Closing the research-implementation gap using data science tools: a case study with pollinators of British Columbia

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32 user-oriented development

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34 **Abstract**

35

36 A challenge in conservation is the gap between knowledge generated by researchers
37 and the information being used to inform conservation practice. This gap, widely known
38 as the research-implementation gap, can limit the effectiveness of conservation practice.
39 One way to address this is to design conservation tools that are easy for practitioners to
40 use. Here, we implement data science methods to develop a tool to aid in conservation
41 of pollinators in British Columbia. Specifically, in collaboration with Pollinator Partnership
42 Canada, we jointly develop an interactive web app, the goal of which is two-fold: (i) to
43 allow end users to easily find and interact with the data collected by researchers on
44 pollinators in British Columbia (prior to development of this app, data were buried in
45 supplements from individual research publications) and (ii) employ up to date statistical
46 tools in order to analyse phenological coverage of a set of plants. Previously, these tools
47 required high programming competency in order to access. Our app provides an
48 example of one way that we can make the products of academic research more
49 accessible to conservation practitioners. We also provide the source code to allow other
50 developers to develop similar apps suitable for their data.

51

52 **Introduction**

53

54 The research-implementation gap is a well known phenomenon in conservation science,
55 where over two-thirds of conservation assessments never lead to conservation action
56 (Knight et al. 2008). This occurs when there is a mismatch between the information
57 available for use by conservation practitioners and the information available in the
58 scientific literature (Dubois et al. 2020). The responsibility of narrowing the
59 research-implementation gap falls on both conservation practitioners and researchers
60 and requires that they both improve communication in order to engage in effective
61 conservation decision-making (Dubois et al. 2020).

62

63 Scientific knowledge is rarely shared and transferred effectively to the public and/or
64 practitioners (Born et al. 2009). Scientists need to communicate with non-scientists in
65 order to extend the findings of their research beyond peer-reviewed publications. One
66 strategy is to actively distill and disseminate information — vs. passively disseminating
67 information in peer reviewed journal articles. Actively disseminating information to a lay
68 audience requires continued communication between researchers and conservation
69 practitioners through activities such as meetings and working groups (Gibbons et al.
70 2008). Beyond active dissemination, researchers can engage stakeholders and policy
71 makers in the process of developing conservation strategies and tools in order to meet

72 the need of these stakeholders and policy makers — this is the goal of translational
73 ecology (Wall et al. 2017).

74

75 Engaging stakeholders from the outset of a research project helps ensure that the
76 resultant products meet their desired needs. For example, in a climate project in the
77 Great Basin region of the US, resource managers collaborated with researchers to
78 incorporate climate modelling into resource planning. One of the first hurdles they
79 encountered was that staff did not have the expertise to apply technical research results
80 (Wall et al. 2017). Because they had included these staff and their managers from an
81 early stage in the project development, they were able to identify these problems and
82 modify their research outputs to ensure they were usable by the staff.

83

84 Here, we design an interactive web app that builds the foundation for addressing this
85 research-implementation gap for pollinator conservation in British Columbia in three
86 ways: (i) actively disseminating information by collating data previously published in many
87 manuscripts into a single database, (ii) lowering the technical barrier to entry by making
88 the information easily accessible and manipulable, and (iii) deliberately engaging with
89 conservation practitioners to produce an application of available data that would meet
90 their needs. We partnered with Pollination Partnership Canada to ensure that the
91 resultant web app would meet general and specific pollinator conservation needs.

92

93 **Conservation practitioner engagement**

94

95 We worked with Dr. Lora Morandin, the Western Canada Program Director at Pollinator
 96 Partnership Canada — an NGO devoted to the conservation of pollinators— so that our
 97 tools could address their need for more information about pollinator distributions and
 98 plant associations, aligning with their goals to create and maintain habitat that supports
 99 native pollinator populations and pollinator diversity. One of their ongoing challenges is
 100 providing locally-relevant information to land managers on the potential impacts of
 101 conservation efforts (largely in the form of habitat restoration) for pollinators. While there
 102 is ample information on the effects of hedgerow restoration for pollinators in places like
 103 California (Kremen et al. 2004, 2019), past research conducted in British Columbia has
 104 been less well disseminated to practitioners. Our discussions identified the development
 105 of a web app providing information on plant-pollinator relationships would be an effective
 106 way to overcome this challenge. The app can also help conservation practitioners more
 107 generally by providing information about the plants most often visited by pollinators for
 108 pollen and nectar resources; such plants would be useful to include in habitat
 109 restorations focussed on supporting pollinator diversity.

110

111 **Data description**

112

113 We collated data from 17 studies that documented some aspect of plant-pollinator
 114 communities across British Columbia. While the aim of each study was different, in all
 115 studies, pollinators were collected as they visited flowers. This type of data provides

insight not only about the abundance and richness of pollinator communities, but also about the types of flowers that pollinators visit and how these visitation rates differ across regions of the province. This can be useful when designing planting schedules aimed at attracting pollinators to crops or for planning rural and urban flower strips for pollinator conservation. Due to the distribution across studies, these data are not currently available in a single, easily accessible format, despite being previously published across several separate manuscripts (Courcelles et al. 2013; Neame et al. 2013; Chamberlain et al. 2014a, 2014b; Wray et al. 2014; Gielens et al. 2014; Button & Elle 2014; Wray & Elle 2015; Elwell et al. 2016; Gibbs et al. 2016; Gillespie et al. 2017; Gillespie & Elle 2018; Toshack & Elle 2019; Kelly & Elle 2020a, 2020b). The collated dataset encompasses surveys of pollinators on plants from 2005 to 2017 across 196 individual sites (8 ecoregions from British Columbia). It contains over 30,000 records of pollinators and the plants they interact with. The data contains both native and non-native plants, and crops.

130

131 **Potential uses**

132

133 *Support of rare, at risk species or monitor introduced species*

134

The western bumble bee (*Bombus occidentalis*) has declined substantially since 1998 (Graves et al. 2020). The main drivers of declines for the western bumble bee include pesticides and land-use change. Conservation of this endangered bumble bee requires

138 not only addressing these main drivers of decline, but also creating or protecting suitable
 139 habitat. Conservation practitioners can use our app to identify which plant species are
 140 known to be visited by *Bombus occidentalis* and, further, whether this pollinator changes
 141 flower resources in different regions. In addition, conservation practitioners can use our
 142 app to monitor introduced species such as *Bombus impatiens* by identifying the flower
 143 resources used by that species.

144

145 *Planting option for non-crop uses*

146

147 Cities are increasingly promoting and incorporating pollinator plantings into their
 148 operations and land management (Hall et al. 2017). Urban plantings designed for
 149 pollinators have been shown to increase pollinator abundance and diversity within city
 150 boundaries (Hofmann & Renner 2020). Urban planners and gardeners could use our app
 151 to identify plant mixes that can grow within a specific region and that also support a high
 152 abundance and diversity of pollinators.

153

154 *Supporting crops*

155

156 Flower strips and hedgerows have been shown to enhance pest control and increase
 157 crop pollination in adjacent fields. While the effect of the flower strip and hedgerows are
 158 dependent on the type of crop and the landscape context (Albrecht et al. 2020), our app

159 could be used as a tool to identify plant mixes that share pollinators with the crop,
160 following the method of M'Gonigle et al. (2017).

161

162 *Education on plants and pollinators*

163

164 Cities and urban centers have become important sites for conservation of pollinators
165 (Hall et al. 2017). Pollinators in urban settings can provide inspiration for school programs
166 that aim to increase scientific literacy (Saunders et al. 2018). In addition to introducing
167 students to standard insect collection techniques, our app could be used to teach
168 students about simple ecological concepts such as species interaction networks and
169 plant-pollinator interactions.

170

171 **Application description**

172

173 *Main selections*

174 The app allows users to filter the data by region. Here, regions are ecosections of British
175 Columbia (Demarchi 1996). We used ecosections, as they represent small scale
176 ecosystem differences in British Columbia. Currently, we include data from the following
177 regions: Nanaimo Lowland, Leeward Island Mountains, Southern Gulf Islands, Southern
178 Okanagan Basin, Fraser Lowland, Southern Pacific Ranges and the Okanagan Range. We
179 also have data from some sites in the Pacific Northwest of the United States. The

180 application provides an interactive map showing where these regions are located (Figure
181 1A). The default option includes all of the regions.

182

183 Users can access the database using either scientific names (most of the specimens in
184 the database are identified to species level) or common names, which typically
185 correspond to genus level identification (Figure 1A). The default option is to use scientific
186 names.

187

188 The app has three primary features: “Build network”, “Get Plants” and “Support Crop”. We
189 will describe each of these features in detail below. These features allow users to
190 visualize the data in three different ways and, in addition, help users select different plant
191 mixes.

192

193 *Build network*

194

195 The “build network” feature allows the user to see all of the pollinators that visit a given
196 plant or all of the plants that a pollinator visits. Therefore, this feature has two modalities,
197 the “pollinator network” and the “plant network” (Figure 1B). The pollinator network
198 allows the user to select pollinators and the resulting network plot shows the chosen
199 pollinator along with the plants that the chosen pollinator visits. The plant network does
200 the same as the pollinator network, but it allows the user to select plants. If a region is
201 chosen, then the app will also filter the database to only show the plants or pollinators

202 available for that region. The app will then produce a ‘network plot’, which shows the
 203 chosen plants/pollinators central to all of the species that they interact with (Figure 2).
 204 The thickness of the lines between plants and pollinators indicates the number of
 205 observations of that interaction. Finally a user can click on any of the species in the
 206 network and they will be directed to the wikipedia page for that species.
 207

209 **Figure 1:** Layout and options in the application. A) Intro pane of application that allows
 210 the users to select the region, the names to be used and the main action. B) Options for

211 building a network. C) Options for selecting groups of plants that support a crop or
 212 maximize pollinator abundance or richness.

213

214

215 **Figure 2:** Example plots for the ‘Build Network’, using all the regions and *Bombus*
 216 *Impatiens* as the chosen pollinator.

217

218 *Get plants*

219

220 The “get plant” main option allows the user to select a specified number of plants that
 221 will be chosen to maximize either pollinator abundance, pollinator richness, or pollinator
 222 phenological coverage (Figure 1C). We refer to phenological cover as the weeks where a
 223 set of plants is flowering. In order to maximize pollinator abundance or richness, we filter
 224 the database based on the region and the plant attributes (such as whether the plants
 225 are native or non-invasive) and then sum the number of pollinator specimens or species,
 226 respectively, found on a given plant species (Figure 3).

227

228 In order to maximize plant phenological coverage we use a genetic algorithm as
 229 developed in (M’Gonigle et al. 2017). Here phenological coverage is the number of
 230 weeks that a mix of plants is blooming. The genetic algorithm then finds the set of plants
 231 that minimize gaps in bloom periods. To run the algorithm we need the blooming period
 232 for each plant in the database. In order to obtain bloom periods for plants, we identify the
 233 weeks that each plant was observed to be ‘interacting’ with pollinators. While this is not
 234 an independent measure of blooming times for each plant, it is consistent across all of
 235 the different surveys done. Given that some of the observations may be outliers, and we
 236 want to focus mainly on ‘peak flowering times’, we removed the extreme 10th percent
 237 dates. Before running the algorithm we filter the database to the specified region and
 238 plant attributes. We also included an option for the user to consider only plants that
 239 bloom within a specified range of dates.

240

Figure 3: Example plot for the ‘Get plants’ feature. Here we selected to maximize pollinator abundance in all regions.

Support crop

Supporting a crop essentially uses the same algorithms and filters, but aims to maximize phenological coverage using the ‘Get plants’ option under the constraint that only pollinators that are known to visit the specified crop(s) are considered (Figure 4).

One additional option that must be specified when selecting plants to support a crop is whether or not the selected plants can bloom at the same time as the crop. We included

253 this option because allowing the support plants to bloom at the same time as the crop
 254 might ‘pull’ the pollinators away from the crop, but on the other hand it can also provide a
 255 more diverse diet to crop pollinators, and floral diversity in adjacent fields are known to
 256 improve crop pollination (Long et al. 1998; Garibaldi et al. 2013). Including this option
 257 allows users to tailor the plant mix to their needs. If the option selected is ‘Yes’, then the
 258 algorithm is the same as in ‘Get plants’. If the option selected is ‘No’, then we force the
 259 algorithm to contain the crop in every step so that the optimization of the flowering times
 260 is around the crop. While the algorithm can still select plants that overlap, the plants will
 261 be less likely to overlap with the crop.

263 **Figure 4:** Example of the “Support crop” feature. In blue we show the crop (Blueberry)
 264 and in green the plant mix that would produce optimal phenological coverage for
 265 pollinators that are present during blueberry bloom.

266

267 The application was developed using the shiny package (Chang et al. 2017) in the R
268 programming language (R core team 2019). All of the code to develop the application can
269 be found in https://github.com/lmguzman/bc_bees. The application is hosted at
270 <https://shiny.rcg.sfu.ca/bc-bees/>.

271

272 **Caveats of the application**

273

274 We worked closely with Pollination Partnership to ensure that the main options for the
275 application would be useful for conservation practitioners wanting to support pollinator
276 populations through habitat creation and maintenance. A major goal in design was to
277 ensure that the application would be accessible to users who do not want or are not
278 comfortable working with the raw data. This app is intended to provide only one tool
279 when choosing plant species. The app does not include information about the
280 commercial availability of plant species, or growing factors such as soil, moisture, and
281 sun requirements. However, the plant growth requirements and preferences can be
282 found online in numerous places. Assessing and incorporating plant availability is difficult
283 to include, as information is limited, regionally variable, and not static. Users can
284 generate plant lists that include more plants than they would use, ensuring that they will
285 be able to obtain some of the species of interest. Finally, our app is limited by availability
286 of data. While the datasets we have incorporated so far are extensive, additional data,
287 particularly from natural habitats, would be beneficial. Currently, the available data was

288 collected with an emphasis mostly on pollination in or around a single crop, Blueberry.

289 The incorporation of more data is a major future goal.

290

291 **Future developments**

292

293 This application is an evolving project and will continue to change as we get feedback

294 from users. A limitation of the application is the quantity and quality of data; however, this

295 is a living application and we intend to incorporate more data, first by expanding the

296 geographic range and second by incorporating other sources of data such as citizen

297 science data (Kremen et al. 2011). Finally, since this application was designed to suit the

298 needs of end users, we will heavily rely on feedback from users for the next development

299 stages.

300

301 **Conclusion**

302

303 We present an interactive application and all of the source code used to develop it, with

304 the goal of reducing the research-implementation gap in pollination conservation using

305 data from British Columbia as a test of concept and first publicly-available tool. One of

306 the main components of our approach was the co-development of the application with

307 stakeholders who will use the application. This application can be used as a template to

308 actively disseminate and make ecological research useful to different stakeholders.

309

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