

1 **Title** Seasonality of salt foraging in honey bees (*Apis mellifera*)

2 **Running Header** Salt foraging in honey bees

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24 **Abstract**

25 1. Honey bees (*Apis mellifera*) prefer foraging at compound-rich, “dirty”,
26 water sources over clean water sources. Since a honey bee’s main floral diet only
27 contains trace amounts of micronutrients—likely not enough to sustain an entire
28 colony—we hypothesized that honey bees forage in dirty water for physiologically
29 essential minerals that their floral diet, and thus the colony, may lack.

30 2. While there are many studies regarding macronutrient requirements of
31 honey bees, few investigate micronutrient needs. From 2013-2015, we conducted
32 preference assays in both summer and fall.

33 3. During all field seasons, honey bees exhibited a strong preference for
34 sodium in comparison to deionized water. There was, however, a notable switch in
35 preferences for other minerals between seasons.

36 4. Calcium, magnesium, and potassium—three minerals most commonly
37 found in pollen—were preferred in fall when pollen is scarce, but avoided in summer
38 when pollen is abundant. Thus, as floral resources change in distribution and
39 abundance, honey bees similarly change their water foraging preferences.

40 5. Our data suggest that, although they are generalists with relatively few
41 gustatory receptor genes, honey bee foragers are fine-tuned to search for
42 micronutrients. This ability likely aids the foragers’ search for a balanced diet for the
43 colony as a whole.

44

45 **Key-words** minerals, nutrition, nutritional ecology, optimal foraging, seasonality

46

47 **Introduction**

48 Nutrition shapes all living organisms, and yet there are few studies that take
49 into account the complexity of nutrition at the ecological level (Raubenheimer,
50 Simpson et al. 2009). Reaching nutrient- and intake-targets is not typically as simple
51 as balancing the intake and output of energy—most organisms require a balance of
52 complex macro (carbohydrates, proteins, lipids) and micro (vitamins, minerals)
53 nutrients (Simpson and Raubenheimer 2011). Reaching this balance is made
54 challenging by the fact that nutrient composition varies between food sources.

55 Thus, foraging organisms face a difficult balancing act which may be made
56 *more* difficult by both abiotic (e.g. temperature, precipitation) and biotic (e.g. floral
57 distribution and abundance, predators) factors (Raubenheimer, Simpson et al. 2009).
58 Social organisms, particularly eusocial insects, face yet another layer of complexity:
59 they have to obtain the right nutritional requirements for both themselves and their
60 nestmates, which often require different ratios of different nutrients depending on
61 caste and age (Lihoreau, Buhl et al. 2015). Although micronutrients are vital for all
62 physiological processes, nutrition is often studied with a focus on macronutrients
63 (Cohen 2004, Rupp 2015). To fully understand an organism’s nutritional ecology,
64 however, it is important to investigate how organisms balance the intake of both
65 macro *and* micronutrients in the field.

66 Honey bees (*Apis mellifera*) are an ideal study system for this area of research;
67 research on honey bee foraging dates back to at least Charles Darwin (Darwin 1872),
68 and research on honey bee nutrition dates back to at least the 1930s (Haydak 1934).
69 Thus, there is a strong baseline understanding of honey bee nutrition and foraging. In
70 addition, there is a suite of ecological factors that affect both honey bee foraging and

71 nutrition that can be manipulated and observed. For example, honey bee nutritional
72 requirements shift with age—dependent larvae require large amounts of protein while
73 the oldest adult workers feed mainly on carbohydrates (Haydak 1970, Paoli, Donley et
74 al. 2014). Importantly, studying honey bees allows for the investigation of fitness
75 effects at both the individual- and colony-level (Lihoreau, Buhl et al. 2015).

76 While we know that diet diversity is important to honey bee health (Alaux,
77 Ducloz et al. 2010), we do not know which nutrients in this diverse diet are important.
78 Bees raised on a polyfloral diet exhibit stronger baseline immunocompetence than
79 bees raised on a monofloral diet, even when the monofloral diet has a higher overall
80 protein content (%) than the polyfloral diet (Alaux, Ducloz et al. 2010). Thus, there is
81 more to developing a strong immune system than getting the right amount of protein.
82 While much is known about the macronutrients honey bees need to maintain a healthy
83 colony, very little is known about the micronutrients that are needed (Haydak 1970,
84 Cohen 2004, Huang 2010).

85 Honey bees tend to prefer compound-rich (hereafter called “dirty”) water
86 sources over clean water sources (Butler 1940). Despite countless observations, there
87 is only one scientific field study (Butler 1940) regarding this specific behavior. Butler
88 (1940) concluded that honey bees prefer dirty water based on strong odor cues. While
89 this provides a proximate mechanism by which honey bees may find dirty water, it
90 does not provide an evolutionary explanation for this behavior. Similar to geophagy,
91 the intentional consumption of earth (Young, Sherman et al. 2011), dirty-water-
92 seeking behavior likely has an adaptive purpose.

93 We hypothesize that honey bees have an optimal diet that includes nutritional
94 resources from both floral and water sources. Since the honey bee’s main floral diet

95 only contains trace amounts of micronutrients (Somerville 2005, Brodschneider and
96 Crailsheim 2010), and sodium-specific foraging is a well-known behavior in social
97 insects (Botch and Judd 2011, Pizarro, McCreery et al. 2012) and across the animal
98 kingdom (Denton 1982, Young, Sherman et al. 2011, Starks and Slabach 2012), we
99 postulate that to obtain a well-rounded diet, honey bees selectively forage in soil and
100 water for minerals that their main floral diet may lack. As the honey bee colony is a
101 dynamic environment and honey bees live in temperate regions, our hypothesis leads
102 us to three main predictions.

103 Firstly, if honey bees have an optimal diet that is satisfied by both floral and
104 water sources, we predict that honey bees will show mineral preferences when
105 foraging for water. Minerals are essential for all physiological functions (e.g. muscle
106 movement and immunity) (Cohen 2004). Universally, sodium is a key player in
107 osmoregulation. While soil is known to contain significant amounts of sodium, the
108 above ground parts of land plants—the main food source for honey bees—rarely
109 contain a great amount of this important mineral (Oates 1978, Cohen 2004). In
110 insects, when coupled with potassium, sodium regulates cellular and body fluid pH.
111 We predict that honey bees will prefer both sodium and potassium in comparison to
112 deionized water.

113 Other minerals we chose for this study were two co-factors (magnesium and
114 calcium) and two minerals that are important to all life forms (phosphate and
115 nitrogen) (Cohen 2004). Aside from its role as a co-factor, calcium is also important
116 in the regulation of muscle movement, and plays an important structural role in
117 invertebrates. Specifically in honey bees, calcium aids in pupation and total
118 antioxidant capacity (Zhang and Xu 2015). In excessive amounts, however, calcium

119 can cause paralysis in honey bees (Somerville 2005). We predict that honey bees will
120 prefer magnesium but not calcium. Lastly, as phosphate is essential to the process of
121 bioenergetic activity and nitrogen is vital for cellular communication and waste
122 removal (among other things), we predict that honey bees will prefer both mineral
123 solutions relative to deionized water.

124 Secondly, if dirty water sources are coupled with floral resources to reach an
125 optimal diet, we predict that the strength of mineral preferences when foraging for
126 water will differ with the distribution and abundance of floral resources (i.e. the
127 seasons). We expect mineral preferences when foraging for water to complement
128 which minerals are available in floral resources (mainly pollen). Major minerals found
129 in bee-collected pollen are potassium, calcium, and magnesium; levels of each
130 mineral vary within and between summer and fall (Herbert and Miller-Ihli 1987,
131 O'Connor, Bonoan et al. *unpublished data*).

132 Lastly, if there is an optimal honey bee diet, we predict that deviations from
133 the presumably well-rounded diet will adversely affect colony fitness. While the
134 specific mineral requirements of honey bees are not known, honey bees likely need
135 minerals to successfully rear brood. Bees fed a semi-synthetic diet with pollen ash
136 (which contained potassium, sodium, and calcium) reared more brood than bees fed a
137 completely synthetic diet of amino acids and vitamins (Herbert and Shimanukia
138 1978).

139 Although honey bee mineral (NaCl, MgCl₂, KCl, Na₂HPO₄) preferences have
140 recently been tested in the lab (Lau and Nieh 2016), our study is the first to
141 investigate the mineral-specificity of honey bee foragers in the field. It is also the first

142 to examine mineral preferences over ecological time (i.e. seasons) and how such
143 nutrient preferences may affect fitness.

144

145 **Materials and methods**

146 This study was performed on the Tufts University Medford/Somerville
147 campus (equipped with eight 2-frame observation hives) during fall 2013, 2014, 2015
148 (Sep-Oct), and summer 2014, 2015 (Jul-Aug). Given general insect micronutrient
149 requirements, we tested preferences for six specific mineral solutions: sodium (NaCl),
150 calcium (CaCl₂), potassium (KCl), magnesium (MgCl₂), phosphorus (KH₂PO₄), and
151 nitrogen (NH₄Cl) (Cohen 2004). Minerals were also chosen based on what honey bees
152 are likely to find in soil or dirty water where they often forage (O'Connor, Bonoan et
153 al. *unpublished data*).

154

155 *Mineral preferences*

156 Once the bees were trained (von Frisch 1967) to forage in an open, grassy
157 location (about 50 - 90 m from the observation hives), we conducted preference
158 assays two to five times a week (weather-permitting). We set up preference assays on
159 a 1.82 m long plastic table which was divided into two 4 x 4 (72 cm x 72 cm) grids
160 (Fig. 1). In addition to the six mineral solutions, a sucrose solution (10% during fall
161 assays, 20% during summer assays) served as the positive control and deionized water
162 served as the negative control (Pizarro, McCreery et al. 2012). Based on honey bee
163 supplemental feeding guidelines (Somerville 2005), all mineral solutions were a 1%
164 concentration. In the lab, honey bees respond to NaCl levels as low as 50 μ M (de
165 Brito Sanchez 2011) and preferentially respond to 1.5% NaCl, 1.5% MgCl₂, 0 – 1.5%

166 KCl, and 0.4 – 0.75% NaH₂PO₄ (Lau and Nieh 2016); thus, it is likely that honey bees
167 were able to taste our salt solutions. There were two tubes of each solution on each
168 grid; bees were allowed to forage at one grid (the experimental grid) while the other
169 grid was covered with mesh to exclude bees (the control grid) and account for volume
170 change due to evaporation (Fig. 1). Control and experimental grids were alternated
171 each trial.

172 At the beginning of each trial, 50 ml falcon tubes were filled with 25 ml of the
173 appropriate solution and randomly allocated (using a random list generator,
174 www.random.org) to a numbered square on each grid (Fig. 1, inset). Once the tasting
175 table was set up, bees were allowed to forage for 5 – 7 hours (depending on weather).
176 At the end of each trial, we measured the amount (ml) of each solution remaining in
177 both the control and experimental grids. The change in volume of the control side
178 subtracted from that of the experimental side yielded the total volume consumed by
179 the foraging bees. In total, we conducted 33 preference assays in summer and 18
180 preference assays in fall. For each year (2013, 2014, 2015), new bees were installed
181 (thus, we have two true replicates for summer and three true replicates for fall) and
182 the eight observation hives, and thus eight colonies, were trained to forage at the
183 tasting table.

184

185 *Colony fitness*

186 To assess what preferences mean for colony fitness, we gave bees a colony-
187 specific, light-weight, colored powder mark during 2014 preference assays (Fig. 2)
188 (Hagler, Mueller et al. 2011, Bonoan and Starks 2016). We constructed marking
189 apparatuses from mesh cloth, filled with non-toxic acrylic colored powders (ECO

190 Pigments, Day-Glo Color Corporation). Using Velcro (Scotch Extreme Fasteners), we
191 affixed the marking apparatuses to each hive entrance such that foragers were dusted
192 with visible colored markings upon exiting (Bonoan and Starks 2016). As each hive—
193 and thus colony—had a unique color, we could approximate the number of visits each
194 colony made to each solution during preference assays (Fig. 2). The approximate
195 number of visits indicates the intensity of colony-specific preference for each mineral
196 solution. We counted the number of bees from each colony at each solution every 15
197 minutes throughout the duration of the trial. Unmarked bees were classified as feral
198 and not included in analysis.

199 To see if colony-specific preferences correlated with internal colony
200 dynamics, we measured two colony fitness parameters three times a week beginning
201 in Jul 2014 and ending in Oct 2014. First, population estimates were recorded
202 according to Sammataro & Avitabile (2011): a standard deep frame entirely covered
203 by one layer of bees is roughly 2000 adult individuals; estimates were taken in
204 increments of 250 bees. Second, the total area of capped brood (i.e. the amount of
205 oldest honey bee brood) was calculated by first measuring the area of the smallest
206 rectangle to encompass the brood patch. As honey bee brood patches tend to be oval-
207 shaped, we then subtracted the area of empty corners from the area of the original
208 rectangle. This was then multiplied by the quality of the queen's laying pattern which
209 was ranked on a scale of one to five depending on the spottiness of brood comb
210 (1=100-80% empty cells; 2=80-60% empty cells; 3=60-40% empty cells; 4=40-20%
211 empty cells; 5=20-0% empty cells). A similar scale was implemented by Vaudo et al.
212 (2011) as a proxy for honey bee colony health. Together, these calculations gave us
213 the total capped brood area of each colony.

214

215 *Statistical analysis*

216 For preference assays, data for all three years (2013, 2014, 2015) were pooled
217 by season as there was no significant effect of year on the amount of each solution
218 consumed. Prior to analysis, we removed data for sucrose, our positive control. To
219 determine whether or not there was an overall effect of season (summer versus fall) or
220 mineral solution, we ran a two-way ANOVA on natural log-transformed data.
221 Following this analysis, we ran two one-way ANOVAs (one for each season) with
222 contrasts. This allowed for the comparison of each mineral solution to our negative
223 control, deionized water. Again, data were natural log-transformed prior to analysis in
224 order to meet test assumptions.

225 To analyze the 2014 data for colony fitness, we combined the counts of visits
226 each colony made to mineral solutions (CaCl_2 , KCl , KH_2PO_4 , NaCl , NH_4Cl , MgCl_2)
227 for each week. To standardize for colony size (colonies ranged from 0 – 7,000
228 individuals throughout data collection), we calculated the approximate proportion of
229 the colony that made visits to mineral solutions each week by dividing the number of
230 visits to mineral solutions by the average colony population for that same week. These
231 calculations yield a colony-size adjusted measure of the intensity of preference for
232 each mineral source.

233 Based on what we know about the honey bee life cycle, we then used a 1 week
234 offset for capped brood area (it takes about nine days for an egg to develop into a 5th
235 instar larvae and get capped over) and a three week offset for the adult population (it
236 takes about twenty-one days for an egg to fully develop into an adult worker bee)

237 (Winston 1987). Since colony fitness parameters are expected to naturally decrease in
238 the fall, we only used summer data for this analysis.

239 For both brood area and adult population, we ran a Poisson regression against
240 a null hypothesis of no effect of minerals (i.e. a line with a slope of 0). We did not
241 have enough measurements per colony to add colony as a random effect. Instead, we
242 standardized visits by calculating the proportion of each colony visiting minerals
243 rather than combined number of visits (see above). For brood area, we examined
244 whether or not the proportion of workers visiting minerals at week t affected the
245 brood area at week $t + 1$. Similarly, for adult population, we examined whether or not
246 the proportion at week t affected the brood area at week $t + 3$. For both models,
247 pseudo- R^2 was calculated by dividing the residual deviance by the null deviance, and
248 subtracting that value from 1.

249 All analyses were run in R version 3.2.4 (2016-03-10) using the mosaic
250 package (R Development Core Team 2008).

251

252 **Results**

253 *Mineral preferences*

254 When all three field years (2013, 2014, 2015) are analyzed together, there is a
255 significant effect of mineral solution on volume collected ($F_{6,700} = 11.803$, $P < 0.001$),
256 however, there is no significant effect of season on volume collected ($F_{1,700} = 0.002$, P
257 $= 0.967$) (Fig. 3a). The bees drank about the same amount of potassium, calcium,
258 magnesium, and nitrogen no matter the season. The bees drank less water, sodium,
259 and slightly less phosphorous in the fall compared to the summer (Fig. 4a).

260 When controlling for deionized water, an effect of season on mineral
261 preferences emerges (Fig. 3b). No matter the season, bees drank significantly more
262 sodium than deionized water (fall: $t_{245} = 3.996$, $P < 0.001$, summer: $t_{455} = 4.008$, $P <$
263 0.001). In the fall, bees drank significantly more potassium than deionized water (t_{245}
264 $= 2.254$, $P = 0.025$) and drank about the same of the two solutions in the summer (Fig.
265 3b). Though the effect was not significant, the bees did drink more calcium and
266 magnesium than deionized water in the fall and less than deionized water in the
267 summer (Fig. 3b). During the summer, bees drank significantly less nitrogen ($t_{455} = -$
268 2.251 , $P = 0.025$) and phosphorous ($t_{455} = -2.064$, $P = 0.040$) than deionized water
269 (Fig. 3b). This trend was not observed in the fall.

270

271 *Colony fitness*

272 There was a significant effect of the approximate proportion of the colony
273 visiting mineral solutions on capped brood area one week out ($X^2_1 = 13.2$, $P < 0.001$)
274 and adult population three weeks out ($X^2_1 = 202.7$, $P < 0.001$). Although the effect is
275 significant, the pseudo- R^2 values (0.0016 for brood area, 0.0072 for adult population)
276 suggest that our current data do not explain the model much better than a straight line
277 (Fig. 4).

278

279 **Discussion**

280 Honey bees showed mineral preferences and, in comparison to deionized
281 water, those preferences varied with season. This supports our hypothesis that honey
282 bees forage in dirty water for minerals that their floral diet may lack. Although the
283 mean volume consumed did not vary with season (Fig. 3a), there are more bees in the

284 colony in the summer than there are in the fall. Thus, on a per-bee basis, there is a
285 difference in the amount of minerals a colony forages for. In the summer, bees receive
286 less “water-derived” minerals on a per-bee basis than in the fall.

287 The seasonality in preferences was made apparent when the mean volume
288 consumed was analyzed relative to deionized water. Relative to deionized water, bees
289 drank significantly more potassium and tended to drink more calcium and magnesium
290 in the fall (Fig. 3b). In the summer, however, there was no significant preference for
291 potassium and bees tended to avoid calcium and magnesium.

292 This switch in preferences is particularly interesting since potassium, calcium,
293 and magnesium are three of the most prominent minerals found in pollen (Herbert and
294 Miller-Ihli 1987). Moreover, the levels of these minerals in pollen vary with season;
295 in the summer, there are high levels of these minerals in pollen while in the fall, there
296 are low levels of these minerals in pollen (Herbert and Miller-Ihli 1987). Taken with
297 our data, this suggests that honey bees are foraging for minerals in water based on
298 what their floral diet is lacking. The bees’ preference for sodium no matter the season
299 also supports our hypothesis—the above ground parts of plants rarely contain much
300 sodium (Oates 1978, Cohen 2004) and herbivores are often sodium-limited (Denton
301 1982). Preliminary analysis of pollen our bees collected throughout the 2015 season
302 (Jul – Oct) shows that out of potassium, calcium, magnesium and sodium, sodium is
303 found at the lowest levels (0 – 4 ppm) (O'Connor, Bonoan et al. *unpublished data*).

304 It was unexpected that bees would avoid nitrogen and phosphorous. Since bees
305 significantly avoided nitrogen in the summer, it is possible that they receive adequate
306 amounts of nitrogen from the abundant pollen sources; pollen is high in amino acid
307 content (Auclair and Jamieson 1948). Additionally, if honey bees are searching in soil

308 for nitrogen sources, nitrogen exists in various forms in the soil. It is possible that our
309 specific nitrogen compound is not the nitrogen compound honey bees prefer. This is
310 also a possible explanation for the unexpected avoidance of phosphorous.

311 Regarding minerals and colony fitness, it is hard to determine anything
312 conclusive with the current data. While stronger colonies do tend to visit more
313 minerals than weaker colonies (Supporting information), it is hard to say which came
314 first. Do strong colonies visit minerals more often because they are strong? Or, are
315 they strong because they visit minerals more often? Unfortunately, our regression
316 with the offset does not help answer the question. Although our data show a
317 significant effect of minerals on both colony fitness parameters, the model does not
318 reveal either a positive or a negative effect. This may be because we do not have
319 enough data or we should collect data from larger, more natural-sized hives.

320 Overall, our data suggest that honey bees forage at dirty water sources for
321 minerals that may be lacking in their floral diet. If such minerals are lacking in their
322 floral diet, they are likely lacking in the colony as a whole. This is currently
323 speculation, however, as our colony fitness data were inconclusive. The effects of
324 minerals on colony fitness could be further tested either in the field with larger hives
325 or in the lab with caged hives.

326 This is the second study to examine honey bee mineral preferences when
327 foraging for water and the first study to examine such preferences on a seasonal basis.
328 Butler (1940) did not find that honey bees exhibited mineral preferences when
329 foraging for water; Butler's (1940) study was done in the spring. The fact that Butler
330 (1940) did not find mineral preferences is in line with our hypothesis and our data; in

331 spring, floral resources are abundant, and thus honey bees do not need to seek out
332 minerals in water sources.

333 Our study has implications in applied and basic science. On the applied side,
334 understanding the seasonality of honey bee mineral requirements can lead to the
335 development of season-specific diet supplements, and better overall nutrition
336 throughout the year for both managed honey bee hives (via diet supplements) and
337 wild pollinator populations (via the planting of diverse flora).

338 Regarding honey bees specifically, our data show that despite having
339 relatively few taste genes (de Brito Sanchez 2011), honey bees can discriminate water
340 sources based on nutritional content. This ability likely helps foragers in their effort to
341 obtain a balanced diet for both themselves and the colony.

342 Being a superorganism, honey bees provide the opportunity to investigate how
343 mineral preferences may correlate with fitness. Although our data suggest that we
344 need to collect more data regarding colony fitness, such parameters are easily
345 measured in both observation hives as well as larger Langstroth hives.

346 More generally, collecting data on mineral preferences in honey bees can
347 bolster our understanding of pollinator health and nutritional ecology. While there is
348 much known about insect nutrition and foraging in general, micronutrient (both
349 vitamin and mineral) requirements remain poorly understood (Cohen 2004), even
350 with the recent decline in pollinator populations. Micronutrients are a physiologically
351 important part of any organism's complex diet (Simpson and Raubenheimer 2011,
352 Simpson and Raubenheimer 2012, Rupp 2015), and should be studied for a more
353 complete understanding of the complex balancing act organisms face when foraging.

354

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363

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447

448 **Fig. 1.** Tasting table with foraging honey bees on the experimental side of the table.
449 The mesh covering on the control side of the table allowed us to exclude bees and
450 account for volume change due to evaporation during the trial. Volume change in the
451 experimental side minus volume change on the control side gave us the amount honey
452 bees actually consumed. Inset: Tasting table grid that was used to randomly allocate
453 solutions for each trial.

454

455 **Fig. 2.** Yellow and pink powder-marked honey bees visiting a solution at the tasting
456 table. Counts of each color bee at each solution were made every 15 minutes.

457

458 **Fig. 3.** (a) Mean volume change of each mineral consumed (ml) by all eight hives
459 separated by season. Error bars are ± 1 standard error and show the variation in
460 volume consumed for each trial within each season. There was no significant effect of
461 season on the volume consumed however, there was an effect of mineral solution. (b)
462 Volume change for each mineral solution relative to volume change of deionized
463 water (negative control, $x = 0.0$), calculated for each field season. Anything above the
464 baseline was preferred compared to deionized water, anything below the baseline was
465 avoided compared to deionized water. Bees significantly preferred sodium no matter
466 the season. In the fall, bees significantly preferred potassium. In the summer, bees
467 significantly avoided nitrogen and phosphorus. Error bars are ± 1 standard error and
468 show the variation in volume consumed for each trial within each season. ($*P < 0.05$,
469 $***P < 0.001$)

470

471 **Fig. 4.** (a) Approximate mean percentage of hives visiting minerals at week t and the
472 mean capped brood area of hives at week $t + 1$. (b) Approximate mean percentage of
473 hives visiting minerals at week t and the mean adult population of hives at week $t + 3$.
474 Offsets were determined based on the honey bee lifecycle (Winston 1987). Although
475 both analyses give significant results, the near-zero pseudo- R^2 values indicate that the
476 model explains our data only slightly better than a straight line.

477

478 **Supporting Information.** Mean percent change per week relative to baseline colony
479 fitness parameters of a representative (a) healthy and (b) unhealthy hive. Anything
480 above “0” represents a percent increase compared to baseline and anything below “0”
481 represents a percent decrease compared to baseline. Approximate mean percentage of
482 the same (c) healthy and (d) unhealthy hives that visited each mineral solution each
483 week. For all graphs, Week 0 is the beginning of the summer (July 7, 2014) and week
484 10 is the end of the summer (September 19, 2014).