2023-11-28

Using citizen science data to assess the vulnerability of bottlenose dolphins to human impacts along England's South Coast

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https://pearl.plymouth.ac.uk/handle/10026.1/21994

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USING CITIZEN SCIENCE DATA TO ASSESS THE VULNERABILITY OF BOTTLENOSE DOLPHINS TO HUMAN IMPACTS ALONG ENGLAND'S SOUTH COAST

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1 # USING CITIZEN SCIENCE DATA TO ASSESS THE

2 # VULNERABILITY OF BOTTLENOSE DOLPHINS TO HUMAN

3 # IMPACTS ALONG ENGLAND'S SOUTH COAST

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25 **Short title for page headings:** Assessing the UK's South Coast Bottlenose Dolphin Population

26 **Keywords**: bottlenose dolphins, conservation, cumulative risk mapping, survival, abundance, citizen

27 science.

28 **Word Count:** 5254

29 **Figure Count:** 7

30 **Table Count:** 2

31

32

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35

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Abstract

Coastal bottlenose dolphin populations are highly vulnerable due to their small population sizes and proximity to human activities. Long-term studies in the UK have monitored populations protected within Special Areas of Conservation (SACs) since the 1990s, but a small community of bottlenose dolphins inhabiting the coastal waters of South England has received much less attention. The English Channel is one of the most heavily impacted marine ecosystems worldwide and increasing anthropogenic pressures pose a severe threat to the long-term viability of this population. Conservation measures to protect these animals have been hindered by a lack of knowledge of population size, distribution, and ranging behaviour. This study aimed to fill these knowledge gaps.

A citizen science sighting network yielded 7,458 sighting reports of bottlenose dolphins between 2000-2020. Resightings of identified individuals were used to estimate abundance, distribution, and ranging behaviour. Social structure analysis revealed a discrete interconnected group of animals in shallow coastal waters, which did not appear to mix with conspecifics identified further offshore. A Bayesian multisite mark recapture analysis estimated that this population comprises around 48 animals (CV= 0.18, 95% HPDI= 38-66).

These dolphins ranged between North Cornwall and Sussex, with an average individual range of 530 km (68-760 km). Areas of high modelled habitat suitability were found to overlap with high levels of anthropogenic pressure, with pollution and boat traffic identified as the most pervasive threats. Although adult survival rates indicated that the population was relatively stable from 2008-2019 (0.945 (0.017±SE)), the small population size implies a significant risk to their long-term viability and resilience to environmental change. By highlighting the most deleterious anthropogenic activities and regions of conservation significance, our results will be useful for developing management policies for threat mitigation and population conservation, to protect this vulnerable group of dolphins.

62 **Introduction**

63 Bottlenose dolphins inhabit temperate and tropical pelagic and coastal waters worldwide. Geographic

64 segregation, environmental change, or ecological specialisation can result in the emergence of

65 discrete populations (Lowry, 2012; Louis *et al*., 2014a; 2021). In the North Atlantic, bottlenose

66 dolphins have been segregated into two ecotypes, the offshore and the coastal (Natoli *et al*., 2005;

67 Louis *et al*., 2014b; Oudejans *et al*., 2015; Nykänen *et al*., 2019a; 2019b). Unlike in US Atlantic

68 waters, where morphological and genetic differences (Mead and Potter, 1995; Perrin *et al*., 2011)

69 indicate that coastal and offshore populations may represent distinct species (Costa *et al*., 2022),

70 there is limited evidence to suggest speciation in the North East Atlantic (NEA).

71 In the NEA, offshore communities usually occur in large groups, exhibiting large ranging movements

72 with low site fidelity (Bearzi, 2005; Silva *et al*., 2009b) whereas, coastal dolphins often live in

73 smaller communities with high site-fidelity over a restricted range (Grellier *et al*., 1995; Ingram and

74 Rogan, 2002; Grellier and Wilson, 2003). These ecotypes can be differentiated through genetic

75 analysis, social associations, and habitat preferences, with coastal communities usually restricted to

76 shallower waters less than 50 m deep (Louis *et al*., 2014a; 2014b; Oudejans *et al*., 2015).

77 Genetic and social analysis has delineated localised populations within each ecotype, with coastal

78 communities demonstrating limited dispersal and low intrapopulation diversity (Mirimin *et al*., 2011;

79 Louis *et al*., 2014b; Nykänen *et al*., 2019b). Differences in the ranging behaviours of coastal

80 populations in the NEA have also been shown. Some exhibit a high degree of site fidelity to small-

81 scale localised areas (Wilson, Thompson, and Hammond, 1997; Ingram and Rogan, 2002; Gasper,

82 2003; Grellier and Wilson, 2003; Feingold and Evans, 2014; Andre, 2017), whilst others demonstrate

83 wide-ranging behaviour inhabiting extended stretches of coastline (Wood, 1998; Mandleberg, 2006;

84 Ingram *et al*., 2009; Giménez *et al*., 2017; Nykänen *et al*., 2020).

4

85　As coastal communities tend to form small, isolated populations (Mirimin *et al*., 2011; Louis *et al*.,

86　2014b; Nykänen *et al*., 2018) they are predisposed to genetic drift due to reduced heterozygosity

87　(Lacy, 1987). This subsequent loss of genetic resilience, exacerbated by low reproductive rates and

88　small population sizes (Connor *et al*., 2000; Baker *et al*., 2018), increases the vulnerability of these

89　coastal communities to anthropogenic stressors and local extinction (Hare *et al*., 2011).

90　Inshore environments are often exposed to higher levels of anthropogenic pressure due to their

91　proximity to human populations (EEA, 2019; He and Silliman, 2019). Consequently, coastal dolphins

92　are subjected to increased levels of direct threats such as entanglement (López, 2006), bycatch (Palka

93　and Rossman, 2001) and vessel strike (Dwyer, Kozmian-Ledward, and Stocking, 2014), and indirect

94　threats such as habitat degradation (Pirotta *et al*., 2013; Agrelo *et al*., 2019), vessel disturbance

95　(Lusseau, 2005; Bejder *et al*., 2006; Pirotta *et al*., 2015), prey depletion (Bearzi *et al*., 2005),

96　pollution (Schwacke *et al*., 2014; Jepson *et al*., 2016), and anthropogenic noise (Buckstaff, 2006;

97　Rako *et al*., 2013). These pressures can negatively impact the health and behaviour of coastal

98　populations, diminishing reproductive output and survivorship (Gulland and Hall, 2007; Bejder *et al*.,

99　2009; McHugh *et al*., 2011). Due to increased human population sizes and subsequent habitat

100　degradation, coastal populations are also likely to be greatly reduced from historic levels (Nichols *et*

101　*al*., 2007). As such, coastal communities require focused conservation management as detrimental

102　changes to environmental conditions can have consequences at the population level.

103　Many studies have focused on the impact of single anthropogenic stressors (e.g. Rako *et al*., 2012;

104　Jepson *et al*., 2016); however, due to additive effects, the cumulative impact of multiple stressors can

105　be greater than if exposed to stressors individually (Crain, Kroeker, and Halpern, 2008; Maxwell *et*

106　*al*., 2013; Pirotta *et al*., 2022). Therefore, attempting to establish the exposure of cumulative stressors

107　over entire population ranges should be a priority for future mitigation (Crain *et al*., 2008; Maxwell

108　*et al*., 2013). Depicting the spatial footprint, intensity, and prevalence of harmful impacts is therefore

109   essential to identify areas for focused conservation efforts (Myers *et al*., 2000; Salafsky and

110   Margoluis, 2003; Tulloch *et al*., 2015).

111   In the NEA, bottlenose dolphins are protected under a variety of legislation including the Agreement

112   of the Conservation of Small Cetaceans of the Baltic and North Seas, the European Union Habitats

113   Directive (92/43/EEC) and in the UK the Wildlife and Countryside Act (1981) and Conservation of

114   Habitats and Species Regulations (2017). Protection in the UK is usually established through Special

115   Areas of Conservation (SACs), with three designated at sites used by the UK's two largest, resident

116   communities in Cardigan Bay & Pen Llŷn a'r Sarnau, Wales, and the Moray Firth, Scotland.

117   Research and funding have been focused at these sites due to monitoring obligations and although

118   multiple distinct populations have been identified and studied at other sites around Britain and

119   Ireland (Wilson *et al*. 1997; Bristow and Rees, 2001; Ingram and Rogan, 2002; Grellier and Wilson,

120   2003; Liret *et al*., 2006; Pesante *et al*., 2008; Feingold and Evans, 2014), comparatively little is

121   known about bottlenose dolphins along England's southwest and Channel coast.

122   The Channel has been classified as one of the most impacted marine ecosystems worldwide (Halpern

123   *et al*., 2008). Not only is it home to one of the busiest shipping routes globally, but multiple

124   economically important industries operate in the region (Hardisty, 1990; McClellan *et al*., 2014;

125   Glegg, Jefferson, and Fletcher, 2015). Growing industrial activities and demand for resources has

126   seen a rise of anthropogenic pressures in recent years (McClellan *et al*., 2014), yet exposure and risk

127   of these threats to coastal dolphins is currently unquantified. To ensure appropriate conservation

128   management, the identification of this community's demographic parameters as well as the impacts

129   of regional anthropogenic pressures is needed (Frederiksen *et al*., 2004; Votier *et al*., 2005; Bejder *et*

130   *al*., 2006).

131   Surveys around Cornwall in the southwest UK in the early 1990s reported about 51 bottlenose

132   dolphins (Wood, 1998) resident along a 650 km stretch of coastal water centred around Cornwall. In

133   2016, following decades of limited data collection and increasing conservation concern for these

134   animals, a citizen science sighting network was initiated demonstrating the year-round presence of a

135   small group of individuals (Dudley, 2017). Previous studies revealed that bottlenose dolphins ranged

136   throughout the Channel coast of England (Tregenza 1992, Williams *et al*., 1997; Liret *et al*., 1998;

137   Brereton *et al*., 2017) but there was no reliable estimate of abundance of bottlenose dolphins resident

138   in the coastal region of the English Channel.

139   Limited information has constrained effective discussion on conservation and management for this

140   small population. Hence, this study aimed to integrate citizen science data throughout England's

141   South Coast to provide robust estimates of abundance, movement patterns, habitat use, and to

142   identify high-risk areas for future mitigation by spatially mapping cumulative stressors throughout

143   the population's known distribution. The aim was to produce outputs useful for planning effective

144   future protection for this population by highlighting regions of conservation importance, informing

145   policy, and assisting management decisions.

146   **Methods**

147   **Study Site**

148   The South Coast of England is characterised by a combination of exposed rocky cliffs and sandy

149   bays with prevailing south-westerly winds (British Geological Survey, 1996; Uncles and Stephens,

150   2007). It accommodates some of the busiest ports and shipping lanes globally as well as coastal

151   tourism spots. Consequently, its waters are subjected to high levels of vessel activity and an increase

152   in recreational boating and marine tourism during summer months.

153   **Data Collection**

154 In 2016, the South West Bottlenose Dolphin Consortium was formed, creating a shared dataset of

155 current and historical bottlenose dolphin encounters from various contributors in the UK's southwest.

156 In response to reports of sightings outside this network, from 2019 we extended the citizen science

157 sighting network throughout the whole southern coast of the UK. Regular boat users such as tour

158 operators, and environmental NGOs with frequent contact with coastal observers were invited to

159 participate. Press releases, radio interviews, webinars, and social media were then used to encourage

160 sighting submissions from the wider public. Contributors were requested to send sightings

161 information including time, location (GPS coordinates if available), numbers of animals, and any

162 photographs taken, with emphasis on photographing all individuals in the group to prevent bias.

163 Photographic identification techniques were used to identify individuals using their unique nicks and

164 scars (Würsig & Würsig, 1977). Individuals were then allocated one of three degrees of marking

165 severity and matched against a catalogue of identified individuals. Permanently marked individuals

166 (M1) possessed persistent markings which allowed long-term re-identification. Superficially marked

167 (M2) individuals possessed markings which although not permanent were observable over a single

168 field season and temporarily marked individuals (M3) had markings which can fade between

169 sightings (Scott, Wells, and Irvine, 1990; Wilson, Hammond, and Thompson, 1999; Oudejans *et al.*,

170 2015). Due to the diverse array of contributors, all photos were graded (G1-4) on factors such as

171 lighting, distance from individual, angle, and focus following Nykänen *et al.*, 2020's criteria. A total

172 of 7458 encounters were collated from citizen science reports between 2000-2020, with

173 identifications made from 326 photo-verified sightings from 2007–2020. To reduce bias from

174 incorrectly identified dolphins the data was restricted to permanently marked individuals (M1, G1-

175 G4) from 2008-2019 for the social and survival analyses; and 2018 for the abundance analysis. All

176 sighting data from 2000-2019 was used for the cumulative impact distribution analysis.

177   **Social Structure**

178   To differentiate between the resident coastal community and other transient animals, the social

179   structure of all identified individuals between 2008-2019 (irrespective of sighting frequency) was

180   investigated using Socprog 2.9 with resultant networks depicted in Netdraw 2.158 (Borgatti and

181   Everett, 2006; Whitehead, 2009a; 2009b). Individuals were considered associated if captured within

182   the same encounter (Whitehead and Dufault, 1999; Whitehead, 2008). To minimise bias, only

183   permanently marked individuals (M1) were used to ensure individuals could be matched throughout

184   the study's duration. The Half Weight Association index was used to calculate the association

185   strength between pairs of individuals, which ranges from 0 (never associated) to 1 (always

186   associated) and reduces bias when individuals are present but not identified (Cairns and Schwager,

187   1987).

188   **Abundance**

189   Due to the wide-ranging nature of this population the broader study region was segregated into three

190   geographically distinct sites (Figure 1) and a multi-site mark-recapture framework was used to assess

191   the abundance across the entire study area (Durban *et al*., 2005). Bayesian inference was used to fit

192   hierarchical log-linear models of likelihood of permanently marked individuals across the three

193   discrete study sites (Cheney *et al*., 2013; Nykänen *et al*., 2020). This method accounts for the

194   movement of individuals between study sites and permits data to be collected opportunistically in

195   different regions (Durban *et al*., 2005). Sightings of permanently marked individuals (M1) from 2018

196   were partitioned via study site (S1) and incorporated into the model, which predicts the number of

197   permanently marked individuals not observed at each study site. Sightings data from 2018 was

198   chosen due to its high proportion of G1-G2 photos (S2) and even distribution of Network A sightings

199   across sites compared to other years. The ratio of marked/to unmarked individuals in each encounter

200   across the framework was then incorporated to estimate the total abundance of the population

201 (Cheney *et al*., 2013; Nykänen *et al*., 2020). Markov Chain Monte Carlo sampling in WinBUGS

202 software was used to conduct model estimation and averaging with 100,000 burn-in followed by

203 100,000 iterations. Reliability and convergence were monitored through the visual inspection of three

204 separate chains (Lunn *et al*., 2000; Durban *et al*., 2005; Nykänen *et al*., 2020).

205 **Survival**

206 Sighting histories of permanently marked (M1) individuals identified during the period from 2008-

207 2019 were used to estimate survival. As mark-recapture modelling requires discrete capture periods,

208 data were partitioned according to year to minimise potential bias from seasonal heterogeneity in

209 sampling effort. Cormack-Jolly-Seber models using the program MARK 9.x were then constructed to

210 estimate capture probabilities for each year (p) and survival between years (φ) (Cormack, 1964; Jolly,

211 1965; Seber, 1965; Lebreton *et al*., 1992; White and Burnham, 1999).

212 Heterogeneity of capture and survival probabilities were evaluated using goodness-of-fit tests in the

213 program U-CARE 2.3.4, along with tests for transience and trap-dependence (Pradel *et al*., 1997;

214 Choquet *et al*., 2005). Overdispersion of data is common in cetacean studies, as the outcomes of

215 individuals travelling in the same school are not independent (Anderson, Burnham, and White, 1994),

216 and was assessed through the variance inflation factor (ĉ) which can be used to correct lack of fit in

217 models. Once a suitable general model was found, increasingly simpler models were fitted. The

218 Akaike Information Criteria (AICc) were used to select the most parsimonious model, with the

219 lowest AICc representing the best fit model. Normalised AICc weights were then used to assess the

220 strength of the evidence for that model over others.

221 **Cumulative Utilisation & Impact Distribution**

222   To assess the impact of anthropogenic pressures on bottlenose dolphins, suitable habitat was

223   identified using presence-only species distribution models in the program MaxEnt 3.4.0 (See

224   Supplementary Info; Phillips, Dudík, and Schapire, 2020). This method connects background

225   environmental data and occurrence records to predict both the probability of a species distribution

226   across geographical space and the most influential environmental driver(s) (Phillips et al., 2006; Elith

227   et al., 2011). All bottlenose dolphin sightings regardless of network from 2000-2019 in waters less

228   than 61 m were incorporated into this model as this was identified as key habitat of network A

229   individuals by depth preference analysis (GEBCO, 2020; Figure 3c). Spatial data of 16 human

230   activities (Table 1) were used to assess the impact of current anthropogenic pressures across the

231   South Coast. Numerous stressor levels were allocated to three sectors: fishing, pollution, and

232   shipping activity, following procedures from Halpern *et al*., 2008 and Trew *et al*., 2019. Non-binary

233   stressor layers, were log-transformed, summed, then rescaled (between 0 and 1) to give an intensity

234   score for each activity (Trew *et al*., 2019). Intensity scores were then rescaled to match the resolution

235   of the relative habitat suitability score (1km²).

236   Cumulative impact scores were determined to identify regions of high risk, where each activity is

237   weighted by the vulnerability of the population to the corresponding stressor. Anticipated impacts

238   from each activity were accessed via a literature review, with vulnerability weightings ascertained via

239   measurements from Maxwell *et al*. 2013 (S3-4). Scores were then summed and rescaled between 0-1.

240   Cumulative Utilisation and Impact Distribution (CUI) scores were calculated by summing all

241   cumulative impact scores and multiplying by the relative habitat suitability score following:

242
$$CUI = \sum_{i=1}^{n}\sum_{j=1}^{m} D_i \times S_j \times U_{i,j}$$

243 Where Di is an activity's intensity score at location i, Sj the relative habitat suitability of species j,

244 and Ui,j is the vulnerability weighting of activity i on species j. To assess which anthropogenic

245 activity or sector exhibited the greatest risk to the population, pairwise linear regression was

246 completed to monitor the effect of individual CUIs on the overall CUI score.

Results

248 Bottlenose dolphin sightings (n= 7,458) were collated from citizen science reports, with 326

249 photographic sightings from 2007–2020 (S5-6). 18% of identifiable dolphins (M1) were resighted

250 (sighting range: 2-90), with 30 individuals (11%) logged in multiple years. School size ranged from

251 1-60 with an average of 9.7 ±8.1 (±SD). The number of individuals (M1-M3) photo-identified per

252 group ranged from 1-25 with an average of 4.0 ±4.01 (±SD).

253

Social Structure

255 Social structure analysis identified 25 clusters of 217 permanently marked (M1) individuals (Figure

256 2). Network A consisted of 32 individuals identified during 90% of encounters (mean group size =

257 9.39 ±5.69 (±SD)). 94% of individuals from network A were re-sighted on more than one occasion

258 (range: 1-87), with 78% seen in multiple years (Figure 2). Networks B-Y consisted of 185

259 permanently marked individuals seen on 10% of encounters, 97% of which were seen only once.

260 Analysis of depth preferences and residency levels (Figures 2b & 3c) confirmed network A as a

261 discrete resident population, therefore, subsequent analysis included individuals from network A

262 only.

263

Range Analysis and Abundance

265   Most of the identified animals ranged between North Cornwall and Dorset. However, 10 individuals,

266   ranged more widely between North Cornwall and East Sussex (Figure 3b). Analysis of individual

267   ranging behaviour revealed a mean minimum distance of 530 km (range: 68 km – 760 km).

268   Occasionally, individuals were also seen to make extended journeys, with ≈460 km travelled within

269   three days.

270

271   Permanently marked (M1) individuals were recorded more frequently in Site 1 (30 individuals)

272   compared to Site 2 (23 individuals) and Site 3 (14 individuals), with 14 individuals (45%), sighted

273   across all three regions. However, whilst sightings in Site 2 have remained relatively stable, sightings

274   in Site 3 have gradually increased in recent years, which could be linked to decreases in sightings in

275   Site 1 since 2015 (S7). In 2018, 18 permanently marked dolphins (M1) were included in the

276   abundance analysis, with a ratio of marked to unmarked individuals of 0.48 (CV = 0.55), and a

277   Bayesian multi-site population abundance estimate of 48 (CV =0.18, 95% HPDI = 38-66).

278

279   **Survival**

280   Sighting data of network A (M1) individuals (n=27) from 2008-2019 exhibited a good overall fit of

281   the underlying model assumptions (($\chi2$ = 13.335, p = 0.42228, df = 13). UCare results indicated no

282   adjustments were required as the data exhibited only minor over-dispersion (ĉ= 1.03), with no

283   significant evidence for trap dependence (z=-1.69, P = 0.091022) or transience (z=1.8656, P =

284   0.062099) within the population. Model 1 ($\phi(.)p(.)$) was the most parsimonious with an AICc of

285   153.54 (Table 2). According to this model the estimated parameters were constant over time with an

286   interannual survival probability of 0.945 (0.017 ± SE, 0.899-0.971 95% CI) and a capture probability

287   of 0.938 (0.020 ± SE, 0.888-0.967 95% CI).

288

289   **Cumulative Utilisation & Impact Distribution**

290 MaxEnt modelling identified the whole of the community's range along nearshore coastal habitat as

291 suitable (raster values >0.5). The most parsimonious model included distance from shore and water

292 depth, with distance from shore (86%) having the greatest influence on the population's distribution.

293 The highest anthropogenic impact scores were around major urban areas, ports, and river mouths,

294 with preferred habitat of coastal dolphins in waters <61m having a significantly higher mean

295 anthropogenic footprint than those of deeper waters (Welch's t-test, t50.22 = 114868, p <0.001).

296 When anthropogenic activities were weighted by vulnerability (cumulative impact scores), the

297 highest impacted areas were found to be adjacent to the coast, with hotspots identified around regions

298 of high urbanisation, such as Plymouth, the Solent, and the Sussex coastline (Figure 3a).

299 Waters directly adjacent to the coast experienced the highest CUI scores, highlighting high risk areas

300 around the Cornish coast, Plymouth Sound, Poole Bay, the Solent and the Sussex coastline (Figure

301 4). Pollution was the most influential anthropogenic layer on the overall CUI score ($R^2 = 0.83$),

302 followed by shipping ($R^2 = 0.55$), indicating that these activities confer the greatest threat to the

303 population.

Discussion

305 This study confirms the residency of a small, socially distinct population of approximately 48 wide-

306 ranging bottlenose dolphins inhabiting the coastal waters of South England. Whilst these animals

307 have been sighted repeatedly over a number of years, site preference and distribution appears fluid.

308 Areas of high cumulative threats were seen to significantly overlap with areas of high habitat

309 suitability, highlighting the vulnerability of this small population. Due to their low abundance and

310 exposure to increased levels of anthropogenic stressors throughout their range, effective management

311 is greatly needed to ensure their long-term viability.

14

312   Increased sighting reports around Sussex combined with a coincidental decrease in Cornwall may

313   indicate a possible home range shift over the course of the study between 2008 and 2019. However, it

314   is unclear at present whether this is a range shift, a range expansion, or an artefact due to increased

315   citizen science reporting in the Eastern Channel. An increase in sightings during summer and autumn

316   months (April-September) was also observed; however, this is likely due to increased observer effort

317   during this period when coastal regions are more frequently traversed due to typically calmer weather

318   in the North Atlantic rather than temporal variation in distribution. Future data will be required to

319   understand long-term habitat use patterns within the Channel coast region.

320   Individuals were shown to travel large distances in relatively short periods, a finding reflected in

321   other studies of coastal bottlenose dolphins in the UK (Wood, 1998; Robinson *et al*., 2012; O'Brien

322   *et al*., 2009a; 2009b; Ryan, Rogan, and Cross, 2011). Although this population appears to be socially

323   isolated, it remains unknown whether it is also genetically distinct, especially as the study area is also

324   utilised by other populations (Network B-Y). If these coastally resident animals constitute an isolated

325   breeding population, an abundance of 48 (CV =0.18, 95% HPDI = 38-66) individuals is significantly

326   lower than most coastal populations in Britain and Ireland (Ingram and Rogan, 2002; Ingram *et al*.,

327   2009; Cheney *et al*., 2013; 2018; Arso Civil *et al*., 2019), and puts them at great risk of local

328   extinction.

329   Survival of permanently marked (M1) individuals was found to be within known ranges of other

330   bottlenose dolphin populations (0.83-0.97: Wells and Scott, 1990; Gaspar, 2003; Fortuna, 2006;

331   Corkrey *et al*., 2008; Currey *et al*., 2009; Silva *et al*., 2009a; Daura-Jorge, Ingram, and Simoes-

332   Lopes, 2013; Ludwig *et al*., 2021). However, due to the opportunistic nature of sighting data, this

333   survival and abundance estimate may be negatively biased as encounter history was dependent on the

334   quality and quantity of data submitted. Owing to this, some individuals may not have been

335   photographed within the study area at capture sessions, or photographs submitted were of too low

336   quality for positive identification. The incorporation of lower quality data could also cause potential

337   biases in which individuals with more distinctive marks could be identified more frequently and thus

338   having higher survival probabilities. Due to the limitations of using incidental photos, analysis by age

339   group or sex was also not possible, restricting insights into the dynamics and stability of this

340   population. Future research should, therefore, include investigations of sex, age class, and

341   reproductive rates to clarify any potential demographic changes.

342   Although the southwest UK has previously been identified as a biodiversity hotspot for UK marine

343   megafauna (McClellan *et al.*, 2014), it is also exposed to high levels of anthropogenic activity

344   (Halpern *et al.*, 2008), with significant declines in sightings and pod size of bottlenose dolphins noted

345   within the area (Pikesley *et al.*, 2012). Coastal waters were found to have significantly higher levels

346   of human activity compared to offshore regions, mirroring that of previous studies (Coll *et al.*, 2012;

347   Batista *et al.*, 2014; Trew *et al.*, 2019). Areas prone to the highest levels were concentrated around

348   urbanised areas, which host industries such as shipping, fisheries, and recreation (McClellan *et al.*,

349   2014; Halpern *et al.*, 2015). We found areas of high CUI intersected with areas of high habitat

350   suitability ($\geq 75\%$) likely due to the population's dependency on the inshore environment (Figure 3c)

351   and intense anthropogenic activity in the region. Boat traffic, pollution and fishing are all significant

352   threats to this population, and mitigation of these drivers in localised regions of high habitat

353   suitability could have a great effect on decreasing the overall cumulative impact of human activities

354   on this resident population.

355   In recent years, the effect of recreational vessel activity has become a growing concern. In summer

356   months, the South and West Coasts experience a rise in vessel traffic (RYA and British Marine,

357   2018), which increases threats such as underwater noise, vessel disturbance, and collision. Persistent

358   vessel disturbance can also cause declines in abundance (Bejder *et al.*, 2006) and displacement from

359   preferential habitat (Gerrodette and Gilmartin, 1990). In 2013, the death of a calf in the Camel

16

360 Estuary, Padstow was attributed to the persistent disturbance and collision with recreational vessels

361 (Morris, 2013). Due to the small size of this population losing a single dolphin confers an important

362 cost, especially if female. Greater education of coastal users and enforcement of protective legislation

363 would contribute to the preservation of this population and other vulnerable wildlife in the area.

364

365 Entanglement and bycatch represent serious threats to small cetaceans worldwide (Read, Drinker,

366 and Northridge, 2006). Since only demersal fisheries had a significant impact on the overall CUI,

367 habitat degradation, vessel disturbance, and prey depletion may instead confer greater threats to this

368 population, with overfishing already linked to reduced bottlenose dolphin abundance in the Ionian

369 and Adriatic Seas (Bearzi *et al.*, 1999; 2005). Overfishing in the Channel has previously been

370 highlighted as a major factor affecting biodiversity in the area, with decreases in higher trophic-level

371 fish observed (Molfese, Beare, and Hall-Spencer, 2014). As bottlenose dolphins can survive in

372 regions of intense human activity when prey is plentiful (Bearzi, Fortuna, and Reeves, 2008b), prey

373 depletion may have a significant effect on this population. Closures of some fisheries in the

374 Amvrakikos Gulf have corresponded to increases in bottlenose dolphin abundance in comparison to

375 adjacent prey depleted areas (Bearzi *et al.*, 2006; 2008a). Therefore, successful management of the

376 fishing sector may assist ecosystem recovery and confer great benefits to this vulnerable population.

377

378 Pollution had the greatest effect on CUI scores, which is of specific concern since persistent

379 polychlorinated biphenyls in bottlenose dolphins in the NEA have been amongst the highest observed

380 in cetaceans worldwide, with a hotspot identified around Cornwall (Jepson *et al.*, 2016).

381 Environmental pollutants are widely known to detrimentally affect the health of marine mammals

382 (Kalinowska, 1991; Baulch and Perry, 2012). Various ubiquitous environmental compounds have

383 been linked to the harm of fundamental reproductive and endocrine processes and immune

384 suppression, resulting in mass mortalities and population declines (Cummins, 1988; Borrell and

385 Aguilar, 1991; Kannan *et al.*, 2000; Schwacke *et al.*, 2002; Law *et al.*, 2012). As apex predators,

386 bottlenose dolphins can bioaccumulate these chemical pollutants that if persistent may have a

387 significant effect at the population level (Aguilar, Borrell, and Reijnders, 2002). As depletion of prey

388 resources can also increase toxicity in cetaceans, as emaciated individuals metabolise lipophilic

389 contaminants (Kannan *et al.*, 2000; Houde *et al.*, 2005), increased pollution and fishing pressures in

390 the region may confer a significant synergistic effect on both reproductive success and survival of the

391 population.

392

393 Efforts to reduce contaminants in riparian and sewage outputs as well as reductions in ocean-based

394 debris should be increased, in combination with the identification and mitigation of pollutant sources.

395 Future investigations should identify and monitor individual toxic compounds present in the region,

396 which together with assessing the likely impact on this small community could assist with the

397 creation of remediation strategies (Schwacke *et al.*, 2002; Porte *et al.*, 2006; Bearzi *et al.*, 2008b).

398

399 The designation of Marine Protected Areas (MPAs) is commonly used in the protection of vulnerable

400 cetacean species to aid population recovery (Taylor, Suckling, and Rachlinski, 2005). However, the

401 success of a fixed-area conservation zone depends on the inclusion of a high proportion of the range

402 and ecologically relevant habitat of the population of interest (Hooker and Gerber, 2004; Cañadas *et*

403 *al.*, 2005; White *et al.*, 2017). Conservation management is therefore increasingly challenging for

404 highly mobile populations, due to the lack of knowledge on temporal and spatial distributions, which

405 is exacerbated by the relatively small coverage of coastal MPAs (Wilson, 2016). Consequently, fixed

406 MPAs may be ineffective for highly mobile populations as they do not encompass sufficient habitat.

407 Nevertheless, SACs are the principal form of bottlenose dolphin protection within Europe. Although

408 SACs may be effective for populations exhibiting high-site fidelity such as the Shannon Estuary

18

409 (Ingram and Rogan 2002) their utility for highly mobile populations has been questioned (Wilson,

410 2016) following the range shift of the Moray Firth population outside its designated SAC (Wilson *et*

411 *al.*, 2004). Although members of the Moray Firth population identified outside the SAC are still

412 afforded the same protection as within the boundaries it has yet to be determined if this approach is

413 appropriate for other highly mobile populations (Arso Civil *et al.*, 2019).

414

415 Distributions can exhibit changes due to prey availability, environmental processes, anthropogenic

416 disturbance, climate change, and habitat degradation (Parmesan and Yohe, 2003; MacLeod *et al.*,

417 2005; Bejder *et al.*, 2006; Friedlaender *et al.*, 2006, Harley *et al.*, 2006; Karczmarski *et al.*, 2017).

418 Thus, a conservation strategy at a regional scale with an integrated management plan that accounts

419 for the threats throughout the population's range may be suitable, alongside long-term population

420 monitoring. Dynamic ecosystem-based management has already successfully reduced incidental

421 bycatch of other wide-ranging species such as loggerhead and leatherback turtles, where real-time

422 preferred habitat information was provided to fisheries to avoid detrimental interactions (Howell *et*

423 *al.*, 2015). Therefore, flexible tracking of the population and management of nearby human activities

424 could also provide an effective management approach.

425

426 Although a thorough understanding of population ecology is required to assess cumulative impacts

427 throughout a population's range, for wide-ranging bottlenose dolphin populations, dedicated surveys

428 covering the entirety of their range are often impracticable. Instead, collaborations between

429 researchers and citizen science networks may be the key to long-term, cost-effective monitoring,

430 alongside dedicated surveys in targeted areas of high importance.

431 Due to the broad nature of threats and temporal shifts in range identified in this study, it is likely that

432 the designation of a traditional static conservation zone would not be effective. Mitigation of all

433 anthropogenic pressures may also prove to be problematic due to the expansive overlap between

434 high-risk areas and suitable habitat. Therefore, using dynamic conservation zones in areas of high-

435 risk spanning the South and West Coasts may be more beneficial, where long-term monitoring and

436 real-time mitigation of relevant pressures could be achieved.

Conclusions

437

438 Although previous studies have demonstrated the occurrence of a resident population of bottlenose

439 dolphins around southwest England (Williams *et al*., 1997; Liret *et al*., 1998; Wood, 1998; Dudley,

440 2017), this is the first integrated study to assess the impact of anthropogenic activities and highlight

441 regions of conservation concern. Thus, it can be used to inform policy and highlight possible

442 protective measures for this population and wider biodiversity in the region. Small, coastal

443 populations are inherently more vulnerable to anthropogenic pressures and environmental

444 disturbance due to their limited genetic variation and high site fidelity (Harzen and Brunnick, 1997;

445 Bejder *et al*., 2006; Torres and Read, 2009). The small size of this population is of particular concern

446 due to the pervasive levels of anthropogenic impact observed throughout their habitat. With

447 anthropogenic activities and climate change pressures likely to increase in the future, the viability of

448 this population is at significant risk, as any further degradation of habitat would likely have

449 consequences at the population level. This study has highlighted the need for swift integrated

450 conservation management, tailored to the ecological needs of this wide-ranging population, with the

451 mitigation of threats throughout the region essential to ensure its survival. Our results have

452 highlighted significant knowledge gaps and greater understanding of population ecology and

453 demographics is clearly needed to support more effective management, with further work into the

454 population's reproductive rate and calf survival required to evaluate current population trends and the

455 impact of direct pressures.

456

20

457   This study demonstrates the advantages of wide-scale collaborations and the value of citizen science

458   data in monitoring highly mobile populations. Indeed, public data can have great value for informing

459   conservation management when analysed appropriately. Although the quality of photos available for

460   analysis in this study was lower than would be expected in dedicated scientific surveys, biases

461   related to poor image quality were mitigated by restricting analysis to permanently marked (M1)

462   animals. The submission of opportunistic sightings in data-sparse regions has helped to identify new

463   key areas, in which possible dedicated research can be undertaken. As this method is more

464   sustainable over broader temporal and spatial scales than traditional surveys (Dickinson *et al*., 2012),

465   it could be part of the solution to long-term monitoring. Therefore, to elucidate the full extent and

466   temporal variation of the population's range, future targeted effort should be directed into expanding

467   the sighting network to mitigate the current spatial bias and increase the quality of submissions.

468

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial

relationships that could be construed as a potential conflict of interest.

Acknowledgments

Author Contributions

479 SC expanded the citizen science network, analysed the data, and wrote the manuscript. RD created the

480 initial sighting database and photo ID catalogue. RW, AC, NC, DJ, TB, TH, PE, SS, NT, and MW

481 conceived the consortium and contributed sighting data. SD compared the catalogue with catalogues from

482 the Moray Firth and the Channel Isles. SI conceived analytical ideas, reviewed and edited the manuscript.

483 All authors contributed critically to the drafts and gave final approval for publication.

484 **Data Accessibility**

485

486 As the sighting database is an amalgamation of privately owned databases under a TOR agreement the

487 raw data file is not publicly available, however extracted data used for this analysis has been submitted to

488 a public repository available here: ☐ Data repository. Electronic supplementary information is also

489 available at this location.

490 **Tables**

491 Table 1- Anthropogenic driver data used in analysis with sources. Activities may include multiple

492 individual stressor datasets and are grouped into 3 sectors: Fishing (F), Pollution (P) and Shipping

493 (S).

Anthropogenic Activity	Activity Sector	Source
Fishing	F	Falco et al., 2019
Sum of PCBs ((CB28 CB52 CB101 CB118 CB138 CB153 CB180):		
Water Column	P	ICES, 2010

Sediment	P	ICES, 2010
Biota	P	ICES, 2010
Shipping:		
Dredging & Underwater Ops	S	Falco et al., 2019
Sailing	S	Falco et al., 2019
Pleasure Craft	S	Falco et al., 2019
High Speed Craft	S	Falco et al., 2019
Tug and Towing	S	Falco et al., 2019
Passenger	S	Falco et al., 2019
Sevice	S	Falco et al., 2019
Cargo	S	Falco et al., 2019
Tanker	S	Falco et al., 2019
Military and Law Enforcement	S	Falco et al., 2019
Unknown	S	Falco et al., 2019
Oher	S	Falco et al., 2019

494

495 **Table 2** - Selection criteria of candidate Cormack-Jolly-Seber models of survival (ϕ) and capture (p)

496 probabilities. Models were produced in program MARK 9.x with (t) = survival/capture probability

497 varies over time and (.) = survival/capture probabilities are constant over time.

#	Model	AICc	Δ AICc	AICc Weight	Likelihood	No. Parameters	Deviance
1	$\phi(.)p(.)$	153.5395	0.0000	0.99906	1.0000	2	87.2780
2	$\phi(t)p(.)$	168.2693	14.7298	0.00063	0.0006	12	80.1046
3	$\phi(.)p(t)$	169.7427	16.2032	0.00030	0.0003	12	81.5780
4	$\phi(t)p(t)$	185.0016	31.4621	0.00000	0.0000	21	74.6102

498

499

500 **Figure 1** - Map of study area with areas of interest indicated (Projection: GCS_WGS_1984). The

501 study area is segregated into three discrete regions: Site 1 (North Devon and Cornwall) in blue, Site 2

502 (South Devon and Dorset) in red and Site 3 (Hampshire and Sussex) in black. Blue diamonds

503 represent photo verified encounters of network A (the resident population) and other networks B-Y in

504 grey.

505 **Figure 2** - Sociogram displaying the social network analysis of all permanently marked individuals

506 encountered between 2008-2019. 25 clusters were identified (A-Y). Square nodes represent

507 individuals, the size of which correspond to the frequency of sightings (range 1-87). Grey squares

508 depict individuals seen only once and blue squares individuals seen on multiple occasions, with the

509 black lines representing associations between individuals.

510 **Figure 2b** - Bar graph depicting the number of sightings of individuals with members of network A

511 in blue and other networks in grey.

512 **Figure 3A** - Cumulative impact distribution (anthropogenic activity weighted by vulnerability)

513 depicting areas of threat hotspots, scaled between 1 (highest cumulative impact distribution) and 0

514 (lowest). Locations of interested are noted with initials, N = Newquay, PE = Penzance, P =

515 Plymouth, BH = Berry Head, DH = Durlston Head and B = Brighton

516 **Figure 3B -** Range (longitudinal distance) of permanently marked individuals from network A from

517 North Cornwall to East Sussex.

518 **Figure 3C** - Depth (m) of encounters of network A (blue) and networks B-Y (diagonal black).

519 **Figure 4** - Cumulative utilisation impact distributions (cumulative impact scores combined with

520 relative habitat suitability) of coastal bottlenose dolphins in the region, scaled between 1 (highest)

521 and 0 (lowest).

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3   1   **Supplementary Tables, Figures & Information**

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7   3   **Supplementary Table (S1)** – Multi-site contingency table depicting the number of permanently
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9   4   marked (M1) individuals identified within each study site in 2018. Y indicates the presence of
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11   5   the individual in the study site and N the absence.
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Site 1	Site 2	Site 3	Number of M1 Individuals
Y	Y	Y	2
Y	Y	N	3
N	Y	N	0
Y	N	N	11
N	Y	Y	0
Y	N	Y	2
N	N	Y	0
N	N	N	N/A

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10   **Supplementary Table (S2)** – Quality grade of photos used in 2018 abundance estimate.

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Grade	Proportion (%)
1	20.87
2	26.96
3	20.87
4	31.30

21 **Supplementary Table (S3)** – Metric to determine vulnerability weightings for anthropogenic

22 activity impact scores, derived from Maxwell *et al*., 2013.

23

| Vulnerability Measure	Category	Grade	Description
Impact Frequency	Never	0	
	Rare	1	Infrequent enough to affect population or long-term population (e.g. oil spill)
	Occasional	2	Frequent but Irregular
	Annual or regular	3	Common/Seasonal
	Persistent	4	Frequently constant year-round, may last multiple years
Does it impact the individual directly?	No impact	0	
	Distant indirect impact	1	Effects are one degree removed (e.g. habitat degradation, impacts prey species)
	Indirect impact	2	Causes effect due to indirect connection (e.g. effects of heavy metals which don't cause death directly)
	Direct impact	3	Mortality
Chance of Mortality	No impact	0	
	Low	1	Mortality unlikely (0-33%)
	Medium	2	Mortality moderate likelihood (34-66%)
	High	3	High chance of mortality (67-100%)
Impact Recovery Time (years)	No impact	0	
	<1	1	
	1-10	2	
	10-100	3	
	>100	4	
Reproductive Impact	No impact	0	
	Low	1	Can alter some aspect (behaviour) but not reproductive capacity
	Moderate	2	Reproductive capacity decreased
	High	3	Direct mortality
Effect on Population	No impact	0	
	Low	1	Impacts one individual
	Moderate	2	Impacts large of specific section of population (e.g. sex specific)
	High	3	Impacts the whole population

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25

Supplementary Table (S4) – Individual vulnerability scores for all 16 anthropogenic activities grouped into 3 different categories: fishing, pollution, and shipping activity.

| Vulnerability Measure	Fishing	Shipping	Pollution
Impact Frequency	4	4	4
Impact on Individual	1	3	2
Change of Mortality	1	2	2
Impact Recovery Time	1	2	2
Reproductive Impact	1	3	2
Effect on Population	3	1	3
Total	**11**	**15**	**15**

Supplementary Figure (S5) – Bar plot depicting photographic effort from years 2007-2019
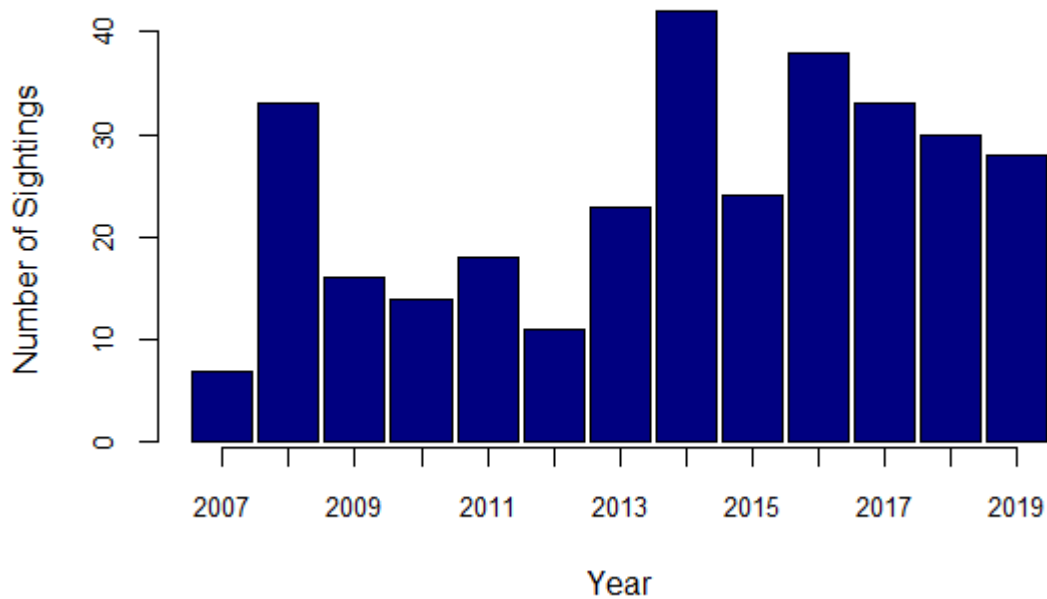
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3   38   **Supplementary Figure (S6)** – Bar plot depicting cumulative individuals identified from 2007-
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5   39   2019, Network A the resident population discovered through the social analysis is shown in
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7   40   blue, transient Networks B-Y are shown in grey.
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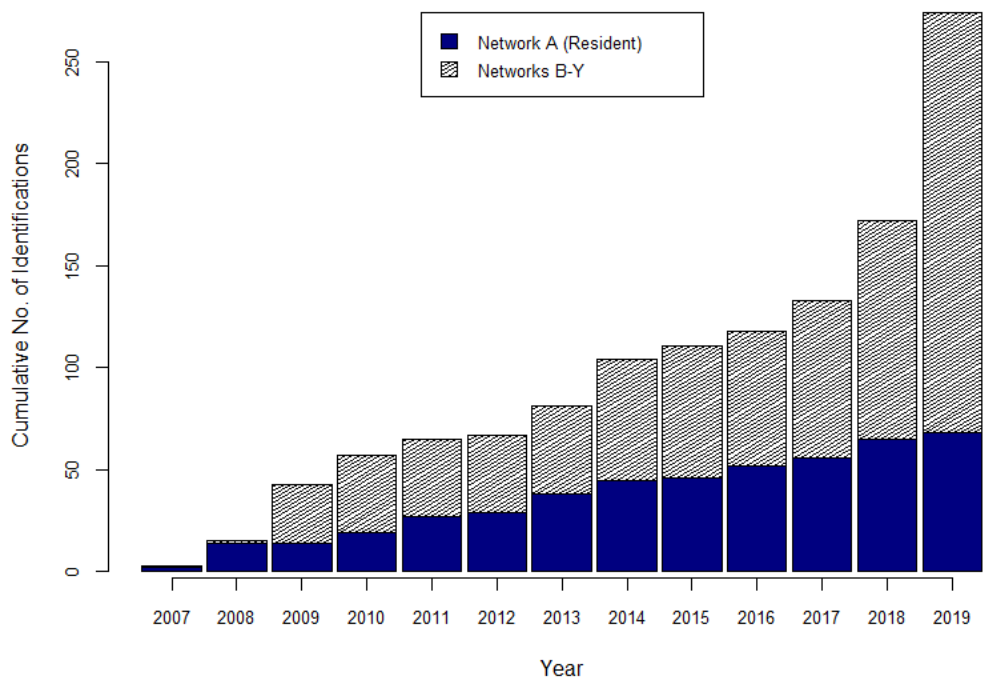
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54 **Supplementary Figure (S7)** – Bar plots depicting sightings of Network A between geographic

55 sites from 2008-2020.

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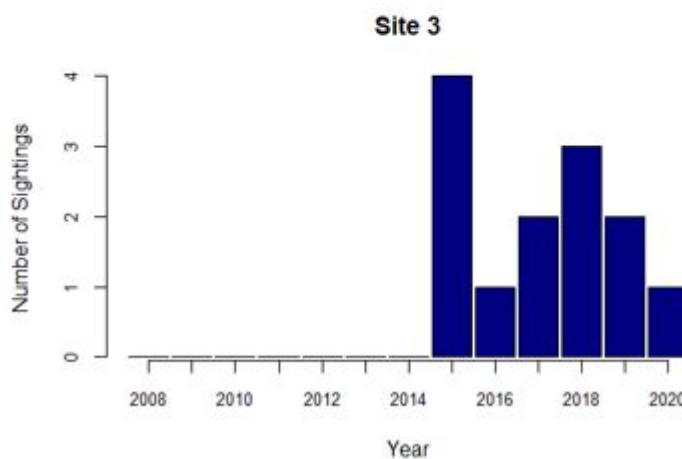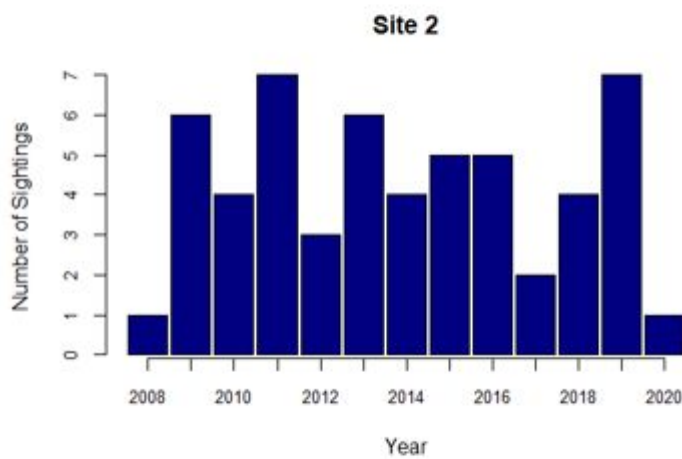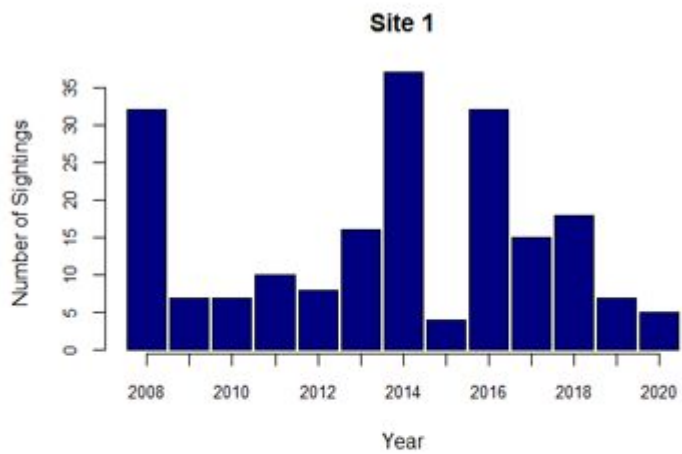
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3 60   **Supplementary Information Section 2.7.1**
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7 62   To assess the impact of anthropogenic pressures on dolphins using coastal waters the entirety of
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9 63   suitable habitat needed to be identified. To reduce effort bias within the sighting data, relative
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11 64   habitat suitability was modeled through maximum entropy techniques using presence-only
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13 65   species distribution models in the program MaxEnt 3.4.0 (Phillips et al., 2020). This method
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15 66   uses a fitted cloglog link function which connects background environmental data and
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17 67   occurrence records to predict both the probability of a species distribution across geographical
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19 68   space and the most influential environmental driver(s) (Phillips et al., 2006; Elith et al., 2011).
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23 70   To ensure correlated environmental variables did not confound model results pair-wise
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25 71   Pearson's correlations were conducted. Those found to be significant (> 0.70) were removed
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27 72   from further analysis. All bottlenose dolphin sightings from 2000-2019 in regions less than 61m
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29 73   deep were used to test and train the model. Environmental variables including averaged water
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31 74   depth, distance from shore, slope and longitude were obtained from GEBCO (GEBCO
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33 75   Compilation Group, 2020), whilst salinity data was obtained from EMODNET (EMODNET,
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35 76   2020). Due to the presence-only nature of this data a bias file was incorporated to account for
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37 77   sampling bias. The bias file is a grid layer which cell values indicate sampling effort, giving
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39 78   weight to random background data. Essentially, the bias file is a sampling probability surface
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41 79   obtained by a Gaussian kernel density map of occurrence locations using the kde2d function
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43 80   from the MASS package in RStudio.
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47 82   To tune the model, R studio was interfaced with Maxent through the dismo package using the
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49 83   'randomkfold' method with 10,000 background points from the bias file and 10 cross validation
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51 84   folds. To obtain the optimum values for the beta regularization multiplier (βM) and permitted
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53 85   features, models were ran testing 6 arrays of permitted features: (linear), (linear, quadratic),
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55 86   (hinge), (linear, quadratic, hinge), (linear, quadratic, hinge, product) and (linear, quadratic,
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57 87   hinge, product, threshold). Each array ran with 10 βM values ranging from 0.5 to 5, from there
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59 88   the final model was selected from 60 models of various settings. Model hyperparameters were
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   89   selected through the lowest delta AICc score and were as follows: linear features, 0.5 βM.

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   91   Jackknife analysis was used to acquire estimates of variable significance, this was conducted by

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3 92 investigating the contribution (gain) of each variable to the model independently and in a
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5 93 stepwise backwards selection. The model's discriminatory power was assessed via the area
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7 94 under the receiver operating characteristic curve (AUC), with values closer to 1 indicating an
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9 95 accurate fit (Phillips et al., 2006; McClellan et al., 2014).
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15 98 **Raw data is unable to be provided to third parties under the data sharing agreement in**
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17 99 **place by the South West Bottlenose Dolphin Consortium, please see following**
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19 100 **documentation for details.**
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Supplementary Document D1 – South West Bottlenose Dolphin Consortium

Terms of Reference and Data Sharing Agreement

Part 1 - Terms of Reference

Bottlenose dolphins in the coastal waters of SW England are under threat and likely in decline. Despite this, these animals have no specific protected area or special protection measures other than via general statutory protection of wildlife and cetaceans in UK waters. In order to ensure the best protection for these vulnerable animals we need to present the best scientific evidence to support and promote conservation action.

What is the SW Bottlenose Dolphin Consortium?

The consortium is a partnership of various stakeholders throughout the southwest of England sharing a common interest in developing understanding and conservation of the region's bottlenose dolphins. The consortium aims to develop an open and collaborative agreement between various private and public contributors who may own and/or collect photos or sightings information which may make a useful contribution to a larger shared data set for evidence gathering and scientific analysis.

All partners within the consortium will be joint and equal, representing individuals and organisations working collaboratively to provide data to enable better scientific assessment of the SW bottlenose dolphin population. All outputs will be to meet the agreed objectives of the consortium and not for the individual needs of partners' own respective organisations.

The actions and use of data shared with the consortium are agreed and managed by a consortium Steering Group. This Steering Group will meet regularly to coordinate the progress and strategy of the consortium and is currently chaired by Cornwall Wildlife Trust, as independent co-ordinator for the project.

Is my data relevant or useful?

Any data on SW bottlenose dolphins is useful and relevant. It is clear that we need to capture all available data to make the best assessment of the status of these animals to promote their conservation. Concentrated volumes of high quality data are vital for estimating abundance but the number of such data sets is limited. Incidental records, photos and sightings data are also important for exploring distribution, occupancy and ranging behaviour. Historic data that may have been collected several (or many) years ago are also useful for reconstructing the status of this 'population' through time to fill the gaps between dedicated survey effort.

Any and all data is therefore useful to this work. All contributed data will only be used for non- commercial conservation use, and should include information on what, where, when and who recorded it.

Suggestions of current and historic data that would be useful would include:

156   ● Ad-hoc / incidental sightings

157   ● Time and location referenced photos suitable for fin identification

158   ● Land based effort related sightings data

159   ● Boat based effort related sightings data

How will my data be used and will I be acknowledged?

161 Wherever possible your data will be used in scientific analysis of the abundance, distribution,
162 range and occupancy of the coastal waters of SW by bottlenose dolphins. The level of
163 integration of your data will be dependent on their quality and quantity and your contribution
164 will be acknowledged accordingly in all analyses and outputs. Significant contributors to this
165 collaboration may also be included as a co-author in any relevant outputs.

166 Data shared to the project will only be used for work led by the consortium steering group,
167 will not be passed to any third parties outside the consortium and will not be used for any
168 analyses outside those agreed by the Steering Group, without prior consent of contributors.
169 Any copies of the datasets will be stored securely and access restricted to permitted
170 individuals, administered by the Steering Group.

What about intellectual property?

172 By agreeing to this Terms of Reference your data will be made available for
173 inclusion in data presentation and analysis according to the strategy agreed by the
174 Steering Group.

175 There are two options for data contributors:

176 1) a blanket agreement for the inclusion of your data for all analysis and for use at the
177 discretion of the consortium

178 2) specific agreement for the inclusion of your data on a case by case basis.

179 Contributors will retain the intellectual property of their data and information supplied,
180 and are free to withdraw their input and data at any future time. If you hold data supplied
181 to you by third parties you should secure permission for their data to be included in this
182 data sharing agreement.

How do I become a contributor?

184 To become a contributor to the consortium simply fill out the attached form and email or post
185 this to the address given. On receipt of your form you will be contacted regarding transfer of
186 your data and included in a list of contributors.

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Part 2 - Data sharing agreement form

1. Personal details

Title	
Surname	
First name	
Affiliation (company/organisation)	
Address	
Postcode	
Contact email	
Contact telephone	

2. Data type:

I have the following data (please select)

- Ad-hoc / incidental sightings ☐

- Time and location referenced photos ☐

- Land based effort related sightings data ☐

- Boat based effort related sightings data ☐

3. Detail of data to be shared:

Data Description (eg: historic sightings, year range, format, etc.)

4. Data sharing status (please select one):

a) I agree for my data to be included and used for non-commercial conservation purposes without further specific consent.

b) I would like my data to be included and used for non-commercial conservation purposes dependent on case by case consent. ☐

    To be signed by Data contributor:

    ☐

11 of 13

I agree to supply the data as specified for the SW Bottlenose Dolphin Consortium. Signed: ……………………………………………………..

Date: …………………

Name: ……………….…………………..

Position: …………….….……………

To be signed by SW Bottlenose Dolphin Consortium:

I agree that the information supplied by the above named data provider will not be put to any other use than that stated in the agreed Terms of Reference above, nor communicated to any third party without prior consent.
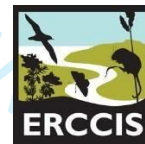
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Please return this form to:

Nicola Clear, ERCCIS Data Officer

Email: Niki.Clear@cornwallwildlifetrust.org.uk

Address: Environmental Records Centre for Cornwall and the Isles of Scilly, Five Acres, Allet, Truro, Cornwall TR4 9DJ

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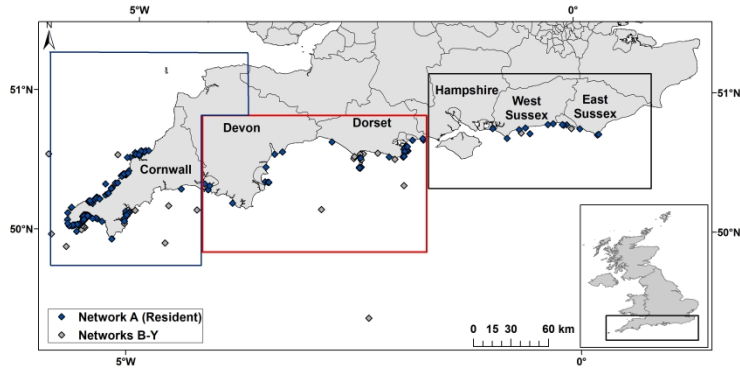10
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Figure 1 - Map of study area with areas of interest indicated (Projection: GCS_WGS_1984). The study area is segregated into three discrete regions: Site 1 (North Devon and Cornwall) in blue, Site 2 (South Devon and Dorset) in red and Site 3 (Hampshire and Sussex) in black. Blue diamonds represent photo verified encounters of network A (the resident population) and other networks B-Y in grey.

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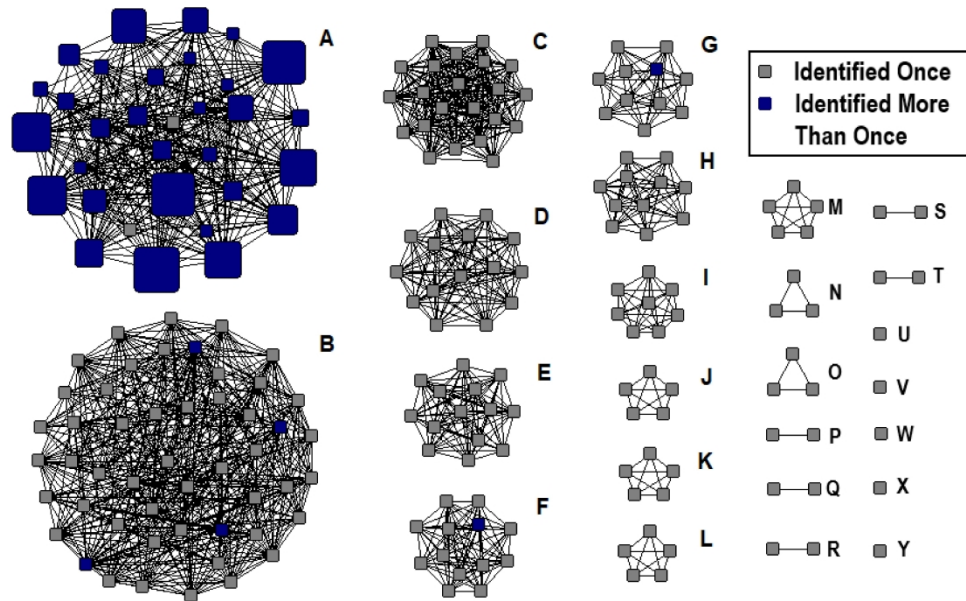
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Figure 2 - Sociogram displaying the social network analysis of all permanently marked individuals encountered between 2008-2019. 25 clusters were identified (A-Y). Square nodes represent individuals, the size of which correspond to the frequency of sightings (range 1-87). Grey squares depict individuals seen only once and blue squares individuals seen on multiple occasions, with the black lines representing associations between individuals.

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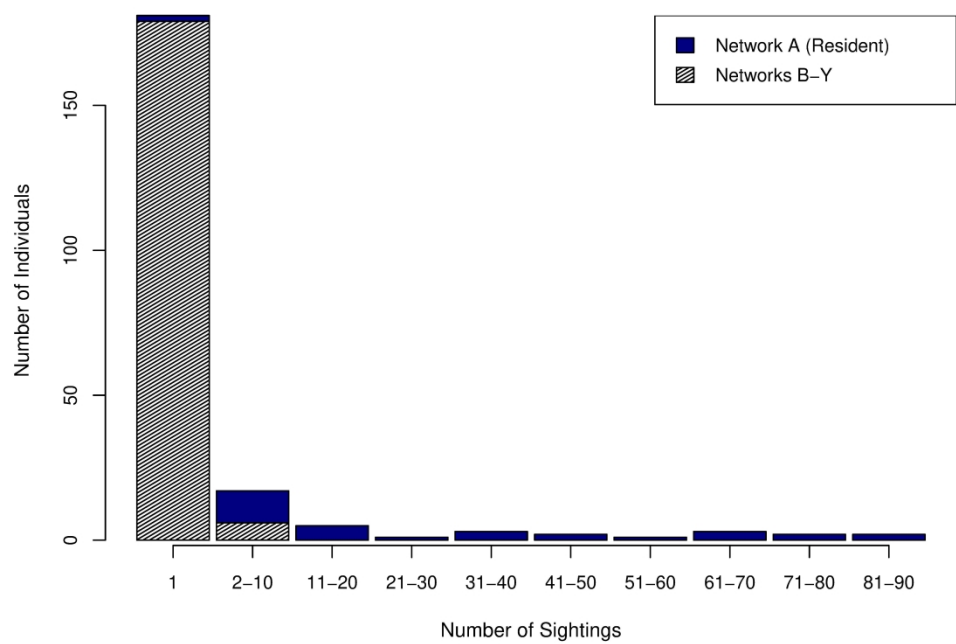15
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Figure 2b - Bar graph depicting the number of sightings of individuals with members of network A in blue and other networks in grey.
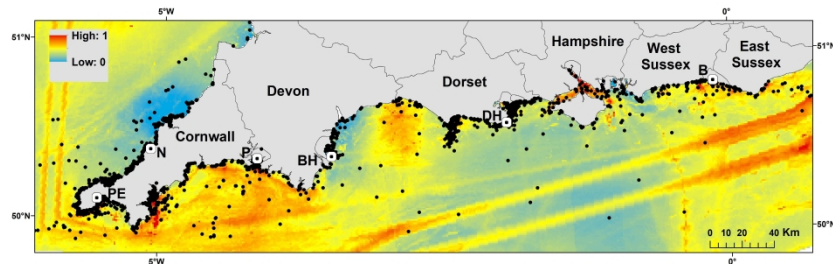
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Figure 3A - Cumulative impact distribution (anthropogenic activity weighted by vulnerability) depicting areas of threat hotspots, scaled between 1 (highest cumulative impact distribution) and 0 (lowest). Locations of interested are noted with initials, N = Newquay, PE = Penzance, P = Plymouth, BH = Berry Head, DH = Durlston Head and B = Brighton

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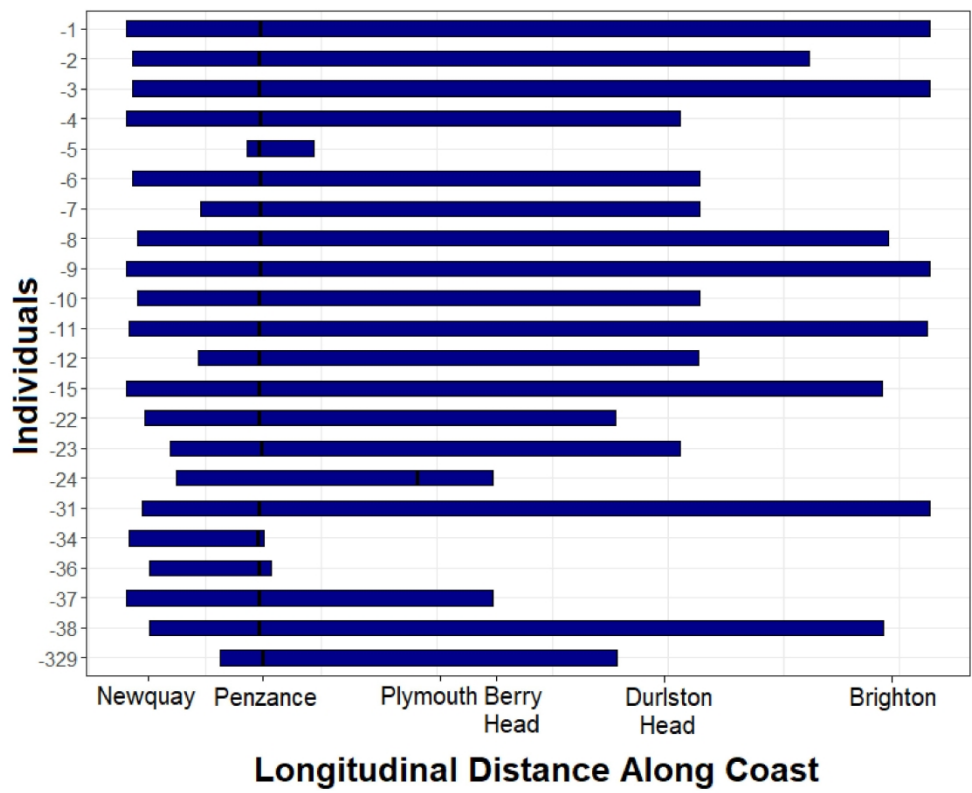16
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Figure 3B - Range (longitudinal distance) of permanently marked individuals from network A from North Cornwall to East Sussex

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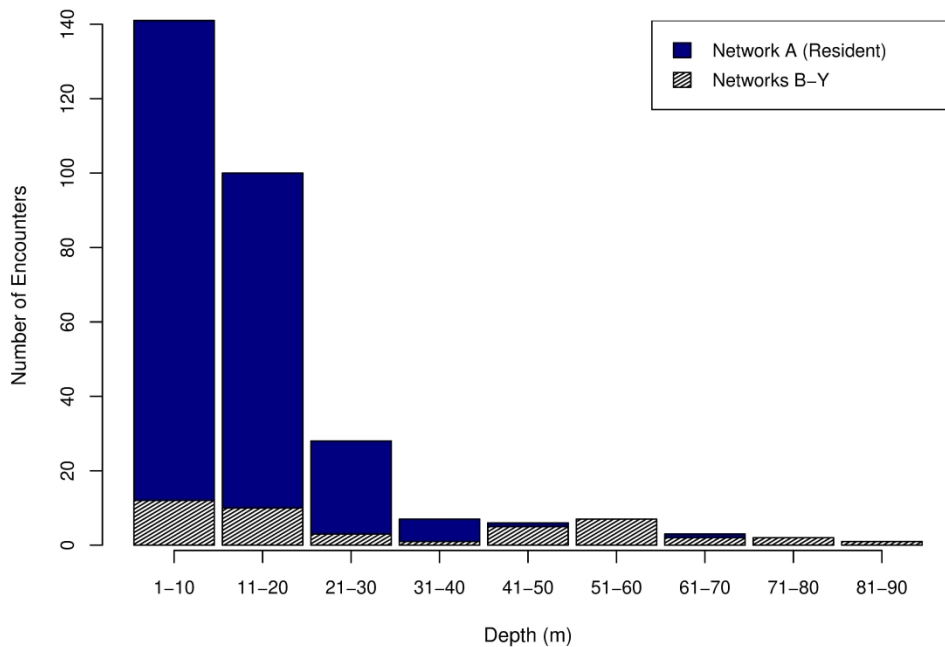51
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Figure 3C - Depth (m) of encounters of network A (blue) and networks B-Y (diagonal black).

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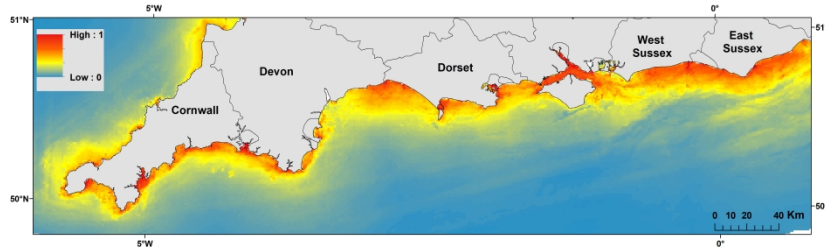51
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Figure 4 - Cumulative utilisation impact distributions (cumulative impact scores combined with relative habitat suitability) of coastal bottlenose dolphins in the region, scaled between 1 (highest) and 0 (lowest).

499x209mm (600 x 600 DPI)