

- 30 when preparing for and recover from important life history events such as whelping and lactation
- 31 for females and competition for mates among males.
- 32 Key words: hooded seal, *Cystophora cristata*, habitat use, habitat model, GAM, First Passage
- 33 Time, sex and age differences, migration

34 Introduction:

35 The hooded seal (*Cystophora cristata*) is an abundant, pelagic, deep-diving pinniped
36 distributed throughout much of the North Atlantic and adjacent Arctic Ocean (Sergeant 1974,
37 Folkow and Blix 1995, 1999, Hammill and Stenson 2006). Two management stocks, the
38 Northwest Atlantic (NW) and Northeast Atlantic (NE) have been recognized, although they
39 cannot be distinguished with genetic analyses (Coltman et al. 2007). NW Atlantic hooded seals
40 have an annual migration pattern, with animals breeding in March off southern Labrador and/or
41 the northern Newfoundland coast (The Front), the Gulf of St. Lawrence (The Gulf) and in Davis
42 Strait (Sergeant 1974, 1976, Hammill 1993, Bajzak et al. 2009). They leave the breeding areas in
43 early April to feed, and migrate to Southeast (SE) Greenland by late June early July to moult
44 (Hammill 1993, Kapel 1996, Anon 2006) (See Fig 1). Following the moult, they migrate along
45 the west coast of Greenland over to the Labrador shelf, Davis Strait and Baffin Bay area where
46 they remain prior to returning to the Newfoundland/Gulf areas in late fall or early winter
47 (Andersen et al. 2009).

48 The NW Atlantic hooded seal population inhabits the waters in marine systems at the
49 border zone between the North Atlantic and the Arctic. These areas are highly dynamic and
50 productive; demonstrating pronounced seasonal and annual variation in ocean climate (e.g.
51 Gulland 1974, Loeng 1991). The ocean environment on the Newfoundland and Labrador Shelf is
52 influenced by several factors including the Labrador Current, cross shelf exchange with warmer
53 continental slope water, and bottom topography (DFO 2006). The Labrador Sea is characterized
54 by high convection activity driven by winter cooling and wind creating deep surface mixed
55 layers, directly linking the atmosphere and the deep ocean, sometimes mixing as deep as to 2000
56 m (Ross and Harrison 2007). Inter-annual variability in water properties and changes in the
57 balance of inflows of fresh water from northern sources and warm, saline waters from the

58 southerly latitudes impact the marine ecosystems of the Labrador region (Ross and Harrison
59 2007) and Baffin Bay. These dynamics result in numerous microhabitats which, in turn, may
60 result in a high abundance of overwintering animals (Heide-Jørgensen and Laidre 2004).

61 Due to the pelagic distribution of hooded seals and our lack of knowledge regarding their
62 prey selection at various times of the year, the extent of fish consumption is difficult to assess
63 (Folkow et al. 1996). Following the groundfish fishery collapse in Atlantic Canada in the 1990s
64 and the lack of recovery of what was historically the most important commercial species, interest
65 into how predation by seals may influence groundfish stocks has intensified (Hammill and
66 Stenson 2000, DFO 2008, 2009). Diet studies indicate that adult hooded seals forage primarily on
67 benthopelagic species (Ross 1992, Anon. 2006, Haug et al. 2007, Tucker et al. 2009), and
68 Hammill and Stenson (2000) estimated that hooded seals accounted for 10% of the total annual
69 prey consumption by four common seal species in Atlantic Canada (harp seal (*Pagophilus*
70 *groenlandicus*), hooded seal, grey seal (*Halichoerus grypus*) and harbour seal (*Phoca vitulina*)).

71 Being a highly sexual dimorphic animal (Sergeant 1976, Hammill and Stenson 2000;
72 males: ~250 kg, females: ~190 kg), males and females may be expected to have different dietary
73 needs throughout the annual migration. Bajzak et al. (2009) found that although adult hooded
74 seals from the Gulf overlapped on a horizontal scale, they were segregated at a vertical scale
75 during the post-breeding migration. A diet study carried out by Tucker et al. (2009) support these
76 findings by showing how male and female hooded seals forage on different benthopelagic prey.
77 They also found a difference in diet preference between seasons and geographical areas for both
78 sexes. Although these studies suggest that there might not be competition for prey between the
79 sexes, there may be overlap in prey preference with other species such as harp seals, beluga
80 (*Delphinapterus leucas*) and narwhal (*Monodon monoceros*) (Richard et al. 1998, Laidre et al.
81 2003, 2004) in important feeding areas for hooded seals during their post moult migration.

82 Here, we hypothesize that hooded seals forage in areas of complex oceanographic
83 conditions. We expect that if complex seafloor relief concentrates prey, hooded seal movement
84 patterns and extended space use will be associated with the continental shelf, deep basins and sea
85 mounts. Variability in primary productivity and temperature observed at the surface (SST) are
86 often reflected by underlying processes driven, in part, by topography. We therefore expect to see
87 seals concentrate their search effort in areas of high chlorophyll concentrations, indicating highly
88 productive areas, and where SST may be a reflection of optimal temperatures for hooded seal
89 prey. Ice cover is important for hooded seals during pupping/breeding and moulting, but the ice
90 edge is also known to be productive (e.g., Smith and Nelson 1986) and could represent a foraging
91 habitat for this species. If hooded seals are following the ice edge, either for foraging, shelter or
92 rest, we would expect to see seasonal shifts in movement in accordance with changes in ice
93 extent. We predict that movement patterns and habitat use shift northward and southward
94 throughout the annual migration in relation to seasonal changes in weather conditions and
95 oceanographic processes such as ice extent, mixing and productivity. We tested these hypotheses
96 with data obtained from multiple hooded seals of the NW population tagged with Satellite Relay
97 Data Loggers (SRDLs) and separated the data into groups of males, females and juveniles to look
98 for segregation by season, age and/or sex.

99

100 Methods

101 Study area

102 The study area is the NW Atlantic Ocean, extending from the Gulf of St. Lawrence
103 northwards covering most of Baffin Bay, including Davis Strait, to SE Greenland (Fig.1).

104

105 Deployment of SRDLs

106 Adult and juvenile hooded seals were captured using a V-shaped pole-net on the ice
107 during July directly after moulting in SE Greenland (2004, 2005 and 2007; approx. 65°N, 37°W)
108 and during March (2004, 2005, 2006 and 2008; approx 49°N, 52°W (the Front) and 46°50'N,
109 62°W (the Gulf)). They were weighed, and subsequently tranquilized using tiletamine
110 hydrochloride and zolazepam hydrochloride (Telazol, AH. Robins Company, Richmond, VZ,
111 USA) administered intramuscularly (1mg. 100kg⁻¹). Satellite Relay Data Loggers (SRDLs; Sea
112 Mammal Research Unit (SMRU), St. Andrews, Scotland) were glued to the head or upper neck
113 of the seal, using quick drying epoxy glue (Cure 5, Industrial Formulators of Canada Ltd.
114 Burnaby, BC Canada) before the seals were released.

115 Seal locations were determined by the ARGOS collection and location system
116 (CLS/Service Argos), and subsequently filtered using an algorithm based on the travelling speed
117 of the tracked animal, distance between successive locations, and turning angle (Freitas et al.
118 2008). We used a maximum swim speed of 2m/s between successive locations which was similar
119 to that used for grey seals (Austin et al. 2003).

120

121 Seal and habitat data:

122 Satellite transmitters were deployed on 65 seals over a period of four years (2004-2008),
123 of which there were 32 adult females, 17 adult males and 16 juveniles (10 female and 6 male)

124 (Table 1). We used First Passage Time (FPT) and Generalized Additive Models (GAMs) to
125 evaluate habitat preferences. Habitat selection was investigated by evaluating how individual
126 annual movement patterns were associated with environmental variables such as water depth, ice,
127 chlorophyll (primary productivity), SST and slope. The distribution patterns of male, female and
128 juvenile hooded seals were compared to look for differences in habitat preference by sex and age,
129 where the year was separated into two periods: spring (April-June = post breed/pre moult period)
130 and fall/winter (August-February = post moult/pre breed period). March and July were excluded
131 from the analysis as hooded seals spend most of their time during these two months hauled out on
132 the ice for breeding and moulting, respectively.

133 Oceanographic information (SST and chlorophyll concentrations) was collected via
134 remotely sensed satellite data (8 day composites data, 4 km resolution) downloaded from
135 NASA's oceancolor web database (<http://oceancolor.gsfc.nasa.gov/>). The data were imported to
136 ArcGIS 9.3 and data values were extracted based on seal locations.

137 Daily ice cover data (25 km by 25 km resolution) were obtained from the National Snow
138 and Ice Data Center in Colorado (<http://nsidc.org/index.html>). Depth, slope and the 1000 m depth
139 contours were derived using bathymetry data from the General Bathymetry Chart of the Ocean
140 (GEBCO; <http://www.gebco.net/>).

141 Kernel maps (Fig. 2a-f) were generated using the package "spatstat" (version 1.21-5;
142 Baddeley and Turner 2005) in R (version 2.11.1, the R Foundation for Statistical Computing).
143 The density plots used a Gaussian kernel to create smoothed histograms where "sigma"
144 determines the bandwidth of the kernel. Extreme values are removed when increasing the
145 bandwidth, and this creates a smoother dataset for visual comparison. We used the bandwidth with
146 sigma value 0.75. The kernel maps were then exported to ArcGIS 9.3 (Environmental Systems
147 research Institute, Redlands, CA) and the raster cell resolution was set to 20 000 metres.

148 First passage Time (FPT) is defined as the time required for an animal to cross a circle of
149 a given radius, hence, it is a measure of how much time an animal spends in a given area
150 (Fauchald and Tveraa 2003). FPT was calculated using the “adehabitat” package (version 1.8-3;
151 Calenge 2006) in R. By calculating FPT between each location for an animal we can identify the
152 Area Restricted Search (ARS) scale which is the scale the animal focuses its search effort
153 (Kareiva and Odell 1987, Fauchald and Tveraa 2003, 2006). This was done by plotting FPT
154 against the distance travelled and the difference in sample size was taken into account by
155 employing a bootstrap routine to extract ARS for each group. We then created a new dataset
156 based on the average ARS scale, and related high use areas and FPT to oceanographic variables
157 through extraction of data and GAM models.

158

159 Statistical analysis: GAM and AIC

160 We divided the tracks into steps equal to the ARS scale, and estimated the FPT for each
161 step. FPT was used as a response in the General Additive Models (GAMs; package “mgcv“ in R;
162 Wood 2011) with habitat variables as predictors in order to investigate how FPT was associated
163 with habitat. To take into account dependencies between observations within individuals,
164 individual seal id was entered as a random factor using a smooth specifier.

165

166 The model is given by:

167 $\text{gam}(y \sim s(x) + s(z) + s(v) + \dots + s(w, \text{bs} = \text{re})), \text{data}, \text{method} = \text{REML})$

168

169 where y is the response variable and x, z, v etc are the predictive variables. A GAM can
170 deal with simple random effects, by exploiting the link between smooths and random effects to

171 treat random effects as smooths (Wood 2008). This is implemented in the GAM by $s(w, bs = "re")$
172 where w is the covariate of the smooth, bs is a basis penalty smoother, and the "re" class
173 implements simple random effects (Wood 2008). REML is a likelihood smoothing parameter,
174 and this approach is a conventional likelihood based treatment of random effects (Wood 2008).

175 The oceanographic habitat variables were log transformed to obtain normal distribution
176 (except ice, which did not improve with transformation). SST was first converted to Kelvin to
177 avoid problems with negative values when log transformed. To select between competing models
178 we applied an information-theoretic approach and examined parameter weightings using Akaike
179 Information Criterion (AIC). Candidate models with $\Delta_i < 2$ are considered to have substantial
180 support (Burnham and Anderson 2002) and only these are presented in this paper (full model
181 results are available in supplementary material (A4a, b, c)). Parameter weights were calculated
182 based on AIC weights for all models. These range from 0-1, where parameter values closer to 1
183 indicate higher importance as explanatory variables for hooded seal habitat selection (Burnham
184 and Anderson 2002).

185 The GAM predictive graphs were derived from the model results and plotted using R. The
186 data were first back transformed, and then the variables were plotted against the predicted mean
187 FPT (days).

188 Results

189 The FPT analysis showed that hooded seals ARS scale is stable for juveniles and males
190 throughout the year, but females show a smaller search radius during spring than fall/winter. The
191 dataset yielded 4011 data locations based on the calculated search radius (Table 2).

192 The kernel maps were created using the modified dataset based on ARS, and we only
193 display FPT (circles) where they spend more than 2 days (based on average FPT at ARS scale;
194 Fig. 2a-f). Dark areas signify that the seals have spent time there, but crossed the ARS circle in
195 less than 2 days. Our results show that females spend shorter periods along the Labrador shelf
196 and at the Reykjanes ridge area (2-10 days), and longer periods in Greenland when preparing for
197 the moult (>10 days; spring: Fig. 2a). Males do not spend much time along the Reykjanes ridge
198 during spring (Fig. 2c) compared to females (Fig. 2a). Females and males breeding in the Gulf
199 tend to remain there, presumably to feed, before heading over to Greenland by July (Fig. 2a and
200 c). Following the moult, females spend extended periods of time along the Labrador shelf area
201 (Fig. 2b) while the majority of males traveled to Baffin Bay and Davis Strait. A few animals
202 remained along the east coast of Greenland before heading directly over to the breeding grounds
203 (Fig. 2b and d). In spring, newborns spent time in the breeding area before heading out to sea for
204 their first migration. This seemed to especially be the case for young born in the Gulf (Fig. 2e). In
205 fall, they start to show a similar migration pattern to adult seals, although they seem to have a
206 wider distribution pattern (Fig. 2f).

207
208 Model selection: Our results for model selection are presented in Table 3 consisting of the best or
209 most equally plausible models ($\Delta_i < 2$) per seal group and season. The best models all include
210 SST, depth and/or chlorophyll. The ranking of the model parameters included in all the models
211 are displayed in Table 4 and 5, and these results are presented below in more detail together with

212 the predicted results from Figures 3-7 (a-f). The model goodness of fit is presented by the
213 deviance explained (%) in Table 3. The plots show the estimated effects as a solid line, with 95%
214 confidence limits shown as dashed lines (Wood 2006). The confidence of the confidence limits
215 and the estimated line, at the point where the line passes through zero on the vertical axis, is a
216 result of the identifiability constraints applied to the smooth terms (Wood 2006).

217
218 Chlorophyll: Chlorophyll plays an important role when it comes to habitat selection by female
219 and juvenile hooded seals during their annual migration. The predictive graphs show that this is
220 not an important variable on its own for males, although it is important in conjunction with other
221 variables (Table 3, 4 and 5; Fig 3b, e). During spring, female and juvenile seals preferred to be in
222 areas with low concentrations of 0-0.5 mg/m³ and from medium to high concentrations of 4
223 mg/m³-30 mg/m³, respectively. In fall/winter they still show a preference in the low ranges: 0.25-
224 0.5 mg/m³, although, females also appear to prefer a second range around 1-1.75 mg/m³.

225
226 Depth: The parameter weights for depth were very high across all categories during spring
227 (females: 1; males: 0.9; juveniles: 0.9; Table 4), and for the fall/winter the scores were slightly
228 lower for males and females (0.86 for both; juveniles: 0.99; Table 5). The predictive graphs (Fig.
229 4) show that this is an important variable for all three groups when it comes to annual habitat
230 selection. In spring, juveniles prefer depths of 0-600 m, males >600 m and females the range of
231 200-1200 m. In fall/winter juveniles use areas with depths from 750 m while females used areas
232 with depths from 600 m and deeper.

233

234 SST: Temperature at the surface seems to influence all seals during their annual migration except
235 for females during the fall/winter season (Fig. 5d, Table 5). Males and females show a preferred
236 temperature range of -2 to +2°C during the spring season, while juveniles use areas within the
237 ranges of -2 to 0°C and +3 to +9°C. The results further indicate that the preferred temperatures
238 vary greatly during fall/winter. Juveniles prefer temperatures in the range of -8 to +5 °C and
239 males -2 to +3°C. As mentioned, females do not show strong trends, although the results suggest
240 a preference towards a temperature range of -7 to +5°C which is similar to that of juveniles (Fig.
241 5d, f).

242

243 Ice: Ice was the least important variable to explain habitat selection for hooded seals (Table 4 and
244 5). Most of the seals used areas with little or no ice, and the model did not identify this as an
245 important factor in hooded seal habitat selection (Fig.7). We did not have enough data to test
246 juveniles for ice associations during spring.

247

248 Slope: Males and juveniles scored a much higher parameter weight for slope during fall/winter
249 than for spring season. In contrast females scored a much higher weight in the spring season
250 compared to fall/winter, although the ranking placed it second to last for all groups (Table 4 and
251 5). However, the predictive graphs do not show that juveniles have a positive relationship
252 towards slope at any season. The graphs show that females prefer a slope from about 1-11
253 degrees in spring, while it does not seem to be of importance in fall/winter. They further indicate
254 that slope does have some influence on habitat selection for males during fall/winter when they
255 tend to prefer a slope of about 1 degree (Fig.6).

256 Discussion

257 This study supports earlier findings that, in general, hooded seals are inclined to migrate
258 along, and use the continental shelf and areas of high topographic relief (Folkow et al. 1996,
259 Anon 2006, Andersen et al. 2009). However, sexually dimorphic animals are often found to differ
260 in habitat use and feeding strategies (Le Boeuf et al. 1993, Mysterud 2000, Breed et al. 2006,
261 Bailleul et al. 2007) and our results suggest that males and females from the largest part of the
262 NW population (Front breeders alone consist of about 90%) are separated on a horizontal scale
263 during annual migration. Females tend to use the Labrador shelf more intensively than males
264 especially in the fall/winter season (post moult and pre breed; Fig. 2b, d) and the Reykjanes ridge
265 area during spring season (post breed and pre moult; Fig. 2a, c). Males use the Baffin Bay and
266 Davis Strait areas more frequently during fall/winter (Fig. 2d), and in spring they spend time in
267 SE Greenland as well as Davis Strait and the Gulf for those who breed there (Fig. 2c). Other
268 sexually dimorphic seals, such as southern elephant seals (*Mirounga leonina*) (Bailleul et al.
269 2007) and grey seals (Breed et al. 2006), share this segregation behavior where males and
270 females are separated on a geographic scale. In contrast, Bajzak et al. (2009) found that adult
271 male and female hooded seals tagged in the Gulf of St. Lawrence during the pupping season
272 overlapped geographically, but differed on the vertical scale, targeting different depths. They
273 suggested that both sexes needed to undergo some replacement of energy resources before
274 undertaking the long migration to southeast Greenland, and that the limited extent of the channel
275 slope area in the Gulf and the possible abundance of resources would reduce opportunities for
276 extensive geographic spatial separation. They further hypothesized that vertical segregation
277 between male and female hooded seals could be due to intra-specific competition for prey, or that
278 the larger males feed on larger prey found at deeper depths (Bajzak et al. 2009).

279 The NW and NE hooded seal populations differ in their migration patterns, both on a
280 population level and by sex. In the NE, Folkow et al. (1996) did not find any sexual segregation
281 between males and females, nor did they observe any seasonal movement patterns as seen in the
282 NW. Seals of the NE population tend to make unsynchronized, longer feeding trips to sea and
283 return to the ice edge off the east coast of Greenland (Folkow et al. 1996) while the NW
284 population embarks on a more or less synchronized annual round-trip with the basin of the
285 Labrador Sea in centre. The differences in migration behavior between these two populations
286 (and also between Gulf animals and the rest of the NW population) may be a reflection of the
287 differential patterns of energy availability within their habitats.

288 As capital breeders, hooded seals do not feed during nursing and mating (e.g. Houston et
289 al. 2006, Trillmich and Weissing 2006). Females leave the breeding grounds to embark on their
290 feeding migration as soon as they have weaned their pup and mated, while males stay behind to
291 mate with more than one female (Kovacs 1989, Kovacs et al. 1996). Following mating, the seals
292 need to replenish their energy stores and recover from the intensive, but short, lactation period
293 and the period of competition for mates among males. Due to differences in size and the different
294 rate of mass loss during breeding (males; ~2.5 kg per day over a 2.5 week period (Kovacs et al.
295 1996), females: ~10 kg per day over a 4 day period (Kovacs and Lavigne 1992)), males and
296 females may seek to recover using different strategies, either in visiting different geographic
297 locations and/or feeding on different prey items (e.g., Bajzak et al. 2009). Beck et al. (2007)
298 found sexual differences in the feeding behavior of grey seals where, during the post breeding
299 period (spring), females selected fewer and higher quality prey species than males. This behavior
300 is consistent with the nutritional-needs hypothesis (NNH) which predicts that when males are
301 much larger than females they should accept a lower diet and habitat quality since high quality
302 items are rare (Myerud 2000). Tucker et al. (2009) found a significant annual difference in the

303 diets of male and female hooded seals, where males consumed a higher concentration of redfish
304 (*Sebastes* sp.) and Greenland halibut (*Reinhardtius hippoglossoides*) while females consumed a
305 greater percentage of blue hake (*Antimora rostrata*) and white baraccudine (*Arctozenus rissoi*).
306 They further found a seasonal difference in diet composition where there was a higher
307 composition of capelin (*Mallotus villosus*) and atlantic argentine (*Argentina silus*) in the pre-
308 breeding period, while the percentage of redfish was much higher in the post-breeding period.
309 This supports our findings regarding the shift in hooded seal distribution patterns within these
310 two seasons. Figure 2a and c illustrate habitat use by adult hooded seals during the spring season
311 (post breed and pre moult) and we can see that males spend more time in the breeding areas than
312 females, and cross over to the moulting grounds in a more direct route (Fig 2a, c). We found that
313 females leave the breeding area immediately after mating and feed over the Reykjanes Ridge and
314 the SE Greenland shelf, which is an area with significant redfish fisheries (ICES 2010). Our
315 results do not show the same pattern for males, although they also appear to feed predominantly
316 on redfish during this time (Tucker et al. 2009). This difference could simply be due to the
317 sample size, or alternatively males may hunt their redfish prey along the shelf area in SE
318 Greenland when building up energy reserves prior to the moult.

319 Figures 2b and d illustrate the habitat use by females and males during the fall/winter
320 migration periods (post moult), respectively. The patterns indicate that males have a more
321 specific, and northern, habitat preference than females during this period. Females display a more
322 southern distribution and use a larger area as they feed along the Labrador shelf. According to the
323 reproductive-strategy hypothesis (RSH), when preparing for the breeding season, males should
324 seek high-quality forage in order to improve body condition and growth, which would greatly
325 increase their reproductive success (Mysterud 2000). However, Tucker et al. (2009) did not find a
326 difference in the energy density of prey between sexes, nor between juvenile and adults. They

327 also found that the energy density was higher during the pre breed period for all groups, not just
328 for the males (Tucker et al. 2009). This could mean that the energy requirements for hooded seals
329 are similar for both sexes when preparing for the short intense nursing and mating period.

330 GAMs have the ability to deal with highly non-linear and non-monotonic relationships
331 between the response and the set of exploratory variables (Guisan et al. 2002). Like GLMs, the
332 ability of this tool to handle non-linear data structures can aid in the development of ecological
333 models that better represent the underlying data, and hence increase our understanding of
334 ecological systems (Guisan et al. 2002). Although collinearity can cause a problem in GAMs, our
335 data show only moderate correlations between some of the variables (<0.5) and the highest r
336 values were between temperature and depth (A2a and A3a; 0.48 and 0.50 respectively).

337 The parameter weightings show that SST and depth were the most important parameters
338 explaining male habitat selection in both seasons (Table 4 and 5). The best models in fall/winter
339 for this group contain all the parameters (depth, SST, ice, slope and chlorophyll) and this may
340 indicate that target prey distribution in cold areas such as Baffin Bay may be more influenced by
341 oceanographic processes driven by topography and mixing in the water column than by water
342 depth. Slope does not appear to be significant for males during spring (Table 4; parameter
343 weighting = 0.24), although the lack of importance for the combination of depth and slope could
344 suggest that they actually feed on top of the shelf or sea mounts. Tucker et al. (2009) found that
345 redfish is the most prominent prey item in their diet during the post breed period. Even though
346 males seem to travel fast when they are crossing the Labrador Sea (< 2 days per ARS distance), it
347 does not necessarily mean that they are not finding food to replenish their reserves. Redfish is
348 among the most dominant deep sea fishes in the Reykjanes ridge area and Greenland shelf
349 (Hareide and Garnes, 2001, ICES 2010) and according to Hareide and Garnes (2001), this species
350 occupy depths between 500-1000 m and can be found close to the top of sea mounts and coral

351 formations. This supports our theory that male hooded seals prefer flat surfaces for foraging
352 during this time.

353 Females tend to prefer deeper waters (> 600 m, Fig 5d) during the fall/winter, while being
354 more generally distributed across various depths (200-1200 m, Fig 5a) in spring. In comparison,
355 males do not have a particular depth preference in fall/winter (ca. 200-1000 m), but prefer
356 somewhat deeper waters in spring (ca. 500-2000 m; Fig. 5b and e, respectively). Folkow et al.
357 (1996) found that adult hooded seals in the NE Atlantic displayed a significant seasonal
358 difference in dive depths and that dive depth was dependent on area, as well as time of day.
359 However, they did not find a significant difference between male and female dive behavior.

360 The variation in preference to SST among the groups, reflect that males, females and
361 juveniles appear to respond to different cues when they select a habitat. Also, SST does not
362 mirror the temperatures at depth, and we need to remember that hooded seals are excellent divers,
363 mainly feeding on benthopelagic species. This means that the seals will dive past the thermocline
364 to the cooler bottom waters to catch their prey. Thus SST itself may not be a very useful predictor
365 of habitat use.

366 Chlorophyll is an important variable for females and juveniles throughout the year
367 (Tables 4 and 5; Fig 3 a, c, d, f), but according to the predictive graphs (Fig 3b, e), male habitat
368 choice does not seem to be influenced by chlorophyll at either times of the year. The best models
369 (Table 3) and the parameter weights tell a different story (Table 4; 0.459 and Table 5; 0.801) and
370 these findings suggest that chlorophyll can be of importance when in combination with other
371 environmental variables. Furthermore, oceanographic parameters, such as those presented in this
372 study, may be acting as proxies for currently undefined processes important for hooded seal
373 habitat selection. Areas with high chlorophyll concentrations are productive, and attract feeding
374 organisms all along the food chain. However, these patches of prey congregations are very

375 dynamic and of a transient nature (Fauchald and Tveraa 2006), which may cause a spatial shift in
376 the actual feeding locations depending on where on the trophic ladder the predator targets its
377 prey. Our results suggest that male and female hooded seals may be foraging on different prey
378 during the annual migration. Incorporating dive behavior and possible prey overlap for this
379 population may allow us to clarify if this in fact occurs. Furthermore, integrating a Topographic
380 Complexity Index (TCI) in the models as a predictor of basins and sea mounts could yield a
381 better understanding of exactly what topographic properties male and female hooded seals hone
382 in on when they select a feeding location.

383 Juveniles share the annual distribution pattern with adults (Fig. 3e, f), although they
384 exhibit a slightly different ranking of parameter weights (Table 4 and 5). Folkow et al. (2010)
385 suggest that juveniles (and especially young of the year) target different prey as they cannot yet
386 dive to the same depths. Additional investigations show that hooded seals do not dive beyond 250
387 meters in their first year (Stenson; unpublished data). Studies on the development of diving
388 abilities in Weddell seal (*Leptonychotes weddellii*) pups show that these do not have the
389 physiological condition to remain submerged for as long as adults (Burns 1999; Burns and
390 Castellini 1996; Burns et al. 1999). However, when they have passed one year of age, they have
391 developed physiologically, and the diving ability now depends on body size and condition rather
392 than age (Burns et al. 1997). This supports our findings that juvenile hooded seals prefer depths
393 between 0-600 m during spring season (Fig 5c). Furthermore, Folkow et al. (2010) found that NE
394 population pups seem to improve their diving abilities greatly in the first year as they use areas
395 deeper than 600 m during fall/winter season (Fig.5f). Tucker et al. (2009) found that juvenile
396 hooded seals target mainly pelagic prey, which coincides with findings by Beck et al. (2007) on
397 the diet preferences of juvenile grey seals. They found that young grey seals had a broader niche
398 breadth than adults and that the diets were of lower energy density. They suggested that juveniles

399 display less selectivity as young and naïve predators, and it is therefore interesting that young
400 hooded seals generally share the movement pattern of adults already in their first year. They
401 follow the same route, but our results suggest that they use the oceanographic proxies or
402 “triggers” differently than adults when locating a feeding habitat.

403 Juveniles also showed a higher affinity to ice than adults (fall/winter; Table 5). This
404 positive relationship between FPT and ice covered areas during fall/winter (~ >5%; Fig. 7e) could
405 have various explanations. For instance, the parameter weights for this category show that
406 chlorophyll is of great importance to juveniles at all times of the year (Table 4 and 5), which
407 could further be linked to the ice results as ice edges are known to be productive. This could also
408 mean that young seals may initially target prey at a trophic level closer to primary production
409 than adult seals (as supported by Tucker et al. 2009). Another reason why juveniles might spend
410 more time in areas with more ice cover could be that they have a higher need for resting than
411 adults, as diving might be more physiologically challenging for younger seals (Burns et al. 1997).
412 Further study on haul-out behavior on ice throughout the year could provide more information of
413 how important ice itself is for hooded seals in general when searching for a feeding habitat.

414 Our models explain a low proportion of deviance in hooded seal habitat use, indicating
415 that habitat variables other than those that are included in this study are important. As hooded
416 seals forage at the top of the food chain, the relationship between habitat use and physical
417 features may be indirect, likely mediated by the responses of their prey or prey’s resources to
418 these physical features (Ballance et al. 2006). As a result, statistical associations between seals
419 and any given set of oceanographic parameters may be weak relative to values for organisms
420 feeding lower on the food chain (Ballance et al. 2006). Nevertheless, this study offers new insight
421 into the preferred conditions and habitat properties for hooded seals in the NW Atlantic Ocean,

422 and will serve as a stepping stone towards finding the habitat variables or combination of, that
423 will best explain hooded seals habitat selection and use.

424 Identifying the spatial scales of where marine predators forage is important for
425 understanding marine ecosystems (Fauchald and Tveraa 2003, Bailleul et al. 2008). FPT analysis
426 is especially useful to identify transitions in movement patterns (Bailleul et al. 2008) (e.g.
427 between travelling, searching and feeding). We used FPT to identify the spatial scale of which
428 hooded seals focus their search effort and linked this to environmental variables that could be
429 influencing habitat selection. As the tracks were interpolated to fit the ARS scale, we lost fine-
430 scaled information on the original track, but gained information about the areas of increased
431 search effort, which was the goal of this paper. Further investigations will focus on the dive
432 activity along the tracks, as well as temperature measurements collected real time vertically and
433 horizontally by the tags, in an attempt to provide more information on habitat use within the areas
434 identified here.

435

436 Conclusion

437 This study has shown that male, female and juvenile hooded seals select habitat differently,
438 although they prefer areas with similar complex topographic properties. A geographic and/or
439 vertical separation may indicate that they have different dietary needs and/or show competition
440 avoidance as they may feed on similar prey. How competition with other species feeding in these
441 same areas may influence habitat choice is yet to be investigated. Our work to date offers new
442 insight into hooded seal habitat selection and how they use their environment. This is important
443 information for making good management decisions and also to understand how environmental
444 change may affect such an arctic species throughout the year as they prepare for important life
445 history events.

446 ACKNOWLEDGEMENTS:

447 We would like to thank D. McKinnon and D. Wakeham for help in capturing the seals and
448 deploying the transmitters; Gjermund Bøthun at the Institute for Marine Research, Bergen, for
449 valuable assistance and input; Catherine Bajzak, and the LESA lab crew at Memorial University.
450 This work was funded through the Atlantic Seal Research program, the International Governance
451 Program (DFO) and by Greenland Institute of Natural Resources as well as a CFI grant to YFW.

452

453 SUPPLEMENTARY MATERIAL:

454 Supplementary material is available at the ICESJMS online version of the paper and includes the
455 following:

456 A1: Summary table presenting tag data, including tag performance

457 A2: Table with Spearman correlation information on the included predictive variables; Spring
458 season.

459 A3a: Table with Spearman correlation information on the included predictive variables;
460 Fall/Winter season.

461 A4a-c: Full AIC table showing all models run for females, males and females per season.

462 References

- 463 Andersen JM, Wiersma YF, Stenson G, Hammill MO, Rosing-Asvid A (2009) Movement patterns
464 of hooded seals (*Cystophora cristata*) in the Northwest Atlantic Ocean during the post-moult and
465 pre-breed seasons. *J Northwest Atl Fish Soc* 42: 1-11
- 466 Anonymous (2006) Report of the joint ICES/NAFO Working Group on Harp and Hooded seals
467 (WGHARP). ICES CM 2006/ACFM:32
- 468 Austin D, McMillan JI, Bowen WD (2003) A three-stage algorithm for filtering erroneous argos
469 satellite locations. *Mar Mamm Sci* 19 (2): 371-383
- 470 Baddeley A, Turner R (2005) Spatstat: an R package for analyzing spatial point patterns. *J Stat Softw*
471 12 (6), 1-42. ISSN: 1548-7660. URL: www.jstatsoft.org
- 472 Ballance LT, Pitman RL, Friedler PC (2006) Oceanographic influences on seabirds and cetaceans
473 of the eastern tropical Pacific :A review. *Prog Oceanogr* 69: 360-390
- 474 Bailleul F, Charrassin JB, Ezratzy R, Girard-Ardhuin F, McMahon CR, Field IC, Guinet C (2007)
475 Southern elephant seal from Kerguelen Islands confronted by Antarctic Sea ice. Changes in
476 movements and diving behavior. *Deep-Sea Res. II* 54:343-355
- 477 Bailleul F, Pineud D, Hindell M, Charrassin JB and Guinet C (2008) Assessment of scale-
478 dependent foraging behavior in southern elephant seals incorporating the vertical dimension: a
479 development of the First Passage Time method. *Journal of Animal Ecology* 77: 948-957
- 480 Bajzak CE, Côte SD, Hammill MO, Stenson G (2009) Intersexual differences in the postbreeding
481 foraging behavior of the Northwest Atlantic hooded seal. *Mar Ecol Prog Ser* 385: 285-294
- 482 Beck CA, Bowen WD, Iverson SJ (2003a) Sex differences in the seasonal patterns of energy
483 storage and expenditure in a phocid seal. *Journal of Animal Ecology* 72:280-291
- 484 Beck CA, Bowen WD, McMillan JI, Iverson SJ (2003b) Sex differences in diving at multiple
485 temporal scales in a size-dimorphic capital breeder. *Journal of Animal Ecology* 72: 979-993
- 486 Beck CA, Bowen WD, McMillan JI, Iverson SJ (2003c) Sex differences in diving behavior of a
487 size-dimorphic capital breeder: the grey seal. *Animal Behavior* 66:777-789
- 488 Beck CA, Iverson SJ, Bowen WD, Blanchard W (2007) Sex differences in grey seal diet reflect
489 seasonal variation in foraging behavior and reproductive expenditure: evidence from quantitative
490 fatty acid signature analysis. *Journal of Animal Ecology* 76:490-502
- 491 Benson AJ, Trites AW (2002) Ecological effects of regime shifts in the Bering Sea and eastern
492 North Pacific Ocean. *Fish and Fisheries* 3: 95-113

493 Biuw M, McConnell B, Bradshaw CJA, Burton H, Fedak M (2003) Blubber and buoyancy:
494 monitoring the body condition of free ranging seals using simple dive characteristics. *J. Exp.*
495 *Biol.* 206: 3405-3423

496 Breed GA, Bowen WD, McMillan JI, Leonard ML (2006) Sexual segregation of seasonal foraging
497 habitats in a non-migratory marine mammal. *Proc. R. Soc. B.* 273: 2319-2326

498 Burnham KP, Anderson DR (2002) Model selection and multimodel inference: a practical
499 information-theoretic approach. 2nd ed. Springer-Verlag, New York, New York, USA, 488pp

500 Burns JM (1999) The development of diving behavior in juvenile Weddell seals: pushing
501 physiological limits in order to survive. *Can. J. Zool.* 77:737-747

502 Burns JM, Castellini MA (1996) Physiological and behavioral determinants of the aerobic dive
503 limit in Weddell seal (*Leptonchotes weddellii*) pups. *J Comp Physiol B* 166:473-483

504 Burns JM, Castellini MA, Testa JW (1999) Movements and diving behavior of weaned Weddell
505 seal (*Leptonchotes weddellii*) pups. *Polar Biol.* 21:23-36

506 Burns JM, Schreer JF, Castellini MA (1997) Physiological effects on individual dive patterns and
507 foraging strategies in yearling Weddell seals (*Leptonchotes weddellii*). *Can. J. Zool.* 75:1796-
508 1810

509 Calenge C (2006) The package adehabitat for the R software: a tool for the analysis of space and
510 habitat use by animals. *Ecol Model*, 197, 516-519

511 Coltman DW, Stenson G, Hammill MO, Haug T, Davis CS, Fulton TL (2007) Panmitic population
512 structure in the hooded seal (*Cystophora cristata*). *Mol. Ecol.* 16: 1639–1648.
513 doi:10.1111/j.1365-294X.2007.03229.x

514 DFO (2006) 2005 State of the Ocean: Physical Oceanographic conditions in the Newfoundland and
515 Labrador Region. DFO. *Can. Sci. Advis. Sec. Sci. Advis. Rep.* 2006/018

516 DFO (2008) Proceedings of the National Workshop on the Impacts of Seals on Fish Populations in
517 Eastern Canada (Part 1); 12-16 November 2007. DFO *Can. Sci. Advis. Sec. Proceed. Ser.*
518 2008/021.

519 DFO (2009) Proceedings of the National Workshop on the Impacts of Seals on Fish Populations in
520 Eastern Canada (Part 2); 24-28 November 2008. DFO *Can. Sci. Advis. Sec. Proceed. Ser.*
521 2009/020.

522 Fauchald P, Tveraa T (2003) Using first passage time in the analysis of area-restricted search and
523 habitat selection. *Ecology* 84(2): 282-288

524 Fauchald P, Tveraa T (2006) Hierarchical patch dynamics and annual movement pattern. *Oecologia*
525 149: 383-395

526 Folkow LP, Blix AS (1995) Distribution and diving behavior of hooded seals. In: A. S. Blix, L.
527 Walløe and Ø. Ulltang (eds.). *Whales, Seals, Fish and Man*. Elsevier, Amsterdam 193–202.

528 Folkow LP, Blix AS (1999) Diving behavior of hooded seals (*Cystophora cristata*) in the Greenland
529 and Norwegian Seas. *Polar Biol.* 22:61-74

530 Folkow LP, Mårtensson PE, Blix, AS (1996) Annual distribution of Hooded seals (*Cystophora*
531 *cristata*) in the Greenland and Norwegian Seas. *Polar Biol* 16: 179-189

532 Folkow LP, Nordøy ES, Blix AS (2010) Remarkable development of diving performance and
533 migrations of hooded seals (*Cystophora cristata*) during their first year of life. *Polar Biol* 33:
534 433-441

535 Freitas C, Lydersen C, Fedak MA, Kovacs KM (2008) A simple new algorithm to filter marine
536 mammal Argos locations. *Mar Mamm Sci* 24(2): 315-325.

537 Guisan A, Edwards TC Jr, Hastie T (2002) generalized linear and generalized additive models in
538 studies of species distributions: setting the scene. *Ecol Model.* 157:89-100

539 Gulland JA. 1974. Distribution and abundance of whales in relations to basic productivity. In the
540 *Whale Problem. A status report*. Ed.: Schevill WE 27-52

541 Hammill MO (1993) Distribution and movements of hooded seals tagged in the Gulf of St.
542 Lawrence. *Polar Biol* 13: 307-310

543 Hammill MO, Stenson G (2000) Estimated Prey Consumption by Harp seals (*Phoca groenlandica*),
544 Hooded seals (*Cystophora cristata*), Grey seals (*Halichoerus grypus*) and Harbour seals (*Phoca*
545 *vitulina*) in Atlantic Canada. *J. Northw. Atl. Fish. Sci.* 26: 1-23

546 Hammill MO, Stenson G (2006) Abundance of Northwest Atlantic hooded seals (1960-2005). DFO
547 Canada. Canadian Science Advisory Secretariat Research Document 2006/068. 19p. Available at
548 <http://www.dfo-mpo.gc.ca/csas/>

549 Hareide NR, Garnes G (2001) The distribution and catch rates of deep water fish along the Mid-
550 Atlantic Ridge from 43 to 61° N. *Fish Res.* 51: 297-310

551 Haug T, Nilssen KT, Lindblom L, Lindstrøm U (2007) Diets of Hooded seals (*Cystophora cristata*)
552 in coastal waters and drift ice waters along the east coast of Greenland. *Mar Biol Res* 3: 123-133

553 Heide-Jørgensen MP, Laidre KL (2004) Declining extent of open-water refugia for top predators in
554 Baffin Bay and adjacent waters. *Ambio* 33(8): 487-494

555 Houston AI, Stephens PA, Boyd IL, Harding KC, McNamara JM (2006) Capital or income
556 breeding? A theoretical model of female reproductive strategies. *Behav Ecol*.
557 Doi:10.1093/beheco/arl1080

558 ICES (2010) Report of the ICES Advisory Committee 2010. ICES Advice. Book 2. 114pp.

559 Kapel FO (1996) Recoveries in Greenland, 1949 – 94, of tagged or branded harp and hooded seals.
560 NAFO Sci. Coun. Studies 26: 87 – 99

561 Kareiva and Odell (1987) Swarms of predators exhibit “preytaxis” if individual predators use Area-
562 Restricted-Search. *Am Nat* 130 (2): 233-270

563 Kovacs KM (1989) Mating strategies in male hooded seals (*Cystophora cristata*)? *Can. J. Zool.* 68:
564 2499-2502

565 Kovacs KM, Lavigne DM (1992) Mass-transfer efficiency between hooded seal (*Cystophora*
566 *cristata*) mothers and their pups in the Gulf of St. Lawrence. *Can. J. Zool.* 70: 1315-1320

567 Kovacs KM, Lydersen C, Hammill M, Lavigne DM (1996) Reproductive effort of male hooded
568 seals (*Cystophora cristata*): estimates from mass loss. *Can. J. Zool.* 74: 1521-1530

569 Laidre KL, Heide-Jørgensen MP, Dietz R, Hobbs RC, Jørgensen OA (2003) Deep-diving by
570 narwhals *Monodon monoceros*: differences in foraging behavior between wintering areas? *Mar*
571 *Ecol Prog Ser* 261: 269-281.

572 Laidre KL, Heide-Jørgensen MP, Logson ML, Hobbs RC, Heagerty P, Dietz R, Jørgensen OA,
573 Treble MA (2004) Seasonal narwhal habitat association in the high Arctic. *Mar Biol* 145: 821-
574 831

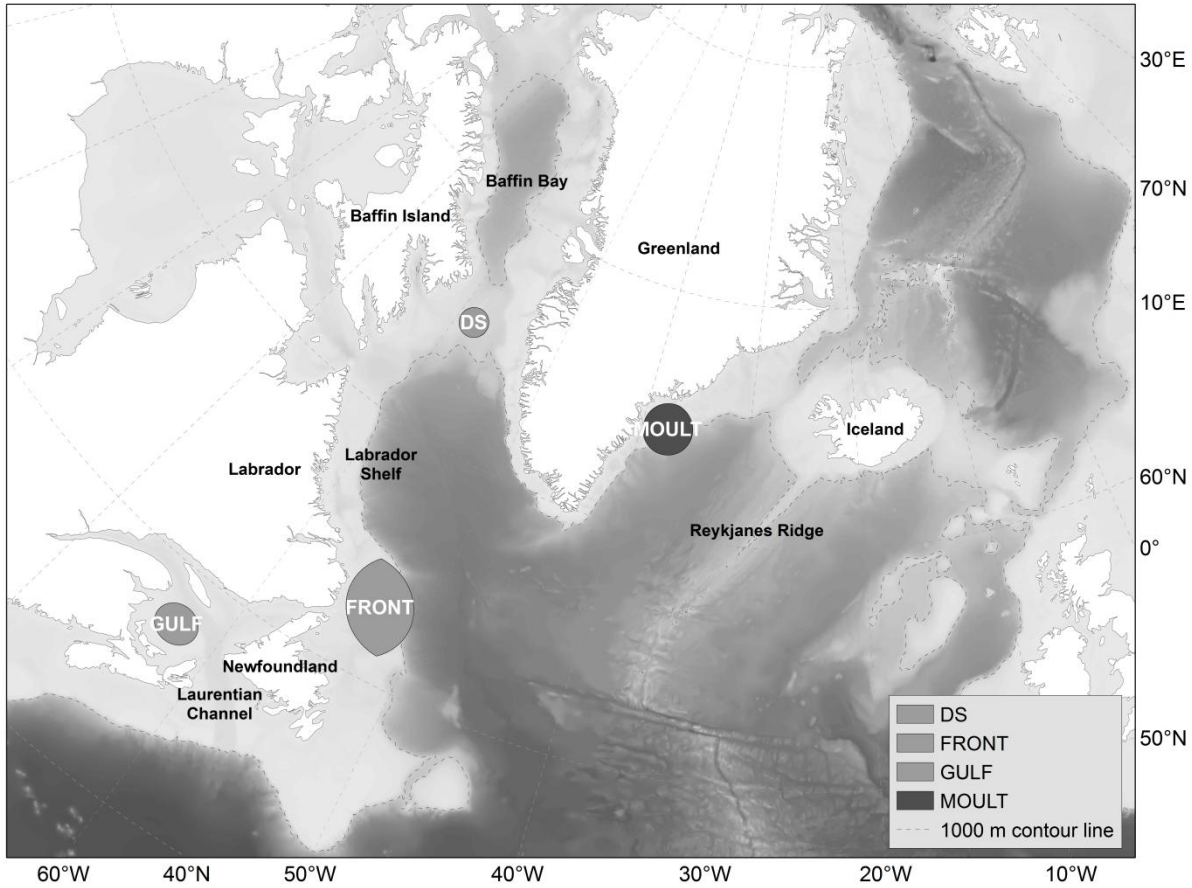
575 Loeng, H (1991) Features of the physical oceanographic conditions of the Barents Sea. Pp. S18 in
576 Sakshaug E, Hopkins CCE, Britsland NA. (eds.): Proceedings of the Pro Mare Symposium on
577 Polar Marine Ecology, Trondheim, 12-16 May 1990. *Polar Research* 10/1.

578 Mysterud A. 2000. The relationship between ecological segregation and sexual body size
579 dimorphism in large herbivores. *Oecologia* 124:40-54

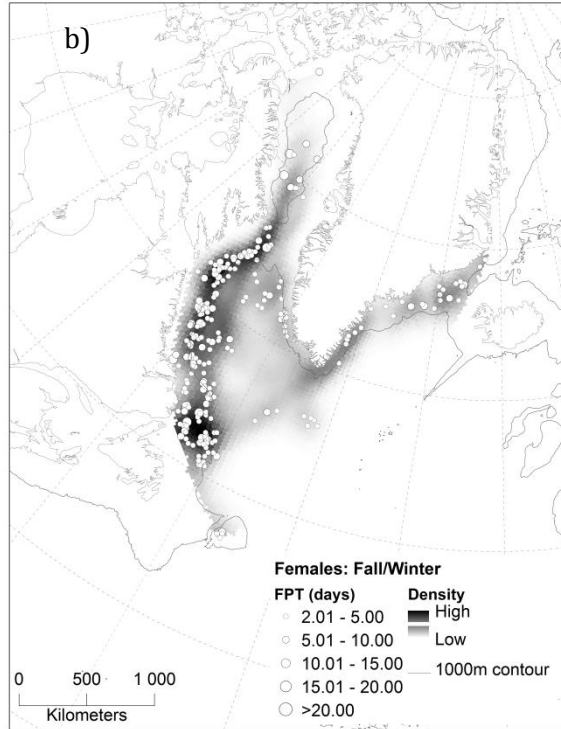
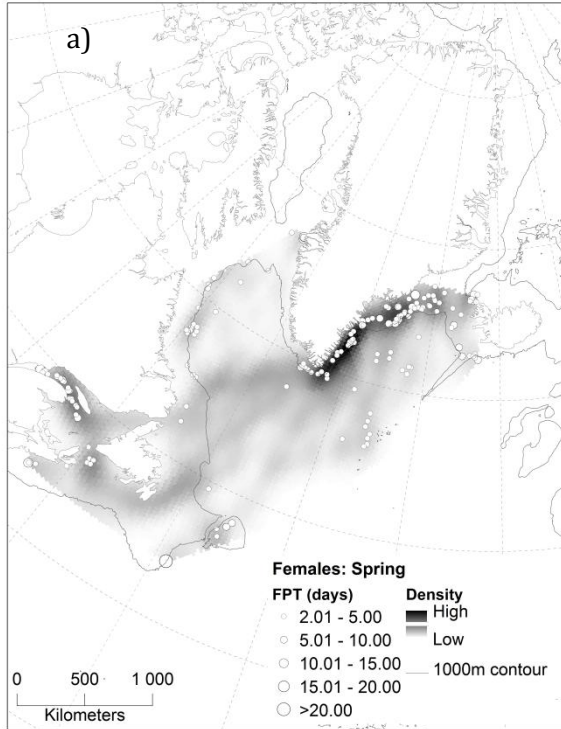
580 Richard PR, Heide-Jørgensen MP, Aubin DST (1998) Fall movements of belugas (*Delphinapterus*
581 *leucas*) with satellite-linked transmitters in Lancaster Sound, Jones Sound, and Northern Baffin
582 Bay. *Arctic* 51: 5-16

583 Ross H and Harrison G (2007) Status of the Labrador Sea. *AZMP Bulletin PMZA*. No.6 11-15
584 Available at: [http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-
pmza/documents/docs/bulletin_6_2007.pdf](http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-
585 pmza/documents/docs/bulletin_6_2007.pdf)

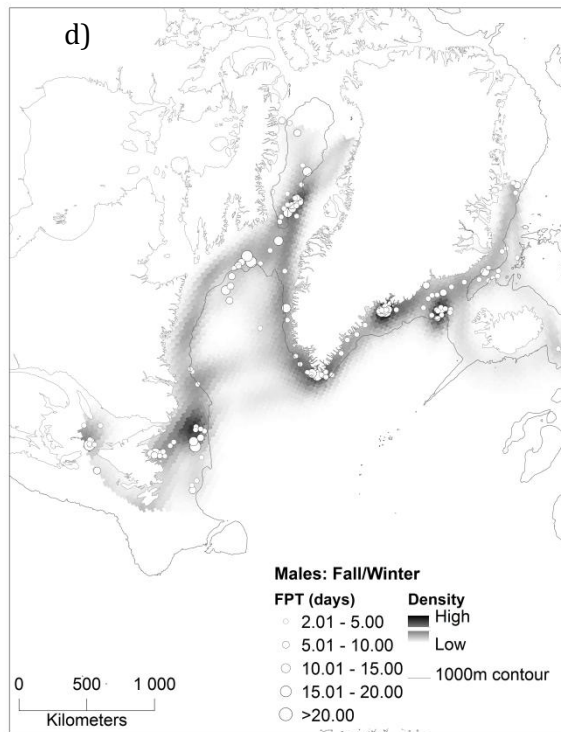
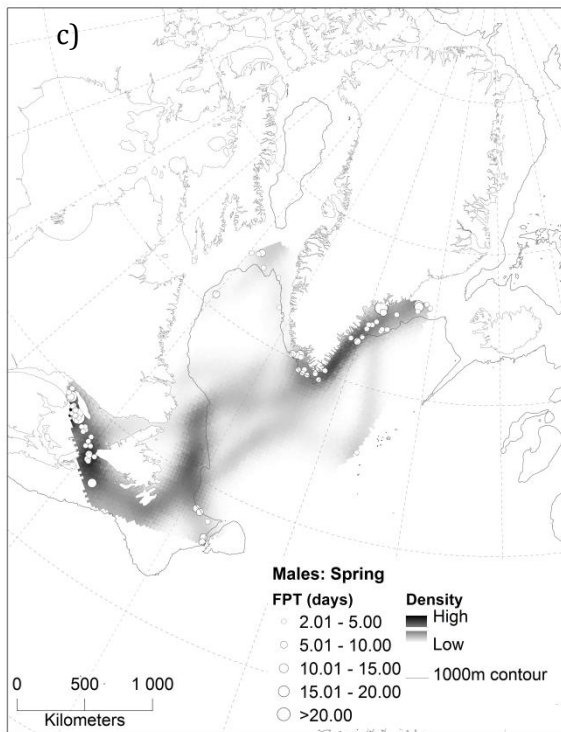
586 Ross SA (1992) Food and Feeding of the hooded seal (*Cystophora Cristata*) in Newfoundland.
587 M.Sc. Thesis Memorial University of Newfoundland. St. John's. Newfoundland
588 Sergeant DE (1974) A rediscovered whelping population of hooded seals, *Cystophora cristata*
589 Erxleben, and its possible relationship to other populations. *Polarforschung* 44 (10): 1-7
590 Sergeant DE (1976) History and present status of populations of harp and hooded seals. *Biol.*
591 *Conserv.* 10: 95-118
592 Smith WO Jr., Nelson DM (1986) Importance of Ice Edge Phytoplankton Production in the
593 Southern Ocean. *BioScience.* 36 (4): 251-257
594 Trillmich F, Weissing FJ (2006) Lactation patterns of pinnipeds are not explained by optimization
595 of maternal energy delivery rates. *Behav Ecol Sociobiol.*60: 137-149
596 Tucker S, Bowen WD, Iverson SJ, Blanchard W, Stenson GB (2009) Sources of variation in diets
597 of harp and hooded seals estimated from quantitative fatty acid signature analysis (QFASA). *Mar*
598 *Ecol Prog Ser* 384:287-302
599 Wood SN (2006). *Generalized Additive Models: An introduction with R.* Chapman and
600 Hall/CRC).
601 Wood SN (2008) Fast stable direct fitting and smoothness selection for generalized additive
602 models. *J R Stat Soc (B)* 70(3):495-518
603 Wood SN (2011) Fast stable restricted maximum likelihood and marginal likelihood estimation of
604 semiparametric generalized linear models. *J R Stat Soc (B)* 73(1):3-36
605



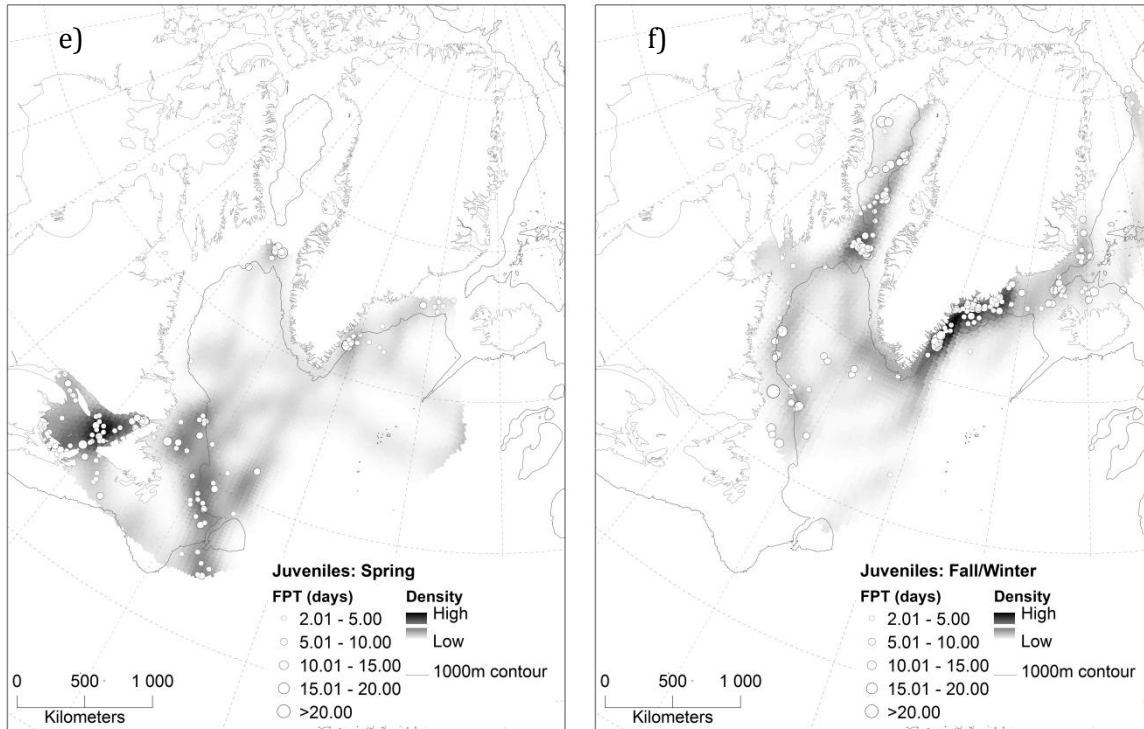
606
 607 Figure 1: Andersen et al.
 608
 609
 610
 611



612

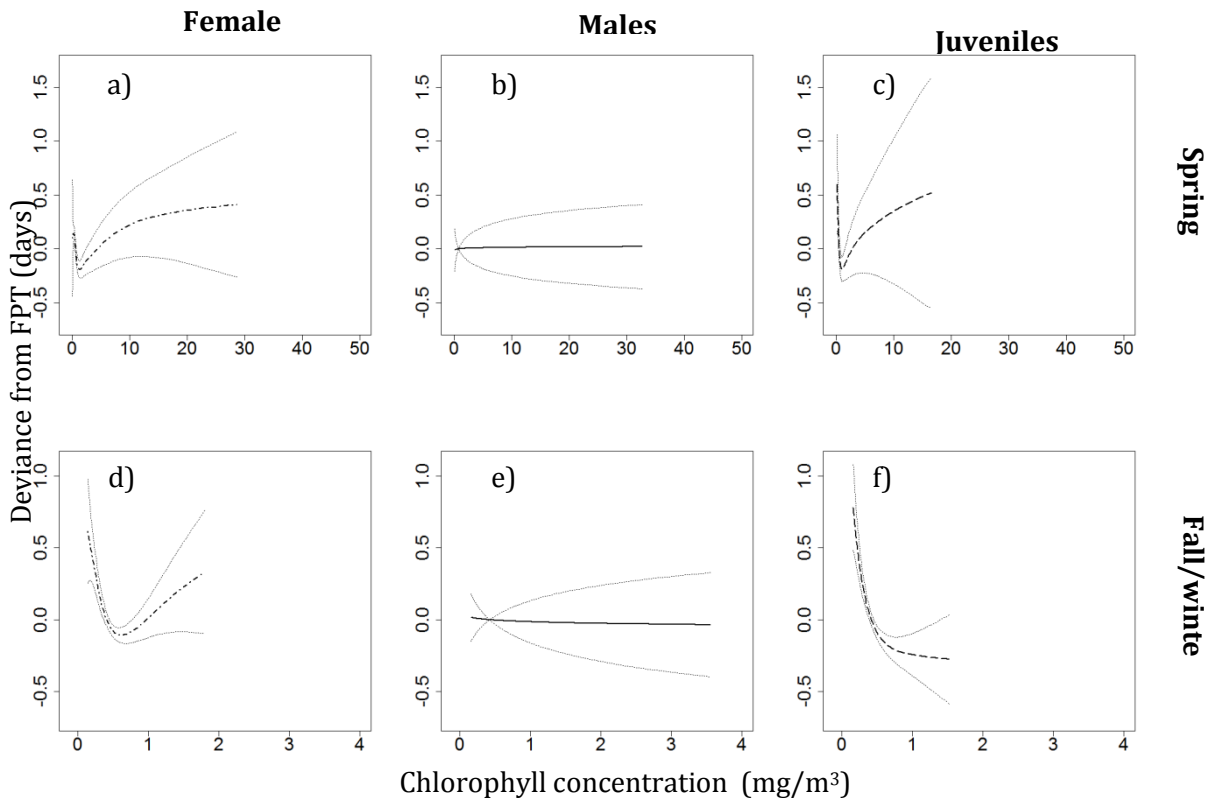


613



614
615 Figure 2 a-f: Andersen et al.

616

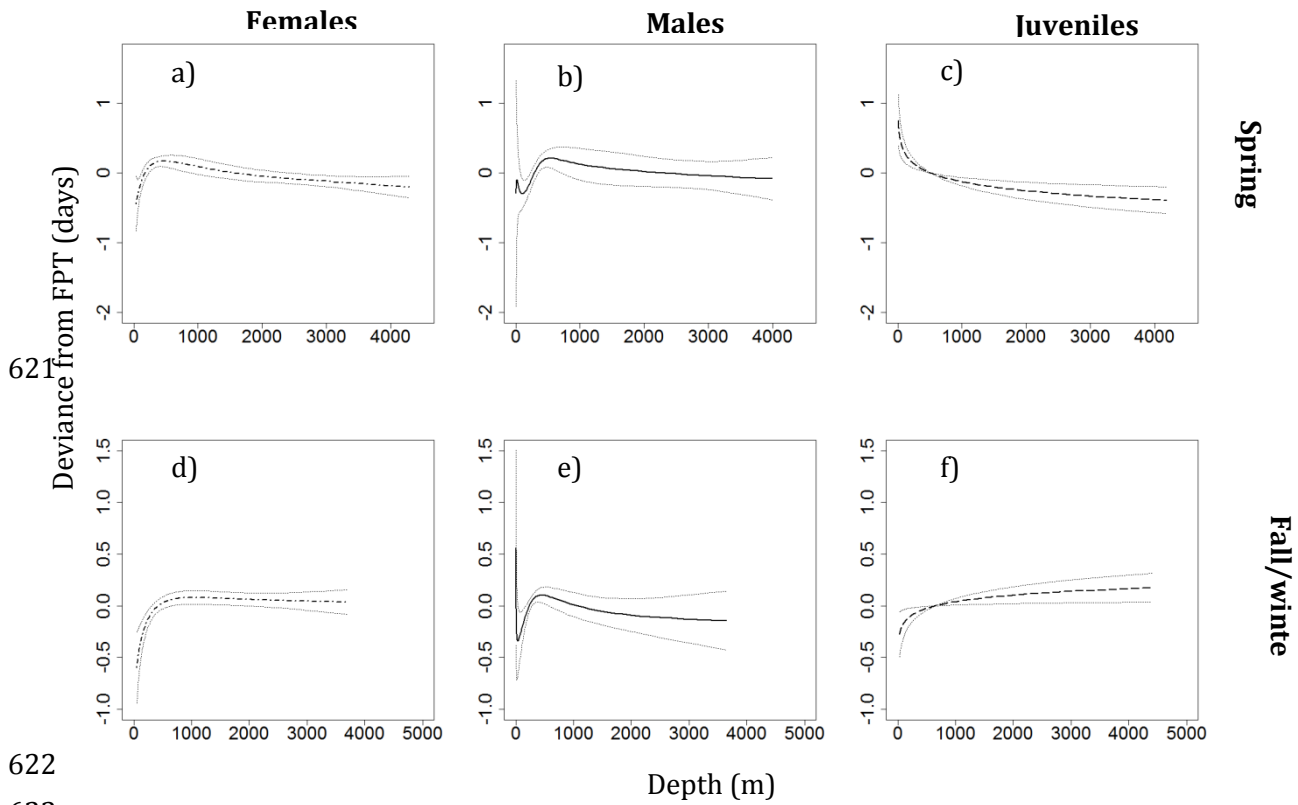


617

618

619

620 Figure 3: Andersen et al.



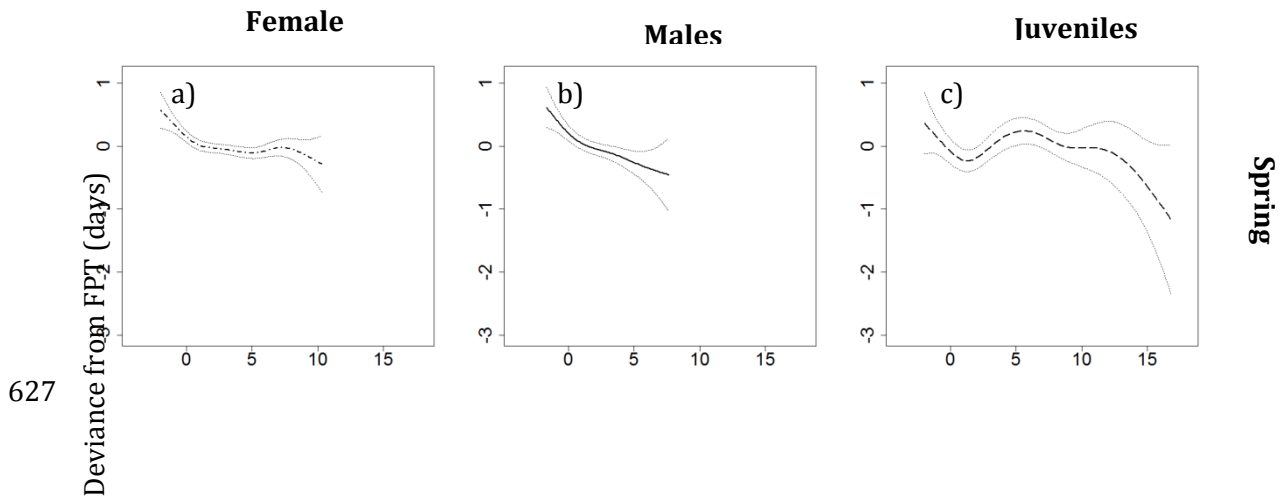
622

623

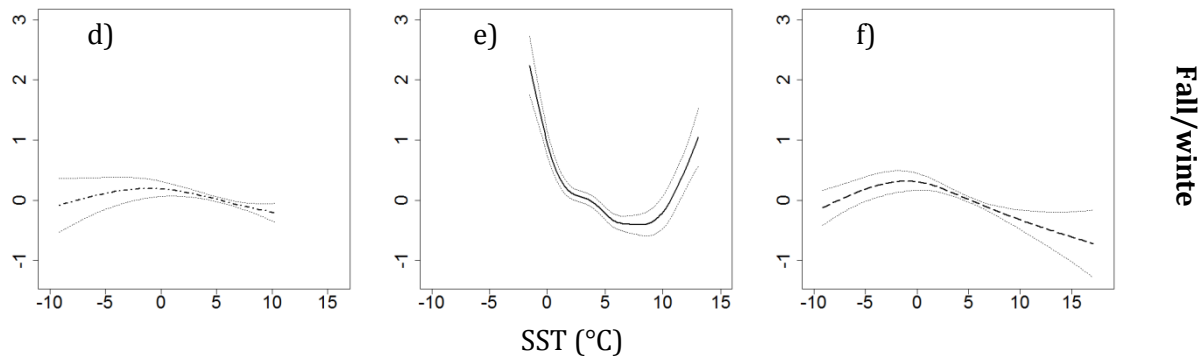
624 Figure 4: Andersen et al.

625

626



627

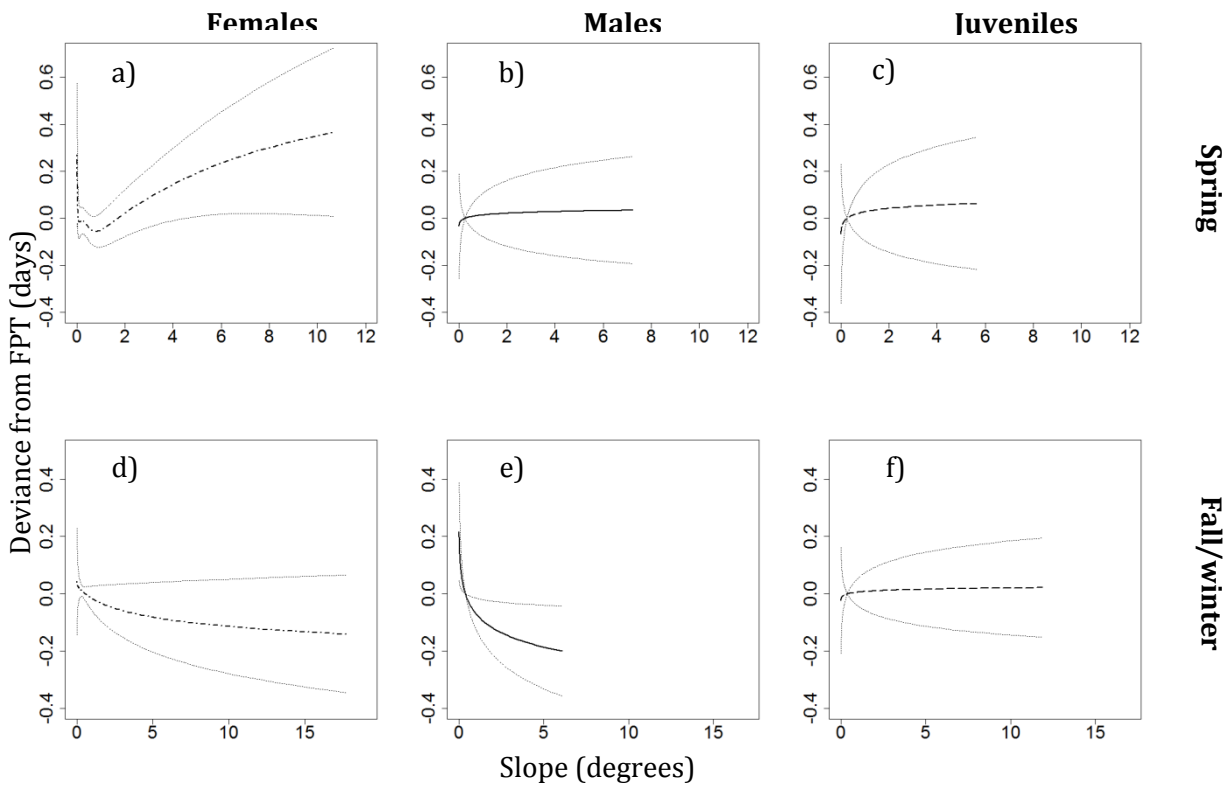


628

629

630 Figure 5: Andersen et al.

631



632

633

634

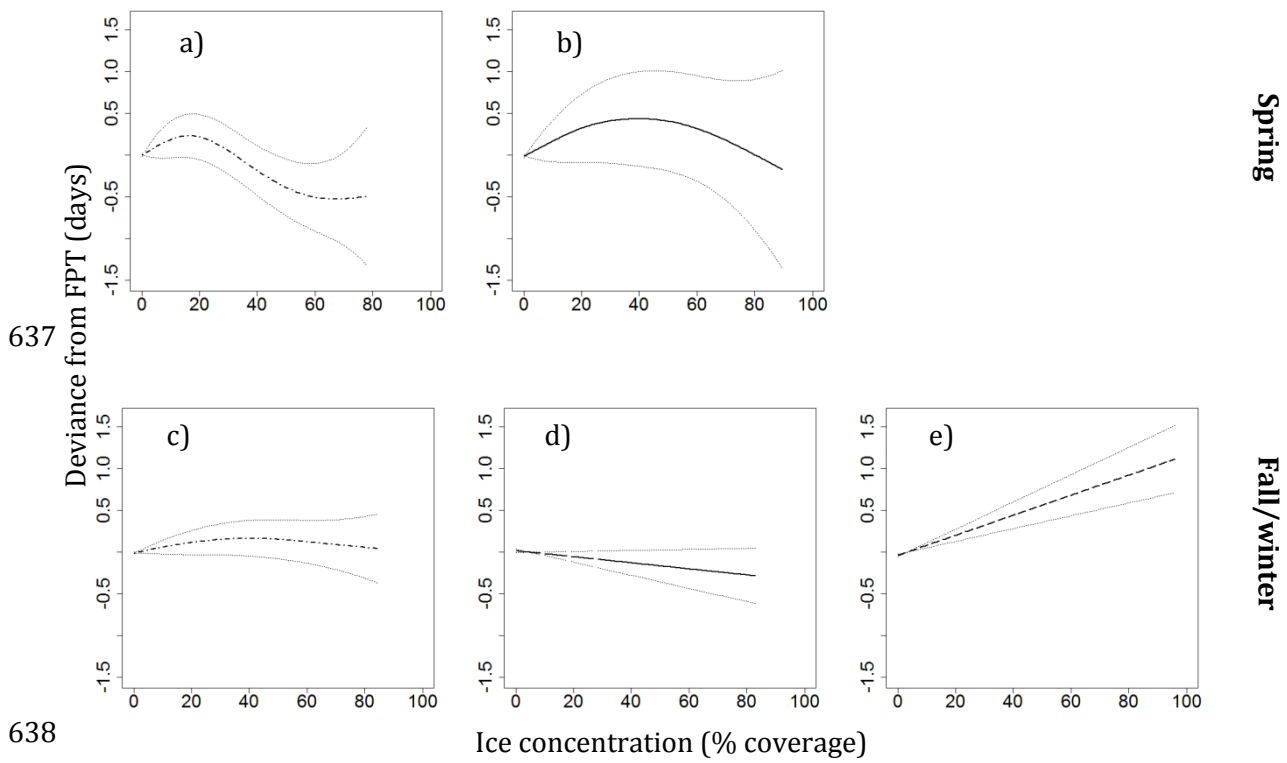
635 Figure 6: Andersen et al.

636

Females

Males

Juveniles



637

638

639

640

641 Figure 7: Andersen et al.

642

643 Table 1: Number of hooded seals tagged with satellite relay data loggers (SRDLs), 2004-2008 for
 644 which data were available for the spring (post breed – pre moult) and fall/winter (post moult –
 645 pre breed) period (Season). A total of 65 individuals were tagged. Sex/Age represent seal group,
 646 and Number is the number of seals represented in each season (Details of the individuals are
 647 provided in the supplementary material (A1)).

Sex/Age	Season	Number
Females	Spring	8
Females	Fall/Winter	1
Males	Spring	2
Males	Fall/Winter	0
Juveniles	Spring	0
Juveniles	Fall/Winter	1

648

649 Table 2: Area restricted search (ARS) scale for all categories (sex, age (Group) and season). ARS
 650 (km) is the search radius estimated per seal group per season.

Group	Season	ARS (km)
Females	Spring (April-June)	7.5
Males	Spring (April-June)	7.5
Juveniles	Spring (April-June)	5
Females	Fall/Winter (August-February)	7.5
Males	Fall/Winter (August-February)	7.5
Juveniles	Fall/Winter (August-February)	5

651

652 Table 3. AIC table showing the best models for each group (F: females, M: males, J: juveniles) per
 653 season. The best models are based on having a $\Delta_i < 2$. Loglik is the loglikelihood. K is the
 654 number of parameters in the model. AIC_i is AIC for model i. and Δ_i is the difference between the
 655 AIC of the best fitting model and that of model i. $\text{Exp}(-0.5\Delta_i)$ represent the relative likelihoods
 656 and the w_i is the Akiawe weights. The percent deviance explained is here presented as a measure
 657 of the models goodness of fit. The full list of models run can be viewed in the supplementary
 658 material.

F/M/J	Season	Best models per	Loglik	K	AIC_i	Δ_i	$\text{Exp}(-\Delta_i)$	w_i	Deviance
-------	--------	-----------------	--------	---	---------	------------	-------------------------	-------	----------

	category and season			0.5□□)		explaine d (%)		
	pring	ST, ice, chlorophyll, slope and depth	2729.231	470.46		.990	2.9	
	all	ST, chlorophyll and depth	391.46	390.92		.332	.15	
	all	ST, chlorophyll, slope and depth	390.97	391.94	.01	.60	.200	.35
	all	chlorophyll	394.35	392.70	.77	.41	.137	.99
1	pring	ST and depth	342.88	691.76		.541	5.6	
1	pring	ST, chlorophyll and depth	342.80	693.59	.83	.40	.216	5.6
1	all	ST, chlorophyll, slope and depth	455.14	14.27		.582	1.3	
1	all	ST, ice, chlorophyll, slope and depth	455.01	16.03	.75	.417	.243	1.3
	pring	ST, chlorophyll and depth	512.1848	032.37		.682	2.9	
	pring	ST, chlorophyll, slope and depth	512.0175	034.04	.67	.435	.296	3.0
	all	ST, ice,	410.3775	32.76		.843	8.1	

chlorophyll,
 slope and
 depth

659 Table 4. Parameter weightings for each seal group (females, males and juveniles) per habitat
 660 variable for spring season (Apr-Jun). Weights are calculated based on the model weights from all
 661 the models.

females:		males:		juveniles:	
variable	weight	variable	weight	variable	weight
depth		ST	.999	depth	.999
chlorophyll		depth	.999	ST	.999
ST		chlorophyll	.459	chlorophyll	.978
slope	.999	slope	.243	slope	.296
ice coverage	.989	ice coverage	.151		

662

663 Table 5. Parameter weightings for each seal group (females, males and juveniles) per variable for
 664 fall/winter season (Aug- Feb). Weights are calculated based on the model weights from all the
 665 models.

females:		males:		juveniles:	
variable	weight	variable	weight	variable	weight
chlorophyll	.880	ST		chlorophyll	.999
depth	.860	depth	.867	depth	.991
ST	.751	chlorophyll	.818	ST	.988
slope	.299	slope	.801	slope	.881
ice coverage	.099	ice coverage	.224	ice coverage	.843

666

667

668

669

670 **Supplementary material:**

671 A1: Summary table presenting tag data, including tag performance. The individual tags are
 672 named by “Seal Id”. “Sex” = Males (M), Females (F) and Juveniles (J). “Wt (kg)” is the weight of
 673 the animal at tagging. “Start” and “End” columns represent the dates the tags began and
 674 stopped transmitting. “Days transmitting” is the number of days the tag transmitted for. “Latitude”
 675 and “Longitude” represent the coordinates at tag location.

sort	Seal Id	Sex	Age	Wt (kg)	Year	Start	End	Days transmitting	Latitude tagged	Longitude tagged
1	hd1_9315_04	F	A	330	2004	14.mar	31.may	78	46°58	-62°40
2	hd1_9256_04	F	A	208	2004	14.mar	09.jul	117	46°64	-62°25
3	hd1_9338_04	F	A	195.5	2004	14.mar	13.jun	90	46°63	-62°24
4	hd1_9324_04	M	A	321	2004	16.mar	15.jun	91	46°60	-61°85
5	hd1_9335_04	M	A	326.5	2004	17.mar	08.jun	83	46°64	-61°87
6	hd1_9255_04	F	A	276	2004	17.mar	17.jun	92	46°62	-61°85
7	hd1_9336_04	M	A	192	2004	17.mar	21.jul	126	46°57	-61°82
8	hd1_9317_04	M	A	274	2004	19.mar	14.jun	87	46°47	-61°90
9	hd2f-9257-04	F	A	148	2004	20.mar	30.jun	103	51°78	-55°52
10	hd2f-9337-04	F	A	150	2004	20.mar	24.may	66	51°77	-55°52
11	hd2f-9350-04	F	A	182.5	2004	20.mar	23.jun	95	51°77	-55°52
12	hd2bb-9340-04	M	J	40.5	2004	20.mar	28.may	69	51°80	-55°44
13	hd2f-9343-04	F	A	162	2004	23.mar	17.jun	86	52°08	-55°15
14	hd2bb-9339-04	F	J	47.5	2004	23.mar	11.mar	353	52°09	-55°17
15	hd2f-9316-04	F	A	147	2004	23.mar	28.jun	97	52°07	-55°16
16	hd2f-9355-04	M	A	246	2004	25.mar	24.jun	92	51°87	-55°40
17	hd2g-9409-04	F	A	116	2004	24.jul	28.jun	340	66°23	-34°28
18	hd2g-9426-04	F	J	81	2004	24.jul	29.jun	340	66°21	-34°23
19	hd2g-9411-04	M	J	155	2004	24.jul	03.jan	163	66°24	-34°24
20	hd2g-9421-04	M	A	172	2004	24.jul	20.mar	239	66°20	-33°48
21	hd2g-9412-04	F	J	85	2004	24.jul	26.jun	337	66°38	-33°56
22	hd1_9397_04	M	A	338	2005	12.mar	16.jun	95	47°98	-61°84
23	hd1_9363_04	F	A	228	2005	13.mar	06.jun	86	48°03	-61°91
24	hd1_9351_04	F	A	188	2005	13.mar	23.jun	102	47°92	-61°99
25	hd1_9341_04	M	A	338.5	2005	14.mar	03.jul	111	47°77	-61°99
26	hd5g-9427-05	M	A	194	2005	20.jul	07.apr	261	65°50	-36°02
27	hd5g-9352-05	M	J	105	2005	20.jul	30.sep	72	65°52	-36°12
28	hd5g-9400-05	F	A	112	2005	20.jul	20.may	304	65°44	-36°29
29	hd5g-9422-05	M	A	253	2005	20.jul	07.sep	49	65°40	-36°28
30	hd5g-9420-05	F	A	138	2005	20.jul	13.jun	328	65°51	-36°37
31	hd5g-9410-05	M	J	127	2005	20.jul	23.jun	338	65°42	-36°34
32	hd5g-9413-05	F	A	90	2005	23.jul	27.jun	338	65°49	-37°09
33	hd5g-9344-05	F	A	108	2005	24.jul	25.aug	33	65°40	-36°64
34	hd5g-10204-05	M	A	146	2005	24.jul	13.jun	324	65°23	-36°83
35	hd5g-10207-05	M	A	174	2005	24.jul	12.jul	353	65°46	-37°23
36	hd5g-10219-05	F	A	117	2005	25.jul	14.jun	324	65°32	-37°47
37	hd5g-10222-05	F	A	98	2005	25.jul	18.jun	328	65°44	-37°14
38	hd5g-10188-05	M	A	109	2005	25.jul	22.mar	240	65°40	-37°46
39	hd5g-10227-05	F	A	114	2005	25.jul	26.may	305	65°46	-37°39
40	hd5g-10206-05	F	A	95	2005	25.jul	04.jul	343	65°50	-37°85
41	hd5g-10205-05	F	A	138	2005	25.jul	14.apr	263	65°38	-37°57
42	hd5bb-9318-05	F	J	51	2006	18.mar	20.nov	246	51°91	-55°20

43	hd5bb-9329-05	F	J	50	2006	18.mar	09.des	265	51°91	-55°19
44	hd5bb-9311-05	M	J	50	2006	25.mar	22.sep	180	51°14	-57°56
45	hd5bb-9304-05	M	J	45	2006	26.mar	21.jul	118	51°40	-55°44
46	hd6-D-06	F	A	73.5	2007	20.jul	02.jun	319	65°36	-37°25
47	hd6-E-06	F	A	98	2007	24.jul	06.sep	44	65°38	-37°92
48	hd6-F-06	M	A	97.5	2007	24.jul	24.jun	336	65°40	-37°82
49	ct18-L-06	M	A	130	2007	24.jul	07.apr	258	65°38	-37°97
50	MH4-10392-08	F	A	182.5	2008	14.mar	18.jun	96	47°69	-61°84
51	MH4-10423-08	F	A	251	2008	14.mar	01.jul	109	47°68	-61°83
52	MH4-10209-08	F	J	46	2008	14.mar	27.apr	43	47°39	-61°86
53	MH4-10348-08	F	A	251	2008	15.mar	26.jun	104	47°69	-61°81
54	MH4-10386-08	F	A	224.5	2008	15.mar	14.jun	91	47°69	-61°77
55	MH4-10349-08	F	J	39	2008	15.mar	25.apr	40	47°69	-61°78
56	MH4-10401-08	M	A	352.5	2008	16.mar	22.jun	98	47°66	-61°76
57	MH4-9391-08	F	J	51	2008	17.mar	11.aug	147	47°59	-61°87
58	hd3-CTD453-08	M	A	230	2008	24.mar	14.may	51	49°66	-52°62
59	hd3-80-08	F	A	155.5	2008	24.mar	11.jul	109	49°87	-52°32
60	hd3-81-08	F	A	158.5	2008	24.mar	02.jul	100	49°69	-52°16
61	hd3-82-08	F	A	139	2008	24.mar	23.jun	90	49°72	-52°18
62	hd3-79-08	F	A	149.5	2008	25.mar	19.jun	86	49°65	-52°30
63	hd3-78-08	F	A	229	2008	25.mar	21.jun	88	49°96	-51°87
64	hd3-76-08	F	J	42	2008	27.mar	18.may	52	49°21	-51°55
65	hd3-77-08	F	J	51.5	2008	28.mar	09.may	42	49°28	-51°33

676

677

678 A2a: Spearman correlation coefficients for the five prediction variables: Spring (April-June)
679 dataset. The r values are presented here where “group” represent the seal group: “J”= Juveniles,
680 “M” = Males, “F” = Females.

		SPRING				
Group	Variable	Temperature	Ice	Chlorophyll	Slope	Depth
J	Temperature	1.00	0.09	-0.07	-0.18	0.21
J	Ice	0.09	1	0.07	-0.06	-0.14
J	Chlorophyll	-0.07	0.07	1	-0.1	-0.24
J	Slope	-0.18	-0.06	-0.1	1	0.29
J	Depth	0.21	-0.14	-0.24	0.29	1
M	Temperature	1.00	-0.11	-0.35	0.03	0.28
M	Ice	-0.11	1	0.09	-0.04	-0.08
M	Chlorophyll	-0.35	0.09	1	-0.12	-0.37
M	Slope	0.03	-0.04	-0.12	1	0.21
M	Depth	0.28	-0.08	-0.37	0.21	1
F	Temperature	1.00	-0.18	-0.24	0.08	0.48
F	Ice	-0.18	1	0.03	0.05	-0.24
F	Chlorophyll	-0.24	0.03	1	-0.15	-0.29
F	Slope	0.08	0.05	-0.15	1	0.09

F	Depth	0.48	-0.24	-0.29	0.09	1
----------	-------	------	-------	-------	------	---

681 A2b: P-values explaining the significant degree of the Spearman correlation test (reported in
 682 Table A2a) between the predictor variables in the spring (April-June dataset). "Group"
 683 represents the seal group: "J"= Juveniles. "M" = Males. "F" = Females.

		SPRING P-value				
Group	Variable	Temperature	Ice	Chlorophyll	Slope	Depth
J	Temperature		0.0976	0.1738	0.0004	0
J	Ice	0.0976		0.2086	0.232	0.0067
J	Chlorophyll	0.1738	0.2086		0.0594	0
J	Slope	0.0004	0.232	0.0594		0
J	Depth	0	0.0067	0	0	
M	Temperature		0.005	0	0.4981	0
M	Ice	0.005		0.0198	0.3366	0.0412
M	Chlorophyll	0	0.0198		0.0037	0
M	Slope	0.4981	0.3366	0.0037		0
M	Depth	0	0.0412	0	0	
F	Temperature		0	0	0.0005	0
F	Ice	0		0.189	0.0435	0
F	Chlorophyll	0	0.189		0	0
F	Slope	0.0005	0.0435	0		0
F	Depth	0	0	0	0	

684

685 A3a: Spearman correlation coefficients for the prediction variables: Fall (Aug - Feb) dataset. The
 686 r values are presented here where "group" represent the seal group: "J"= Juveniles. "M" = Males.
 687 "F" = Females.

		FALL				
Group	Variable	Temperature	Ice	Chlorophyll	Slope	Depth
J	Temperature	1.00	-0.04	0.13	0.1	0.46
J	Ice	-0.04	1	-0.06	-0.06	-0.13
J	Chlorophyll	0.13	-0.06	1	-0.04	-0.13
J	Slope	0.10	-0.06	-0.04	1	0.22
J	Depth	0.46	-0.13	-0.13	0.22	1
M	Temperature	1.00	-0.13	0.17	-0.05	0.16
M	Ice	-0.13	1	0.04	-0.11	-0.13
M	Chlorophyll	0.17	0.04	1	0.08	0.05
M	Slope	-0.05	-0.11	0.08	1	0.24
M	Depth	0.16	-0.13	0.05	0.24	1
F	Temperature	1.00	-0.22	0.46	-0.09	0.5
F	Ice	-0.22	1	-0.04	0.01	-0.18

F	Chlorophyll	0.46	-0.04	1	0.02	0.26
F	Slope	-0.09	0.01	0.02	1	-0.02
F	Depth	0.50	-0.18	0.26	-0.02	1

688

689 A3b: P-values explaining the significant degree of the Spearman correlation test (reported in
690 Table A3a) between the predictor variables in the fall (Aug – Feb dataset). “Group” represents
691 the seal group: “J”= Juveniles. “M” = Males. “F” = Females.

Group	Variable	FALL P-value				
		Temperature	Ice	Chlorophyll	Slope	Depth
J	Temperature		0.5423	0.0226	0.0851	0
J	Ice	0.5423		0.3184	0.3142	0.0306
J	Chlorophyll	0.0226	0.3184		0.4992	0.03
J	Slope	0.0851	0.3142	0.4992		0.0002
J	Depth	0	0.0306	0.03	0.0002	
M	Temperature		0.027	0.0031	0.4141	0.0071
M	Ice	0.027		0.5368	0.0525	0.0226
M	Chlorophyll	0.0031	0.5368		0.1455	0.4101
M	Slope	0.4141	0.0525	0.1455		0
M	Depth	0.0071	0.0226	0.4101	0	
F	Temperature		0	0	0.0637	0
F	Ice	0		0.4343	0.7694	0.0001
F	Chlorophyll	0	0.4343		0.6652	0
F	Slope	0.0637	0.7694	0.6652		0.6523
F	Depth	0	0.0001	0	0.6523	

692

693 A4a: Full AIC table including all GAM model results for females: Loglik is the loglikelihood. K is
 694 the number of parameters in the model. AIC_i is AIC for model i . and Δ_i is the difference between
 695 the AIC of the best fitting model and that of model i . $\text{Exp}(-0.5\Delta_i)$ represent the relative
 696 likelihoods and the w_i is the Akiake weights.

Sex/ Age	Season	Best models per category and season	loglik	K	AIC_i	Δ_i	$\text{exp}(-0.5\Delta_i)$	w_i
F	Spring	SST. ice. chlorophyll. slope and depth	-2729.23	6	5470.462	0	1	0.989492355
F	Spring	SST. chlorophyll. slope and depth	-2734.78	5	5479.564	9.102	0.010556642	0.010445717
F	Spring	SST. chlorophyll and depth	-2740.91	4	5489.82	19.358	6.25841E-05	6.19264E-05
F	Spring	Chlorophyll and depth	-2752.65	3	5511.302	40.84	1.35427E-09	1.34004E-09
F	Spring	SST and depth	-2754.58	3	5515.156	44.694	1.97161E-10	1.95089E-10
F	Spring	Slope and depth	-2763.28	3	5532.556	62.094	3.28442E-14	3.24991E-14
F	Spring	Depth	-2769.14	2	5542.284	71.822	2.53543E-16	2.50878E-16
F	Spring	SST	-2772.42	2	5548.84	78.378	9.55946E-18	9.45902E-18
F	Spring	Chlorophyll	-2793.15	2	5590.292	119.83	9.53336E-27	9.43319E-27
F	Spring	Slope	-2795.67	2	5595.342	124.88	7.63225E-28	7.55205E-28
F	Spring	Ice	-2799.69	2	5603.372	132.91	1.37708E-29	1.36261E-29
F	Fall	SST. chlorophyll and depth	-691.46	4	1390.9246	0	1	0.331680726
F	Fall	SST. chlorophyll. slope and depth	-690.97	5	1391.9376	1.013	0.602600996	0.199871136
F	Fall	Chlorophyll	-694.35	2	1392.6974	1.7728	0.412136778	0.136697826
F	Fall	SST and depth	-693.50	3	1393.0056	2.081	0.353277999	0.117175503
F	Fall	Chlorophyll and depth	-693.55	3	1393.0962	2.1716	0.337631573	0.111985885
F	Fall	SST. ice. chlorophyll. slope and depth	-690.67	6	1393.336	2.4114	0.299482289	0.099332503
F	Fall	SST	-698.17	2	1400.3376	9.413	0.00903635	0.002997183
F	Fall	Depth	-701.43	2	1406.8544	15.9298	0.000347446	0.000115241
F	Fall	Ice	-702.21	2	1408.4278	17.5032	0.000158208	5.24745E-05
F	Fall	Slope and depth	-701.34	3	1408.68	17.7554	0.000139465	4.62577E-05
F	Fall	Slope	-702.36	2	1408.7234	17.7988	0.000136471	4.52647E-05

697

698 A4b: Full AIC table including all GAM model results for males: Loglik is the loglikelihood. K is the
699 number of parameters in the model. AIC_i is AIC for model i . and Δ_i is the difference between the
700 AIC of the best fitting model and that of model i . $\exp(-0.5\Delta_i)$ represent the relative likelihoods
701 and the w_i is the Akiake weights.

Sex/ Age	Season	Best models per category and season	loglik	K	AIC_i	Δ_i	$\exp(-0.5\Delta_i)$	W_i
M	Spring	SST and depth	-842.88	3	1691.76	0	1	0.540807744
M	Spring	SST. chlorophyll and depth	-842.80	4	1693.59	1.8318	0.400156323	0.216407639
M	Spring	SST. ice. chlorophyll. slope and depth	-841.15	6	1694.31	2.5468	0.279878416	0.151360415
M	Spring	SST. chlorophyll. slope and depth	-842.66	5	1695.32	3.5576	0.168840635	0.091310323
M	Spring	SST	-852.88	2	1709.76	17.9974	0.00012357	6.68278E-05
M	Spring	Depth	-853.87	2	1711.74	19.9796	4.58654E-05	2.48044E-05
M	Spring	Chlorophyll and depth	-853.66	3	1713.33	21.5698	2.07099E-05	1.12001E-05
M	Spring	Slope and depth	-853.68	3	1713.36	21.5972	2.04281E-05	1.10477E-05
M	Spring	Ice	-868.30	2	1740.60	48.8422	2.47771E-11	1.33997E-11
M	Spring	Chlorophyll	-871.68	2	1747.35	55.5928	8.47573E-13	4.58374E-13
M	Spring	Slope	-871.76	2	1747.52	55.7578	7.80454E-13	4.22076E-13
M	Fall	SST. chlorophyll. slope and depth	-455.14	2	914.27	0	1	0.582137986
M	Fall	SST. ice. chlorophyll. slope and depth	-455.01	3	916.03	1.7512	0.416611977	0.242525657
M	Fall	SST	-441.26	2	886.52	2.9386	0.230086489	0.132708287
M	Fall	SST and depth	-441.26	3	888.53	4.9444	0.084398977	0.048679276
M	Fall	SST. chlorophyll and depth	-441.29	4	890.57	6.9932	0.030300229	0.017476435
M	Fall	Slope and depth	-457.10	3	920.20	36.6162	1.11916E-08	6.45506E-09
M	Fall	Depth	-458.74	2	921.47	37.8908	5.91721E-09	3.41291E-09
M	Fall	Chlorophyll and depth	-458.41	3	922.81	39.2302	3.0288E-09	1.74694E-09
M	Fall	Slope	-462.89	2	929.79	46.208	9.24827E-11	5.33417E-11
M	Fall	Ice	-463.54	2	931.08	47.4996	4.84834E-11	2.7964E-11
M	Fall	Chlorophyll	-463.68	2	931.35	47.7692	4.23692E-11	2.44375E-11

702 A4c: Full AIC table including all GAM model results for juveniles: Loglik is the loglikelihood. K is
 703 the number of parameters in the model. AIC_i is AIC for model i . and Δ_i is the difference between
 704 the AIC of the best fitting model and that of model i . $\text{Exp}(-0.5\Delta_i)$ represent the relative
 705 likelihoods and the w_i is the Akiake weights.

Sex/ Age	Season	Best models per category and season	loglik	K	AIC_i	Δ_i	$\text{exp}(-0.5\Delta_i)$	W_i
J	Spring	SST. chlorophyll and depth	-512.18	4	1032.37	0.00	1	0.681467
J	Spring	SST. chlorophyll. slope and depth	-512.02	5	1034.04	1.67	0.434874	0.296352
J	Spring	SST. chlorophyll and depth	-512.18	4	1032.37	0.00	1	0.681467
J	Spring	SST. chlorophyll. slope and depth	-512.02	5	1034.04	1.67	0.434874	0.296352
J	Spring	SST and depth	-516.62	3	1039.24	6.87	0.032242	0.021972
J	Spring	Chlorophyll and depth	-521.81	3	1049.62	17.25	0.00018	0.000123
J	Spring	SST	-523.19	2	1050.39	18.02	0.000122	8.33E-05
J	Spring	Depth	-527.19	2	1058.37	26.00	2.26E-06	1.54E-06
J	Spring	Chlorophyll	-527.28	2	1058.56	26.19	2.05E-06	1.4E-06
J	Spring	Slope and depth	-526.71	3	1059.43	27.06	1.33E-06	9.07E-07
J	Spring	Slope	-533.00	2	1070.00	37.64	6.72E-09	4.58E-09
J	Fall	SST. ice. chlorophyll. slope and depth	-410.38	6	832.76	0.00	1	0.8432
J	Fall	SST. chlorophyll. and depth	-414.45	4	836.91	4.15	0.125506	0.105827
J	Fall	SST. chlorophyll. slope and depth	-414.46	5	838.93	6.17	0.045721	0.038552
J	Fall	Chlorophyll	-418.96	2	841.92	9.17	0.010209	0.008608
J	Fall	Chlorophyll and depth	-418.98	3	843.96	11.20	0.00369	0.003111
J	Fall	SST and depth	-420.71	3	847.42	14.66	0.000655	0.000552
J	Fall	SST	-423.43	2	850.87	18.11	0.000117	9.83E-05
J	Fall	Ice	-424.14	2	852.28	19.52	5.77E-05	4.86E-05
J	Fall	Depth	-427.90	2	859.80	27.05	1.34E-06	1.13E-06
J	Fall	Slope	-428.14	2	860.27	27.52	1.06E-06	8.92E-07
J	Fall	Slope and depth	-427.87	3	861.75	28.99	5.07E-07	4.27E-07

706

707

708