Assessment of the sustainability on the emerging live wrasse fishery in the South West UK.

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Highlights

- There has been no statistically significant change in Catch per Unit Effort of wrasse between the baseline 2017 and 2018.
- Seasonal and interspecific variations in CPUE were observed despite month and year having no statistically significant effect on wrasse abundance or composition.
- Wrasse abundance and assemblage composition changed significantly with location.
- The use of underwater video can provide additional information than that obtained by surveys alone, thus aiding calculations and standardization of CPUE.

Abstract

Fisheries catch per unit effort (CPUE) is regularly used to determine the status of many commercially important fisheries, and is currently used within the live wrasse fishery in order to monitor local wrasse abundance. However, using relative abundance indices based on CPUE can be ambiguous as several factors such as trap saturation can affect catch rates. This study investigates whether wrasse traps saturate and examines trends in CPUE since baseline. Underwater video was used to calculate three relative abundance indices (MaxN, MeanN and MeanCount). These were compared to each other for the use of abundance estimates and assemblage composition between two locations. CPUE showed no decline during the time period sampled, with no significant effect of month or year on abundance, assemblage composition or size. Location and the three methods of calculating relative abundance had significant effects on abundance and assemblage composition with a significant interaction between both factors. In Plymouth significant differences were detected between all video indices for relative abundance and assemblage composition. However only differences between MeanN and MeanCount were observed for Torbay. The relative abundance of wrasse based on the index MaxN was more than double in Plymouth than Torbay with location having a significant effect on abundance and assemblage composition. The use of underwater video in addition to trap surveys may therefore provide additional information that can be integrated into relative abundance indices in order to provide more abundance estimates and ultimately, more effective management.

Keywords: Catch per Unit Effort, relative abundance index, MaxN, trap saturation, wrasse fishery

1. Introduction

The Atlantic salmon aquaculture industry is a major sector in finfish aquaculture with Scotland being one of the top three producers of Atlantic salmon globally, producing 162.817 tonnes equal to a value of £765 million in 2016 (Kenyon and Davies 2018). However, sea lice infestation is a major challenge and threat to their sustainability and development (Salama et al., 2017). The two most common species of sea lice, *Lepeophtheirus salmonis* and *Caligus elongates* are ectoparasites that attach to and feed on the mucus and skin of the host salmon (Pike and Wadsworth 2000). This results in the formation of lesions which can cause considerable body fluid loss and eventually death, if the infestation is not managed. Salmon farmers face annual costs in the region of €38 million and significant economic impacts from production loss (Costello Mark 2009; Powell et al., 2017). Traditional methods of sea lice control involve the use of pesticides, administered orally or through a bath treatment (Tully et al., 1996; Treasurer and Grant 1997). However, these chemical treatments can pose a health risk to farm staff (Bruno and Raynard 1994), have detrimental impacts on the environment and subsequent marine organisms (Tucca et al., 2014) and treatments are becoming less effective due to evolved resistance (Jones et al., 2013; Besnier et al., 2014). Therefore, new alternatives to seal lice control have been considered, predominately the biological method of using cleaner fish, such as wrasse (Tully et al., 1996; Powell et al., 2017).

The wrasse family (Teleostei: Labridae) is a large and widely distributed group of marine fishes, found in both tropical and temperate seas (Darwall et al., 1992a). Wrasse display a wide variety of life history strategies, making them one of the most ecologically and morphologically diverse fish families (Lek et al., 2018). The first observations of European wrasse cleaning behaviour was made in 1973 and 1983 (Darwall et al., 1992b). This lead to trials being conducted in Norway in 1987 by Bjordal who identified the use of wrasse to control parasites in European salmonid aquaculture (Bjordal 1988; Darwall et al., 1992b). As a result, a commercial fishery targeting live wrasse began in 1988 in Norway, 1989 in Scotland and 1990 in England and Ireland (Darwall et al., 1992b; Skiftesvik et al., 2014a). The majority of UK salmon farms are located in Scotland and initially only used locally caught wrasse. However, due to shorter fishing seasons as a result of cooler waters, potential depletion of local populations (Riley et al., 2017) and a recommended wrasse to salmon ratio of 1:20 (or 5%) (Skiftesvik et al., 2013), local supply was not meeting demand. Wrasse are therefore being sourced from outside local areas, particularly from southwest England due to warmer sea temperatures providing a longer fishing season (Riley et al., 2017).

Fishing for live wrasse began in southwest England in 2015, with wrasse being caught in Dorset, Devon and Cornwall and transported to Scottish salmon farms (Davies 2016). Four species of wrasse are targeted within the fishery, being, goldsinny (*Ctenolabrus rupestris*), corkwing (*Crenilabrus melopsI*), ballan (*Labrus bergylta*), and rock cook (*Centrolabrus exoletus*). Additionally cuckoo wrasse (*Labrus mixtus*) are caught but not retained. Concerns within the scientific community have been raised over the ecological impacts of targeting wild wrasse (Skiftesvik et al., 2014; Halvorsen et al., 2016). Due to specialised life history traits, such as, sexual dimorphism, territoriality, small home ranges, nest building and parental care (Darwall et al., 1992a; Halvorsen et al., 2016), these species may be vulnerable to overexploitation. For example, previous studies conducted in Ireland have shown declines in Catch per Unit Effort (CPUE) within two years, attributed to reduced local wrasse abundance (Darwall et al., 1992a).

In Devon, four commercial vessels targeting wrasse, operate within Plymouth Sound and the surrounding coastal waters between July to November (Davies and Ross 2017). Due to the complex nature of the fishery and in order to ensure its sustainability, Devon and Severn Inshore Fisheries and Conservation Authority (D&S IFCA) implemented management measures in 2017, through the potting byelaw conditions. These include, a limit of 120 pots per vessel, minimum and maximum conservation size references for landings, temporal and spatial closures, and have a fully documented fishery (Clarke and Townsend 2017). As part of the fully documented fishery, it is compulsory for fishermen to complete a logbook of catches and additional onboard observer surveys are carried out. These data aim to capture trends in CPUE allowing D&S IFCA to monitor local wrasse abundance in order to implement effective management measures (Ross, 2016).

However, if catches during the surveys are highly variable or there are insufficient sample sizes, significant changes in abundance over time may go undetected due to a lack of sampling power (Cappo et al., 2003; Bacheler et al., 2013b). Therefore, independent survey data may benefit from the addition of underwater video as it can help determine if low or zero catches in a trap is due to either fish being absent from the surrounding habitat or present around the trap but not caught (Bacheler et al., 2013b). In addition, using relative abundance indices based on CPUE can be ambiguous (Maunder et al., 2006). A key assumption of CPUE is that the catchability coefficient (*q*) or efficiency of the gear is constant over time, space and environmental variables (Bacheler et al., 2013a).

This may be true for mobile fishing gear due to shorter fishing periods and adequate space for organisms to accumulate (Ragonese et al., 2001). In the live wrasse fishery, traps are used as this is the most effective means of catching reef associated fish. Traps also have minimal impact on the surrounding habitat and benthic community (Shertzer *et al.,* 2016). Therefore, catch rates are more likely to be inconsistent, as soak times can vary from hours to days and space within a trap is limited (Bacheler et al., 2013a). Consequently, catch rates can decline with soak time, known as catch/trap saturation (Bacheler et al., 2013a; Shertzer et al., 2016). This can result in a catch that relates non-linearly to local abundance, reducing the accuracy and reliability of CPUE estimates (Harley et al., 2001; Li et al., 2011; Shertzer et al., 2016).

Previous studies have identified various factors that contribute to saturation. These include, space limitation (Bacheler et al., 2013), inter and intraspecific agonistic behaviour (Jury et al., 2001), loss or degradation of bait through consumption and gear avoidance (Bacheler et al., 2013; Shertzer et al., 2016), and entry and exit rates (Bacheler et al., 2013a; Cole et al., 2004). Whilst these studies indicate trap saturation does occur within finfish fisheries, to date, no trap saturation data has been collected in the live wrasse fishery.

The first objective was to establish whether wrasse traps saturate and compare CPUE between 2017 and 2018. Analysis focused on three response variables: assemblage composition, abundance and size category, split into juveniles and adults. The second objective was to assess how representative CPUE is of wrasse abundance by using underwater video cameras to calculate the MaxN, MeanN and MeanCount. A final objective was to compare the estimated abundance and assemblage of wrasse between two locations, based on three relative abundance indices calculated from video footage. For the purpose of this study when comparing the data, 2017 is defined as the baseline.

Methods

2.1. Study site one

The study took place within Plymouth sound and the surrounding coastal area. Plymouth sound is a bay on the English Channel, located in Plymouth, Devon, on the south west coast (Figure 1). The English Channel to the south provides the marine input, with two freshwater inputs from the River Tamer to the northwest and the River Plym from the northeast. Due to its high diversity of reef and sedimentary habitats it has been designated a Special Area of Conservation (SAC).

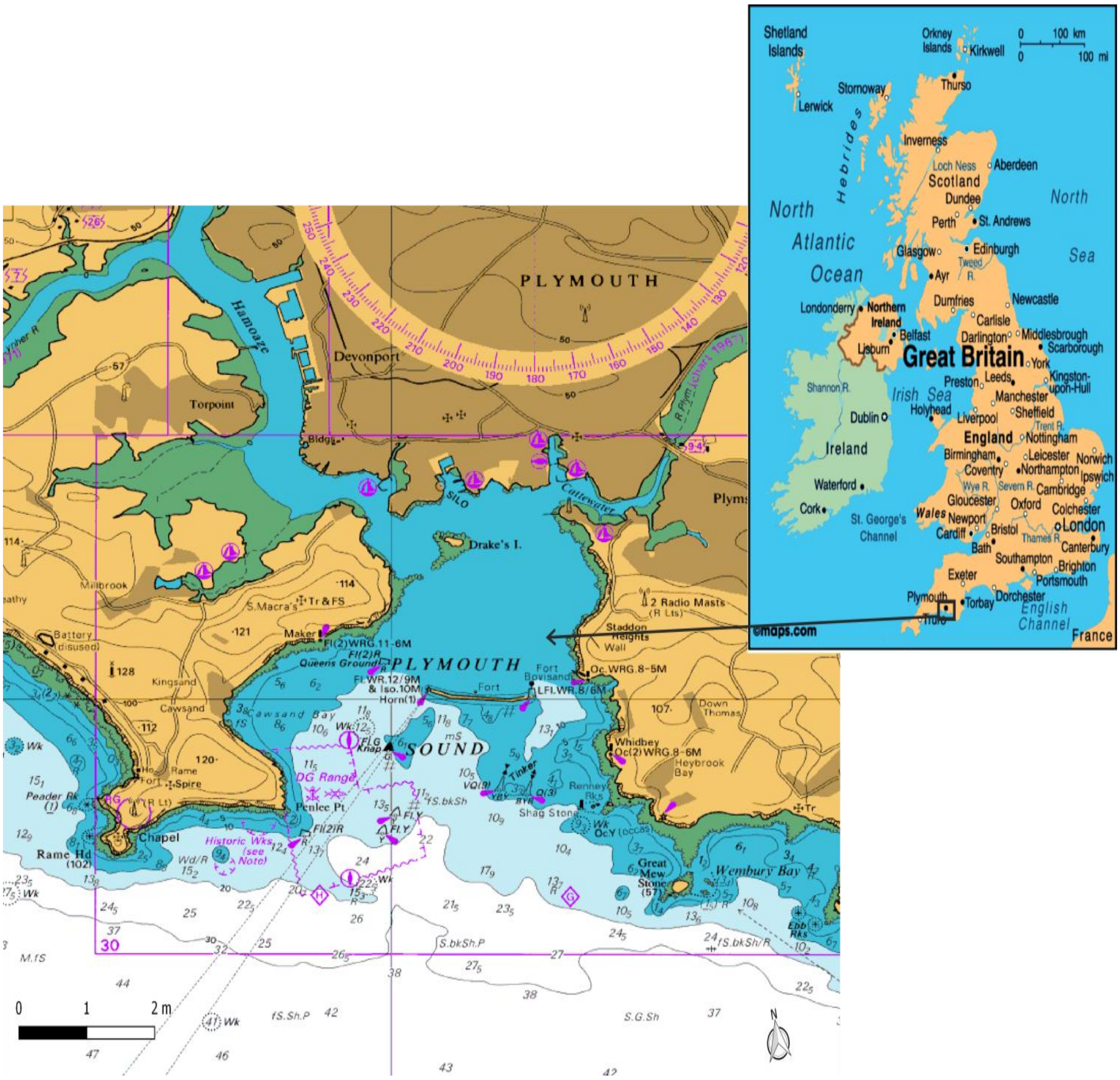

Figure 1. Map of Plymouth Sound located in South Devon UK

2.2. Sampling techniques

Nine sampling locations were selected at random based from the 2017 fishing and survey locations (Figure 2 and Table 1). A minimum distance of 200 m between locations was chosen in order to avoid catches from one string affecting the catches in another sting. Sampling was carried out between May to July 2018 onboard a vessel currently operating within the D&S IFCA district. Strings were deployed in sets, with 19 wrasse traps along the same connecting bottom line, defined as one string. Traps were attached to the string at a spacing of 9 m. One string was deployed at each sampling station at a depth between 6-10 m. Traps were baited with approximately 170 g of brown crab and left to soak for a period of 24 hours.

Table 1. Location (latitude and longitude) of the nine sampling stations located within Plymouth Sound.

Sampling station	Latitude (N)	Longitude (W)
1	50 19.939	004 08.220
2	50 20.053	004 07.397
3	50 19.677	004 07.540
4	50 19.936	004 07.551
5	50 18.818	004 06.684
6	50 19.561	004 07.516
7	50 18.685	004 06.211
8	50 19.421	004 07.501
9	50 19.525	004 07.512

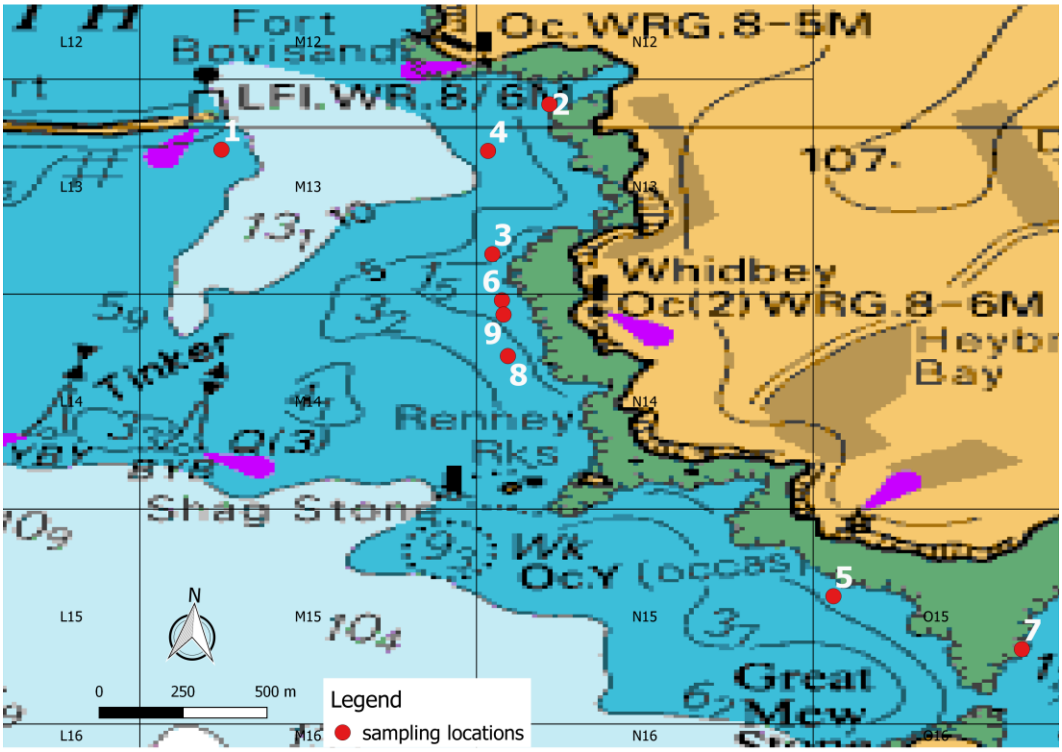

Figure 2. Map of study area one showing where the 9 sampling stations are located within Plymouth Sound.

Wrasse traps are composed of small mesh netting with a self-closable parlour entrance; each trap is 72 cm in length, 40 cm wide and 28 cm high and weighs around 3.7 kg (Figure 3). The traps have escape gaps fitted to reduce the numbers of undersized individuals retained in the parlour (Figure 3). Strings were fitted with surface buoys marked with the vessel port letter and number. The start and end position of each string, weather, start and end time, date and tide times were recorded. Wrasse catches were identified to species level, measured, sex identified where possible and signs of spawning (the presence of milt, eggs and colouration patterns) were recorded.

Figure 3. Carapax wrasse trap and escape gap for undersized individuals to escape

Underwater video cameras were affixed to trap number 18 on each string. In this study high definition Go-Pro Hero® video cameras were contained in underwater housings and positioned over the mouth and escape gaps of the trap, so that all entrance and exit points could be observed (Figure 4). In addition, trap 19 on each string was fitted with two cameras facing away from the trap in order to obtain counts on the abundance of the population. Due to the small size of the fishing vessel, traps fitted with cameras were standardized to allow for camera set up prior to trap deployment. Cameras were turned on and set to record prior to deployment and left to continuously run during the 24 hour soak period. Data collected from the video cameras varied due to the different Go-Pro Hero® models used but obtained between 3-4 hours of footage.

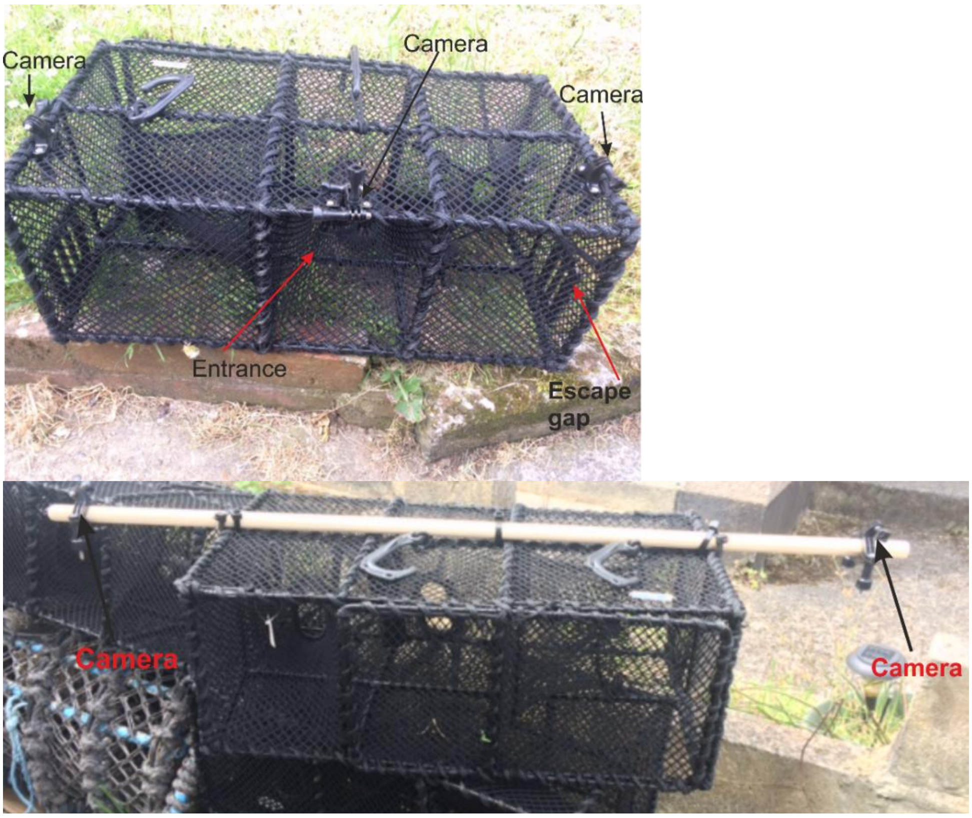

Figure 4. Picture of wrasse trap video set up. The design allows for entries, exits and movements around the traps to be recorded.

2.3. Study site two.

In order to obtain data from a control site, three sites in and around Brixham with a rocky reef habitat and three sites within the eelgrass beds at Broadsands were sampled (Figure 5).

One wrasse trap was deployed in each location and left to soak for 4 hours (total recording time of the cameras). Traps were baited with 170 g of brown crab and the video camera set up was identical to that of the Plymouth sampling stations. One adjustment was made in having one less camera facing away from the trap. This resulted in having a consistent model of Go-Pro Hero® on the traps and maximized the amount of video footage captured.

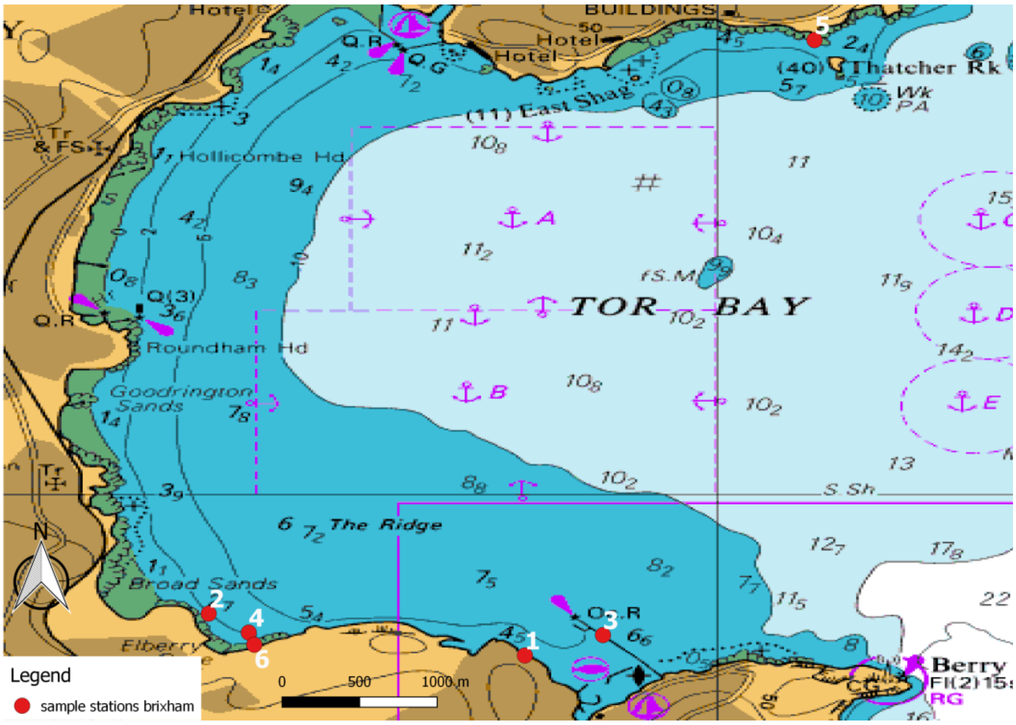

Figure 5. Map of Torbay showing the location of the six sampling stations. Sample stations 1, 3 and 5 being rocky reef habitats and stations 2, 4 and 6 being eelgrass.

2.4. Video analysis

A total of 54 videos from Plymouth sound were included in the analysis totalling 152 hours. The time the trap landed on the seabed and time of trap retrieval was recorded. Soak time was defined as the time passed between the wrasse pot landing on the seabed to the time when pot retrieval began. The number of entries and exits for each string were recorded at 30 minute time intervals up to a maximum of 120 minutes and then 60 minute intervals up to 300 minutes. Each individual wrasse must have crossed its entire body past the plane of the trap mouth opening or escape gap in order to constitute an entry or exit (Figure 6a). Exit rates were calculated as the proportion of fish entering that ultimately exited.

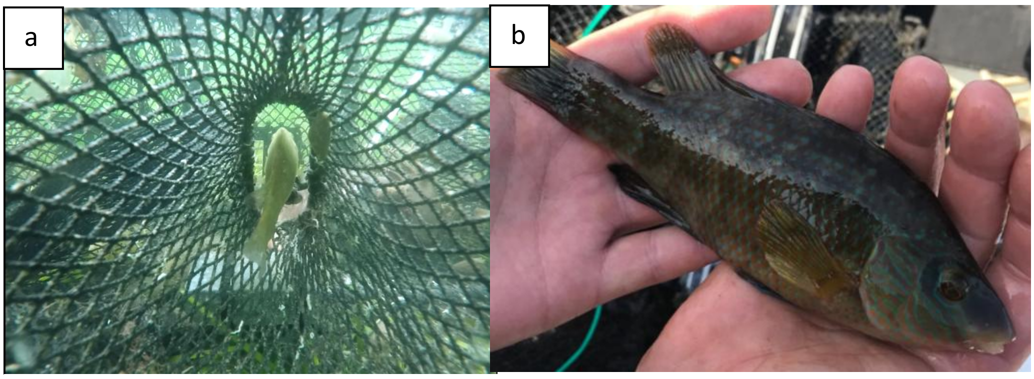

Figure 6. a). Still image from the underwater video camera showing wrasse trap mouth opening used to quantify entry rates. b). Picture taken of corking wrasse caught in the trap

One video out of two was randomly selected from the Plymouth sites in order for data to be comparable to Torbay. Relative abundance of individual wrasse species from videos was estimated using the metrics MaxN, MeanN and MeanCount. MaxN was calculated as the maximum number of individual wrasse visible at any point during 5 minute intervals over 160 minutes. MeanN was calculated as the mean MaxN from 5 minute periods throughout the 160 minute time interval. The average number of individual wrasse species in 32 video frames (5 minute snapshots over 160 minutes) were also integrated and used as the MeanCount. For a single video *v*, the MeanCount of a species across a frame was defined using the following equation;

$$MeanCount = n_f / F$$

Where n_f is the number of individuals observed in frame *f* and F is the total number of frames read.

2.5. Data Analysis

Catch per Unit Effort (CPUE) was calculated in MS excel using the survey data collected during the sampling period and additional onboard observer survey data obtained during 2017 and collected in August 2018. This data includes both fish above and below the minimum/maximum conservation size references.

CPUE was calculated using the following formula:

$$CPUE = Ct / Et$$

Where Ct is catch C, during time period t, and Et is Effort, E measured by the number of pots hauled during time period t.

2.6. Statistical analyses

As data was zero inflated, all statistical analysis was performed in PRIMER version 6.1.6 (www.primer-e-.com). Permutational analysis of variance (PERMANOVA) was preferred as it is deemed a distribution-free nonparametric test (Anderson, 2001).

2.6.1. CPUE data

To test the hypothesis that abundance and assemblage composition of wrasse differed between months and years, I used a PERMANOVA based on the Bray-Curtis similarity index for assemblage structure and Euclidean distance for abundance, permuted 9,999 times (Clarke and Warwick 1998). 'Similarity Percentages' (SIMPER) assessed the species influential in causing similarity among plots within treatments and dissimilarity among different treatments (Clarke and Warwick 1998). Non-metric multi-dimensional scaling (MDS) (Kruskal and Wish 1978) was used to graphically represent trends in multivariate data. In order to test for effects of month and year on the size class of wrasse, catches from Plymouth were first categorised into two size classes, juveniles and adults. Individuals under 15cm for Ballan and 12cm for all other species were classed as juveniles as per the minimum conservation size references. Catches within each size class were then transformed into CPUE and a PERMANOVA based on the Bray-Curtis similarity index and permuted 9,999 times was used to test for significant effects.

2.6.2. Video data

Permutational multivariate analysis of variance (PERMANOVA) was used to assess whether relative abundance metric and location had a significant effect on assemblage composition and abundance. Post-hoc pairwise tests then determined where differences existed between the levels within factors. Non-metric multi-dimensional scaling (MDS) (Kruskal and Wish 1978) was used to graphically represent similarities between groups.

3. Results

3.1. Pot saturation

After analysis of the video footage, there was insufficient data to establish whether wrasse traps saturate. There were minimal entries and exits recorded during each deployment (Table 2).

Table 2. Station level information for each of the strings included in the analysis of entry and exit rates of wrasse for traps deployed in Plymouth Sound.

Sample Station	Soak time (Hrs)	Total catch	Total entries	Total exits
1	24	10	1	0
2	24	18	0	0
3	24	18	0	0
4	24	26	0	0
5	24	10	0	0
6	24	9	1	1
7	24	7	1	0
8	24	28	1	1
9	24	27	1	0

This may have been due to a number of reasons, including the size and positioning of the underwater housing for the cameras, lights on the camera display deterring wrasse, and a general lack of wrasse in the local area possibly attributed to sampling occurring during the spawning period and at the start of the fishing season. For the purpose of this study these results have been removed from further analysis.

3.2 Catch per Unit Effort

Based on the surveys conducted in Plymouth, Catch per Unit Effort (CPUE) in 2017 consistently increased during June, July and August. An initial increase can be seen in 2018 during June and July, followed by a decline in August (Figure 7). June shows similar levels of CPUE between 2017 and 2018 superseded by an increase during July and August. PERMANOVA test on the Euclidean distance matrices indicated no significant effect of month (df=2, F=4.637, p=0.236) or year (df=1, F=2.1849, p=0.3084) on the abundance of wrasse.

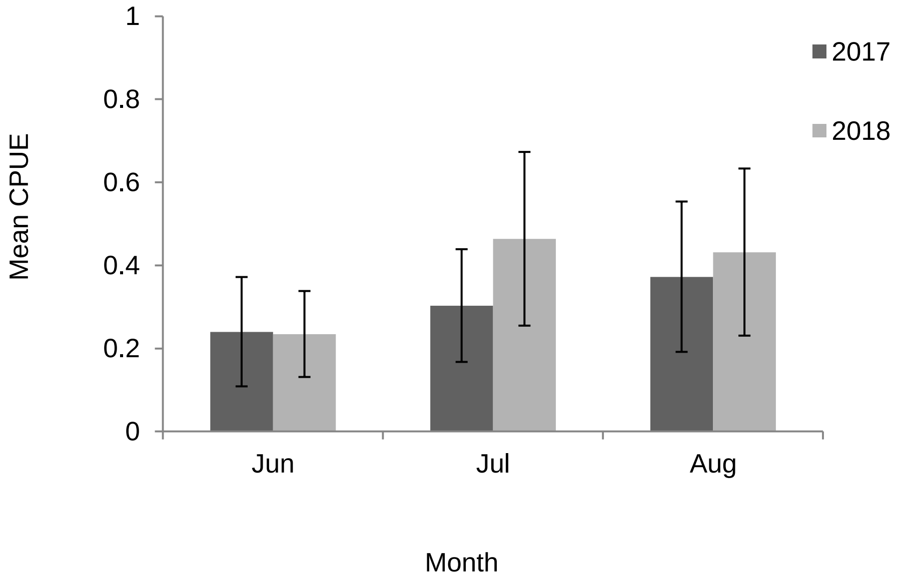

Figure 7. CPUE across June, July and August 2017 and 2018 based on data collected from onboard observer surveys (Mean ± SE).

Catch per Unit Effort (CPUE) in Plymouth remains consistently low across both years for ballan wrasse and cuckoo from June to August. The CPUE for corkwing shows a similar pattern across both years in that it increases slightly from June to August (figure 8). The MDS plot (Figure 9) highlights the insignificance of years in the assemblage composition of wrasse and indicates some similarity between months. Despite this, PERMANOVA highlighted no significant difference in the assemblage composition of wrasse between months (df=2, -*F*=3.7619, *p*=0.0963) and years (df=1, *F*=0.33797, *p*=0.8004). SIMPER highlighted the most influential species driving variations in the assemblage structure of wrasse between months and years as rock cook and goldsinny (Table 3) which coincides with a notable fluctuation in CPUE for these species between June to August (Figure 8).

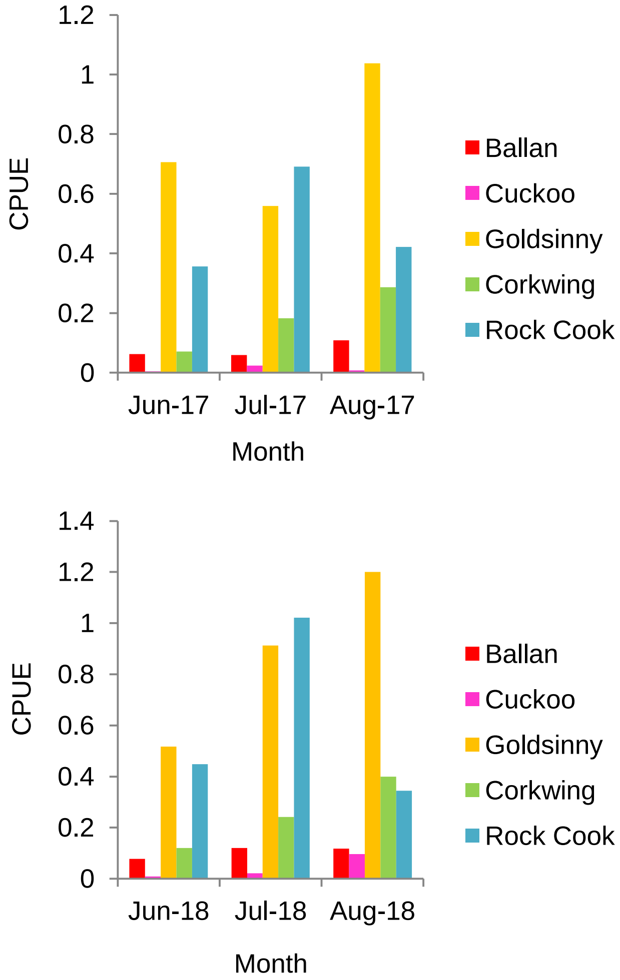

Figure 8. Assemblage composition of CPUE between June to August and 2017-2018

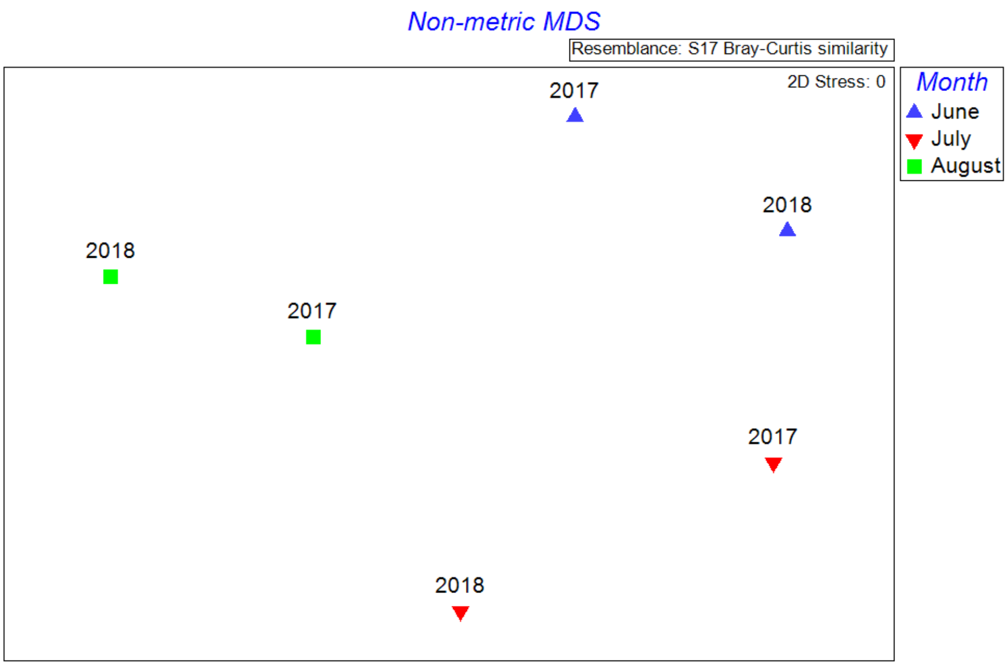

Figure 9. Bray Curtis based non-metric multidimensional scaling (nMDS) ordination illustrating similarities in assemblage composition based on months and years.

In 2017 notably more adults were caught in Plymouth during June and July (74% and 58% of the total catch respectively), with a decline seen in August to 35%. In contrast to this a higher percentage of juveniles were caught during June (74%), July (78%) and August (64%) in 2018. Despite these differences PERMANOVA indicated no significant effect of year (df=1, *F*=4.6101, *p*=0.2283) or month (df=2, F=2.2872, *p*=0.3916) in juveniles and no significant effect of year (df=1, *F*=1.6984 *p*=0.3765) or month (df=2, *F*=0.12208, *p*=0.9271) in adults. It should noted however that size class was only split between two categories based on current minimum conservation size references and is not species specific.

Table 3. SIMPER analysis of the most influential species (in bold) contributing to differences in assemblage composition between months and years.

Mean abundance	June	0.4	**0.61**	0.1	0.07	0.01
	July	**0.86**	0.74	0.21	0.09	0.02
% contribution to dissimilarity		**51.75**	**30.11**	13.65	2.49	1.99
Mean abundance	June	0.4	**0.61**	0.1	0.07	0.01
	August	0.38	**1.12**	0.34	0.11	0.05
% contribution to dissimilarity		9.12	**54.51**	**26.85**	4.67	4.86
Mean abundance	July	**0.86**	0.74	0.21	0.09	0.02
	August	0.38	**1.12**	0.34	0.11	0.05
% contribution to dissimilarity		**42.8**	**38.16**	12.25	3.95	2.84
Mean abundance	2017	0.49	**0.77**	0.18	0.08	0.01
	2018	0.6	**0.88**	0.25	0.11	0.04
% contribution to dissimilarity		**30.64**	**45.08**	13.79	5.28	5.21

3.3. CPUE representative to abundance

Catch per Unit effort was calculated for the total catch during the sampling period period May to July Plymouth. This was compared to MeanN and MeanCount, to assess how relative CPUE is to abundance. There were instances where either some wrasse species were caught in traps but not seen on the video footage or seen on videos but not caught in the traps. This may be due to the limited video footage available as cameras were only attached to one trap out of nineteen. Table 4 indicates that CPUE may not be representative of abundance for goldsinny, cuckoo and ballan with MeanN and MeanCount calculating higher means for these species. Overall it would appear that the metric MeanN may be a more accurate relative abundance index compared to CPUE.

Table 4. Mean catch, catch per unit effort, MaxN, MeanN and MeanCount calculated for total catch during the sampling surveys in Plymouth. MaxN, MeanN and MeanCount calculated using video data.

	Goldsinny	**Cuckoo**	**Rock Cook**	**Corkwing**	**Ballan**	**Total**
Mean catch	8.44	0.38	5.78	2.00	0.44	17.04
CPUE	0.46	0.02	0.31	0.11	0.02	0.00
MaxN	18.00	19.00	5.00	1.00	10.00	53.00
MeanN	3.88	2.13	0.31	0.03	0.84	7.19
MeanCount	0.34	0.47	0.00	0.00	0.03	0.84

3.3. Abundance and composition between locations

The relative abundance index MaxN was used to estimate mean wrasse abundance in Plymouth and Torbay. This index is based on the maximum number of individual wrasse visible at any point during 5 minute video intervals over 160 minutes. Based on this index mean abundance was more than 2.5 times higher in Plymouth than Torbay (Figure 10) with location having a significant effect on abundance (df=1, F=9.1071, p=0.0103) and assemblage composition (df=1, F=5.68, p=0.0023) in the PERMANOVA analysis. The dissimilarity in assemblage composition between locations is illustrated by the clear separation of the two locations in the MDS plot (Figure 11). This analysis is based purely on estimates and does not use any catch data. In addition the two locations consist of different habitats and are therefore do not reflect a direct comparison.

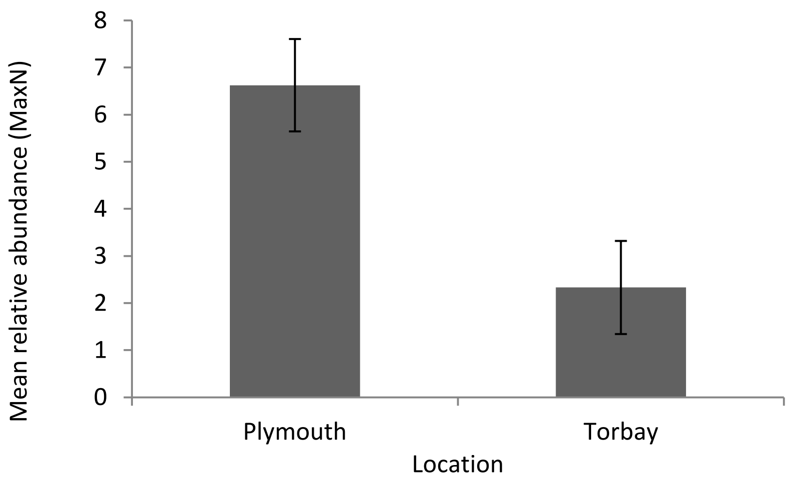

Figure 10. Relative abundance of wrasse based on MaxN for Plymouth and Torbay (Mean ± SE).

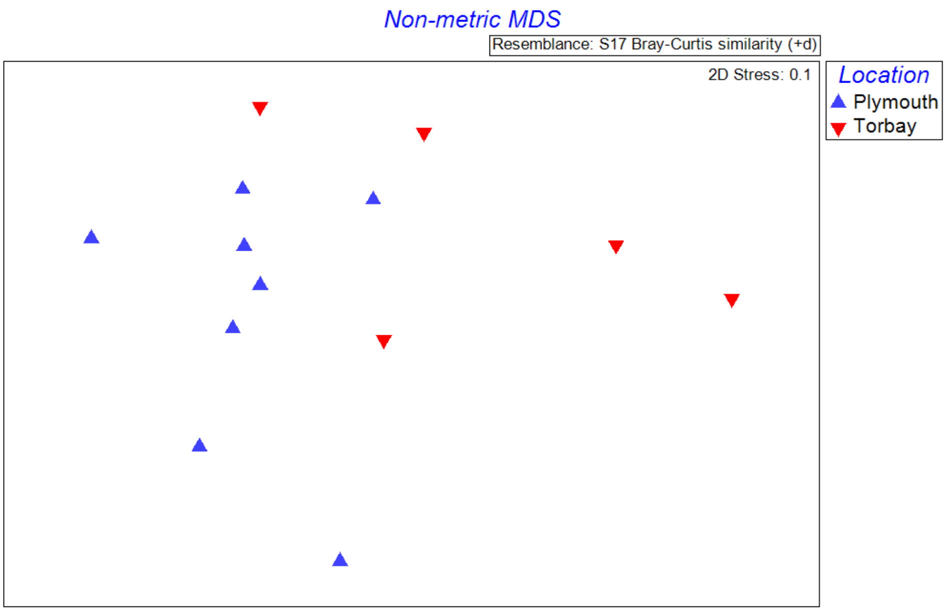

Figure 11. Bray Curtis based non-metric multidimensional scaling (nMDS) ordination illustrating similarities in assemblage composition based on MaxN between locations.

When comparing the three relative abundance indices in each location, PERMANOVA analysis highlighted significant differences in abundance and assemblage composition of wrasse between index used and location, with significant interactions existing between both factors (Table 5). Pairwise tests revealed that assemblage composition and abundance of wrasse in Plymouth differed significantly between all indices used, whereas composition and abundance in Torbay only showed significant differences between the indices MeanN and MeanCount (Table 5). Assemblage composition using the index MaxN and MeanN were significantly lower in Torbay than Plymouth. Abundance based on MaxN and MeanCount were significantly lower in Torbay than Plymouth (Table 5). The nMDS plot (Figure 12) illustrates how the assemblage composition differs between location and indices used.

Table 5. (a) PERMANOVA analysis comparing wrasse abundance and assemblage composition between location and relative abundance index used. (b) Post-hoc pairwise comparisons of location and video index groupings. Significant *p*- values are shown in bold.

(a) Main test	**Factor**	**Df**	**Sum Sq**	**MS**	**Pseudo-F**	**P(perm)**
All video indices						
Assemblage	Index	2	22006	11003	21.625	**0.0001**
	Location	1	4261.5	4261.5	8.3752	**0.0001**
	Index*Location	2	3099.5	1549.7	3.0457	**0.0072**
Abundance	Index	2	182.35	91.173	36.578	**0.0001**
	Location	1	25.715	25.715	10.317	**0.0017**
	Index*Location	2	37.901	18.951	7.6029	**0.0014**
(b) Pairwise tests assemblage	**Group 1**	**Group 2**	**t**	**P**		
Plymouth	MaxN	MeanN	4.224	**0.0002**		
	MaxN	MeanCount	6.7088	**0.0001**		
	MeanN	MeanCount	2.3382	**0.0025**		
Torbay	MaxN	MeanN	1.3414	0.1836		
	MaxN	MeanCount	2.3936	0.0586		
	MeanN	MeanCount	1.7231	**0.0139**		
MaxN	Plymouth	Torbay	2.3833	**0.0024**		
MeanN	Plymouth	Torbay	1.7306	**0.008**		
MeanCount	Plymouth	Torbay	1.815	0.568		
Pairwse tests abundance						
Plymouth	MaxN	MeanN	5.6171	**0.0001**		
	MaxN	MeanCount	6.6433	**0.0002**		
	MeanN	MeanCount	2.8328	**0.0014**		
Torbay	MaxN	MeanN	1.7494	0.1387		
	MaxN	MeanCount	2.349	0.0615		
	MeanN	MeanCount	1.9912	**0.0253**		
MaxN	Plymouth	Torbay	3.0178	**0.0115**		
MeanN	Plymouth	Torbay	0.90025	0.3833		
MeanCount	Plymouth	Torbay	2.454	**0.0394**		

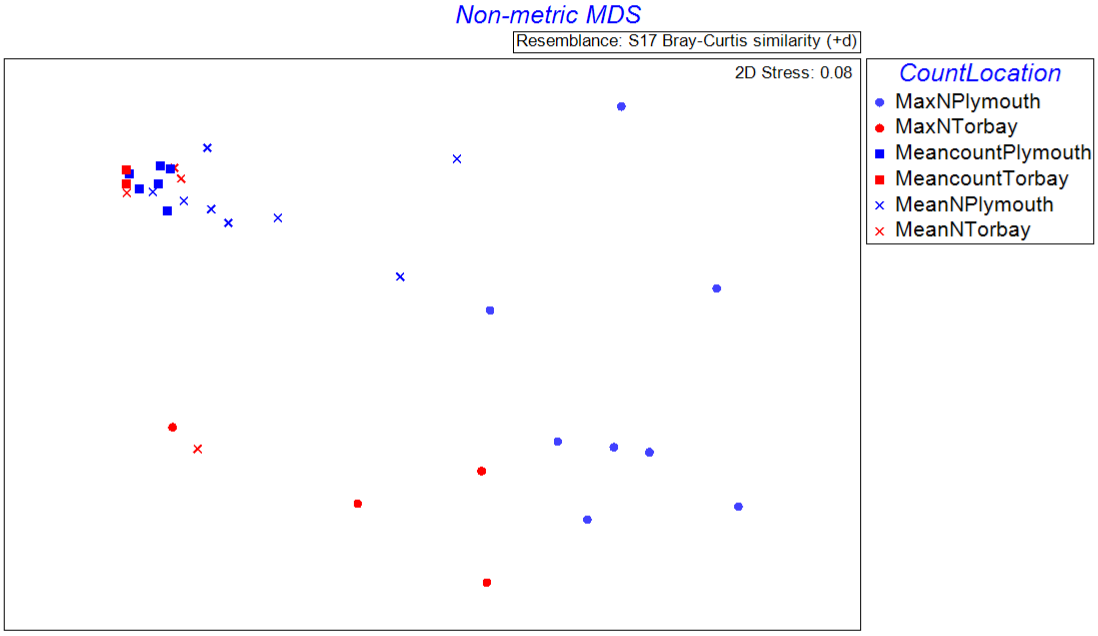

Figure 12. Non-metric multidimensional scaling (nMDS) ordination illustrating similarities in assemblage composition between video metric and location.

4. Discussion

4.1. Comparison of CPUE from 2017-2018.

Fishery independent and dependant data play a major role in fisheries assessment and management as they are used to create the relative abundance index CPUE that is assumed to be proportional to the actual abundance of a population (Bacheler et al., 2013b; Maunder et al., 2006). However several studies have shown that the use of CPUE indices in isolation can be problematic as several factors can influence the relationship between CPUE and true abundance (Harley et al.,2001; Maunder et al., 2006; Tsuboi and Endou 2008). It was not possible to establish whether wrasse traps saturate due to limitations of the data, however my results indicate that there has been no consistent decline in CPUE since 2017. Total CPUE (across the three months) in Plymouth has increased by 23.36%. This elevation in CPUE could be attributed to various factors. One explanation is that catchability has increased due to increased efficiency of fishers. Increased efficiency can be due to fishers learning more since 2017 about the behaviour and location of wrasse (Maunder et al., 2006; Phillips, 1983). An additional explanation is as a consequence of wrasse moving into areas of preferred habitat as others are removed through harvest, resulting in areas of high catch rates and consequently misleading increases in CPUE (Ward et al., 2013). This has been shown for several commercial and recreational fisheries but is more prevalent where spawning aggregations are found (Erisman et al 2011; Rose and Kulka 1999). Non-territorial individuals of goldsinny have been reported to aggregate in shoals during the spawning season and rock cook have been observed leaving their territories after spawning to aggregate in shoals (Thangstad, 1999). These species primarily spawn from May to June, with reports of rock cook spawning until August (Matland, 2015; Skiftesvik et al., 2014b). This type of behaviour could also explain why these two species were the most influential in driving variations in assemblage composition between months. This increase is in contrast to previous studies (Darwall et al., 1992a) that found a decline in CPUE within two years in a wrasse fishery in Ireland. It should be noted that this study is comparing the first year to baseline. Therefore, continual monitoring of CPUE should be carried over the next year in order to determine long term trends in CPUE.

4.2. Assemblage composition of wrasse in Plymouth

Although month had no significant effect on CPUE or assemblage composition, seasonal and interspecific variations in CPUE were observed which could result from differences in behaviour and habitat preferences (Darwall et al., 1992a, Jones, 1984). For example, goldsinny are less active during the winter and have been shown to remain in refuges for long periods (Sayer, 1999) which could affect CPUE. Sea temperature has previously been indicated as a factor driving seasonal changes in CPUE. For example, Darwall et al., (1992a) observed an increase in CPUE between May and August in an Irish wrasse fishery which they attributed to increased sea temperature. My results follow a similar pattern apart from a slight decrease in CPUE in August 2018. The seasonal changes observed in my results could therefore be attributed to sea temperature, however this was not recorded during the study to confirm this hypothesis.

The spatial composition of wrasse is an important consideration when interpreting temporal trends in CPUE (Ross and Davies, 2017). Skiftesvik et al., (2014b) reported that species composition was highly variable over small distances in a Norwegian fjord wrasse fishery. Species specific spatial compositions can vary due to interactions between the ecology of individual species and habitat use (Ross and Davies, 2017, Skiftesvik et al., 2014b). For example, goldsinny have a wide ecological niche and can be found in rocky reef habitats in the intertidal zone with crevices up to a depth of 50 meters. They are also able to withstand areas of high wave exposure (Darwall et al., 1992a; Skiftesvik et al., 2014b). In contrast, corkwing are more specialised and invest in nest building and territory defence during the spawning season and prefer sheltered shallower water (<5m) within kelp forests and eel grass beds (Skiftesvik et al., 2014b). Environmental factors such has wave energy and circulation can determine the amount of algal cover and invertebrate communities present within a habitat, resulting in species being spatially distributed based on their diet (Skiftesvik et al., 2014b). In this study spatial differences were seen in the composition and relative abundance of wrasse between Plymouth and Torbay (section 3.3), likely as a result of the different types of habitat between the locations. However, the spatial distribution of individual species was not investigated. Therefore, erroneous conclusions can easily be made as changes in CPUE between species could be the result of fishers moving traps to different areas within Plymouth Sound (Skiftesvik et al., 2014b). Hence, future monitoring would benefit from repeated surveys being conducted in the same location in order to understand the underlying causes of any spatial and temporal trends in CPUE.

4.3. Proportion of juveniles and adults in catch

Catches from Plymouth for the period June to August were pooled together and classified as juveniles or adults based on the minimum conservation size references. Ballan wrasse under 15cm and all other species 12cm were classed as juveniles. It should be noted that is a basic metric of size category and does not truly reflect the age structure of wrasse. Male goldsinny and rock cook have been reported to mature at 9cm, with female goldsinny maturing at 8cm and female rock cook at 8.5cm (Matland, 2015). Female ballan mature at 16-18cm and males 28cm (Darwall et al., 1992a). Despite this, it does highlight the importance of including size structure in CPUE analysis. There was a notable increase of juveniles caught in 2018 (68%) compared to 2017 (49%) which is an initial concern as a reduction in mean length could imply overexploitation. It is important to note, however, that size structure and CPUE should be considered together as a decrease in the proportion of adults can be interpreted as heavy exploitation or high recruitment of juveniles. As my data shows a rise in CPUE and is for a relatively short period, this would suggest an increase in the recruitment of individual species. Goldsinny is the dominant species across all months and between both years. This species matures at an early age and produce large numbers of planktonic eggs (Darwall et al., 1992a), producing up to five times as many eggs than Corkwing (Davies and West, 2017). These characteristics indicate populations may be resilient to fishing and coincide with the observed higher CPUE compared to other species. Furthermore, environmental changes, such as a change in ambient temperature, can decrease the average size of some species of fish (Yemane et al., 2004). However, this is an unlikey explanation as there is no evidence of a long-term trend in coastal ocean temperatures off the South West Coast of Devon. It is clear that size structure is an important consideration when interpretirng CPUE. As the size classififcation in this study was quite broad and the whole catch was pooled together, it would be unable to detect any subtle changes in size classes within and between species. As this is the first comparrison to the baseline, species specific size classificaion data based on the size of maturity is required in order to identify trends in average size and accurately understand changes in size structure of the overall population.

4.4. Is CPUE representative of wrasse abundance?

Underwater video was used to calculate three relative abundance indices which were compared to CPUE. MeanN and MeanCount estimated higher mean averages of abundance than CPUE for goldsinny, cuckoo and ballan over the sampling period (May to July) in Plymouth (table 4). This suggests that more individuals are being captured by video compared to trap data. Relative abundance indices using video may therefore be more capable of detecting changes in abundance over time (Harvey et al., 2012). Cuckoo and ballan wrasse can reach sizes of 35cm and 60cm respectively (Darwall et al., 1992a; Quignard and Pras, 1986) and can therefore become too large to be caught by traps. In addition, the mouth opening of traps may become obstructed by kelp or traps may land incorrectly on the seabed, preventing individuals from entering the trap. In these instances, underwater video may be able to index the abundance of these species that traps cannot catch due to their large body size.

4.5. The use of MaxN, MeanN and MeanCount to estimate abundance and assemblage composition.

A common approach to measure relative fish abundance is MaxN as it is easy to obtain and provides a conservative index of abundance (Stobart et al., 2015). In this study the video indices MaxN, MeanN and MeanCount were calculated and compared to each other and between two locations, Plymouth and Torbay. These indices take different levels of sampling effort into consideration and may provide useful for future monitoring of the wrasse fishery. My results show the interactive effects of index and location on the calculation of relative wrasse abundance and assemblage composition. In Plymouth, significant differences were detected between all video indices for relative abundance and assemblage composition. However only differences between MeanN and MeanCount were observed for Torbay. The non-significant relationship of MeanCount on assemblage composition between the two locations would indicate that this relative abundance index underestimates the presence of a species at a given sampling site, potentially impacting estimates of population abundance. This is not surprising given that large sections of video are excluded from analyses and the probability of observing an individual species on a video is reduced as the interval increases (Campbell et al., 2015). The use of MeanN as a relative abundance index compared to MaxN could also result in a failure to detect changes in actual abundance. This showed no significant difference between locations despite MaxN highlighting geographic differences in relative abundance, suggesting there are differences in ambient wrasse densities between Plymouth and Torbay, likely due differences in habitat as described in section 4.2. Therefore, MaxN may be preferable over MeanCount and MeanN. This is somewhat in contrast to previous studies (Conn et al., 2011; Stobart et al., 2015) that have indicated MaxN to be prone to sampling saturation and therefore not linearly track true abundance. However, it should be noted that this study did not investigate whether the relationships between MaxN, MeanN and MeanCount were linear or nonlinear. Future studies should therefore use linear models to test whether any relationship between trap and video indices of abundance are linear or nonlinear.

Regardless of all three indices showing variability surrounding relative abundance estimates and assemblage composition, the use of underwater video in fishery independent surveys provides additional information that is not taken into consideration when calculating and standardizing CPUE. Details of habitat type can be recorded, traps that do not fish effectively due to environmental conditions can be identified and excluded from analyses and fish behaviour including interspecific interactions that may influence catch rates can be recorded (Bacheler et al., 2013b; Harris, 1995). However, the collection and reading of video samples can be time consuming and expensive and turbidity caused by large spring tides or adverse weather can affect visibility and therefore the effectiveness of video.

5. Conclusion

In conclusion, although CPUE shows no consistent decline since baseline, these results should be interpreted with some caution. Raw CPUE can be misleading if not interpreted in context of other data and biological information. Although variation between the relative abundance indices is shown in this report, it highlights how the use of underwater video may be more appropriate, particularly for certain species, in the continual monitoring of the wrasse fishery. It is important to realise that no single methodology will efficiently collect all the information required about a fish stock. Therefore, integrating underwater video with trap survey data can provide information on a population that can be used to produce more estimates of abundance. Continued monitoring of CPUE trends within the wrasse fishery is required in order to establish the causes behind any trends and determine whether further management measures are required.

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Appendix 1

General Risk Assessment Form
(Revised February 2018)

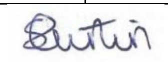
Date:	16 February 2018	Assessed by:	**Sarah Curtin**	Activity/Location	Plymouth Sound sampling with wrasse pots 2018

Hazards	No. at risk	Controls in place at present	L (1 – 2)	M (3 – 4)	H (6 – 9)	Further controls necessary	Residual risk rating	Responsible person
Travel								
Accidents enroute Weather conditions Slips / trips	1	Personal awareness Suitable footwear Local contact Mobile phone for contact ETA with line manager Follow off-site activities and fieldwork Code of Practice (see link in adjacent column)	2x2					Sarah Curtin
Illness Accident	1	Ensure everyone is fit to undertake activity on the day Contact of local doctor Contact of A&E Numbers in mobile phone	2x2			Derriford Hospital 01752 202082		Sarah Curtin
Boat activities								
Fire	Skipper and student	Fire procedures explained in safety briefing prior to leaving the Sound. Boats Safe Operating Procedures (SOP) if applicable/ skipper's instructions to be followed at all times. Fire extinguisher location and type. Fuel tap location, Equipment maintained by qualified contractors - Chubb. Routine maintenance and inspections of engines.	1x4					Sarah Curtin Skippers Mark Hagger

		Boat designed and operated under COP to limit or prevent fires. Plymouth University (PU) staff and students to have undertaken Sea Survival training.						
Man over board (MOB)	Skipper and student	MOB procedure explained prior to leaving harbour. Boats Safe Operating Procedures (SOP) if applicable/ skipper's instructions to be followed at all times. Personal Protective Equipment (PPE) in the form life jackets must be worn by all persons on board at all times. PPE to be **serviced** if appropriate. Students to have undertaken Sea Survival training	2x2			Nadine Hanlon Mark Hagger Keiran Perree		Sarah Curtin Skippers Mark Hag 11
Collision	Skipper and student	Boats Safe Operating Procedures (SOP) if applicable/ skipper's instructions to be followed at all times. Maintaining a look out is the duty of all on board. Location of flares and life raft procedure explained in safety briefing prior to leaving Marina. PU staff and students to have undertaken Sea Survival training.	1x3					Sarah Curtin Skippers Mark Hagger
Grounding	Skipper and student	Echo sounder giving real-time water depth. Boats Safe Operating Procedures (SOP) if applicable/ skipper's instructions to be followed at all times. Passengers to carry out orders of crew should grounding take place. Anchors available for rapid deployment, Skippers local knowledge gained through induction and	1x3					Sarah Curtin Skippers Mark Hagger

		local experience. PU staff and students to have undertaken Sea Survival training.						
Slips, trips and falls	Skipper and student	Nonslip surfaces. Boats Safe Operating Procedures (SOP) if applicable/ skipper's instructions to be followed at all times. Moving about the boat to be as appropriate to sea state. Appropriate footwear to be worn. Safety brief and tool box talk to be delivered by skipper. Access to foredeck where applicable is controlled	2x2					Sarah Curtin Skippers Mark Hagger
Hypothermia / hyperthermia and sunburn	Skipper and student	PPE must be worn by all persons in the form of warm clothing and waterproofs if cold, or hats and cool clothing if hot. Shelter and appropriate drinks (hot or cold) should be available.		2x3				Sarah Curtin Mark Hagger
Seaksickness	Skipper and student	Seasickness tablets should be taken by those susceptible. Seasickness scale explained and monitored. Fluids should be administered after vomiting and return to shore depending on severity of sickness.		4x2				Sarah Cur… Mark Hagger
Entrapment in rope	Skipper and student	Boats Safe Operating Procedures (SOP) if applicable/ skipper's instructions to be followed at all times. Fixed ropes on pontoons	1x3					Sarah Curtin Skippers Mark Hagger
Falls between the boat and pontoon	Skipper and student	Boats Safe Operating Procedures (SOP) if applicable/ skipper's instructions to be followed at all times.	1x3					Sarah Curtin Skippers Mark Hagger
Drowning	Skipper and student	Vessels designed, maintained and equipped either to national COP or university COP. All skippers to have had appropriate training/induction.	1x4					Sarah Curtin Skippers Mark Hagger
Strain injuries	Skipper and	Follow manual handling guidelines (see	2x2			Obtain additional		Sarah Curtin

	student	link in adjacent column) Assess all manual activities before undertaking the task**.**				equipment if necessary		Mark Hagger
Office work								
Lone work	Student	Mobile phone to hand to call security in case of emergency.	2x2					Sarah Curtin

SIGNATURE:  (Responsible Person) Conduct Risk Assessment in conjunction with Code of Practice

PRINT: SARAH CURTIN

APPROVED SIGNATURE ___________________________________

PRINT: EMMA SHEEHAN

DATE: ____

REVIEW DATE: __________________________________