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Economic performance and fishing strategies of the Welsh coastal fleet

PRIFYSGOL BANGOR UNIVERSITY

Giulia Cambiè, Julia R. Pantin, Harriet Salomonsen & Michel J. Kaiser

School of Ocean Sciences, College of Natural Sciences, Bangor University

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CONTENTS

EXECUTIVE SUMMARY

- Three main segments were identified as representative of the Welsh fleet from a socio-economic perspective, one small scale (pots and nets small scale) and two medium scale (scallop dredge medium scale and pots and nets medium scale). All three segments were characterized by a profitable fishing activity, with a moderate ROI (rate of return on investment, which depends on the rate of profit/capital invested) for scallop dredge and small scale vessels and a high ROI for medium scale pots and nets vessels. For small scale vessels, the moderate ROI was the result of a moderate profit, while for scallop dredge medium scale it was the result of the large capital invested by the segment.

  A regular monitoring of the economic performance of scallop dredge medium scale segment is therefore needed to understand if the large investments in harvesting capacity yield progressively lower returns to fishers. In this case scallop dredge medium scale could be close to a situation of overcapitalisation (and possibly overcapacity). With the high ROI, the pots and nets medium scale segment could have invested part of the benefits into vessel technology and fishing gears. This investment of capital in vessel and gear improvement would have possibly resulted in an increase in fishing capacity in 2013.

- A total of 18 *métiers* were identified, clearly demonstrating the complexities of the fishing strategies adopted by the Welsh fleet. Differences in the fishing strategies employed were detected between the three fleet segments. While medium scale vessels appeared more specialised in using one or two single *métiers*, small scale vessels were characterised by higher diversity, which reflected a higher dynamic nature of their fishing operations.

- The use of the different *métiers*, as well as the contemporary use of multiple *métiers* over a period of time, had a strong seasonal and spatial component. For small scale vessels the most significant association (contemporary use) of *métiers* in spring was between lobster pot targeting lobster and rod and line targeting bass, while in winter between lobster pot targeting lobster and prawn pot, between lobster pot targeting brown crab and whelk pot and between lobster pot targeting brown crab and prawn pots. The knowledge of the associations of fishing *métiers* are essential from a management perspective as the effort restriction of one can lead to an increase in effort of the other.

- The knowledge of the different association of *métiers* by area is also essential as the consequences of the effort control of a specific *métier* can have different effects between North, Mid and South Wales. The main associations of fishing *métiers* were lobster pot with rod and line targeting bass in North Wales, lobster pot with prawn pots in Mid Wales and lobster pot with rod and line, prawn pot and whelk pot in South Wales. In this sense, adaptive management measures coherent with local specificity should be adopted.

- Our study also revealed that the traditional assumption that fishers act rationally in terms of maximising their profit/utility is not always true. For small scale vessels, only 25% of the association between *métiers* was characterised by higher profit. Commercial species were often targeted when they were more abundant and not when their value was higher. This behaviour could respond to the risk-averse aptitudes of fishers towards high but uncertain profits to which they prefer low risk fishing operations with reduced profit margin.

- The reduction of the costs associated with the fishing activity (operating costs) can explain the aptitude of increasing the number of *métiers* used at monthly and yearly scales. Increasing the number of *métiers* used significantly decreased the maximum amount of operating costs. As these costs are positively related with the incomes, their decrease implied a decrease on the maximum expected incomes and, ultimately, on the maximum expected profits. Our findings thus revealed that the reductions of operating costs is a more important economic driver than profit maximisation. These results also need to be taken into account when implementing management measures, as the limitation of *métiers* characterised by lower operating costs (e.g. gill net from shore, tangle nets, etc.) could result in a non-profitable fishing activity for the vessels characterised by a marginal economic condition.

1. INTRODUCTION

In the last few decades there has been increasing interest in the role of fishers' behaviour in the exploitation of marine resources and a highly interdisciplinary collection of literature has been developed, with publications by economists, anthropologists, sociologists and natural scientists (Branch et al. 2006). This viewpoint came from the recognition that the knowledge of fishers' behaviour is essential when using fishery-based data for stock assessment and population dynamics as these data could be affected by changes in the distribution of fishing effort and capacity (van Putten et al., 2011; Gillis and Frank 2001). In this sense, a correct interpretation of changes in variables such as catch rates, discards, etc. require a deep understanding of the associate changes in fishing behaviour.

Hilborn (1985) suggests that most fisheries problems, including the collapse of many fisheries, can be attributed to a lack of knowledge of fishers' behaviour, rather than of fishery resources. A direct expression of the fishers' behaviour is represented by the fishing *métiers*, defined as a group of fishing operations targeting a specific assemblage of species, using a specific gear, during a precise period of the year and/or within a specific area (Deporte et al., 2012; Pelletier and Ferraris, 2000; Laloë and Samba, 1991; Biseau and Gondeaux, 1988). Understanding the behavioural drivers responsible for the fishing *métiers* use is also crucial from a management perspective, as the knowledge of fishers' operations in relation to their preferences is essential to model the responses to regulations and thus to achieve efficient management schemes (Salas and Gaertner, 2004).

A growing literature has been focused in defining the main drivers of the fisher's behaviour and the associated strategies (sequence of decisions, which includes *métier* choice, at monthly, seasonal or yearly scale), often related with economic, socio-cultural and biological aspects of the fisheries (e.g. Robinson and Pascoe, 1997; Marchal et al., 2009; Andersen et al., 2012). In the fisheries economic literature, the most common approach to studying fisher decision-making is based on the profit maximisation concept focused in optimising net revenues at minimal cost (Gordon, 1954; Hilborn and Kennedy, 1992). This approach represents the base of the bio-economic models usually employed to assess possible management scenarios (e.g. Prellezo et al., 2012). However, it has been questioned by various authors as fishers' behaviour may be based on a number of other drivers that can also vary by individual (Robinson and Pascoe, 1997; Holland, 2008; Herrero and Pascoe, 2003; van Putten et al., 2012).

Socio-cultural drivers, such as the competitive interactions among vessels and the adherence to traditions, often play an essential role in determining fishers' choices and the consequent use of one or more fishing *métiers* (e.g. Gillis and Peterman 1998; Rijnsdorp et al. 2008; Marchal et al., 2009). Habits and fisher' experience are also an important determinant in fishers' behaviour and the related tendency to maintain or abandon traditional fishing patterns (Holland and Sutinen, 1999; Marchal et al. 2009).

Seasonal fishing patterns related to the availability of the individual target species is another essential component of fishing behaviour. For many fisheries, there is a seasonal component driven by differences in the spatio-temporal migration dynamics of target species (Andersen et al., 2012). Fishers' knowledge about fish behaviour, species availability and the catch previously obtained play an essential role in the individual decision-making process (Salas et al., 2004).

Even though all these elements have been described, analysed and reviewed in multiple published works (e.g. Salas and Gaertner, 2004; Branch et al., 2006; van Putten et al., 2012), few studies have applied a multidisciplinary quantitative analysis of the drivers of fishing *métiers* on multi-species multi-gears coastal fisheries (Salas et al., 2004; Andersen et al., 2012; Marchal et al., 2009).

The present work aims to understand the main factors affecting the use of one or more fishing *métiers* for multi-species multi-gears coastal fisheries in Wales, UK. To achieve this, three main aspects will be analysed: 1) the economic performance of the main segments of the Welsh fleet, 2) the identification and description of the fishing *métiers* used, and 3) the relative importance of the seasonality of target species, fishing location, costs and incomes on the fishing *métiers* employed.

2. MATERIALS AND METHODS

2.1 Data source and fleet segmentation

Data on technical characteristics, landings and economic performance of 56 fishing vessels were obtained from interviews with vessel owners between July and December 2013. The information requested during the interviews was related to the fishing activity along the Welsh coast in 2012. Fishers were randomly selected from the main base ports of the Welsh coast (Figure 1) and, when possible, they were previously contacted through the main fishing associations.

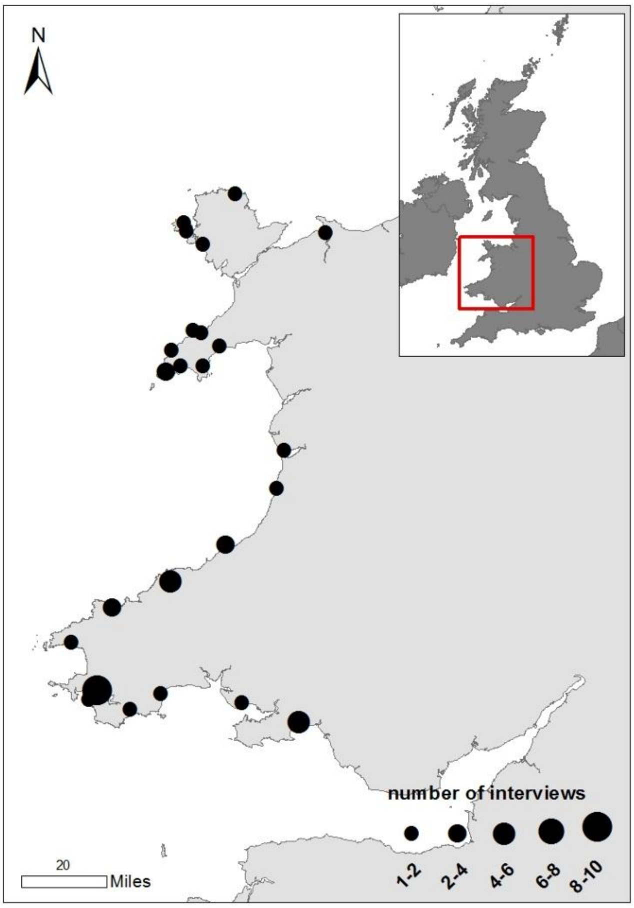

Figure 1. Study area showing the base ports of the owners interviewed.

The fleet was divided into six main segments according to the fleet segmentation protocol adopted by Seafish, the national body responsible of providing the economic indicators of the fishing fleet at the UK level (e.g. Lawrence & Anderson, 2014). However, according to the data collection framework (DCF) of the European Commission, the description of the segments referred to all gears used by the vessels and not only to the main one.

Six fleet segments were identified through the interviews:

1. PMP ≥ 10 m. Vessels ≥ 10 m length combining mobile (scallop dredge) and passive (pots) gears
2. PGO ≥ 10 m. Vessels ≥ 10 m length using passive gears (pots and nets)
3. PGO < 10 m. Vessels < 10 m length using passive gears (pots and nets)
4. PMP < 10 m. Vessels < 10 m length combining mobile (scallop dredge) and passive (pots and nets) gears
5. DTS < 10 m. Vessels < 10 m length using demersal trawl
6. Low activity < 10 m. Vessels < 10 m length fishing part-time with passive gears (pots and nets)

As the aim of this study was to assess the main drivers of the fishing *métier* use, we focused our survey effort on a subgroup of segments based on the *a priori* hypothesis that the fishing capacity was related with the fishing *métier* use (Tingley et al., 2003). For this reason, we focused the interviews on the most representative small scale (vessel length < 10 m) and medium scale (vessel length ≥ 10 m) segments of the Welsh fleet from a socio-economic perspective (number of vessels, fishing effort and income produced). In accordance with the economic indicators of the UK fleet (e.g. Lawrence & Anderson, 2014) and with the suggestions obtained from the main fishing associations, the interviews were focused on: PMP ≥ 10 m (we refer to this segment as "scallop dredge medium scale (MS)"), PGO ≥ 10 m ("pots and nets medium scale (MS)") and PGO < 10 m ("pots and nets small scale (SS)").

To assess the accuracy/representativeness of the economic information for each of the selected segments, the heterogeneity of fishing incomes within a fleet segment was first estimated. The coefficient of variation *CV* (standard deviation divided by mean) of a parameter of interest (CV_i) taken to be a proxy for fishing incomes was thus estimated across all vessels. This parameter was obtained by multiplying the vessel length by the number of fishing months for each vessel of the whole population, obtained through the official census of Welsh vessels registered in 2012 (European Fleet Register, http://ec.europa.eu/fisheries/fleet). Afterwards an extension of the Neyman optimal allocation (Cochran, 1977; Van Iseghem et al., 2011) was applied to the official census. The minimum sample size n_i for segment *i* was computed as:

$$n_i = N_i \frac{1}{1 + N_i L^2 / (4CV_i^2)}$$

Where N_i is the segment size (total number of vessels), CV_i is the coefficient of variation of proxy fishing incomes and L is the minimum required precision (L = 0.25) to be achieved for the fleet estimate of the parameter of interest under the DCF regulation.

We reached the minimum sample size of the three main segments identified: scallop dredge medium scale (MS) (38%), pots and nets medium scale (MS) (26%) and pots and nets small scale (SS) (9%).

2.2. Economic analysis

Data collected during the interviews included information about the crew (number of fishers and the sharing system under which the fishing income was divided among members of the crew and the boat owner) and fishing effort (total number of fishing days by gear and month). The costs data included the variable costs (fuel, lubricating oil, bait, ice), fixed costs (including dockage, insurance, maintenance costs required to keep the vessel in working condition and the annual fee for the bank in the case of debt) and investments (type, cost and lifetime of investments made in 2012). The production data included the total monthly catch and monthly catch by species (in weight, kg) and the average landing price by species and month (£/kg). Finally, we asked each owner to estimate the current value of their vessel and the vessel's equipment and gears, in the case that he had to sell it or purchase it in the same condition. This information was essential for estimating the value of the total invested capital (TC), as suggested by Franquesa et al. (2001).

Cost, profit and profitability indicators were thus assessed for the three main segments previously identified (Table 1, according to Cambiè et al., 2012). Cost indicators included fixed costs (administrative costs, maintenance costs and depreciation), variable costs, opportunity cost (benefits that the owners could have obtained by investing their capital in an alternative risk-free investment, e.g. national debt) and average wage. Profit indicators comprised the Vessel Physical Productivity (tons of landings), Capacity Physical Productivity (tons of landings per gross tonnage) and the Vessel Productivity (total incomes). Finally, the profitability indicators included the total capital invested, the net profit (the difference between the total incomes and all costs) and the Rate of Return on Investment (percent ratio of yearly net profits plus the opportunity cost in relation to the investment).

Table 1. Economic indicators selected for assessing the performance of the Welsh fleet in 2012 and the equations used for quantifying them.

	Type	Description	Equation
Cost Indicators	Fixed Costs (FC)	Administrative costs (AC), maintenance costs (MC), depreciation (D)	AC+MC+D
	Variable Costs (VC)	Annual cost of fuel (CF), lubricating oil (LO), bait (BC), ice (I) and crates (C)	CF+LO+BC+I+C
	Opportunity Cost (OP)	Benefits that the owner could have obtained by investing their capital (TC) in an alternative risk-free investment (national debt). It is calculated by multiplying the total capital (TC) by the average real interest rate (R)	TC · R
	Average Wage (AW)	Average salary obtained by each employee, calculated by dividing the salary cost (SC) by the number of crew (N)	SC/N
Profit Indicators	Vessel Physical Productivity (VPP)	Average production of each vessel in terms of weight of landings	
	Capacity Physical Productivity (CPP)	Average production in terms of weight of landings for each capacity unit (GT) of the vessel.	
	Vessel productivity (VP)	Average production in terms of market value at first sale for each vessel. It is calculated by multiplying the VPP by the landing prices (LP)	VPP · LP
Profitability Indicators	Total capital (TC)	Current price assigned to the vessel and the vessel's equipment	
	Net Profit (NP)	Difference between VP and all costs (VC, fixed costs (FC), OP and SC)	VP-VC-FC-OP-SC
	Rate of Return on Investment (ROI)	Percent ratio of yearly net profits plus the opportunity cost in relation to the investment.	OP+NP/TC

2.3 Identification of the *métiers* used and their association

To determine the fishing métiers, we aggregated the catch of each species by boat on a monthly scale, according to Pelletier and Ferraris (2000). Per each fishing gear used by the main segments identified, a matrix with the catch in kg was constructed with rows denoting monthly fishing operation × boat and columns denoting species. Only month x boat with nonzero catch were considered. The data matrix was then transformed to the percentage species composition, to produce the catch profile in terms of kg.

A similarity matrix based on the minimum variance criterion of Ward (1963) and Chord's distance was used to run an agglomerative hierarchical clustering. The silhouette coefficient was calculated to determine the correct number of clusters for each fishing gear. For each cluster, one species was found to be highly characteristic. Each cluster thus identified a specific *métier*.

To assess what variables of the fishing operations were associated with the main *métiers* identified, a multiple correspondence analysis (MCA) was applied to the data matrix built with the 601 monthly fishing operations as individuals and the three categorical variables: fishing area (North, Mid and South Wales), *métiers* and month. To avoid redundant variables, the target species were not included in the analysis (each *métier* was defined by target species). To calculate the percentage of the data variation (inertia) explained by the MCA, adjustment to inertias in the Burt matrix analysis was applyed (Greenacre, 2006; Greenacre et al., 2010).

Association of *métiers* by season and fishing area was assessed by testing for simultaneous pairwise marginal independence (SPMI) (with Bonferroni adjustment) between two *métiers*. If the Bonferroni adjusted p-value of the SPMI test was < 0.05, the relative independence of the two *métiers* combination was rejected and their association was thus considered significant. To achieve this, a matrix was constructed with rows denoting fisher × month and columns denoting *métiers*, which were considered a categorical variable assuming a value of 0 if not used and 1 if used. The R package "MRCV" for multiple response categorical variables was used to perform the analysis (Koziol and Bilder, 2014).

For each *métier* identified we also estimated the associated incomes and operating costs by month and season to assess the relation between these economic indicators and the type and number of *métiers* used.

3. RESULTS

3.1 Economic structure

The three segments most representative of the studied fleet (scallop dredge medium scale, pots and nets medium scale and pots and nets small scale) were characterised by different technical characteristics and economic structure. The fishing capacity in terms of engine power, number of crew and length of vessels of the three fleet segments increased from pots and nets SS to pots and nets MS up to the scallop dredge MS (Table 2).

Table 2. Technical and operational data per vessel for the three fleet segments of the Welsh fleet in 2012 (mean ± SD).

Technical features	**Scallop dredge MS**	**Pots and nets MS**	**Pots and nets SS**
Age (y)	20 (± 11.3)	27 (± 8.4)	16 (± 11.5)
GT (t)	47.9 (± 46.3)	21.6 (± 16.7)	3.9 (± 2.8)
Engine power (hp)	153.5 (± 10.5)	161.9 (± 136.5)	83.7 (± 68.2)
Length (m)	13.9 (± 5.2)	12.9 (± 3.3)	7.8 (± 1.6)
Crew (n)	4 (± 1.4)	3.8 (± 1.3)	1.5 (± 0.6)
Fishing days (n)	165.7 (± 81.3)	249 (± 39.3)	170.1 (± 59.2)

For the three fleet segments, the variable, fixed, salary and opportunity costs varied in nature and importance. The variable costs were directly related to the number of fishing days (Table 3). While fuel was the most expensive item for Scallop dredge MS, the bait was the most important variable cost for pot and nets MS and SS (Table 3).

Table 3. Variable cost per vessel for the three fleet segments of the Welsh fleet in 2012 (mean ± SD).

Fleet segment	fuel	bait	oil	food
Scallop dredge MS	49618 ±20654	1713 ±1084	2322 ± 1047	8267 ±2110
Pots and nets MS	45699 ± 15955	49774 ± 18615	1882 ± 577	7583 ± 2482
Pot and nets SS	5856 ± 907	7252 ± 2210	630 ± 178	1042 ± 108

The yearly fixed costs included administrative costs, maintenance costs, the annual fee for the bank in the case of debt, and depreciation of the vessel and equipment. In terms of depreciation, the fishing gears were the most common and expensive investment for the medium scale segments, while engine, winch and other parts of the vessel represented the most important type of investment for small scale vessels (Figure 2).

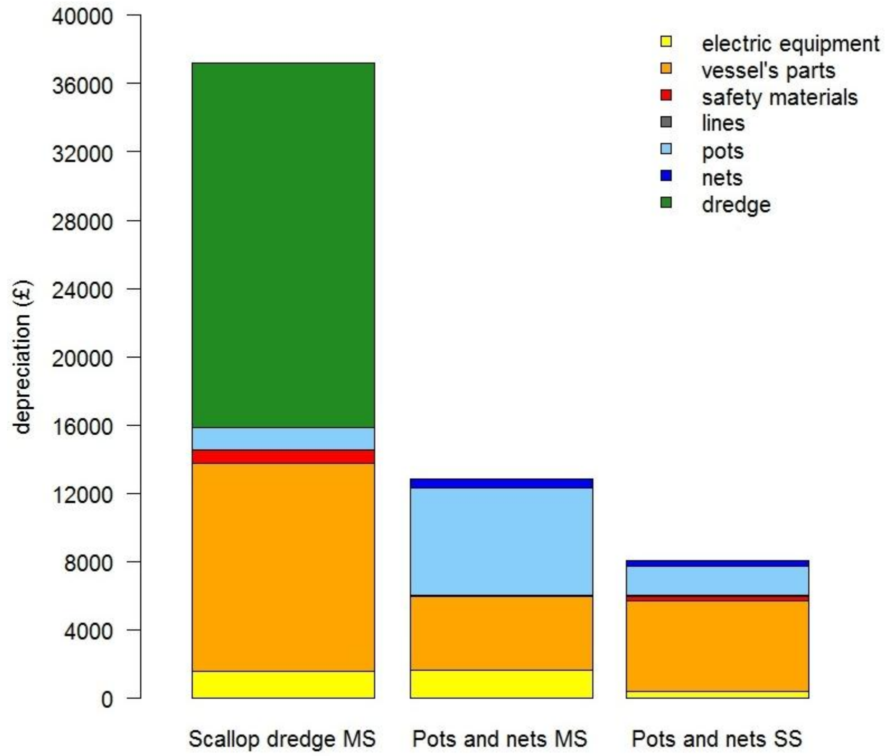

Figure 2. Type of investments and depreciation of the three fleet segments of the Welsh fleet in 2012.

The salary cost is of great social importance, and can vary according to the status of each crew member and for each fleet segment (Figure 3). For the small scale vessels no significant difference in wage between the skipper and deckhand was detected. In this segment, there was usually no task division and specialisation of crew members and therefore all the fishers generally received equal parts. In contrast, the medium scale vessels had a different work structure, with a clear separation between the tasks of the crew. It is possible that this difference was also influenced by the nature of the relationship between the crew members, which is usually business-like and not familiar.

Finally, the opportunity cost was estimated using the value of the total invested capital (TC) declared by the owners, which corresponded to the actual value estimated for the vessel including all the investments (Figure 4). For all segments analysed the profit derived from the fishing activity in 2012 was higher than a potential profit derived from a free risk investment.

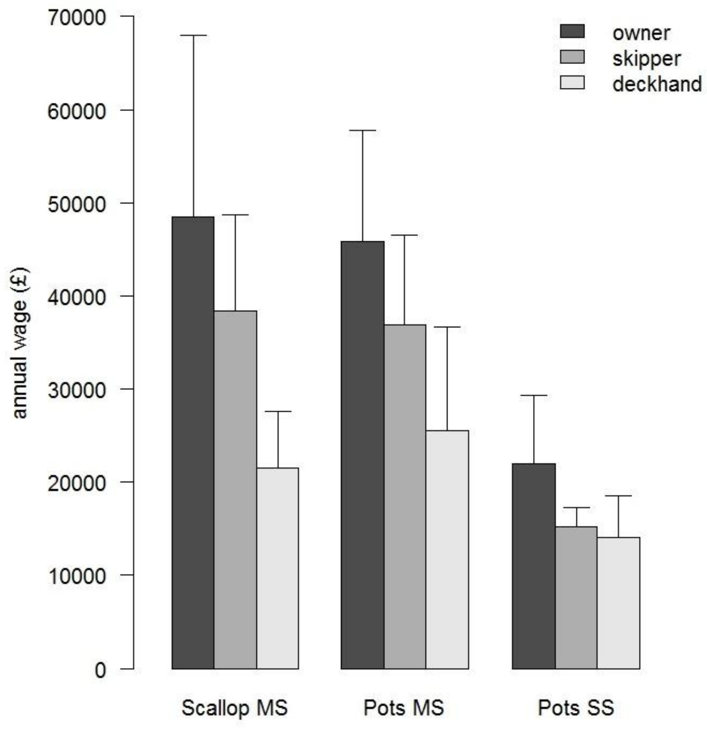

Figure 3. Salary cost by crew member for scallop dredge medium scale, pot and net medium scale and pot and nets small scale vessels in 2012.

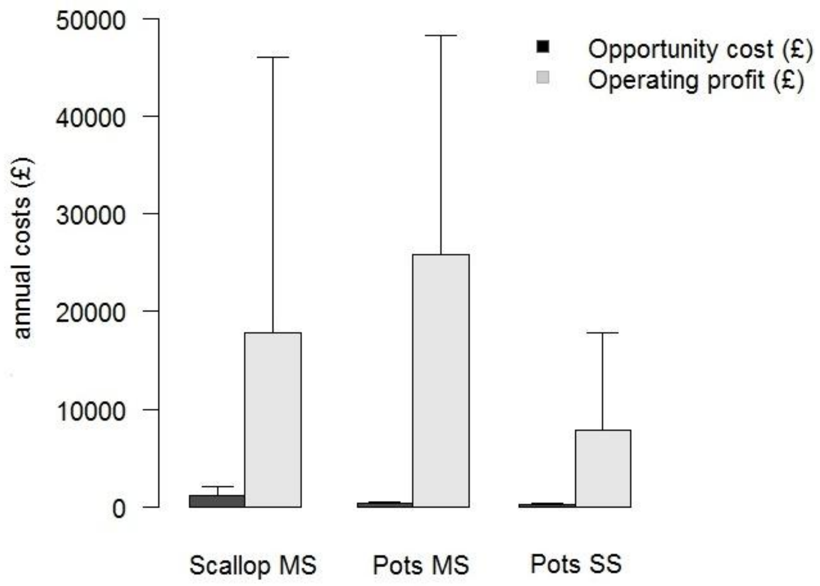

Figure 4. Opportunity cost and operating profit for the fishing activity of 2012.

Profit indicators in terms of average annual incomes per vessel by fleet segments are shown in Table 4. Medium scale vessels were characterized by similar annual incomes and captures with one order of magnitude higher than small scale vessels.

Table 4. Average annual incomes and captures per vessel by fleet segment in 2012.

Fleet segment	Average annual income (£)	Average annual capture (t)
Scallop dredge MS	299 094 ± 79 039	309 ± 182
Pots and nets MS	319 681 ± 92 267	307 ± 166
Pot and nets SS	61 584 ± 9 670	2 ± 0.9

A different relationship between the average daily incomes and the investments has been detected for medium and small scale vessels. While for small scale vessels the incomes strongly depended on the total capital invested and not on the investments of a particular year, for medium scale vessel the yearly investments were essential to determine higher incomes (Figure 5).

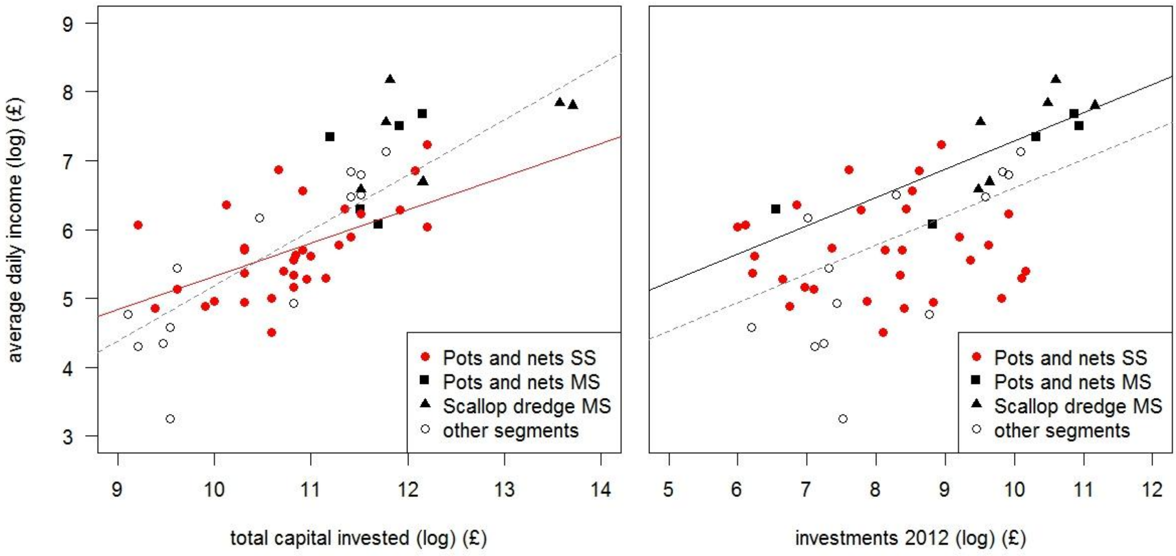

Figure 5. Relationship of the daily income with the total capital invested (left) and with the investments made in 2012 (right). Dashed lines indicate the linear relation for all vessels, red and black lines indicate the relation for small scale and medium scale vessels respectively.

The relationship between incomes and operating costs has been also investigated on a monthly basis. Operating costs represented the variable costs of fuel, bait, food and ice but not salaries, which were estimated on a yearly basis from the vessels characterised by more than one crew member. A highly significant relationship between monthly incomes and monthly operating costs ($p<0.0001$ and R2 adjusted 67%) was detected demonstrating that higher variable costs implied higher incomes (Figure 6).

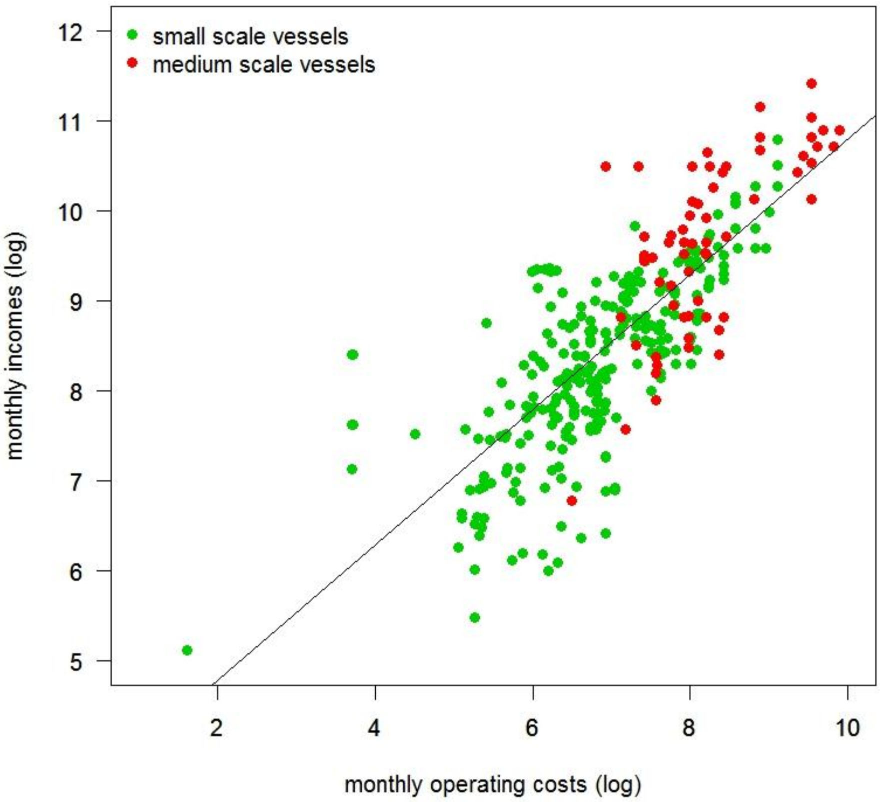

Figure 6. Relationship between monthly operating costs (log transformed) and the related monthly incomes (log transformed) for small scale and medium scale vessels.

Cost, profit and profitability indicators per vessel for the three fleet segments are summarised in Table 5. Scallop dredge appeared to be the most powerful segment in terms of net profit while pots and nets medium scale in terms of Rate of Return on Investment. This difference is mainly due to the higher amount of investments that Scallop dredge MS made, which resulted in a reduction of the related ROI.

Table 5. Indicators of costs, profit and profitability per vessel for the three fleet segments of the Welsh fleet during 2012.

		Scallop dredge MS	Pots and nets MS	Pots and nets SS
Costs Indicators	Variable Costs (VC) (£)	64 520	132 334	16 028
	Maintenance Cost (MC) (£)	32 463	6 750	518
	Opportunity Cost (OP) (£)	1 183	402	202
	Average Wage (AW) (£)	36 318	35 304	17 062
Profit Indicators	Vessel Physical Productivity (VPP) (t)	308.5	307.2	28.1
	Capacity Physical Productivity (CPP) (t)	6.3	10.4	7.6
	Vessel Productivity (VP) (£)	299 094	319 681	61 584
Profitability Indicators	Total Capital (TC) (£)	372 500	126 560	63 552
	Net Profit (NP) (£)	54 906	25 473	7 535
	Rate of Return on Investment (ROI) (%)	6.8	21.6	6.5

The analysis of incomes was performed not only at segment level but also at gear (Figure 7) and species (Annex 1) level. Lobster pot, gill net and rod and line were the fishing gears characterised by an income composition derived from different target species.

The multispecies nature of Welsh fisheries, with various fishing gear harvesting a wide range of species, was the starting point for an in-depth analysis of the different fishing *métiers* employed by the studied fleet.

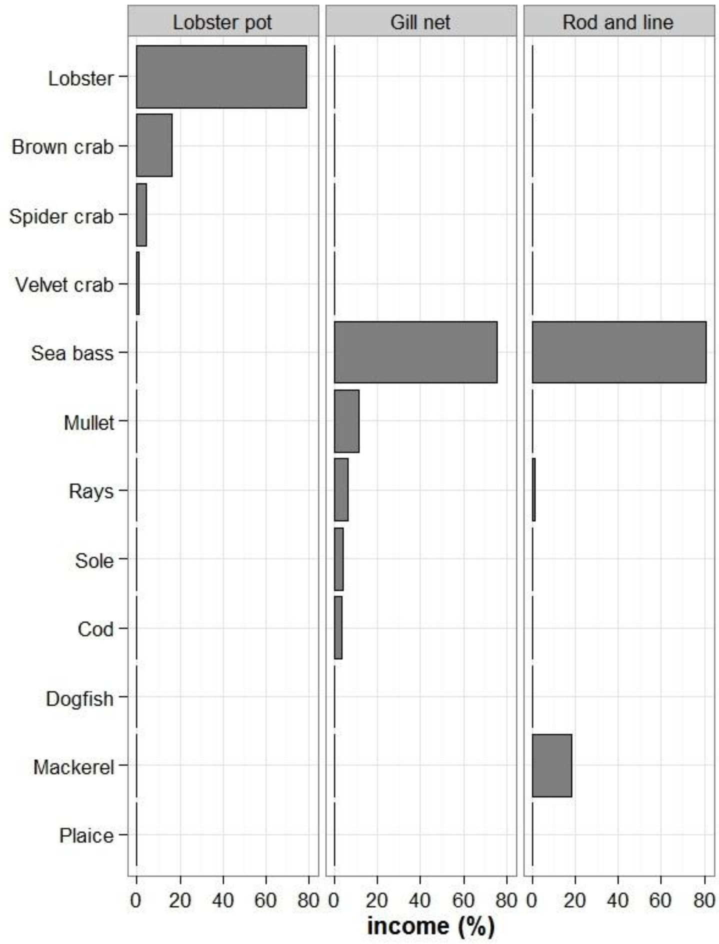

Figure 7. Income composition per vessel obtained from the sale of the species caught with lobster pot, gill net and rod and line in 2012.

3.2 Fishing *métiers* used by the Welsh fleet

A cluster analysis of the catch profile showed that, out of the 13 fishing gears used by the studied fleet, four fishing gears (lobster pot, gill net, rod and line and tangle nets) were characterised by different *métiers* (Figure 8). The cut-off points chosen for each gear ranged from 15 to 20% dissimilarity and they were determined from the silhouette coefficient: 0.46 for lobster pot, 0.63 for gill net, 0.96 for tangle nets and 0.67 for rod and line. Each fishing *métier* was characterised by specific seasonality (Figure 9) and catch profile (Table 6).

Lobster pot appeared to be the gear characterised by the highest diversity in terms of catch profile and the related *métiers*. It was also the gear most widely used by the studied fleet, representing the main gear for 74% and 60% of the “pots and nets” small scale and medium scale respectively. On a yearly basis, the small scale segment used an average of 2.6 *métiers* per vessel, followed by pots and nets medium scale vessels (with 2 *métiers* per vessel) and scallop dredge medium scale (1.8 *métiers* per vessel).

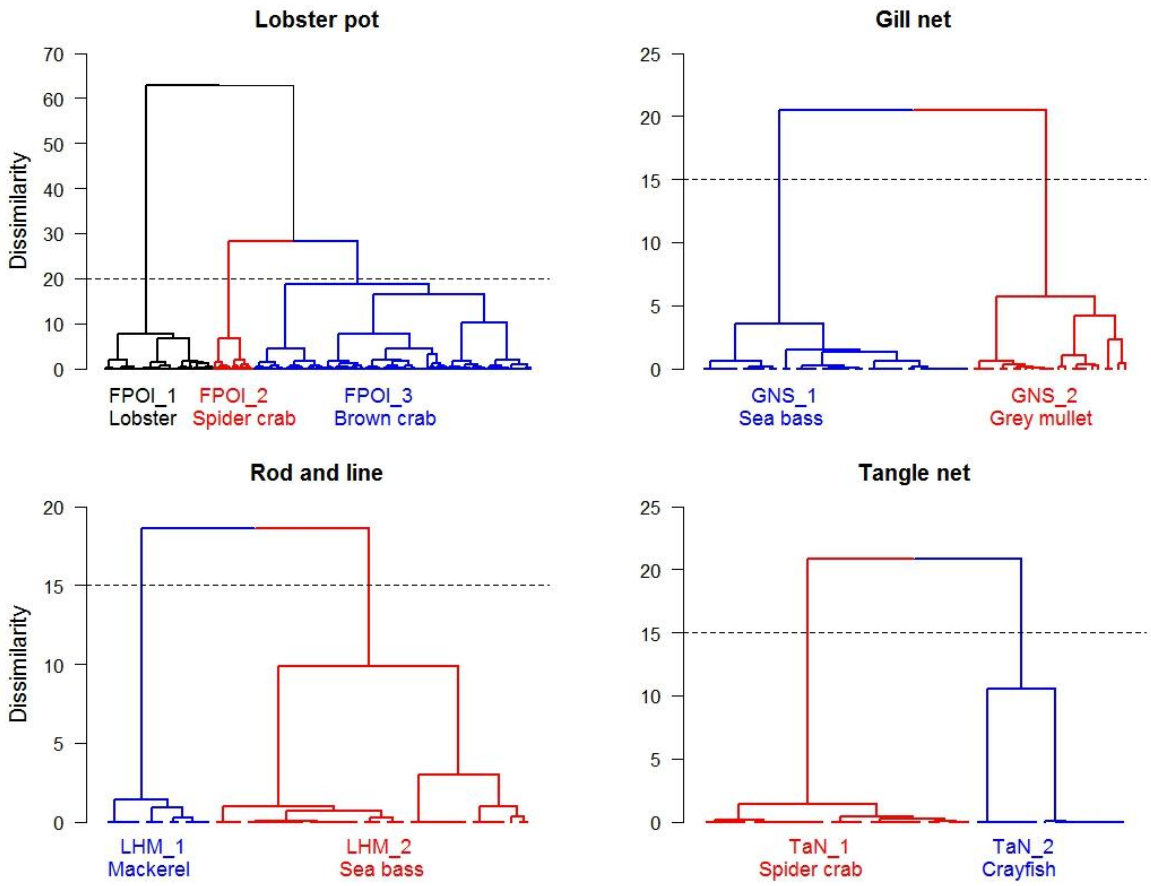

Figure 8. Cluster analysis showing the different *métiers* for each fishing gear.

Fishing *métiers*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FPOl_1	D	C	D	C	C	B	A	A	A	C	D	D
FPOl_2	D	D	D	C	A	A	A	A	C	D	D	D
FPOl_3	B	B	B	A	B	B	B	B	B	A	B	B
FPOp_1	B	B	B	B	D	D	D	D	B	A	B	B
FPOw_1	B	B	B	A	B	B	B	B	B	B	B	B
FPOsp_1	D	D	D	D	A	A	A	C	C	D	D	D
GNS_1	D	C	C	D	D	D	D	C	B	B	B	C
GNS_2	D	C	C	C	D	C	C	C	B	C	C	B
TaN_1	D	D	D	C	A	A	A	B	B	D	D	D
TaN_2	C	C	C	D	C	C	C	C	A	B	B	B
LHM_1	D	D	D	D	B	A	B	B	D	D	D	D
LHM_2	D	D	D	B	B	A	A	A	B	B	C	D
LLS_1	D	D	D	D	D	D	C	B	C	D	D	D
DRBk_1	A	A	B	B	D	D	D	D	D	D	A	A
OTB_1	C	B	A	C	A	A	A	A	A	A	C	D

% OF VESSELS	
D	0-25
C	25-50
B	50-75
A	75-100

Figure 9. Seasonality of the fishing *métiers* used by the studied fleet.

Table 6. Catch profile of the 18 fishing *métiers* used by the studied fleet

Gear and *métiers*	No vessels	Target species	Accessory species
Lobster pot (FPOl)	**35**		
FPOl_1	16	Lobster (90.8%)	Brown crab (8.1%), Velvet crab (0.9%), Spider crab (0.2%)
FPOl_2	7	Spider crab (56.3%)	Brown crab (26.4%), Lobster (13.9%), Velvet crab (3.4%)
FPOl_3	28	Brown crab (59%)	Lobster (37.6%), Velvet crab (2.1%), Spider crab (1.3%)
Prawn pot (FPOp)	**12**		
FPOp_1	12	Prawn (100%)	
Whelk pot (FPOw)	**12**		
FPOw_1	12	Whelk (100%)	
Spider crab pot (SP)	**2**		
FPOsp_1	2	Spider (100%)	
Gill net (GNS)	**13**		
GNS_1	10	Sea bass (98.4%)	Cod (1.6%)
GNS_2	5	Grey mullet (62.6%)	Sea bass (20.7%), Cod (9%), Rays (5.2%)
Tangle net (TaN)	**9**		
TaN_1	6	Spider crab (100%)	
TaN_2	3	Crayfish (56%)	Flatfish (44%)
Trammel net (TrN)	**1**		
TrN_1	1	Rays (56%)	Dogfish (24.1%), Sole (16.8%), Cod (3.1%)
Drift net (GND)	**1**		
GND_1	1	Mackerel (100%)	
Rod and line (LHM)	**10**		
LHM_1	4	Mackerel (92.9%)	Sea bass (7.1%)
LHM_2	7	Sea bass (83.9%)	Mackerel (11.6%), Rays (4.5%)
Longline (LLS)	**4**		
LLS_1	4	Sea bass (100%)	
King scallop dredge (DRBk)	**10**		
DRBk_1	10	King scallop (100%)	
Beam trawl (TTB)	**1**		
TTB_1	1	Rays (46.6%)	Sole (23.3%), Brill (15%), Turbot (15%)
Otter trawl (OTB)	**6**		
OTB_1	6	Rays (51.8%)	Sole (22.9%), Plaice (22.1%), Cod (3.2%)

3.3 Fishing *métiers* and relationship with seasonal, spatial and economic drivers

The relationship between fishing *métiers*, fishing location and month was assessed with a multiple correspondence analysis (MCA). The explained inertia (a measure of variance) in the first two dimensions was 51%. Therefore, 51% of the variation in fishing operations was explained by the relationship between *métiers*, season and location (Figure 10).

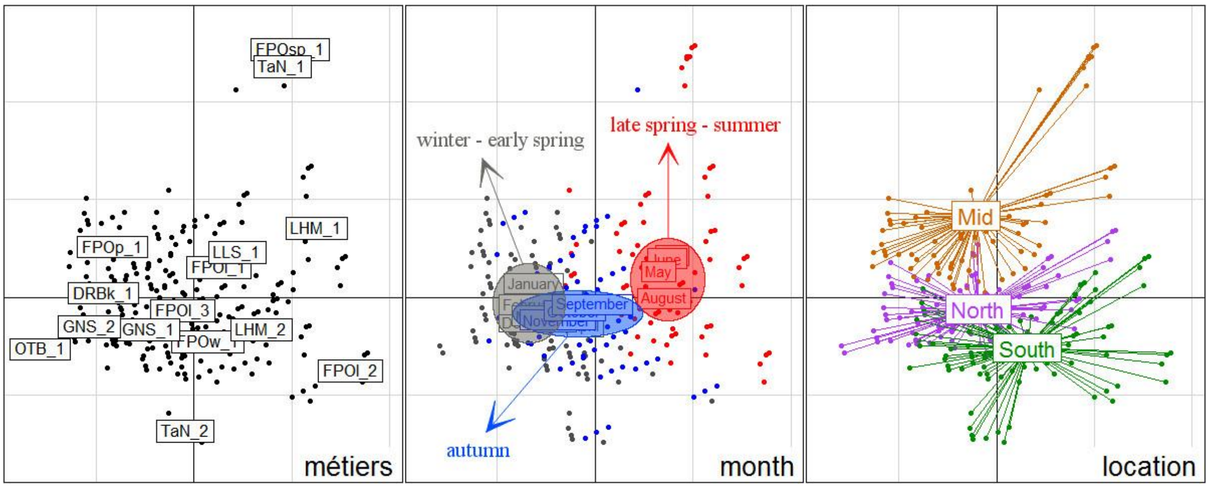

Figure 10. Multiple correspondence analysis showing the relationship between *métiers*, months and capture location.

The MCA thus showed the annual variation of the use of the *métiers* was mainly related with the seasonality of the target species and the capture location. For example, spider crab represented the main target species for three different *métiers* (FPOl_2, TaN_1 and FPOsp_1). Although all three *métiers* were used mainly in summer (when the spider crab is more abundant), they were employed in different locations: lobster pot in South Wales and tangle net and spider pot in Mid Wales. The prawn fishery also showed a strong seasonality (almost absent in summer, with an increase of use in spring, autumn and winter) and a strong relationship with the fishing location, as it was concentrated in Mid Wales. The use of tangle net targeting crayfish was typical of South Wales during winter while the scallop fishery was mainly concentrated in North and Mid Wales.

The MCA performed showed a strong relationship between *métiers*, seasons and fishing areas. However, it did not provide a picture of the most significant association between multiple *métiers*. Moreover, it is important to investigate the presence of other drivers than season and fishing location in determining the choice of using one or more *métiers*. As profit maximisation is believed to be one of the most important driver in fishers' behaviour and the related *métiers* choice, we estimated a proxy of the daily profit (the difference between daily incomes and daily operating costs, where operating costs are all variable costs except for salaries) associated to each *métier* for small scale (Figure 11) and medium scale (Figure 12) vessels.

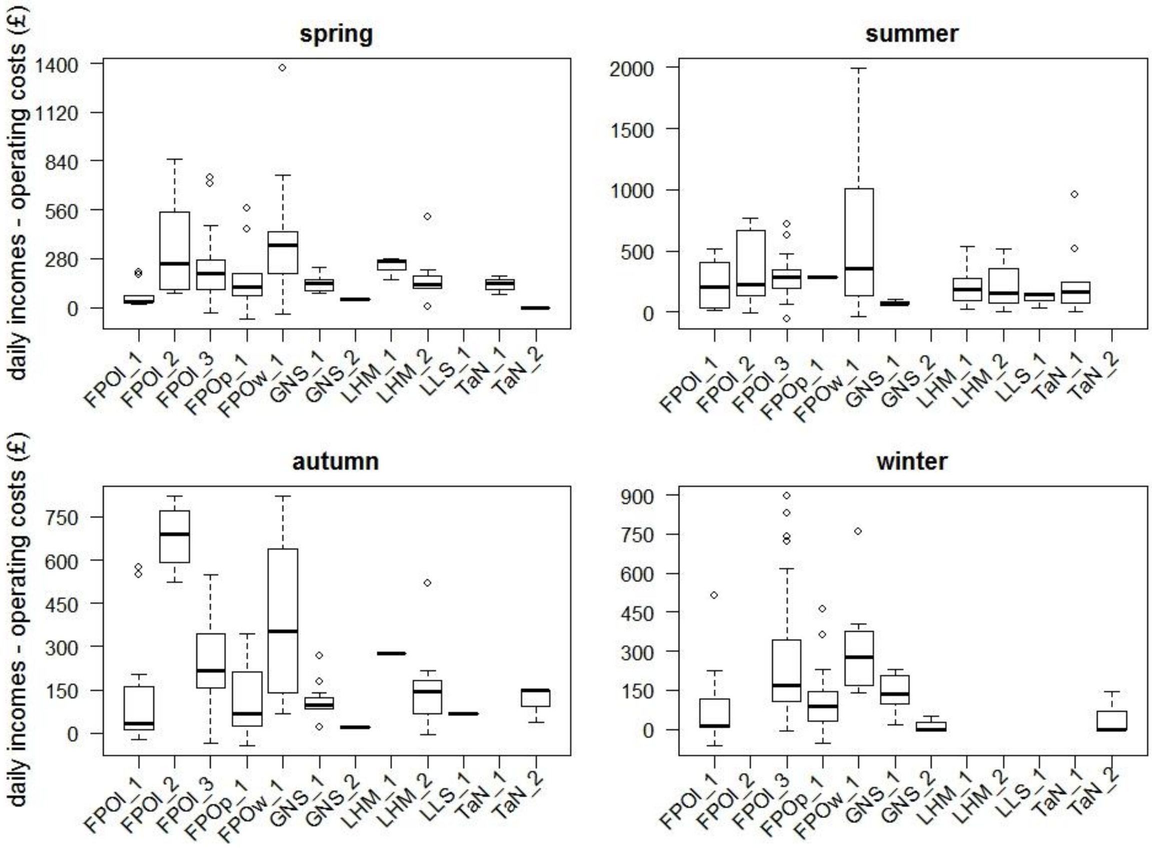

Figure 11. Value of daily incomes-daily operating costs (considered as a proxy of daily profit) per season for each *métier* used by small scale vessels in 2012.

For small scale vessels, whelk pot (FPOw_1) was one of the most profitable *métiers* during the entire year. Lobster pot targeting spider crab (FPOl_2) was associated with high profits during spring, summer and autumn. Lobster pot catching brown crab as the main species (FPOl_3) appears to be the most constant *métier* in terms of profits provided during the entire year.

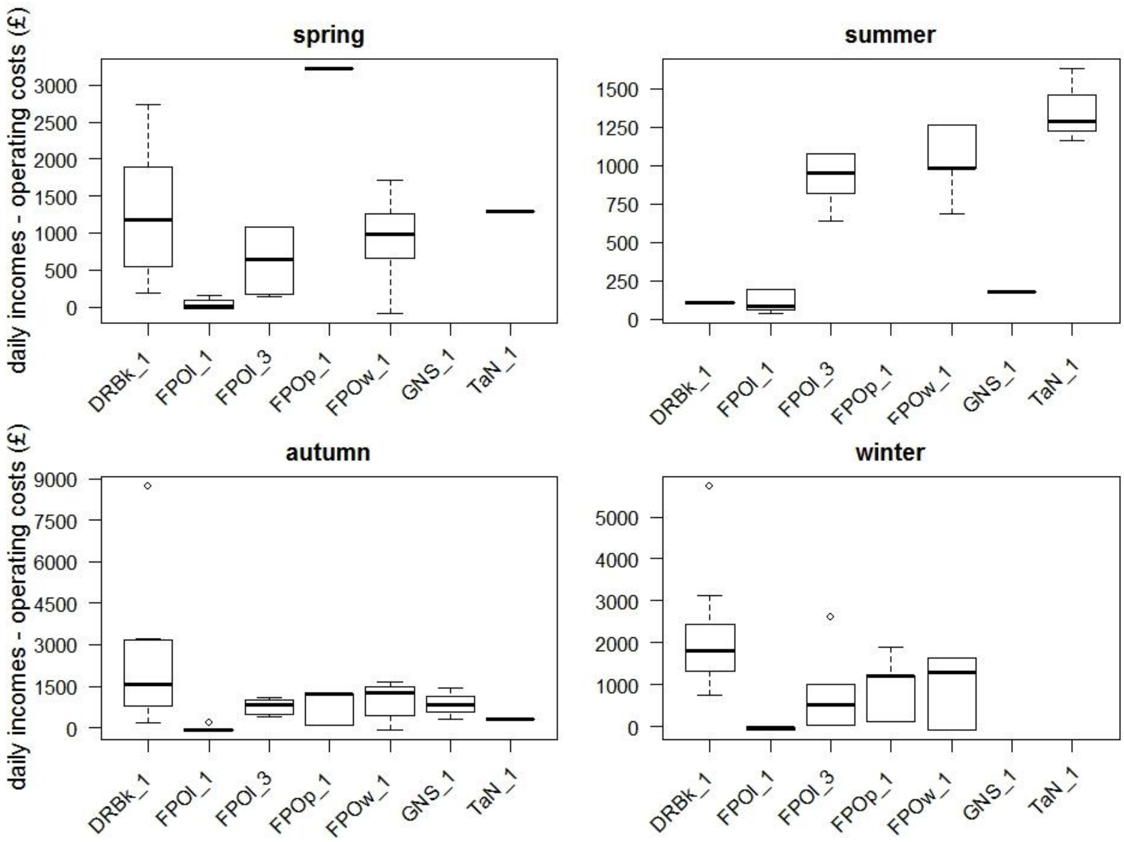

Figure 12. Value of daily incomes-daily operating costs (considered as a proxy of daily profit) per season for each *métier* used by medium scale vessels in 2012.

For medium scale vessels, scallop dredge (DRBk_1) appeared to be the most profitable *métier* in spring, autumn and winter, while in summer tangle net targeting spider crab (TaN_1) was the most profitable followed by whelk pot (FPOw_1) and lobster pot catching brown crab as the main species (FPOl_3).

When combining different *métiers*, small scale vessels used on average 2.2 *métiers* and medium scale vessels 2.4 on a monthly basis. The most important associations between *métiers* were thus assessed by testing the independence between two *métiers* through the simultaneous pairwise marginal independence test (SPMI) for small scale (Table 7) and medium scale (Table 8) vessels.

The Bonferroni adjusted p-values provided strong evidence for rejecting SPMI and indicate a significant association for the *métiers* combinations described in Table 7. In particular, significant associations have been detected during spring, when lobster pot targeting lobster (FPOl_1) and rod and line targeting sea bass (LHM_2) were highly associated. During winter, prawn pot (FPOp_1) was highly associated with lobster pot targeting brown crab (FPOl_3) and with lobster pot targeting lobster (FPOl_1) and whelk pot was highly associated with lobster pot targeting brown crab (FPOl_3).

Significant association of the fishing *métiers* was also detected for different fishing areas. While in North Wales, lobster pot targeting lobster (FPOl_1) and brown crab (FPOl_3) were associated with rod and line targeting sea bass (LHM_2), in Mid Wales the only significant association was between lobster pot targeting brown crab (FPOl_3) and prawn pot (FPOp_1). In South Wales three main associations were detected: lobster pot targeting brown crab (FPOl_3) with rod and line targeting sea bass (LHM_2) and with whelk pot (FPOw_1) and between lobster pot targeting lobster (FPOl_1) and prawn pot (FPOp_1).

Table 7. Results of the simultaneous pairwise marginal independence test and the corresponding Bonferroni adjusted p-value indicating the significant associations of *métiers* for small scale vessels.

factor	level	*Métier* 1	*Métier* 2	p-value
Season	spring	FPOl_1	LHM_2	0.0002
	winter	FPOl_3	FPOp_1	0.0019
		FPOl_1	FPOp_1	0.0040
		FPOl_3	FPOw_1	0.0006
Fishing area	North	FPOl_1	LHM_2	0.0002
		FPOl_3	LHM_2	0.0007
	Mid	FPOl_3	FPOp_1	0.0420
	South	FPOl_1	FPOp_1	<0.0001
		FPOl_3	FPOw_1	0.0005
		FPOl_3	LHM_2	0.0474

For medium scale vessels the SPMI analysis was performed for the “Pot and nets MS” without distinction between season and fishing areas due to the small amount of data (Table 8). Considering that scallop dredge, when used, was never associated with another *métier*, the main associations of *métiers* were lobster pot targeting lobster (FPOl_1) with prawn pot (FPOp_1) and with tangle net targeting spider crab (TaN_1) and lobster pot targeting brown crab with whelk pot (FPOw_1).

Table 8. Results of the simultaneous pairwise marginal independence test and the corresponding Bonferroni adjusted p-value indicating the significant associations of *métiers* for medium scale vessels (Pots and nets MS).

segment	*Métier* 1	*Métier* 2	p-value
Pot and nets MS	FPOl_1	FPOp_1	<0.0001
	FPOl_3	FPOw_1	<0.0001
	FPOl_1	TaN_1	0.0002

Comparing the most significant associations of fishing *métiers* by season for small scale vessels with the correspondent profit, only 25% of those associations were characterised by profit maximisation, where both *métiers* had the higher profits than the rest of the *métiers* used by the segment (association between lobster pot targeting brown crab (FPOl_3) and whelk pot (FPOw_1)). On the other hand, 50% of the *métiers* associations were characterised by a strong seasonality, where both *métiers* had the maximum use in the season considered (in winter, FPOl_3 with FPOp_1 and with FPOw_1). For medium scale vessels, 33% of the *métiers* association were characterised by profit maximisation, but only in spring and partially in summer.

The relationship between the number of *métiers* used on a monthly basis and the related incomes and operating costs was further analysed. The aim of this analysis was to assess if the increase of the number of *métiers* used by month was associated with a decrease in the monthly operating costs (variable costs as fuel, bait, food and ice but with salaries excluded) or with an increase of the monthly incomes.

A quantile regression analysis was used to fit the data for both small scale and medium scale vessels. This regression revealed the presence of a limiting effect of the number of *métiers* per vessel used on a monthly basis on the maximum amount (90% quantile) of monthly operating costs (Figure 13). Therefore, increasing the number of *métiers* resulted in a decrease in the maximum average monthly costs. This finding could explain the tendency to alternate different fishing *métiers* during the year. However, the reduction of the monthly costs can result in the reduction of the monthly incomes, which can explain the presence of a significant quantile regression between the number of *métiers* used by a single vessel and the maximum amount of monthly incomes.

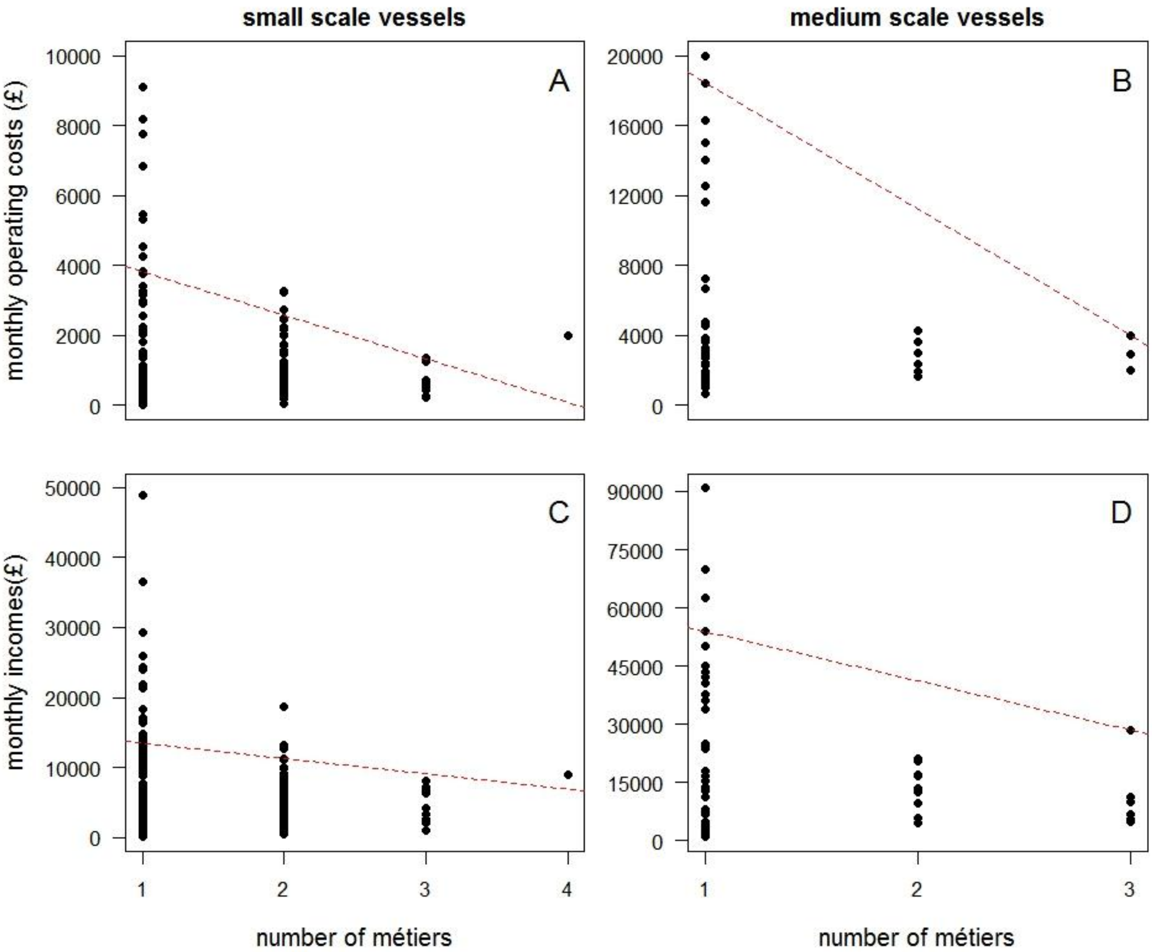

Figure 13. Relationship between the number of *métiers* per vessel used on a monthly basis and the relative monthly operating costs and incomes for small scale and medium scale vessels. Dashed lines represent the quantile regression (at 90 quantile, p=0.0004 (A), p<0.0001 (B), p<0.01 (C) and p=0.01 (D)).

To avoid any possible bias due to the different level of fishing effort between vessels, the analysis was also performed between the number of *métiers* per vessel used on a monthly basis and the daily operating costs and incomes (Figure 14). As before, the regression showed the presence of a limiting effect of the number of *métiers* used by a single vessel on the maximum amount (90% quantile) of daily operating costs and incomes for both small scale and medium scale vessels.

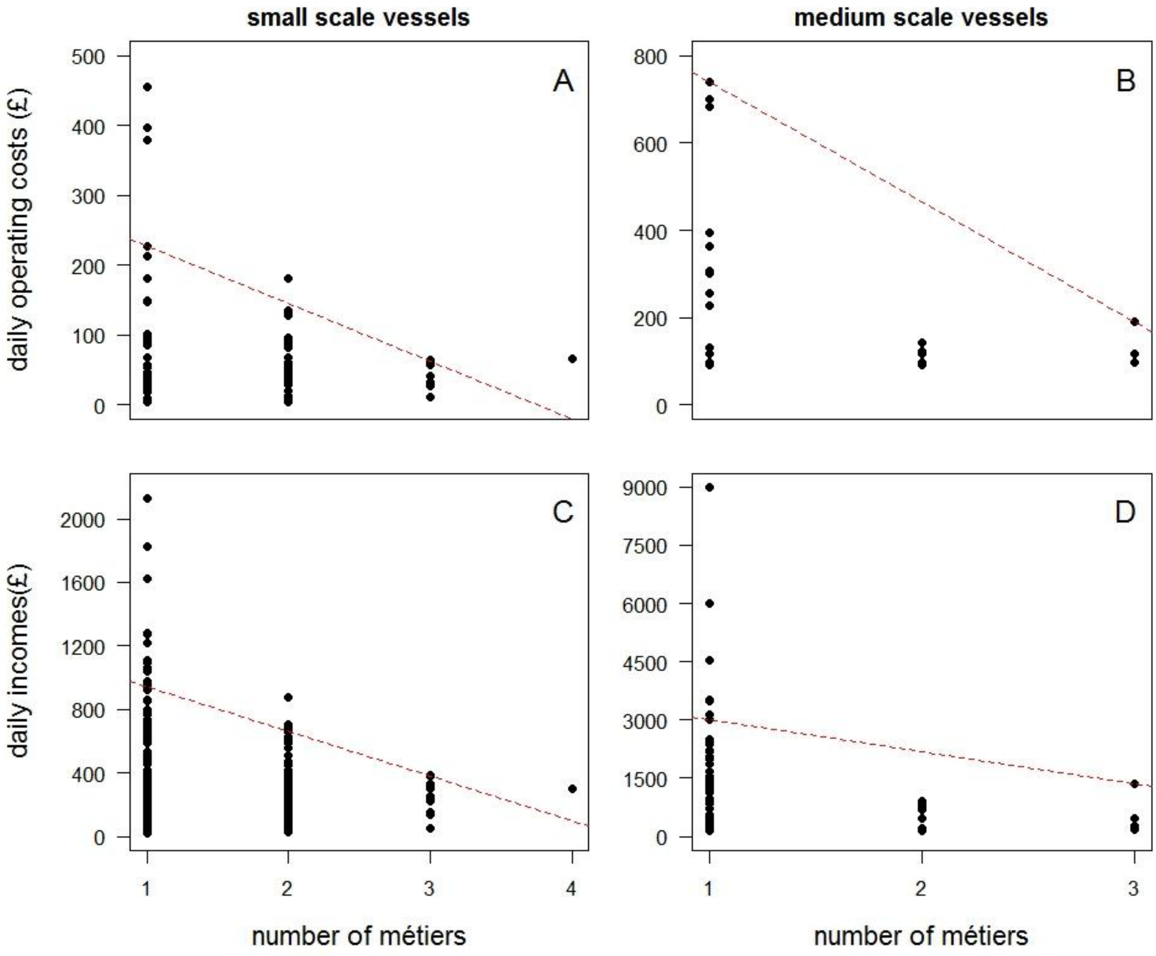

Figure 14. Relationship between the number of *métiers* per vessel used on a monthly basis and the relative daily operating costs and incomes for small scale and medium scale vessels. Dashed lines represent the quantile regression (at 90 quantile, $p<0.0001$ (A), $p<0.0001$ (B), $p<0.0001$ (C) and $p=0.002$ (D)).

A quantile regression analysis was also performed to assess the relationship between the number of *métiers* per vessel used on a monthly basis and a proxy of the related monthly profit. This proxy was the difference between the daily incomes and the daily operating costs, which included all variable costs except the salaries. Salaries were not taken into account because many small scale vessels were characterized by a one-man crew. The absence of a proper share distribution makes it difficult to estimate the related salaries. However, due to the positive correlation between salaries and incomes, we considered the difference between the daily incomes and the daily operating costs as a valid proxy of the daily profits. The regression showed the presence of a limiting effect of the number of *métiers* used by a single vessel on the maximum amount (90% quantile) of daily profits for both small scale and medium scale vessels (Figure 15).

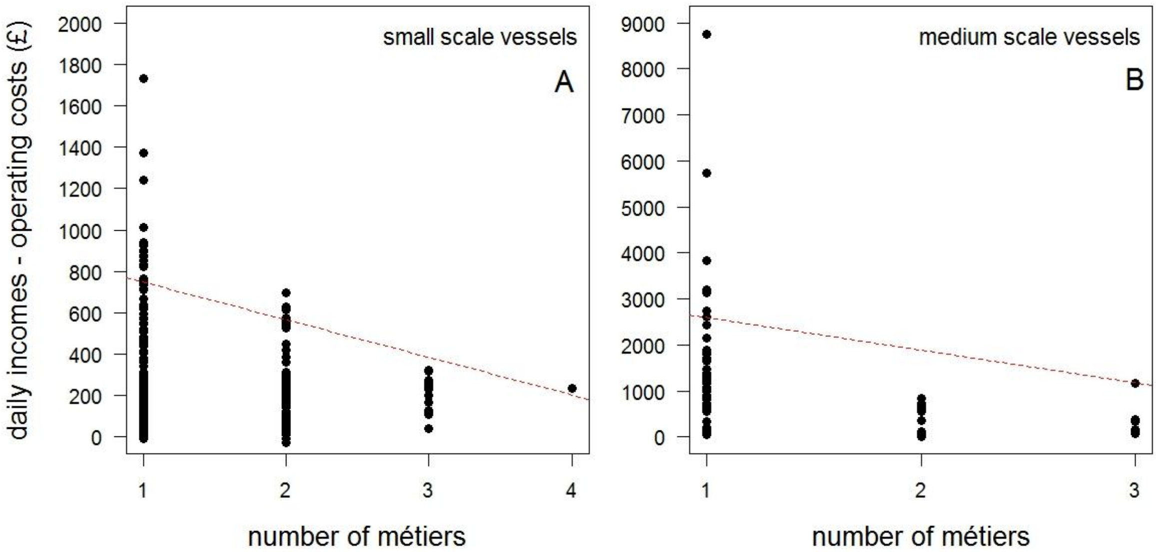

Figure 15. Relationship between the number of *métiers* per vessel used on a monthly basis and the relative proxy to the profit value (daily incomes – daily operating costs) for small scale and medium scale vessels. Dashed lines represent the quantile regression (at 90 quantile, p<0.0001 (A) and p=0.01 (B)).

Finally we estimated the relationship between the number of *métiers* per vessel used on a yearly basis and the average daily costs and incomes. This analysis allowed all the *métiers* used on a yearly basis to be considered in the analysis (with a maximum amount of five *métiers* per year). Quantile regression showed the presence of a limiting effect of the number of *métiers* used by a single vessel on the maximum amount (95% quantile) of daily costs and incomes for small scale vessels, while for medium scale vessels the limited amount of data prohibited investigation of this relationship (Figure 16).

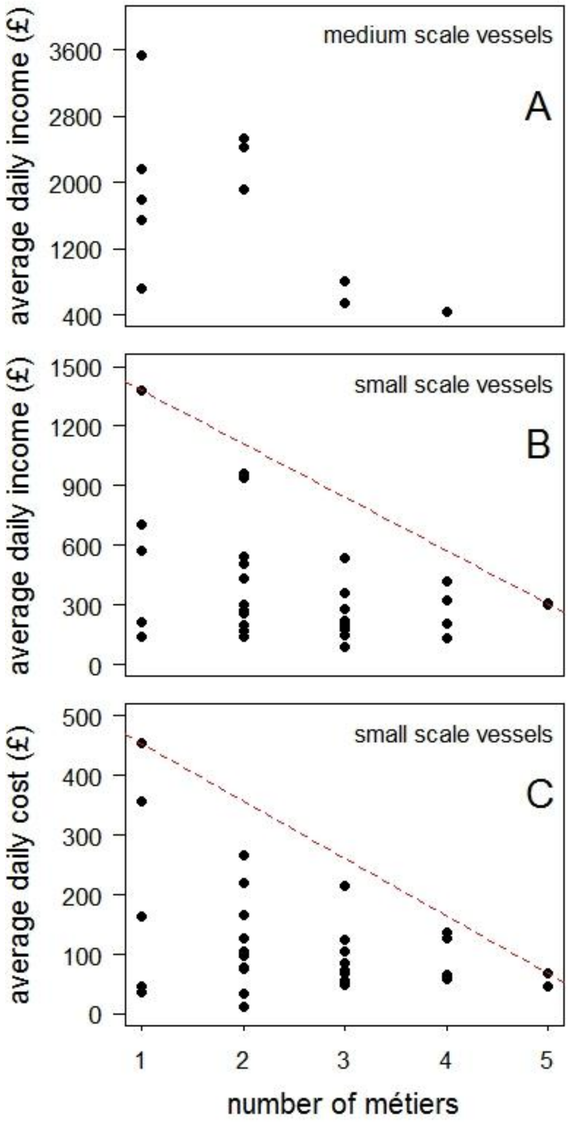

Figure 16. Relationship between the number of *métiers* per vessel and the average daily income and cost of the three fleet segments. Dashed lines represent the quantile regression (at 95 quantile, p=0.0004 (B) and p<0.0001 (C))

4. DISCUSSION

Our study provided a comprehensive analysis of the fishing strategies employed by the small scale and medium scale segments of the Welsh fleet. This analysis was based on the premise that the fishers' behaviour behind the choice of the fishing strategies was related with the economic aspects associated to the fishing operations, the seasonality of target species and fishing location.

Three main segments were identified as representative of the Welsh fleet from a socio-economic perspective (number of vessels, fishing effort and income produced), one small scale (pots and nets small scale) and two medium scale (scallop dredge medium scale and pots and nets medium scale). All three segments were characterised by a profitable fishing activity, with a moderate ROI (rate of return on investment, which depends on the rate profit/capital invested) for scallop dredge and small scale vessels and a high ROI for pots and nets medium scale vessels. The ROI for small scale vessels and scallop dredge medium scale was similar (around 7% per vessel). However, this similarity was not an expression of a similar economic structure which, on the contrary, appeared extremely different between the two segments. In fact, for small scale vessels, the moderate ROI was the results of a moderate profit, while for scallop dredge medium scale it was the result of the large capital invested by the segment. A regular monitoring of the economic performance of scallop dredge medium scale segment is therefore needed to understand if the large investments in harvesting capacity yield progressively lower returns to fishers. In this case scallop dredge medium scale could be close to a situation of overcapitalisation (and possibly overcapacity).

Conversely, the pots and nets medium scale segment appeared highly profitable with a ROI of about 20%. This value indicates that this fleet segment performed well economically during 2012, since 10% is already considered a good result (Tietze et al. 2005). Profitability indicators are particularly useful for assessing capacity levels of fisheries (Ward et al. 2004) and a good economic performance can encourage investment in fishing. It is therefore likely that the pots and nets medium scale segment invested at least part of the benefits in vessel technology, for example, by upgrading their engines, electronic equipment or fishing gears (e.g. number of pots). The investment of capital in vessel improvement would have led to a possible increase in fishing capacity in 2013. In fact, in an open-access regime, excess capacity could occur under a harvesting strategy driven by profit maximisation (Nøstbakken et al. 2011) with a consequent difficulty in achieving the long term sustainability of the fishery. Thus, the effect of technological progress and investment needs to be taken into account and possibly limited, especially in profitable fisheries (Kirkley and Squires 2003; Ward et al. 2004; Villasante and Sumalia 2010).

The analysis performed incorporated data representing any activity being undertaken in each month to reflect the multi-purpose, multi-*métier* nature of fleet activities. A total of 18 *métiers* were identified, clearly demonstrating the complexities of the fishing strategies adopted by the Welsh fleet. Differences in the fishing strategies employed were detected between the three fleet segments. Scallop dredge medium scale was characterised by a relatively small diversity in the fishing strategies adopted, as the *métiers* different from scallop dredge were only used during the seasonal closure of dredge fishery. On a yearly basis, scallop dredge medium scale used an average of 1.8 *métiers* per vessel, followed by pots and nets medium scale vessels (with 2 *métiers* per vessel) and small scale vessels (2.6 *métiers* per vessel). Therefore, while medium scale vessels appeared more specialised in using one or two single *métiers*, small scale vessels were characterised by higher diversity, which reflected a higher dynamic nature of their fishing operations.

The drivers behind the fishing *métiers* choice and, ultimately, the fishing strategies have been analysed and in particular, the seasonal fishing patterns related with the availability of the individual target species, the fishing location and the economic aspects associated with the fishing operations. The use of the different *métiers* identified appeared to be highly related with the seasonality of main target species and the fishing location. For example, spider crab represented the main target species for three different *métiers* (FPOl_2, TaN_1 and FPOsp_1). Although all three *métiers* were used mainly in summer (when the spider crab is more abundant), they were employed in different locations: lobster pot in South Wales and tangle net and spider pot in Mid Wales. The prawn fishery also showed a strong seasonality (almost absent in summer and an increase of use in spring, autumn and winter) and a strong relationship with the fishing location, as it was concentrated in Mid Wales. The use of tangle net targeting crayfish was typical of South Wales during winter while the scallop fishery was mainly concentrated in North and Mid Wales.

Associations between *métiers* also have a strong seasonal and spatial component. For small scale vessels the most significant association of *métiers* in spring was between lobster pot targeting lobster and rod and line targeting bass while in winter between lobster pot targeting lobster and prawn pot, between lobster pot targeting brown crab and whelk pot and between lobster pot targeting brown crab and prawn pots. The knowledge of the associations of fishing *métiers* are essential from a management perspective. For example, limiting the effort exerted with lobster pot during spring could lead to an increase in the use of rod and line, while a reduction of the fishing effort with prawn pot in winter could result in an increase of the use of lobster pot. The knowledge of the different association of *métiers* by area is also essential as the consequences of the effort control of a specific *métier* can have different effects between North, Mid and South Wales. In this case, limiting the effort of lobster pot could lead to an increase of the use of rod and line targeting bass in North Wales, prawn pots in Mid Wales and rod and line, prawn pot and whelk pot in South Wales. Predicting the effect of the fishing effort restriction for a specific *métier* through the knowledge of the fishing strategies and the conservation status of the target species can help managers in avoiding collateral effects resulting from the implementation of a management scheme. In this sense it is important to consider that decisions impacting fishers' communities and local stocks should not be implemented on a larger scale if local conditions differ. In such cases, adaptive management measures coherent with local specificity should be adopted (Salas et al., 2004).

Our study also revealed that the traditional assumption that fishers act rationally in terms of maximising their profit/utility (e.g. van Putten et al., 2011) is not always true. For small scale vessels, only 25% of the association between *métiers* was characterised by higher profit (lobster pot associated with whelk pot in winter). Once again, the seasonality of the target species played an essential role explaining 50% of the association between *métiers*. Commercial species were often targeted when they were more abundant and not when their value was higher. This behaviour could respond to the risk-averse aptitudes of fishers towards high but uncertain profits to which they prefer low risk fishing operations with reduced profit margin. Other economic drivers have been found important in determining the type and number of *métiers* used. The reduction of the costs associated with the fishing activity (operating costs) can explain the aptitude of increasing the number of *métiers* used at monthly and yearly scales. Increasing the number of *métiers* used significantly decreased the maximum amount of operating costs. As these costs are positively related with the incomes, their decrease implied a decrease in the maximum expected incomes and, ultimately, in the maximum expected profits. Our findings thus revealed that the reductions of operating costs is a more important economic driver than profit maximisation. These results also need to be taken into account when implementing management measures, as the limitation of *métiers* characterised by lower operating costs (e.g. gill net from shore, tangle nets, etc.) could result in a non-profitable fishing activity for the vessels characterised by a marginal economic condition.

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Annex 1

Captures of the main target species and related incomes per vessel for the main fleet segments identified

SCALLOP DREDGE MEDIUM SCALE

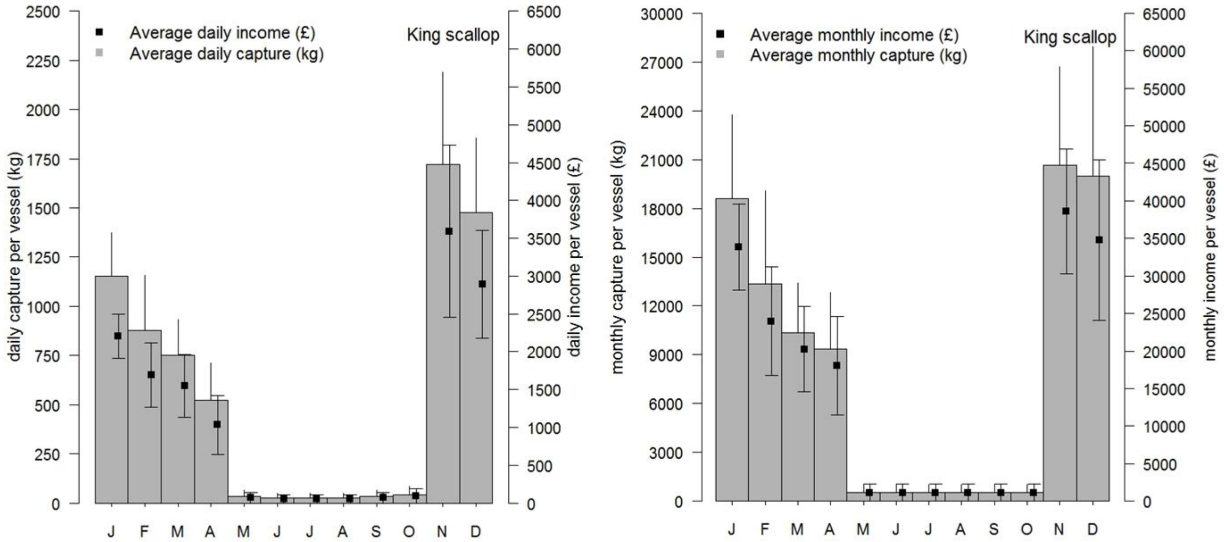

Figure 1. Daily (left) and monthly (right) captures and incomes per vessel of king scallops caught with scallop dredge by an average “scallop dredge medium scale” vessel.

POTS AND NETS MEDIUM SCALE

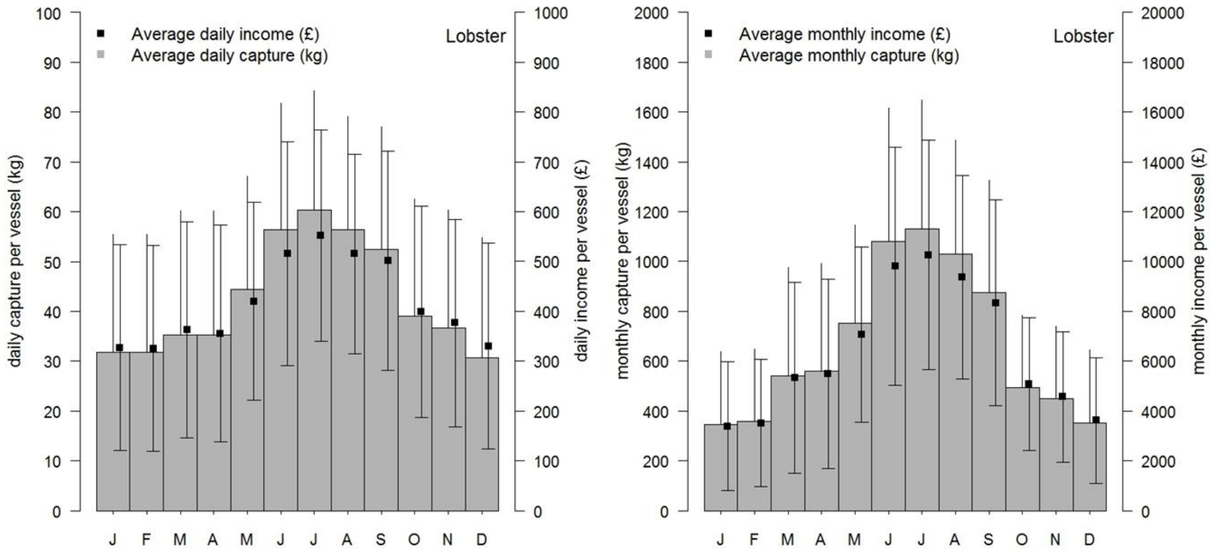

Figure 2. Daily (left) and monthly (right) captures and incomes per vessel of lobster caught with lobster pot by an average “pots and nets medium scale” vessel.

POTS AND NETS SMALL SCALE

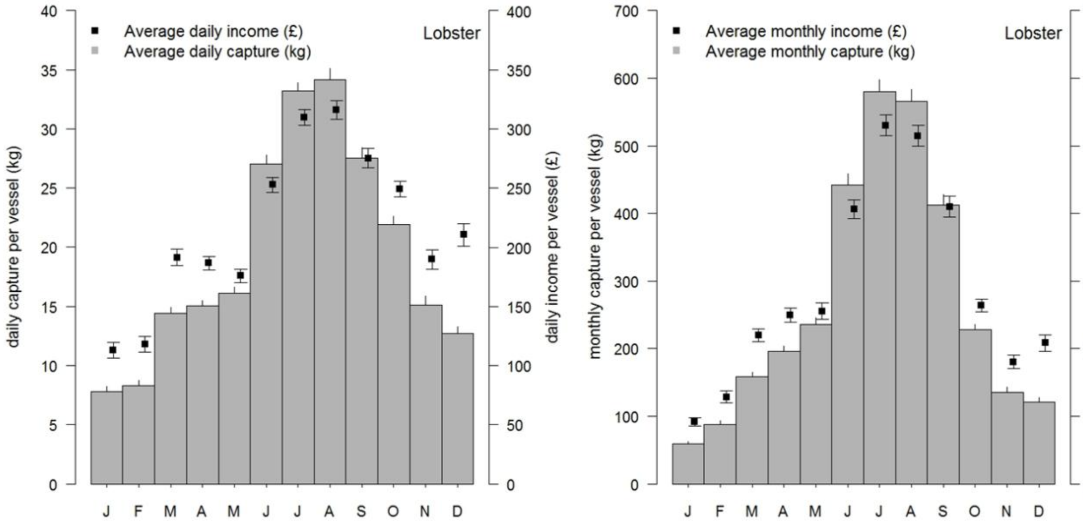

Figure 3. Daily (left) and monthly (right) captures and incomes per vessel of lobster caught with lobster pot by an average “pots and nets small scale” vessel.

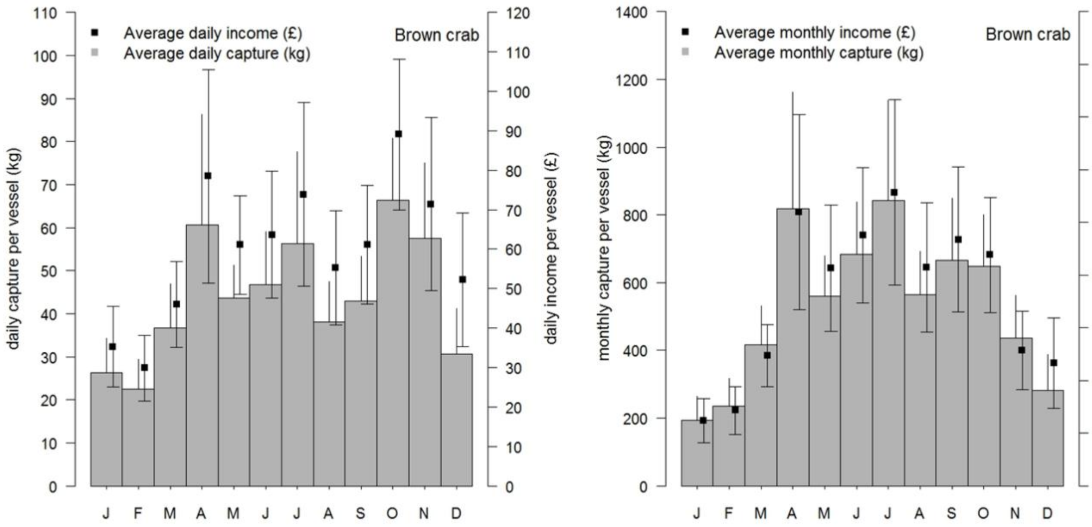

Figure 4. Daily (left) and monthly (right) captures and incomes per vessel of brown crab caught with lobster pot by an average “pots and nets small scale” vessel.

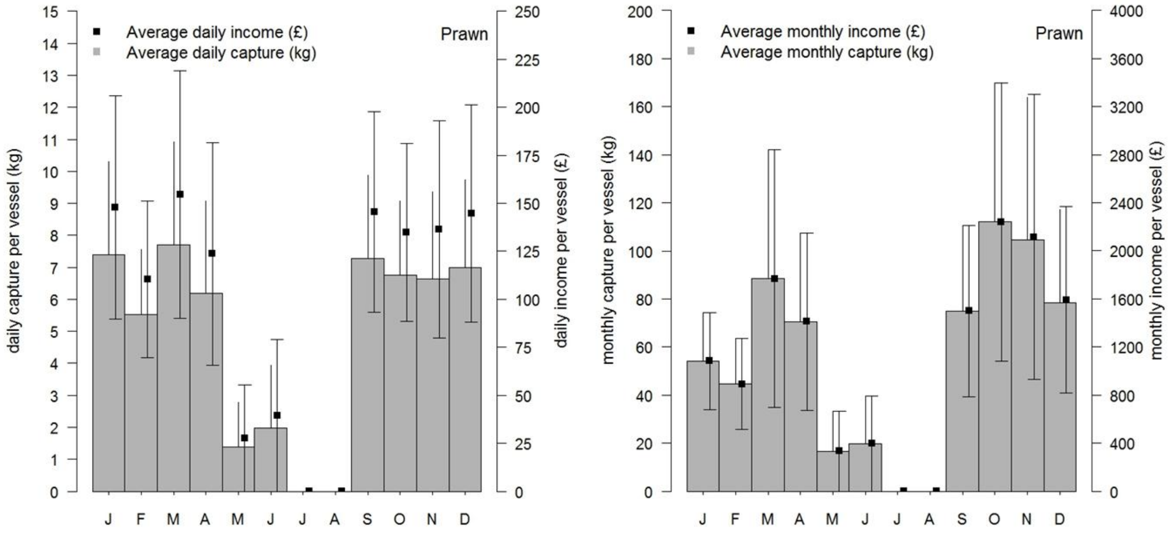

Figure 5. Daily (left) and monthly (right) captures and incomes per vessel of prawns caught with prawn pot by an average "pots and nets small scale" vessel.

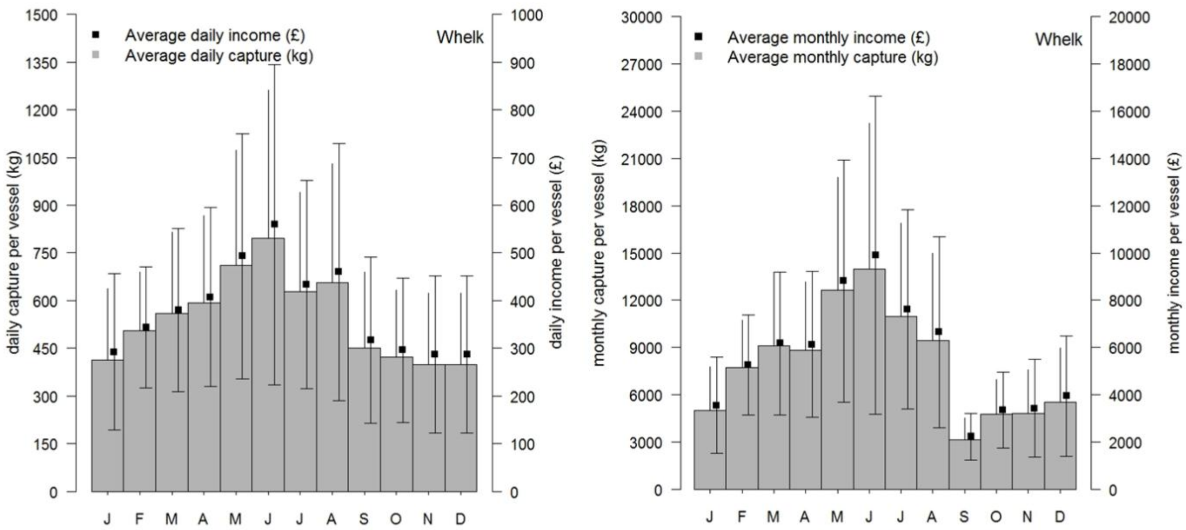

Figure 6. Daily (left) and monthly (right) captures and incomes per vessel of whelks caught with whelk pot by an average "pots and nets small scale" vessel.

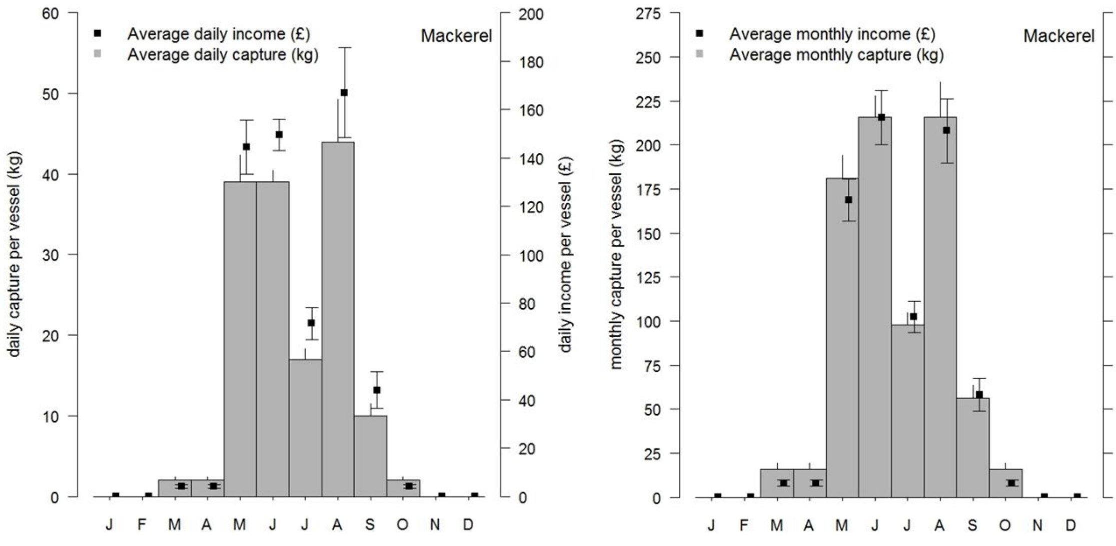

Figure 7. Daily (left) and monthly (right) captures and incomes per vessel of mackerel caught with rod and line by an average "pots and nets small scale" vessel.

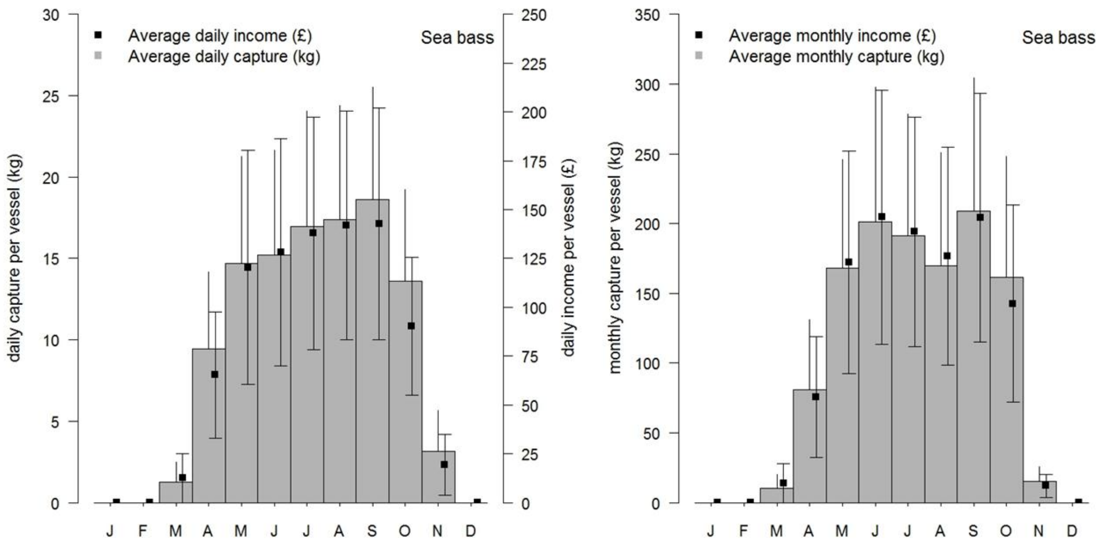

Figure 8. Daily (left) and monthly (right) captures and incomes per vessel of sea bass caught with rod and line by an average "pots and nets small scale" vessel.

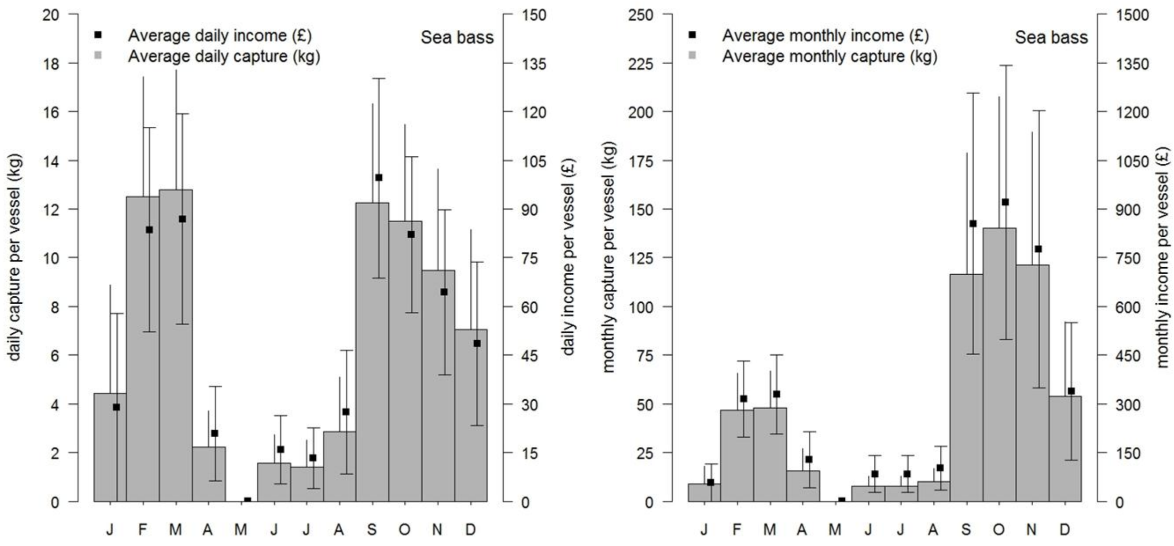

Figure 9. Daily (left) and monthly (right) captures and incomes per vessel of sea bass caught with gillnet by an average "pots and nets small scale" vessel.

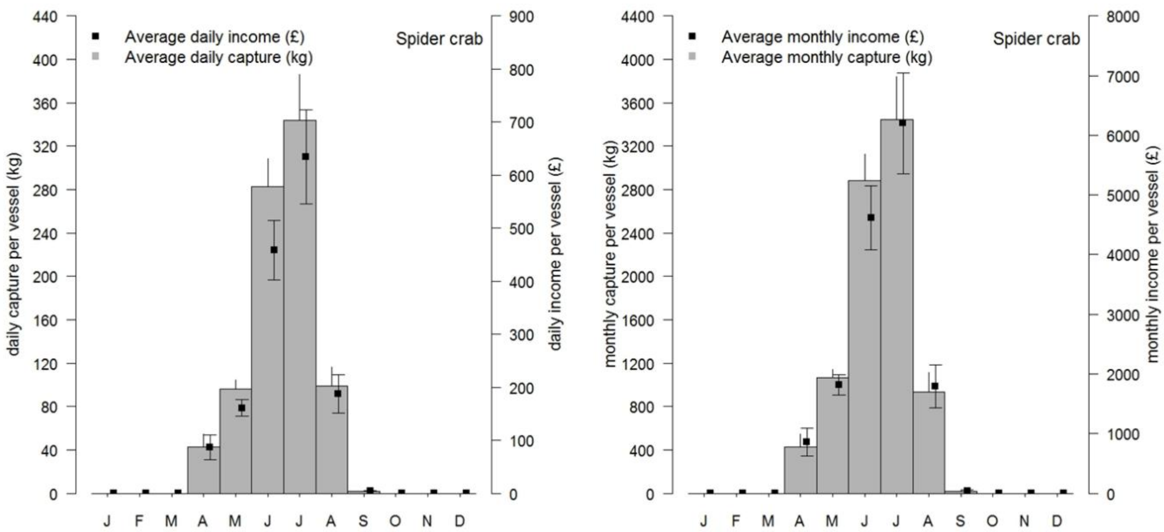

Figure 10. Daily (left) and monthly (right) captures and incomes per vessel of spider crab caught with tangle net by an average "pots and nets small scale" vessel.