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The impact of potting for crustaceans on temperate rocky reef habitats: Implications for management

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2 **management**

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15

16 **ABSTRACT**

17 Multi-use marine protected areas (MPAs) are increasingly designated towards achieving

18 global conservation targets. To develop effective management, the impact of permitted

19 activities must be understood. Potting for shellfish occurs on temperate rocky reefs globally

20 with impact not fully quantified. This UK-based study used underwater video to quantify (a)

21 benthic condition of rocky reefs, (b) mechanisms of potting interaction and (c) true footprint

22 of potting. Assemblages in static gear areas were more indicative of a healthy reef than those

23 in mixed gear areas. Damage was recorded during pot hauling, but the area of damage was

24 not the entire pot haul path. 25-30 % of individuals were damaged (commonly through tissue

25 abrasion) or removed. Notably, damage occurred to some long-lived, slow growing taxa

26 raising concerns over impacts. Potting is more destructive than previously thought and

27   managers must balance ecology with social and economic considerations to determine what

28   level of impact is acceptable.

29

30   **HIGHLIGHTS**

31   • Impacts of potting on UK temperate rocky reefs quantified using underwater video

32   • Novel method using GoPro cameras to observe direct potting impacts

33   • Areas fished with pots characterised by species indicative of a healthy reef system

34   • Damage to long lived, slow growing taxa of potential concern

35   • Managers must decide what level of impact is 'acceptable'

36

37   **KEYWORDS**

38   Potting; *fishery management*; static gear; temperate rocky reef; *benthic ecology;* marine

39   protected areas; *conservation;* underwater video; impact assessment; monitoring

40

41   **1. INTRODUCTION**

42

43   Temperate rocky reefs are characterised by sensitive, emergent epifauna, which are often

44   long lived, slow growing and sensitive to human impacts. They provide important topographic

45   complexity, and support commercially important species through, for example, provision of

46   nursery areas, refuges from predators and habitat for the settlement of invertebrate spat

47   (Beaumont, 2009; Beck et al., 2001; Beukers-Stewart and Beukers-Stewart, 2009; Dayton et

48   al., 1995; Grecian et al., 2010; Hiddink et al., 2011; Jennings and Kaiser, 1998; Jennings et al.,

49   2001; Monteiro et al., 2002; Parsons et al., 2016; Ryer et al., 2004). These systems are

50   vulnerable to habitat destruction caused by fishing gear impacting the benthos (Gray, 1997;

51   Gray et al., 2006; Kaiser et al., 2006; Sangil et al., 2013; Sheehan et al., 2017). The

52   consequences of this are varied, but may result in broad scale, assemblage level change such

53   as change in species composition, reduction in biomass, diversity and productivity and the

54   removal of key species, all of which compromise the resilience of the ecosystem and its role

55   in providing habitat to support species of commercial importance (Auster et al., 1996;

56   Bradshaw et al., 2002; Collie et al., 1997; Jennings and Kaiser, 1998; Roberts and Polunin,

57   1991). Complexity and biodiversity within an ecosystem are key to its resilience, and are

58   consequently of key relevance to marine conservation and human wellbeing (Cardinale et al.,

59   2012; Howarth et al., 2014). Thus, in order to maintain the ecosystem services provided by

60   rocky reefs it may be necessary for management measures to be implemented to reduce the

61   impact of damaging fishing activities on sensitive habitats and species (Worm et al., 2006).

62

63   The coastal location of temperate rocky reefs makes them easily accessible for vessels of any

64   size and they are targeted by commercial fisheries across the globe (Figure 1). In particular,

65   these areas are favoured by fisheries for crustaceans, such as crab and lobster, which inhabit

66   rocky reefs, or softer sediment occurring in areas between and within rocky reef patches

67   (Howard and Bennett, 1979; Martel et al., 1986; Sheehan et al., 2013a). Crustacean fisheries

68   associated with rocky reefs occur as a global industry throughout the northern and southern

69   temperate zones, present in 48 countries, which also have multi-use MPAs within their waters

70   (data derived through literature review; Figure 1). They are commonly located in inshore,

71   shallow reef areas and target species include, for example, edible crab (*Cancer pagurus*) in

72   north west Europe (e.g. Bannister, 2009; FAO, 2017), Juan Fernández rock lobster (*Jasus*

73   *frontalis*) in Chile (e.g. Arana et al., 2011), mud crab (*Scylla* spp.) in Africa (e.g. Le Vay, 2001)

74   and spiny red rock lobster (*Jasus edwardsii*) in Southern Australia (e.g. Treble et al., 1998).
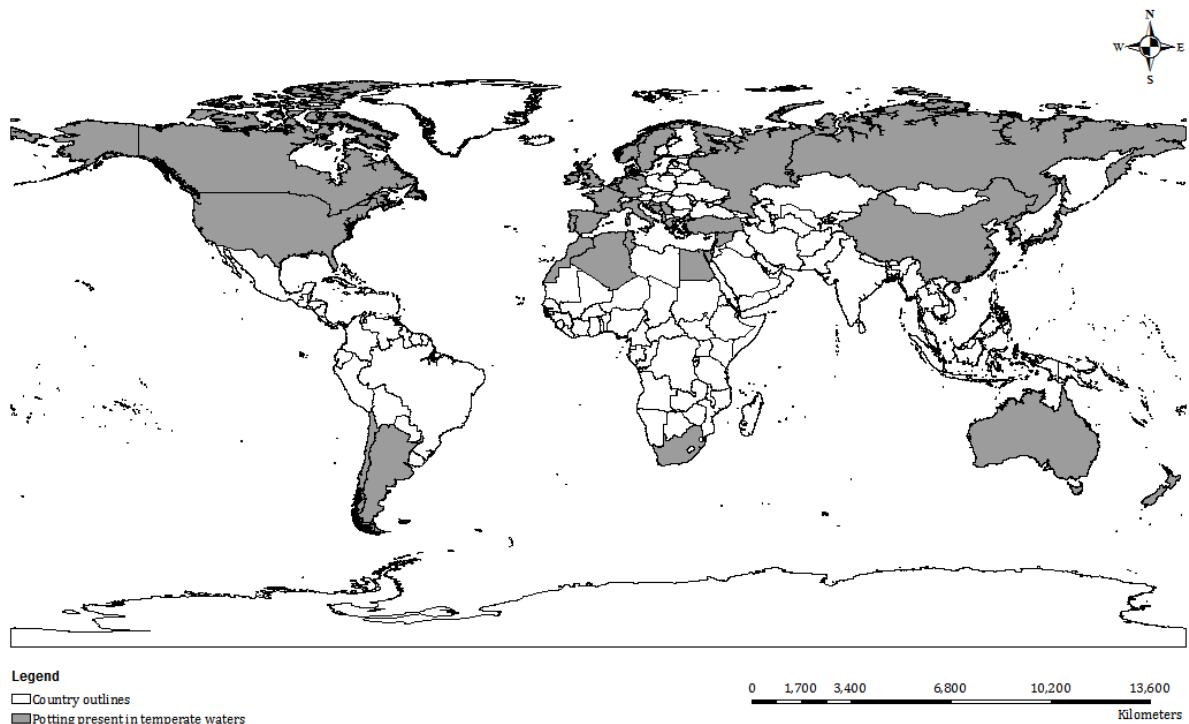
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Figure 1: Global map showing countries where potting is conducted in temperate waters
and where multi-use MPAs exist. Data sourced from literature searches. Map created using
ArcGIS 2017.

80   Crustacean fisheries are a very valuable component of the UK fishing industry, with 1,342

81   vessels fishing with pots and traps in 2016; the majority of which were under 10m vessels

82   fishing in inshore waters (Seafish, 2017). In 2017, total shellfish landings accounted for 38 %

83   of all landings by UK vessels into the UK and abroad, and during the year of 2017, 34,100

84   tonnes of crab and lobster were landed into the UK by UK vessels, worth £98.1 million (MMO,

85   2018).

86

87   The most common method of capture for crustacean species are pots and traps (termed 'pots'

88   from here on in). All pots are referred as "static gear" as they are deployed and left to soak

4

89 in situ, before being hauled after a period of time. The design and material of the pots varies

90 between locations, with pots made of wood, metal or plastic, but all share this common mode

91 of operation, meaning that the impacts may be assumed to be broadly similar (Slack-Smith,

92 2001).

93

94 Where MPAs are designated to protect temperate rocky reefs it is possible that they will

95 overlap with areas where pot fishing occurs, and, as potting has commonly been an activity

96 assumed to have little or no impact (Jennings & Kaiser, 1998), it is often permitted where

97 MPAs are multi-use. There is, however, increasing attention placed on this, with researchers

98 and policy makers wishing to understand more about potential impacts from potting to

99 ensure such activities are compatible with the conservation goals of MPAs (e.g. Casement and

100 Svane, 1999; Coleman et al., 2013; Eno et al., 2001; Lewis et al., 2009; Rees, 2018; Shester &

101 Micheli, 2011; Stephenson et al., 2017; Troffe et al. 2005; Walmsley et al., 2015). Impacts

102 from pots may occur during deployment, soak time or hauling of the pot, impacting the

103 benthos and associated taxa through contact with the pot and/or end weight, or from scour

104 caused by the associated ropes.

105

106 Rocky reef habitats are thought to have a medium-high sensitivity to potting impacts and a

107 medium level of resilience (defined as the time required for a habitat (and its constituent

108 species and physical features) to recover to its characteristic state after disturbance), (Eno et

109 al., 2013). Impacts pose a threat in particular to long lived, slow growing sessile epifauna that

110 characterise rocky reef habitats (Coleman et al., 2013; Jennings and Kaiser, 1998; Sheehan et

111 al., 2013b), including species of gorgonian, soft coral, bryozoan and erect branching sponges

112 which are known to be particularly vulnerable due to their erect body-forms, and life histories

113   (Coleman et al., 2013; Langmead et al., 2010). Despite these risks, the impact of pots on

114   benthic marine ecosystems is often regarded as minor in comparison with the impact of

115   mobile benthic gear (Jennings and Kaiser, 1998), and consequently, research efforts have

116   been focussed on the assessment of mobile gear.

117

118   The limited research that has taken place has suggested that whilst some damage does occur

119   it is unlikely to be significant (see Casement and Svane, 1999; Coleman et al., 2013; Eno et al.,

120   2001; Lewis et al., 2009; Shester & Micheli, 2011; Stephenson et al., 2017; Troffe et al. 2005)

121   unless potting intensity is high (defined as ~ 30 pots per 500m^2) where some decline in

122   abundance of indicator species was identified by Rees (2018). The true footprint of potting

123   (contact that the pot makes with the benthos) has not yet been fully quantified, however, and

124   there is a need for more evidence relating to the underwater behaviour and habitat

125   interaction of pots to support these conclusions (Eno et al., 2013; Stephenson et al., 2017).

126

127   Studies suggest that recovery of emergent slow-growing fauna from the impacts of bottom

128   towed fishing gear occurs on decadal timescales (Babcock et al., 1999; Watling and Norse,

129   1998), but that potting activity is unlikely to impede recovery of benthic systems (Blyth et al.,

130   2004; Sheehan et al., 2015; Sheehan et al., 2013b). What is not clear, however, is whether

131   potting activity compromises their ability to reach a fully functional state (Tett et al., 2013) or

132   whether it allows them to meet their ecological goals and achieve favourable conservation

133   status (Jones, 2002). Furthermore, in areas where more destructive fishing practises are

134   restricted, use of static gear may increase (Mangi et al., 2011) and the consequences of this

135   need to be understood.

136

137   The global presence of potting on rocky reefs makes these questions of key importance and

138   more research is required to answer them, particularly in light of the drive for evidence-based

139   policy development and decision making (e.g. Defra, 2011; European Commission, 2015;

140   House of Commons, 2017;), and the requirement to meet international targets for marine

141   conservation. One such target is the Convention on Biological Diversity (CBD) Aichi

142   Biodiversity Target 11 which has resulted in an increasing number of marine protected areas

143   (MPAs) globally (Thomas et al., 2014) and calls to increase protection of each marine habitat

144   from 10-30 % (WCC-2016-Res-050-EN; IUCN WCPA, 2018; IUCN, 2014, 2016; O'Leary et al.,

145   2016) by 2030 (Johnson et al., 2019).

146

147   The requirement to meet these targets increases the likelihood of new MPAs being

148   designated multi-use, and consequently the chance of sites being located on areas of rocky

149   reef where potting occurs. Designation decisions require an ecosystem approach to

150   management to be taken where humans are considered integral to the ecosystem and socio-

151   economic factors are considered alongside ecological (Pikitch et al., 2004; Gaines et al. 2010).

152   As part of these decisions there is also an increasing emphasis on assessing management

153   effectiveness of multi-use sites, with those newly designated designed to include

154   representation targets requiring spatially accurate mapping of habitat types (Day & Dobbs,

155   2013; Johnson et al., 2019; Pomeroy et al., 2005; Garces et al., 2013) in order to avoid the

156   push for meeting targets coming at the expense of the quality and effectiveness of regulation

157   and management (De Santo, 2013). Increasing our knowledge of impacts and their

158   consequences is therefore vital for effective assessment of these sites and ensuring we

159   implement appropriate management measures.

160

161 The aim of this research was therefore to provide robust evidence, which quantified whether

162 the extractive activity of potting is compatible with designation of multi-use MPAs. This was

163 achieved using the Inshore Potting Agreement (IPA) area in South Devon, UK as a test case

164 study site. Unfortunately the nature of human use of the ocean and the relatively recent

165 addition of marine protected areas around the UK coast means that there were no pristine

166 control areas available for this study, hence the following research questions were addressed:

167 (a) is benthic condition and provision of ecosystem services greater in areas within an MPA

168 where trawling has been excluded but potting is permitted than in areas where trawling

169 occurs; (b) what are the mechanisms of physical potting interaction with the benthos and (c)

170 what is the true footprint of potting. For ease of understanding, these are termed (a) benthic

171 condition (b) mechanisms of potting interaction, and (c) true footprint of potting.

172

173 **1.1   Case study site: The Inshore Potting Agreement, South Devon, UK**

174 Although not initially designated this way, the IPA falls under the commonly recognised

175 definition of an MPA (Kelleher 1999) as bottom towed fishing gear was excluded in 1978 from

176 large areas to reduce conflict between mobile and static gear types. This led to the

177 establishment of a zoned fisheries management scheme which was incorporated into

178 statutory legislation in 2002 (Hart et al., 2003) and has provided ecological benefits to areas

179 where bottom towed fishing gear was excluded (Blyth et al., 2004). Furthermore its use aligns

180 with that of IUCN Category VI MPA, which allows the protection of natural ecosystems and

181 sustainable use of natural resources, when conservation and sustainable use can be mutually

182 beneficial (Day et al., 2019). The area is overlain by the Start Point to Plymouth Sound and

183 Eddystone Site of Community Importance (SCI), designated for the protection of reef habitat

184 under the Habitats Directive (Council Directive 92/43/EEC) and from which bottom towed

185   fishing gear was excluded in 2014 (Figure 2), (Natural England, 2013), and overlaps the

186   Skerries Bank and Surrounds Marine Conservation Zone. The presence of the MCZ was not

187   considered during the study as management plans were not yet established.

188

189   The IPA covers an area approximately 500 km^2 and includes zones where static gear (pots and

190   static nets) is exclusively allowed, areas where towed gear is exclusively allowed and areas

191   where gear types are managed seasonally (Figure 2). The area is managed by the Devon &

192   Severn Inshore Fisheries & Conservation Authority whose remit cover 0-6 nm and who seek

193   to ensure that their management secures the right balance between social, environmental

194   and economic benefits.

195

196   The IPA area is very important both locally and nationally for its brown crab (*C. pagurus*)

197   fishery, with landings from boats into the ports of Dartmouth and Salcombe the largest in

198   England, totalling almost £3.4 million in 2014 (Marine Management Organisation, 2015).

199   Fishers in the area use two different types of pot, inkwell and parlour (see Figure 3). The

200   difference in potential impact of these pot types is unknown, with fishers choosing which to

201   use based on the type of boat they work from and personal preference due to differences in

202   size and shape between the pots (South Devon & Channel Shellfishermen, pers comm.).

203

204   Due to the long history of management within the IPA it is possible to test whether, following

205   approximately 35 years of exclusion of bottom towed fishing gear, the relative health of the

206   ecosystem is greater within the exclusion area than outside where bottom towed fishing gear

207   use continues. In the absence of pristine control sites, this method can help determine

208   whether the presence of potting activity has allowed the ecosystem to recover and deliver

209   more ecosystem services than unprotected areas, or whether potting interactions are

210   compromising benthic rocky reef habitats and the ability of a site to achieve or maintain

211   favourable conservation status (Jones, 2002).

212

213   In the context of this study the term 'relative health' is used due to the absence of data to

214   allow an *a priori* definition of health to be determined. The work of Tett et al. (2013) can be

215   used to develop indicators for the relative health of the ecosystem. The indicators selected

216   included univariate metrics such as number of individuals (individuals m^{-2}), number of taxa

217   (taxa m^{-2}), diversity (Simpson's 1-λ), number of individuals of selected indicator taxa including

218   *Eunicella verrucosa* and *Pentapora foliacea* which are known to be sensitive to fisheries

219   impacts (individuals m^{-2}), and assemblage composition.

220

221   Using the metrics outlined above, the study examined the hypotheses that:

222   (1) Benthic condition:

223   *H1 = number of taxa, number of individuals, diversity and assemblage composition differ*

224   *between potted areas where bottom towed fishing is not permitted and areas open to bottom*

225   *towed fishing*

226   (2) Mechanisms of potting interaction*

227   *H2 = during pot hauls the seabed contact area is smaller than the total possible contact area*

228   *for inkwell and parlour pots*

229   (3) True footprint of potting*

230   *H3 = during pot hauls fewer benthic fauna are damaged or removed than not damaged within*

231   *the seabed contact area for inkwell and parlour pots*

232

233 *Observation of fishing methods and discussion with members of the fishing community in

234 the study area influenced survey design for the mechanisms of potting interaction and true

235 footprint of potting. It may be assumed that a pot will drag constantly across the benthos

236 during the haul, but the uneven topography of a rocky reef area dictates that whilst pots are

237 likely to make some contact the entire base of the pot would not be likely to drag along the

238 benthos; and as such the area of impact (seabed contact area) may be smaller than might

239 initially be assumed (total possible contact area).

240

241 H1 was tested using video footage taken from a towed flying array across ten areas and over

242 three years, and H2 and H3 were tested using video footage taken from cameras mounted on

243 pots for two gear types (parlour and inkwell) across three areas and two years.

244

245 **2. METHODS**

246

247 **2.1 Case study site & survey design**

248 The survey was conducted in South Devon UK, in the IPA area, with the majority of sites also

249 within the SCI (Figure 2). Surveys took place on an annual basis over the summer months from

250 2013-2015 for benthic condition and 2014 & 2015 for mechanisms of potting interaction and

251 true footprint of potting.

252

253 The target habitat type was rocky reef as defined by the Habitats Directive as 'habitats where

254 animal and plant communities develop on rock or stable boulders and cobbles' (Jackson &

255 McLeod, 2000). Suitable habitat was identified within the areas overlapping the SCI using

256 sidescan data provided to Devon & Severn IFCA (D&SIFCA) by Cefas, and from a video survey

257   report completed for Natural England (Ross, 2011). In addition, and particularly for the areas

258   outside the SCI where no habit mapping was available, the working knowledge of the fishers

259   and D&SIFCA was used (Figure 2). No data on frequency of fishing activity was available, but

260   potters fish specific areas and there is known to be little space available for additional boats

261   to join the fishery (Blyth et al., 2002; Devon & Severn IFCA, pers. comm.), giving confidence

262   that sites known to be potted would have been regularly fished.
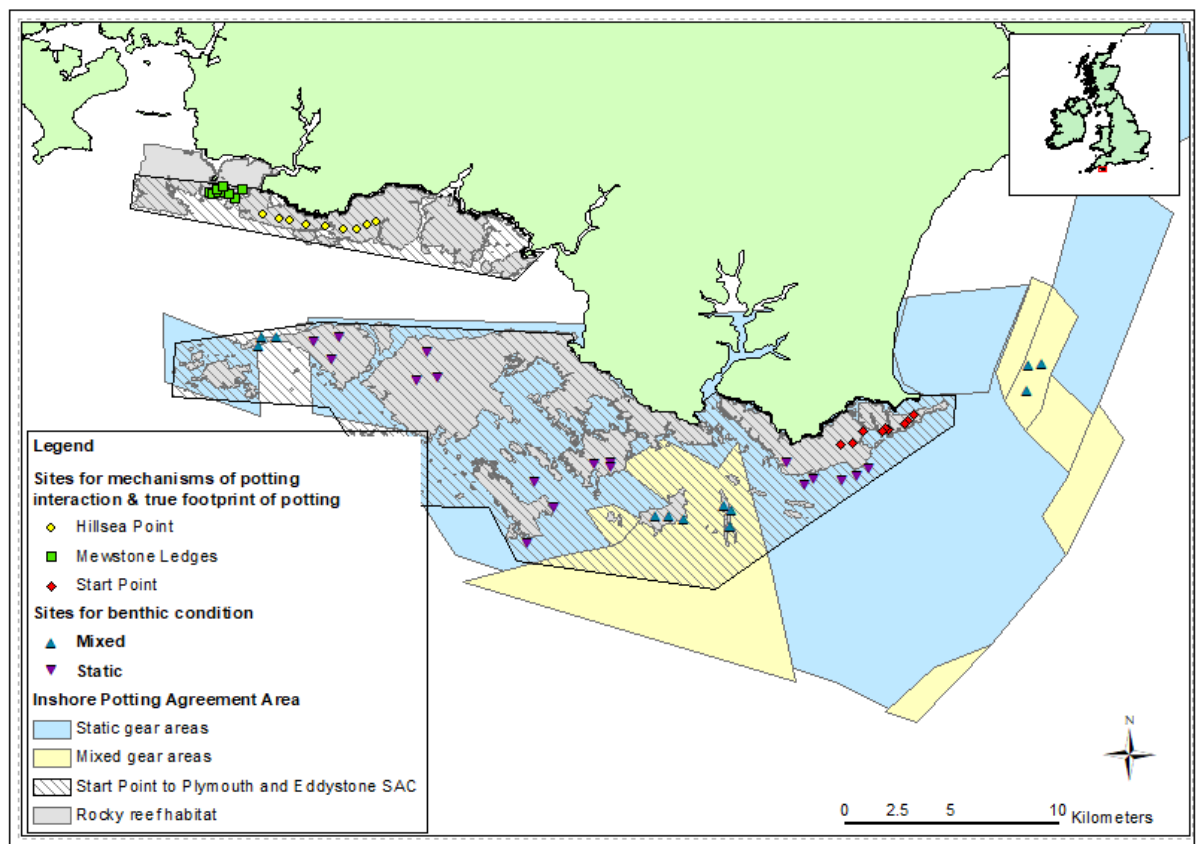
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264

265   **Figure 2: Survey sites for: benthic condition (Mixed – blue triangles, Static – purple triangles)**
266   **mechanisms of potting interaction & true footprint of potting (Start Point – red circles,**
267   **Hillsea Point – yellow circles, Mewstone Ledges – green squares). Map created using ArcGIS**
268   **2017**

269

2.2   Benthic condition

Two treatments were selected, "Static" where only static gear (mainly pots) had been fished since the IPA was established in 1978, and "Mixed", where areas are open to both mobile and static gear (only one area was open to mobile gear alone and did not provide enough suitable habitat type). A total of 30 sites were sampled at a target depth of 50 m, and were distributed across the survey area in groups of three "Locations" (A-J see Figure 2) to account for any effects resulting from the known differences in topography and exposure to tidal streams. Eighteen sites were sampled in the Static treatment, and 12 in the Mixed (Figure 2). At each site a 20-minute video transect was recorded to sample sessile and sedentary taxa using a High Definition camera mounted on a flying array towed behind the boat at a speed of approximately 0.4 knots, equating to approximately 200 m per tow (Figure 3). The method followed that developed by Sheehan et al. (2010) to ensure that sampling was cost-effective, relatively non-destructive and to minimise the risk of snagging on uneven rocky reef or boulders (Sheehan et al., 2016).

Sampling aimed to quantify differences in the univariate metrics: number of individuals (m^{-2}), number of taxa (m^{-2}), diversity (Simpson's 1-λ) and a number of selected indicator taxa (m^{-2}), namely *Alcyonidium diaphanum, Alcyonium digitatum*, branching sponges, *Cliona celata, Eunicella verrucosa, Metridium senile, Pentapora foliacea* and *Urticina felina,* plus the multivariate metric assemblage composition. Indicator taxa were those expected to be susceptible to damage from fishing impacts (Coleman et al., 2013; Langmead et al., 2010) and were selected based on life history, tolerance to disturbance and recoverability, following Jackson et al. (2008) and Langmead et al. (2010).
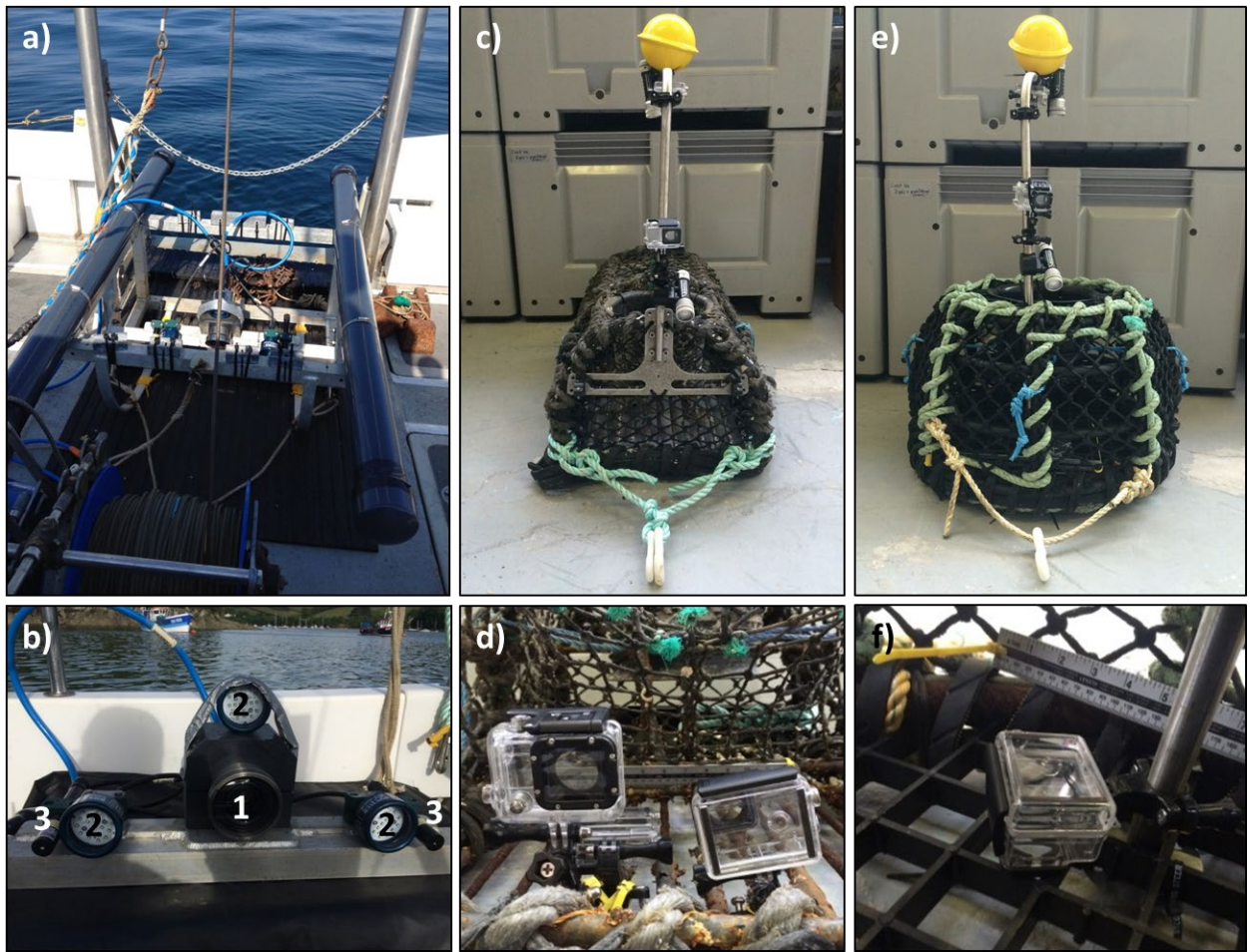
Figure 3: a) flying array on deck, b) flying array HD camera (1), LED lights (2) and lasers (3), c) set up of GoPro cameras mounted on a parlour pot d) back view camera (left hand side) and the inside view camera (right hand side), e) set up of GoPro cameras mounted on an inkwell pot, and f) the down view camera

2.2.1 Field methods

The video system included a HD camera (Bowtech Products Limited, Surveyor-HD High Definition Underwater Colour Zoom Video Camera, 720p), LED lights (Bowtech Products Limited, LED-K-Series Underwater LED Light), and two laser pointers to allow the field of view to be calibrated (Apinex Inc. BALP-LG05-B105). The camera was positioned at an oblique angle to the seabed with the LED lights mounted on either side and above the camera, and the lasers fixed outside of the lights 30 cm apart (Figure 3). The camera was connected via an

14

308   umbilical to a Bowtech System power and control unit, which gave topside control of the

309   focus, zoom and aperture of the camera and the intensity of the lights.

310

311   **2.2.2 Video analysis**

312   Data were extracted by examination of individual HD video frames taken at two second

313   intervals to avoid overlap using 3Dive Frame Extraction software (Cybertronix). Images were

314   overlain with a 0.25 m^2 counting grid calibrated using the position of the lasers which allowed

315   extraction of density and percentage cover information for each taxon. Strict criteria were

316   adhered to during the selection of frame grabs suitable for analysis following methods

317   developed by Sheehan et al., (2013b) and Stevens et al. (2014), and only those where the

318   habitat fitted the definition of a rocky reef (Jackson & McLeod, 2000) were included. Once

319   those suitable for analysis were finalised, 30 frame grabs were randomly selected for analysis

320   (Stevens et al., 2014). Data were averaged by transect prior to analysis to avoid pseudo-

321   replication.

322

323   All taxa present in each frame were identified to the lowest taxonomic level possible. Number

324   of individuals was enumerated using count (ind. m^{-2}) or cover (% m^{-2}) as appropriate.

325   Taxonomically similar species that could not be distinguished with confidence, such as

326   branching sponges or hydroids, were grouped to ensure confidence in the data recorded.

327

328   **2.2.3 Data analysis**

329   Multivariate and univariate analyses were conducted using Permutational Multivariate

330   Analysis of Variance (PERMANOVA, Anderson (2001); Clarke and Warwick (2001)) based on

331   similarity matrices using PERMANOVA+ for Primer in PRIMER 6 (Clarke and Warwick, 2001).

332 Multivariate data were dispersion weighted and fourth root transformed to down weight

333 species with large or erratic abundances and allow rarer species to contribute to the outcome

334 (Clarke et al., 2006). Bray-Curtis similarity indices were used to construct similarity matrices.

335 Univariate data were also fourth root transformed and Euclidean dissimilarity indices were

336 used to construct similarity matrices (Clarke and Warwick, 2001). Each term in the analyses

337 used 9999 permutations of the appropriate units (Anderson and Braak, 2003).

338

339 Four factors were used in the analyses, Year (random: 2013, 2014, 2015), Treatment (fixed:

340 Static, Mixed), Location (random and nested in Treatment: 6 Static, 4 Mixed) and Site (random,

341 nested in Location: 3 per Location). The lowest significant effect was interpreted for each test

342 ($P < 0.05$) and significant interactions involving fixed factors were interpreted using pairwise

343 tests. Data were visualised using Non-metric Multi-Dimensional Scaling (nMDS) with vectors

344 overlain showing key SIMPER results.

345

346 **2.3   Mechanisms of potting interaction and true footprint of potting**

347 A total of 27 sites were selected, in three areas, Start Point (SP), Mewstone Ledges (ML) and

348 Hillsea Point (HP), (Figure 2). At each site, one string of inkwell pots and one string of parlour

349 pots were deployed approximately 200 m apart, with four pots per string, and GoPro Hero 2,

350 3 and 4 Silver and Black edition (GoPro Inc) cameras fitted to alternate pots. Each camera pot

351 had 5 cameras mounted to give: (a) a bird's eye view over the pot; (b) an inside view from

352 within the pot; (c) a downwards view through the base of the pot (d) a rope view of where

353 the rope connecting the pot attached (e) a backwards view at the opposite end to where the

354 rope attaches to the pot to show the ground the pot was being hauled over (Figure 3). Surveys

355 were conducted from commercial fishing vessels to ensure that pot deployment and hauling

356 was representative of true fishing conditions (for detailed descriptions of how this was

357 conducted, please see Supplementary Material).

358

359 As discussed, the uneven topography of a rocky reef area dictates that pots are likely to make

360 some contact but that the entire base of the pot would not be likely to drag along the benthos

361 during hauling; and as such the area of impact (seabed contact area) may be smaller than

362 might initially be assumed (total possible contact area). Estimation of impact based on length

363 of total possible contact area would therefore result in an overestimation.

364

365 Sampling aimed to quantify the mechanisms of potting interaction and the true footprint of

366 a pot through quantification of: settle duration (seconds from point of first contact to

367 becoming stationary) pot stability during the soak, haul duration (seconds from first

368 movement to clearing the reef), total possible contact area (defined as total distance travelled

369 x area of base of pot (m^2)) and seabed contact area (defined as distance where pot contacted

370 seabed x area of base of pot (m^{-2})), (see Figure 4). The start and end GPS position of the haul

371 were unknown. To estimate the length of each tow the known pot dimensions were used as

372 a reference to visually assess how much distance was covered by each pot. Videos were

373 played x2 slower than real-time to aid this assessment.

374

375 In addition, biotic metrics were also used: number of individuals ((not damaged, damaged,

376 removed), (number of individuals m^{-2})), and for selected indicator taxa known to be sensitive

377 to fishing impact (Coleman et al., 2013; Jackson et al., 2008; Langmead et al., 2010),

378 *Alcyonium digitatum*, branching sponges, *Cliona celata, Eunicella verrucosa and Pentapora*

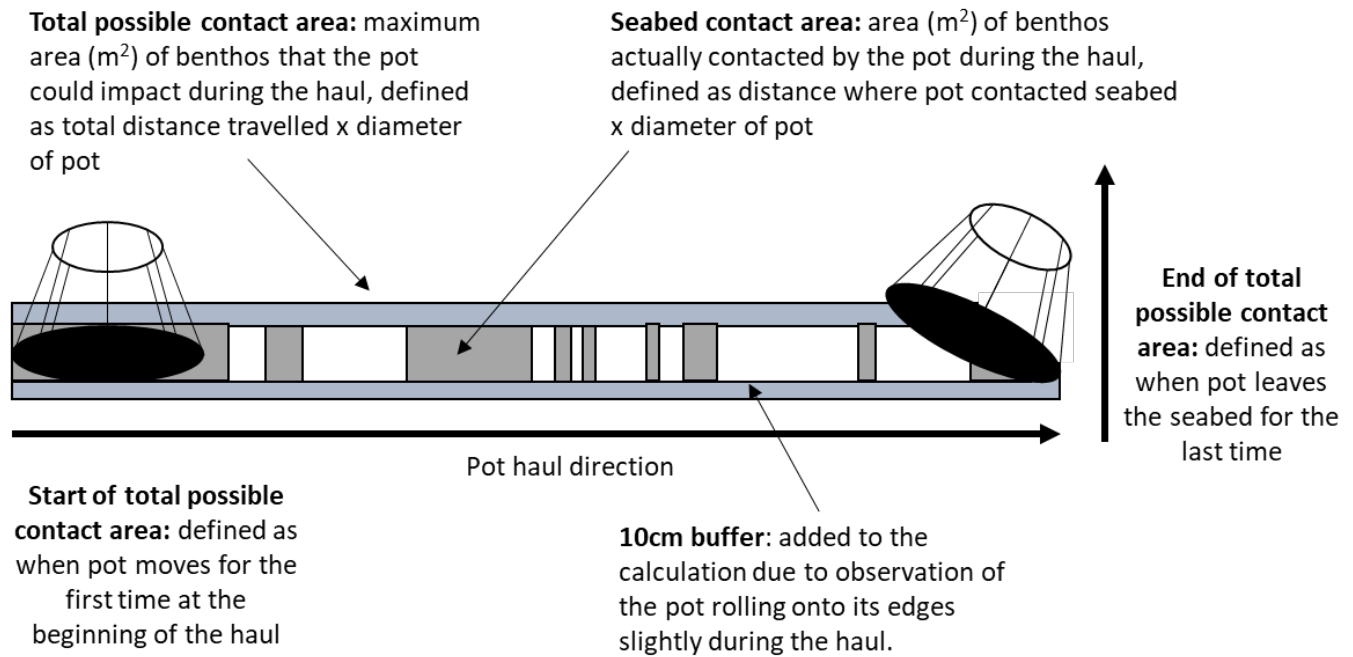379 *foliacea*, number of individuals ((not damaged, damaged, removed), (m^{-2})) was also calculated.

17

Total possible contact area: maximum area (m^2) of benthos that the pot could impact during the haul, defined as total distance travelled x diameter of pot

Seabed contact area: area (m^2) of benthos actually contacted by the pot during the haul, defined as distance where pot contacted seabed x diameter of pot

End of total possible contact area: defined as when pot leaves the seabed for the last time

Pot haul direction

Start of total possible contact area: defined as when pot moves for the first time at the beginning of the haul

10cm buffer: added to the calculation due to observation of the pot rolling onto its edges slightly during the haul.

380

381 **Figure 4: Diagrammatic example of how the total possible contact area and seabed contact**

382 **area were calculated during the pot haul**

383

384 The strings of pots were set as they would be under normal fishing conditions, in

385 approximately 30 m of water. End weights were used to anchor each end of the string, and a

386 leaded line joined the string to the buoy on the surface. Leaded line was also used between

387 the pots, which were deployed for 25 minutes, allowing sufficient time to settle, and were

388 then hauled and redeployed at the next site.

389

390 All cameras were set to record in the 1080p, 30 frames per second mode, giving high quality

391 footage while conserving battery life. Two Underwater Kinetics Aqualite torches were also

392 mounted on each pot, one under the rope view camera and the other by the bird's eye camera

393 to counteract poor light conditions (Figure 3).

394

2.3.1 Video analysis

Despite having five cameras mounted on the pots, it became apparent that all metrics except for the rope movement were best quantified using the video from the bird's eye camera. The rope view camera was used for assessing rope movement. Whilst the other three cameras provided useful observational information and contributed to the understanding of the pot movements and impacts, they were not used for data analysis. The greatest constraint on the survey was the battery life of the GoPro cameras and on the few occasions where they did not last for the full haul the data were excluded from the analysis.

2.3.1.1 Mechanisms of potting interaction

HD video was watched from each camera view for each haul, and data were extracted for each metric (for details see section 2.3). A 10 cm buffer was added to the pot area to calculate the total possible contact area and seabed contact areas as video analysis revealed that pots were often unstable as they moved across the ground during the haul, resulting in some slight rolling onto their sides (Figure 4). The seabed contact area is therefore expected to be a calculation of maximum impact.

2.3.1.2 True footprint of potting

Taxa were identified to the highest taxonomic level possible, although taxonomically similar species were grouped to avoid misidentification, with groupings as stated in benthic condition. Hauls were conducted at a relatively constant speed so video quality was consistent and only those species for which a positive ID could be made with confidence were included in the analysis. Description of taxon damage is given in Table 4, where 'abrasion' is visible rubbing commonly resulting in clouding of the water suggesting tissue removal, and 'sections

419 removed' where injury occurred resulting in clouding of the water and the presence of small

420 sections of tissue in the water column. The implications of these were considered comparable

421 and the definitions apply to interactions from both the pots and the ropes.

422

423 **2.3.2 Statistical analysis**

424 Data were pooled per string (two pots) and multivariate and univariate analyses were

425 conducted for data on seabed contact area and number of individuals using Permutational

426 Multivariate Analysis of Variance (PERMANOVA+, (Anderson, 2001; Clarke and Warwick,

427 2001)) based on similarity matrices using PERMANOVA+ for Primer in PRIMER 6 (Clarke and

428 Warwick, 2001). Multivariate data were square root transformed and Bray Curtis similarity

429 indices were used to construct similarity matrices. Univariate data were untransformed and

430 Euclidean dissimilarity indices were used to conduct similarity matrices (Clarke and Warwick,

431 2001). Each term in the analyses used 9999 permutations of the appropriate units (Anderson

432 and Braak, 2003).

433

434 Three random factors, Year (2014, 2015), Location (Start Point (SP), Mewstone Ledges (ML),

435 Hillsea Point (HP)), and Site (1-9 nested in Location) and one fixed factor Pot Type (Parlour (P),

436 Inkwell (I)) were used in the analysis. To test whether the number of individuals not damaged

437 was significantly greater than the number of individuals damaged or removed, a repeated

438 measures approach to ANOVA was used with the additional random factor Pot haul path (1-

439 102), nested in Year, Pot type and Site (added as the measures of individuals not damaged,

440 damaged and removed were taken from the same pot haul path for each haul (Bob Clarke,

441 pers. comm.)), and the fixed factor Response (No Damage (ND), Damaged (D) and Removed

442 (R). The lowest significant effect was interpreted for each test (P < 0.05) and significant

443 interactions involving fixed factors were interpreted using pairwise tests.

444

445 **2.3.3 Effect size analysis**

446 In addition to the statistical testing, effect size was also calculated on un-pooled data to allow

447 further examination of the impacts of potting and the differences between the two pot types.

448

449 **2.3.3.1 Mechanisms of potting interaction**

450 For each pot haul, the strip length (total distance moved during the haul) was estimated from

451 the video using visual reference points on the seabed. Seabed contact area was estimated as

452 the number of pot lengths where the pot was in contact with the seabed, multiplied by the

453 footprint of the pot.

454

455 Seabed contact area and strip length (total distance (m) moved during the haul; note this

456 differs from total possible contact area (m^2)) were calculated for each pot. The effect of strip

457 length, pot type (fixed factors), location and year of sampling (random factors), and their

458 interactions on seabed contact area was tested using linear models in the software package

459 R (R Core Team 2019) with the lme4 package (Bates et al., 2015). Overall effects of the two

460 pot types were calculated as mean contact areas and (95 %) confidence intervals using the

461 package emmeans (Lenth 2019).

462

463 **2.3.3.2 True footprint of potting**

464 The effect of pot hauling on benthic fauna was explored for the identified assemblage, and

465 for species grouped according to body type (erect-emergent and low-encrusting) based on

466   the BIOTIC database (MarLIN, 2006) for each species or its closest available relative. Species

467   were quantified in terms of abundance not damaged, damaged or removed. For pot-level

468   observations, the mean value of species responses was calculated for each pot, before

469   estimating effect sizes and confidence intervals. For body type statistics, abundances were

470   calculated for each species, then a mean for each body type within each pot was calculated,

471   before calculation of mean effects and confidence intervals. Mobile benthic species were

472   omitted from this analysis owing to only one record of damage.

473

474   Effects were calculated as fractions of fauna removed, damaged or undamaged by the two

475   different pot types, with overall mean fractions and 95 % confidence intervals calculated using

476   a nonparametric bootstrap method from the Hmisc package (Harrell, 2019). Responses were

477   compared between pot types using Wilcoxon-Mann-Whitney tests in the R package coin

478   (Hothorn et al., 2008), and effect sizes calculated as Wilcoxon r values using the R package

479   rstatix (Kassambara 2020).

480

481   **3. RESULTS**

482

483   When interpreting the results, the phrasing 'significantly greater' has been used where there

484   is statistical significance ($p < 0.05$). Where the phrase 'consistently greater' is used there has

485   not been a statistical significance identified, but highlighting the trends seen was felt to be of

486   importance. All significant interactions are reported below. Full PERMANOVA tables and

487   results from linear modelling and effect size analyses can be found in the supplementary

488   material (Tables S1-S10).

489

3.1 Benthic condition

490

491 A total of 91 taxa were recorded from eight phyla. A significant Treatment effect was

492 identified for the abundance of "cover" individuals ($p < 0.05$), with abundance significantly

493 greater in the Static than Mixed treatment (Static = 16.88 m^{-2} % ± 1.75, Mixed = 8.73 m^{-2} % ±

494 2.16; Figure 5). Abundance of "count individuals", number of taxa and diversity was also

495 consistently greater in the Static than the Mixed treatment (Count: Static = 549.41 ind. m^{-2} ±

496 54.86, Mixed = 260.45 ind. m^{-2} ± 16.24; Number of taxa: Static = 20.37 m^{-2} ± 0.35, Mixed =

497 17.00 m^{-2} ± 0.49; Diversity: Static = 0.54 ± 0.01, Mixed = 0.49 ± 0.02; Figure 5), although no

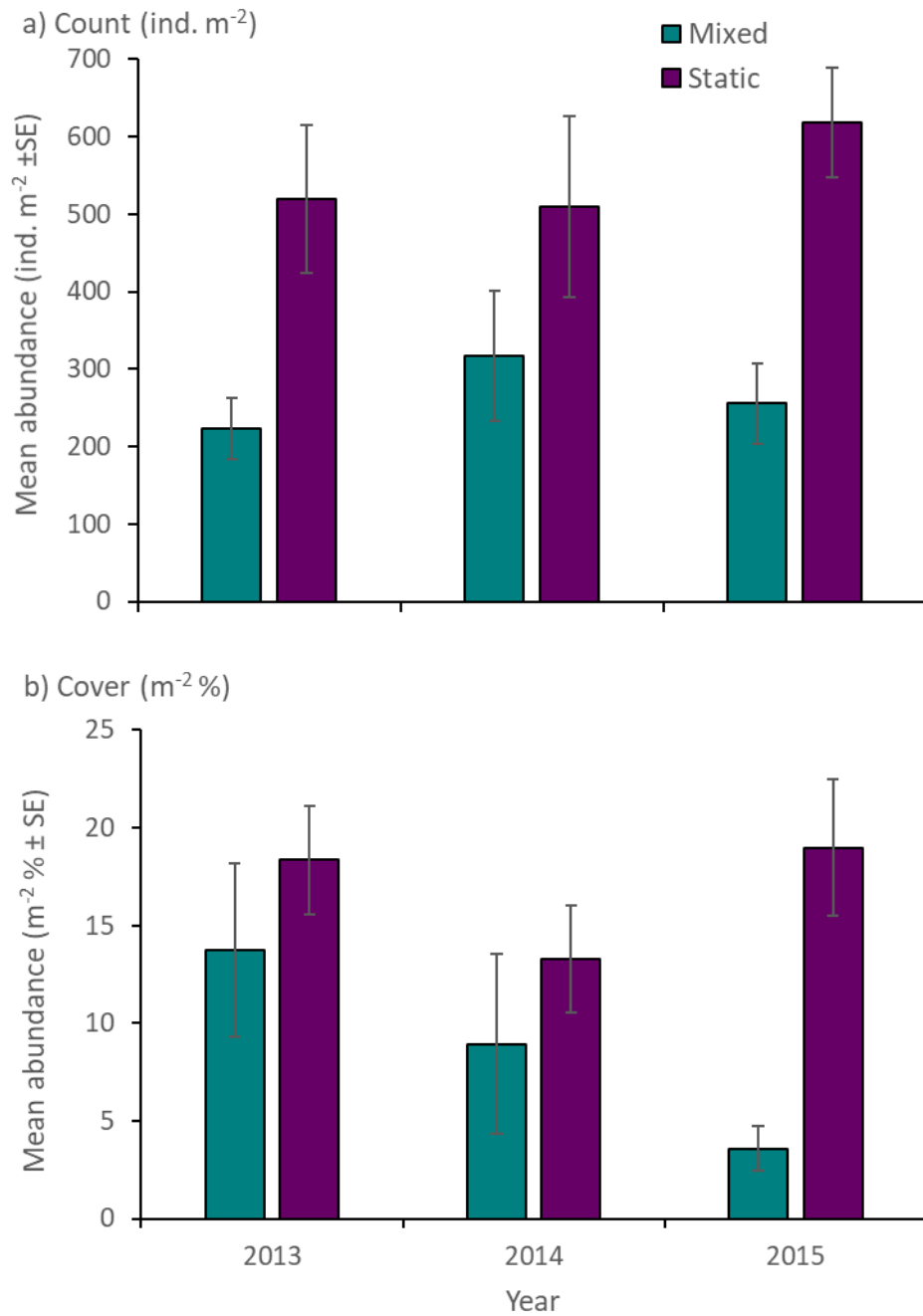498 Treatment effect was identified.

499

Figure 5: Mean abundance of all a) Count (individuals m^{-2} ± SE) and b) Cover (m^{-2} % ± SE) individuals in the Static and Mixed treatments per year (2013, 2014, 2015)

Despite significant temporal and spatial variation, a significant treatment effect was identified for assemblage composition, with two distinct groupings apparent ($P < 0.05$, Table 1, Figure

506   6): despite some overlap, sites in the static treatment were more similar to each other than

507   to the sites in the mixed treatment.

Source	df	MS	Pseudo-F	P(perm)
Year	2	3812.80	3.16	**0.0002**
Treatment	1	13717.00	1.82	**0.04**
Location(Treatment)	8	6373.50	2.80	**0.0001**
Year x Treatment	2	1833.80	1.55	0.07
Site(Location(Treatment))	20	1326.90	1.68	**0.0001**
Year x Location(Treatment)	16	1178.60	1.50	**0.0004**
Res	37	787.55		
Total	86			

508

509   **Table 1: PERMANOVA to test the differences in assemblage composition between Years**
510   **(2013, 2014, 2015), Locations (A-J, nested in Treatment), Sites (1-30, nested in Location) and**
511   **Treatments (Static, Mixed). Data were dispersion weighted and fourth root transformed**
512   **prior to the construction of a Bray Curtis resemblance matrix. Bold values indicate**
513   **significant differences.**
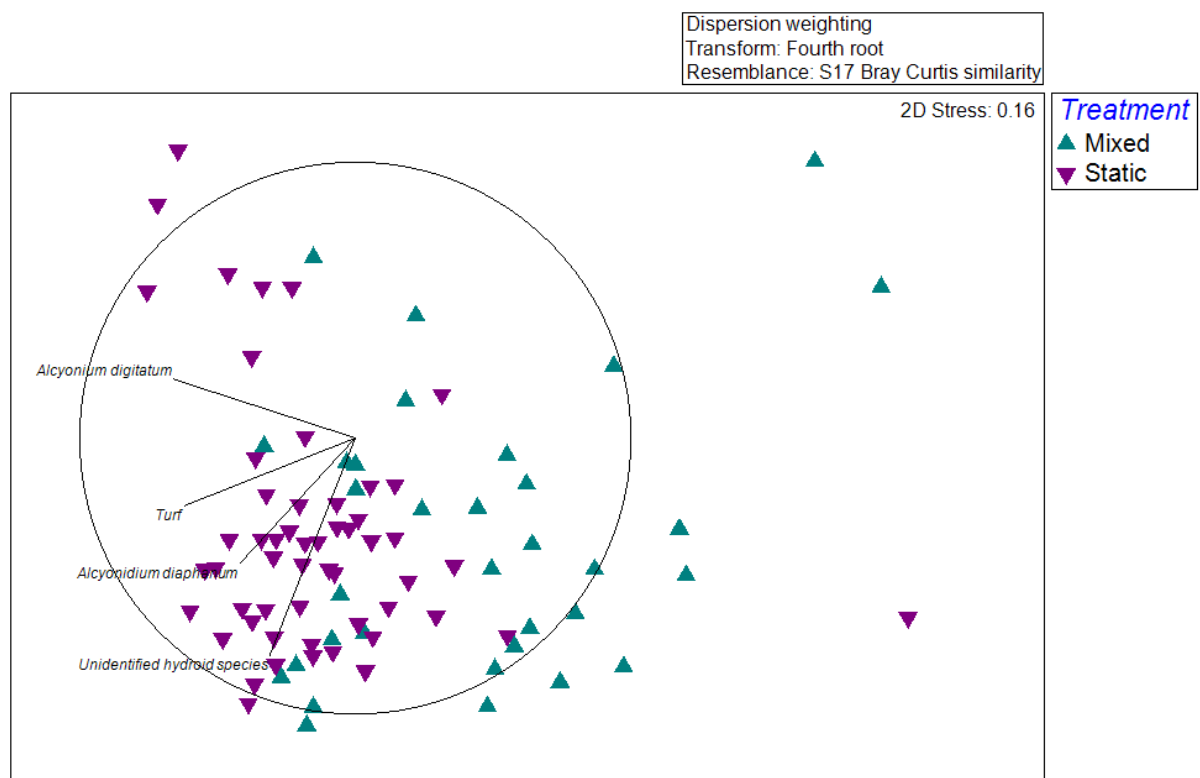
514

515

516

517   **Figure 6: nMDS ordination illustrating similarities in assemblage composition between**
518   **Treatments. Vectors show key species driving differences as identified through SIMPER**
519

520 Results of SIMPER (Table S4; Supplementary material) showed the distinction between

521 Treatments was driven primarily by differences in the abundance of hydroid and bryozoan

522 turf, *A. digitum*, hydroids, and *Alcyonidium diaphanum* (Figure 6; cumulative contribution =

523 34.10 %). Abundance was greatest in the Static treatment for all but one indicator, *M. senile*

524 (Table S4; Supplementary material). Treatment effects were identified for *A. digitatum*, *C.*

525 *celata* and *M. senile* and as with assemblage composition some variation was observed

526 between random factors for most indicators.

527

528 **3.2 Mechanisms of potting interaction**

529 Pots took an average of 3.46 seconds (± 0.27) to settle (from first touch to stationary), with

530 Inkwell pots taking 3.29 seconds (± 0.35) and Parlour pots taking 3.63 seconds (± 0.42). The

531 majority of pots (82.5 %) landed upright, with more parlour than inkwell pots landing on end

532 (Parlour = 17.82 %, Inkwell = 4.04 %), as would be expected due to their design. Pots were

533 relatively stable (no movement = 86.36 % of soaks), although movement did occur in some

534 instances (some occasional movements = 8.08 % of soaks; small movements throughout soak

535 = 4.04 %; large movements throughout the soak = 1.52 % of soaks).

536

537 The pots took 41 seconds (± 3.24) to haul (from first movement to clearing the seabed for

538 good). The total time that the pots moved across the seabed (rather than being stationary or

539 off the seabed), however, was 20.71 seconds (±1.36), meaning that they were in contact with

540 the seabed for approximately half the time it took for them to be lifted clear. Rope movement

541 during the soak was observed for 51.02 % of soaks, although 45.91 % of the time this

542 movement was described as minimal, where the rope moved slightly with the tide but no

543 scour or species impacts were observed.

544 **3.2.1   Seabed contact area**

545 The total possible contact area (total distance travelled x area of base of pot) was 6.20 m^2 ±

546 0.61, and the length of the seabed contact area (distance where pot contacted seabed x area

547 of base of pot) was 3.04 m^2 ± 0.24 (49.07 % of the total possible contact area).

548

549 Differences between pot types were apparent with a significant Pot x Site(Location)

550 interaction identified; total possible contact areas were significantly larger than seabed

551 contact areas for both pot types, and were larger for inkwell pots than for parlour pots

552 (inkwell, total possible contact area = 7.16 m^2 ± 1.00, seabed contact area = 3.51 m^2 ± 0.40,

553 parlour, total possible contact area = 5.24 m^2 ± 0.67, seabed contact area = 2.57 m^2 ± 0.24, P

554 < 0.05; Table 2). These trends were consistent between Areas.

555

556 **Table 2: Mean, N, standard error (SE), minimum (Min) and maximum (Max) values for**
557 **seabed and total possible contact area by pot type (Inkwell and Parlour)**

	Mean	N	SE	Min	Max
Seabed contact area					
Inkwell	3.51	54.00	0.40	0.00	15.56
Parlour	2.57	54.00	0.24	0.00	7.16
Total possible contact area					
Inkwell	7.16	54.00	1.00	0.00	27.45
Parlour	5.24	54.00	0.67	0.00	24.26

558

559 Linear modelling indicated mean seabed contact areas varied by pot type and strip length

560 ($F_{2,91}$ = 74.9, p < 0.0001) (Supplementary Material, Table S6), increasing linearly with strip

561 length (Figure 7). This pattern was consistent between pot types, with no significant

562 interaction between strip length and pot type. For completeness, pot-specific relationships

563 between strip length and contact area are presented in the Supplementary Material (Table

564 S7).

The plot shows the equation:

$$y = 0.317 \cdot x + 0.699$$

$$R^2 = 0.614$$
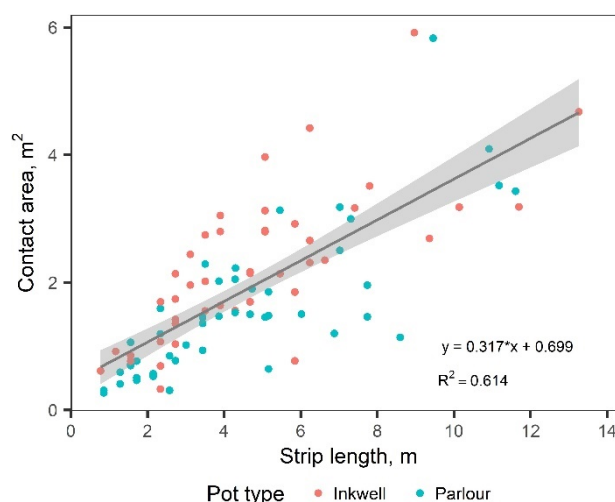
Pot type • Inkwell • Parlour

Figure 7: Contact area of pots during hauling as a function of distance travelled during the haul (strip length), for the two pot types, Inkwell (red) and Parlour (blue). Linear model fit and 95 % confidence interval overlaid.

3.3 True footprint of potting

A total of 18 taxa were identified from the videos (Table 4), from six phyla. Abundance across all sites was greatest for the solitary baked bean ascidian *Dendrodoa grossulaira* (8.46 ind. m^{-2} ± 2.95), macroalgae (2.20 ind. m^{-2} ± 0.40) and the soft coral *A. digitatum* (1.75 ind. m^{-2} ± 0.28), (Table 4).

Species name	Common name	Phylum	Damage description	Total	Inkwell			Parlour		
					ND	D	R	ND	D	R
Alcyonidium diaphanum	Sea chervil	Bryozoa	Abrasion	0.33 ± 0.11	68.72	31.28	0.00	71.66	27.77	0.57
Alcyonium digitatum	Dead Man's Fingers	Cnidaria	Abrasion and/or sections removed	1.75 ± 0.28	63.76	26.63	9.60	66.87	21.05	12.09
Asterias rubens	Common starfish	Echinodermata	None	0.11 ± 0.03	100.00	0.00	0.00	100.00	0.00	0.00
	*Branching sponges	Porifera	Abrasion and/or sections removed	0.18 ± 0.06	50.59	49.41	0.00	83.52	16.48	0.00
Cliona celata	Boring sponges	Porifera	Abrasion and/or sections removed	0.10 ± 0.02	44.58	54.26	1.16	76.48	22.23	1.29
Dendrodoa grossularia	Baked bean ascidian	Chordata	Abrasion	8.46 ± 2.95	61.97	37.90	0.13	66.38	31.42	2.20
Diazona violacea	Football ascidian	Chordata	None	0.003 ± 0.002	0.00	0.00	0.00	100.00	0.00	0.00
Echinus esculentus	Edible sea urchin	Echinodermata	None	0.03 ± 0.01	100.00	0.00	0.00	100.00	0.00	0.00
Eunicella verrucosa	Pink sea fan	Cnidaria	Abrasion	0.12 ± 0.03	44.96	55.04	0.00	64.62	35.38	0.00
Flustra foliacea	Bryozoans	Bryozoa	Abrasion and/or sections removed	0.22 ± 0.10	57.85	42.15	0.00	68.49	31.51	0.00
Gymnangium montagui	Yellow feathers	Cnidaria	Abrasion and/or sections removed	0.005 ± 0.005	0.00	0.00	0.00	0.00	100.00	0.00
Holothuria forskali	Cotton spinner	Echinodermata	None	0.09 ± 0.02	100.00	0.00	0.00	100.00	0.00	0.00
Laminaria digitata	Kelp		Abrasion and/or sections removed	0.003 ± 0.003	80.00	20.00	0.00	0.00	0.00	0.00
	Macroalgae		Abrasion and/or sections removed	2.20 ± 0.10	71.69	27.26	1.05	90.34	9.66	0.00
Marthasterias glacialis	Spiny starfish	Echinodermata	Abrasion and/or damage to a leg	0.26 ± 0.04	100.00	0.00	0.00	97.70	2.30	0.00
	Massive sponges	Porifera	Abrasion and/or sections removed	0.13 ± 0.04	65.50	34.50	0.00	74.80	25.20	0.00
Nemertesia antennina	Sea beard	Cnidaria	Abrasion and/or sections removed	0.23 ± 0.09	86.59	13.41	0.00	83.54	16.46	0.00
Pentapora fascialis	Ross coral	Bryozoa	Abrasion and/or sections removed	0.07 ± 0.02	13.39	82.13	4.49	60.83	36.95	2.23

Table 4: Description of the damage caused to the taxa present in the pot haul path, mean number of individuals (individuals m^{-2}) and percentage of individuals (individuals m^{-2}) Not Damaged (ND), Damaged (D) and Removed (R) during the haul. An asterix (*) denotes indicator taxa.

581 Of the 18 taxa identified, 14 suffered damage from pot impacts, including all five indicator

582 taxa, and individuals of six taxa were removed from the reef, including three indicator taxa

583 (Table 4). Pot hauling damaged or removed between 25 and 30 % of observed epibenthic

584 species recorded by the pot-mounted cameras (Table 5), with broadly consistent patterns

585 between pot types for all responses (p > 0.05), and small effect sizes (Wilcoxon r) of 0.124 and

586 0.127, and 0.006 for the responses Not Damaged, Damaged, and Removed, respectively.

587

588 **Table 5: Pot-level effects. Mean fraction of all species abundance responses to pot hauls for**
589 **Inkwell (n = 45) and Parlour (n = 46), 95 % confidence intervals (CI) and standard error (SE)**
590

Pot type	Response	Mean fraction	Lower CI	Upper CI	SE
Inkwell	Not Damaged	0.697	0.629	0.769	0.035
	Damaged	0.282	0.214	0.350	0.037
	Removed	0.021	0.011	0.035	0.006
Parlour	Not Damaged	0.754	0.696	0.803	0.029
	Damaged	0.217	0.168	0.275	0.027
	Removed	0.029	0.014	0.049	0.009

591

592 ### 3.3.1   Species specific responses

593 Only four species suffered no damage or removal from potting activity; individuals of *Echinus*

594 *esculentus*, *Holothuria forskali* and *Asterias rubens* were observed to roll (*E. esculentus*) or be

595 moved out of the way by the pressure wave from a pot. No damage was observed suggesting

596 they may be able to withstand the gentle movement caused. During the survey no instances

597 of direct impact were observed, however.

598

599 In four of the five instances where rope movement occurred, the rope was in full contact with

600 the substratum; impact was, however, limited to abrasion of *A. digitatum* and *E. verrucosa*.

601 Five instances occurred where damage was evident from rope contact during the haul,

602   including four occasions (3.70 % of hauls) where rope caught on *A. digitatum* causing abrasion

603   and the removal of two individuals from the reef.

604

605   The mean number of individuals (all taxa) was 0.79 ind. m^{-2} ± 0.17. A significant Year x Location

606   x Response interaction was identified, and despite some spatial variation there were

607   significantly more individuals not damaged (0.54 ind. m^{-2} ± 0.05 (68.35 %)) than damaged

608   (0.23 ind. m^{-2} ± 0.03 (29.11 %)), not damaged than removed (removed = 0.02 ind. m^{-2} ± 0.00

609   (2.53 %)) and damaged than removed.

610

611   There were four taxa for which more individuals were more damaged than not damaged,

612   three of which were indicator species; (Inkwell pots: *C. celata* (D = 54.26 %, ND = 44.58 %), *E.*

613   *verrucosa* (D = 54.04 %, ND = 44.96 %) and *P. foliacea* (D = 82.13 %, ND = 13.39 %); Parlour

614   pots *Gymnangium montagui* (D = 100 %, although only one colony was observed during the

615   study and this was damaged by a parlour pot haul)).

616

617   The taxa removed from the reef included two upright, branching taxa, *Alcyonidium*

618   *diaphanum* and *A. digitatum*, two taxa with massive forms projecting from the reef, *C. celata*

619   and *P. foliacea*, *D. grossularia* which attaches to the reef at its base and has a lifespan of 1-2

620   years (MarLIN, 2006) and macroalgae which was observed in dense clumps at some sites and

621   whose growth is annual.

622

623   **3.3.2   Indicator taxa responses**

624   The most abundant indicator taxon was *A. digitatum* (1.15 ind. m^{-2} ± 0.18) and the least

625   abundant was *P. foliacea* (0.03 ± 0.01 m^{-2}) but abundance varied between sites and years for

626   all species (Figure 8). All indicator taxa were damaged during the haul, but only individuals of

627   *A. digitatum*, *C. celata* and *P. foliacea* were removed (Table 4, Figure 8). A significant Pot Type

628   x Site(Location) interaction was identified for the response of *A. digitatum* to potting impact

629   (Pot Type x Site(Location), $P < 0.05$, Table S8; Supplementary material), and while no

630   significant pairings were identified there were significantly more individuals not damaged

631   than damaged. The distribution of all indicator taxa was patchy, but it is important to note

632   that pots were not damaging all individuals that fell within the total possible contact area,
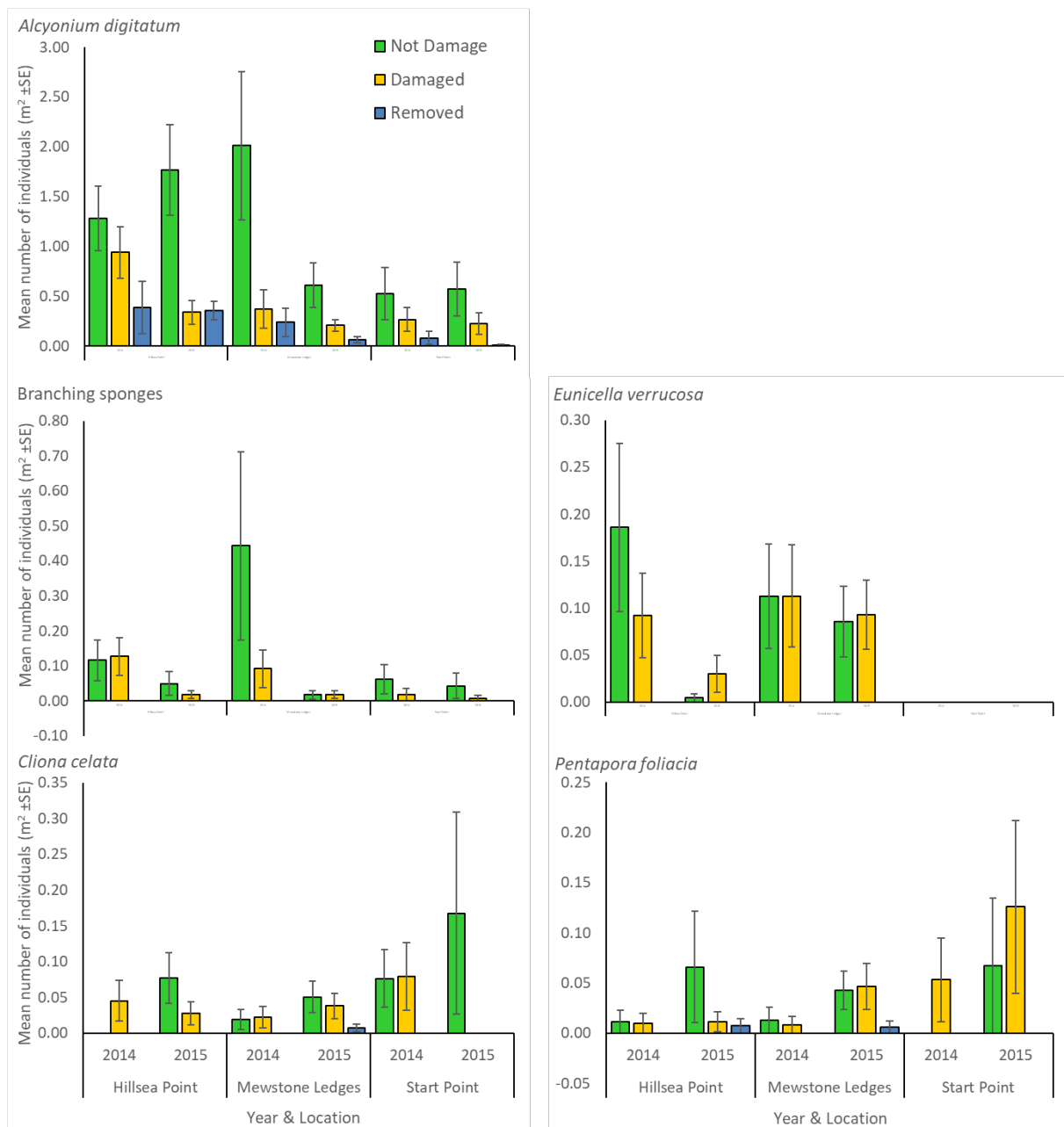
633   and instances of removal were uncommon.

634

635

Figure 8: Number of individuals (individuals m^{-2} ± SE) of the 5 indicator species, *Alcyonium digitatum*, Branching sponges, *Cliona celata*, *Eunicella verrucosa*, and *Pentapora foliacea* at the different Locations (SP = Start Point, ML = Mewstone Ledges, HP = Hillsea Point) and different Year (1 = 2014, 2 = 2015). Note the scales on the Y axis vary.

3.3.3 Response by body type

Both groups of species (erect emergent, low encrusting) were impacted by pot hauling, and this was consistent across pot types (p > 0.05) for both groups. Small effect sizes for comparisons between pot types within each response type were observed, with Wilcoxon r

646   values up to 0.142 for erect emergent species, and 0.099 for low encrusting species

647   (Supplementary Material, Table S10).

648

649   For erect emergent species, the proportion of species not damaged was greater than that of

650   those damaged or removed, but for low encrusting species the fraction of species in the

651   damaged and no damage categories were similar (Table 6). The response of low encrusting

652   species is more variable, but this may be due to the lower number of samples in which low

653   encrusting species were recorded (Table 6).

654   **Table 6: Responses of benthic fauna to pot hauling by body type and pot type. Fractional**
655   **abundance responses of each body type were calculated for each pot prior to calculation of**
656   **mean values, 95 % confidence intervals (CI) and Standard Error (SE).**

Pot type	Response	Erect emergent					Low encrusting				
		n	Mean fraction	Lower CI	Upper CI	SE	n	Mean fraction	Lower CI	Upper CI	SE
Inkwell	No damage	43	0.664	0.589	0.736	0.036	19	0.504	0.311	0.714	0.109
	Damaged	43	0.311	0.238	0.385	0.039	19	0.486	0.275	0.684	0.109
	Removed	43	0.025	0.013	0.042	0.007	19	0.011	0.000	0.032	0.011
Parlour	No damage	46	0.706	0.628	0.775	0.038	12	0.597	0.333	0.833	0.135
	Damaged	46	0.261	0.192	0.342	0.038	12	0.389	0.153	0.667	0.137
	Removed	46	0.033	0.015	0.056	0.01	12	0.014	0.000	0.042	0.014

657

658

659   **4. DISCUSSION**

660

661   This study aimed to determine whether, with the removal of trawling, potting allows for

662   greater relative health of the ecosystem, and to quantify the mechanisms and true footprint

663   of potting. The results have shown that whilst areas fished with static gear (predominantly

664   pots) had consistently greater abundance, species richness and diversity than those open to

665   bottom towed fishing, significant differences were only identifiable for assemblage

666   composition and abundance of cover taxa, where there was significantly greater abundance

667 in static treatments (partial acceptance of hypothesis 1). They have also shown that the

668 seabed contact area is smaller than the total possible contact area for both pot types, with

669 contact areas smaller for parlour pots, and seabed contact area increasing linearly with strip

670 length (distance travelled during the haul), (acceptance of hypothesis 2). Finally, despite

671 significant spatial and temporal variation, significantly more species were not damaged within

672 the total possible contact area than were damaged or removed, but, 25-30% of taxa were

673 damaged or removed, and erect emergents were found to be particularly vulnerable to pot

674 impact (acceptance of hypothesis 3).

675

676 **4.1   Benthic condition**

677 For a system to be considered fully functional it would be expected that in addition to

678 significant differences in assemblage composition, abundance, diversity and species richness

679 would be significantly greater in static gear areas (Tett et al., 2013) and this was not the case.

680 The finding of a significant difference in assemblage composition was, however, important.

681 Species characterising areas fished with static gear were more representative of fully

682 functional benthic rocky reef areas than areas open to bottom towed fishing gear. This was

683 demonstrated by a greater abundance of all but one taxa and differences between treatments

684 being driven by biogenic habitat forming species of hydroid, bryozoan and soft coral (Beck et

685 al., 2001; Beukers-Stewart and Beukers-Stewart, 2009; Dayton et al., 1995; Jennings and

686 Kaiser, 1998; Jennings et al., 2001; Monteiro et al., 2002; Ryer et al., 2004). Biogenic habitat

687 is particularly important for slowing water movement and stabilising sediment, increasing

688 structural complexity and promoting greater biodiversity and productivity through increasing

689 the range of habitats and surface area for settlement (Bradshaw et al., 2003).

690

691   The results are in partial agreement with those of others studies considering potting impacts,

692   most of which identified no significant negative impacts. It has confirmed, however, that

693   there are potential concerns with potting identified here, which most other studies have not

694   identified, and consequently that potting is more destructive than originally thought. Eno et

695   al. (2001) concluded that pot fishing had no immediate detrimental effect on the benthos,

696   finding no significant difference in abundance of taxa before and after potting impacts.

697   Coleman et al. (2013) found no detectable effect of potting on benthic assemblages over a

698   four year period at Lundy Island (UK) with differences over time apparent in both potted and

699   control sites. Stephenson et al. (2017) found no decline in abundance of benthic species even

700   following periods of intensive potting in NE England (equivalent to 30,000 pot hauls month^{-1}.km^{-2}),

701   as they also identified any changes in their control areas. They concluded that even

702   where potting activity causes damage to erect species, the frequency with which a pot would

703   be expected to impact the same area twice means that species would be able to recover

704   (recovery time given as 6-36 months) sufficiently between fishing events (Stephenson et al.,

705   2017).

706

707   In contrast, and similarly to this study, the findings of Rees (2018) raised some concerns. They

708   concluded that that only cessation of potting activity would truly permit recovery of species

709   following the removal of bottom towed fishing gear within an MPA (Rees, 2018). The study,

710   which experimentally potted at different intensities, found significant treatment impacts for

711   the indicator species *P. folicacea* and *Phallusia mammillata* with abundance especially

712   impacted in high intensity potting areas (Rees, 2018).

713

714 In addition, the results of this study can be compared to those of Blyth et al. (2004) who

715 surveyed the IPA area in 2002 and concluded that areas fished using static gear had

716 significantly greater species richness and biomass than sites open to bottom towed fishing

717 gear, and also partially of Sheehan et al. (2015) who identified recovery of benthic

718 assemblages in the Lyme Bay MPA despite the continuation of potting activity. The

719 differences between these findings and the results of the current study may suggest a decline

720 in species richness over time in the survey area, may be a result of differences in survey

721 methodology and metrics (Sheehan et al., 2016) or may be down to external factors such as

722 natural variation or fishing pressure at a local or regional scale (Babcock et al., 1999).

723

724 When considering the potential for external factors to confound the results of this study, the

725 winter storms of 2013/2014 must be acknowledged. These were substantial in the south-west

726 of the UK and would have had an impact on benthic communities. Wave height in the study

727 area reached 5.25 m during the peak of the storms in February 2014 compared to an average

728 annual wave height for the period 2007 – 2013 of 3.69 m (Channel Coastal Observatory, 2014).

729 The storm season prevented fishers from going to sea to retrieve their gear, so pots were left

730 on the ground (in water depth of approximately 60 m) with many losses suffered (South

731 Devon & Channel Shellfishermen Ltd, Pers comm.). A study carried out in Lyme Bay on

732 comparable habitat into the impacts of the 2013/2014 storms found significant reductions in

733 abundance, diversity and richness after the storms, and significant impacts on selected

734 indicator taxa within the MPA. Sites closed to bottom towed fishing gear became more similar

735 to those open to bottom towed fishing gear outside the MPA (Sheehan et al, unpublished

736 data), and due to the proximity of Lyme Bay to the IPA, it may be that similar trends would

737 have been identified here if temporal comparisons were possible with sufficient 'before' data.

738   In a study of Caribbean lobster traps, Lewis et al. (2009) found that movement during storms

739   and hurricanes caused abrasion, fragmentation and removal of corals and sponges with a

740   reduction in benthic species cover. The true impacts of potting may therefore have been

741   confounded by impacts from the storms and this must be acknowledged in interpretation of

742   the results.

743

744   **4.2   Mechanisms of potting interaction**

745   This study is the first of its kind to quantify the seabed contact area during pot hauls. It has

746   shown that the haul is the period during which damage may be caused by potting activity, but

747   the finding that seabed contact area is roughly half that of the total possible contact area is

748   of importance for furthering understanding of potting impact. Furthermore, the existence of

749   significant differences in impact between parlour and inkwell pots may be of relevance to

750   future decisions on sustainable potting gear and management of potting activity, particularly

751   where habitats may be considered to be at risk.

752

753   **4.3   True footprint of potting**

754   Significant spatial and temporal variation was apparent in the data, but despite this,

755   significantly more species were not damaged than were damaged or removed. With the

756   exception of *D. violacea* which was not directly contacted by the pots, the species not

757   damaged were sedentary but mobile. Similarly to the observations made by Eno et al. (2001)

758   about sea pens in soft sediment, it was noted that mobile taxa were moved out of the way of

759   the pot by the pressure wave caused as it neared the seabed, suggesting that they are less

760   susceptible to damage than sessile species.

761

762 Damage included abrasion, and removal of sections of the individual. 25-30 % of taxa were

763 damaged or removed and all five indicator species were damaged in some way, with more

764 instances of damage than no damage occurring for *C. celata*, *E. verrucosa* and *P. foliacea*.

765 These taxa are long-lived and slow growing species that were thought to be most susceptible

766 to potting impacts and would take the longest to recover (Langmead et al., 2010). Impacts of

767 abrasion are not well studied, but evidence suggests that species such as sponges and soft

768 corals may be left vulnerable to disease (Bavestrello et al., 1997; Hiscock, 2007; Shester and

769 Micheli, 2011; Wassenberg et al., 2002). Abrasion was observed for *E. verrucosa*, and

770 although colonies are thought to be able to re-grow over a period of about 1 week if damaged

771 (Hiscock, 2007), if areas of the coenenchyme are scraped off and recovery fails to occur

772 promptly they may be vulnerable to colonisation by epibiota (Bavestrello et al., 1997). This

773 could cause mechanical stress through increased resistance to water movement, and

774 susceptibility to weakening from the burrowing activities of epibiota.

775

776 Two indicator species known to be important for ecosystem function were *E. verrucosa* which

777 creates complex elevated surfaces available for the settlement of spat and acts as habitat for

778 other organisms (Howarth et al., 2011; Jones et al., 1994) and *P. foliacea* a functionally

779 important bio-constructor forming biogenic reefs (Cocito and Ferdeghini, 2001; McKinney and

780 Jackson, 1989) and structurally complex habitat important as a nursery habitat for juvenile

781 fish (Bradshaw et al., 2003). Impacts on these two species would be of particular concern due

782 to their long projected recovery time of 17-20 years (Kaiser et al., 2018). In the case of *E.*

783 *verrucosa*, although few instances occurred where a pot landed directly on top of an

784 individual, where this did occur the results were similar to those of other studies. Eno et al.

785 (2001) observed that it tended to 'bounce back' once the pot had passed, while Shester and

786   Micheli (2011) reported no incidence of removal of gorgonians as a result of lobster trap

787   impact in the Gulf of Mexico and Rees (2018) found that whilst abundance decreased over

788   time in areas fished at the highest potting density (~30 pots per 500m^2), this was not

789   significant.

790

791   Pots contacting *P. foliacea* commonly caused pieces to break off. Of the 16 colonies observed,

792   only one was removed from the reef, but their fragile and brittle structure meant that more

793   individuals were damaged than not damaged. The longer-term implications of damage are

794   unknown, and due to the low abundance of *P. foliacea* across the study site, conclusions were

795   not possible. The findings of Rees (2018) of a significant difference in abundance between

796   control/low potting density sites and medium/high density sites may be cause for concern,

797   however. This study did not calculate potting density across the site so direct comparisons

798   cannot be made, but the results of Rees (2018) suggest that impacts may be more substantial

799   in areas where abundance is greater. What can be concluded here is that as abundance was

800   greater in the static treatment, the impact of potting has a lesser effect than the impact of

801   trawling on this species; a conclusion also drawn by Sheehan et al. (2015).

802

803   When considering body type, the finding that despite their greater vulnerability, a smaller

804   proportion of erect emergents were damaged or removed compared to those not damaged

805   is of note. For low encrusting organisms, similar numbers were damaged and not damaged.

806   The greater variability seen for these taxa may be due to the low number of encrusting species

807   recorded, or it may be a result of pots making contact with a larger area of the species in

808   question owing to differences in morphology between body types. The work of Stephenson

809   et al. (2017) which found no significant impact of potting on benthic organisms also

810   commented that encrusting species are unlikely to be damaged as their size and shape enable

811   them to withstand impacts from physical disturbance and abrasion; a result which does not

812   seem to hold true here.

813

814   **4.4   Implications for management**

815   This study has contributed to the evidence base for assessing the impact of potting on

816   temperate rocky reefs. It is the first study to quantify the true footprint of potting, the first to

817   use GoPro cameras for such work, and one of the first to consider the impact of a string of

818   pots throughout their deployment, soak and haul. The findings suggest that current levels of

819   potting within the IPA are allowing benthic condition to be maintained and the relative health

820   of the ecosystem to be greater than in adjacent areas where bottom towed fishing gear

821   operates, but they have raised concerns over impacts, in particular those to some long lived

822   and slow growing taxa, which are particularly sensitive to potting. The haul has been identified

823   as the time during which most impacts may occur, and despite the fact that the area of

824   damage is not the entire pot haul path, potting has been found to be more destructive than

825   previously thought.

826

827   In particular, the damage caused to sensitive taxa may be of concern; and with the longer-

828   term impacts unknown it is difficult to predict the consequences. The behaviour of pot fishing

829   makes it very unlikely that pots would be deployed such that they would land, soak and haul

830   in the same location on successive trips, however (Eno et al., 2001), and a recovery time of

831   between 6-36 months for the majority of species (Jackson, 2004; Tyler-Walters, 2006; Tyler-

832   Walters & Ballerstedt, 2007; Budd, 2008) also gives some confidence that species may recover

833   without further disturbance occurring (Stephenson et al., 2017). Consideration must however,

834   be given to recovery trajectories of the most sensitive species which may be as long as 17-20

835   years (Kaiser et al., 2018). The presence of these species throughout the potted areas of the

836   IPA, and the time over which the IPA management has been in place suggests that the reefs

837   may be resilient to current potting levels, but the lack of comparable historical data prevents

838   temporal comparisons and it is unknown whether abundance would be greater if potting

839   levels were reduced or potting was no longer permitted in the area.

840

841   The call for ecosystem based fisheries management means that regulators must decide what

842   level of impact is 'acceptable' and will not compromise the ability of an MPA to meet defined

843   conservation objectives and targets. The D&SIFCA have responsibility for this in the study area.

844   Alongside consideration of ecological impact, they must consider the value of the fishing

845   activity occurring within a protected area and determine the social and economic impacts of

846   management decisions. This study has contributed to a decision to allow potting activity to

847   continue at current levels in the Start Point to Plymouth Sound & Eddystone SCI highlighting

848   its value in supporting decision-making (D&SIFCA, pers. comm.). Continued monitoring of the

849   IPA is required, however, to ensure continued confidence in this decision, and the adaptive

850   management approach of the D&SIFCA should mean that if any decline was identified the

851   continuation of potting in the area would be reviewed.

852

853   The results will be applicable globally where similar habitats and species are found and similar

854   potting methods used. As such, they are particularly important in light of the global drive to

855   increase the coverage of MPAs in order to meet Aichi Biodiversity Target 11 by 2020, and the

856   need to take an ecosystem approach to management, which incorporates social and

857   economic elements (CBD, 2010; Pikitch et al., 2004; Gaines et al., 2010). The increasing

858   designation of multi-use MPAs necessitates identification of extractive activities, which are

859   compatible with meeting conservation goals whilst supporting a viable fishing industry.

860   Potting may be such an activity, but the results suggest careful monitoring of impact is needed,

861   as it cannot be described as a benign fishing method. Furthermore, the issue of shifting

862   baselines must be recognised, especially with regard to what constitutes a fully functional

863   rocky reef ecosystem as continued anthropogenic pressure may result in gradual change and

864   loss of ecosystem services if management measures are not effective (Tett et al., 2013).

865

866   **4.5   Further work**

867   The body of literature surrounding the impact of potting has grown, but the differences

868   between the findings of this and other studies suggest that, as expected, more research is

869   required to further knowledge and understanding of potting impacts. Any future work should

870   build on that already completed. In particular, this work has highlighted the need for

871   consideration of impacts on key species, the effect of depth, string length and position of pot

872   on the string, and development of long-term studies, which can assess change over time and

873   have the power to overcome confounding factors.

874

875

886

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Supplementary material

1181 **Description of pot setting and hauling process**

1182 When setting pots, the fishers used cast iron end weights at either end of the sting. The skipper set
1183 the boat on course and steamed slowly whilst the gear deployed. The end weight was deployed first
1184 and then each pot followed in turn and was taken through an open door in the side of the vessel
1185 once the slack rope had become taught. Pots and ropes were arranged on deck such that they
1186 deployed automatically as the boat steamed. Once the final end weight was deployed, the surface
1187 bouy followed, and the pots were left on the sea bed.

1188 The haul process involved picking up the surface bouy, then winching the line in so that the end
1189 weight and then each pot re-entered the vessel over the side to be stacked on deck in turn and the
1190 rope coiled ready for the next deployment.

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1192 **Results for benthic condition**
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1194 **Table S1: PERMANOVA to test the differences in number of count and cover individuals between**
1195 **Years (2013, 2014, 2015), Locations (A-J, nested in Treatment), Sites (1-30, nested in Location) and**
1196 **Treatments (Static, Mixed). Data were fourth root transformed prior to the construction of a**
1197 **Euclidean distance resemblance matrix. Bold values indicate significant differences**
1198

Source	df	MS	Pseudo-F	P(perm)	Source	df	MS	Pseudo-F	P(perm)
Count taxa					*Cover taxa*				
Ye	2	3820.50	3.08	**0.001**	Ye	2	3338.60	1.97	**0.07**
Tr	1	12338.00	1.57	0.08	Tr	1	19842.00	3.41	**0.01**
Lo(Tr)	8	6756.80	2.89	**0.000**	Lo(Tr)	8	4890.30	1.79	**0.002**
YexTr	2	1925.50	1.58	0.07	YexTr	2	1429.70	0.86	0.51
Si(Lo(Tr))	20	1345.30	1.67	**0.0001**	Si(Lo(Tr))	20	1591.50	1.52	**0.02**
YexLo(Tr)	16	1212.80	1.51	**0.0004**	YexLo(Tr)	16	1656.80	1.59	**0.02**
Res	37	804.24			Res	37	1045.20		
Total	86				Total	86			

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1202 **Table S2: PERMANOVA to test the differences in number of taxa and diversity (Simpsons 1-λ)**
1203 **between Years (2013, 2014, 2015), Locations (A-J, nested in Treatment), Sites (1-30, nested in**
1204 **Location) and Treatments (Static, Mixed). Data were fourth root transformed prior to the**
1205 **construction of a Euclidean distance similarity matrix. Bold values indicate significant differences**
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Source	df	MS	Pseudo-F	P(perm)	Source	df	MS	Pseudo-F	P(perm)
Number of taxa					*Diversity*				
Ye	2	0.10	7.55	**0.01**	Ye	2	0.00	0.17	0.85
Tr	1	0.26	3.44	0.07	Tr	1	0.01	0.27	0.95
Lo(Tr)	8	0.07	1.25	0.26	Lo(Tr)	8	0.04	1.72	0.06
YexTr	2	0.01	0.91	0.43	YexTr	2	0.01	2.00	0.16
Si(Lo(Tr))	20	0.05	4.97	**0.0001**	Si(Lo(Tr))	20	0.02	3.38	**0.0004**
YexLo(Tr)	16	0.01	1.37	0.21	YexLo(Tr)	16	0.01	1.28	0.27
Res	37	0.01			Res	37	0.01		
Total	86				Total	86			

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Table S3: ANOVA to test the differences in number of individuals of the indicator taxa *Alcyonidium diaphanum, Alcyonium digitatum,* Branching sponges, *Cliona celata, Eunicella verrucosa, Metridium senile, Pentapora foliacea* and *Urticina felina* between Years (2013, 2014, 2015), Locations (A-J, nested in Treatment), Sites (1-30, nested in Location) and Treatments (Static, Mixed). Pairwise tests were used to examine significant interactions between fixed factors. Data were fourth root transformed prior to the construction of a Euclidean distance resemblance matrix. Bold values indicate significant differences.

Source	df	MS	Pseudo-F	P(perm)	Source	df	MS	Pseudo-F	P(perm)		
Alcyonidium diaphanum					*Alcyonium digitatum*						**M&S**
Ye	2	3.91	8.53	**0.003**	Ye	2	0.35	2.57	0.11	2013	0.073
Tr	1	0.75	0.70	0.64	Tr	1	19.09	6.56	**0.01**	2014	**0.017**
Lo(Tr)	8	1.56	2.31	**0.01**	Lo(Tr)	8	2.41	5.01	**0.0001**	2015	**0.024**
YexTr	2	0.18	0.40	0.66	YexTr	2	0.54	4.01	**0.04**		
Si(Lo(Tr))	20	0.31	1.33	0.22	Si(Lo(Tr))	20	0.39	1.43	0.17		
YexLo(Tr)	16	0.45	1.88	0.06	YexLo(Tr)	16	0.13	0.49	0.94		
Res	37	0.24			Res	37	0.27				
Total	86				Total	86					
Branching sponges					*Cliona celata*						
Ye	2	0.04	1.95	0.18	Ye	2	0.01	1.69	0.21		
Tr	1	0.43	2.39	0.14	Tr	1	0.11	5.02	**0.02**		
Lo(Tr)	8	0.18	3.55	**0.001**	Lo(Tr)	8	0.02	1.48	0.13		
YexTr	2	0.01	0.69	0.52	YexTr	2	0.01	0.85	0.45		
Si(Lo(Tr))	20	0.03	1.48	0.13	Si(Lo(Tr))	20	0.01	1.09	0.39		
YexLo(Tr)	16	0.02	0.92	0.56	YexLo(Tr)	16	0.01	1.09	0.39		
Res	37	0.02			Res	37	0.01				
Total	86				Total	86					
Eunicella verrucosa					*Metridium senile*						
Ye	2	0.07	0.70	0.53	Ye	2	0.01	0.44	0.67		
Tr	1	0.06	0.11	1.00	Tr	1	0.22	3.76	**0.05**		
Lo(Tr)	8	1.30	8.54	**0.0001**	Lo(Tr)	8	0.05	1.54	0.11		
YexTr	2	0.11	1.12	0.36	YexTr	2	0.01	0.75	0.51		
Si(Lo(Tr))	20	0.05	2.79	**0.004**	Si(Lo(Tr))	20	0.03	1.13	0.34		
YexLo(Tr)	16	0.10	5.17	**0.0001**	YexLo(Tr)	16	0.02	0.77	0.76		
Res	37	0.02			Res	37	0.03				
Total	86				Total	86					
Pentapora foliacea					*Urticina felina*						
Ye	2	0.03	5.17	**0.02**	Ye	2	0.18	3.55	**0.04**		
Tr	1	0.01	1.25	0.36	Tr	1	0.10	0.38	0.88		
Lo(Tr)	8	0.01	1.43	0.15	Lo(Tr)	8	0.39	4.75	**0.0001**		
YexTr	2	0.00	0.23	0.79	YexTr	2	0.03	0.52	0.62		
Si(Lo(Tr))	20	0.00	1.34	0.20	Si(Lo(Tr))	20	0.04	1.16	0.33		
YexLo(Tr)	16	0.01	2.08	**0.03**	YexLo(Tr)	16	0.05	1.65	0.10		
Res	37	0.00			Res	37	0.03				
Total	86				Total	86					

Table S4: Results of SIMPER showing the contribution of different species to the differences seen
between Mixed and Static treatments. * denotes indicator species. Bold text denotes the higher
abundance.

	Mean abundance		Diss/SD	Contrib%
	Mixed	Static		
Turf	0.26	**0.48**	1.47	9.44
Alcyonium digitatum	0.13	**0.47**	1.41	9.43
Unidentified hydroid species	0.72	**0.81**	1.01	8.45
Alcyonidium diaphanum	0.23	**0.29**	1.22	6.78
Nemertesia antennina	0.17	**0.30**	1.28	6.10
Ophiothrix fragilis	0.06	**0.14**	0.49	4.83
Ophiocomina nigra	0.06	**0.16**	0.77	4.55
Unidentified bryozoan species	**0.12**	0.11	0.91	3.75
Eunicella verrucosa	0.07	**0.10**	0.62	3.20
Urticina felina	0.05	**0.09**	0.69	2.79
Pecten maximus	**0.10**	0.05	0.66	2.68
Halecium halecinum	0.06	**0.10**	0.99	2.62
Lanice conchilega	0.04	**0.05**	0.43	2.41
Cellepora pumicosa	**0.08**	0.06	0.75	2.34
Nemertesia ramosa	0.04	**0.08**	0.95	1.97
Flustridae spp.	0.01	**0.06**	0.49	1.58
Unidentified anemone	**0.05**	0.02	0.47	1.52
Unidentified macroaglae	**0.04**	0.02	0.56	1.47
Aequipecten opercularis	**0.04**	0.01	0.67	1.38
Unidentified cup coral	0.02	**0.05**	0.59	1.35
Dendrodoa grossularia	0.00	**0.05**	0.43	1.20
Echinus esculentus	0.01	**0.05**	1.02	1.20
Branching sponge 1	0.01	**0.04**	0.72	1.16
Marthasterias glacialis	0.02	**0.04**	0.84	1.08
Cliona celata	0.00	**0.04**	0.72	1.01
Metridium senile	**0.04**	0.00	0.41	0.99
Cerianthid spp.	**0.04**	0.00	0.38	0.92
Branching sponge 2	0.00	**0.04**	0.50	0.87
Sycon ciliatum	0.02	**0.03**	0.87	0.83
Pagurus bernhardus	**0.03**	0.00	0.58	0.78
Pentapora foliacea	0.02	**0.03**	0.80	0.75
Aglaophenia tubulifera	**0.03**	0.01	0.45	0.74

Average dissimilarity M : S = 60.64

Mechanisms of potting interaction

Table S5: PERMANOVA to test the differences in mechanisms of potting interaction between Years (Yr, 2014, 2015), Locations (Lo, Start Point, Mewstone Ledges, Hillsea Point), Sites (Si, 1-9, nested in Location) and Pot Types (Po, Inkwell, Parlour). Pairwise tests are used to examine significant interations between fixed factors. Data were untransformed prior to the construction of a Euclidean Distance resemblance matrix. Bold values indicate significant differences.

a)

Source	df	MS	Pseudo-F	P(perm)
Ye	1	3994.7	2.1721	0.276
Lo	2	867.56	0.69558	0.7059
Po	1	962.86	1.391	0.3825
Si(Lo)	24	641.58	0.77098	0.7364
YexLo	2	1778.1	2.1448	0.1355
YexPo	1	616.41	3.43	0.2075
LoxPo	2	143.23	0.57233	0.8087
YexSi(Lo)**	23	816.47	2.632	**0.0174**
PoxSi(Lo)	24	697.27	2.2584	**0.0381**
YexLoxPo	2	140.14	0.45176	0.6454
Res	19	310.21		
Total	101			

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b)

Pairing	SP	ML	HP
Site 1			
P & I	0.4763	0.2478	0.2484
Site 2			
P & I	0.2489	0.2413	0.2412
Site 3			
P & I	-	0.4896	-
Site 4			
P & I	0.2384	-	0.4948
Site 5			
P & I	0.2342	0.504	0.2387
Site 6			
P & I	0.2467	0.2478	0.2363
Site 7			
P & I	0.522	0.5015	0.2641
Site 8			
P & I	-	0.2662	0.2239
Site 9			
P & I	-	0.5249	0.2344

Table S6: Contact area (m2) by pot type and linear relationship of contact area against strip length. Confidence level = 0.95. NB. Differences in mean occur between these figures and the statistical analysis as no pooling was required for this analysis.

Pot type	Mean effect	Lower CI	Upper CI	SE	Intercept ± CI	Slope ± CI	Adjusted R^2
Inkwell	2.12	1.91	2.34	0.108	0.699 ± 0.328	0.317 ± 0.054	0.614
Parlour	1.60	1.38	1.81	0.108			

Table S7: Pot-specific regression coefficients for the effect of strip length on pot contact area.

Pot type	Mean effect	Lower CI	Upper CI	SE	Intercept ± CI	Slope ± CI	Adjusted R2
Inkwell	2.12	1.91	2.34	0.109	0.688 ± 0.415	0.319 ± 0.077	0.610
Parlour	1.60	1.38	1.81	0.109	0.185 ± 0.400	0.314 ± 0.077	

Pot-specific responses derived from the model Contact area ~ Strip length * Pot type. This model did not perform as well (based on AIC) as the model Contact area ~ Strip length + Pot type, suggesting

1251 that there is no interaction between pot type and strip length. Pot types both respond similarly to
1252 movement along the seabed in terms of their contact areas.

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1255 **True footprint of potting**
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1257 **Table S8: PERMANOVA to test the differences in true footprint between Years (Yr, 2014, 2015),**
1258 **Locations (Lo, Start Point, Mewstone Ledges, Hillsea Point), Sites (Si, 1-9, nested in Location) and**
1259 **Pot Types (Po, Inkwell, Parlour). Pairwise tests are used to examine significant interations between**
1260 **fixed factors. Data were untransformed prior to the construction of a Euclidean Distance**
1261 **resemblance matrix. Bold values indicate significant differences.**

a)

Source	df	MS	Pseudo-F	P(perm)
Ye	1	16052	2.4495	0.1171
Lo	2	19696	1.9914	**0.0248**
Po	1	4754.3	1.4815	0.2381
Re	2	84028	7.3349	**0.0002**
Si(Lo)	25	4963.7	1.4588	**0.0363**
YexLo	2	6235	1.8007	0.0873
YexPo	1	3826.9	1.0687	0.4323
YexRe	2	5651.7	1.6358	0.1593
LoxPo	2	1546.7	0.64817	0.9011
LoxRe	4	6123.2	1.5427	**0.0259**
PoxRe	2	606.5	1.0605	0.449
YexSi(Lo)**	23	3397.6	No test	
PoxSi(Lo)**	24	3930.3	1.2702	0.1211
Si(Lo)xRe**	48	1574.4	0.96096	0.625
YexLoxPo	2	3402.9	1.1025	0.359
YexLoxRe	4	3324.9	2.0645	**0.0088**
YexPoxRe	2	964.37	0.59191	0.8437
LoxPoxRe	4	1315.8	0.88001	0.6917
YexPoxSi(Lo)**	19	3079.6	No test	
YexSi(Lo)xRe**	46	1576.3	No test	
PoxSi(Lo)xRe**	48	1286.2	0.93635	0.6863
YexLoxPoxRe	4	1721.9	1.2566	0.2115
Co(YexPoxSi(Lo))	0		No test	
YexPoxSi(Lo)xRe**	37	1370.2	No test	
Total	305			

** Term has one or more empty cells

b)

	SP	ML	HP
2014			
ND & D	0.6804	**0.0015**	**0.0026**
ND & R	**0.0154**	**0.0003**	**0.0003**
D & R	**0.0071**	**0.0008**	**0.0049**
2015			
ND & D	0.1719	**0.0011**	**0.0021**
ND & R	**0.0016**	**0.0002**	**0.0003**
D & R	**0.0021**	**0.0047**	0.0597

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Table S9: ANOVA to test the differences in number of individuals for the indicator taxa *Alcyonium digitatum,* Branching sponges, *Cliona celata, Eunicella verrucosa* and *Pentapora foliacea* between Years (Yr, 2014, 2015), Locations (Lo, Start Point, Mewstone Ledges, Hillsea Point), Sites (Si, 1-9, nested in Location) and Pot Types (Po, Inkwell, Parlour). Pairwise tests are used to examine significant interations between fixed factors. Data were untransformed prior to the construction of a Euclidean Distance resemblance matrix. Bold values indicate significant differences.

Source	df	MS	Pseudo-F	P(perm)
Alcyonium digitatum				
Ye	1	3.75	0.50	0.63
Lo	2	11.72	0.97	0.53
Po	1	15.08	4.83	**0.04**
Si(Lo)	25	7.30	2.43	**0.02**
YexLo	2	7.39	2.47	0.08
YexPo	1	1.37	0.85	0.46
LoxPo	2	1.66	0.59	0.84
YexSi(Lo)**	23	2.94	2.21	**0.03**
PoxSi(Lo)**	24	3.58	2.69	**0.01**
YexLoxPo	2	1.51	1.13	0.33
Res	18	1.33		
Total	101			

	SP	ML	HP
1			
I & P	0.49		0.50
2			
I & P	0.25	0.25	0.24
3			
I & P		0.25	
4			
I & P	0.51		0.25
5			
I & P	0.51	0.24	0.49
6			
I & P	0.50	0.25	0.25
7			
I & P	0.50	0.50	0.50
8			
I & P		0.25	0.50
9			
I & P		0.24	0.50

Source	df	MS	Pseudo-F	P(perm)
Cliona celata				
Ye	1	0.12	4.07	0.12
Lo	2	0.08	1.73	0.16
Po	1	0.07	1.25	0.39
Si(Lo)	25	0.06	0.84	0.69
YexLo	2	0.03	0.39	0.78
YexPo	1	0.09	0.86	0.45
LoxPo	2	0.05	0.60	0.84
YexSi(Lo)**	23	0.07	1.41	0.18
PoxSi(Lo)**	24	0.06	1.15	0.34
YexLoxPo	2	0.10	2.00	0.13
Res	18	0.05		
Total	101			
Eunicella verrucosa				
Ye	1	0.13	1.49	0.32
Lo	2	0.21	1.91	0.10
Po	1	0.03	1.16	0.43
Si(Lo)	25	0.05	0.82	0.74
YexLo	2	0.09	1.35	0.26
YexPo	1	0.07	0.60	0.60
LoxPo	2	0.07	0.75	0.72
YexSi(Lo)**	23	0.06	0.93	0.59
PoxSi(Lo)**	24	0.06	0.82	0.71
YexLoxPo	2	0.12	1.83	0.15
Res	18	0.07		
Total	101			
Pentapora foliacea				
Ye	1	0.09	2.24	0.20
Lo	2	0.05	1.28	0.32
Po	1	0.06	2.11	0.18
Si(Lo)	55	0.04	0.91	0.52
YexLo	2	0.04	0.83	0.53
YexPo	1	0.07	1.56	0.22
LoxPo	2	0.01	0.31	0.75
YexSi(Lo)**	37	0.04	No test	
PoxSi(Lo)**	0		No test	
YexLoxPo	0		No test	
Total	101			

Source	df	MS	Pseudo-F	P(perm)
Branching sponges				
Ye	1	0.84	1.58	0.35
Lo	2	0.38	0.97	0.55
Po	1	0.42	2.81	0.14
Si(Lo)	55	0.24	0.73	0.71
YexLo	2	0.47	1.45	0.26
YexPo	1	0.42	1.31	0.31
LoxPo	2	0.06	0.20	0.71
YexSi(Lo)**	37	0.32	No test	
PoxSi(Lo)**	0		No test	
YexLoxPo	0		No test	
Total	101			

1273 **Table S10: Effect size (Wilcoxon r) and 95 % confidence intervals of pot type (inkwell and parlour)**
1274 **on fractions of individuals damaged, removed, or exhibiting no damage as a response to pot hauling.**
1275 **Effect sizes calculated using the package coin (Hothorn et al., 2008) in the R programme (R core team**
1276 **2019).**

Response	Erect emergent				Low encrusting		
	Effect size	Lower CI	Upper CI		Effect size	Lower CI	Upper CI
No damage	0.139	0.0096	0.34		0.099	0.0078	0.44
Damaged	0.142	0.0079	0.35		0.091	0.0041	0.44
Removed	0.010	0.0022	0.23		0.051	0.0074	0.40

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