment evidence, combined with the presence of *Ruppia* pollen, led to the suggestion that Moore Lake water levels were low between about 8,000 and 6,500 ^{14}C yr BP (Hickman and Schweger 1996). Moore Lake is much shallower (only about 26 m maximum depth) and smaller than Cold Lake, and thus is likely more sensitive to changing moisture inputs. Nevertheless, we may expect a similar pattern to have occurred at Cold Lake. Reduced lake levels at Cold Lake would have exposed considerable areas of shoreline around Murray Island and French Bay, broadening the shoreline vegetation zone, while the deep basins remained water-filled and attractive to animals. By comparison, present-day water level fluctuations are only about 1.5 m (Stantec Consulting Ltd. 2017). If our

hypothesis is correct, it would substantiate evidence of warmer, arid conditions in western Canada during the mid-to-late Holocene (e.g., Vance et al. 1983; Beaudoin 1999) and suggest that lake levels were low relative to present-day. Moreover, any exposed sediments would have been vulnerable to wind and wave erosion and redistribution, with deflation leading to heavier faunal remains of different ages ending up at the same level. The Wally's Beach site in southwestern Alberta (Kooyman et al. 2001) provides an analogue for this scenario.

We note that a lower lake level is more congruent with the deposition of remains of some smaller-bodied taxa at Murray Island (e.g. *Castor canadensis*, *Lontra canadensis*) whose remains could reasonably be expected along shoreline environments, but are less likely to accumulate as a result of falling through ice. Unfortunately, we were not able to directly date any remains of smaller animals, either because of specimen conservation efforts or because of the impact that destructive sampling would have on rare specimens. Therefore, the suggestion that smaller-bodied taxa are more consistent with an interpretation of lower lake levels in the mid-Holocene is equivocal, barring recovery and dating of additional specimens.

Bone modification preserved on some of the elements is consistent with either taphonomic scenario. Breakage and fractures are apparent on some of the bones of large ungulates, and include spiral fractures (e.g., P14.9.24, Fig. 4c). In addition to the spiral fracture, P14.9.24 is missing the distal end, an area that contains considerable fat content in some taxa (Brink 1997). We interpret the spiral fractures as resulting from carnivore gnawing, and the preservation of several other bones (e.g., P13.2.5, P14.9.15, P14.9.16, P14.9.18, P14.9.38, P14.9.39, P14.9.56, P15.9.2, P15.9.12, P15.9.19, P15.9.25) is consistent with that interpretation. At a minimum, evidence consistent with gnawing indicates that at least some remains were exposed and available for modification by carnivores indicating exposure to the elements,

as a result of consumption of animal remains either on ice or at near-shore localities at times when lake levels were lower than today.

Collectively, the records presented here provide insight into the establishment of the modern biota in post-LGM time. The Late Pleistocene records from the AB-SK site indicate that *Bison* occupied recently deglaciated landscapes shortly after recession in some areas of western Canada, where they persisted until historic times. In terms of the human history of this region, the remains of *Bison* and other animals provides new evidence for the range of faunal resources available to people during the postglacial interval. The oldest occurrence of *Bison* reported here is roughly contemporaneous with the earliest human occupation in the region (i.e., Duckett site) and these reported faunal remains provide additional context for the archaeological record. The proximity of the bison remains to known present-day and historic distributions of both plains bison (*Bison bison bison*) and wood bison (*B. b. athabascaae*) are of interest for understanding population-level dynamics in the region. Although such an analysis is beyond the scope of this paper, recovered specimens present the possibility for population level studies based on aDNA. Mid-Holocene records of *Bison*, *Canis lupus*, and *Cervus* indicate the establishment of modern large mammal biotas in the Cold Lake region by the mid-Holocene.

In summary, late Quaternary faunal remains collected from underwater settings in Cold Lake provide insight into the post-LGM biotic history of east-central Alberta and west-central Saskatchewan. The presence of an essentially present-day, large mammal biota is suggested for the mid-Holocene, and possibly earlier, if the absence of extinct or extirpated taxa in association with Late Pleistocene *Bison* at the AB-SK site is meaningful. Taphonomically, the remains may have accumulated in different ways, including the trapping of animals in lake ice or as part of a shoreline accumulation during lower lake water levels during the mid-Holocene. The recovery of late Quaternary faunal remains from a present-day lacustrine setting is novel, and suggests the possibility that similar records may occur in other

northern lakes. Should that prove to be true, the sparse record of late Quaternary vertebrates from boreal regions of western Canada could be greatly enhanced.

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Table 1. Radiocarbon dates on vertebrates from Cold Lake, Alberta and Saskatchewan. Calibrated ages were determined using OxCal v4.2.4 (Bronk Ramsey 2009) and are based on IntCal13 (Reimer et al. 2013).

Locality/ taxon	Specimen number	C-14 lab number	C-14 age	$\delta^{13}\text{C}$	Calibrated age (95.4% probability)
<u>AB-SK</u>					
<i>Bison</i> sp.	P13.1.1	Beta-358781	10350 $\pm$ 40 yr BP	-18.9	Cal BP 12392 to 12025
<u>French Bay</u>					
<i>Cervus elaphus</i>	P13.2.6	Beta-368274	800 $\pm$ 30 yr BP	-21.1	Cal BP 767 to 675
<u>Murray Island</u>					
<i>Alces alces</i>	P15.9.73	UOC-4686	161 $\pm$ 23 yr BP	-20.5	Cal BP 285 to 0 (*Seuss Effect)
<i>Bison</i> sp.	P14.9.1	n/a	Insufficient collagen	n/a	n/a
<i>Bison</i> sp.	P15.9.86	UOC-2602	4833 $\pm$ 26 yr BP	-19.63	Cal BP 5641 to 5637 and Cal BP 5611 to 5577 and Cal BP 5533 to 5480
<i>Bison</i> sp.	P15.9.88	UOC-2601	Failed to produce collagen	n/a	n/a
<i>Canis lupus</i>	P15.9.60	UOC-4685	6113 $\pm$ 28 yr BP	-18.1	Cal BP 7156 to 7097 and Cal BP 7086 to 7077 and Cal BP 7070 to 7044 and Cal BP 7031 to 6896
<i>Cervus elaphus</i>	P15.9.1	Beta-428750	4310 $\pm$ 30 yr BP	-19.4	Cal BP 4962 to 4835
<i>Odocoileus</i> sp.	P15.9.72	UOC-4687	364 $\pm$ 23 yr BP	-18.5	Cal BP 499 to 425 and Cal BP 394 to 318
<i>Ursus</i> sp.	P13.3.7	UOC-4684	Failed to produce collagen	n/a	n/a

Table 2. Measurements on cranial elements of *Bison* from the AB-SK site (P13.1.1) and Murray Island area (P14.9.1) compared to ranges for males (m) and females (f) of Late Pleistocene and Holocene taxa (from McDonald 1981). Numbers in parentheses in table indicate measurement following Skinner and Kaisen (1947). (l) = left; (r) = right.

	P13.1.1	P14.9.1	<i>B. antiquus</i>	<i>B. occidentalis</i>	<i>B. b. bison</i>	<i>B. b. athabasca</i>
Horn core length on upper curve, tip to burr (3)	-	281.67* (l)	203–364 (m) 145–253 (f)	186–392 (m) 165–235 (f)	124–270 (m) 93–177 (f)	165–323 (m)
Length, tip of core to upper base at burr (5)	-	255.02* (l)	185–330 (m) 136–234 (f)	175–350 (m) 154–212 (f)	120–243 (m) 92–161 (f)	154–277 (m)
Vertical diameter of core (6)	102.62 (l) 102.55 (r)	90.21 (l)	81–126 (m) 53–79 (f)	70–114 (m) 54–71 (f)	69–99 (m) 43–59 (f)	81–106 (m)
Circumference of core at base (7)	313.33 (l) 312.67 (r)	272.67 (l)	233–392 (m) 173–241 (f)	237–355 (m) 168–219 (f)	199–324 (m) 136–191 (f)	254–322 (m)
Greatest width at auditory openings (8)	297.56	-	251–318 (m) 221–264 (f)	238–294 (m) 208–237 (f)	220–270 (m) 187–219 (f)	243–298 (m)
Width of condyles (9)	140.16	-	132–181 (m) 116–149 (f)	111–151 (m) 115–140 (f)	111–140 (m) 111–129 (f)	118–139 (m)
Transverse diameter of core (12)	100.22 (l) 100.03 (r)	86.32 (l)	76–129 (m) 54–75 (f)	77–120 (m) 52–73 (f)	67–103 (m) 44–61 (f)	93–109 (m)
Width between bases of horn cores (13)	396.30	-	-	-	-	-
Width of cranium between cores and orbits (14)	308.19	-	276–352 (m) 238–303 (f)	261–348 (m) 214–262 (f)	237–318 (m) 198–233 (f)	273–313 (m)
Greatest postorbital width (15)	372.51	-	338–400 (m) 289–341 (f)	311–394 (m) 276–310 (f)	289–356 (m) 248–291 (f)	326–384 (m)

*Minimum value; tip of horn core missing.

FIGURE CAPTIONS

Fig. 1. Quaternary fossil localities discussed in this paper: (1) French Bay; (2) AB-SK border site; (3) Murray Island area. Arrows indicate direction of water flow for major drainages. Inset shows location of Cold Lake. [Print at two-thirds page width (120 mm wide); greyscale in both print and on-line versions.]

Fig. 2. Bones of Late Quaternary rodents and carnivorans from Cold Lake. (a) *Castor canadensis*, P15.9.75, skull fragment with left I1, P4–M2, right P4–M1, left lateral view; (b) *Ondatra zibethicus*, P13.3.34, partial skull with right I1, M1–M2, left I1, M1, lateral view; (c) *Canis lupus*, P15.9.60, right tibia (proximal portion), lateral (left) and posterior (right) views; (d) *Ursus* sp. P13.3.7, right femur fragment (proximal epiphysis), anterior view; (e) *Lontra canadensis*, P13.3.33, skull with right I3, C1, P4, left P2, P4–M1, dorsal (top) and right lateral (bottom) views; (f) *Neovison vison*, P15.9.82, skull with right P4, left P2, P4, dorsal (top) and left lateral (bottom) views. Scale bars correspond as follows: 3 cm = a, b, f; 5 cm = c–e. [Print at two-thirds page width (120 mm wide); greyscale in print version and color in on-line version.]

Fig. 3. Bones of Late Quaternary artiodactyls from Cold Lake. (a) *Bison* sp., P13.1.1, cranium with horn cores, dorsal view; (b) *Bison* sp., P14.9.1, partial braincase and horn core, dorsal view; (c) *Bison* sp., P15.9.3, right metacarpal, anterior view; (d) *Cervus elaphus*, P15.9.1, partial cranium with right pedicle; (e) *Odocoileus* sp., P14.9.3, right metatarsal, anterior view; (f) *Alces alces*, P15.9.73, partial right dentary with dp4, p3–m2, lateral view. Scale bars correspond as follows: 10 cm = a, b; 5 cm = c–f. [Print at two-thirds page width (120 mm wide); greyscale in print version and color in on-line version.]

Fig. 4. Long bones of Late Quaternary artiodactyls from Cold Lake exhibiting breakage consistent with carnivore modification. (a, b) *Bison* sp., P15.9.19, left humerus, anterior (a) and lateral (b) views. (c) Artiodactyla indeterminate, P14.9.24, left femur, medial view. [Print at one column width (86 mm wide); greyscale in print version and color in on-line version.]

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Fig. 1. Quaternary fossil localities discussed in this paper: (1) French Bay; (2) AB-SK border site; (3) Murray Island area. Arrows indicate direction of water flow for major drainages. Inset shows location of Cold Lake. [Print at two-thirds page width (120 mm wide); greyscale in both print and on-line versions.]

119x92mm (300 x 300 DPI)

Fig. 2. Bones of Late Quaternary rodents and carnivorans from Cold Lake. (a) *Castor canadensis*, P15.9.75, skull fragment with left I1, P4–M2, right P4–M1, left lateral view; (b) *Ondatra zibethicus*, P13.3.34, partial skull with right I1, M1–M2, left I1, M1, lateral view; (c) *Canis lupus*, P15.9.60, right tibia (proximal portion), lateral (left) and posterior (right) views; (d) *Ursus* sp. P13.3.7, right femur fragment (proximal epiphysis), anterior view; (e) *Lontra canadensis*, P13.3.33, skull with right I3, C1, P4, left P2, P4–M1, dorsal (top) and right lateral (bottom) views; (f) *Neovison vison*, P15.9.82, skull with right P4, left P2, P4, dorsal (top) and left lateral (bottom) views. Scale bars correspond as follows: 3 cm = a, b, f; 5 cm = c–e. [Print at two-thirds page width (120 mm wide); greyscale in print version and color in on-line version.]

91x70mm (300 x 300 DPI)

Fig. 3. Bones of Late Quaternary artiodactyls from Cold Lake. (a) *Bison* sp., P13.1.1, cranium with horn cores, dorsal view; (b) *Bison* sp., P14.9.1, partial braincase and horn core, dorsal view; (c) *Bison* sp., P15.9.3, right metacarpal, anterior view; (d) *Cervus elaphus*, P15.9.1, partial cranium with right pedicle; (e) *Odocoileus* sp., P14.9.3, right metatarsal, anterior view; (f) *Alces alces*, P15.9.73, partial right dentary with dp4, p3-m2, lateral view. Scale bars correspond as follows: 10 cm = a, b; 5 cm = c-f. [Print at two-thirds page width (120 mm wide); greyscale in print version and color in on-line version.]

176x259mm (300 x 300 DPI)

Fig. 4. Long bones of Late Quaternary artiodactyls from Cold Lake exhibiting breakage consistent with carnivore modification. (a, b) *Bison* sp., P15.9.19, left humerus, anterior (a) and lateral (b) views. (c) *Artiodactyla* indeterminate, P14.9.24, left femur, medial view. [Print at one column width (86 mm wide); greyscale in print version and color in on-line version.]

62x44mm (300 x 300 DPI)