1 **Predicting the time needed to conduct an environmental systematic review or systematic**

2 **map: analysis and decision support tool**

3 Neal R Haddaway[1*]

4 Martin J Westgate[2]

5

6 1 – Mistra EviEM, Stockholm Environment Institute, Linnégatan 87D, Stockholm Sweden

7 2 – Fenner School of Environment and Society, The Australian National University, Acton

8 ACT 2601, Australia

9 * Corresponding author: neal_haddaway@hotmail.com

10

11 **Acknowledgements**

14

1

Abstract

Systematic reviews aim to maximise transparency and comprehensiveness, whilst also minimising subjectivity and sources of bias. Because of these time-consuming and complex tasks, systematic reviews are perceived as being resource-intensive. To date, published estimates of systematic review resource requirements have been largely anecdotal, being imprecise and not based on evidence. However, it is valuable to provide reliable means of estimating the resource and time requirements of systematic reviews and maps. We analysed all CEE systematic reviews (n=66) and maps (n=20) published or registered between 2012 and 2017 to estimate the average time needed to complete a systematic review and map. We then surveyed 33 experienced systematic reviewers to collate information on time needed for each stage of the review process. Our results show that the average CEE systematic review takes 157 days (SD; ±22), whilst the average CEE systematic map takes 209 days (SD; ±53). While screening of titles and abstracts is widely accepted to be time-consuming, in practice meta-data extraction and critical appraisal can take as long (or even longer) to complete, especially when producing systematic maps. Finally, we present a tool that allows the user to predict the time requirements of a review or map given information known about the planned methods and evidence base likely to be identified. Our tool uses evidence-based defaults as a useful starting point for those wishing to predict the time requirements for a particular review. Our analyses shed light on the most time-consuming stages of the systematic review and map process, and highlight key bottlenecks from the perspective of time requirements, helping future reviewers to plan their time accordingly. Future predictions of effort required to complete systematic reviews and maps could be improved if CEE and CEE review authors provided more detailed reporting of the methods and results of their reviewing processes.

Introduction

42 Systematic review methods were developed in the field of healthcare in the 1990s as a means

43 of collating, appraising and synthesising broad (and sometimes contradictory) bodies of

44 primary research studies [1]. The methods revolve around a suite of practices during the

45 conduct of a literature review that aim to maximise transparency and comprehensiveness,

46 whilst also minimising subjectivity and sources of bias [2, 3]. Systematic reviews are now

47 viewed as a 'gold standard' in evidence synthesis across not only healthcare [1], but also

48 social welfare, education, international development, crime and justice [4], and conservation

49 and environmental management [2]. Within these fields, not-for-profit organisations have

50 been established to govern standards in systematic review and publish and endorse reviews

51 that meet specific minimum standards (e.g. the Collaboration for Environmental Evidence,

52 the Campbell Collaboration and Cochrane). Since their inception and development, the

53 number of systematic reviews published by these coordinating bodies and more broadly

54 across the research literature has increased considerably [3].

55 Systematic reviews should involve a number of important methodological steps to ensure the

56 syntheses are reliable [5]. These include: 1) the publication of a peer-reviewed *a priori*

57 protocol that sets out the planned methodology for the review, including detailed information

58 regarding the search, screening, critical appraisal and data synthesis strategies; 2)

59 comprehensive, tried-and-tested searches across a suite of resources for both traditional

60 academic research studies and grey literature [6]; 3) screening of identified studies at title,

61 abstract and full text levels using inclusion criteria that have been trialled and tested for

62 consistency amongst reviewers; 4) considered critical appraisal of all sources of uncertainty

63 and bias (validity) in each study, along with an assessment of the validity of all evidence

64 collectively; 5) consistent extraction of data (both descriptive information, or meta-data, and

65 quantitative or qualitative study findings); 6) accurate and reliable synthesis of study findings

66 through appropriate quantitative (e.g. meta-analysis) or qualitative (e.g. meta-ethnography)

67 methods; 7) throughout the process, full transparent documentation of all activities to allow

68 verification and repeatability. Because of these time-consuming and complex tasks,

69 systematic reviews are widely perceived as being particularly resource-intensive [7].

70 Although it is accepted that systematic reviews are challenging, the published estimates of

71 the resource requirements of systematic reviews have been largely anecdotal, and as such are

72 both imprecise and highly variable [e.g. 8]. One exception was a recent study by Borah et al.

3

73 [9] who found that the average time from the date of registry to date of submission of final

74 reports in the PROSPERO database was 67 weeks. There is notable uncertainty in this

75 estimate, however, since the dates held by the PROSPERO database do not necessarily

76 closely relate to the dates work commenced. Nor is there a clear link between the total

77 duration of a systematic review and the actual time requirements in person-days. No

78 comparable analysis of systematic review effort has been completed in the field of

79 conservation and environmental management; but any such estimate based on protocol and

80 final review report submission dates for the CEE journal Environmental Evidence (i.e.

81 duplicating the approach of Borah et al.) is unlikely to be reliable. Indeed, an assessment of

82 this data for the 86 reviews published by CEE between May 2012 and March 2017 suggest a

83 mean time from protocol to review submission of 737 days (SD=±364) with a range of 48 to

84 1,524 days. At the lower range, this represents an impossible speed for review conduct, and at

85 the upper end we know these data represent projects that underwent numerous significant

86 hiatuses.

87 Since systematic reviews are known to be resource-intensive, and since current estimates of

88 their time requirements are largely based on anecdote or uncertain data linked to reviews in

89 other fields, there is a clear need to provide evidence-based estimates of the time needed to

90 conduct a systematic review. Here, we report the results of a project that aimed to collate data

91 from a variety of sources and summarise the time requirements of CEE systematic reviews.

92 We use a combination of data reported within published systematic reviews and protocols

93 along with data from a survey of systematic review practitioners in the environmental field.

94 We produce an estimate of the mean time required to conduct a CEE systematic review or

95 systematic map split by the key steps of the review process. We also describe a tool based on

96 this data that allows those planning a systematic review or map to predict the time needed for

97 their review based on their own scoping activities that reveal the likely volume of relevant

98 evidence and the working speeds of their team. To our knowledge this is the first evidence-

99 based tool for predicting workloads in a systematic review and has a broad applicability

100 across a range of disciplines.

101 **Methods**

102 *Assessment of published CEE SRs/SMs*

103 An assessment was conducted of all CEE systematic reviews published since May 2012 in

104 both the journal *Environmental Evidence*

105 (https://environmentalevidencejournal.biomedcentral.com/) and the CEE Library

106 (http://www.environmentalevidence.org/completed-reviews). Key meta-data were extracted

107 from all completed systematic reviews and systematic maps, along with systematic review

108 and map protocols where no final review report had yet been published at the time of analysis

109 (March 2017). This meta-data included the following: protocol submission date and review

110 submission date (for all completed reviews and maps); the number of databases searched; the

111 number of grey literature resources searched; the number of search results identified from

112 database searching; the number of duplicates removed; the number of titles included after

113 screening; the number of abstracts included after screening; the number of titles and abstracts

114 included (where screened together); the number of full texts retrieved; the number of full

115 texts included after screening; the number of studies included following critical appraisal;

116 and, the number of studies with meta-analysable data. Data were separated according to

117 whether they came from systematic maps or systematic reviews and summary figures and

118 calculations were undertaken independently for these two types of review.

119

120 *Survey of systematic review practitioners*

121 A list of potential respondents (n=61) was assembled from authorship lists of CEE systematic

122 reviews, maps and protocols published between May 2012 and March 2017. The list was

123 supplemented with personal contacts from the systematic review community (n=34). A total

124 of 12 email addresses were no longer functioning and alternative authors from each EEJ

125 publication were selected as target respondents. One further email address failed to work and

126 so a tertiary alternative was selected and emailed. In total 95 respondents were targeted using

127 functioning email addresses. An email invitation to an online survey was sent to each

128 potential respondent (see Additional File 1 for survey questions). The key data collected are

129 outlined in Table 1.

130

5

131   Some 30 responses were received through the online survey, yielding a response rate of 32%.

132   Three responses were discarded because of incomplete information (only one page of

133   responses received), resulting in a total of 27 valid responses. In addition, data from 6

134   systematic reviewers at one organisation in Canada were collated by their line manager and

135   forwarded for use in the analysis. This resulted in a maximum of 33 data points or each

136   question.

137

138   *Compilation of data and calculation of metrics*

139   Following collation of the data from published articles and survey respondents, data were

140   summarised using means and standard errors. Data were then transformed into the same units

141   and information regarding the volume of evidence at each stage of the review process were

142   combined with data on processing speeds to yield a set of summary data on the mean time

143   taken for each main stage of the review process, along with a standard error. Standard errors

144   were propagated for each individual calculation using an online error propagation tool

145   (https://www.eoas.ubc.ca/courses/eosc252/error-propagation-calculator-fj.htm). The main stages

146   of the review process were identified as outlined in Table 2. These stages are based on the

147   CEE guidelines in systematic review [5]. Some data were arbitrarily set where CEE guidance

148   exists (e.g. the percentage of titles used as a subset for testing consistency before

149   commencing screening) or where data depend heavily on the experience level and efficiency

150   of the reviewer (e.g. time taken for meta-analysis). Details of the sources of each line of data

151   used in the calculation of times is provided in Table 3. Default values, the summary data and

152   the calculations used to arrive at the metrics in Table 2 are provided in Additional File 2.

153

154   *A software tool for estimating effort in future reviews*

155   Following calculation of summary time metrics for each stage of the review process (and

156   propagated standard errors), an interactive research effort estimation tool was produced that

157   builds on our framework by allowing end users to replace the default or mean data with

158   specific values based on their own experiences or knowledge. Key requirements for the tool

159   were: transparency in indicating the sources and evidence behind default values through

160   methodological documentation provided herein; helping the user understand the nature of

161   each step in the review process; building in details and instructions from published guidance

162   on systematic reviews; and, ease of use. The aim of this tool is to provide an indication of the

163   minimum time requirements for a systematic review. It is hoped that this tool will continue to

164   develop as the dataset upon which it is based expands and the models are refined. The

165   structure that provides caveats for missed steps is therefore intended as a conservative

166   warning where it is not based on evidence, and is informed by existing published systematic

167   review methodology and guidance.

168   The tool is provided in two formats. One format is based in an Excel spreadsheet, since this

169   format is downloadable and readily usable. The second format is a web-based app, which is

170   more easily updated and refined. The app was built in the R statistical environment [10] using

171   the R packages Shiny [11] and shinydashboard [12] to construct the interactive framework,

172   and plotly [13] to draw the diagrams. Both software tools make identical calculations, and

173   return identical results.

174   The software tool utilises several different types of user input. First, it requires an initial

175   number of articles that are returned by the 'search' stage of the systematic review or

176   systematic map. This is typically easy to estimate, as it is simply the sum of the number of

177   hits from all databases searched during the review. The software tool then combines this total

178   number of articles with estimates of the proportion of articles retained at each stage (i.e., title

179   screening, abstract screening, etc.), and the rate at which articles can be processed during

180   those stages. Typically, the proportion of articles retained increase as the review progresses,

181   while the number processed per day decreases. Finally, the user can add estimates of the time

182   taken to undertake specific tasks within the review process, such as conducting a meta-

183   analysis or writing a report. These data are then combined into plots of the number of articles

184   expected, and the total time spent, on each review stage.

185   The tool underwent substantial revisions and alterations during our analyses. Over time, we

186   developed an increasing level of detail to reflect the variability and nuance across the suite of

187   activities that make up a systematic review or map. Our final tool is published here along

188   with detailed explanatory notes to guide the user through its use and to ensure that reliable,

189   contextualised data (i.e. through scoping) is provided where possible to increase the accuracy

190   of predictions. The excel version of the app is available in the supplementary information

191   (Additional File 3), while the web app can be used online at

192   https://mjwestgate.shinyapps.io/revtime/ or downloaded for use in R using the source code on

193   github (https://github.com/mjwestgate/revtime/).

194   **Results**

195   *Assessment of published CEE SRs*

196   A total of 108 systematic review publications were produced by CEE between May 2012 and

197   March 2017, of which 66 represented systematic reviews and 20 were systematic maps (86 in

198   total), though 35 of these documents (41%) were protocols for as-yet incomplete projects.

199   The majority of the data comes from systematic reviews, and of these data the majority relate

200   to as yet unfinished systematic reviews (Figure 1).

201   The mean number of records remaining after each key stage in the conduct of a systematic

202   review is outlined in Figure 2 and Table 4. The variability around the data is clearly large,

203   particularly for some points in the review process where data were lacking (e.g. meta-

204   analysis, n=3). Some notable reviews could be perceived as outliers: for example, the

205   systematic review on the timing of mowing impacts on biodiversity in meadowland that

206   resulted in a particularly small set of search results (n=367) and a relatively high inclusion

207   rate at title screening stage (74.0%) [14], and the systematic map of on-farm water quality

208   mitigation measures that resulted in a very large set of search results (n>145,000) and a

209   relatively high percentage of duplicates (49.5%) [15]. However, given the low sample size

210   these cases have been left in to reflect the real variability present.

211   It is also worth noting that there is a lack of consistent reporting in published systematic

212   reviews and maps. Despite the existence of published standards for the reporting of activities

213   in systematic reviews (e.g. PRISMA; [16]) and requirements for a high level of detail in

214   reporting within the journal *Environmental Evidence*, only 8 or the 32 completed systematic

215   reviews and maps reported data for all stages of the review process (i.e. searching, duplicate

216   removal, title, abstract and full text screening and full text retrieval).

217

218   *Survey of systematic review practitioners*

219   Of the 33 included responses, only 7 provided data for all 15 questions asked about their

220   experience with reviews, while a further 12 provided data for the stages up to data/meta-data

221   extraction and beyond. On average, respondents had conducted a median of 2 systematic

222   reviews (minimum=0, maximum=18). Only one respondent had not previously conducted a

223   review before: data from this respondent were in relation to full text retrieval alone, since

224   they had acted as an assistant for a larger group of reviewers. We received fewer responses

8

225   about later stages of the review than early stages (Table 5), and particularly few responses

226   about the time taken to complete quantitative synthesis (effect size calculation and meta-

227   analysis; n=7 and 8 respectively).

228   A typical CEE systematic review results in a mean of just over 11,000 search results, which

229   falls to approximately 8,500 unique records following duplicate removal (Table 4). Just over

230   1,200 records remain following title screening and around 300 following abstract screening.

231   With the addition of evidence from other sources, the total number of full texts obtained is on

232   average c. 400. Screening of these full texts leaves just over 90 relevant articles/studies.

233   Critical appraisal retains approximately 60 articles/studies, and suitable data are present in a

234   little over 40 of them.

235   The sample size for systematic maps was much smaller than for systematic reviews (n=20

236   versus n=66), but the volume of evidence was far greater for these maps: almost 35,000

237   search results were obtained on average, leaving over 20,000 unique records. Title screening

238   left over 4,000 relevant records and abstract screening left over 1,000. Just over 1,100 full

239   texts were retrieved, with over 400 being relevant at full text. Across the two cases where

240   critical appraisal was performed within a systematic map, on average of over 100 studies

241   were retained in the final map.

242

243   *Estimated effort*

244   The time taken for each stage of a systematic review were lower, on average, for the

245   corresponding stage of a systematic map (Figure 3). The total time estimated for an 'average'

246   systematic review is 157 days (SD; ±22), whilst the total time for an 'average' systematic

247   map is 252 days (SD; ±67) when including an optional critical appraisal step, or 209 days

248   (SD; ±53) excluding critical appraisal. This estimate includes a large amount of time allotted

249   to planning and administration, in an effort to be conservative (45 days for systematic

250   reviews and 60 days for systematic maps [including critical appraisal]). Stages that are

251   calculated by the model include those from searching to effect size calculation, whilst other

252   stages are set as arbitrary defaults that must be changed by the user (see 'The tool', below).

253   For these calculated stages, the most time consuming are title screening, full text screening

254   and critical appraisal, with meta-data and data extraction also requiring considerable time.

255   Searching (for traditional academic and grey literature), assembling a library of evidence, full

256   text retrieval, and consistency checking required less time than most other stages. The

257   uncertainty around this data is substantial, resulting from the propagation of errors across the

258   models and the variability in the underlying source data.

259

Discussion

261   In this paper, we have presented the most comprehensive estimate to date of the effort needed

262   to complete environmental systematic reviews and systematic maps. Our results revealed

263   substantial variability in the number of articles included in synthesis projects, and the total

264   time taken to complete them. However, we also found key bottlenecks during early screening

265   and at critical appraisal and data extraction stages of each review. Below we expand on these

266   findings and their implications for future research practice.

267

Emergent patterns

269   We found several trends during our analysis that did not match our expectations about which

270   stages of the review would take the most time. Particularly surprising was the observation

271   that a relatively small proportion of time is spent on performing searching activities: between

272   7 and 7.5 days for reviews and maps, respectively. This result may reflect detailed

273   preparation, given that searching should be preceded by in depth building and testing of

274   search strategies, that will be outlined in an *a priori* protocol. Whilst we did not explicitly ask

275   expert reviewers how long they spent designing and testing a search strategy, this part of the

276   review process requires careful planning to ensure the review results are comprehensive and

277   representative of the true evidence base for a particular topic [17, 18].

278   Equally unexpected was our finding that respondents' reported time spent on administration

279   was particularly large: on average 19% of their total time. For reviews this corresponded to

280   24 days, whilst for maps it was almost 40 for those including critical appraisal (35.5 for those

281   without critical appraisal). Reported administration time varied substantially (SD=12.3),

282   perhaps indicating discrepancies in respondents' definitions of what should be included.

283   However, this likely reflects the fact that systematic reviewing often requires time spent

284   coordinating a large, possibly international team, and may also require substantial learning or

285   'relearning' of particular skills, such as experimental design or statistics. We have not

10

286 factored in training time in our analysis, but this is worth considering for novel teams or those

287 that will rely heavily on group tasks using subject but not methodology expertise.

288 More expected was the large amount of time spent on screening (including retrieval); an

289 average of 80 and 27 days for systematic reviews and maps respectively. This is a large

290 proportion of the time budget (17% and 32% for reviews and maps, respectively [39% for

291 maps excluding critical appraisal]). These differences highlight the fact that resources are

292 predominantly shifted towards identifying evidence in maps, whereas far more time is

293 devoted to synthesis in reviews. In reviews a similar time is spent on extracting and analysing

294 the data as screening (25 days). In maps, however, the proportion of total time on extracting

295 meta-data and coding is relatively lower (also 25 days).

296

The implications for 'optional' activities

298 Our calculations allow us to estimate the impacts of various optional activities on the total

299 time requirements of a systematic review or map. Current CEE guidance suggests that a

300 subset of articles is checked for consistency in the application of inclusion criteria between

301 two reviewers prior to commencing screening in earnest [5], and it suggests that 10% of

302 records should be checked as a minimum. However, in the field of healthcare systematic

303 reviews, dual coding is common [e.g. 19]. By altering the level of consistency checking from

304 the recommended minimum of 10% at each stage to 100% (i.e. complete dual screening), the

305 total time required changes from 155 days to 183 days, an increase of 18%. Whilst regarded

306 by some as a gold standard for systematic review methodology [1], this increase in time

307 requirements is substantial and may prove too costly for some. However, it may be an

308 important concession to maximise reliability and minimise human error in some cases.

309 Similarly, the CEE guidance suggests a selection of review bibliographies is screened to help

310 to maximise comprehensiveness of the search [5]. Increasing this bibliographic checking or

311 'citation chasing' can require considerable time if, for example, all identified reviews are

312 screened in this way, or even if all articles' bibliographies are screened. Assuming that the

313 inclusion rate at title, abstract and full text (and retrieval rate) remain the same in

314 bibliographic checking as for the core of the review, one can readily predict the additional

315 time needed to screen a certain number of reviews or articles in this way. Within a systematic

316 map, a larger volume of reviews is likely to be found, and the user can specify this number.

317   For example, in a systematic map of the impacts of vegetated strips within and around fields

318   [20], around 100 review bibliographies were checked for additional potentially relevant

319   articles. Altering the number of bibliographies checked in our tool to 100 increases the time

320   requirement from 255 to 271 days (6%).

321

322   *Comparison with existing estimates*

323   Previous estimates of the resource requirements of systematic reviews have been imprecise

324   and vary substantially, from between 6 months and 24 months or several years (Table 6).

325   Anecdotally, we have heard estimates that are as long as 5 years by a leading institute that

326   produces systematic reviews in healthcare in Sweden (SBU, http://www.sbu.se/en/). Our

327   analyses demonstrate that the time requirements for an 'average' CEE-style systematic

328   review need only take 157 days (FTE). This estimate represents just under 1 year FTE, taking

329   vacation, public holidays, and other regular disruptions to full time work into account.

330   Therefore, our analysis reveals a resource requirement in the lower end of the rough estimates

331   provided in the literature. Interestingly, our estimate is under half that of the only other

332   evidence-based assessment of which we are aware, which corresponds to approximately 337

333   days [9]. It is vital to remember that the time estimate by Borah et al. (2017) and the other

334   rough time estimates in the literature are typically meant to reflect the time required to

335   conduct a systematic review, rather than the resource requirements. However, the average

336   total salary costs for a postdoctoral research at Bangor University (chosen arbitrarily due to

337   our knowledge of the university, including National Insurance and USS pension

338   contributions) for 12 months is 48,593 GBP at the time of writing

339   (https://www.bangor.ac.uk/finance/py/documents/pay-scales-en.pdf). Including other

340   costs, such as support staff time and travel and subsistence for meetings, this sum is unlikely

341   to rise above 100,000 GBP. This value, again, sits below the mid points for the roughly

342   estimated cost ranges provided in the literature.

343   Our estimates do not attempt to predict a full costing of a systematic review. Furthermore,

344   our analyses are based on reported volumes of work and efficiency rates from the literature

345   and expert systematic reviewers. As such, the numbers are in need of validation using

346   detailed, accurate records of recently completed reviews. However, our estimates and tool are

12

347   a useful starting point for those wishing to better understand the demands and likely time

348   requirements of a systematic review or map.

349   The times estimated by our tool for the time required to undertake a systematic review are

350   realistic relative to the reviews conducted by Mistra EviEM. This 6 year project funded by

351   Mistra to undertake systematic reviews and maps in the field of environment relevant to the

352   Swedish environmental goals (www.eviem.se/en). The project will have completed 17

353   systematic reviews and maps over a 6.5 year period, with c. 20 years of full time equivalent

354   staff resources (review project managers); approximately 2.2 years of time per review.

355   However, our estimates for systematic maps are somewhat higher than those indicated for

356   EviEM maps in our experience. This is almost certainly the result of a small and

357   heterogeneous evidence base for completed systematic maps: fewer systematic maps have

358   been completed to date and the variability around the volume of evidence is substantial (SD

359   for systematic review total search results is 11,786 records, whist it is 39,434 for systematic

360   maps). Systematic maps are more adaptable by their very nature [21, 22], but a larger

361   evidence base would be useful in increasing the precision of the data in our tool.

362

363   *Limitations of our analysis and the evidence base*

364   Our analysis presents the best available information on the number of articles, and the

365   amount of time, included in a typical environmental systematic review or map. However, it is

366   possible that a number of factors may adversely affect the reliability of our analyses of the

367   'average' time needed to complete a review or map. Below we outline some of these points

368   so as to avoid the risk of faulty interpretation of our results.

369   First, our systematic review calculations assume a quantitative synthesis will be performed,

370   which may be true for the majority of current systematic reviews in the field of environment.

371   However, qualitative synthesis is a valuable evidence synthesis method [23], and its use will

372   likely increase in CEE reviews in the future. However, qualitative systematic reviews often

373   do not hold the same regard for issues such as comprehensiveness that quantitative systematic

374   reviews do. For example, qualitative syntheses may stop screening after a certain point

375   because of information saturation. Accordingly, these reviews should be dealt with different

376   when performing an analysis relating to time requirements, and tools for predicting times

377   should be built specifically for these kinds of analysis. It may be the case, however, that

13

378   specific qualitative reviews could adapt our tools to fit the desired methods. Our intention,

379   however, is not to make a universal analysis or tool for all types of reviews. Instead, we focus

380   on traditional quantitative systematic reviews.

381   Second, all of the data in our analyses have a high level of variability, poor levels of

382   reporting, or both. This results both from a heterogeneous evidence base and a relatively

383   small sample size. For example, of the 19 completed systematic reviews, only 8 reported the

384   number of duplicates removed from total search results. Similarly, whilst 18 reviews reported

385   the total number of included articles, only 10-11 articles reported the number of articles

386   following title screening, abstract screening and full text retrieval. Future CEE reviews

387   should strive to report such methodological information consistently, and CEE should create

388   or adhere to accepted reporting standards for all published reviews (e.g. PRISMA [16] or

389   ROSES [24]). Future analyses should increase sample size, making the most of the rapidly

390   expanding body of reliable systematic reviews. Indeed, efforts to record descriptive summary

391   information regarding systematic review methods are underway (e.g. ROSES [24]).

392   Third, we were not able to provide evidence-based data for all parts of our analysis. A

393   number of key variables have been estimated from our personal experience, including the

394   time required for additional searching for literature, and the number of bibliographies

395   screened. Where possible, future analyses should attempt to examine the evidence base for

396   these data.

397   Fourth, there are clear exceptional circumstances that would affect the reliability of

398   predictions made from our tool. For example, a change in core staff midway through a project

399   would likely require a significant proportion of time to acquaint new staff with what has been

400   done to date. However, careful file management and clear record keeping could reduce this to

401   a minimum. Large review teams may require more resources to train and manage,

402   particularly if meeting remotely. Novice teams may require substantial training time and may

403   suffer from low efficiency in the earlier stages of a review. Finally, undertaking reviews over

404   an extended time period can result in particularly low efficiency if core staff must reacquaint

405   themselves with their own work after significant gaps.

406   Fifth, our tool allows the end user to estimate the time required to complete a systematic

407   review or systematic map, and our analyses of the evidence base provide useful default

408   values should any information be unknown to the user. These default values, however are

14

409   based on an 'average' systematic review or map. It is important to note that the heterogeneity

410   across CEE reviews means that this 'average' review, whilst helpful as a starting point, is

411   perhaps not a meaningful entity. Context is highly important for each review, and knowing

412   something about the volume or the nature of the evidence (e.g. proportional relevance of a

413   subset) will allow end users to estimate time requirements much more accurately. We should

414   not assume that all reviews are alike and that the times calculated in our analysis are a

415   reliable estimate alone when planning a review. We encourage users to undertake good

416   quality scoping, as suggested in the CEE Guidelines [5] so as to provide reliable predictions

417   of the volume of evidence, the proportional relevance of articles and studies, and the time

418   required by the user's team to undertake specific tasks.

419   Finally, we have calculated mean volumes of evidence at each stage of the review process

420   and have used inclusion rates and working speeds to calculate an independent mean time

421   requirement for each stage based on available evidence. However, many reviews do not

422   report all data for each stage of the review, and the results of one stage are dependent upon

423   the nature of the stages preceding it. In ideal circumstances, we would have full data from all

424   reviews that would allow us to model the time requirement based on various contextual

425   variables, for example the inclusion rate of the preceding stage. This is not possible with our

426   limited dataset, however, and our methods represent a necessary compromise.

427

428   *Future work needed*

429   As described above, there is a need for a greater number of data points in future analyses,

430   both for published systematic reviews and maps and for survey data relating to processing

431   speeds. This itself would be aided by better reporting of methods used and records found at

432   all stages of the review process in CEE reviews. Some efforts are underway to record this

433   data more consistently (e.g. ROSES [24]).

434   We also highlight the need for evidence-based estimates of the financial costs associated with

435   systematic reviews, taking into account the price of necessary software, consultancy support

436   (e.g. from an informatician), registration and publication fees, communication materials, and

437   physical meetings. Although there will be considerable local and regional variability in the

438   real world prices of these services, an itemised list of recommended activities is a vital point

439   of departure for those planning an efficient and successful review.

15

440   Finally, results from our analyses and predictions using our tool should be continually tested

441   and the tool refined in order to match developments in systematic review methodology (e.g.

442   machine learning and prioritised screening [25]).

443

444   **Conclusions**

445   Our analyses shed light on the most time-consuming stages of the systematic review and map

446   process. We have highlighted key bottlenecks from the perspective of time requirements, and

447   our results allow future reviewers to plan their time accordingly. Our tool uses evidence-

448   based defaults as a useful starting point for those wishing to predict the time requirements for

449   a particular review. We also call on CEE and CEE review authors to improve the reporting of

450   the methods and results of their reviewing processes.

451 **References**

452 1. Higgins JP, Green S. Cochrane handbook for systematic reviews of interventions:
453 John Wiley & Sons; 2011.
454 2. Pullin AS, Stewart GB. Guidelines for systematic review in conservation and
455 environmental management. Conservation biology. 2006;20(6):1647-56.
456 3. Haddaway N, Woodcock P, Macura B, Collins A. Making literature reviews more
457 reliable through application of lessons from systematic reviews. Conservation Biology.
458 2015;29(6):1596-605.
459 4. Shlonsky A, Noonan E, Littell JH, Montgomery P. The role of systematic reviews and
460 the Campbell Collaboration in the realization of evidence-informed practice. Clinical Social
461 Work Journal. 2011;39(4):362-8.
462 5. CEE. Guidelines for Systematic Review and Evidence Synthesis in Environmental
463 Management. Version 4.2. Environmental Evidence:

464 http://environmentalevidence.org/wp-content/uploads/2014/06/Review-guidelinesversion-
465 4.2-finalPRINT.pdf2013.
466 6. Haddaway NR, Bayliss HR. Shades of grey: two forms of grey literature important for
467 reviews in conservation. Biological Conservation. 2015;191:827-9.
468 7. Westgate MJ, Lindenmayer DB. The difficulties of systematic reviews. Conservation
469 Biology. 2017.
470 8. Collins A, Coughlin D, Miller J, Kirk S. The production of quick scoping reviews and
471 rapid evidence assessments: a how to guide. 2015.
472 9. Borah R, Brown AW, Capers PL, Kaiser KA. Analysis of the time and workers
473 needed to conduct systematic reviews of medical interventions using data from the
474 PROSPERO registry. BMJ open. 2017;7(2):e012545.
475 10. R Core Development Team. R: a language and environment for statistical computing.
476 Version 3.4.1. R Foundation for Statistical Computing, Vienna, Austria. 2017.
477 11. Chang W, Cheng J, Allaire J, Xie Y, McPherson J. shiny: Web Application
478 Framework for R. R package version 1.0. 3. 2017.
479 12. Chang W. shinydashboard: Create Dashboards with 'Shiny'. R package version 05.
480 2015;1.
481 13. Sievert C, Parmer C, Hocking T, Chamberlain S, Ram K, Corvellec M, et al. plotly:
482 Create Interactive Web Graphics via plotly. js. R package version 4.7.1. https://CRAN.R-
483 project.org/package=plotly. 2017.
484 14. Humbert J-Y, Pellet J, Buri P, Arlettaz R. Does delaying the first mowing date benefit
485 biodiversity in meadowland? Environmental Evidence. 2012;1(1):9.
486 15. Randall NP, Donnison LM, Lewis PJ, James KL. How effective are on-farm
487 mitigation measures for delivering an improved water environment? A systematic map.
488 Environmental Evidence. 2015;4(1):18.
489 16. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for
490 systematic reviews and meta-analyses: the PRISMA statement. PLoS medicine.
491 2009;6(7):e1000097.
492 17. Bayliss HR, Beyer FR. Information retrieval for ecological syntheses. Research
493 synthesis methods. 2015;6(2):136-48.
494 18. Livoreil B, Glanville J, Haddaway NR, Bayliss H, Bethel A, Lachapelle FF, et al.
495 Systematic searching for environmental evidence using multiple tools and sources.
496 Environmental Evidence. 2017;6(1):23.

497   19.   Jones E, Taylor B, MacArthur C, Pritchett R, Cummins C. The effect of early
498   postnatal discharge from hospital for women and infants: a systematic review protocol.
499   Systematic reviews. 2016;5(1):24.
500   20.   Haddaway NR, Brown C, Eggers S, Josefsson J, Kronvang B, Randall N, et al. The
501   multifunctional roles of vegetated strips around and within agricultural fields. A systematic
502   map protocol. Environmental Evidence. 2016;5(1):18.
503   21.   Haddaway NR, Bernes C, Jonsson B-G, Hedlund K. The benefits of systematic
504   mapping to evidence-based environmental management. Ambio. 2016;45(5):613-20.
505   22.   James KL, Randall NP, Haddaway NR. A methodology for systematic mapping in
506   environmental sciences. Environmental Evidence. 2016;5(1):7.
507   23.   Flemming K. The synthesis of qualitative research and evidence-based nursing.
508   Evidence-based nursing. 2007;10(3):68-71.
509   24.   Haddaway NR, Macura B, Whaley P, Pullin AS. ROSES RepOrting standards for
510   Systematic Evidence Syntheses: pro forma, flow-diagram and descriptive summary of the
511   plan and conduct of environmental systematic reviews and systematic maps. Environmental
512   Evidence. in press.
513   25.   Shekelle PG, Shetty K, Newberry S, Maglione M, Motala A. Machine learning versus
514   standard techniques for updating searches for systematic reviews: a diagnostic accuracy
515   study. Annals of Internal Medicine. 2017;167(3):213-5.

516

517   **Additional Files**

518   Additional File 1. Email survey sent to systematic review practitioners.

519   Additional File 2. Data and calculations used to arrive at metrics and standard errors
520   compiled to produce time requirements for the various steps of a systematic review.

521   Additional File 3. Systematic review and map time planner tool (Excel version).

522 **Figure legends**

523 **Figure 1.** The number of publications from CEE between May 2012 and March 2017.

524 **Figure 2.** The mean number of records remaining after each key stage of the a) systematic

525 review and b) systematic map processes. Error bars are ±1 standard deviation. Labels are data

526 values.

527 **Figure 3.** Time taken for each stage of the systematic map process in days. Error bars are ±1

528 standard deviation.

20

529 **Tables**

530 **Table 1.** Key data collated from the survey of systematic review practitioners.

How many SRs have you undertaken?
Time taken to download search results from each database (days)
Time taken to assemble library of results and remove duplicates
Time taken to screen organisation websites (each in days)
Number of titles screenable per day
Number of abstracts screenable per day
Number of titles and abstracts screenable per day (together)
Number of full texts retrievable per day
Number of full texts screenable per day
Number of articles for meta-data extraction/coding per day
Number of articles for critical appraisal per day
Number of articles for data extraction per day
Number of articles for effect size calculation per day
Time taken for meta-analysis
Time taken for report writing
Percentage of time required for administration

531

532 **Table 2.** The main stages of a systematic review used to predict time requirements.

Activity	Source of data
Planning time (stakeholder engagement, Q formulation)	Semi-fixed values to be inputted by reviewer (arbitrary defaults)
Protocol development	Semi-fixed values to be inputted by reviewer (arbitrary defaults)
Searching (academic literature)	Values calculated by tool
Searching (grey literature)	Values calculated by tool
Assembling library and removing duplicates	V Data from survey
Title screening	Values calculated by tool
Abstract screening	Values calculated by tool
Full text retrieval	Values calculated by tool
Full text screening	Values calculated by tool
Consistency checking (screening)	Values calculated by tool
Meta-data extraction	Values calculated by tool
Critical appraisal	Values calculated by tool
Data extraction	Values calculated by tool
Effect size calculation	Values calculated by tool
Meta-analysis	Data from published reviews/protocols
Report writing	Data from published reviews/protocols
Communication materials	Data from published reviews/protocols
Administration	Data from survey

533

21

534 **Table 3.** Summary metrics used in intermediate steps of time calculation and the sources of

535 data used to calculate metrics in Table 2.

Activity	Source of data
Number of searching databases	Data from published reviews/protocols
Time taken to download one database's search results (days)	Data from survey
Number of grey literature website sources	Data from published reviews/protocols
Time required for additional grey literature sources (other languages, etc.) (days)	Semi-fixed values to be inputted by reviewer (arbitrary defaults)
Number of grey literature sources (website) screenable per day	Data from survey
Number of search results (total)	Data from published reviews/protocols
Estimated duplicate rate (percent)	Data from published reviews/protocols
Number of search results after duplicate removal	Data from published reviews/protocols
Estimated inclusion rate (title) (percent)	Data from published reviews/protocols
Screening speed (titles per day)	Data from survey
Estimated inclusion rate (abstract) (percent)	Data from published reviews/protocols
Screening speed (abstracts per day)	Data from survey
Retrieval rate (percent retrievable)	Data from published reviews/protocols
Retrieval speed (articles per day)	Data from survey
Estimated inclusion rate (full text) (percent)	Data from published reviews/protocols
Screening speed (full texts per day)	Data from survey
Percentage of results screened for consistency (title)	Semi-fixed values to be inputted by reviewer (arbitrary defaults)
Percentage of results screened for consistency (abstract)	Semi-fixed values to be inputted by reviewer (arbitrary defaults)
Percentage of results screened for consistency (full text)	Semi-fixed values to be inputted by reviewer (arbitrary defaults)
Number of consistency checkers at each stage	Semi-fixed values to be inputted by reviewer (arbitrary defaults)
Meta-data extraction rate (articles per day)	Data from survey
Critical appraisal rate (articles per day)	Data from survey
Percentage of studies with meta-analysable data	Data from published reviews/protocols
Data extraction rate (articles per day)	Data from survey
Effect size calculation rate (articles per day)	Data from survey
Estimated inclusion rate following critical appraisal	Data from published reviews/protocols
Percentage of time needed for administration	Data from survey

536

537

538

22

539 **Table 4.** Mean number of records remaining in each stage of the systematic review and map

540 process, along with minima, maxima, standard errors (SE) and sample sizes (n=number of

541 reviews/protocols providing data).

542 *Systematic reviews*

Number of items remaining after:	Mean	SD	SE	n543
Searching	11,786	10,230	2347	19
Duplicate removal	8,493	6,040	2135	8
Title screening	1,236	766	231	11
Abstract screening	309	269	85	10
Full text retrieval	405*	347	105	11
Full text screening	93	85	20	18
Critical appraisal	60	41	15	8
Narrative synthesis	60	41	15	8
Quantitative synthesis	45	43	25	3

544

545 *Systematic maps*

Number of items remaining after:	Mean	SD	SE	n546
Searching	34,165	39,434	11,384	12
Duplicate removal	22,584	20,578	6,204	11
Title screening	4,118	2,002	817	6
Abstract screening	1,027	575	217	7
Full text retrieval	1,126*	859	286	9
Full text screening	423	371	117	10
Critical appraisal	116	22	16	2
Narrative synthesis	116	22	16	2

547

548 * The number of full texts is greater than the number of screened abstracts due to the inclusion of grey

549 literature at the full text stage that have been externally screened for relevance from the searching of

550 websites, web-based search engines, etc.

551
552
553

554

23

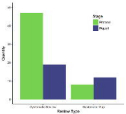555 **Table 5.** Summary data for respondents to the survey: n, sample size; SD, standard deviation.

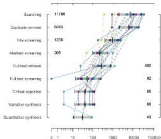| Survey question	Mean response	n	SD
Time taken to download search results from each database (days)	0.25	20	0.220
Time taken to assemble library of results and remove duplicates	1.37	18	1.403
Time taken to screen organisation websites (each in days)	0.15	21	0.122
Number of titles screenable per day	854.35	23	533.622
Number of abstracts screenable per day	192.29	24	111.900
Number of titles and abstracts screenable per day (together)	468.14	22	128.216
Number of full texts retrievable per day	170.94	24	137.369
Number of full texts screenable per day	43.99	30	31.014
Number of articles for meta-data extraction/coding per day	16.69	21	11.574
Number of articles for critical appraisal per day	11.68	19	8.145
Number of articles for data extraction per day	6.87	19	5.093
Number of articles for effect size calculation per day	24.00	7	34.083
Time taken for meta-analysis	6.75	8	5.092
Time taken for report writing	15.53	20	10.228
Percentage of time required for administration	19.00	22	12.276

556

24

557   **Table 6.** Estimates of the resource requirements for systematic reviews from a non-systematic search of the literature.

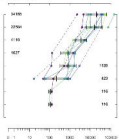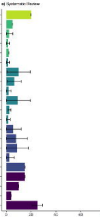| Financial cost	Time requirement	Review type	Citation
	0.5-3 years	Systematic review	Dicks, L.V., Walsh, J.C. and Sutherland, W.J., 2014. Organising evidence for environmental management decisions: a '4S'hierarchy. *Trends in ecology & evolution*, 29(11), pp.607-613.
30,000-300,000 USD	Several years	Systematic review	Collaboration for Environmental Evidence. 2013. Guidelines for Systematic Review and Evidence Synthesis in Environmental Management. Version 4.2. Environmental Evidence: www.environmentalevidence.org/Documents/Guidelines/Guidelines4.2.pdf
80,000-120,000 GBP	10-18 months	Systematic review	Collins, A., Coughlin, D., Miller, J. and Kirk, S., 2015. The production of quick scoping reviews and rapid evidence assessments: a how to guide.
<=250,000 USD		Systematic review	McGowan, J. and Sampson, M., 2005. Systematic reviews need systematic searchers. Journal of the Medical Library Association, 93(1), p.74.
	9-24 months	Systematic review	Centre for Cognitive Ageing and Cognitive Epidemiology (http://www.ccace.ed.ac.uk/research/software-resources/systematic-reviews-and-meta-analyses)
	67.3 weeks	Systematic review	Borah, R., Brown, A.W., Capers, P.L. and Kaiser, K.A., 2017. Analysis of the time and workers needed to conduct systematic reviews of medical interventions using data from the PROSPERO registry. BMJ open, 7(2), p.e012545.

558

a) Systematic Review   b) Systematic Map

a) Systematic Review

Stage
Planning
Searching
Screening
Extracting
Synthesis
Reporting