1   **An evaluation of the social and economic impact of a Marine Protected Area on commercial**

2   **fisheries.**

5   Siân E. Rees[1*], Matthew Ashley[1], Louisa Evans[,2], Stephen Mangi[3], Emma V. Sheehan,[1]

6   Tom Mullier,[1] Adam Rees[1,4], Martin J. Attrill[1]

7

8   [1] University of Plymouth, School of Biological and Marine Science, University of Plymouth, Drake
9   Circus, Plymouth, PL4 8AA, UK.

10   [2] University of Exeter, 407. Amory C355b. Amory Building, University of Exeter, Rennes Drive, Exeter,

11   EX4 4RJ , UK.

12   [3]MRAG Ltd, 18 Queen St, Mayfair, London W1J 5PN, UK.

13   [4] Blue Marine Foundation, South Building, Somerset House, London WC2R 1LA United Kingdom

14

15   *corresponding author

16

17   **Abstract**

18   This study is an insight into the spatial use and economic performance of a fishery and linked

19   fisher wellbeing across economic, social and health domains over a 12 year timescale pre and

20   post Marine Protected Areas (MPA) designation. Since the MPA designation, there has been an

21   increase in vessels using static gear inside and outside the MPA with a significant positive trend

22   for vessels using static gear inside the MPA. Over time, static gear landings have decreased by

23   110kg per vessel per month though there has been a significant positive trend over time in value

24   achieved (landings of £1452 per vessel per month), linked to catches of high value species such

25   as lobster, which are linked to the reef ecosystem. Fishing activity providing high volume

26   (weight) and value landings from vessels using mobile demersal gears within the MPA ceased in

27   July 2008. Mobile demersal gear fishing effort has since increased significantly outside the MPA.

28   The value of mobile demersal gear landings in 2017 are comparable to fishing activity prior to

29   the MPA designation but has not reached the peak landings values of 2008 at the point of MPA

30   designation. Fishers predominantly using mobile demersal gear report lower subjective

31   wellbeing and material losses. Static gear fishers report higher levels of subjective wellbeing over

32   time compared to their mobile demersal gear counterparts. Positive subjective wellbeing are

33   pronounced when the fishers are involved with an independent working group. Sustainability

34   across ecological, social and economic systems requires an integrated rather than sequential

35   approach to fisheries management and marine conservation.

36

37   Key words: conservation; Lyme Bay; sustainable development; reef; trawl; protected areas
38

39
40
41
42
43
44

1. Introduction

The Sustainable Development Goals (SDGs) advocate a 'triple bottom line' approach to maintaining human wellbeing; these being economic development, environmental sustainability and social inclusion (UN General Assembly 2015). SDG Goal 14 to 'conserve and sustainably use the oceans, seas and marine resources for sustainable development' places the designation of Marine Protected Areas (MPAs), as a means to mitigate biodiversity loss, firmly within the economic and social context of global development.

MPAs are recognised as having linked social and economic dynamics (Rees, Pittman et al. 2018) and thus (with the respective resource users) form a complex social-ecological system (SES) (Ostrom 2009). The science underpinning the need for MPAs is considered to be mature (Lubchenco and Grorud-Colvert 2015). MPAs where all forms of fishing are removed (no –take) are shown to be the most effective mechanism to restore and preserve biodiversity (Lester and Halpern 2008, Sala, Lubchenco et al. 2018). The parameters for the ecological success of an MPA further rely on the size of the MPA (large) and isolation of the MPA from human pressures (Edgar, Stuart-Smith et al. 2014). However, such thresholds for MPA success are unrealistic given that the majority of MPAs are small and located close to coastlines where much human activity exists (Halpern 2014).

Commercial fishing takes many forms and is widespread. Fishing often overlaps with MPAs and predates their designation. Whilst the objectives for MPAs are typically for conservation purposes, commercial fisheries are dependent on healthy functioning marine ecosystems (inside and outside MPAs), with many of the features of conservation interest (within MPAs) fundamental in supporting fish and shellfish during essential life history stages (Kritzer, DeLucia et al. 2016, Stewart and Howarth 2016). A more realistic pathway to sustainability will rely on the identification of synergies between conservation goals and fisheries management (Gaines, Lester et al. 2010, Brooker, Devenport et al. 2018, Rees, Sheehan et al. 2020). Ecosystem based fisheries management (EBFM) is proposed as a structured whole-of-system place-based planning process that uses adaptive

70   management to provide opportunities to consider overarching management goals for the social-

71   ecological system (Levin, Essington et al. 2018).

72   It is reported that an overarching obstacle to improving the management of the marine environment

73   is the limited empirical evidence of MPA impacts on socioeconomic outcomes despite the many

74   descriptive arguments of the potential for economic benefits resulting from conservation (Wells, Ray

75   et al. 2016, Rees, Sheehan et al. 2020). To date, there is very limited empirical evidence of how

76   MPAs contribute towards human wellbeing and sustainable development (Haines, Hattam et al.

77   2018, UNEP-WCMC, IUCN et al. 2018). Studies to link ecological and social metrics are rare (Gaines,

78   Lester et al. 2010, Pollnac, Christie et al. 2010). Studies that explicitly link the conservation goals of

79   an MPA to the performance of commercial fisheries inside and outside an MPA are equally rare in

80   the European context (Haines, Hattam et al. 2018). A global synthesis of the literature confirms that

81   most empirical work evaluating the social impacts of MPAs has focussed on economic outcomes and

82   the processes of governance that can support improved wellbeing (e.g., rights and participation)

83   (Ban, Gurney et al. 2019). To improve the evidence base, this study offers an insight into the

84   economic performance of a fishery and linked fisher wellbeing across economic, social and health

85   domains over a 12-year timescale pre and post an MPA designation.

86   **1.1 Case study site and context**

87   In June 2008, the United Kingdom's (UK) Department of Environment, Food and Rural Affairs (Defra)

88   established a Statutory Instrument (SI), The Lyme Bay Designated Area (Fishing Restrictions) Order

89   2008, SI 2008/1584, under the Sea Fish (Conservation) Act 1967. The SI came in to force in July 2008

90   and prevented mobile fishing gear, namely dredging and trawling (mobile demersal fishing gear) in

91   206km^2 of Lyme Bay (SI 2008/1584). The SI enabled the reef and the inter reef sediment areas to be

92   protected from mobile demersal fishing gear across a whole-site (Solandt, Mullier et al. 2019, Rees,

93   Sheehan et al. 2020). Creating, at that time, the UK's largest and the most strongly protected MPA

94   for reef features. Within the SI boundary, static gear fishing (pots and nets) and SCUBA diving to

95   collect King scallops (*Pecten maximus*, Pectinidae) are permitted.

96   Overlapping and extending the SI is a 312km² Special Area of Conservation (SAC) designated under

97   the European Union Habitats Directive 92/43/EEC to protect Annex I reef features. In 2013, the

98   regional Inshore Fisheries and Conservation Authority's (IFCA) implemented byelaws to protect

99   236km² of reef across the SAC and the SI. Outside of the SI and within the SAC, fishers using mobile

100   demersal fishing gear are allowed to fish between the reef features, where they are currently

101   delineated. The combination of the SI and the SAC form the boundary of the Lyme Bay Marine

102   Protected Area (MPA) Figure 1.

103   *[inset Figure 1 here]*

104   Since the initial SI closure in 2008, ecological data on macro benthic sessile and sedentary organisms

105   have been collected annually. The results demonstrate that there have been positive responses for

106   species richness, total abundance and assemblage composition inside the SI and abundances of

107   seven out of thirteen indicator taxa showed a positive response inside the SI (Sheehan, Stevens et al.

108   2013, Davies, Attrill et al. 2020). These species were found in greater abundance on reef habitat and

109   pebbly-sand habitat in areas within three years of being closed to mobile demersal fishing to areas

110   outside the SI exposed to mobile demersal fishing (Sheehan, Cousens et al. 2013, Sheehan, Stevens

111   et al. 2013). Collection of socio-economic data has been more limited, confined to one year post SI

112   closure for the fishing industry (2009-2010). Initial results demonstrated that there had been

113   displacement of the mobile demersal fishing fleet, but that permitted commercial fishing activities

114   (fishing with pots) had proliferated within the SI closure (Mangi, Rodwell et al. 2011). In the three

115   years post SI closure, data also shows that recreation participants (divers and anglers) and providers

116   (charter boat operators and dive businesses), had increased their use of the area within the SI

117   closure citing the recovery of the reef and the reduction in conflict with the mobile demersal fishing

118   fleet as key reasons for undertaking their activity in the area (Rees, Rodwell et al. 2010, Rees, Mangi

119   et al. 2015).

120   In 2011, a non-governmental organisation (NGO), the Blue Marine Foundation, formed a pro-active

121   working group for the Lyme Bay MPA. An initial Memorandum of Understanding (MoU) between

122   interested parties established the basis for the Working Group (the Lyme Bay Consultative

123   Committee (LBCC)) for members to promote and implement best practice in fishery and

124   conservation management. Fishery and conservation management actions included a voluntary

125   Code of Conduct, proposed as a means of achieving effective management to maintain sustainable

126   fishing practices within the Lyme Bay MPA. Wider partnership activities by the LBCC have included

127   development of new markets and branding, investment in post-harvest icing infrastructure,

128   knowledge-sharing and training activities.

129   **2. Methods**

130   **2.1 Fishing activity and landings 2005 - 2017 data collection and analysis**

131   Data on the weight and value of species landed by different gear types were obtained from the

132   Marine Management Organisation (MMO) for each vessel that fished in Lyme Bay (International

133   Council for the Exploration of the Sea (ICES) statistical rectangles 30E6 and 30E7, Figure 1) from 2005

134   to 2017. The catch data included the wet weight and value of landings from ports around Lyme Bay

135   reported by fishers and fish merchants to the MMO. The dataset included the date the landing took

136   place, species caught, ICES rectangle fished, and the gear type used. It is noted that these data could

137   be underestimating the actual landings and fishing effort as there is no statutory requirement for

138   fishers to declare their catches for 10 metre and under vessels. Landings records for 10 metre and

139   under vessels were therefore collated from log sheets and landings declarations supplied by fishers

140   and sales notes from buyers and sellers (MMO 2016). This log book data was cross referenced with

141   the MMO landings data to provide a complete data set of weight and value of species landed by the

142   under 10 and over 10 metre fishing fleet.

143   Information from management and enforcement agencies (MMO, IFCA) (sightings data and expert

144   opinion) were used to match locations of fishing effort as either inside or outside the MPA, treating

145   the SI as a whole site closure (reef in inter sediment areas) and the SAC as a feature based (reef)

146   closure to mobile demersal fishing gear. Data were further divided into vessels that are

147   predominantly set up for either mobile (specifically using mobile demersal gear – dredging and

148   trawling) or static gear fishing (pots and nets). Whilst it must be noted that individual fishers may (at

149   different times of year) switch to an alternate form of fishing to take advantage of available stocks,

150   e.g. predominantly mobile gear vessels may also set static gear (pots) for whelks. The gear

151   separation reflects activities which are no longer permitted in the SI section of the Lyme Bay MPA

152   and conservation (reef) features within the SAC that intersect with the IFCA "no mobile (demersal)

153   gear", byelaws.

2.2. Commercial Species

Commercial species that are not subject to quota restrictions in ICES Area 7e, the ICES area that interacts with the study site, are the focus for this research. The under 10 metre commercial fleet, dominant in this section of Lyme Bay, receive less than 5% of UK fish quota allocation (Urquhart, Symes et al. 2014, Anbleyth-Evans and Williams 2018, MMO 2019). Additionally, landings of non-quota species are more linked to fishing opportunity and availability than quota allocated species (Urquhart 2014). Landings data for these non-quota species are presented within gear categories.

Static gear: Pots: brown crab (*Cancer pagurus,* Cancridae) and european lobster (*Homarus gammarus*, Nephropidae); SCUBA diver: king scallop (*P. maximus*); Other pots: whelk (*Buccinum undatum,* Buccinidae), common cuttlefish (*Sepia officinalis,* Sepia); Static nets: lemon sole (*Microstomus kitt,* Pleuronectidae).

Mobile demersal gear: Scallop dredge (king scallop *P. maximus*); demersal trawl (cuttlefish *S. officinalis*); demersal trawl (lemon sole *M. kitt*).

2.3. Statistical analysis of fishing activity and landings data

Fishing within the Lyme Bay MPA is dominated by smaller under 10 m (inshore) vessels that mainly fish within 6 mile from the shore. Under 10 metre vessels comprise approximately 74% of the total number of vessels registered to ports within Lyme Bay as a whole and 96% of vessels registered to ports within the boundary of the MPA. Over the 10 year evaluation period the number of under 10 metre vessels registered to ports within Lyme Bay MPA has remained stable, between 38 to 44 vessels, representing approximately 38-73 at sea jobs (Rees, Ashley et al. 2016). In the same period, there were 1-4 over 10m vessels registered to ports within the MPA, noting that post 2008 three of these vessels with scallop licences would operate predominantly outside the MPA boundary (Rees, Ashley et al. 2016).

177   Fishing activity and landings data were separated into categories. First, the data were separated by

178   vessel gear type, mobile (demersal gear such as trawls or dredges) or static gear (such as pots, static

179   nets or collection of seafood by scuba diving). Fishing effort data (number of vessels and number of

180   trips per month) were separated spatially depending on if the vessel was recorded as fishing within

181   the area of the MPA or outside, using a July to June year to reflect before and after designation of

182   the SI.

183   Values such as fisheries landings for a species may rise and fall between years and do not necessarily

184   provide a linear trend over time. Therefore, to visually identify if a trend over time occurred, annual

185   data (2005/06 – 2016/17) were first plotted in line charts in Microsoft Excel to observe inter-year

186   changes. To statistically test for the presence of a trend, Kendall's tau-b statistical tests were

187   calculated in Statistical Package for the Social Sciences (IBM SPSS®) to test for presence of a

188   monotonic relationship between fishing effort or landings data and time (2010-2017). A significant

189   positive or negative trend was assessed at the 95% confidence limit (>0.05). To test for changes

190   between data from years before the SI closure and after, Welch's *t*-test was used as a more reliable

191   test due to unequal variance present between data sets.

192   Three year averages were also compared where possible, to identify a change in average values

193   between the most recent 3-year period and the three year periods previous to it (e.g. increase,

194   decrease or no change in the 3-year average between 2012-2014, and 2015-2017).

195   **2.4 Fisher wellbeing**

196   A learning history approach was adapted to measure how the wellbeing of Lyme Bay fishers was

197   impacted by regulatory and environmental change events over time (Douthwaite and Ashby 2005, K.E.

198   Abernethy, Ö. Bodin et al. 2014). First, a multi-stakeholder workshop (n=16) was held to: i) develop

199   an integrated timeline of events impacting Lyme Bay between 2005 and 2015, and; ii) prioritise key

200   indicators of subjective and objective wellbeing.

201 Following development of the event timeline, workshop participants were introduced to the concepts

202 of subjective and objective wellbeing across the domains of social, economy, health and environment.

203 Participants then identified and ranked in order of importance indicators they deemed most relevant

204 to the wellbeing of Lyme Bay fishers. The workshop identified four indicators of subjective wellbeing

205 (job satisfaction, income satisfaction, stress and conflict) and three objective indicators of material

206 wellbeing (turnover/profit, investment in the industry and sales strategy) as the most important.

207 These workshop results were used to design a questionnaire survey for fishers. Along a ten-year

208 timeline, fishers were asked to identify a year when a specific aspect of subjective wellbeing, such as

209 job satisfaction, was highest. They were asked to rank on a scale of 0-10 (none – complete/extremely

210 high) their wellbeing at that time. They repeated this for the time of lowest and current wellbeing (as

211 of 2015). Respondents were then asked to identify key events that explained the highest, lowest and

212 current levels of wellbeing, i.e. changes in wellbeing over time. Finally, fishers were asked to rank

213 perceived levels of support for the Lyme Bay MPA on a scale of 0-10 (no support – full support). Fishers

214 were surveyed face to face in pre-arranged meetings. A total of 28 fishers using static and/or mobile

215 demersal fishing gear were interviewed representing the main ports in the study region.

216 Approximately 41 vessels were registered in Lyme Bay ports within the MPA boundary resulting in an

217 interview sample size of 68%. Of this sample 19 reported to operate predominately inside the MPA

218 (n=19) and 9 outside the MPA (n=9).

219 For all survey analyses, fishers were categorised into three groups: static-gear fishers involved in the

220 Lyme Bay Consultative Committee (LBCC) partnership (Static Y), static gear fishers not involved in the

221 LBCC partnership (Static N) and mobile gear fishers (using mobile demersal gear). Only one of these

222 was not involved in the LBCC partnership (mobile). For each category of subjective wellbeing

223 respondents provided three data points reflecting highest, lowest and current wellbeing. To create a

224 timeline for every respondent which could be aggregated, the highest or lowest data points were

225 repeated each year at the same value until the next reported data point. This assumed that fishers did

226   not experience dramatic changes in wellbeing in-between the years they nominated as significant and

227   provided a mean ranking that better reflects the average scores of all respondents across the years.

228   **3. Results**

229   **3.1. Changes in fishing activity and spatial effort**

230   Overall, the number of vessels actively fishing inside and outside the Lyme Bay MPA and reporting

231   landings from ICES statistical rectangles 30E6 and 30E7 per month, increased over the period

232   2004/05-2016/17, aside for those using mobile demersal gear inside the MPA (Figure 2). Fishing

233   activity providing high volume (weight) and value landings from vessels using mobile demersal gears

234   within the MPA ceased, following the SI closure in July 2008 (Figure 3). There is a corresponding

235   increase in mobile demersal gear effort outside the MPA in the years following the SI designation.

236   (Figure 2).

237   *[insert figure 2 here]*

238   There has been an increase in effort from vessels using static gear across the study region, with a

239   significant positive trend for vessels using static gear inside the MPA between 2005/6 and 2016/17,

240   Kendall's tau-b 0.489 p = 0.03) and increase of 7 vessels between the first and last 3-year average in

241   the time series (Table 1).

242   *[inset table 1 here]*

243   Fishing effort (mean number of trips per month) for vessels with static gears increased significantly

244   within the MPA in comparison of annual data before and after the 2008 SI closure (Welch's *t* test =

245   7.45, p= <0.001) and displayed smaller significant increase outside the MPA (Welch's *t* test = 3.83, p

246   0.05) (Table 1, Figure 2). There was an increase of 223 fishing trips per month inside the MPA and

247   185 outside the MPA between the first 3-year average before the 2008 SI closure and the most

248   recent 3-year average (Table 1).

249   Despite an increase in number of trips per month by vessels using static gear over the time series,

250   there was a decrease in overall landings weight (Table 1). However, there was a significant positive

251   trend over time in value of those landings from fishing activity using static gears inside the MPA

252   (Kendall's tau-b 0.788 p = <0.001) and outside (Kendall's tau-b 0.485 p = 0.03) (Table 1, Figure 3).

253   This was represented by a £1452 increase (per vessel per month) between first 3-year average and

254   last 3-year average for static gear landings inside the MPA and £866 (per vessel per month) for static

255   gear landings from outside the MPA (Table 1).

256   *[insert figure 3]*

257   Mobile demersal gear effort (average number of trips per month) has displayed a significant positive

258   trend outside the MPA during the study period (Kendall's tau-b 0.840, p = >0.001) (Table 1, Figure 2).

259   There was also a significant increase in effort (number of trips) outside the MPA, from vessels using

260   mobile demersal gears, when comparing years before and after the SI closure (Welch's t test = 5.49,

261   p <0.001). The increase in effort from vessels using mobile demersal gears outside the MPA

262   following the SI closure provided increased value (+£2231 average per vessel per month) from

263   landings, when comparing 2004/05-2007/08 and 2014/15-2016/17, 3-year averages (Table 1, Figure

264   3). Value of landings for vessels using mobile demersal gears in Lyme Bay have shown some return

265   to those achieved prior to the SI closure, with a value of £9021 (average per vessel per month), from

266   landings outside the MPA in 2016/17. However, values have not reached the peak values prior to the

267   SI closure, where inside the MPA alone landings per vessel per month in 2005/06 were valued at

268   £15311 (Table 1, Figure 3).

269   3.2. **Changes in landings weight and value related to species landings from Lyme Bay 2005/06 -**

270   **2016/17** (ICES rectangles 30E6 and 30E7)

271   *Static gear fisheries*

272   Increase in weight (+735 kg pre vessel per month, 177% increase) and value (+£1507 per vessel per

273   month, 412% increase) of diver caught scallops between 3-year averages at either end of the time

274   series (Table 2), had the greatest contribution to the significant uplift in value obtained for landings

275   from all static gear fishing effort, inside the MPA (Table 2). Due to high values for scallop landings in

276   all years since the SI closure, the positive trend in value over time, for landings from scallop diving

277   was not significant (Kendalls tau-b 0.44, p = 0.15).

278

279   [inset table 2 here]

280   Significant positive trends in landings from potting (combined crab and lobster landings) also

281   contributed to the uplift in value inside the MPA (+178kg, 66% increase in weight, resulting in +£628,

282   104% increase in value) (weight Kendall's tau-b = 0.5, *p* = <0.01; value Kendall's tau-b = 0.87, *p* =

283   <0.001). Increase in landings weight and value associated with potting fisheries also occurred outside

284   the MPA (Table 2) with the 51% increase in value over time also being significant (weight Kendall's

285   tau-b = 0.36, *p* = 0.1; value Kendall's tau-b = 0.51, *p* = 0.01).

286   Landings from net fisheries of the high value species, such as lemon sole *M. kitt,* also contributed to

287   the uplift in value from static gear activity within the MPA (+£285, 4750% increase, Kendall's tau-b

288   0.75, *p* = 0.005). Of the other trap fisheries targeting non-quota species, whelk *B. undatum* provided

289   the largest contribution to value from static gear activity inside and outside the MPA in all years,

290   especially within the MPA (Table 2). Landings of cuttlefish *S. officinalis* are extremely variable across

291   years based on factors (such as previous recruitment strength, sea surface temperature, exploitation

292   of stocks offshore) that influence the availability of the stock to the inshore fisheries. When available

293   to the inshore fisheries this high value stock adds significantly to the overall value of the static trap

294   fisheries. Excluding cuttlefish *S. officinalis* landings, whelk *B. undatum* average annual landings value,

295   per vessel per month, from inside the MPA between 2014/15 - 2016/17 was £7832.

296   *Mobile demersal gear fisheries*

297   High value associated with mobile demersal gear activity before the SI closure was due to scallop *P.*

298   *maximus* landings (2005/6-07/08 3-year average, £11,479) (Table 3). Following the SI closure,

299   increased landings of scallops from dredge activity, as well as greater landings of non-quota species

300   associated with mobile demersal fishing effort occurred outside the MPA (Table 3). Significant

301   positive trends in value from mobile demersal gear landings from outside the MPA occurred over

302   time (all landings: Kendall's tau-b 0.840, *p* = < 0.001). Scallop landings provided the greatest

303   contribution to increase in weight and value over time from effort outside the MPA (Kendall's tau-b

304   0.66, *p* = <0.017). However, 3-year average values over the final 3-year period in the time series

305   were still below those for scallop landings from within the MPA before the SI closure (£4,717

306   compared to £11,479) (Table 3). Increased whelk landings were also associated with vessels that had

307   principally used mobile demersal gears (Table 3). There was a very large increase in weight and value

308   of whelk landings associated with those vessels, which occur within 1-2 years of the SI closure (Table

309   3). This resulted in a significant increase when comparing years before and after the SI closure

310   (Welch's t test = 5.49, p <0.001). The positive trend was not significant over the 12 year time series,

311   as landings rapidly increased from a pre-closure 3 year average weight of 9kg and value of £11, to 3

312   year averages immediately post-closure of 1583kg and £968 and remained high throughout the 9

313   year post-closure time series (value, Kendall's tau-b 0.32, *p* = 0.148).

314   **3.3. Subjective wellbeing**

315   The subjective wellbeing data reveals different wellbeing trajectories over the past decade for

316   different sub-sectors of the Lyme Bay fishery (Figure 4). On average across the ten-year period,

317   mobile demersal gear fishers report lower levels of job and income satisfaction and higher levels of

318   perceived stress and conflict than the static-gear fishers (Figure 4). For static gear fishers involved in

319   the LBCC partnership, job and income satisfaction were high in 2005 (2005 job satisfaction: Static Y =

320   7; income satisfaction: Static Y = 6.8) and have increased marginally in the last ten years (2015

321   reported job satisfaction: Static Y = 8.3; income satisfaction: Static Y = 7.5). Perceived levels of stress

322   and conflict were low for this group (2005 stress Static Y = 4.5; conflict: Static Y= 3.4) and have

323   decreased over the last ten years (2015 stress: Static Y = 4.3; conflict: Static Y= 2) (Figure 4). This

324   group of respondents identified the SI closure and LBCC partnership activities, in particular the

325   Reserve Seafood brand and investments in port-storage and icing as the two most beneficial events.

326   Gear conflicts prior to the closure in 2008, winter storms (2013/2014) and poor weather (2014-2015)

327   were viewed as the most negative events. For static-gear fishers not involved in the LBCC

328   partnership, job and income satisfaction were also high (2005 job satisfaction: Static N = 7.7; income

329   satisfaction: Static N = 7.3) but have decreased or remained steady over the last ten years (2015 job

330   satisfaction: Static N = 5.9; income satisfaction: Static N = 7.5). Perceived levels of stress were

331   moderate and have increased marginally over the last ten years (2005 stress: Static N =3.3; 2015

332   stress: Static N= 4.3). Perceived levels of conflict were moderate but have decreased to low levels in

333   the last ten years (2005 conflict: Static N =5.7; 2015 conflict: Static N= 1.8). Many of these fishers

334   were initially negatively impacted by the closure in 2008 but, having converted to static gears, have

335   experienced improvements in subjective wellbeing. Poor weather in 2014-2015 and low quotas, in

336   particular the combination of the two, were the most important negative events reported by this

337   group. For mobile demersal gear fishers, job and income satisfaction were high (2005 job

338   satisfaction: Mobile= 9.3; income satisfaction: Mobile= 10) but declined sharply into low reported

339   levels of subjective wellbeing in 2008, at the point of the SI closure, (2008 job satisfaction: Mobile=

340   3.4; income satisfaction: Mobile= 3.4) and have steadily increased since (2015 job satisfaction:

341   Mobile= 5; income satisfaction: Mobile= 6.6) (Figure 4). Perceived levels of stress and conflict were

342   low, spiked in 2008 and have decreased steadily over the last ten years (2005 stress: Mobile = 2.4;

343   2008 stress: Mobile=8.6; 2015 stress Mobile =4.3) (Figure 4). Individuals from this group (group n=9)

344   reported examples of symptoms of psychological and physical ill health during the process for the SI

345   closure, for example suicidal thoughts, heart problems and persistent headaches. Stress has reduced

346   since due to increased experience, 'just getting on with things', and good catches for some species.

347   With respect to conflict, where the SI closure reduced gear conflicts for many static-gear fishers, it

348   increased gear conflicts outside of the closed area particularly when extended through the SAC

349   bylaws in 2013.

350   Overall, respondents identified 2007-2008 and 2014-2015 as the years in which they experienced

351   the greatest impacts on their fishing activities and related subjective wellbeing. The introduction of

352   the Lyme Bay SI closure in 2008 was the event mentioned the most often by respondents (n=25).

353   The event was identified as positive for 25% of respondents and negative for the majority of fishers

354   (at the time), including those that used static gear in the SI closure but who had to change or adjust

355   gears when the SI closure was established. Other events mentioned that had a consistently negative

356   impact included quota limitations (n=11), loans (n=5), fuel and insurance costs (n=5) and general

357   concerns about future changes to regulation or the industry (n=5). On the contrary, supporting more

358   positive wellbeing, a number of fishers stated that they were always satisfied with fishing and their

359   income from fishing (n=7) while others mentioned that their satisfaction had improved (n=7) or

360   their stress levels decreased as a result of being older, having cleared debts and generally being

361   more experienced (n=5). In the latter few years, winter storms and general bad weather were

362   identified as the events that had the greatest negative impact on fishers' wellbeing (n=20). Half of

363   these (n=20) fishers surveyed reported 'pushing the weather' (going out in more dangerous sea

364   conditions) when the weather had been bad for a while, or in order to avoid debt or use up quota.

365   The most recent comments linked to 2015 demonstrate that subjective wellbeing concerns are also

366   linked to a perception that the fishery is over crowded (n=6) and there is gear conflict (n=6).

367

368   [inset figure 4 here]

369   3.4. **Objective wellbeing**

370   Fishers stated their annual turnover for 2015 and estimated what percentage of their turnover was

371   profit. Ten respondents chose not to answer and two did not know. Data from respondents suggests

372   that mobile demersal gear fishers turnover was substantially more (+£200,000; n=9) than that of

373   static gear fishers (<£60,000; n=8), on average. In terms of profit, three static gear fishers replied

374   that they made "no profit", "just enough to cover costs" and "the minimum wage". Data indicate

375   that for mobile demersal gear fishers there are large disparities in profits with five respondents

376   earning between £10,000-£30,000 per annum and the remaining three respondents earning

377   between £100,000 and +£250,000.

378   In the ten years preceding 2015, over 85% of the fishers we sampled across all sectors invested in

379   their fishing business. Just over a third planned to invest further in the next five years with moderate

380   confidence that future investments would be sufficiently profitable (Table 4). Investments related

381   primarily to boat and gear renovation, upgrades or expansion with the aim of fishing more safely

382   and/or for longer. The majority of these fishers did not have additional livelihoods. Only a few

383   operators (n=3) invested in processing or selling facilities.

384   Approximately a third of the catch from static-gear fishers is sold to local retailers, restaurants and

385   hotels compared to 5% of the catch of mobile demersal gear vessels in Lyme Bay. On average, 15%

386   of the catch of static-gear fishers involved in the LBCC partnership is now sold as 'Reserve Seafood'

387   at a premium price directly to London. A third of fishers sampled across all sectors would prefer

388   more local or direct sales, but noted as constraints the limitations of time after fishing, infrastructure

389   and transport requirements, and the potential risks of maintaining a good selling price while relying

390   on fewer buyers.

391

4. Discussion

This study offers a first insight into the social and economic performance of a fishery over a 12-year timescale, covering a period pre and post an MPA designation. The results demonstrate that whilst there have been subjective and material losses for mobile demersal gear fisheries, there have been social and economic gains for fisheries predominantly operating static gear inside and outside the MPA. These fishers report higher levels of subjective wellbeing over time compared to their mobile gear counterparts. These parameters of subjective wellbeing are further pronounced when the fishers are involved with the LBCC partnership. The economic loss to mobile demersal gear fishers who were annexed from the MPA by the SI is significant. The high point of dredge caught scallop landings (kg and £) in 2005-2007 (prior to the SI) has never been repeated. For those mobile demersal gear fishers who were displaced or remained operating outside the SI part of the MPA, there has been an increase in weight and value of shellfish landings from grounds outside, in relation to increased effort outside the MPA. Self-reported turnover and profit data suggest that in 2015 mobile demersal gear fishers enjoyed higher returns from fishing than static gear fishers. Nevertheless, factors such as storms and poor weather and a requirement to increase effort further offshore, to maintain an income, has increased the personal risk to these operators. Overall, mobile demersal gear fishers report much lower levels of subjective well-being linked to their livelihood. Such differences in social impacts between groups of fishing industry stakeholders reflect findings from other MPA interventions (McNeill, Clifton et al. 2018). The impacts of the MPA in Lyme Bay are therefore nuanced and dynamic over time.

The main social and economic effect of the MPA (SI and SAC) has been due to the introduction of a spatial management measure that has enabled a clear separation of gear types that had previously been in conflict for fishing grounds. The introduction of the MPA has primed a behavioural response within the local fleet with a significant increase in static gear fishing effort within the boundary of the MPA and lower levels of perceived conflict. Fisheries which set pots for species such as whelks *B. undatum,* cuttlefish *S. officinalis)* brown crab *C. pagurus* and european lobster *H. gammarus* all

19

418   continue to make use of the MPA, as well as fisheries using nets for finfish species. Dive caught

419   scallops *P.maximus* fishing effort has also significantly increased within the MPA as a direct result of

420   the removal of mobile demersal gear. Demonstrated here is the rapid reflex of fisheries activity to

421   MPAs with the conservation designation acting as a (fisheries) spatial management measures. The

422   increase in static gear fisheries has triggered a local post-ante fisheries management response to

423   limit further increases in static gear effort (https://www.devonandsevernifca.gov.uk). From a

424   governance and sustainability perspective there has been a sequential response to the MPA

425   designation rather than an integrated plan for fisheries and conservation. The lack of early

426   integration of the synergistic effects has the potential to 'mask' or hinder MPA performance

427   (ecological goals) through the removal of one pressure and the unmanaged/unintended introduction

428   of another.

429   The link between conservation designation and fisheries performance is a key tool to the delivery of

430   ecosystem-based fisheries management. Noting that counterfactuals in social and economic

431   protected area research are extremely challenging to identify (Ferraro and Pressey 2015) it is

432   necessary to observe the findings of this study against wider data sources and trends. For example,

433   any changes in landings by fishers using different gear must also be considered against factors

434   affecting fishing site preferences, rather than simple assumptions of increased abundance. In the

435   Lyme Bay SI, *P. maximus* and *Cancer pagurus* both continue to increase in abundance along with

436   sessile species such ross coral *Pentapora foliacea* and Hydroids that create stable nursery habitats

437   for commercial species to settle and develop (Sheehan, Cousens et al. 2013, Sheehan EV, Holmes L

438   et al. 2020). There has been a significant increase in landings weight and landings value of scallops

439   *P.maximus* from within the MPA (dive caught) and landings value outside the MPA (dredge). For

440   example, the national trend for scallop *P.maximus* landings (weight and value) into England by UK

441   vessels decreased between 2009 and 2014, the period when the greatest increase in landings

442   occurred from within Lyme Bay MPA (increased mean per vessel per month) (Elliott 2014). In

443   agreement with this, the Lyme Bay MPA ecological studies have demonstrated greater abundances

444   of *P.maximus* within the MPA (Sheehan, Stevens et al. 2013). This potentially signals that this fishery

445   (inside and outside the MPA) is directly benefitting from the MPA management that enables

446   protection and recovery of the reef.

447   There have also been significant increases in landings of brown crab *C. pagurus* from sites both

448   inside and outside the MPA. The ecological studies demonstrate an increased abundance of *C.*

449   *pagurus* between 2008 and 2011 in benthic monitoring studies in regions outside the MPA but close

450   to the boundary (Sheehan, Stevens et al. 2013). Interestingly, no corresponding observed abundance

451   recorded from the ecological monitoring studies within the MPA. This suggests that the fishing effort

452   has increased within the MPA to potentially 'top slice', by removing a proportion of the increased

453   abundance. Set within the national performance, fisheries statistics, landings (weight and value) of

454   crab to ports in England by UK vessels increased between 2009 and 2015, suggesting changes in

455   Lyme Bay may be within this national trend (regardless of the MPA) (Elliott 2014).

456   In terms of the impact of MPAs on measures of subjective and objective wellbeing, the MPA (SI

457   closure) designation was identified as the most impactful event on subjective wellbeing across the

458   fishing sector interviewed. Subjective wellbeing improved for negatively impacted static and mobile

459   fishers since establishment, yet mobile demersal gear fishers still reported lower levels of subjective

460   wellbeing than static gear fishers. Objective measures of wellbeing suggest that mobile demersal

461   gear fishers receive higher income returns from fishing than the static gear sector and that they

462   continue to invest in the fishery, often investing in bigger boats to increase safety and number of

463   days at sea. In their global review of MPAs, Ban et al. (2019) report overall benefits to wellbeing

464   from MPAs and highlight that the benefits to subjective wellbeing are lower than objective measures

465   of wellbeing, and find that older MPAs report more benefits. Our findings similarly suggest

466   differences between subjective and objective measures of wellbeing, and indicate that wellbeing can

467   recover over time post MPA establishment. Wellbeing benefits (Static gear) are most strongly

468   attributed to the role of the Lyme Bay Consultative Committee. In particular, they perceived high

469   benefits to their fishing business from the additional icing and port storage facilities and the Reserve

470   Seafood brand, and more moderate benefits from the voluntary Code of Conduct and Fully

471   Documented fisheries projects.

472   Finally, changes in effort, profits or landings data cannot be solely attributed to the MPA. The fishing

473   industry is agile to markets and demand for seafood as well as being responsive to exogenous (e.g.

474   price elasticity, environmental shocks) and endogenous factors (e.g. shifts in fishing technology,

475   species-habitat interactions) driving the outcomes observed (van Putten, Kulmala et al. 2012). The

476   rapid pace of change in the mobile gear fleet size is demonstrated clearly in the years preceding the

477   MPA when there was a significant increase in mobile gear vessels (dredgers) in Lyme Bay.

478   2006/2007 was a "bumper" year for scallop *P.maximus* landings from the local fleet and it was also

479   reported that additional vessels (with greater fishing capacity) joined the fleet in Lyme Bay from

480   fishing grounds as far as Scotland and the Channel Islands where changes in scallop *P.maximus*

481   availability and restricted access, fuelled displacement of their activity to Lyme Bay (Rees, Attrill et

482   al. 2010). The arrival of this fleet operating over the reef, with a greater fishing capacity (compared

483   to the local fleet) triggered the MPA designation to protect the reef habitat (Rees, Attrill et al. 2010).

484   Fishing for cuttlefish *S. officinalis* also demonstrates market agility and opportunity for the fleet.

485   Cuttlefish spend the winter months in deeper offshore waters, where the water temperatures

486   remain above 9 °C (Bloor, Attrill et al. 2013, Bloor, Wearmouth et al. 2013). Both adults and sub-

487   adults are then assumed to undertake an inshore migration to shallow water areas during the spring.

488   Despite variable landings by volume (weight) cuttlefish provide high value landings to static-gear

489   fishers operating inside the MPA, as well as fishers using mobile demersal and static gear outside the

490   MPA. In good years (such as 2007/08 or 2015/16), the cuttlefish fishery provides a noticeable bonus

491   income in spring months, between April and June.

492   Landings of whelks *B. undatum* in such high volumes is a relatively new occurrence in Lyme Bay (over

493   the last 10 years). This species significantly dominates the catch, driven by demand from the Asian

494   markets and now representing the highest value contribution to the overall landings value for static

495   gear fisheries operating both inside and outside the MPA, and since the closure has contributed to

496   overall landings value for mobile demersal gear fisheries diversifying into the whelk fishery. Mobile

497   demersal gear fishers operating outside the MPA have potentially switched to pots to either take

498   advantage of the market or supplement income due to displacement effects. Overall, whelks are not

499   associated solely with the reef ecosystem but naturally occur on all broadscale habitats present in

500   Lyme Bay. *B. undatum* are scavengers and carnivorous predators feeding on polychaetes, bivalves

501   and carrion, feeding across the range of habitats present in Lyme Bay (Hancock 1967, Scolding,

502   Richardson et al. 2007). In the UK as a whole, fishing effort has generally increased on whelk stocks

503   due to displacement of effort from whitefish and pot fisheries and the development of improved

504   markets. In recent years, whelks have become increasing valuable. In 2017 whelk landings into

505   English ports represented the fifth most valuable landings stock after scallops, cuttlefish, crabs and

506   lobster respectively (Lawler 2013).

507   **5. Conclusion**

508   Sustainability across ecological, social and economic systems is a key requirement to maintaining

509   human wellbeing. Despite the fact that the majority of MPAs support fishing within and adjacent to

510   their boundaries, fisheries management and conservation goals are largely unlinked in current

511   management frameworks. Progress towards sustainability is therefore fractured. Social-ecological

512   theory suggests that transformations to sustainability occur in 'niches' at local level (Lotz-Sisitka,

513   Wals et al. 2015). Lyme Bay is an example of such a 'niche', a unique UK example where much

514   research and community effort has been placed on documenting and securing sustainable

515   outcomes. With more forethought given to the metrics used to define ecological change, an

516   integrated rather than sequential approach to fisheries management, MPAs and fisheries can form a

517   positive social-ecological feedback loop. From this learning, wider social changes and

518   transformations towards sustainability can potentially emerge.

526   **7. Data Availability Statement** To remain GDPR compliant on the holding of social and economic

527   data. Aggregated data is available on request to the corresponding author.

528

8. References

Anbleyth-Evans, J. W. and C. Williams (2018). "Fishing for Justice: England's Inshore Fisheries' Social Movements and Fixed Quota Allocation." Human Geography **11**(1): 28-43.

Ban, N. C., G. G. Gurney, N. A. Marshall, C. K. Whitney, M. Mills, S. Gelcich, N. J. Bennett, M. C. Meehan, C. Butler, S. Ban, T. C. Tran, M. E. Cox and S. J. Breslow (2019). "Well-being outcomes of marine protected areas." Nature Sustainability **2**(6): 524-532.

Bloor, I. S. M., M. J. Attrill and E. L. Jackson (2013). A Review of the Factors Influencing Spawning, Early Life Stage Survival and Recruitment Variability in the Common Cuttlefish (Sepia officinalis). Advances in Marine Biology, Vol 65. M. Lesser. **65:** 1-65.

Bloor, I. S. M., V. J. Wearmouth, S. P. Cotterell, M. J. McHugh, N. E. Humphries, E. L. Jackson, M. J. Attrill and D. W. Sims (2013). "Movements and behaviour of European common cuttlefish Sepia officinalis in English Channel inshore waters: First results from acoustic telemetry." Journal of Experimental Marine Biology and Ecology **448**: 19-27.

Brooker, E., E. Devenport, C. R. Hopkins, S. Hennige, J. M. Roberts and C. Duncan (2018). "Scotland as a case study for how benefits of marine ecosystem services may contribute to the commercial fishing industry." Marine Policy **93**: 271-283.

Davies, B. F. R., M. J. Attrill, L. Holmes, A. Rees, M. J. Witt and E. V. Sheehan (2020). "Acoustic Complexity Index to assess benthic biodiversity of a partially protected area in the southwest of the UK." Ecological Indicators **111**: 106019.

Douthwaite, B. and J. Ashby (2005). Innovation histories: A method from learning from experience. ILAC Brief 5**:** 4.

Edgar, G. J., R. D. Stuart-Smith, T. J. Willis, S. Kininmonth, S. C. Baker, S. Banks, N. S. Barrett, M. A. Becerro, A. T. F. Bernard, J. Berkhout, C. D. Buxton, S. J. Campbell, A. T. Cooper, M. Davey, S. C. Edgar, G. Forsterra, D. E. Galvan, A. J. Irigoyen, D. J. Kushner, R. Moura, P. E. Parnell, N. T. Shears, G. Soler, E. M. A. Strain and R. J. Thomson (2014). "Global conservation outcomes depend on marine protected areas with five key features." Nature **506**(7487): 216-220.

Elliott, M., Ellis, G, Murray, A, Pilgrim, S, Reade, S, Williamson, K, Wintz, P, (2014). UK Sea Fisheries Statistics 2014. M. M. Organisation.

Ferraro, P. J. and R. L. Pressey (2015). "Measuring the difference made by conservation initiatives: protected areas and their environmental and social impacts." Philosophical Transactions of the Royal Society B: Biological Sciences **370**(1681): 20140270.

Gaines, S. D., S. E. Lester, K. Grorud-Colvert, C. Costello and R. Pollnac (2010). "Evolving science of marine reserves: New developments and emerging research frontiers." Proceedings of the National Academy of Sciences of the United States of America **107**(43): 18251-18255.

Haines, R., C. Hattam, M. Pantzar and D. Russi (2018). Study on the Economic Benefits of MPAs. Luxembourg, European Commission**:** 93.

Halpern, B. S. (2014). "Making marine protected areas work." Nature **506**: 167.

Hancock, D. (1967). Whelks. Laboratory Leaflet (new series) No. 15, . Ministry of Agriculture, Fisheries and Food; Fisheries Laboratory, Burnham on Crouch, Essex, England.

K.E. Abernethy, Ö. Bodin, P. Olsson, Z. Hilly and A. Schwarz (2014). "Two steps forward, two steps back: The role of innovation in transforming towards community-based marine resource management in Solomon Islands." Global Environmental Change **28**: 309-321.

Kritzer, J. P., M.-B. DeLucia, E. Greene, C. Shumway, M. F. Topolski, J. Thomas-Blate, L. A. Chiarella, K. B. Davy and K. Smith (2016). "The Importance of Benthic Habitats for Coastal Fisheries." BioScience **66**(4): 274-284.

Lawler, A. (2013). Determination of the Size of Maturity of the Whelk Buccinum undatum in English Waters – Defra project MF0231, Defra**:** 38.

Lester, S. E. and B. S. Halpern (2008). "Biological responses in marine no-take reserves versus partially protected areas." Mar Ecol Prog Ser **367**.

Levin, P. S., T. E. Essington, K. N. Marshall, L. E. Koehn, L. G. Anderson, A. Bundy, C. Carothers, F. Coleman, L. R. Gerber, J. H. Grabowski, E. Houde, O. P. Jensen, C. Möllmann, K. Rose, J. N. Sanchirico and A. D. M. Smith (2018). "Building effective fishery ecosystem plans." Marine Policy **92**: 48-57.

Lotz-Sisitka, H., A. E. J. Wals, D. Kronlid and D. McGarry (2015). "Transformative, transgressive social learning: rethinking higher education pedagogy in times of systemic global dysfunction." Current Opinion in Environmental Sustainability **16**: 73-80.

Lubchenco, J. and K. Grorud-Colvert (2015). "Making waves: The science and politics of ocean protection." Science **350**(6259): 382-383.

Mangi, S. C., L. D. Rodwell and C. Hattam (2011). "Assessing the Impacts of Establishing MPAs on Fishermen and Fish Merchants: The Case of Lyme Bay, UK." Ambio **40**(5): 457-468.

McNeill, A., J. Clifton and E. S. Harvey (2018). "Attitudes to a marine protected area are associated with perceived social impacts." Marine Policy **94**: 106-118.

MMO. (2016). "Guidance Fishing data collection, coverage, processing and revisions."   Retrieved January, 2016, from www.gov.uk/guidance/fishing-activity-and-landings-data-collection-and-processing.

MMO. (2019). "Current catch limits: 10 metres and under non-sector pool "   Retrieved April 2020, from https://www.gov.uk/government/publications/current-catch-limits-10-metres-and-under-pool.

Ostrom, E. (2009). "A General Framework for Analyzing Sustainability of Social-Ecological Systems." Science **325**(5939): 419-422.

Pollnac, R., P. Christie, J. E. Cinner, T. Dalton, T. M. Daw, G. E. Forrester, N. A. J. Graham and T. R. McClanahan (2010). "Marine reserves as linked social–ecological systems." Proceedings of the National Academy of Sciences **107**(43): 18262-18265.

Rees, S. E., M. Ashley, L. Evans, S. Mangi, L. Rodwell, M. Attrill, O. Langmead, E. Sheehan and A. Rees (2016). An evaluation framework to determine the impact of the Lyme Bay Marine Protected Area and the activities of the Lyme Bay Consultative Committee on ecosystem services and human wellbeing. A report to the Blue Marine Foundation by research staff the Marine Institute at Plymouth University, Exeter University and Cefas. Pp139.

Rees, S. E., M. J. Attrill, M. C. Austen, S. C. Mangi, J. P. Richards and L. D. Rodwell (2010). "Is there a win–win scenario for marine nature conservation? A case study of Lyme Bay, England." Ocean & Coastal Management **53**(3): 135-145.

Rees, S. E., S. C. Mangi, C. Hattam, S. C. Gall, L. D. Rodwell, F. J. Peckett and M. J. Attrill (2015). "The socio-economic effects of a Marine Protected Area on the ecosystem service of leisure and recreation." Marine Policy **62**: 144-152.

Rees, S. E., S. J. Pittman, N. Foster, O. Langmead, C. Griffiths, S. Fletcher, D. E. Johnson and M. Attrill (2018). "Bridging the divide: Social–ecological coherence in Marine Protected Area network design." Aquatic Conservation: Marine and Freshwater Ecosystems **28**(3): 754-763.

Rees, S. E., L. D. Rodwell, M. J. Attrill, M. C. Austen and S. C. Mangi (2010). "The value of marine biodiversity to the leisure and recreation industry and its application to marine spatial planning." Marine Policy **34**(5): 868-875.

Rees, S. E., E. V. Sheehan, B. D. Stewart, R. Clark, T. Appleby, M. J. Attrill, P. J. S. Jones, D. Johnson, N. Bradshaw, S. Pittman, J. Oates and J.-L. Solandt (2020). "Emerging themes to support ambitious UK marine biodiversity conservation." Marine Policy: 103864.

Rees, S. E., E. V. Sheehan, B. D. Stewart, R. Clark, T. Appleby, M. J. Attrill, P. J. S. Jones, D. Johnson, N. Bradshaw, S. Pittman and J. L. Solandt (2020). "Emerging themes to support ambitious marine biodiversity conservation." Marine Policy (In Press).

Sala, E., J. Lubchenco, K. Grorud-Colvert, C. Novelli, C. Roberts and U. R. Sumaila (2018). "Assessing real progress towards effective ocean protection." Marine Policy **91**: 11-13.

Scolding, J. W. S., C. A. Richardson and M. J. Luckenbach (2007). "Predation of cockles (Cerastoderma edule) by the whelk (Buccinum undatum) under laboratory conditions." Journal of Molluscan Studies **73**: 333-337.

628 Sheehan EV, Holmes L, Rees A, Cartwright A, Bridger D and A. MJ. (2020). "Rewilding enhances
629 resilience of marine ecosystems to extreme climatic events." Nature Communications **In prep.** .
630 Sheehan, E. V., S. L. Cousens, S. J. Nancollas, C. Stauss, J. Royle and M. J. Attrill (2013). "Drawing lines
631 at the sand: Evidence for functional vs. visual reef boundaries in temperate Marine Protected
632 Areas." Marine Pollution Bulletin **76**(1): 194-202.
633 Sheehan, E. V., T. F. Stevens, S. C. Gall, S. L. Cousens and M. J. Attrill (2013). "Recovery of a
634 Temperate Reef Assemblage in a Marine Protected Area following the Exclusion of Towed Demersal
635 Fishing." PLoS ONE **8**(12): e83883.
636 Solandt, J.-L., T. Mullier, S. Elliott and E. Sheehan (2019). Managing Marine Protected Areas in
637 Europe: Moving from 'feature-based' to 'whole-site' management of sites, Elsevier.
638 Stewart, B. D. and L. M. Howarth (2016). Chapter 14 - Quantifying and Managing the Ecosystem
639 Effects of Scallop Dredge Fisheries. Developments in Aquaculture and Fisheries Science. S. E.
640 Shumway and G. J. Parsons, Elsevier. **40:** 585-609.
641 UN General Assembly (2015). Transforming our world : the 2030 Agenda for Sustainable
642 Development, 21 October 2015, A/RES/70/1, available at:
643 https://www.refworld.org/docid/57b6e3e44.html [accessed 26 February 2020].
644 UNEP-WCMC, IUCN and NGS (2018). Protected Planet Report 2018 Cambridge UK; Gland,
645 Switzerland; and Washington, D.C., USA., UNEP-WCMC, IUCN and NGS**:** 70.
646 Urquhart, J. (2014). Introduction: Social Issues in Sustainable Fisheries Management. Social Issues in
647 Sustainable Fisheries Management. J. Urquhart, T. Acott, D. Symes and M. Zhao. Netherlands,
648 Springer 1-20.
649 Urquhart, J., D. Symes, T. Acott. and M. Zhao (2014). Social issues in sustainable fisheries
650 management, Springer.
651 van Putten, I. E., S. Kulmala, O. Thébaud, N. Dowling, K. G. Hamon, T. Hutton and S. Pascoe (2012).
652 "Theories and behavioural drivers underlying fleet dynamics models." Fish and Fisheries **13**(2): 216-
653 235.
654 Wells, S., G. C. Ray, K. M. Gjerde, A. T. White, N. Muthiga, J. E. Bezaury Creel, B. D. Causey, J.
655 McCormick-Ray, R. Salm, S. Gubbay, G. Kelleher and J. Reti (2016). "Building the future of MPAs –
656 lessons from history." Aquatic Conservation: Marine and Freshwater Ecosystems **26**(S2): 101-125.
657
658

659   9. **Tables**

660   Table 1 Range +/- between 3-year average pre SI closure (2004/05-2007/08 and the 3-year average >6years

661   post SI closure (2014/15-2016/17), significant monotonic trends (Kendall's tau-b) between 2004/05 and

662   2016/17 data are indicated by ***.**

Gear Category and Location	Wet weight mean per vessel per month (Kg)		Value per vessel per month (£)		Approximate number of vessels per month		Approximate number of trips per month by all vessels		Overall change across categories +/-
	2014-2017, 3-year average	Change over time 2005/08 to 2014/17	2014-2017, 3-year average	Change over time 2005/08 to 2014/17	2014-2017, 3-year average	Change over time 2005/08 to 2014/17	2014-2017, 3-year average	Change over time 2005/08 to 2014/17	
Static gear inside.	2851	-110	3739	**+1452***	36	**+7***	281	**+223***	+
Static gear outside.	1672	-391	3399	**+866***	52	+12	343	**+185***	+
Mobile gear inside.	0	-6381	0	-9960	0	-7	0	-52	-
Mobile gear outside.	5116	-7659	8144	2231	21	**+7***	144	**+99***	+

663

664   Table 2 Landings weight (kg) and value (£) associated with static gear fishing effort, most recent 3-

665   year average data in the time series (2014-17) are compared to the 3-year average before the SI

666   closure (2005-08) for gear types and associated non-quota species inside and outside the MPA.

Gear Category and Location	Non-Quota Species Included	Weight (kg)			Value (£)		
		2014-2017 Average	Change over time 2005/08 to 2014/17	% change	2014-2017 Average	Change over time 2005/08 to 2014/17	% change
Static gear inside the MPA							
Pots	Crab, Lobster	448	**178***	↑ 66%	1232	**628***	↑ 104%
Scuba Dive	Scallop	1008	**735***	↑ 177%	1874	**1507**	↑ 412%
Other Traps	Whelk, Cuttlefish	8268	-4803	↓ 37%	8456	**311**	↑ 4%
Nets	Lemon sole	58	**57***	↑ 5700%	291	**285***	↑ 4750%
Static gear outside the MPA							
Pots	Crab, Lobster	966	183	↑ 24%	2700	**909***	↑ 51%
Scuba Dive	Scallop	2459	-559	↓ 0.18%	3524	-2059	↓ 0.37%
Other Traps	Whelk, Cuttlefish	3955	-3714	↓ 0.48%	3798	-560	↑ 13%
Nets	Lemon sole	2	-93	↓ 98%	10	-364	↓ 97%

667 Table 3 Landings weight (kg) and value (£) associated with mobile demersal gear fishing effort, most

668 recent 3-year average data in the time series (2014-17) are compared to the 3-year average before

669 the SI closure (2005-08) for gear types and associated non-quota species inside and outside the

670 MPA, * indicates significant positive or negative trends.

Gear Category and Location	Non-Quota Species Included	Weight (kg)			Value (£)		
		2014-2017 Average	Change over time 2005/08 to 2014/17	% change	2014-2017 Average	Change over time 2005/08 to 2014/17	% change
Mobile gear inside the MPA							
Scallop dredge	Scallop	0	-7705	↓ 100%	0	**-11479***	↓ 100%
Trawl / mobile nets	Lemon sole	0	-22	↓ 100%	0	**-121***	↓ 100%
Trawl	Cuttlefish	0	-365	↓ 100%	0	**-442***	↓ 100%
Trap	Whelk	0	-6	↓ 100%	0	-3	↓ 100%
Mobile gear outside the MPA							
Scallop dredge	Scallop	3889	1540	↑ 65%	8216	**4717***	↑ 136%
Trawl / mobile nets	Lemon sole	357	**308***	↑ 628%	1587	**1362***	↑ 605%
Trawl	Cuttlefish	689	469	↑ 213%	1586	1315	↑ 485%
Trap	Whelk	839	830	↑ 9222%	810	800	↑ 7900%

671

672 Table 2 Past and future investment in the fishing industry, and sales strategy for static-gear fishers

673 involved in the Lyme Bay Consultative Committee (Static Y), static gear fishers not involved in LBCC

674 (Static N) and mobile demersal gear fishers.

	Objective wellbeing metrics	Static (Y)	Static (N)	Mobile
Investment	Proportion of respondents who have invested previously	100%	75%	80%
	Proportion of respondents with plans to invest in the next five years	20%	50%	50%
	Average confidence that future investment will be beneficial (score 0-10 with 10 being extremely high confidence)	8.0/10	6.5/10	7.1/10
Sales strategy	Reserve Seafood brand	15%		
	Local shops and restaurants	38%	22%	5%
	Processors / auctions	47%	78%	95%

675

676   **10. Figure legends**

677   Figure 1 The Lyme Bay Marine Protected Area (MPA) comprising of the Statutory Instrument - The

678   Lyme Bay Designated Area (Fishing Restrictions Order) and the European Union Habitats Directive

679   92/43/EEC Special Area of Conservation.

680   Figure 2 Number of vessels per month (mean) and Number of trips per month (mean) actively fishing

681   inside and outside the Lyme Bay MPA for a) static gear inside the MPA b) mobile demersal gear inside

682   the MPA c) static gear outside the MPA d) mobile gear outside the MPA.

683   Figure 3: Wet weight of landings (kg) and value of landings (£) per vessel per month for a) static gear

684   vessels fishing inside the MPA, b) mobile demersal gear vessels fishing inside the MPA, c) static gear

685   vessels fishing outside the MPA and d) mobile demersal gear vessels fishing outside the MPA.

686   Figure 4: Fishers' subjective wellbeing over time a) job satisfaction, b) income satisfaction, C)

687   perceived levels of stress and d) perceived levels of conflict. Static Y = fishers using static gear who are

688   involved in the Lyme Bay Consultative Committee partnership. Static N = fishers using static gear who

689   are not involved in the LBCC partnership. Mobile = fishers using mobile demersal gears who are not

690   involved in the LBCC partnership (with the exception of one respondent).

691

692

693

694

695