Live Wrasse Fishery in Devon and Severn IFCA District

Research Report November 2018

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Executive Summary

A fishery for the live capture of wrasse for use as cleaner fish in Scottish salmon farms developed in the Devon and Severn Inshore Fisheries and Conservation Authorities' (D&S IFCA) District in 2015. In 2017 management was introduced via the D&S IFCA potting permit byelaw. These early management measures were largely based on best practice identified in the literature and included minimum and maximum conservation references sizes (MCRSs), a closed season, a fully documented fishery and a cap on effort. A fully documented fishery was also implemented including fisher log books and observer surveys. After the first year of data collection, some adaptations to the MCRSs and spawning closed season were adopted. The fully documented fishery continued in 2018 and the results are presented in this report.

There was a reduction in overall effort in 2018 compared to 2017 with a 68% reduction in the number of days vessels targeting wrasse in the D&S IFCA District. The reduction is thought to have been caused by a combination of mechanical issues with vessels, individual fisher's circumstances, fishers targeting Cornish waters within the Plymouth Sound during the Devon closed season and vessels remaining in Cornwall once Devon waters reopened.

The mean target observer effort was exceeded; however, the coverage of the vessels and the months was uneven despite extensive efforts in survey planning. There was a 29% decrease in mean landings per unit effort (LPUE) for 2018 compared with 2017. In contrast, there was a slight (~5%) increase in catch per unit effort (CPUE) from 2017 to 2018. The disparity between CPUE and LPUE could be caused by the relatively small sample size of CPUE resulting in an unrepresentative trend, or the proportion on small individuals increasing so that CPUE (which includes undersize and oversized fish) has a genuinely different trend to LPUE (which only includes fish above the Minimum CRS and below the Maximum CRS). The reduction in LPUE could also be caused by the change in Minimum and Maximum CRSs for corkwing, which has resulted in much higher numbers of fish being returned.

Spatially and temporally explicit data analysis was undertaken using the high-resolution CPUE analysis. No consistent trend in CPUE was found within individual grid cells between 2017 and 2018. Out of two vessels which could be compared between years, one had a small but significant reduction in CPUE. Differences in CPUE between months varied with months showing slightly reduced catches (June, July, September) and one month having increased CPUE (August). None of these comparisons were statistically significant.

Size-frequency distributions were remarkably similar between years as were mean sizes of individual wrasse species.

A more in-depth analysis of catch-composition and changes in size-structure between years is required but was not possible given the time-constraints of reporting. The complex spatial and temporal dynamics of the fishery will require a new approach to analysis in 2019.

Observer coverage should at least maintain the current effort, but with more even coverage, where possible. Greater coverage would improve statistical analyses, but this is unlikely given the current level of resource. Similarly, a fisheries-independent data set would be beneficial to separate changes in catch from spatial changes in effort, or observer coverage, but would require significant extra resource which is not currently available.

1. Introduction

Sea lice infestation is one of the most challenging issues faced by the Atlantic salmon aquaculture industry. Farmers face annual costs in the region of €38 million to control and manage infestation (Costello, 2009, Powell *et al*., 2017). Traditional methods of sea lice control involve the use of pesticides, however these chemical treatments are becoming less effective due to evolved resistance (Jones *et al.*, 2013). New alternatives to sea lice control are now being implemented, predominately through the use of cleaner fish such as wrasse (Powell *et al*., 2017).

The cleaning behaviour of wrasse was first observed in 1973 with trials being conducted by Bjordal in Norway in 1987, who identified the use of wrasse to control parasites. A commercial fishery targeting live wrasse was subsequently created in Norway in 1988 and 1990 in England (Darwall *et al*., 1992). UK salmon farms are predominately based in Scotland and initially only locally caught wrasse were used. However, due to shorter fishing seasons, local supply was not meeting demand. Therefore, wrasse started being sourced from outside local areas, particularly from Southwest England (Riley *et al*., 2017).

Fishing for live wrasse began in Devon in 2015. Four species of wrasse are targeted; goldsinny, ballan, corkwing and rock cook. These species may be vulnerable to local overexploitation due to complex life history strategies and limited territory sizes (Darwall *et al*., 1992, Halvorsen *et al*., 2016). Previous studies conducted in Ireland have shown declines in catch per unit effort (CPUE) within two years of the fishery commencing due to reduced local wrasse abundance (Darwall et al., 1992).

In Devon, four commercial vessels targeting live wrasse operate within Plymouth Sound and the surrounding coastal waters as described in previous reports (Davies 2016; Davies & West 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 June 2017, through the Potting Permit Byelaw conditions (Clark and Townsend 2017). These included a limit of 120 pots per vessel, minimum and maximum conservation reference sizes (Min and Max CRS) for landings, temporal and spatial closures and the implementation of a fully-documented fishery.

As part of the management measures, an intensive data collection programme was introduced in 2017 to capture temporal and spatial trends in catch per unit effort (CPUE). This involves the collection of landings data recorded by fishers and IFCA officers carrying out onboard observer surveys. Data collected from the fisheries first year in 2017 have been used to implement changes to original management measures in order to make them more effective. Temporal closures have been amended in order to improve protection of spawning individuals, and the existing Min and Max CRS for corkwing has been changed in order to protect nesting males and juvenile females. Voluntary closed areas were also introduced and amended following the fisheries first year. Approximately 46,497 wrasse were retained from boats working in Plymouth in 2017 and there was no consistent decline in CPUE or landings per unit effort (LPUE) between April and October (Davies & West 2017). This paper presents the results of data collection from the second year of the fishery, compares the results to 2017 and discusses any differences in trends seen between the two years.

2. Methodology

A fully documented fishery was implemented by D&S IFCA in 2017 and continued in 2018, with two primary sources of data collected; i) landings data, recorded by the fishers and ii) on-board observer surveys, undertaken by IFCA Environment Officers. These two datasets have different strengths and weaknesses which are described below and summarised in Table 1.

Table 1. Difference between landing data and on-board observer surveys

	Landings data (from fishers)	***On-board observer surveys***
Data from every day of fishing effort	✓	
Fishing effort (no. pots per day) recorded	✓	✓
Daily total number of fish caught recorded	✓	✓
Daily total number of fish returned recorded		✓
Total number of fish caught per string		✓
Spatial LPUE/CPUE		✓
Species-level data recording		✓
Sizes of fish (kept and returned) recorded		✓
Spawning state of fish recorded		✓
Approximate location of fishing effort recorded (1 km^2 grid)	✓	✓
Precise location of fishing effort recorded		✓

2.1. Landings Data

Fishers completed landings forms which included the total numbers of wrasse retained per day, split into ballan, cuckoo and all other wrasse species, grouped. Fishers cannot sort their catch by species on-board as they are often working single-handed and need to keep fish handling and processing time to a minimum. It is important to note that where data are presented from the fishers' data, they refer to *landings only* (i.e. do not take into account the number of fish returned alive). Figures from the on-board observer surveys include numbers of fish caught and retained, and also those returned alive. Therefore, fishers' data are reported as landings and observer surveys are reported as catch.

Fishers also recorded which grid cells they fished in each day but were not required to report how many fish were caught in each grid cell, as again this would be extremely disruptive to their normal fishing behaviour. The major strength of the fishers' logbook dataset is that it records every single day of fishing activity, and results in the documentation of every single retained wrasse. It also allows for data collection from boats which are too small to host an observer. These logbooks allow for the continuation of data collection when on-board observer surveys cannot be carried out due to weather or logistic reasons. The location information also allows D&S IFCA to monitor fishing activity to ensure voluntary closed areas are being adhered to.

There is no landings data for April, May and June in 2018 as the fishery was closed during the spawning season.

2.2. On-board Observer Surveys

Observer surveys were planned to allow approximately a 10% coverage of days fished, with even coverage over the four vessels engaged in the fishery over the survey season. The fishery was closed in April, May and June in 2018 following the implementation of a closed season for wrasse spawning (Clark and Townsend 2017). A fisher was chartered to undertake three surveys during the closed season to provide at least some comparable data during this the spawning period between 2017 and 2018. The fisher was asked to fish in his normal location, in his normal pattern but was required to return all of the catch. Once the fishery reopened officers' observations took place on the fisher's routine fishing trips between July and October 2018.

D&S IFCA officers recorded the start and end position of each string, weather, start and end time, date and tide times. Pots were hauled by the fisher and wrasse were emptied into a bucket of seawater. Each wrasse was identified to species level, measured, sexed where possible and identified if spawning by the presence of milt or eggs. Individuals within the Min and Max CRS were retained in large tanks or barrels with a continuous flow of seawater. Individuals below the Min CRS and above the Max CRS were returned to the sea immediately by hand to minimise the risk of predation by seabirds.

2.3. Data Analysis

2.3.1. Total Landings

Total landings were calculated using the fisher's landings forms, verified by transport documents supplied to the Marine Management Organisation (MMO) by the fishers.

2.3.2. Observer Effort

The percentage of observer effort was calculated by the number of days fishing within a month, divided by the number of surveys carried out that month.

2.3.3. Catch Per Unit Effort

Catch per unit effort (CPUE) was calculated in MS Excel using the data collected during the onboard observer surveys. This data includes both fish above and below the Min and Max CRS.

CPUE for each vessel was calculated using the following formula:

$$CPUE = C_t / E_t$$

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

Mean CPUE for the fleet was calculated as:

$$\text{Mean CPUE} = (C_1+C_2+....C_n)_t / (E_1+E_2+....E_n)_t$$

Where C_1 is the number of wrasse caught by vessel 1, C_2 is the number of wrasse caught by vessel 2 up to C_n vessels, during time period, t. E_1 is the number of pots fished by vessel 1, E_2 is the number of pots fished by vessel 2, up to E_n vessels during time period t.

2.3.4 High Resolution CPUE Analysis

For more in-depth statistical analyses a second approach to calculating the CPUE was adopted in 2018. CPUE was calculated for every string fished during observer surveys where the total amount of fish caught (including both those kept and those returned) for each string was divided by the number of pots in that string. No adjustment was made for the soak time based on the lack of conclusions from a pot saturation experiment (Curtin 2018) and the conflicting information in the literature. The string therefore served as the sampling unit or replicate. CPUE data were transformed using a square root transformation. Two-way ANOVAs were used to determine whether there were statistical differences in CPUE between 2017 and 2018 and IFCA District and within and between years, and to assess whether there were interactions between the predictor variables.

A comparison of CPUE in individual months between 2017 and 2018 was undertaken. Only months where a minimum of three strings had been observed in 2017 and three strings in 2018 were included in the analysis. Mann-Whitney U-tests (Wilcox tests) were conducted in R for each month, comparing 2017 and 2018 data for that month and raw data were used to create box-and-whisker plots for each month.

A comparison of CPUE in individual grid cells between 2017 and 2018 was undertaken. Only grid cells where a minimum of three strings had been observed in 2017 and three strings in 2018 were included in the analysis. Mann-Whitney U-tests (Wilcox tests) were conducted in R for each grid cell, comparing 2017 and 2018 data for that cell and raw data were used to create box-and-whisker plots for each grid cell.

For vessels which had fished in both 2017 and 2018 and had a minimum of three strings observed in both years, Mann-Whitney U-tests were conducted to compare CPUE in 2017 and 2018.

2.3.5. Landings Per Unit Effort

Landings per unit effort (LPUE) was calculated in MS Excel from the fisher's landings data and therefore only represents fish above the Min and below the Max CRS. Landings data includes fish that were caught within the Cornish IFCA District as well as the D&S IFCA District. Due to the nature of the fishery and the data, it is not possible to separate out the amount of fish caught within each District. LPUE for individual vessels was calculated as:

$$\text{LPUE} = L_t / E_t$$

Mean LPUE for the fleet was calculated as:

$$\text{Mean LPUE} = (L_1+L_2+....L_n)_t / (E_1+E_2+....E_n)_t$$

Where L_1 is the number of wrasse landed by vessel 1, L_2 is the number of wrasse landed by vessel 2, up to L_n vessel, during time period, t. E_1 is the number of pots fished by vessel 1, E_2 is the number of pots fished by vessel 2, up to E_n vessels during time period t.

2.3.6. Spatial and Temporal Fishing Effort

The geospatial distribution of fishing activity was ascertained using the GPS co-ordinates of each string obtained from on-board observer surveys. Fishing effort maps with equal ranges based on the number of pots hauled per grid square were produced in QGIS v2.14.19.

2.3.7. Catch Composition

Data from the on-board observer surveys on the number of individual wrasse species caught were used to produce pie charts of catch composition in MS Excel.

2.3.8. Size Frequency

Size frequency histograms were produced in MS Excel using the number of individual species recorded per size group from the on-board observer surveys.

2.3.9. Spawning State

The percentage of catch per month that was spawning or not spawning was calculated in MS Excel. The number of spawning wrasse per species was calculated per week, based on the data collected from the on-board observer surveys. This includes data from both D&S IFCA and Cornwall IFCA.

3. Results

3.1. Total Landings

A total of 13,129 wrasse (including ballan, goldsinny, corkwing and rock cook) have been landed from vessels which fish in the D&S IFCA's portion of Plymouth Sound between May and the beginning of October 2018 (Table 2). It should be noted that three out of the four vessels did not start fishing in D&S IFCA's District until August and after this time had strings in both D&S IFCA and CIFCA District. Some fishers only recorded landings that relate to catches within D&S IFCA District.

Sales notes, supplied to the MMO by the salmon farm company, indicate that 39,324 wrasse have been landed in total in Plymouth Sound during the same timeframe (Table 3). The discrepancies between the landings forms and the sales notes are caused by a number of factors. The sales notes include all landings for Cornwall from the four vessels, including during the D&S IFCA closed season (highlighted in green, Table 3). Damaged, undersized and dead-on-arrival fish are also included in the sales notes, so this will elevate the numbers. The sales notes data are complete up to 3rd October 2018, however Vessel 2 fished for several days after this period, resulting in the landings for this period being omitted from Table 3 below. Four days of landings are missing for Vessel 3 due to incomplete landings forms. Fishers may have experienced mortalities of wrasse within their holding pens prior to loading, however these data are not available.

Table 2. Landings data (number of fish retained) from the fisher's landings forms.

	Date		Returns			
Vessel	First entry	Last entry	Devon only	Cornwall only	Devon & Cornwall	**Total**
Vessel 2	04/07/2018	09/10/2018	5,303	N/A	N/A	**5,303**
Vessel 3	06/08/2018	22/08/2018	1,383	Not recorded	N/A	**1,383**
Vessel 4	30/08/2018	13/10/2018	Not recorded	Not recorded	4,802	**4,802**
Vessel 5	02/08/2018	14/09/2018	1,641	Not recorded	N/A	**1,641**
Totals			**1,525**		**4,802**	**13,129**

Table 3. Transport data taken from sales notes of the number of wrasse species landed per vessel and the total number of payable fish. Sales notes were provided by the Marine Management Organisation. Figures and dates in green represent fish caught during the D&S IFCA District closed season.

	Number of fish loaded per vessel								
Transport date	**Vessel 2**	**Vessel 3**	**Vessel 4**	**Vessel 5**	**Total Landed**	**No. of fish dead on arrival**	**No. of fish damaged**	**No. of undersized fish**	**Total amount of payable fish**
01/05/2018	-	-	576	522	1,098	60	-	8	1,030
11/05/2018	-	-	580	1,432	2,012	163	120	-	1,729
20/05/2018	-	-	664	1,278	1,942	30	-	-	1,912
31/05/2018	-	150	570	1,671	2,391	134	-	284	1,973
06/06/2018	-	257	204	841	1,302	28	-	-	1,274
19/06/2018	-	407	602	1,310	2,319	21	-	65	2,233
27/06/2018	-	160	862	619	1,641	-	-	-	1,641
07/07/2018	-	225	453	820	1,498	-	-	-	1,498
11/07/2018	475	502	125	865	1,967	-	-	421	1,546
22/07/2018	-	706	-	-	706	-	400	-	306
01/08/2018	196	814	148	636	1,794	-	-	-	1,794
08/08/2018	569	946	-	1,279	2,794	-	-	-	2,794
22/08/2018	531	961	-	978	2,470	-	-	-	2,470
29/08/2018	396	952	608	700	2,656	-	-	-	2,656
05/09/2018	722	720	720	720	2,882	-	-	-	2,882
12/09/2018	696	1,625	1,258	1,460	5,039	-	-	-	5,039
19/09/2018	380	682	956	1,102	3,120	-	-	578	2,542
03/10/2018	347	-	596	750	1,693	-	-	-	1,693
Totals	**4,312**	**9,107**	**8,922**	**16,983**	**39,324**	**436**	**520**	**1,356**	**37,012**

3.2. Survey Effort

A target survey effort of 10% (with a minimum of 5%) was set in 2017. In 2018 12% of fishing trips in the D&S IFCA District had an observer onboard (Table 4). Whilst survey effort was planned to achieve as even a coverage as possible across the four vessels during the sampling period, observer coverage did vary widely from 4-25% (Table 4). This uneven coverage was caused by a number of factors: Two vessels were fishing only in Cornish waters until the end of July, one vessel was out of the water for a considerable amount of time due to damage, a period of high winds prevented officers from carrying out surveys and trying to coincide officer availability with sporadic fishing activities was a challenge. Despite these challenges, fourteen surveys were undertaken between May and the start of October 2018 (Table 5.

Table 4. Survey effort coverage per vessel for 2018.

Vessel	No. days fished	No. surveys	Percentage observer coverage
Vessel 2	59	7	12%
Vessel 3	11	1	9%
Vessel 4	24	1	4%
Vessel 5	20	5	25%
All vessels	114	14	12%

Table 5. On -board observer surveys completed during 2018.

Vessel	Survey by	Date	Month
Vessel 2	D&S IFCA	22/05/2018	May
Vessel 2	D&S IFCA	08/06/2018	June
Vessel 2	D&S IFCA	20/06/2018	
Vessel 4	CIFCA	25/06/2018	
Vessel 2	D&S IFCA	06/07/2018	July
Vessel 2	D&S IFCA	25/07/2018	
Vessel 2	D&S IFCA	08/08/2018	August
Vessel 5	D&S IFCA	09/08/2018	
Vessel 5	D&S IFCA	16/08/2018	
Vessel 3	D&S IFCA	22/08/2018	
Vessel 5	D&S IFCA	24/08/2018	
Vessel 4	D&S IFCA	30/08/2018	
Vessel 5	D&S IFCA	31/08/2018	
Vessel 5	D&S IFCA	14/09/2018	September
Vessel 2	D&S IFCA	04/10/2018	October

3.3. Catch Per Unit Effort and Landings Per Unit Effort

3.3.1. Landings Per Unit Effort

The mean LPUE for the period July to October has decreased from 1.14 in 2017 to 0.81 in 2018. Overall effort decreased during the same time period; the number of days fished in the D&S IFCA District in 2018 across all vessels totals 114 (Table 4) compared to 362 days recorded in 2017. LPUE increased from July to September 2018 and then declined in October. This follows the same trend seen in 2017 (Figure 1). It should be noted that the LPUE for 2017 has been recalculated for this report due to additional data becoming available after the report was produced in 2017.

Appendix 1 shows the LPUE for each individual vessel. Only Vessel 2 started fishing in the D&S IFCA District in July. Vessels 2, 4 and 5 were fishing in Cornwall only until August in 2018. LPUE varies substantially between all four vessels. Vessel 5 had the highest landings for August and Vessel 2 had the highest landings for September. Vessels 2 and 4 saw an increase in LPUE from August to September and then a decrease in October. In contrast, LPUE for vessel 5 decreased from August to September.

3.3.2. Catch Per Unit Effort

Mean CPUE for the period June to October 2018 has increased from 1.72 in 2017 to 1.82 in 2018. In 2018 CPUE increased in June followed by a decline in July (Figure 2). This is in contrast with 2017 where CPUE increased from June to July. August and September 2018 show a consistent increase in CPUE with a decline in October which follows the same trend seen in 2017 (Figure 2). Mean CPUE per month was generally lower for 2018 compared to 2017 with the exception of August and September.

It should be noted that CPUE per month and per species for 2017 has been recalculated for this report due to an error in the 2017 database. Therefore, the figures from this report should be used when comparing CPUE, the 2017 report will be amended accordingly.

Catch Per Unit Effort (CPUE) remains consistently low across both years for ballan and cuckoo wrasse from June to August. An increase in CPUE was seen from August to September 2017 for these species which did not occur during 2018 (Figure 3). The CPUE for corkwing shows a similar pattern across both years in that it increases from June to September, with September seeing the highest CPUE across both years, followed by a decrease in October (Figure 3). Goldsinny is the species caught in the highest proportion for the majority of the year in 2017, apart from April. This is less consistent in 2018 with goldsinny making up the highest proportion of the catch in May, June and August only. Rock cook dominates the catch in July and corkwing in September and October 2018. The CPUE for rock cook seemed to fluctuate on a monthly basis during 2017. This is in contrast with 2018 which shows a steady increase in CPUE from June to August, followed by a decrease in September and October (Figure 3).

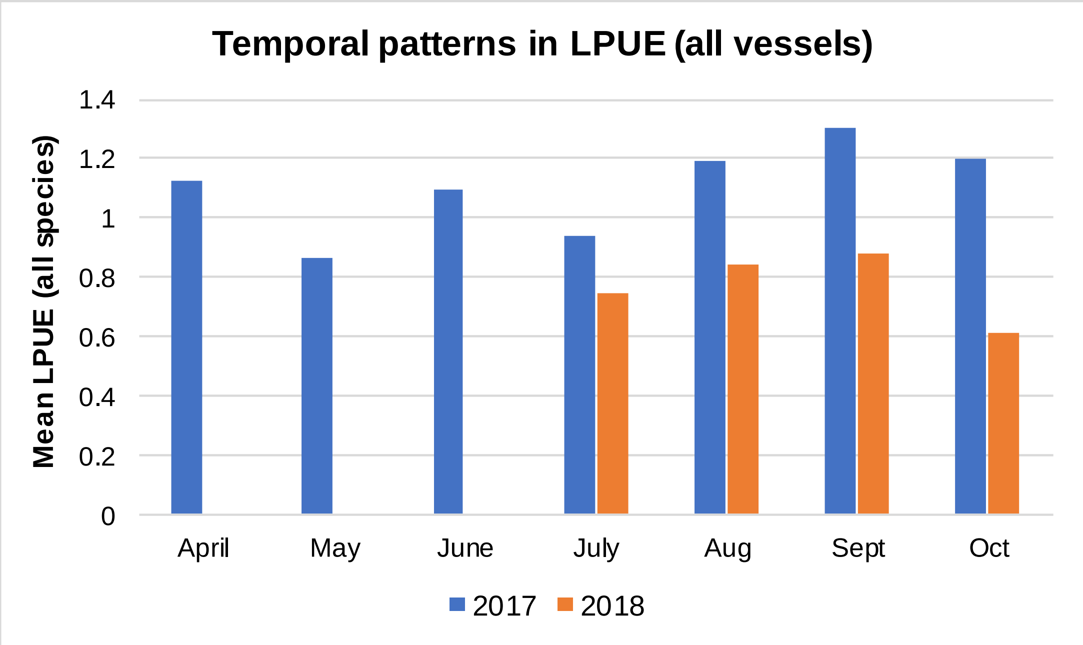


Figure 1. LPUE (all species) for all vessels during 2017 and 2018. Data taken from the fisher's landings forms.

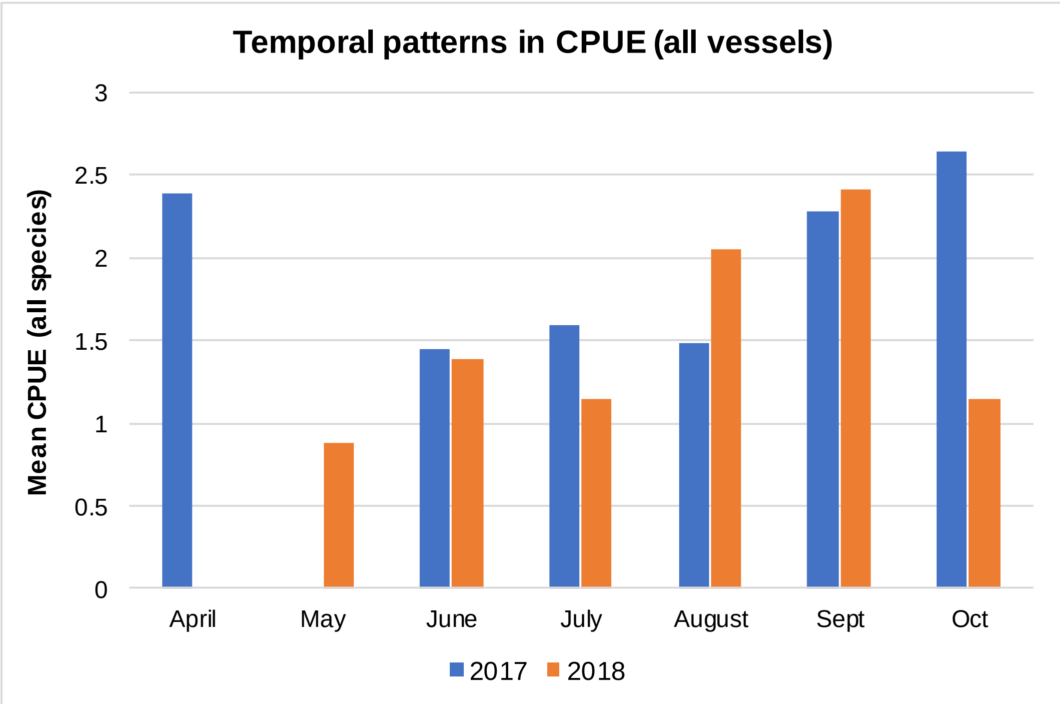


Figure 2. CPUE (all species) for all vessels for 2017 and 2018 calculated from data collected during the on-board observer surveys.

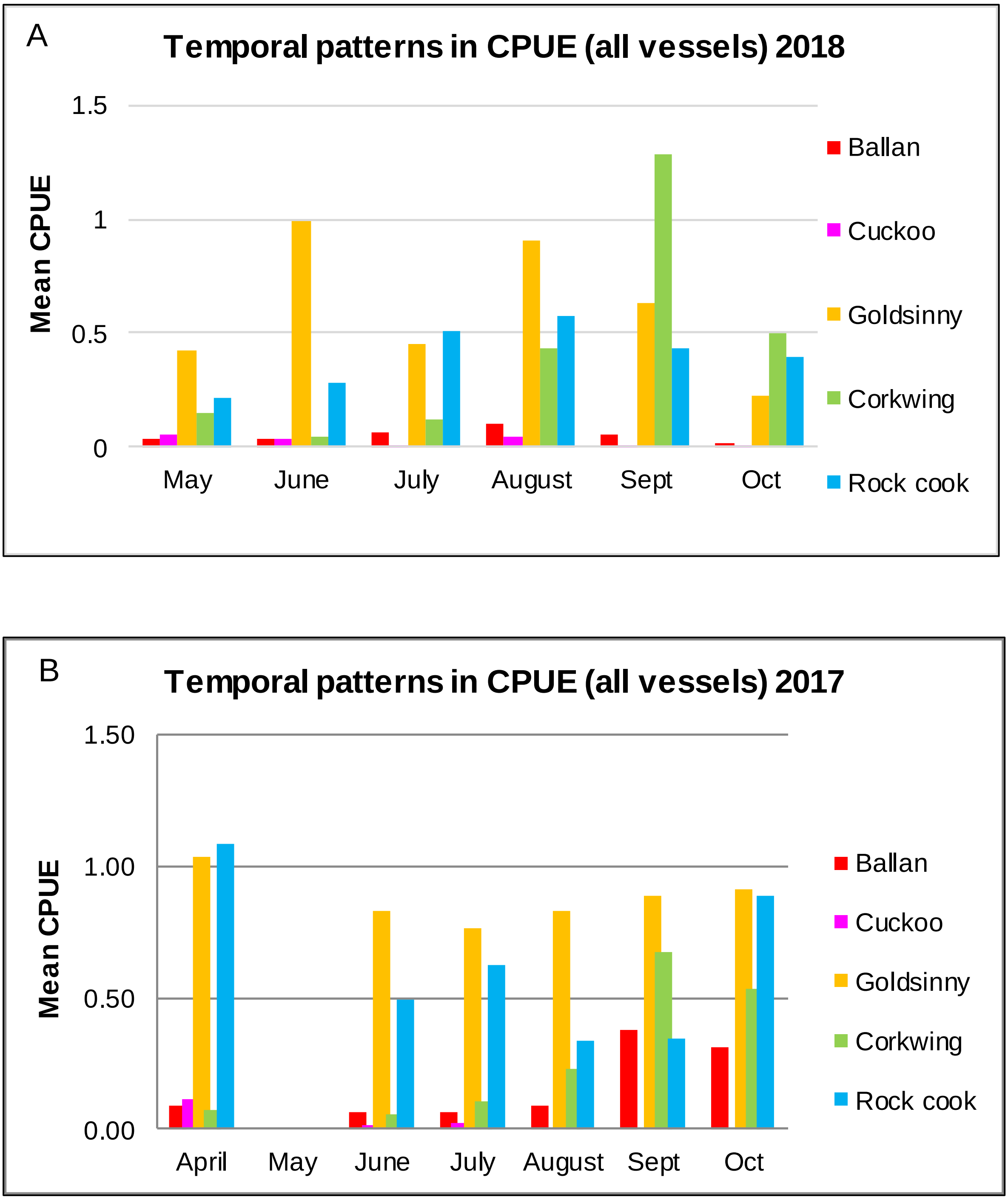


Figure 3. Assemblage composition of CPUE for all vessels for 2018 (A) and 2017 (B). Calculated from data collected during the on-board observer surveys

3.4. Spatial Effort

At the start of the 2018 season, two of the four vessels were fishing in Cornish waters only, up until the end of July. After this time, all four vessels were fishing within the D&S IFCA District, however three of these vessels continued to have pots within Cornish waters. Because not all fishers recorded their Cornish pots, Cornish effort data were excluded from the maps.

The reduction in overall effort in the D&S District between 2017 and 2018 has resulted in fewer grid cells being fished, and with less effort per grid cell (Figures 6 and 5 respectively) with a maximum total number of 4,322 pot-hauls per grid cell in 2017, compared to 2,726 in 2018. Fishing effort has predominately been concentrated around Drakes Island, Renney rocks and the Mew Stone area. Although effort was more spread out across Plymouth Sound in 2017, this coincides with areas identified as fishing hotspots last year. The voluntary closed areas that were amended from the 2017 season and implemented in April 2018 were adhered to in 2018 (Figure 4).

Fishers generally fished similar areas in 2017 and 2018 (Figures 7-12). Vessel 2 has worked solely in D&S IFCA District. The majority of fishing was carried out around the Shag Stone area, with some pots being moved closer towards the Mew Stone (Figures 7 and 8). Vessel 3 has worked both in D&S IFCA and CIFCA District. Fishing within the D&S IFCA District has taken place predominately around Drake's Island. It should be noted that some of this vessels' landings forms were not completed and returned, therefore effort is only reflective of the on-board observer surveys and landings forms that were returned (Figures 9 and 10). Vessel 4 fishes mostly in CIFCA District with some effort near Drake's Island, in the D&S IFCA District (Figures 11 and 12). Vessel 5 entered the fishery in 2018 this year and therefore there is no fishing effort map for this vessel in 2017. Vessel 5 worked in both D&S IFCA and CIFCA District during August and September. Fishing within D&S IFCA District has been carried out from Fort Bovisand down to Wembury Bay (Figure 13).

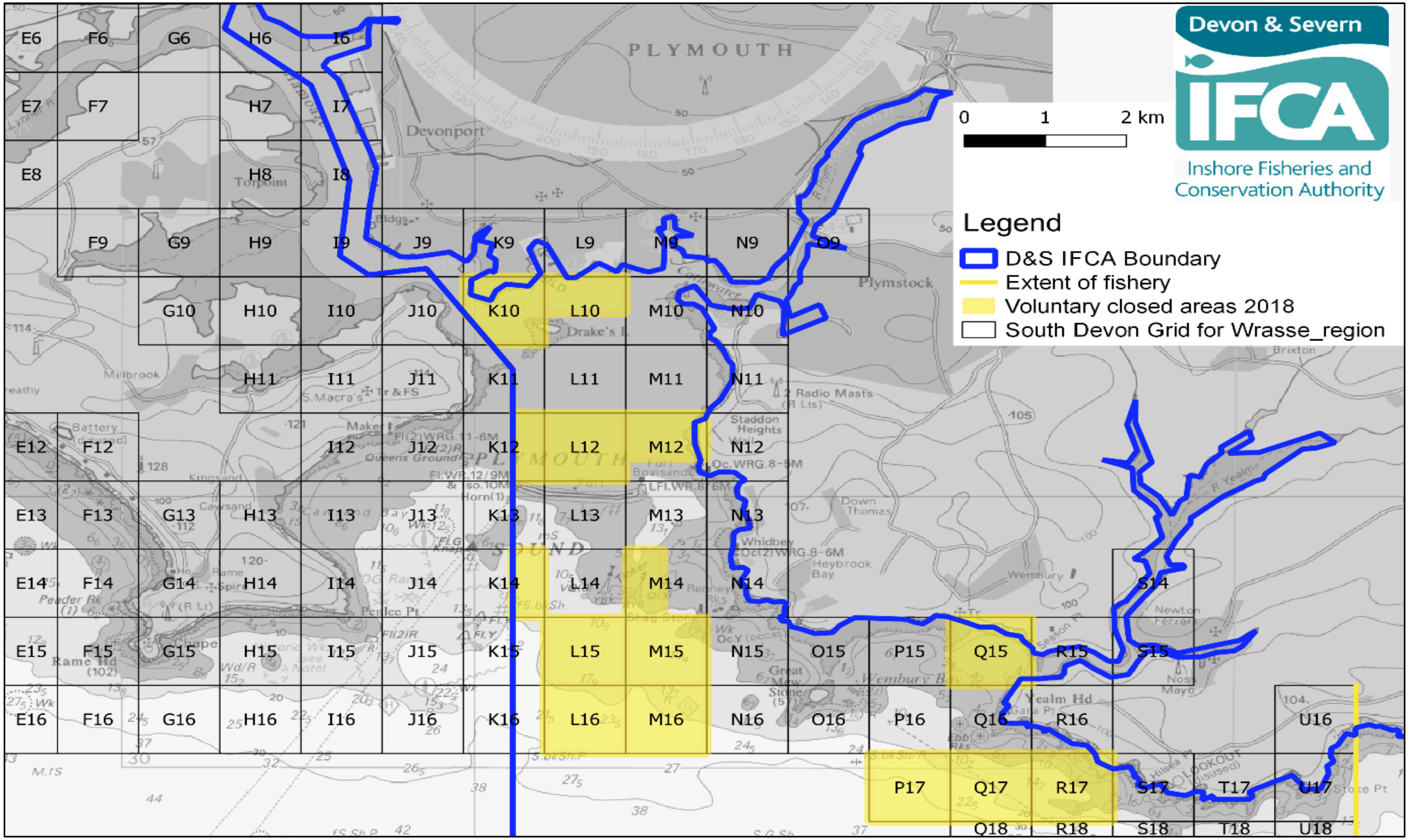


Figure 4. Chart of voluntary closed areas 2018.

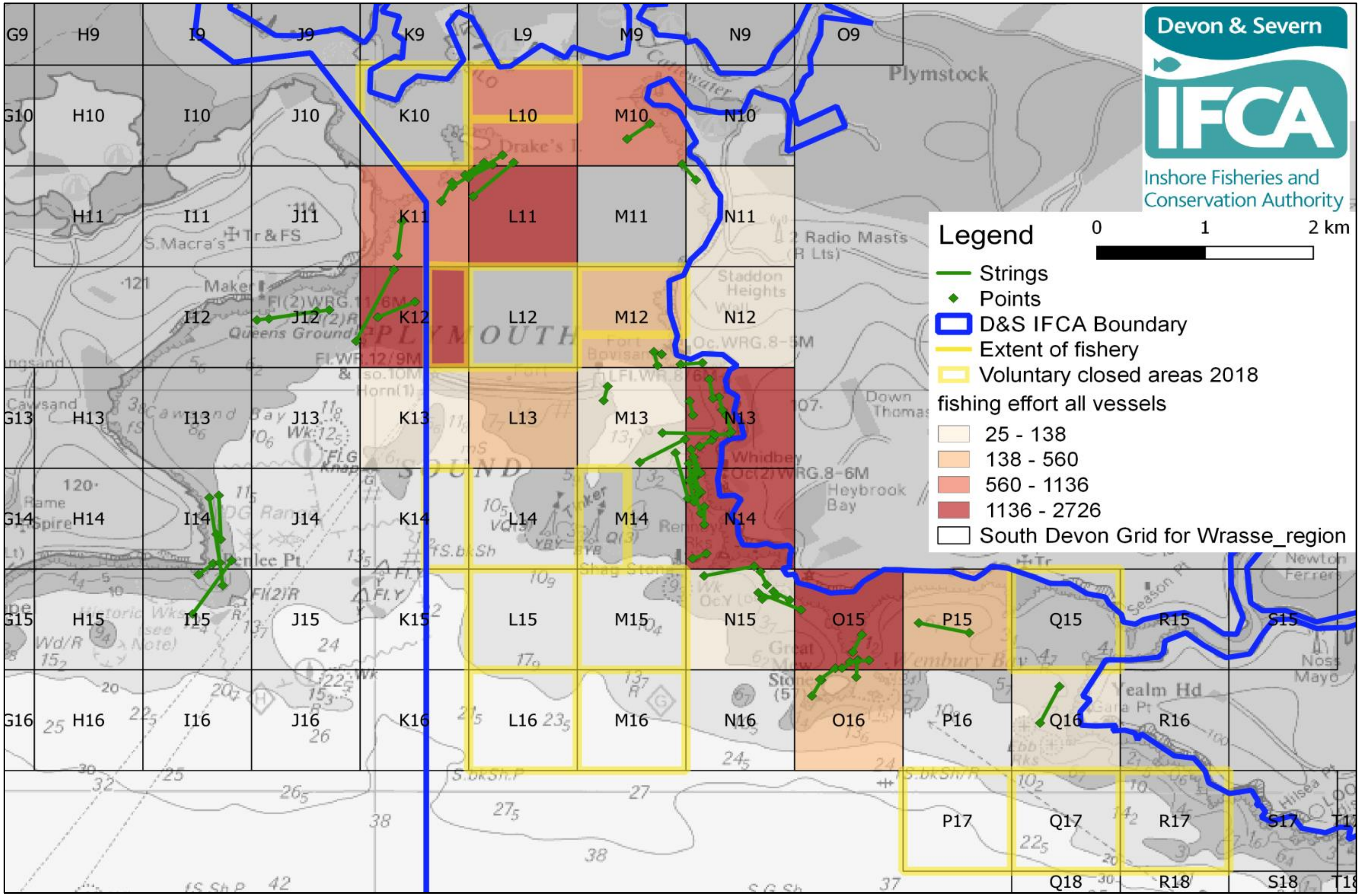


Figure 5. Chart of Plymouth Sound showing location of strings for all vessels from observer surveys and fishing effort per grid during May to October 2018 from fisher's landings forms.

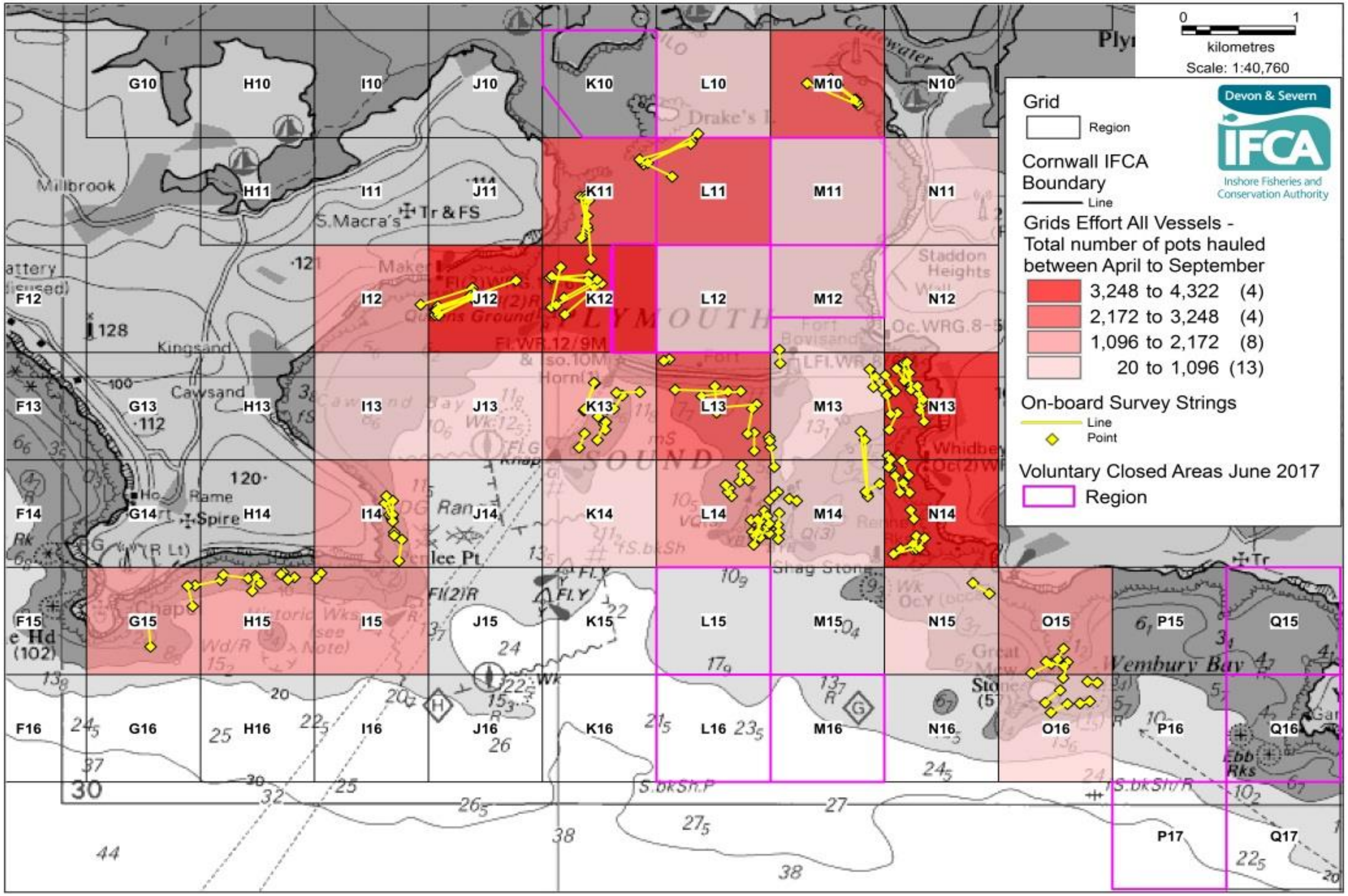


Figure 6. Chart of Plymouth Sound showing location of strings for all vessels from observer surveys and fishing effort per grid from landings forms during 2017.

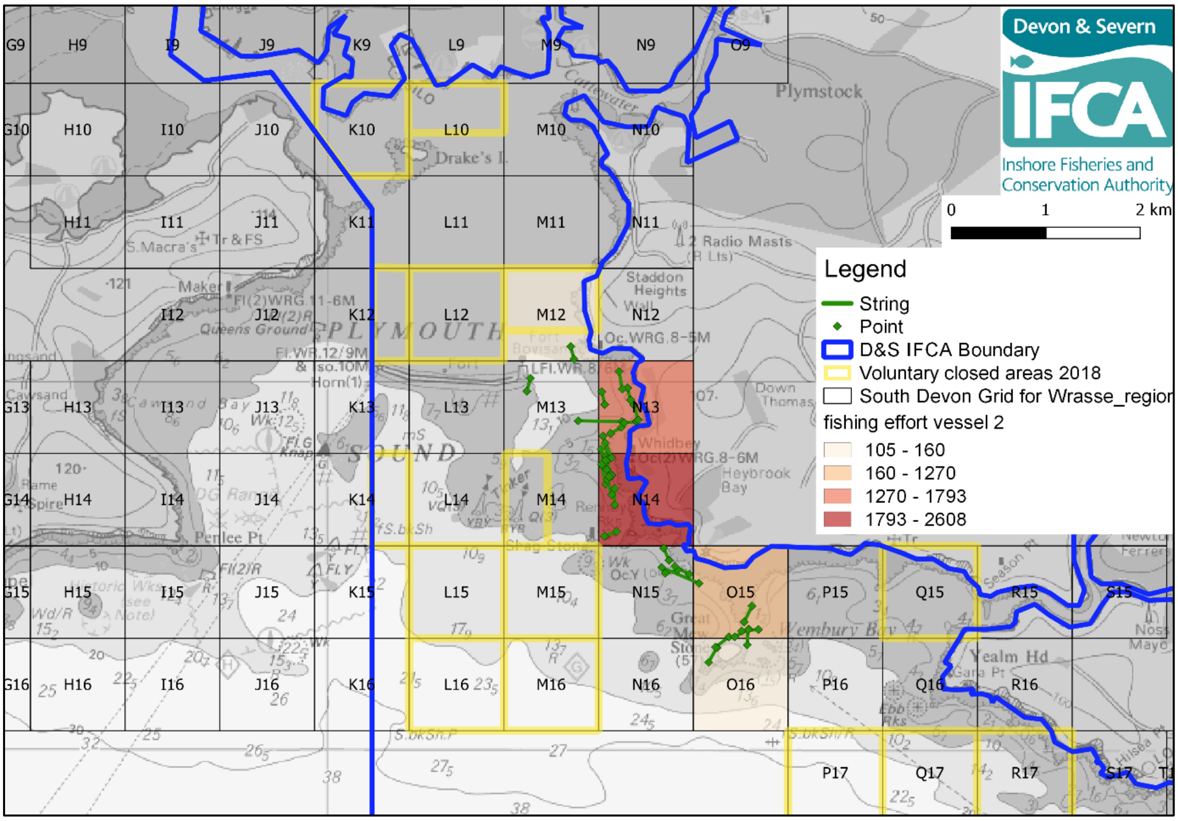


Figure 7. Chart of Plymouth Sound showing areas worked by vessel 2 during 2018 from landings forms

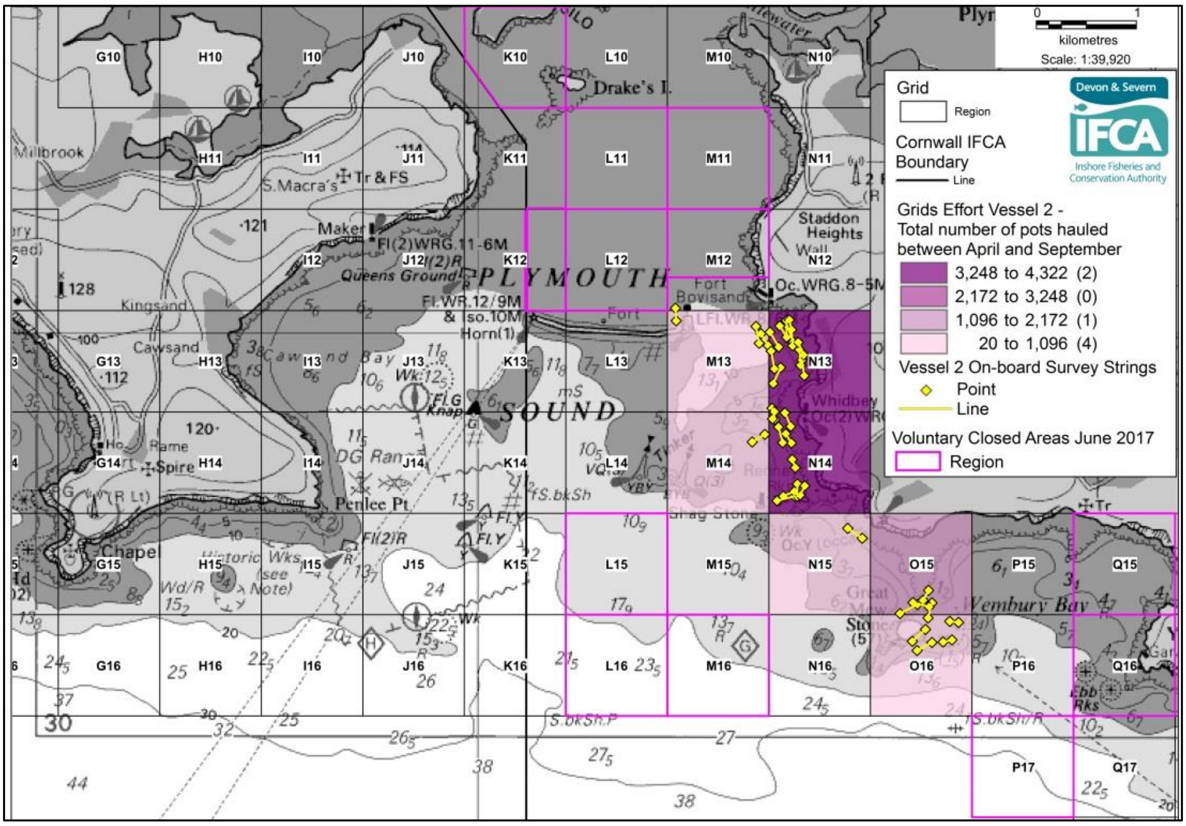


Figure 8. Chart of Plymouth Sound showing areas worked by vessel 2 during 2017 from landings forms

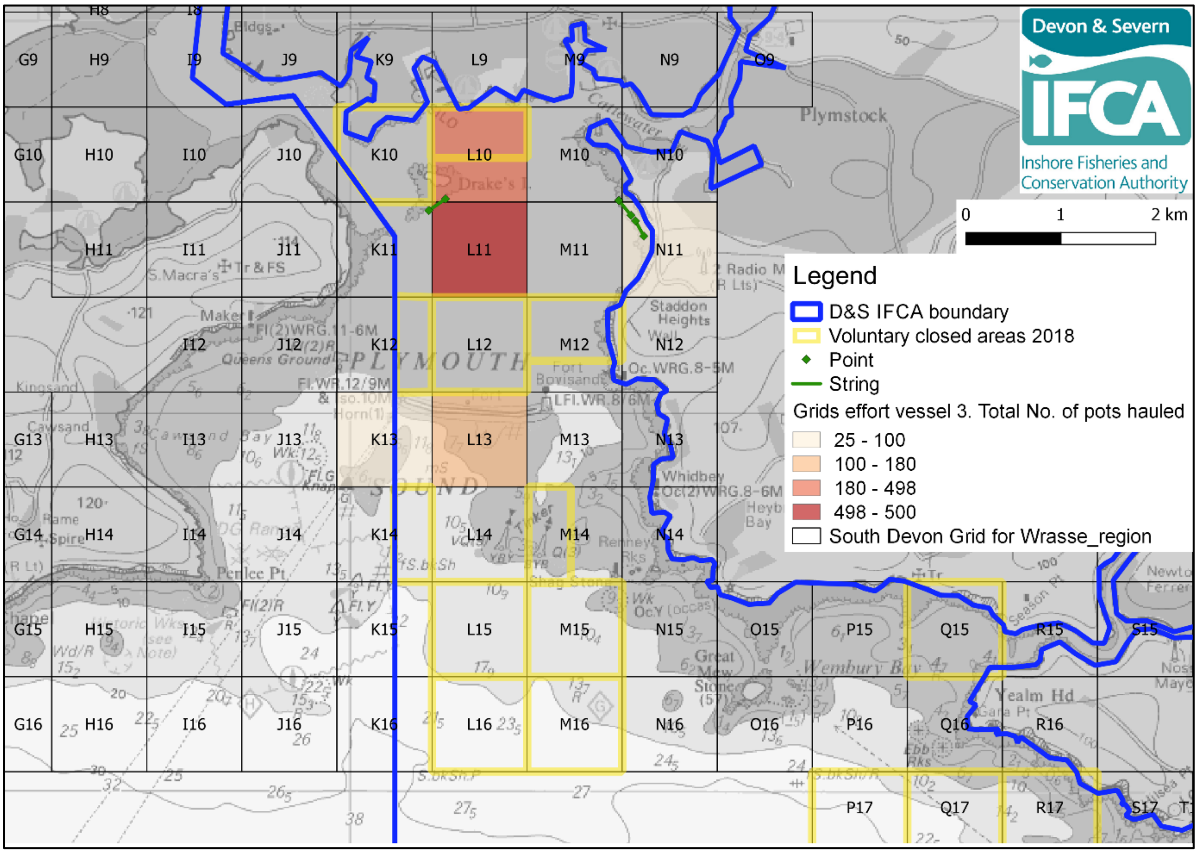


Figure 9. Chart of Plymouth Sound showing areas worked by vessel 3 during 2018 from landings forms

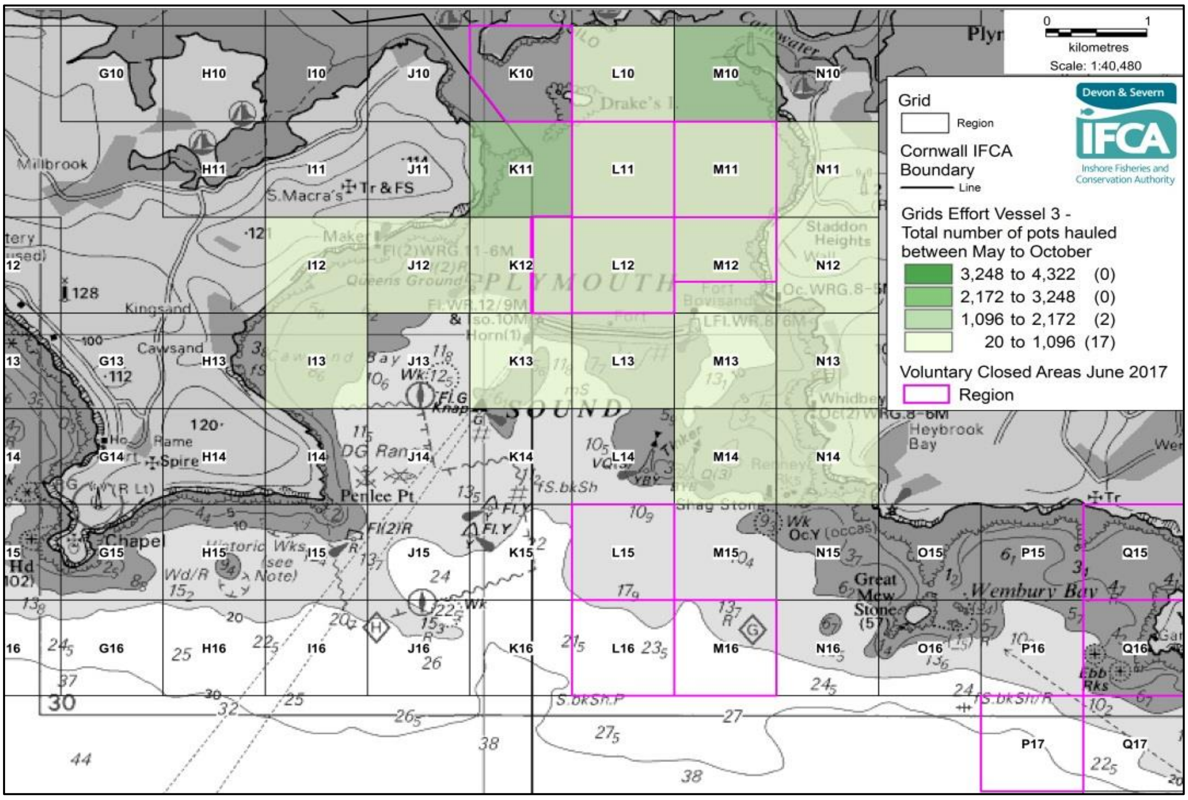


Figure 10. Chart of Plymouth Sound showing areas worked by vessel 3 during 2017 from landings

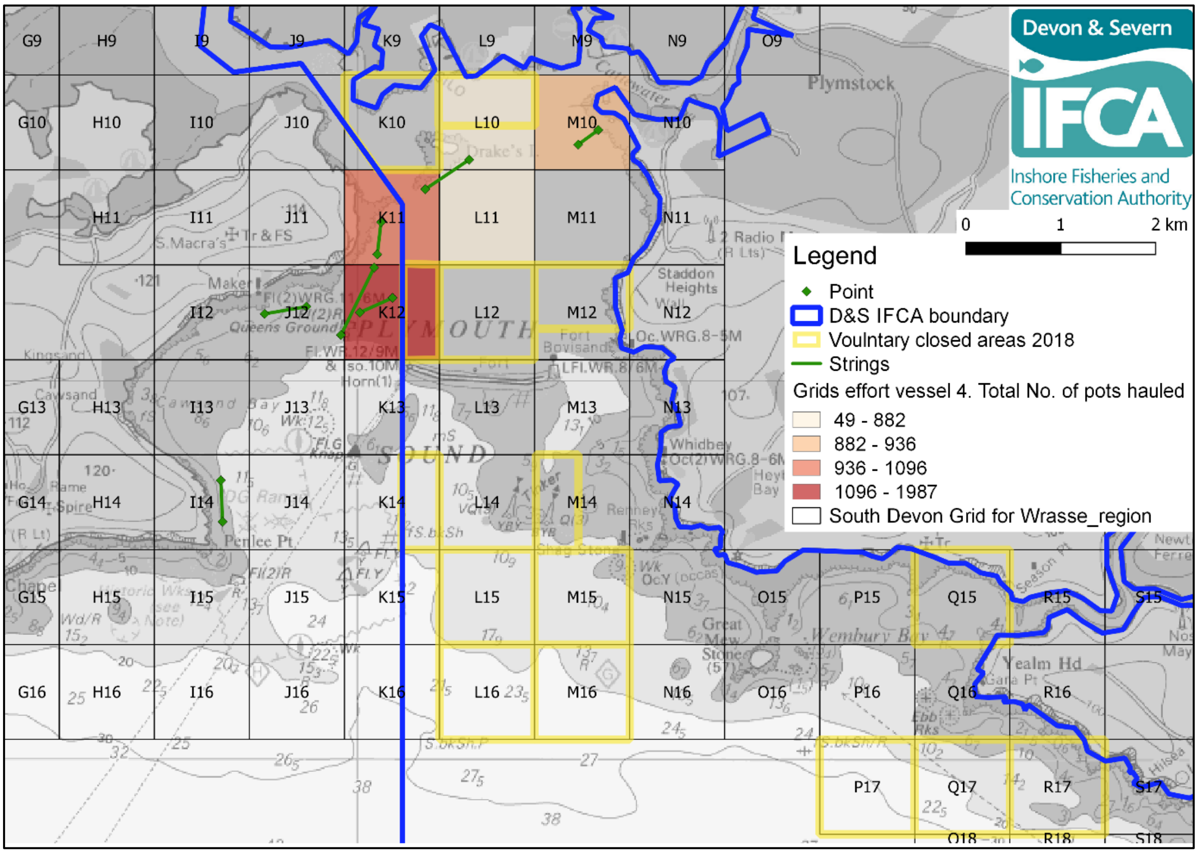


Figure 11. Chart of Plymouth Sound showing areas worked by vessel 4 during 2018 from landings forms.

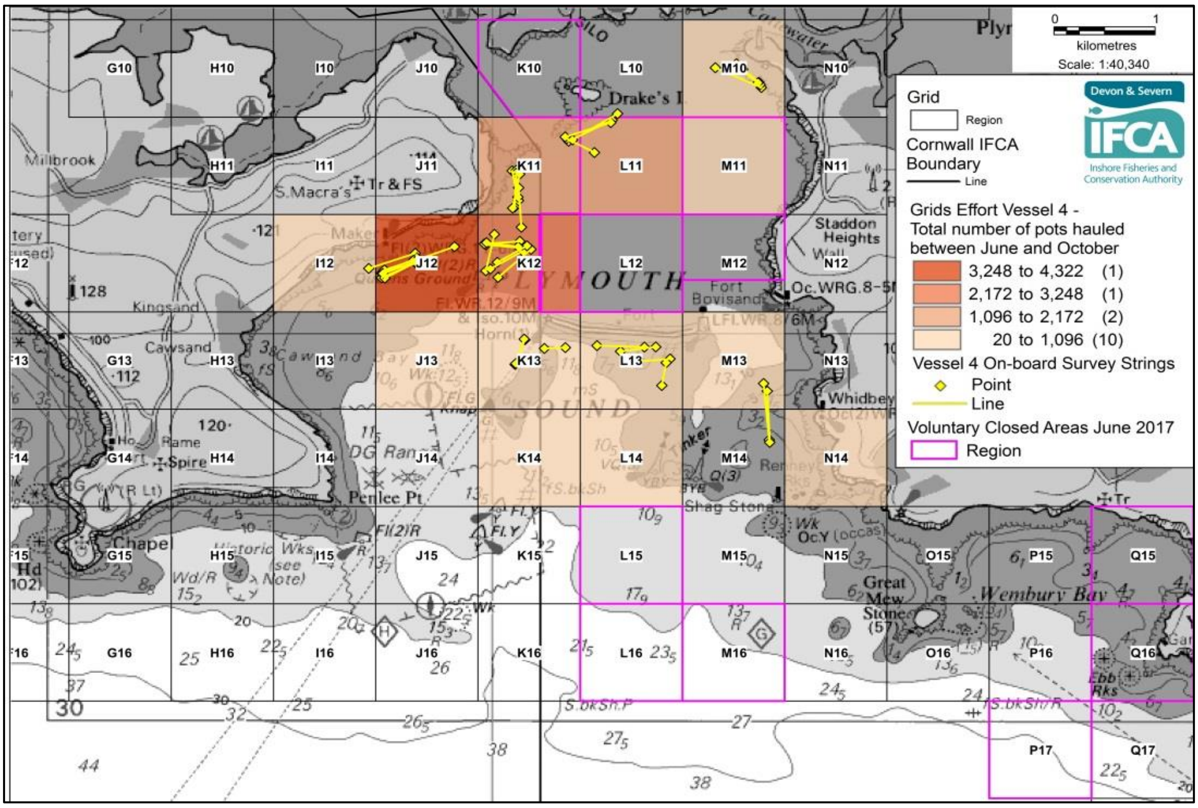


Figure 12. Chart of Plymouth Sound showing areas worked by vessel 4 during 2017 from landings forms

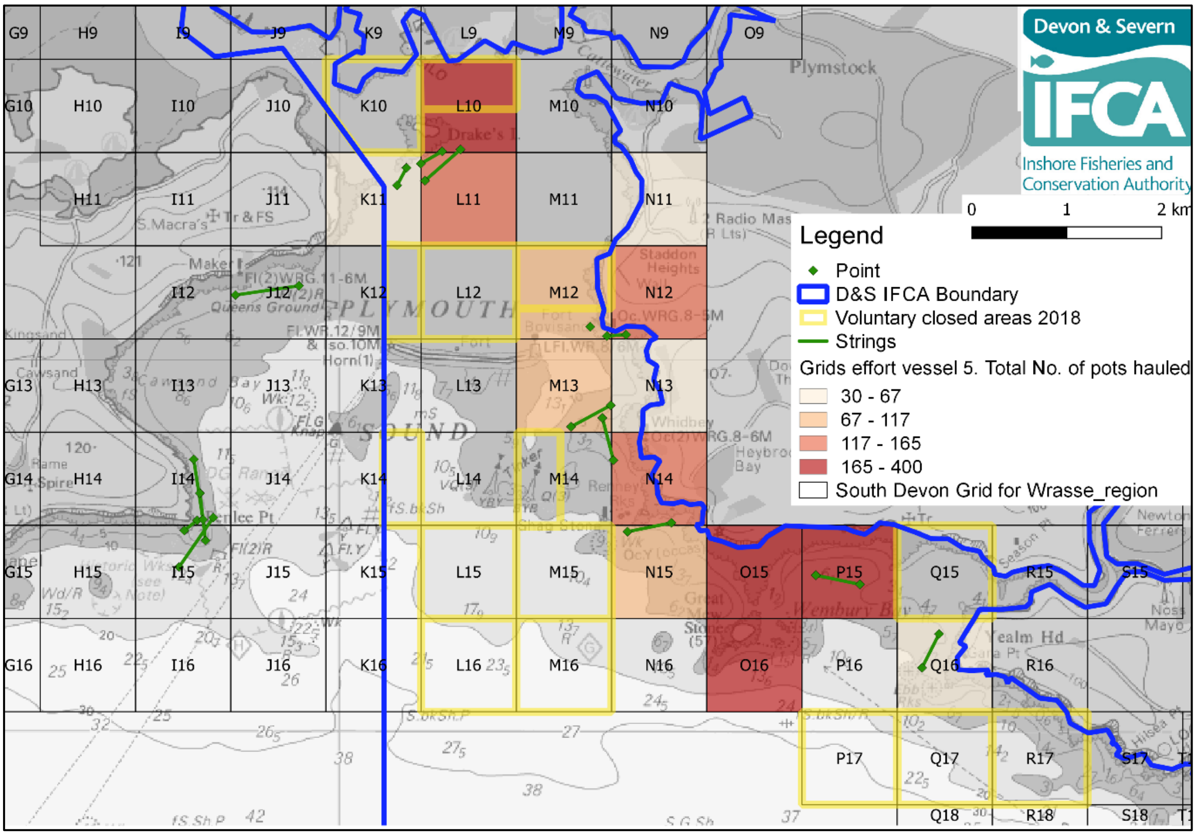


Figure 13. Chart of Plymouth Sound showing areas worked by vessel 5 during 2018 from landings forms.

3.5. High Resolution CPUE Analysis

3.5.1 Differences in CPUE Between 2017 and 2018 and Between IFCA Districts

The box-and-whisker plot for CPUE between Districts (2017 and 2018 data combined) shows a slightly lower median but a similar range in CPUE for Devon compared to Cornwall (Figure 14a). The same plot for 2017 compared to 2018 data (both Districts pooled) shows that in 2017 there were more instances of above average catches (the ‘outliers’ in the plots) compared to 2018 (Figure 14b). However, the two-way ANOVA found no significant differences in CPUE between IFCA Districts, or between years (Table 6). The interaction between the predictor variables (year and District) was also statistically non-significant. Interaction effects represent the combined effects of factors (year, district) on the dependent measure (CPUE). When an interaction effect is present, the impact of one factor depends on the level of the other factor.

Table 6. Summary of two-way ANOVA on the differences in CPUE between IFCA Districts and Years and interaction between the two predictor variables

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Year	1	0.277	0.27732	2.871	0.0921
IFCA District	1	0.310	0.30972	3.206	0.0752
Year:District	1	0.016	0.01588	0.164	0.6857
Residuals	162	15.651	0.09661		

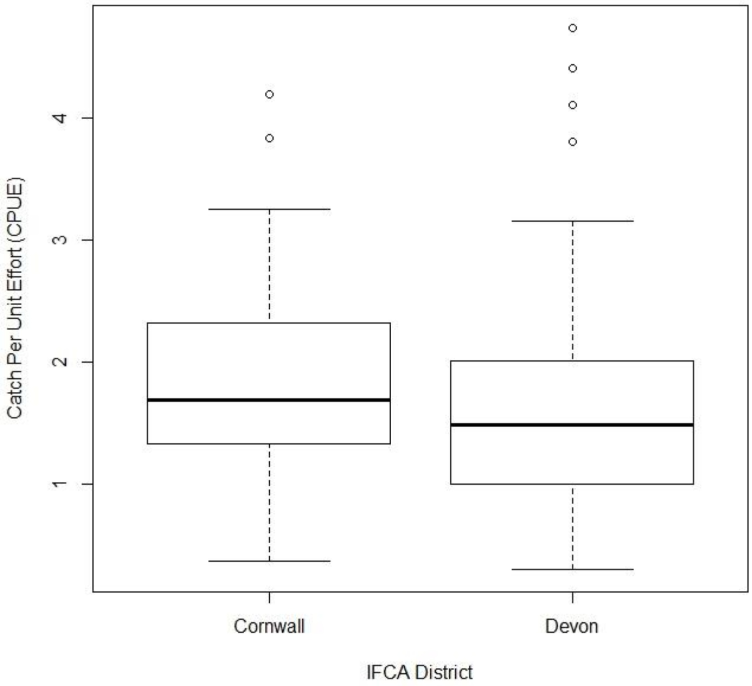


Figure 14a **-** Box-and-whisker plots of the CPUE for each IFCA District (2017 and 2018 data pooled) showing median (dark line), the lower and upper quartiles (25% and 75%) (the top and bottom of the box) the minimum and maximum values excluding the outliers (the 'whiskers'), and the outliers (hollow circles)

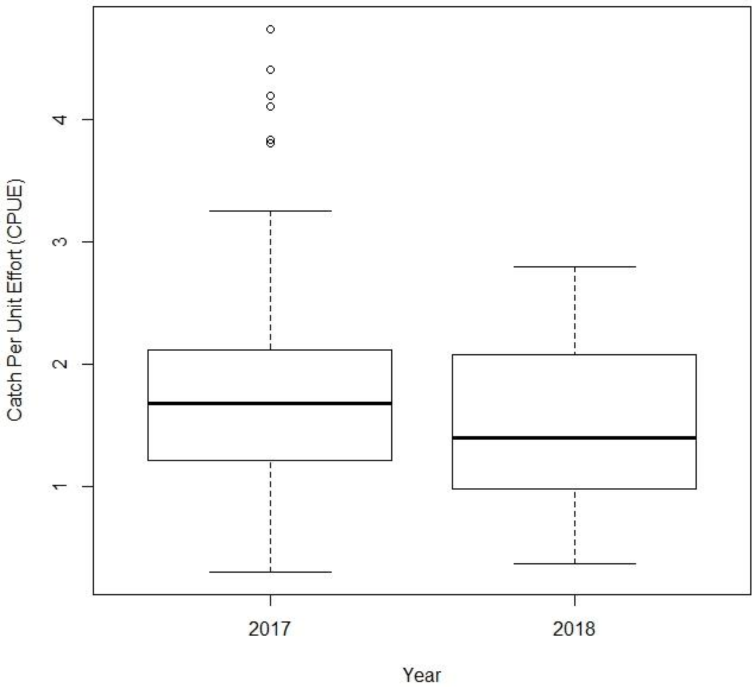


Figure 14b **-** Box-and-whisker plots of the CPUE for 2017 and 2018 (Devon and Cornwall data pooled) showing median (dark line), the lower and upper quartiles (25% and 75%) (the top and bottom of the box) the minimum and maximum values excluding the outliers (the 'whiskers'), and the outliers (hollow circles)

3.5.2 Temporal Changes in CPUE Within Grid Cells

Comparisons of CPUE between individual grid cells showed no overall pattern, with only one cell (N14) showing a significant change in CPUE between 2017 and 2018. The box-and-whisker plot for grid N14 shows that this difference relates to an increase in CPUE from 2017 to 2018 (Figure 15). Although the Mann-Whitney U-tests were not significant, the box-and-whisker plots show an increase in CPUE in grid cell I14, and a decrease in cell O15 between 2017 and 2018 (Figure 15). It should be noted that sample sizes (the number of strings observed) were relatively small for this analysis (Table 7) and so comparisons should be treated with caution.

Table 7. Summary of U-tests for differences in CPUE between 2017 and 2018 for individual grid cells

Grid cell	**Mann -Whitney U tests for differences between years**			
	Number of strings observed in 2017	**Number of strings observed in 2018**	**P-value**	**Statistical significance**
I14	5	4	0.19	Non-significant
L11	4	3	0.86	Non-significant
M13	4	3	0.86	Non-significant
N13	12	8	0.33	Non-significant
N14	8	10	**0.03***	**Significant**
O15	4	6	0.47	Non-significant

3.5.3 Temporal Changes in CPUE Within Vessels, Between Years

Trends in CPUE between years for individual vessels could only be explored for two vessels. Two vessels were excluded as they had fished in only one of the two years (Vessel 1 and Vessel 5) and one vessel had insufficient strings sampled in both years (Vessel 3). Vessel 2 had a statistically significant reduction in CPUE from 2017 to 2018 (Mann-Whitney U-test, W = 1527.5, p-value = 0.04). Vessel 4 did not have statistically significant change in CPUE over the same time period (Mann Whitney U-test, W = 154, p-value = 0.52). Box-and-whisker plots for both vessels show reduced upper range limits and less upper-limit outliers in 2018 compared to 2017 (Figure 16). When the data from the two years are pooled and the two vessels which fished either in 2017 only (Vessel 1) or 2018 only (Vessel 2) are plotted together (Figure 17) it can be seen that the median and interquartile range of CPUE for each vessel is similar, but that only a few vessels have the high ‘outlier’ CPUEs (previous plots have confirmed that these data points are from 2017.

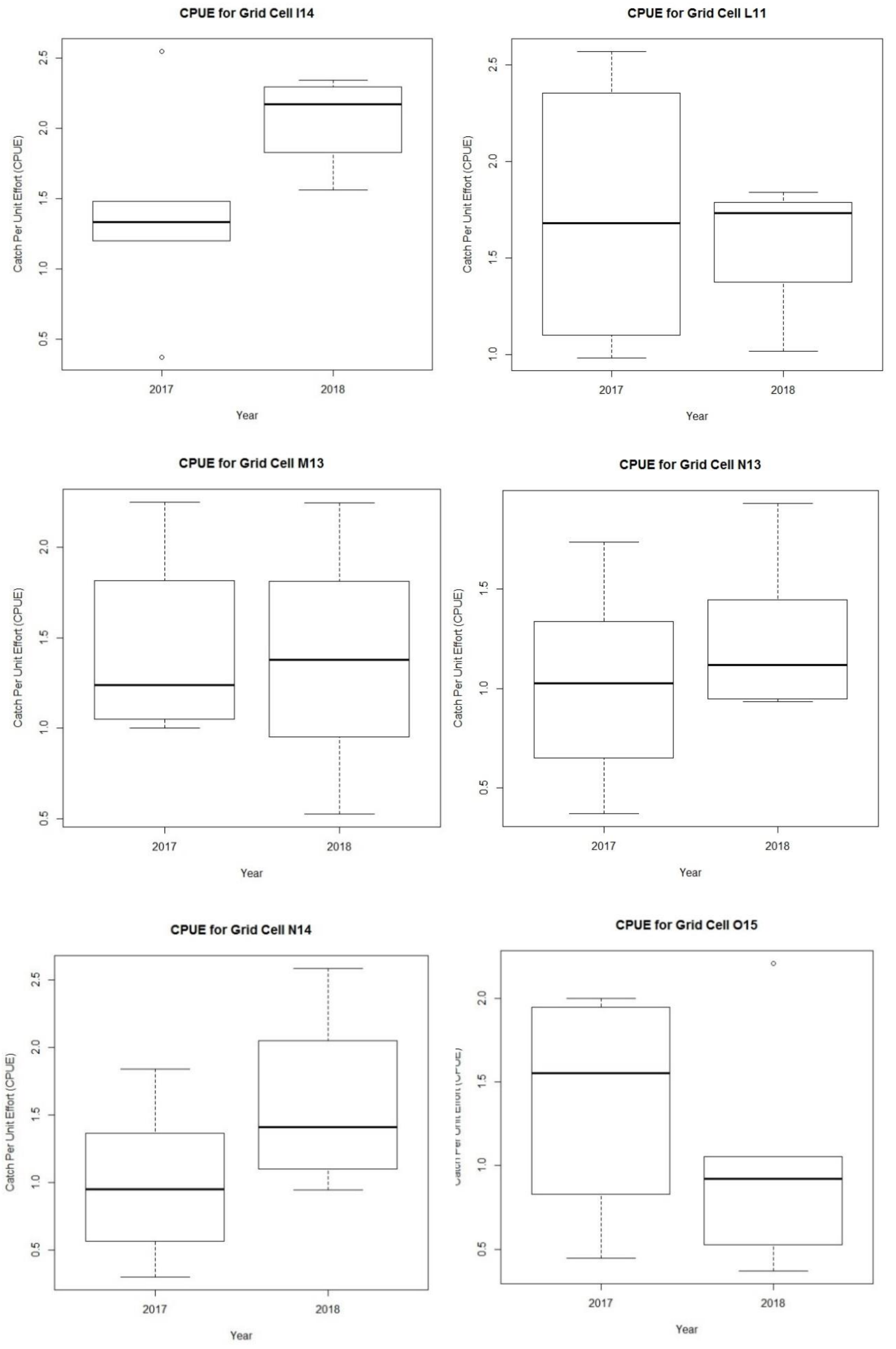


Figure 15A-E. Box-and-whisker plots of the CPUE for individual grid cells in 2017 and 2018 showing median (dark line), the lower and upper quartiles (25% and 75%) (the top and bottom of the box) the minimum and maximum values excluding the outliers (the ‘whiskers’), and the outliers (hollow circles)

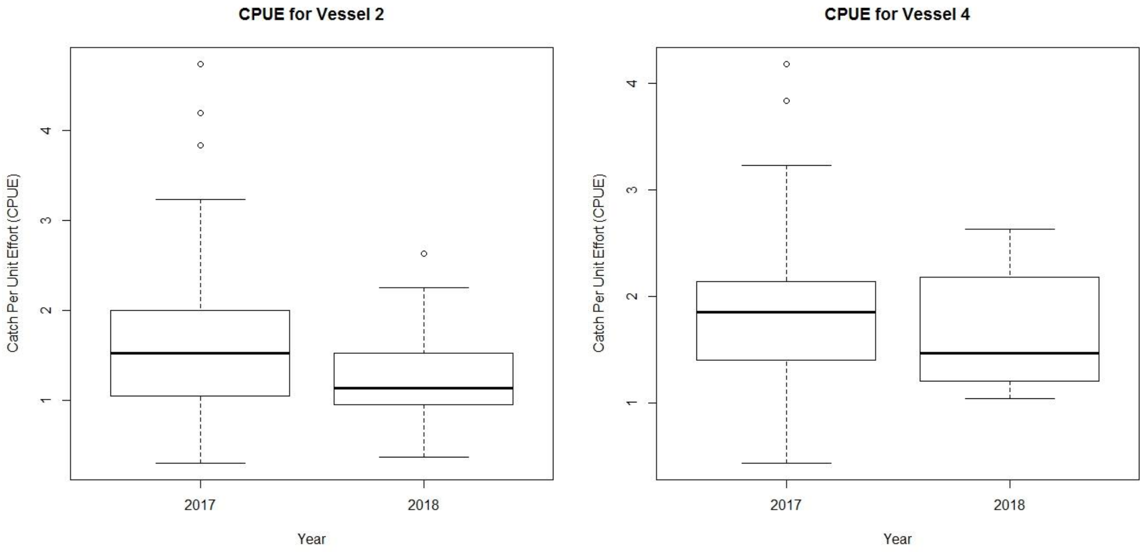


Figure 16. Box-and-whisker plots of the CPUE for Vessel 2 and Vessel 4 in 2017 and 2018 showing median (dark line), the lower and upper quartiles (25% and 75%) (the top and bottom of the box) the minimum and maximum values excluding the outliers (the ‘whiskers’), and the outliers (hollow circles)

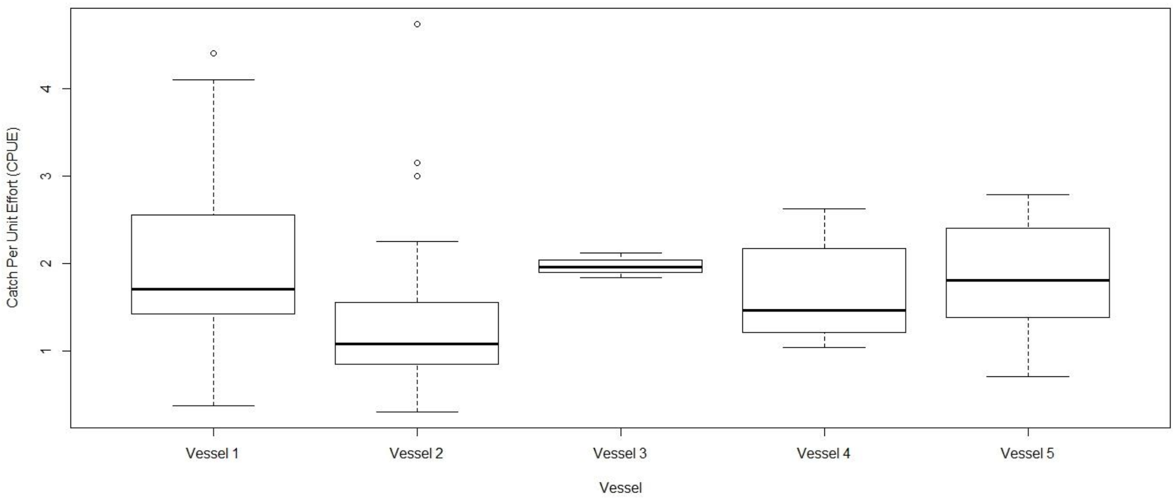


Figure 17 - Box-and-whisker plots for all vessels. Vessel 1 fished only in 2017 only, Vessel fished only in 2018, Vessel 3 was sampled only in 2018.Showing median (dark line), the lower and upper quartiles (25% and 75%) (the top and bottom of the box) the minimum and maximum values excluding the outliers (the ‘whiskers’), and the outliers (hollow circles).

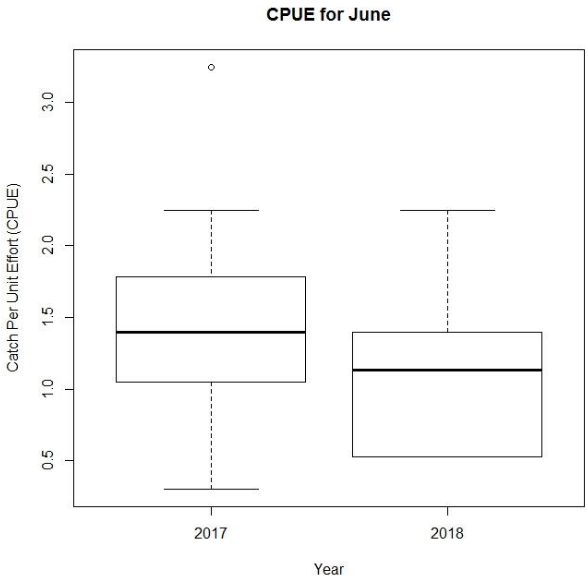
3.5.4 Temporal Changes in CPUE Within Months, Between Years

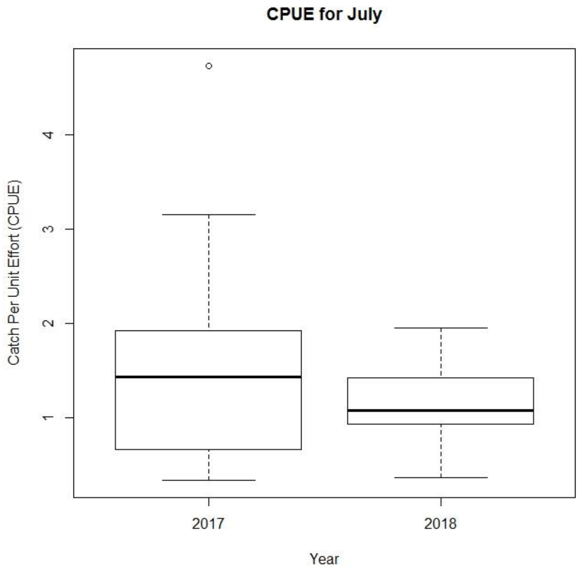
Mann Whitney U-tests did not find any statistical differences between 2017 and 2018 for June, July, August or September (Table 8). Differences were found between October 2017 and October 2018, however as only (approximately) the first week was sampled in both years, this result should be treated with caution. Similarly, only one survey was carried out in September 2018 and two surveys in June 2018, so these comparisons should also be treated with caution.

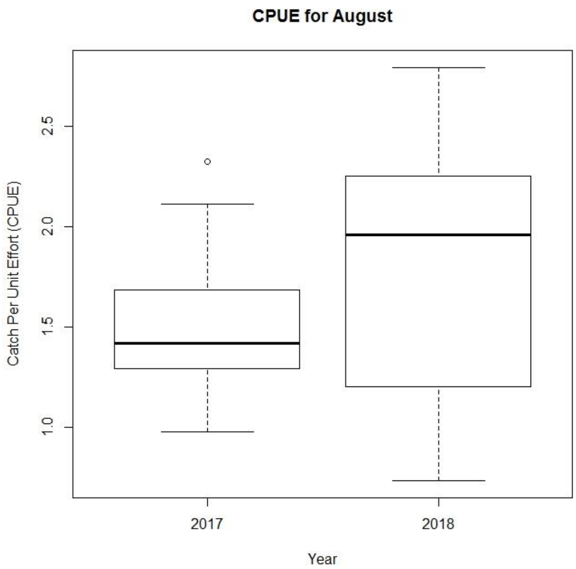
Table 8. Summary of U-tests for differences in CPUE between 2017and 2018 for each month

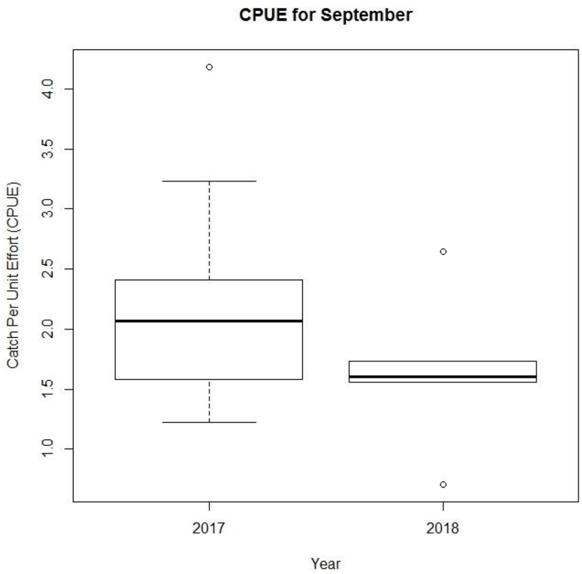
	Mann-Whitney U tests for differences between years			
Month	**Number of strings observed in 2017**	**Number of strings observed in 2018**	**P-value**	**Statistical significance**
June	30	6	0.3726	Not significant
July	30	10	0.3731	Not significant
August	15	27	0.2818	Not significant
September	10	5	0.2974	Not significant
October	4	5	**0.03175**	**Significant**

Box-and-whisker plots for within-month, between year comparisons (Figure 18) show that medians have declines slightly for all months, except August which has a higher median CPUE. Anecdotal information from fishers suggests that catches were actually very good in September and exceeded the average for the rest of the year. This is confirmed by the LPUE recorded above (Figure 1) and indicates that insufficient sampling occurred on the observer surveys in September 2018.









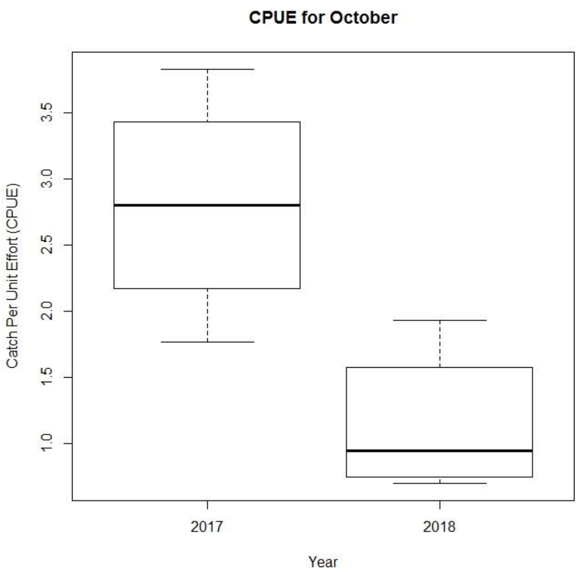


Figure 18 - Box-and-whisker plots for within month and between years CPUE. Showing median (dark line), the lower and upper quartiles (25% and 75%) (the top and bottom of the box) the minimum and maximum values excluding the outliers (the 'whiskers'), and the outliers (hollow circles).

3.6. Catch Composition

The assemblage composition of wrasse caught and recorded per month during the 2018 on-board observer surveys are shown in Figure 19. Figure 20 illustrates the catch composition for the 2017 period. Goldsinny and rock cook dominate the catch in May through to August, apart from July when rock cook catches exceed that of goldsinny. The percentage of corkwing starts to increase from August and more than doubles in September, with catches exceeding those of goldsinny and rock cook during September and October. Ballan remains consistently low over the survey period with very few cuckoo wrasse seen in catches. This contrasts with 2017, which showed a marked increase in ballan wrasse in September and October rather than corkwing.

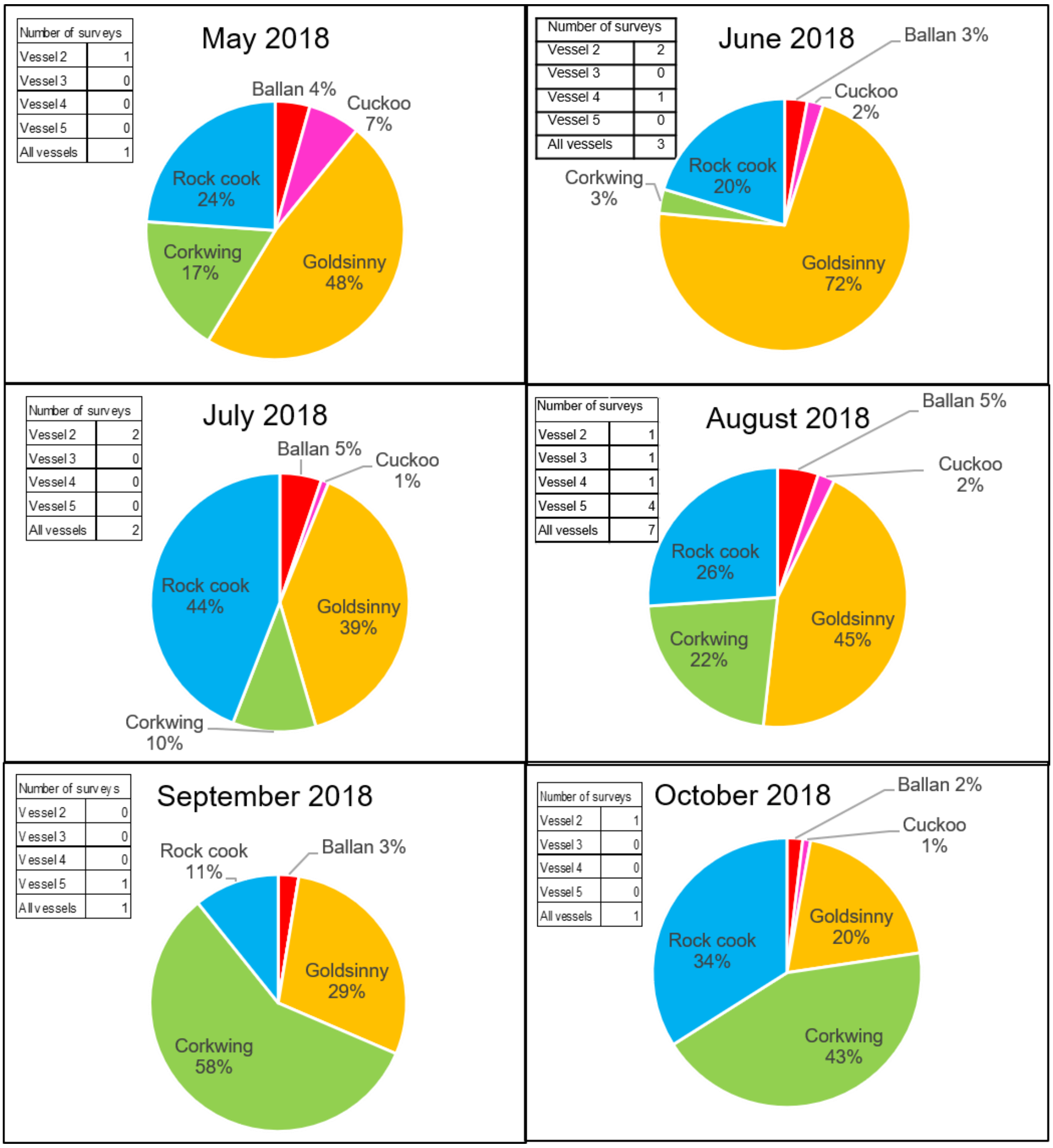


Figure 19. Assemblage composition of wrasse catches per month 2018. Taken from data obtained during the on-board observer surveys.

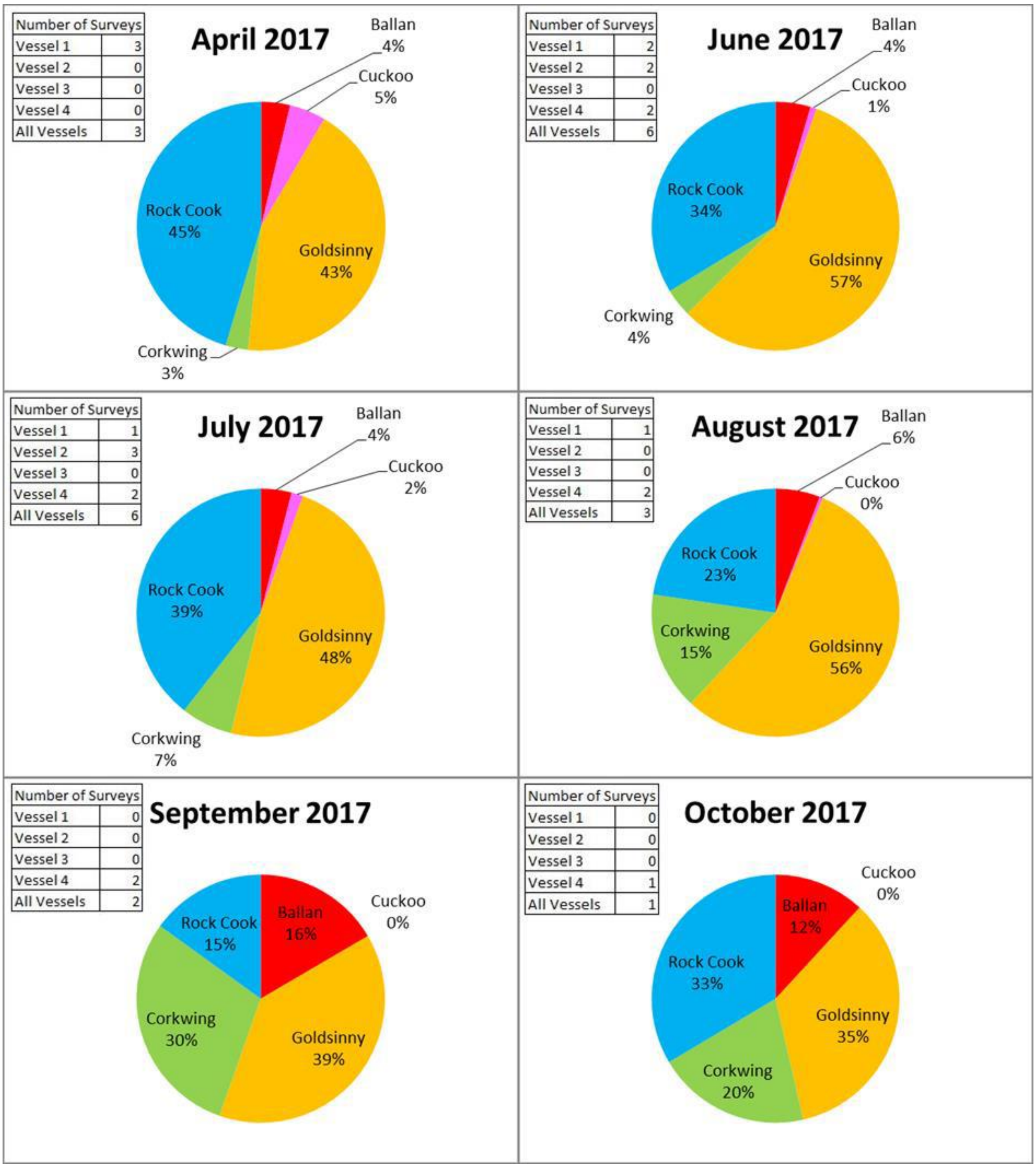


Figure 20. Assemblage composition of wrasse catches per month 2017. Taken from data obtained during the on-board observer surveys.

Assemblage composition of wrasse catches per vessel are shown in Figure 21. Goldsinny contributes the highest proportion of catch for vessels 3, 4 and 5. Rock cook and goldsinny make up an equal proportion of the catch for vessel 2. Assemblage composition follows a similar trend across all vessels, with a slightly higher proportion of goldsinny caught by vessel 3 compared to the others. These compositions per vessel relate to both the spatial effort (Figures 7,9,11 and 13) and the catch compositions per grid square (Figure 22).

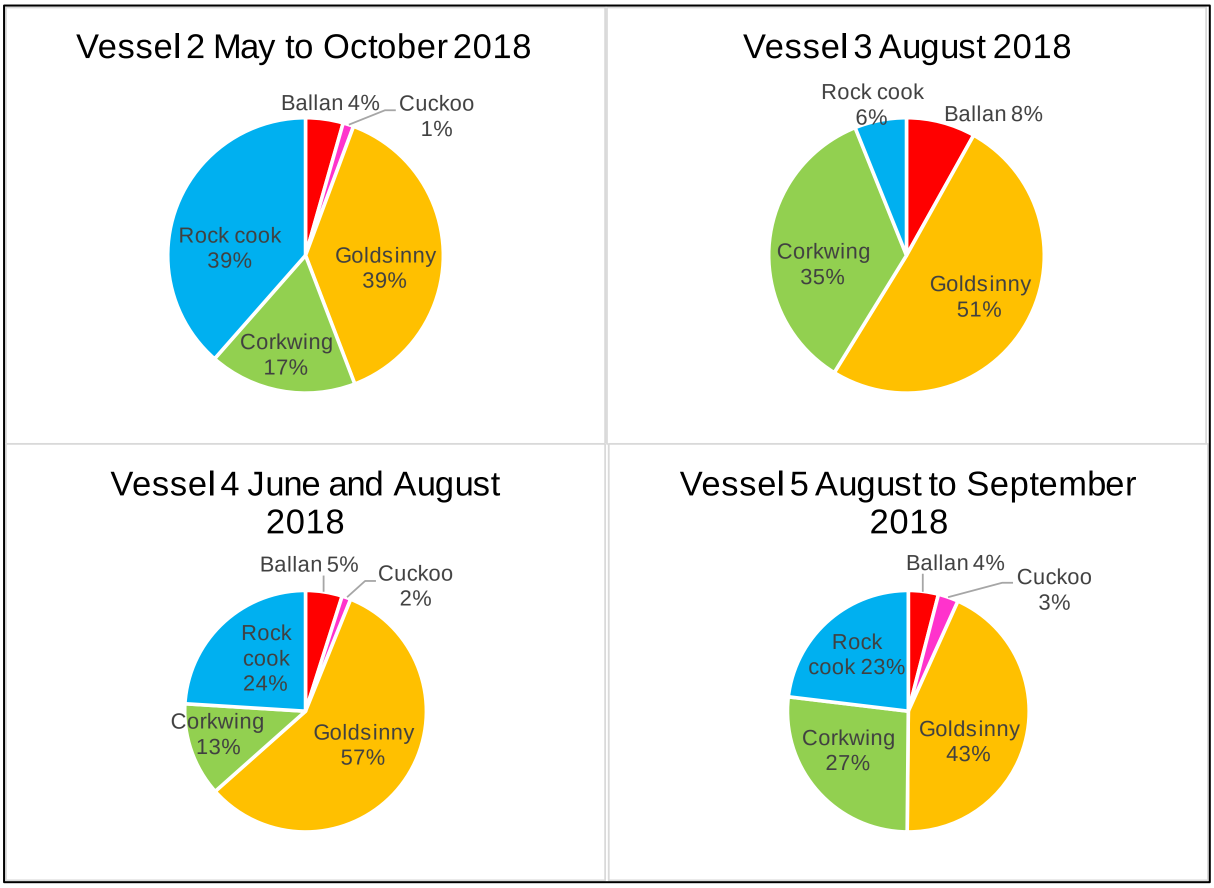


Figure 21. Assemblage composition of wrasse catches per vessel using the data collected from the on-board observer surveys.

Figures 22 and 23 illustrates the assemblage composition of wrasse catches per grid square for 2018 (Figure 22) and 2017 (Figure 23). As can be seen the composition of wrasse varies considerably across Plymouth sound for 2018, as shown in Figure 21. Goldsinny catches were highest in the south east corner around Wembury Bay and the Mewstone. Heybrook Bay and Wembury Bay seem to be a preferred area for rock cook, while corkwing dominated around the shallower coastal area of Staddon Heights. Ballan seemed to dominate in the north of the sound around Drakes Island. The small amount of cuckoo wrasse caught were in the more exposed area south of the breakwater around Wembury Bay.

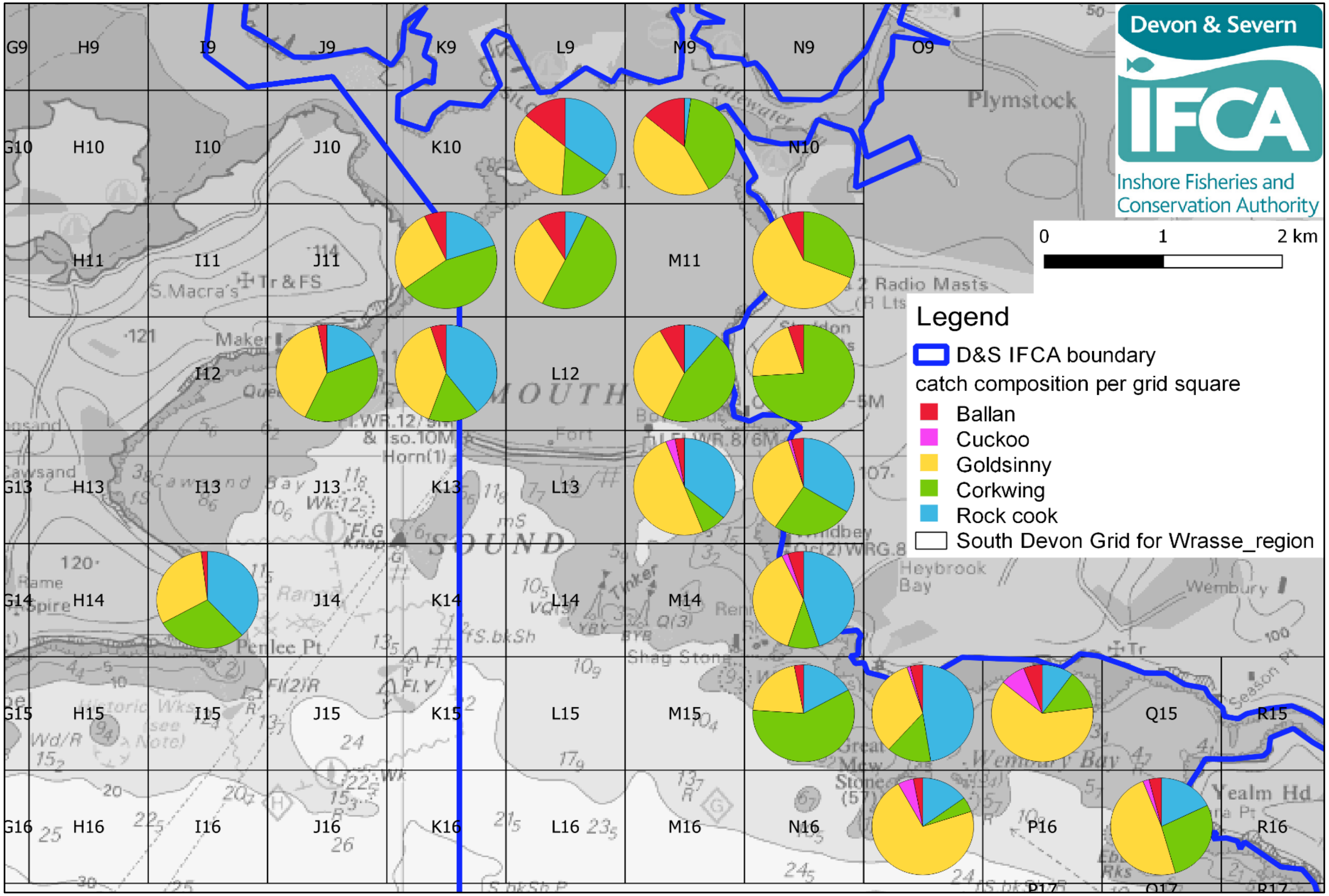


Figure 22. Assemblage composition of wrasse catches per grid in Plymouth Sound during 2018. Data taken from the on-board observer surveys.

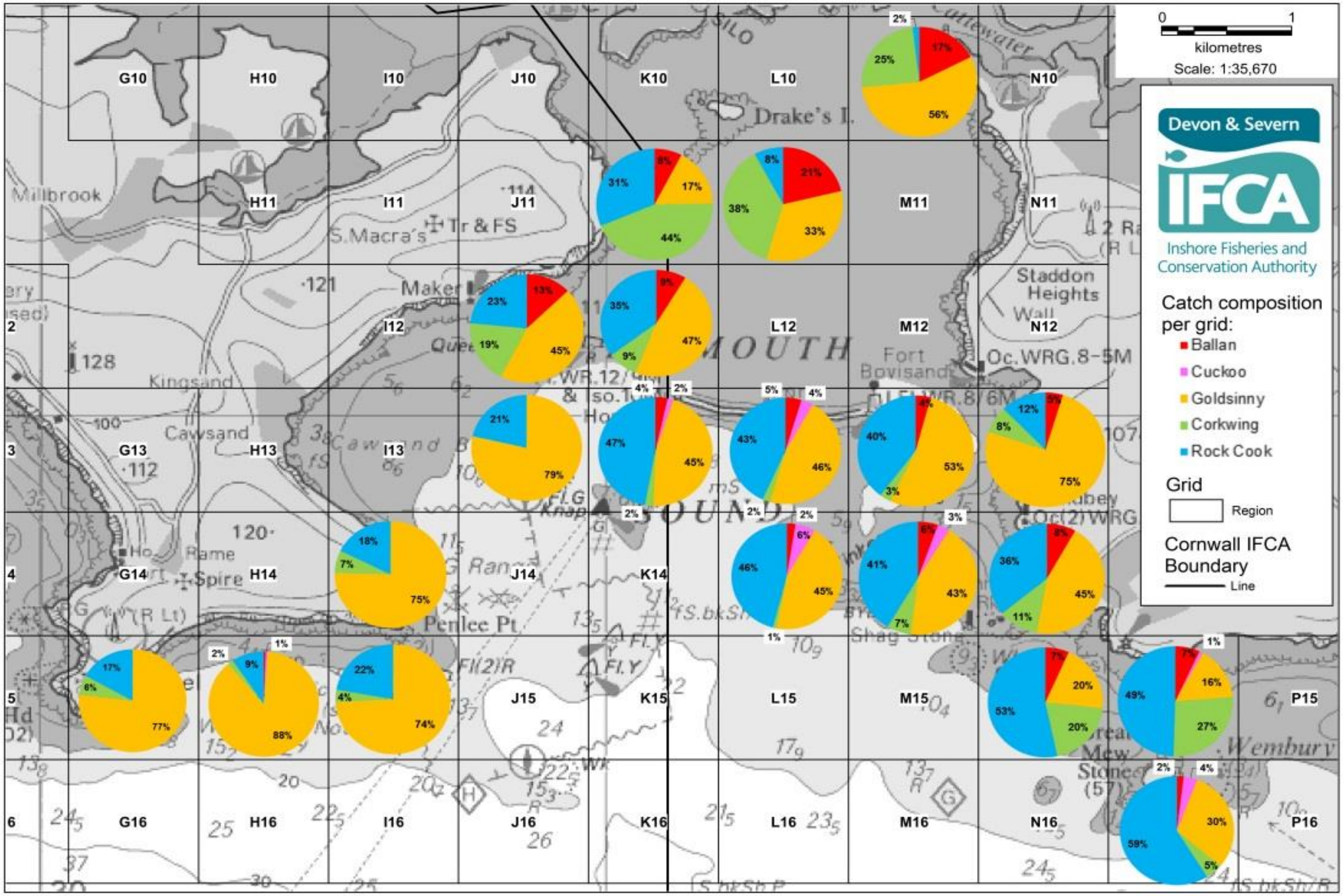
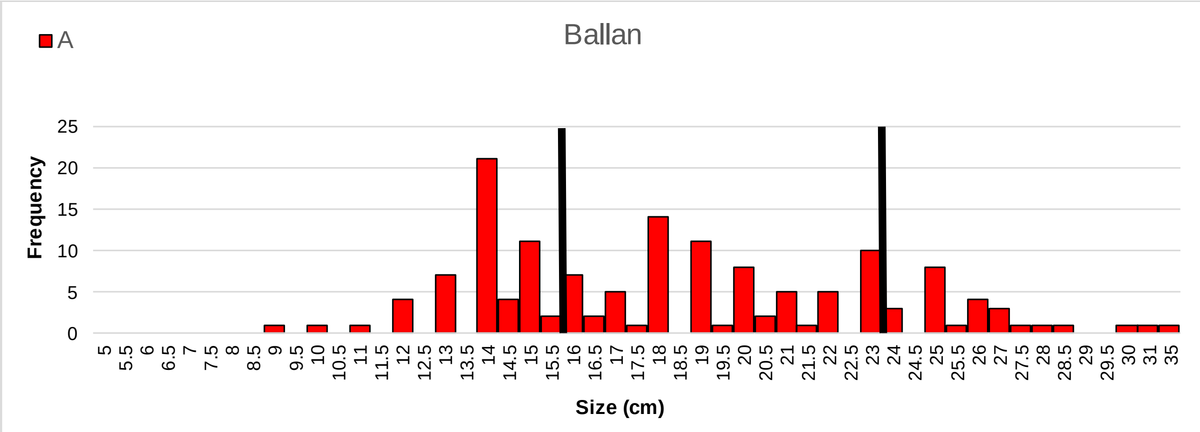
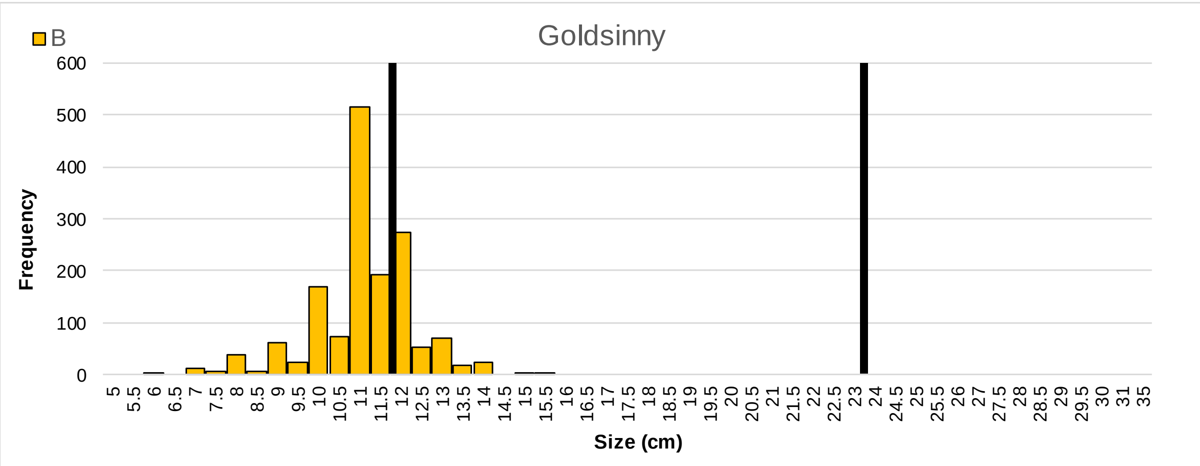


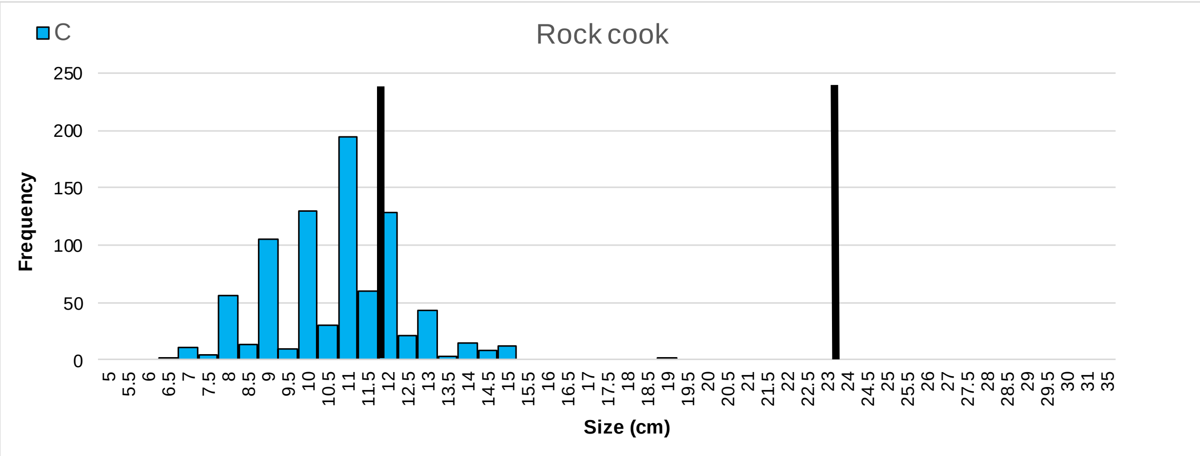
Figure 23. Assemblage composition of wrasse catches per grid in Plymouth Sound during 2017. Data taken from the on-board observer surveys.

3.7. Size Distributions

Figures 24 (A-F) illustrate size frequency histograms of all wrasse caught during the on-board observer surveys during 2018. Figures 25 and 26 show the size frequency histograms of all wrasse caught during the on-board observer surveys in 2017.These histograms show the slot size ranges for each individual species to establish whether the current Min and Max CRS are sufficient as a management measure. There are two figures for corkwing as the Min and Max CRS was amended under the new potting byelaw permit conditions, which came into force on 13 August 2018. The Min and Max CRS size changed from 12-23cm (Figure 24D) to 14-18cm (Figure 24E).







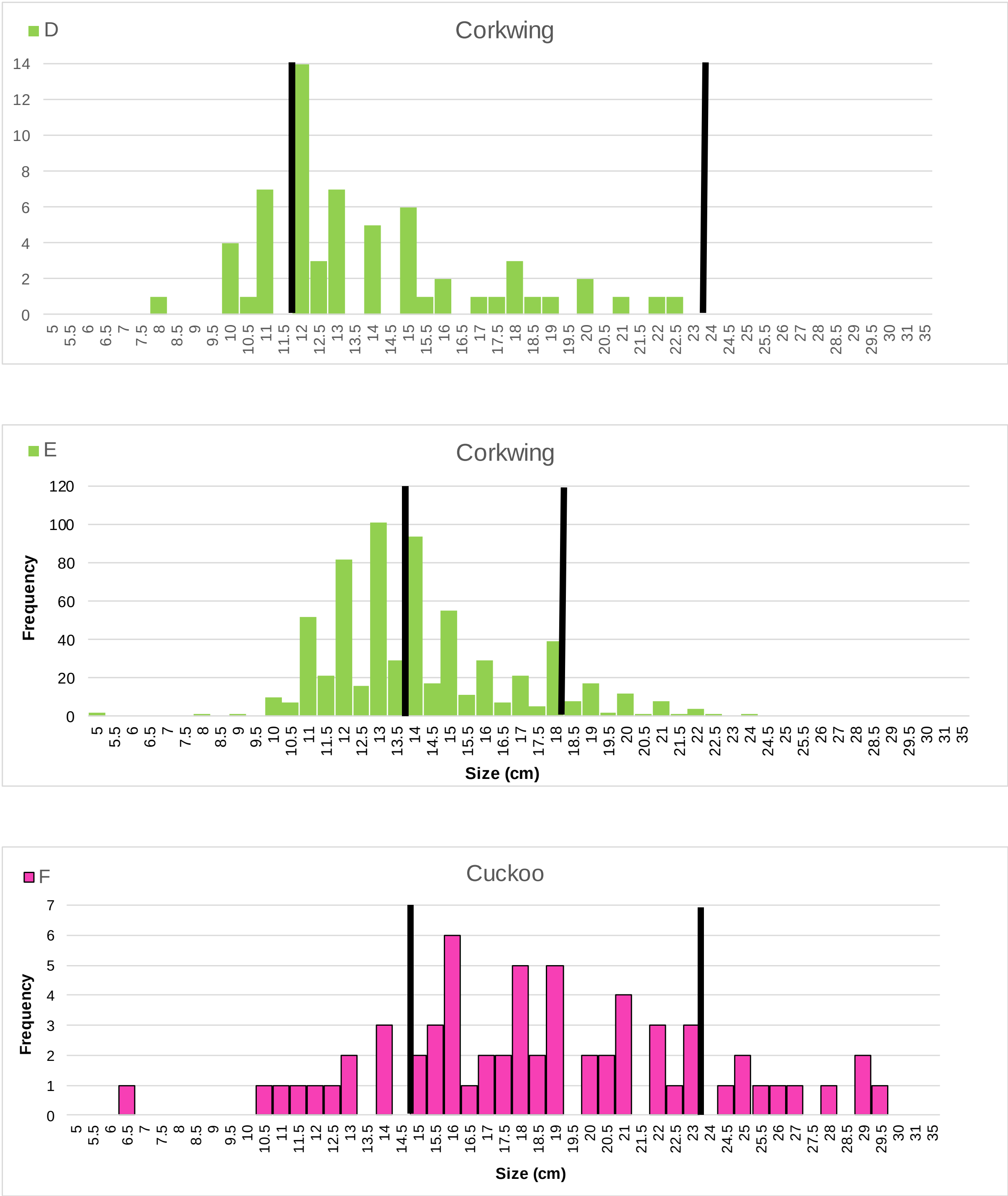


Figure 24 (A-F). Size frequency histograms for individual species of wrasse caught (regardless of whether they were retained or returned) during on-board observer surveys. Black lines indicate the minimum and maximum conservation reference size. Figure 24D is for the period up to 12 August 2018. Figure 24E is after the new potting permit byelaw conditions were implemented on 13 August 2018

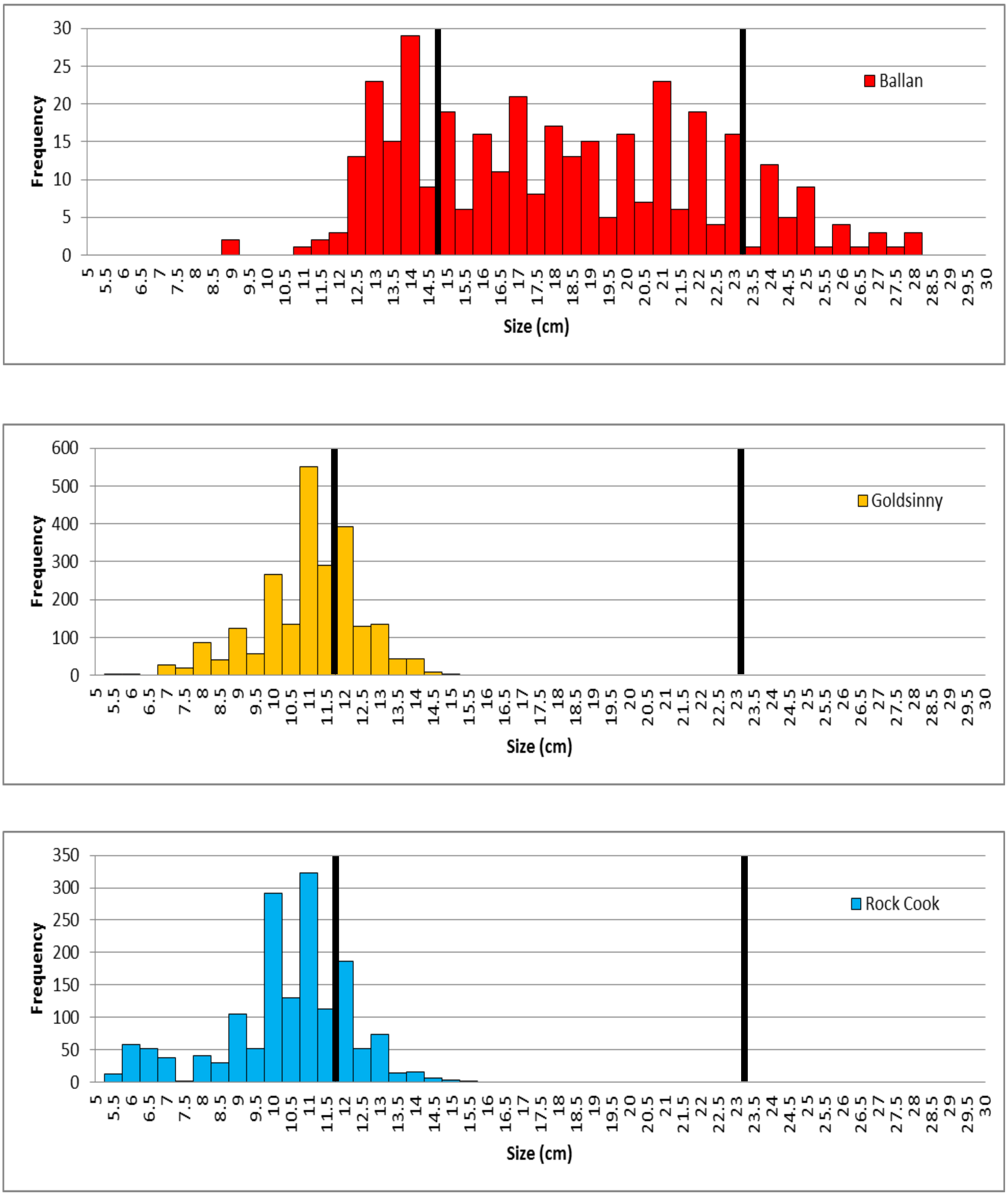
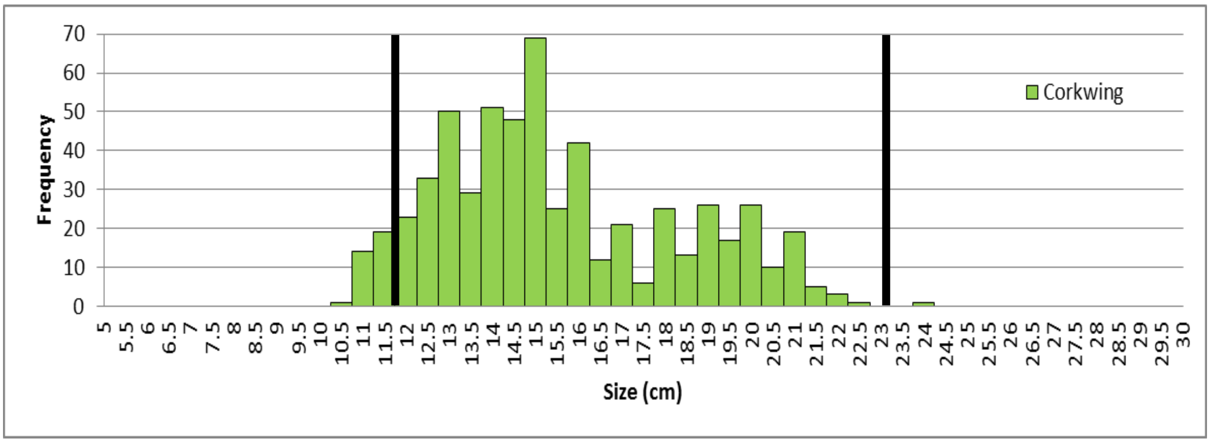


Figure 25. Size frequency histograms for ballan, goldsinny and rock cook caught during 2017 (regardless of whether they were retained or returned) during on-board observer surveys. Black lines indicate the minimum and maximum conservation reference size.



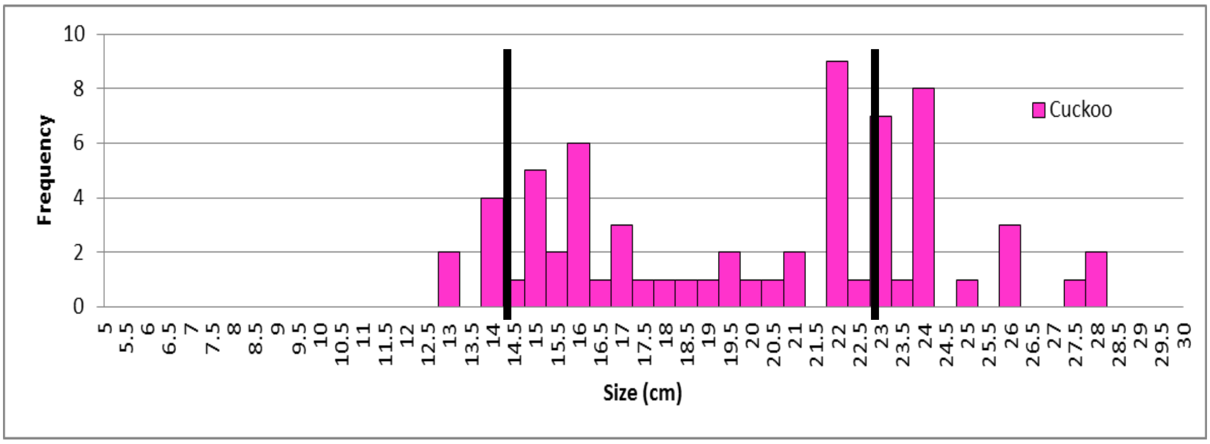


Figure 26. Size frequency histograms for corkwing and cuckoo caught during 2017 (regardless of whether they were retained or returned) during on-board observer surveys. Black lines indicate the minimum and maximum conservation reference size.

The size of ballan wrasse caught ranges from 9cm up to a maximum of 35cm (Figure 24A). Just under half (48%) the ballan caught and recorded during surveys were within the size range that can be landed. 35% were below the Min CRS and 17% above the Max CRS. The salmon farm company implemented a new minimum size for ballan of 16cm, hence the change in size from 15cm in 2017 to 16cm. The average size of ballan was 19cm (SD±4.79cm), which is a slight increase of 1cm from 2017.

The majority of goldsinny and rock cook caught were under the Min CRS, 71% and 73% respectively, resulting in a large proportion of these species being returned. Goldsinny ranged from 6cm to a maximum of 15.5cm with an average size of 11cm (SD±1.21cm). The size range of rock cook was 6.5cm to 19cm with an average size of 11cm (SD±1.69cm). The size ranges and average sizes of these two species follow the same trend as 2017, with a slight increase in average size for rock cook.

Figure 24D shows the size range for corkwing caught and recorded during the on-board observer surveys from 1st of May up to 12th August 2018. During this time, sizes ranged from 8cm to 22.5cm. Of the corkwing caught during this time, 80% were within the size range that can be landed. The average size of corkwing during this period was 14cm (SD±3.33cm).

From 13th August 2018 onwards, the new potting permit byelaw conditions were implemented which included an amendment to the slot size for corkwing of 140mm to 180mm. This management measure was brought in due to nearly all corkwing caught (94%) being within the size range that could be landed in 2017. Figure 24E shows the size range for corkwing caught and recorded from 13th August to October 2018. Sizes ranged from 5cm to 24cm, with an average size of 14cm (SD±2.66cm). Around half (49%) of the corkwing caught were under the Min CRS, 42% were within the size range that can be landed and 8% were above the Max CRS.

Catches of cuckoo remained low, which follows the same trend as 2017. Figure 24F shows the minimum and maximum sizes recorded were 6.5cm and 29.5cm respectively. Of the individuals caught, 39% were below the Min CRS and 9% were above the Max CRS. The average size of cuckoo was 12cm (SD±2.96cm).

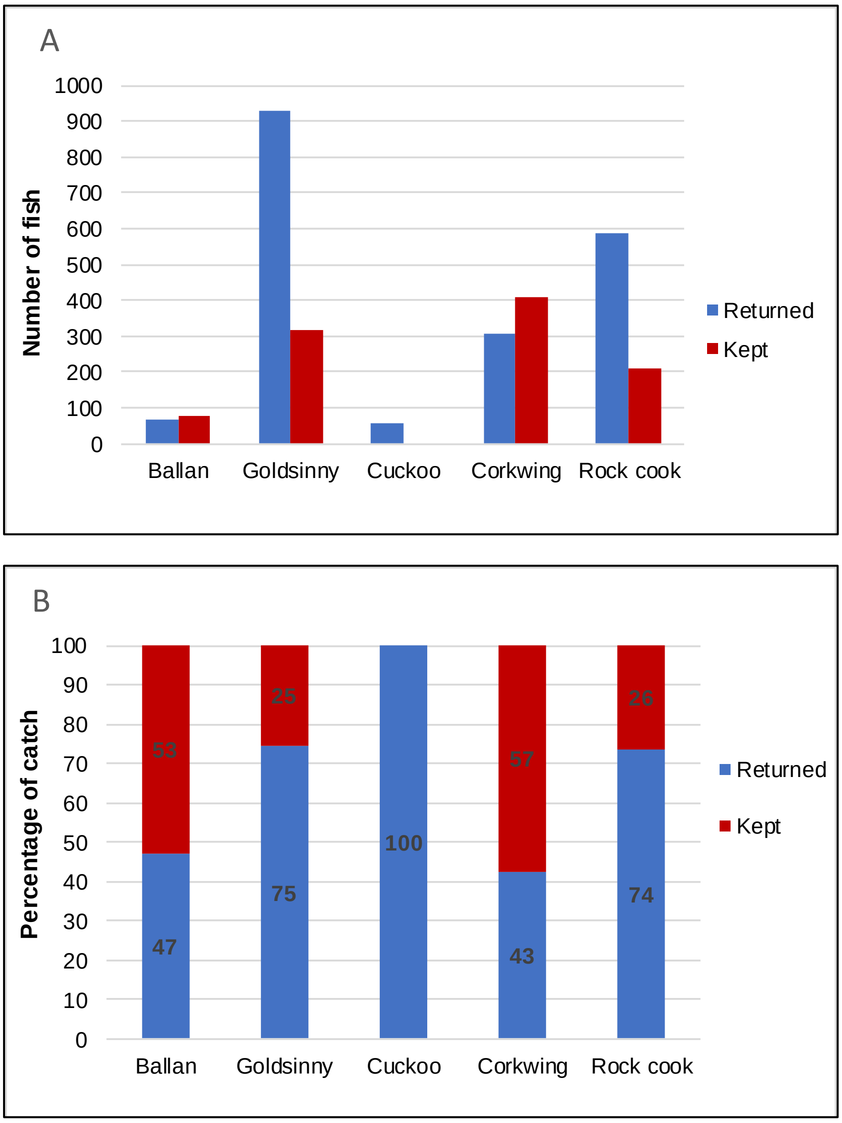


Figure 27 (A-B). The number (A) and percentage (B) of wrasse kept and returned during on board observer surveys. The number of corking is for the whole period from May to October 2018.

Figure 27 illustrates the number (A) and percentage (B) of wrasse species landed and returned to sea during the on-board observer surveys. The percentage for corkwing is across the whole surveys period and incudes the two different slot sizes. As can be seen from Figure 27B over half of corkwing caught are landed. The proportion of goldsinny and rock cook returned follows a similar pattern to 2017 with a slight increase, from 64% in 2017 to 75% this year for goldsinny and 73% in 2017 to 74% this year for rock cook. The amount of ballan returned has also increased from 12% in 2017 to 47% this year. Cuckoo are not targeted by the fishery and all fish caught are returned to the sea.

Figure 28 shows the breakdown of the percentage of corkwing kept and returned during the time period prior to the change in slot size (Figure 28A) and after the amendment (Figure 28B). As can be seen, the amendment to the slot size has increased the number of individuals returned to the sea, resulting in an overall x7 percentage increase (6% to 43%) (Figure 28B) in the amount of individuals returned compared to 2017.

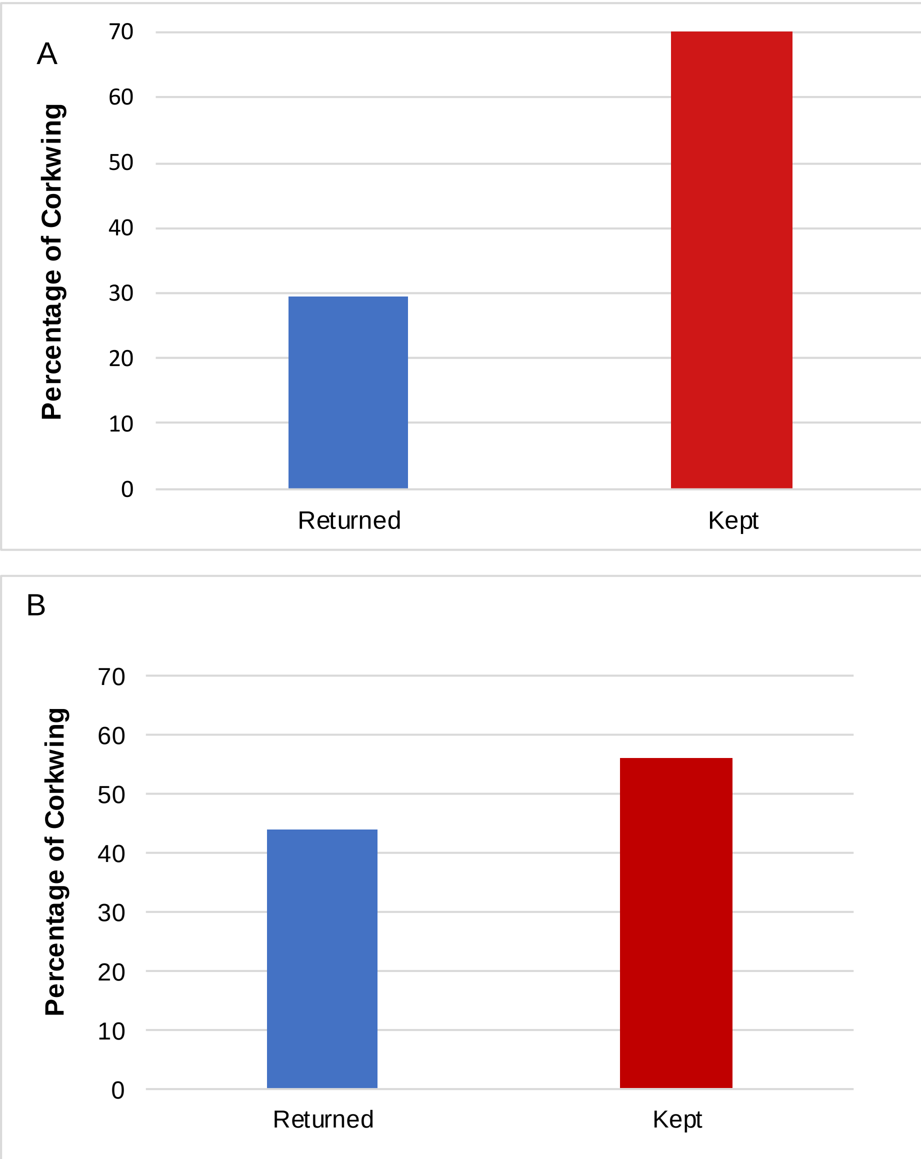


Figure 28 (A-B). Breakdown of percentage of corkwing returned to sea and kept prior to the change in slot size (A) 12-23cm and after the change in slot size (B) from 14-18cm. Taken from the on-board observer surveys.

3.8. Spawning State

During the on-board observer surveys, officers carried out a technique called stripping in order to identify whether milt or eggs were present for each individual fish. This was used as an indicator for spawning. Figure 30 indicates the number of each species of wrasse observed spawning over the survey period with data included from Cornwall IFCA on-board surveys in Falmouth Bay and within Plymouth Sound. This also indicates the current closed season between 1st April and 30th June.

Spawning was first observed in one goldsinny at the beginning of May (Figure 30) in Cornwall. Only 5 individuals were seen spawning in May, however this is reflected by the limited amount of surveys carried out this month. Spawning increased to 53 individuals in June, made up of 21 goldsinny, 11 corkwing, 20 rock cook and 1 ballan wrasse. Numbers of spawning individuals declined in the following months, with 22 individuals in July, one rock cook in August and none in September and October.

In 2019 the closed season will be amended to 1st May to 15th July. As can be seen in Figure 29, the new closure period of the fishery will protect the majority of spawning individuals. The amount of individual species observed spawning during on-board observer surveys during 2017 can be seen in Figure 31.

The percentage of wrasse observed spawning or not spawning can be seen in Figure 29. It should be noted that during on-board observer surveys officers carried out stripping at every available opportunity but there may have been occasions when this was not possible due to logistical reasons. Therefore, the percentage of wrasse not observed spawning may include a proportion of individuals not assessed.

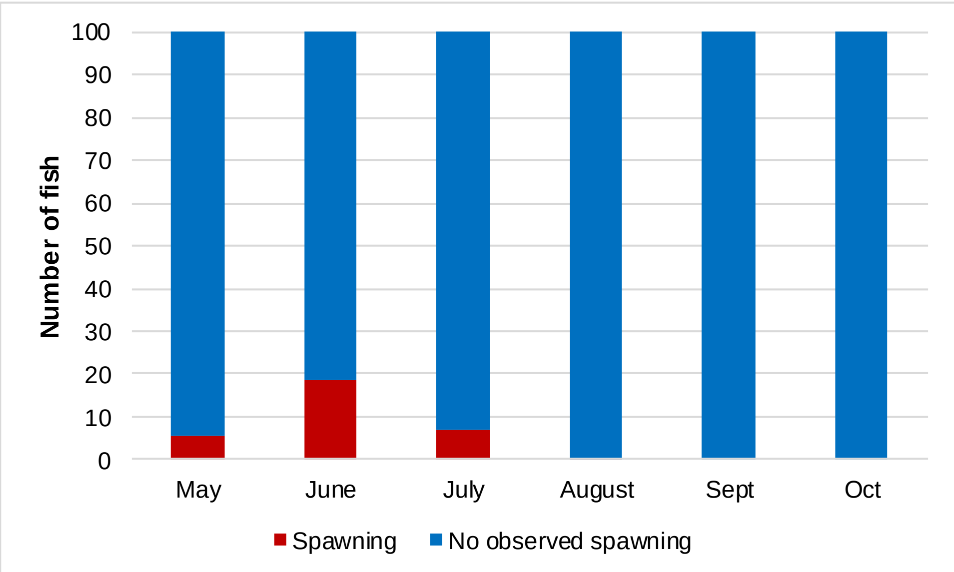


Figure 29. Percentage of wrasse spawning and not observed spawning. Data taken from the on-board observer surveys conducted by D&S IFCA and CIFCA during 2018.

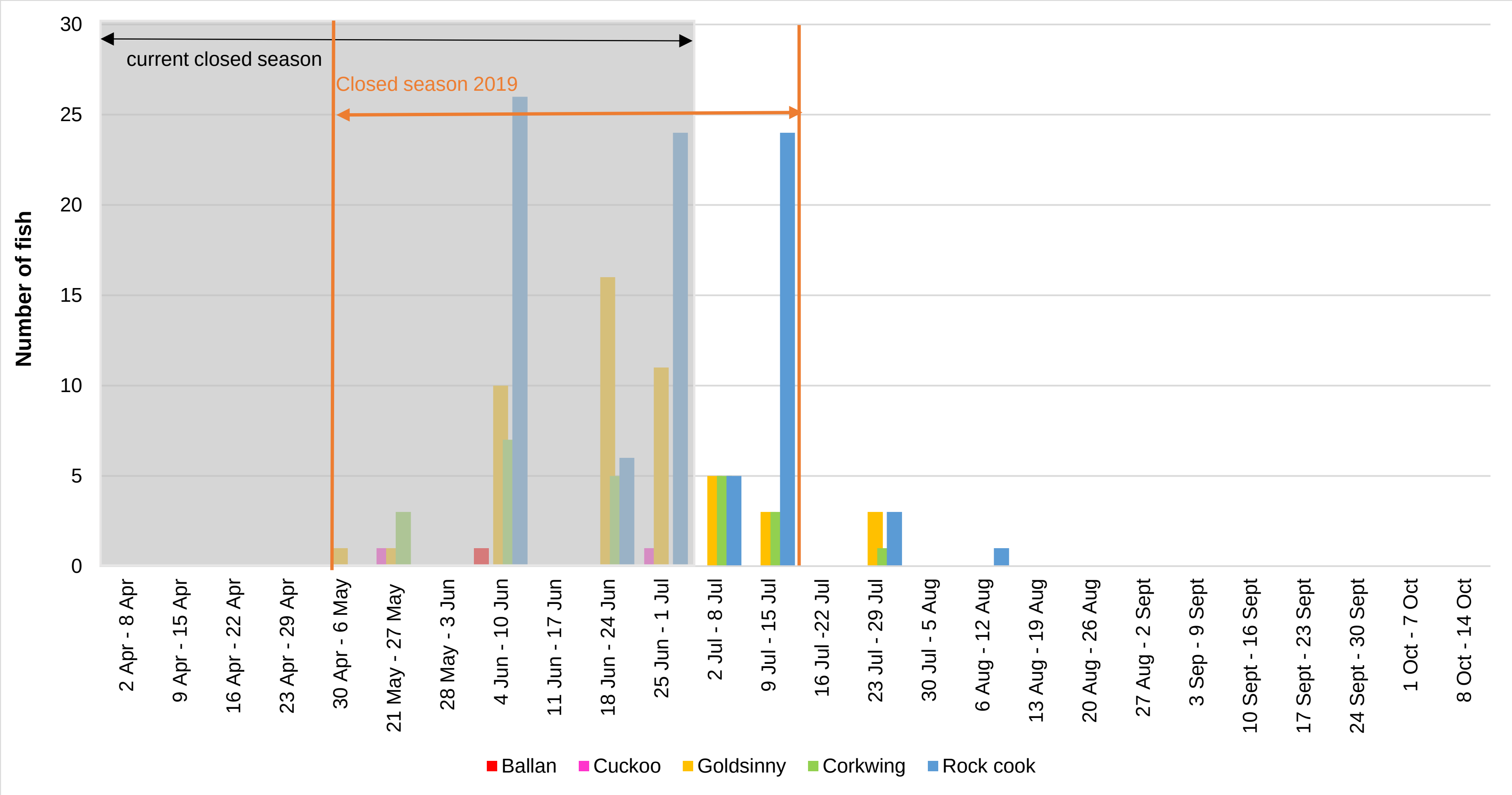


Figure 30. Spawning state of wrasse species seen during on-board observer surveys from D&S IFCA & CIFCA during 2018

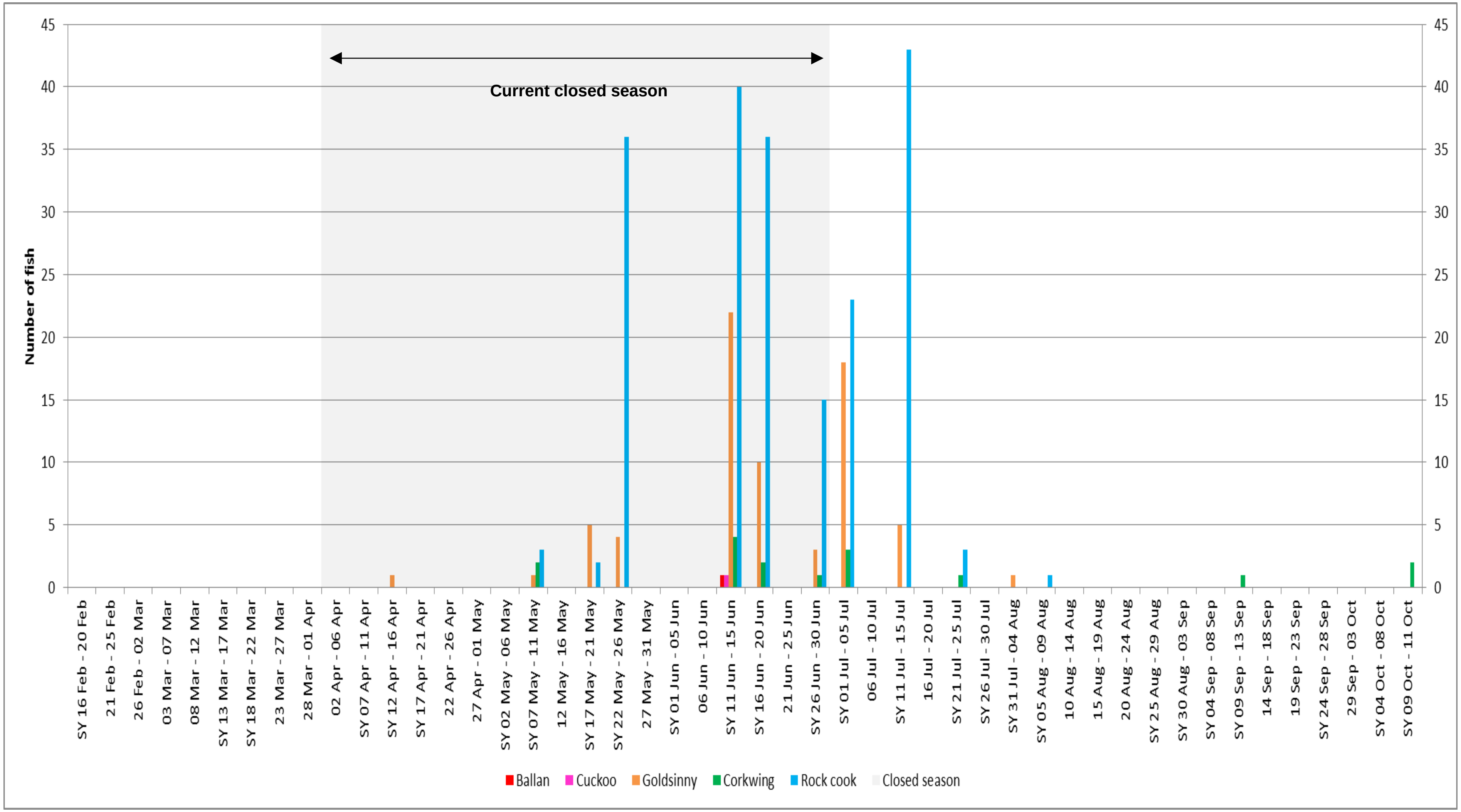


Figure 31. Spawning state of wrasse species seen during on-board observer surveys from D&S IFCA & CIFCA during 2017.

4. Discussion

4.1. Trends in Catches and Early Indications of Sustainability

The stages of exploitation of a fishery have been described by Hilborn & Walters (1992) as; i) unexploited ii) fishery development iii) fully exploited iv) over exploited v) collapse and vi) recovery. According to this model, as a new fishery develops, more fishers/boats enter the fishery because it is profitable for them to do so. The first fisher to enter the fishery will catch the most, with the least effort. During the fishery development phase, the effects of fishing are thought to be evident in a slight reduction in catch rates and the size of individuals in the catch (Hilborn and Walters 1992). The fully exploited phase is characterised by slightly lower but stable catches as recruitment is sufficient to maintain production. When catches exceed recruitment, over exploitation occurs, resulting in a fall in profits for individual fishers. If fishing effort is not reduced this can lead to collapse with marked reductions in catch and abundance. There have been conflicting results from other wrasse fisheries on the impacts of commercial fishing. Reductions in CPUE over a two-year period from the first year of fishing have been reported for an Irish wrasse fishery (Darwall *et al.* 1992, Varian et al. 1996). Other studies, looking at goldsinny wrasse found correlations in CPUE to temperature, but not fishing effort (Gjøsæter 2002). In a comparison of fished and unfished areas in a Norwegian fjord, three of four MPAs had higher CPUE with the relative difference between MPAs and control areas ranging from −16% to 92% (Halvorsen et al. 2017).

The decline in mean LPUE and increase in mean CPUE from 2017 to 2018 could be interpreted in a number of ways. It could suggest that the observer surveys are not achieving a great enough coverage to get a true picture of trends in catches reported in the LPUE. Although mean observer coverage exceeded the target in 2018, coverage between vessels between months was very patchy. However, it is also possible that the increased Min and decreased Max CRS for corkwing, which resulted in greater returns of this species from early August would have reduced LPUE but not CPUE, and this may account for some of the observed differences. Finally, it may be related to a larger proportion of juveniles in the population in 2018 relative to 2017 resulting in catches staying high, but landings dropping. This last hypothesis seems unlikely, given the similarity in size frequency distributions and mean sizes for each species between 2017 and 2018. The large reduction in overall effort in the D&S IFCA District was caused by a combination of mechanical issues with vessels, individual's circumstances, fishers targeting Cornish waters within Plymouth Sound during the Devon closed season, and possibly remaining here once Devon waters reopened.

The in-depth CPUE analysis found no statistical difference in CPUE between the years. The occurrence of sporadic high CPUE 'outlier' days which were evident in the observer data for 2017 but not in 2018 is notable, and the reduction of occasional larger catches could be caused by fishing pressure. Understanding how CPUE and LPUE relate to abundance is extremely difficult in this fishery either overall, or on a species-by-species basis. The reef association of wrasse may also result in a complex relationship between fisher behaviour and stock dynamics which is likely to make the relationship between CPUE and stock abundance particularly hard to discern (Ross 2016). CPUE may stay high as fishers move from reef to reef even if the overall population is reduced considerably (known as hyperstability) (Hilborn and Walters 1992). Or the opposite may occur – where an early reduction in CPUE occurs because of local depletions on individual reefs but stock abundance remains stable as other reefs remain unfished (known as hyperdepletion). Hyperdepletion is generally thought to be the more likely scenario for sedentary fish stocks (Hilborn and Walters 1992). However, the exact nature of the interaction will be dependent on both fisher behaviour and sink-source ecological dynamics of wrasse populations, how these relationships differ between reefs of different physical characteristics (depth, exposure, size, habitat complexity) and, if the fishery moves into new areas, between different habitats (e.g. reefs vs seagrass). Hyperstability seems unlikely in this case, as fishers have maintained their effort over similar areas (grid cells) between 2017 and 2018, rather than moving around a lot following local depletions. The lack of a clear pattern in temporal trends in CPUE within grid cells suggests that either hyperdepletion is not occurring, or that it is occurring at a spatial scale smaller than an individual grid cell.

The multi-species nature of the fishery with species displaying various life-history traits adds an extra complication as species are likely to respond differently to fishing pressure. Mean CPUEs for a number of species combined will often decrease more rapidly than the total abundance of the individual populations. This is because the population with the highest catchability often contributes a greater proportion to the CPUE (Maunder et al. 2006) and is the population that is most depleted. Often a single species can dominate the decline in CPUE & catchability is rarely constant over time.

Additionally, ecological interactions may affect any straightforward relationship between fishing pressure and species abundance. CPUE of wrasse has been found to be positively correlated to water temperature with CPUE increasing from June to September (Darwall *et al.* 1992, Gjøsæter 2002). Similar patterns have been observed in D&S IFCA in 2017 and 2018. The reasons for this increase are unknown but could include increased activity related to metabolic reactions to water temperature or increased feeding rates post-spawning (resulting in increased catchability). It is note-worthy that overall trends between months are broadly similar in 2017 and 2018, given the extremely cold spring and hot summer of 2018 compared to more seasonable weather conditions over the same time-period in 2017.

4.2. Using CPUE or LPUE to Estimate Abundance (Pot Saturation Effects)

Careful consideration must be given to the relationship between wrasse behaviour and catchability in order be able to make assumptions about stock abundance based on patterns of CPUE. In any survey where the central objective is to provide indices of relative abundance over space and time, it is imperative that the basic survey sampling device should be one that catches fish in proportion to their abundance in that area (Hilborn and Walters 1992). A key assumption of CPUE is that the efficiency of the gear is constant over time, space and environmental fluctuations (Bacheler et al*.,* 2013). As pots are used in the wrasse fishery, catch rates may be inconsistent as soak times can vary and space within a trap is limited (Bacheler et al*.,* 2013). As a result, catch rates can decline known as catch/trap saturation. This can result in a catch that relates non-linearly to local abundance, reducing the accuracy and reliability of CPUE estimates (Shertzer et al., 2016). Several factors have been shown to contribute to saturation including entry and exit rates (Bacheler et al*.,* 2013), bait degradation, space limitation and inter and intraspecific agnostic behaviour (Jury et al., 2001). A pot-saturation experiment, using cameras on baited pots, was trialled in Plymouth Sound in May 2018 but there was insufficient data to establish whether the traps saturate (Curtin 2018).

4.3. Spatial Effort and Catch Composition

Spatial differences in the catch composition can be seen in Plymouth Sound within and between years. Catch composition across Plymouth Sound will vary due to interactions between the ecology of individual species, habitat use and diet (Ross and Davies, 2017, Skiftesvik *et al.,* 2014). For example, goldsinny have a wide ecological niche and can be found in areas of high exposure with a rocky reef habitat (Darwall *et al.,* 1992). In contrast corkwing are more specialised and prefer sheltered shallower water within kelp forests (Skiftesvik *et al*., 2014). Catch composition within several grid squares varies between 2017 and 2018. This may be due to vessels fishing in slightly different locations within a grid square as species specific composition has been shown to vary over very small spatial scales (Skiftesvik *et al*., 2014). It could also be due to surveys being carried out at different times of the year and the difference in the amount of surveys carried out between years.

Seasonal trends in catch composition has remained similar to 2017 (Figure 14 and 15), with the exception of September and October. These months have seen a reduction in goldsinny and ballan wrasse and an increase in corkwing in 2018. However, this is likely due to individual fishers fishing in different grid cells when on-board observer surveys were conducted between years, rather than a change in assemblage composition. A more in-depth analysis of changes in catch composition, and possible causes is required that was beyond the scope of this report.

4.4. Size Distribution

The size distributions of goldsinny and rock cook (Figure 18A and 18C) illustrate that the majority of the catch is returned to sea. This follows the same pattern as 2017. 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). Therefore, the current Min CRS of 12cm for these species is protecting individuals that have the potential to spawn and restock the population. The average size for goldsinny has remained the same as 2017 but rock cook has seen an increase in 2018. Goldsinny was the dominant species across all months in 2017 and is for the majority of months in 2018. This species matures at an early age and produces large numbers of planktonic eggs (Darwall et al., 1992), producing up to five times as many eggs than corkwing (Davies and West, 2017). These characteristics indicate populations may be resilient to fishing and coincides with the observed higher CPUE compared to other species and consistency in average size between the two years.

As cuckoo wrasse are not targeted by the fishery and all individuals are returned to sea, this species will no longer be discussed in this report. The salmon farm company has introduced their own minimum landing size for ballan wrasse for the 2018 season of 16cm. This is an increase from the Min CRS of 15cm. Female ballan mature at 16-18cm and males at 28cm (Darwall et al., 1992). 35% of ballan caught were below the Min CRS of 16cm and 17% were above the Max CRS of 23cm. Ballan wrasse are protogynous hermaphrodites, starting life as female and later change to male. It has been reported that this sex change can be associated with body size and social cues (the absence of functional males), which is an important consideration within the fishery as the removal of one particular sex over another could result in a shift in sex ratio and have consequences on future recruitment and breeding (Muncaster et al., 2013). The removal of larger males may result in reproductive output being compromised However, the size at which ballan appear to change sex is between 34 and 41cm (Muncaster et al., 2013). The current Min and Max CRS are therefore protecting juvenile females and larger dominant mature males, reducing the risk of disproportionate male loss. It is currently not possible to determine the sex of ballan wrasse when carrying out surveys and therefore D&S IFCA is unable to assess the current sex ratio of this species.

In 2017 the Min and Max CRS for corkwing was 12-23cm.The results from the 2017 report indicated that all mature corkwing males, females and a proportion of immature males were retained. Corkwing are a species with sexual dimorphism (males can have female secondary sexual characteristics, called sneaker males). Territorial nest building males grow faster and mature later than sneaker males and females (Halvorsen *et al*., 2016), meaning that the fishery may be selecting for the faster growing nesting building males. Constant removal of these individuals may induce changes in sex ratios, having consequences on sexual selection and recruitment within the population. Furthermore, removal of dominant males may destabilise social structures (Darwall et al., 1992). As a result of this and the results from the 2017 report an amendment to the potting permit conditions became effective from 13 August 2018. This changed the Min and Max CRS from 12-23cm to 14-18cm in order to protect nesting mature males, females and sneaker males, which have been reported to have an average length of 12-14cm, 13cm and 10-12cm respectively (Halvorsen *et al*., 2016). Further monitoring will be required in order to determine whether the new Min and Max CRS is a sufficient management measure to prevent the fishery being sex selective.

4.5. Spawning Season

Previous studies have indicated that the spawning period for corkwing and goldsinny is from May to mid-June, possibly until the end of July and peaking in June for corkwing (Halvorsen *et al*., 2016, Matland 2015, Skiftesvik *et al*., 2015). Matland (2015) reported rock cook spawning throughout May to August with no peak observed in Norway. The spawning observed during the on-board observer surveys coincide with these periods, with the majority of observed spawning taking place between May to July. The number of goldsinny wrasse observed spawning peaked in mid-June when 16 individuals were recorded. In contrast to Matland (2015) who found no peak in rock cook spawning in Norway, spawning appeared to peak three times, at the beginning and end of June and at the start of July (Figure 22). This species was observed spawning the most. There seemed to be a consistent amount of corkwing observed spawning during June, tailing off towards the end of July. This follows the same trend observed in these three species as 2017 which would suggest the main spawning period for corkwing, goldsinny and rock cook is from May to July. The temporal closure in 2019 from 1st May to 15th July will therefore protect the majority of spawning individuals.

Only one ballan wrasse was observed spawning at the beginning of June 2018 which follows the same trend as 2017. One explanation for the lack of observed spawning may be due to their strategy of spawning synchronously (at the same time) (Darwall *et al*., 1992). Previous studies have indicated that spawning takes place from April to July in Norway (Matland 2015) and January to April in Spain (Villegas-Rios *et al*., 2013). Due to the lack of ballan observed spawning across both years it is not possible to determine whether the spawning period has changed or whether the temporal closures protect spawning individuals of this species.

4.6. Fully Documented Fishery, Implementation and Adaptation

During the first year of the fishery in 2017, 5.5% observer coverage was achieved across all vessels. Although fewer on-board observer surveys were carried out in 2018, 12% observer coverage was achieved across all vessels. The higher percentage coverage was largely driven by a reduction in the amount of days fished in 2018 compared to 2017. Despite meeting targets for observer coverage, because of the highly spatially dynamic nature of the fishery, data must be broken down spatially and temporally in order to look for meaningful trends. Often, once significantly segmented, the data set was not sufficiently large enough to look for statistical patterns. Given the current level of resource available, and the already large allocation given to monitoring the wrasse fishery, it seems to be unlikely that these problems will be overcome in future sampling, although D&S IFCA will once again aim to cover boats evenly throughout the sampling window.

Difficulties in arranging on-board observer surveys arose due to fisher's not fishing within the D&S IFCA District until the beginning of August. Vessels 3 and 4 were out of the water for extended periods of time due to boat repairs being carried out. Other than logistical reasons, fishers co-operated with officers and officers were allowed on board on the vessels when requested.

There are still some issues with the fisher's landings forms not being completed and returned on a weekly basis. Repeated requests by IFCA officers were required to obtain the forms, with some forms still not being returned, meaning data were missing from the analysis. Discussing these issues with the fishers prior to the fishery opening will be required to ensure compliance next year.

In addition to their own on-board observer surveys, Cornwall IFCA has been carrying both fishery-dependent sampling and fishery-independent surveys in control areas. A mark and recapture study using Visible Implant Elastomer (VIE) tags to estimate population sizes. Habitat Regulations Assessments (HRAs) have also been undertaken for fish traps within Plymouth Sound and Estuaries Special Area of Conservation. Cornwall IFCA is also developing a live wrasse fishing (Limited Permit) Byelaw which has been through informal and formal consultation this year. The byelaw is currently with Defra for consideration.

4.7. Voluntary Closed Areas

The voluntary closed areas were amended in April 2018. Fishers were sent a chart showing the new closures prior to the fishery opening. These closures are important for maintaining natural population sizes and size structure (Halvorsen *et al*., 2017). During the period May to October 2018, all of the vessels have adhered to the closures. This has been taken from the on-board observer surveys.

5. Conclusions and Officer Comments

The ultimate goal of the fully documented fishery implemented by D&S IFCA is to elucidate a relationship between some measure of fishing pressure and stock abundance. In this case CPUE and LPUE estimates are assumed to be related to the abundance of wrasse in Plymouth Sound. Whilst entirely consistent with global efforts to measure fisheries trends, this approach does have some caveats, especially in a fishery as complex as the live wrasse fishery (Ross 2016). However, it cannot be ruled out that reductions in LPUE and reductions in the occurrence of above-average catches may be caused by fishing pressure reducing the stock size. A reduction in the stock size is entirely consistent with the development phase of a new fishery and does not necessarily mean that the fishery is unsustainable. Due to the sensitive nature of the site the fishery should continue to be closely monitored, with the observer coverage remaining at least at its current level. A more even coverage of vessels would allow for a more powerful statistical analysis, but this is often hampered by logistical circumstances and realistically could only be managed by an increase in observer effort which would not be possible at the current level of resource.

Fishers must be reminded of their obligation to submit landings forms on a weekly basis. This was not regularly conformed to in 2018 with IFCA officers having to chase fishers to submit landings. Fishers should also be required to submit all landings for both D&S IFCA and Cornwall IFCA Districts, as fishers are currently inconsistent in their approach.

The Habitat Regulation Assessments for fish traps in Plymouth Sound will be updated following the 2018 report.

Further interrogation of the data collected in 2017 and 2018 will help in the interpretation of CPUE and LPUE and officers will continue with this work in 2018 and 2019. The amount of data collected, and the number of potential interacting factors influencing CPUE (e.g. water temperature, month, pot saturation, habitat type, depth, bait, exposure) means that statistical analyses are becoming increasingly complex and are unlikely to remain fit-for-purpose. A more appropriate method (such as generalized linear modelling) will be developed in time for the 2019 data analysis. With each subsequent year of data collection, the analysis becomes more complex and the time required to analyse and report on findings increases. It would be pertinent to consider this in the planning of future Byelaw and Permitting Subcommittee meetings.

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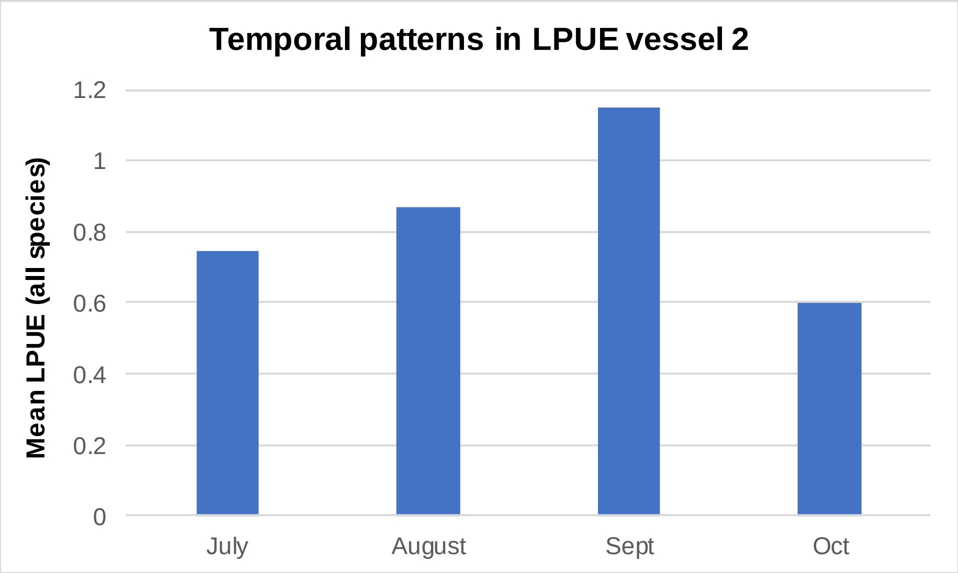
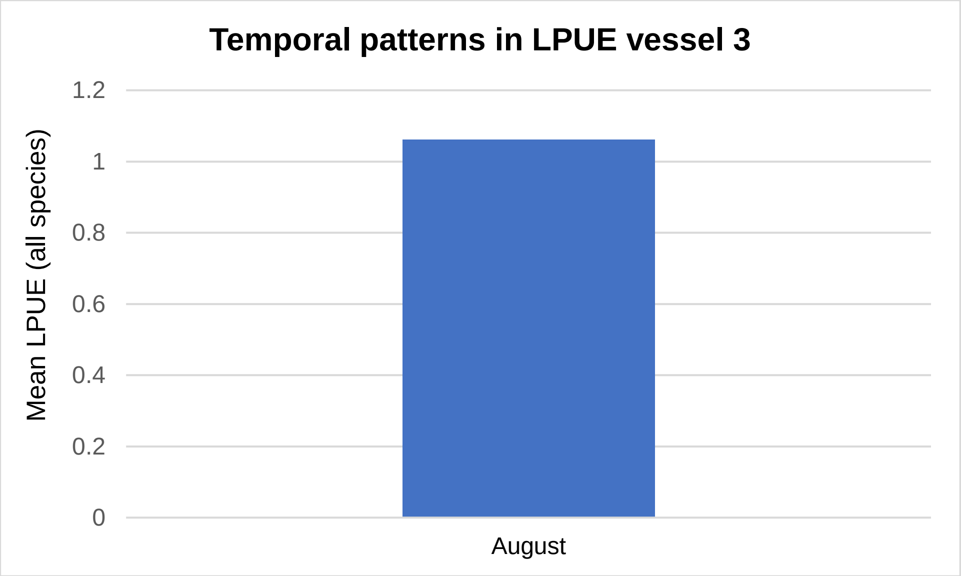
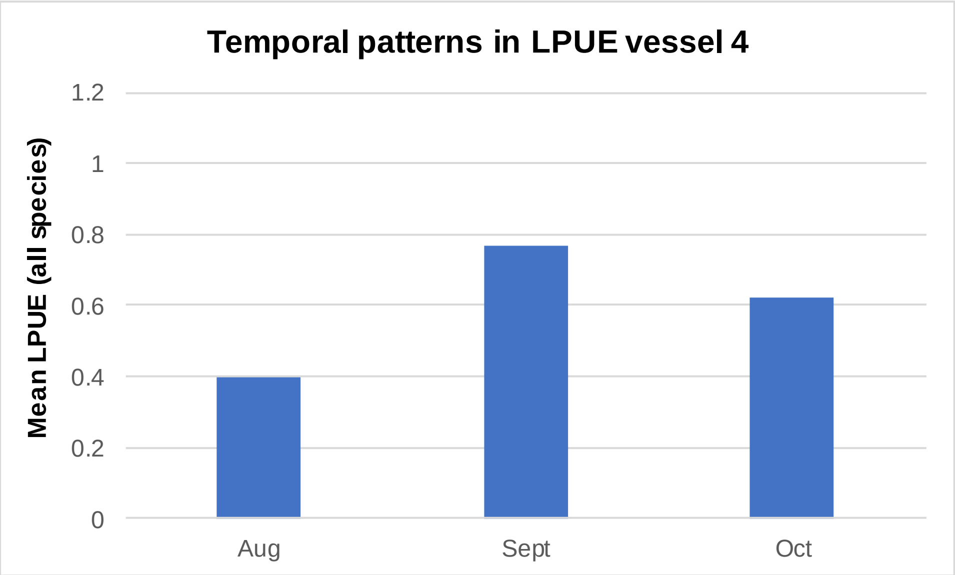
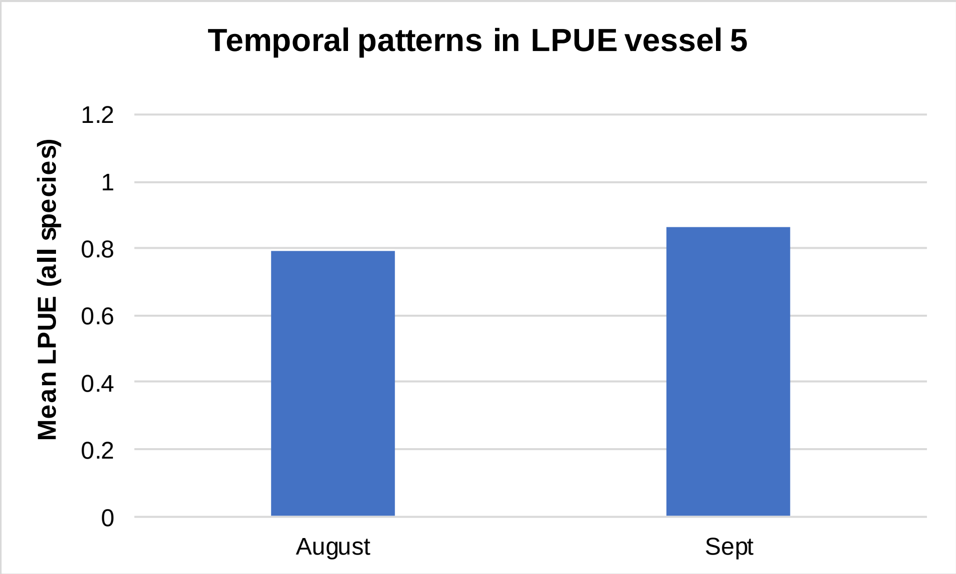
Appendix 1 – LPUE per vessel








Temporal patterns in LPUE vessel 5
Mean LPUE (all species)
1.2
1
0.8
0.6
0.4
0.2
0
August
Sept

Appendix 2 – Survey forms

Live Wrasse Pot Fishery			Data Collection by Fishermen			Devon & Severn IFCA		
Date:		Port:	Date:		Port:	Date:		Port:
Vessel:		PLN:	Vessel:		PLN:	Vessel:		PLN:
Grid number	Total no. pots	No. strings fished	Grid number	Total no. pots	No. strings fished	Grid number	Total no. pots	No. strings fished
Daily Totals: No. fish retained			Daily Totals: No. fish retained			Daily Totals: No. fish retained		
Ballan			Ballan			Ballan		
Cuckoo			Cuckoo			Cuckoo		
Corkwing, Goldsinny, Rock Cook			Corkwing, Goldsinny, Rock Cook			Corkwing, Goldsinny, Rock Cook		
The information you supply is covered by the Data Protection Act 1998. The data are processed by the D&S IFCA in accordance with the Data Protection principles contained within the Act. The information you provide will be used by the Authority for fisheries management purposes and anonymised data may be shared with other interested parties.								

Fishers landings forms

Live Wrasse Pot Fishery - On-Board Surveys							
Vessel:			PLN:		Port:	Survey Officer:	
Date:		Weather:		Soak time:	Tide HW time/Ht:	Bait Used:	
String no.	Start time:		Start Depth (m)	End Time:		End Depth (m)	Pot no.
	Start lat	Start long		End lat	End long		
Wrasse Species Ballan/Cuckoo/Corkwing/ Rock Cook/Goldsinny (B/C/CW/R/G)			Sex M/F	Size (cm)	Fate Kept/Returned/ Dead (K/R/D)	Maturity Milt/Eggs M/E	Other notes

On-board observer survey forms

Appendix 3 – Summary of life history characteristics

Characteristics	Ballan wrasse (*Labrus bergylta*)	Cuckoo wrasse (*Labrus mixtus*)	Rock cook (*Centrolabrus exoletus*)	Goldsinny (*Ctenolabrus rupestris*)	Corkwing (*Symphodus melops*)
Size range (cm)	Typical size 30-40cm (Campbell, 2004; Irving, 1998; Dipper, 1987). Grows to over 50cm (Naylor, 2005; Bagengal, 1985). Up to 60 (Gibson, 2001; Darwall *et al.* 1992; Dipper, 1987).	Grows to 35cm (Campbell, 2004; Gibson, 2001; Darwall *et al.* 1992; Dipper, 1987; Bagengal, 1985) and females generally smaller (Naylor, 2005; Irving, 1998).	Usually grows to 12cm (Dipper, 1987), but some reach 15cm (Naylor, 2005; Campbell, 2004; Darwall *et al.* 1992; Bagengal, 1985; Dipper, 1987).	Usually 12cm, some reach 18cm (Gibson, 2001; Irving, 1998; Dipper, 1987). Up to 15cm (Kay, 2009; Campbell, 2004; Darwall *et al.* 1992). Up to 20cm (Naylor, 2005).	Usually 15cm, some reach up to 25cm (Kay, 2009; Naylor, 2005; Campbell, 2004; Gibson, 2001; Irving, 1998; Darwall *et al.* 1992; Dipper, 1987). Rarely grows above 18cm (Bagenal, 1985).
Maximum age (years)	29 (Dipper *et al.* 1977)	17	9 (Treasurer, 2005)	16 (Treasurer, 2005)	9
Age at maturity (years)	F & M 6-9	F 2, M 6-9	F 2. M 2 (Matland, 2015)	F 2. M 3 (Matland, 2015)	F 2-3. M 1-3 (Matland, 2015)
Size at maturity (cm)	F 16-18, M 28	F 16, M 24	F 8.5, M 9 (Matland, 2015)	9.5. F 8, M 9 (Matland, 2015)	10. F 9, M 14 (Matland, 2015)
Sex change	Yes	Yes	?/No	No	No
Accessory males	No	No	?	Yes	Yes
Territorial	Yes	Yes	Yes	Yes	Yes
Spawning season (Atlantic)	April – August. Peaking in June (Dipper *et al.* 1977).	May - July	May - August	April - September	April - September
Spawning place	Nest (gravel & rock)	Nest (gravel)	?	Mid-water	Nest (algae)
Fecundity (1000 eggs yr^{-1})	150	?	?	20	50
Egg type	Benthic	Benthic	Benthic	Planktonic	Benthic
Nest building by	Female	Male and female	?	N/A	Male
Parental care	Male	Male	?	None	Male
Key habitat	Juveniles found in the intertidal and rock pools, adults found in sublittoral rocky areas (Dipper *et al.* 1977), reef and kelp forests.	Sublittoral rocky reefs (Naylor, 2005; Dipper, 1987).	Rocky reefs and seaweed (Naylor, 2005; Dipper, 1987). Often found in seagrass beds (Dipper, 1987).	Rocky reefs and boulder slopes, with holes, caves and crevices for refuge (Sayer *et al.* 1993). Distribution unaffected by macroalgal cover (Sayer *et al.* 1993).	Common in the intertidal and rock pools, with dense seaweed. Subtidal rocky areas with dense seaweed. Often found in seagrass beds (Dipper, 1987).
Depth (m)	Depth range from 5m to at least 30m (Ager, 2008; Dipper, 1987). Juveniles can be in <5m.	Depth range from 2-200m, but mainly between 20-80m (Gregory, 2003).	Depths of 3-25m (Galeote *et al.* 1998; Dipper, 1987).	Occasionally found <10m, mostly juveniles (Sayer *et al.* 1993). Prefer deeper water between about 10 to 50m (Campbell, 2004; Gibson, 2001; Irving, 1998; Sayer *et al.* 1993; Dipper, 1987).	More commonly found at depths <5m (Darwall *et al.* 1992; Costello, 1991), although they can occur to depths of 30m (Gibson, 2001; Irving, 1998; Bagenal, 1985) or up to 50m (Skewes, 2008).
Exposure	All conditions of exposure (Gibson, 2001). Mostly found in intermediate wave exposure stations (Skiftesvik *et al.* 2015).	No specific exposure level, found at all stations (Skiftesvik *et al.* 2015).	Relatively more abundant at more exposed stations, Smaller fish (<11cm) occurred mainly in sheltered areas (Skiftesvik *et al.* 2015).	Mostly found in intermediate wave exposure, smaller fish (<11cm) occurred mainly in sheltered areas (Skiftesvik *et al.* 2015). Distribution unaffected by current speed (Sayer *et al.* 1993).	More abundant in sheltered area (Skiftesvik *et al.* 2015). Nests found in sheltered north facing crevices (Potts, 1985).
Main diet type	Crustacea and Mollusca	Crustacea and Mollusca	Crustacea and Mollusca	Crustacea and Mollusca	Crustacea and Mollusca
Growth rate	5cm/year	3.5cm/year	3cm/year	3cm/year	4cm/year