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Identifying Métiers Using Landings Profiles: An Octopus-Driven Multi-Gear Coastal Fleet

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Abstract: The multi-gear coastal vessels in the Algarve (South Portugal) own licenses for various fishing gears. However, it is generally uncertain what gears they use, which is problematic as each individual gear is responsible for unique impacts on the resources and the environment. In this study, landing profiles identified for the multi-gear coastal fleet (2012–2016) were used as support in defining potential métiers using k-mean clustering analysis (CLARA) along with information from past studies on métiers. The results showed that more than 50% of the vessels were engaged in the octopus fishery year-round, using traps, while a small percentage (~13%) were entirely dedicated to clam dredging. In general, gillnets (21%) were used to target monkfish, hake and bastard soles, while trammel nets (6%) were used to target cuttlefish, with some vessels alternating the fishing gears (either seasonally or annually) according to target species. The method for the initial characterization of this fleet's métiers and its efficiency with limited data is discussed, as well as the utility of this segmentation in support of management advice.

Keywords: fishing métiers; landing profiles; multi-gear fleet; coastal fleet; fisheries management; Portugal

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1. Introduction

The current European Common Fisheries Policy, which became effective from 1 January 2014, focuses on long-term sustainability. Emphasis is placed on a regionalized approach to fisheries management, with the establishment of fishery-based plans tailored to specific fisheries. Fisheries management using the single stock management approach is thus being progressively replaced by a fleet-based management approach, particularly important for multi-gear and multi-species fleets [1]. In mixed fisheries in particular, management decisions based on fleets and métiers can be more effective than using approaches designed for single-species stocks, such as Total Allowable Catches. The study of mixed-species fisheries' métiers is especially important for management when there are temporal changes in landing composition and abundances of commercial species due to environmental and fisheries-related factors [2].

In fact, the latter requires accurate tracking of stock fluctuations and reported landings and can lead to the well-known problem of "choke" species, when quotas for some species are exhausted quicker than for others, resulting in an increase in discards and incentivizing underreporting [3,4]. Fleet-based management requires fleet segmentation, aiming at the definition of métiers, i.e., fishing operations characterized by similar exploitation patterns, targeting similar species using similar gear during the same time of year and/or area. The characterization of the different métiers, as well as of their impact on both the living resources and the ecosystems exploited [5], is an important tool in assisting appropriate management decisions, contributing to the economic sustainability of the fisheries [6,7]. In the Southern Portuguese multi-gear coastal fishing fleet, comprising vessels from 9 to 23 m in length, each vessel owns licenses for more than one gear, making it difficult to identify particular métiers within the fleet and assess biological and environmental fishing impacts. A high number of commercial species are landed by this fleet, from which only some are subject to formal assessment, resulting in TACs and quotas. The number of vessels and trips sampled by the National Biological Sampling Plan is very low, resulting in poor knowledge of the fleet dynamics, namely the existence of métiers and the fishing gear used. For this fleet, fisheries-dependent data are an important, alternative source of information in support of fisheries management. While fishing logbooks can potentially assist in the identification of métiers, they are mandatory only for vessels equal to or above 10 m in length, and they are not readily available for analysis [8]. Electronic logbooks, on the other hand, are required for vessels equal to or above 12 m in length; however, vessels between 12 and 15 m absent from the port for less than 24 h are exempt from this obligation, which is the case for all vessels in this fleet belonging to this length interval [8]. With logbooks available only for a limited number of vessels, most of the information on the stocks comes from landings and respective sales at auction.

Segmentation of this fleet requires an appropriate method based on the definition of landing profiles, corresponding to groups of landings with similar composition of target and by-catch species. In previous studies, métiers were identified through the definition of landing profiles, such as in the Western Mediterranean, where daily auction records (data on species landing weight and first sale value by vessel) have been analyzed through multivariate analysis for this purpose [9,10]. Métiers can be time-limited, having a seasonal pattern related to the abundance of the target species, as was found by Palmer et al. [11] within small-scale fisheries in Mallorca, with transparent goby (*Aphia minuta*) targeted in winter, cuttlefish (*Sepia officinalis*) in spring, spiny lobster (*Palinurus elephas*) in summer and dolphinfish (*Coryphaena hippurus*) in fall. When identifying métiers in Patraikos Gulf in Greece, Tzanatos et al. [12] found that only two out of the 12 different métiers identified (one of which is considered the most important métier, targeting hake with gillnets), were active during most of the year, while the remainder were seasonal.

In the Algarve region, South Portugal, Borges et al. [13] analyzed the catch composition onboard vessels of the coastal fleet, identifying multiple métiers, including the crustacean trawl fishery, targeting shrimps and Norway lobster (*Nephrops norvegicus*), the demersal purse seine fishery targeting sea breams (*Diplodus* spp. and *Pagellus* spp) and seabass (*Dicentrarchus labrax*), the pelagic purse seine fishery targeting small pelagics such as sardines (*Sardina pilchardus*) and the trammel net fishery targeting cuttlefish. Despite a considerable amount of existing knowledge for the multi-gear fleet derived from short-term (1 to 2 years) gear selectivity and by-catch and discards projects, involving high costs (interviews of vessels' skippers and onboard observations), no studies are available aiming at the identification of métiers through fleet segmentation and identification of landing profiles. In fact, within this fleet, most vessels alternate between gears along fishing trips or even in the same trip, and gear changes occur over the years, adding complexity to the analysis.

In this study, landing profiles, along with knowledge from previous studies on defined métiers and fishing licenses, are used for the first time to identify potential métiers and their temporal dynamics in a multi-gear coastal fleet operating in southwestern Iberian waters, in the Algarve, South Portugal. The temporal fishing patterns are identified for the main species, followed by an attempt to assign fishing gears to the vessels in the study. The results are expected to contribute to improving the fleet-based, regional management of the multi-species coastal fisheries while using an effective and low-cost approach.

2. Materials and Methods

2.1. Data Collection

The information analyzed included vessels' daily sales, fishing gear licenses and vessel characteristics from a total of 163 vessels of the coastal multi-gear fishing fleet, including

39 vessels below 10 m, 59 between 10 and 12 m, 49 between 12 and 15 m and 16 equal to or above 15 m in length, landing in the Algarve (South of Portugal). The data were provided by the Portuguese fisheries administration (Directorate-General for Natural Resources, Safety and Maritime Services—DGRM) for the period of 2012–2016, within the framework of the project Mar2020 TecPescas (Tecnologia da Pesca e Seletividade, MAR2020 16-01-04-FMP-0010). All data were provided in an anonymized format, i.e., each vessel was assigned a code and no vessel names were included.

Logbooks obtained for 25 vessels included data on fishing gear, spatial information through the Vessel Monitoring System (VMS) data (coordinates for beginning and end of hauling), species landed and the respective biomass (in kg) and temporal information by date and hour.

2.2. Data Analysis

The analysis included 163 vessels using 50 pre-selected species that accounted for approximately 99% of the total weight in the original dataset, comprising a total of 297 species. The first step in the analysis was to identify landing profiles (LP) based on daily landing species composition. Landing profiles were identified by multivariate analysis (clustering of vessels based on their landings) [10,14,15]. A non-hierarchical classification technique, Clustering LARge Applications (CLARA—[16]), was applied, consisting of a partitioning algorithm (partitioning around medoids or PAM) that divides the dataset into k clusters, where k needs to be specified a priori. The K-means clustering algorithm is a method using random probability distribution by repeating clustering, allowing for a specific métier to be identified and assigned to a trip [17,18]. This method deals with large datasets by considering data subsets, avoiding the need to store the dissimilarity matrix of the entire dataset. The algorithm was run many times for optimal search, allowing k to vary between 2 and 30, using Euclidean distance. To define the ideal number of groups or clusters, k was chosen based on a quality index provided by the algorithm, the Average Silhouette Width (ASW, [19]); Table S1 in the Annex defines four different cluster categories based on ASW: strong, reasonable, weak, and unstructured.

The CLARA method was applied to analyze variations in the targeted species/métiers across the years and seasons, with each season being designated according to months (e.g., Spring–Month 3–5). The top three species and the percentage that they contributed in weight and value (kg and €) for each LP were defined, as well as the number of vessels and individual landings/trips, and the ASW and Silhouette class were identified for each cluster. Unstructured and weakly structured clusters were not considered as landing profiles in this study.

E-logbooks were examined in order to check for consistency regarding the number of trips and haul registered per vessel and the associated fishing gears, in order to decide whether they could be used in support of métier identification, as well as checking for missing data (e.g., hauling coordinates).

Multivariate regression tree (MRT) analysis implemented in the archived R package 'mvpart 1.6.2′ was used to evaluate the importance of different factors on the species caught [20]. Each leaf was analyzed by the main factor and indicator species. The factors used for the analysis included Gear (FPO = trap, GTR = trammel net, GNS = gillnet, LLS = bottom longline and DRB = dredge), season (Fall, Spring, Summer and Winter) and Year (2012, 2013, 2014, 2015 and 2016). This resulted in a total of 2174 data points in the MRT analysis.

3. Results

3.1. Logbooks

After analyzing the e-logbooks, the information was found to be very inconsistent. A single vessel accounted for most of the data inputs during several years, whereas other vessels only occasionally recorded the information from their landings, with as little as seven landings registered by one vessel. Furthermore, the quantity and quality of the information varied, with "0s" for the starting and finishing coordinates of the hauls, trip departure data and times, trip return data and times, port of departure and port of return.

3.2. Target Species

A total of 9,423,901 kg in landings from 163 vessels and 50 species contributed to defining the nine k-mean clusters (CLARA) in Table 1. Four of the clusters were strongly structured, three were reasonably structured, and two were unstructured according to their SilClass (Annex Table S1). The number of vessels contributing to the clusters ranged between 14 and 113 and the number of trips (landings) between 1763 and 22,798.

Table 1. Cluster analysis in weight (Annex Figure S1) with the cluster ID, average silhouette width of the cluster (ASW), the silhouette class (SC; S = strong, in bold; R = reasonable; W = weak; U = unstructured), number of vessels (No. V), number of trips (No. T), total weight (in tonnes), average price (AP) in Euros, total value in Euros, the three top species (Spp) and the percentage (Spp%) that each species represented in total landings. (FAO Codes: BRB = Black seabream; COE = Conger eel; CTC = Cuttlefish; DON = Donax clams; FOR = Forkbeard; HKE = Hake; MKG = Thickback sole; MON = Monkfish; OCC = Octopus; RJC = Thornback ray; THS = Bastard soles; SBA = Axillary seabream; SCL = Catshark; SOL = Common sole; SVE = Striped venus clam; ULO = Surf clam).

Clust ID	ASW	SC	No. V	No. T	Wt(t)	AP(€)	Value (10^5 €)	Spp 1	Spp%1	Spp 2	Spp% 2	Spp 3	Spp% 3
1	**0.85**	**S**	**31**	**2233**	**224**	**6.35**	**10.13**	**CTC**	**66**	**RJC**	**7**	**SOL**	**4**
2	−0.02	U	110	17,578	2288	6.05	128.3	COE	10	HKE	7	FOR	7
3	0.57	R	49	2477	575	4.52	18.46	HKE	74	MKG	5	SCL	5
4	**0.79**	**S**	**34**	**2985**	**637**	**5.65**	**34.36**	**MON**	**75**	**RJC**	**3**	**HKE**	**3**
5	**0.95**	**S**	**113**	**27,798**	**4061**	**4.65**	**187.85**	**OCC**	**98**	**COE**	**1**	**BRB**	**0**
6	0.68	R	27	1938	237	4.96	14.35	THS	45	SBA	8	RJC	7
7	0.68	R	20	4506	649	1.45	9.52	SVE	89	ULO	8	DON	3
8	0	U	14	1763	346	1.13	3.35	ULO	75	SVE	22	DON	3
9	**1**	**S**	**18**	**2618**	**205**	**2.33**	**4.93**	**DON**	**93**	**SVE**	**4**	**ULO**	**2**

Target species in strong clusters (ASW with 0.71 or above) were octopus (*Octopus vulgaris*: OCC), representing 98% of the total landings in cluster 5, with 113 vessels involved and a total of 27,798 trips; Donax clam (*Donax* spp.: DON), 93% in cluster 9, with 18 vessels and 2618 trips; monkfish (*Lophius piscatorius*; MON), representing 75% of the total landings in cluster 4, with 34 vessels and 2985 trips, and cuttlefish (CTC), for which 31 vessels contributed with a total of 2233 trips (cluster 1).

Reasonable clusters (ASW of 0.51–0.70) related to the striped venus (*Chamelea gallina*: SVE), representing 89% of the landings in weight in cluster 7, with 20 vessels and 4506 trips; to hake (cluster 3), with 49 vessels and 2477 trips, and to bastard soles (*Microchirus* spp.: THS), representing 45% of the landings in cluster 6, with 27 vessels and 1938 trips.

3.3. Yearly Trends

Octopus (caught in traps) and the bivalve species Donax clams or wedge clams (caught with dredges) were the main species represented in strongly structured clusters for all five years (Table 2). Regarding octopus, over the five years, the number of vessels for this fleet rose from 64 to a maximum of 92 in 2015, while its average price dropped in 2013. The number of trips and weight landed of octopus, however, decreased with each year following. The number of clam dredgers was stable and so was the average price. The striped venus clam, caught with dredges, was represented in strongly structured clusters from 2012 to 2015. Hake and monkfish, caught with gillnets, were represented in strongly structured clusters: hake in 2012 and 2013 with a decrease in the number of vessels, while monkfish was the main species represented in 2014 and 2015, with similar numbers of vessels in both years. The conger eel (*Conger conger*), caught with longlines, was the main species represented in strongly or reasonably structured clusters from 2012 to 2014, while the surf clam (*Spisula solida*), caught with dredges, and cuttlefish, caught with trammel nets, were the main species in similarly structured clusters in 2015–2016 and 2014–2015, respectively. Some of the target species were only present in reasonably and strongly structured clusters in a single year, such as the thickback sole (*Microchirus variegatus*) and the bastard sole, caught with gillnets in 2012.

Table 2. Outputs for yearly clusters (Annex Figure S2) with the cluster ID, average silhouette width of the cluster (ASW), the silhouette class (SC; S = strong, in bold; R = reasonable), number of vessels (No. V), number of trips (No. T), total weight in tonnes (in tonnes), average price (AP) in Euros, total value in Euros, the three top species (Spp) and the percentage (Spp%) that each species represented within the species (in quantity). (FAO Codes of primary species for reasonable and strongly structured clusters (Annex Table S2): BRB = Black seabream; COE = Conger eel; CTC = Cuttlefish; DON = Donax clam; HKE = Hake; MON = Monkfish; OCC = Octopus; RPG = Red porgy; SVE = Striped venus clam).

Clust ID/Year	ASW	Sil Class	No. V	No. T	Wt(t)	AP(€)	Value (10^5 €)	Spp 1	Spp% 1	Spp 2	Spp% 2	Spp 3	Spp% 3
2012													
2	0.51	R	28	822	76	4.35	3.94	MKG	40	HKE	25	MAS	4
4	**0.73**	**S**	**30**	**476**	**103**	**4.20**	**2.84**	**HKE**	**81**	**SCL**	**4**	**MON**	**3**
6	**0.91**	**S**	**34**	**228**	**22**	**4.53**	**0.83**	**COE**	**45**	**OCC**	**36**	**BRB**	**7**
10	**0.97**	**S**	**64**	**4709**	**610**	**4.55**	**27.55**	**OCC**	**98**	**COE**	**1**	**FOR**	**0**
11	**0.76**	**S**	**13**	**250**	**20**	**4.56**	**1.23**	**THS**	**63**	**RJC**	**6**	**HKE**	**5**
12	**1.00**	**S**	**16**	**627**	**90**	**1.47**	**1.33**	**SVE**	**93**	**ULO**	**5**	**DON**	**2**
13	**1.00**	**S**	**13**	**482**	**29**	**2.38**	**0.70**	**DON**	**96**	**SVE**	**3**	**ULO**	**1**
2013													
3	**0.76**	**S**	**24**	**454**	**107**	**4.17**	**2.86**	**HKE**	**84**	**SCL**	**3**	**MKG**	**3**
5	**0.96**	**S**	**74**	**5370**	**1154**	**3.34**	**37.46**	**OCC**	**98**	**COE**	**1**	**BRB**	**1**
7	0.58	R	20	571	115	5.85	5.76	COE	32	BRF	23	FOR	17
8	**0.88**	**S**	**15**	**1015**	**128**	**1.49**	**1.89**	**SVE**	**86**	**ULO**	**10**	**DON**	**5**
9	**1.00**	**S**	**11**	**732**	**62**	**2.22**	**1.46**	**DON**	**89**	**SVE**	**6**	**ULO**	**5**
2014													
2	**0.79**	**S**	**15**	**414**	**58**	**6.10**	**2.30**	**CTC**	**77**	**RJC**	**6**	**OCC**	**3**
4	**0.91**	**S**	**17**	**729**	**161**	**5.63**	**8.60**	**MON**	**74**	**RJI**	**4**	**RJC**	**3**
5	0.64	R	28	547	104	6.20	4.27	COE	44	FOR	24	BRF	14
6	**0.92**	**S**	**79**	**6146**	**891**	**4.92**	**45.88**	**OCC**	**98**	**COE**	**1**	**FOR**	**0**
7	**0.84**	**S**	**16**	**1372**	**172**	**1.41**	**2.47**	**SVE**	**90**	**ULO**	**9**	**DON**	**1**
8	**1.00**	**S**	**16**	**410**	**34**	**2.37**	**0.83**	**DON**	**97**	**SVE**	**2**	**ULO**	**1**
2015													
3	0.66	R	13	340	30	6.43	1.38	CTC	71	SOL	6	RJC	5
4	**0.75**	**S**	**18**	**687**	**146**	**5.75**	**8.46**	**MON**	**74**	**JOD**	**3**	**HKE**	**3**
5	**0.96**	**S**	**92**	**6003**	**723**	**5.11**	**39.23**	**OCC**	**98**	**COE**	**1**	**FOR**	**0**
7	0.60	R	14	695	160	1.10	1.76	ULO	55	SVE	45	DON	0
8	**1.00**	**S**	**18**	**869**	**158**	**1.45**	**2.34**	**SVE**	**98**	**ULO**	**2**	**DON**	**0**
9	**1.00**	**S**	**16**	**432**	**38**	**2.47**	**0.95**	**DON**	**99**	**ULO**	**0**	**SVE**	**0**
2016													
2	**0.95**	**S**	**89**	**5439**	**666**	**5.23**	**37.07**	**OCC**	**97**	**COE**	**2**	**FOR**	**0**
3	**0.78**	**S**	**11**	**851**	**154**	**1.04**	**1.27**	**ULO**	**92**	**SVE**	**7**	**DON**	**1**
5	**1**	**S**	**15**	**499**	**32**	**2.46**	**0.80**	**DON**	**99**	**ULO**	**1**	**SVE**	**0**

3.4. Seasonal Trends

Octopus, along with striped venus and Donax clams, were the main species represented in strongly structured clusters all year round (Table 3). Monkfish was the main species represented in either strongly or reasonably structured clusters in winter, spring and summer, hake in spring, summer and fall, and the surf clam in fall, winter and spring. The bastard sole and thickback sole were the main species represented in reasonably structured clusters in fall and winter, and the cuttlefish in winter and spring. The purple dye murex (*Bolinus brandaris*) and Norway lobster were the main species represented in strongly structured clusters in spring.

Table 3. Outputs for seasonal clusters (Annex Figure S3) with the cluster ID, average silhouette width of the cluster (ASW), the silhouette class (SC; S = strong, in bold; R = reasonable), number of vessels (No. V), number of trips (No. T), total weight (in tonnes), average price (AP) in Euros, total value in Euros, the three top species (Spp) and the percentage (Spp%) that each species represented within the species (in quantity). (FAO Codes of primary species for reasonable and strongly structured clusters (Annex Table S3): BOY= Spiny-dye murex; COE= Conger eel; CTC = Cuttlefish; DON = Donax clam; HKE = Hake; MKG = Thickback sole; MON = Monkfish; OCC = Octopus; THS = Bastard sole; SBG = Gilt-head seabream; SVE = Striped venus clam; ULO = Surf clam).

Clust ID/Season	ASW	Sil Class	No. V	No. T	Wt(t)	AP(€)	Value (10^5 €)	Spp 1	Spp% 1	Spp 2	Spp% 2	Spp 3	Spp% 3
Winter													
1	0.58	R	29	1133	121.69	6.17	6	CTC	61	RJC	9	SOL	7
4	**0.95**	**S**	**15**	**186**	**48.80**	**5.04**	**3**	**MON**	**72**	**RJI**	**5**	**JOD**	**2**
5	0.53	R	34	936	134.40	5.03	8	THS	49	RJC	9	HKE	6
6	**1.00**	**S**	**88**	**6290**	**1090.88**	**4.66**	**49**	**OCC**	**98**	**COE**	**1**	**BRB**	**0**
7	**1.00**	**S**	**12**	**483**	**93.08**	**1.09**	**1**	**ULO**	**87**	**SVE**	**10**	**DON**	**3**
8	**1.00**	**S**	**16**	**545**	**69.83**	**1.50**	**1**	**SVE**	**81**	**ULO**	**12**	**DON**	**6**
9	**1.00**	**S**	**18**	**979**	**78.42**	**2.31**	**2**	**DON**	**92**	**SVE**	**5**	**ULO**	**3**
Spring													
1	0.56	R	24	1016	103.83	6.42	4.39	CTC	68	RJC	8	OCC	4
3	0.69	R	25	1122	277.09	5.71	13.30	MON	81	RJC	3	RJI	3
6	**0.75**	**S**	**30**	**464**	**93.47**	**4.67**	**2.90**	**HKE**	**68**	**SCL**	**9**	**MON**	**5**
10	**1.00**	**S**	**6**	**47**	**1.94**	**45.94**	**0.93**	**NEP**	**100**				
11	**0.78**	**S**	**7**	**164**	**4.20**	**9.26**	**0.46**	**BOY**	**69**	**CTC**	**7**	**TOE**	**7**
14	**0.98**	**S**	**99**	**7580**	**1148.61**	**4.87**	**54.65**	**OCC**	**98**	**COE**	**1**	**BRB**	**0**
17	**0.85**	**S**	**10**	**187**	**34.91**	**1.15**	**0.31**	**ULO**	**87**	**SVE**	**11**	**DON**	**2**
18	**1.00**	**S**	**16**	**568**	**67.88**	**1.47**	**1.01**	**SVE**	**97**	**ULO**	**3**	**DON**	**1**
19	**0.79**	**S**	**17**	**599**	**39.29**	**2.38**	**0.97**	**DON**	**97**	**SVE**	**2**	**ULO**	**1**
Summer													
2	0.67	R	29	1091	180.98	6.17	11.12	MON	64	HKE	6	RJC	4
3	**0.99**	**S**	**99**	**7660**	**1020.07**	**4.61**	**47.93**	**OCC**	**97**	**COE**	**2**	**BRB**	**0**
4	0.63	R	29	898	273.38	4.36	7.74	HKE	83	MON	4	SCL	4
6	**1.00**	**S**	**20**	**1992**	**292.67**	**1.51**	**4.41**	**SVE**	**97**	**DON**	**2**	**ULO**	**2**
7	**0.75**	**S**	**18**	**368**	**32.34**	**2.32**	**0.78**	**DON**	**93**	**SVE**	**4**	**ULO**	**2**
Fall													
4	**0.84**	**S**	**38**	**436**	**117.42**	**4.17**	**3.59**	**HKE**	**72**	**MON**	**4**	**SCL**	**4**
5	0.57	R	22	683	64.01	4.46	3.92	MKG	45	HKE	24	SBA	4
9	**0.98**	**S**	**99**	**6240**	**794.96**	**4.45**	**36.19**	**OCC**	**98**	**COE**	**1**	**FOR**	**0**
10	0.66	R	11	346	70.19	1.20	0.82	ULO	50	SVE	45	DON	4
11	**1.00**	**S**	**18**	**911**	**111.29**	**1.47**	**1.65**	**SVE**	**93**	**ULO**	**5**	**DON**	**2**
12	**0.91**	**S**	**12**	**334**	**55.64**	**0.98**	**0.45**	**ULO**	**94**	**SVE**	**5**	**DON**	**1**
13	**1.00**	**S**	**18**	**648**	**51.27**	**2.38**	**1.25**	**DON**	**95**	**SVE**	**4**	**ULO**	**1**

3.5. Factors Influencing Landings

Figure 1 shows the results of the MRT analysis conducted with the commercial species biomass (kg), which confirmed that "Gear" was the main variable explaining the landings. The best MRT had three splits. Landed species composition varied strongly across the four leaves, with octopus defining the first split against the remaining species, while in the second split, the bivalves were separated from fish species, and in the last split, different fish species were separated according to different fishing gears. In terms of fishing gears, the left leaf on the initial split was explained by octopus traps (FPO), with 52% of the points. The remainder of the gears were represented (dredges, gillnets, trammel nets and longlines) on the right-hand side of the initial split, for which hake, the thornback ray and forkbeard were the indicator species. The third split was between dredges, on one hand, and nets and longlines, on the other. Dredges were represented on the left-hand side, for which the three main clams were the indicator species, while on the right-hand side, the nets and longlines were represented, with the indicator species being hake, forkbeard and thornback ray. In the final split below, the left-hand side corresponds to trammel nets and longlines, with the indicator species being conger eel, forkbeard and cuttlefish, while on the right-hand side, gillnets are represented, associated with hake, axillary seabream and monkfish.

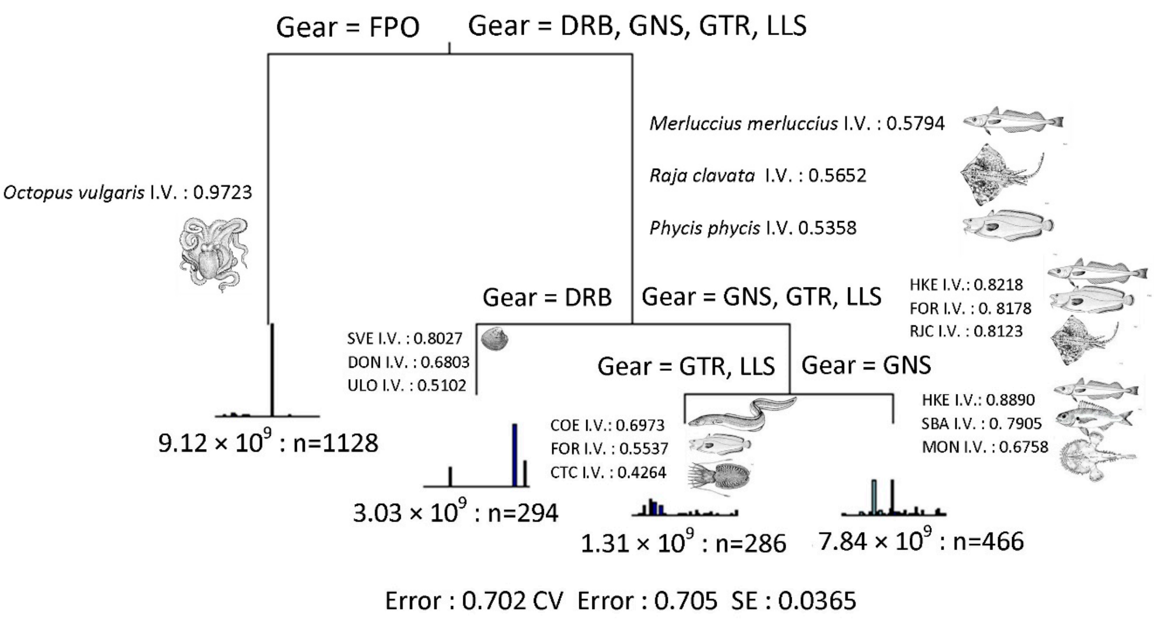

Figure 1. Multivariate regression tree (MRT) with 3 splits and 4 leaves, where gear type is the strongest factor, with the indicator species (I.V. indicator values), the percentage of deviance explained and the number of vessels representing each node. (FPO = Traps; DRB = Dredges; GTR = Trammel nets; GNS = Gillnets; LLS = Longlines).

3.6. Métiers

When cross-referencing all the results and previous studies in order to propose the métiers (Table 4), it was found that: (a) cuttlefish is targeted with trammel nets specifically in winter and spring [21–24], (b) hake with gillnets (80 mm mesh size) from spring through fall [25]; (c) monkfish with gillnets (100 mm and higher) from winter through summer [26], (d) bastard soles with gillnets usually in winter, (e) octopus with traps (including pots) all year round [27], and (f) the striped venus clam and Donax clams with dredges also all year round, while the surf clam is targeted from fall through spring [28].

Table 4. Métiers proposed including the main species, the gear type and the season in which they are targeted.

Métiers	Fall	Winter	Spring	Summer
Monkfish gillnet (MONGNS)				
Hake gillnet (HKEGNS)				
Octopus traps (OCCFPO)				
Striped venus dredge (SVEDRB)				
Donax clam dredge (DONDRB)				
Surf clam dredge (ULODRB)				
Cuttlefish trammel net (CTCGTR)				
Norway lobster traps (NEPFPO)				
Purple-dye murex trammel net (BOYGTR)				
Bastard sole gillnet (THSGNS)				
Thickback sole gillnet (MKGGNS)				

“Lesser” yearly and seasonal métiers were identified, representing possible shifts in gears. Despite fishers having licenses for more than a single gear, they often do not use all the gears; rather, owning these licenses makes all fishing options available, allowing them to switch gears according to resource availability or seasonally. Four main species were represented in yearly and seasonal clusters, including the conger eel targeted with longlines, the thickback sole, which was present in both yearly and seasonal clusters, targeted with gillnets in fall (Table 4), the purple dye murex targeted with trammel nets and the Norway lobster targeted with traps, both in spring.

4. Discussion

Single-species or single-stock management based on Total Allowable Catches (TACs) and regulation of fishing mortality (F) has, in many cases, failed to achieve the intended management goals and conservation benefits, mainly because of the multi-species nature of most fisheries, where it is difficult to control total catches and constrain fishing mortality [29,30]. Discarding and misreporting of landings when TAC allocations are exceeded are problems associated with TAC-based management [29]. Fleet- or métier-based management is a better way of controlling fishing effort and fishing mortality, reducing discards and is a pathway to multi-species and ecosystem-based fisheries management [30,31]. Furthermore, fleet or métier-based management is a means of promoting the use of more selective fishing gear [29], such as the use of creels rather than trawls to target high-value crustaceans such as Norway lobster, and improved management through the reallocation of fishing effort [32]. The implementation of fleet-based or métier-based management is contingent upon the correct identification of the different fleet or métier components. In this study, we focused on the identification of métiers in the multi-species, multi-gear coastal fisheries of the south of Portugal.

This study was carried out on a selected group of vessels fishing species that fall under Category 5 (stocks with only landings data provided by the national auction network/DGRM) [33]. As only fishing licenses were provided, there was little or no information on which gears were actually used to target the different species, as well as on the fishing strategy or the métier.

Previous studies have used principal component analysis (PCA), hierarchical agglomerative clustering (HAC), hierarchical clustering analysis (HCA) and other multivariate methods. The CLARA method applied in this study was purposely developed to analyze large datasets, as is the case in the present study [16], resulting in significant and consistent clusters in terms of target species and landing composition [7,34].

Métiers can be used as a baseline in our understanding of fishers' behavior through the characterization of individual trips and fishing pressure on certain species, giving fisheries managers additional insight for informed advice [35]. In the present study, the initial cluster analysis resulted in the definition of seven strongly or reasonably structured clusters, providing the foundation to define potential métiers using gear type, which was found to be the strongest explanatory variable for these métiers. Clusters classified as unstructured comprised two métiers, characterized by having a "mixed" composition, with no clear target species.

Seven of the 11 métiers exhibited seasonality, including the four gillnet métiers targeting hake, monkfish, bastard soles and the thickback sole, two trammel net métiers targeting cuttlefish and the purple dye murex and one métier targeting Norway lobster with traps. Yearly shifts are apparent within this fleet, with some vessels switching between hake and monkfish as target species caught with gillnets. In 2012 and 2013, hake was the main species in strongly structured clusters and landed by 30 and 24 vessels, respectively. Moreover, 14 of the forementioned vessels made a switch and were landing monkfish in 2014 and 2015, years in which hake was not a main species in a strongly or reasonably structured cluster. This could be a result of the implementation of the southern hake and Norway lobster recovery plan in 2008 (Council Regulation (EC) No 2166/2005), with the progressive reduction of the fishing effort and temporary cessation of the activity for vessels affected by this plan. Cuttlefish also appeared to be an important species in the same year as monkfish, being targeted seasonally by this fleet in winter and spring. Interestingly, nearly 50% of the vessels that were targeting hake in 2012 were targeting monkfish and cuttlefish in 2014, with approximately 30% of these vessels targeting both species, possibly indicating seasonal gear switching. Cuttlefish are usually targeted in fall and winter with trammel nets, as well as in spring [23,24], while monkfish are targeted mostly year-round with gillnets, with the exception of January and February, months during which monkfish can represent only a small percentage of the total catch (Ordinance 315/2011).

The number of vessels operating with dredges remained similar across the years and seasons. It is clearly a very strong fishery, which was further confirmed by the MRT, targeting exclusively bivalve species including the striped venus, surf clam and *Donax* species, which are targeted year-round, with the exception of a closure that occurs between May 1 and June 15. However, one of the identified clusters was classified as unstructured, dominated by *Spisula solida* with a relatively high percentage of *Chamelea gallina*. This is most likely due to the fact that the two species are sympatric and therefore neither of them is considered the main target species [36].

Octopus was consistently in strong clusters among the years and seasons as well as being the only species clearly separated from the remaining based on the gear used, since it is exclusively targeted with traps. However, the number of vessels dedicated to the octopus fishery has increased over the years. It is clear that these vessels were in fact actively using traps to target octopus, with increasing effort. This is one reason for monitoring these shifts over time and understanding how they are impacting these populations.

Octopus is an extremely important species in economic terms [37], with large quantities landed and a generally high first sale price. Setting, baiting and hauling traps requires less effort, as opposed to longlines and nets, and the individuals are more easily retrieved, as opposed to nets, where fish and invertebrates either need to be untangled, which is time consuming, or ripped out, which implies costly repair to nets. Therefore, it seems reasonable that more vessels are leaning towards the use of traps. The octopus fishery in Portugal is highly regulated (DGRM, [38,39]), including a fishing ban during weekends, minimum distance of at least one mile from the coast for vessels larger than 9 m, maximum number of traps per vessel and a minimum landing weight requirement of 750 g. Despite these restrictions, there is a high abundance of octopus in the Algarve, making it a preferential target species for a large part of the fleet and thus resulting in an increase in effort.

Several studies have evaluated the relationships between landings, landings per unit effort, species composition and environmental and fisheries-related explanatory variables in Portugal [2,40–46]. While fishing effort was found to be one of the most important factors [2,46], combinations of regional environmental variables associated with global change, including sea surface temperature (SST) and river runoff, were also found to be associated with the main trends [2,41–45]. Thus, the shift in fishing effort towards the octopus might be influenced by alterations in environmental conditions, or most probably by the decreasing abundance of many commercial fish species. Indeed, since the late 1990s, total Algarve landings for all species (DGRM official auction data) have decreased steadily from a maximum of 37,414 t in 1998 to 11,846 t in 2017. During this period, while finfish landings have been in decline, octopus landings have increased in importance from 3.6% (1341 t) of the total biomass landed in 1998 to a maximum of 18.4% (3702 t) in 2013. Changes in the abundance of commercial finfish species and in species composition lead to changes in fishing strategies, highlighting the importance of the study of temporal changes in métiers for the improved conservation and management of coastal resources.

The eleven métiers defined in this study in terms of target species, gear type and season can be used in different ways to support fisheries management. Compliance with fishing regulations can be checked for species such as the monkfish, which defines a strong cluster in winter despite only being allowed to represent 3% of the total catch during this period. Implementing a sampling program for this fleet is of the utmost importance, allowing us to monitor fishing activities over time and create a management plan including time or depth restrictions, or gear replacement. Using smaller mesh trammel nets to target cuttlefish and bastard soles, which are generally targeted during winter, can be a useful measure in such a management plan. It is recommended that there should be greater awareness, demand and enforcement regarding the effective and rigorous completion of logbooks by the fishing captains, particularly with regard to the métier used in each fishing trip.

5. Conclusions and Further Developments

This study contributed to the definition of métiers, necessary for fleet-based management, when only landings data are available and logbook information is limited due to a portion of the fleet not meeting the necessary length or trip requirements. It also contributed with a less costly methodology in time and money and covered a longer time period compared to previous studies that were conducted through interviews with skippers and onboard observations. The analysis of the landings data was found to be a good alternative to detect fishing métiers and their dynamics over time. This information is of great utility in improving the design of sampling schemes in this fleet as well as in similar multi-gear fleets, which is the case of many Southern European fleets in the Mediterranean, where the number of vessels and trips sampled is very low and the exploited stocks are not subject to a formal assessment. The methods used here can contribute to improving fisheries management for the populations of the main species/stocks that are being targeted and possibly overexploited, when using these types of gears.

Due to the lack of information from logbooks, regular questionnaire surveys and onboard observations are recommended in the future, at the scope of a sampling program, using surveys and Local Ecological Knowledge (LEK) [47,48].

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/jmse9091022/s1, Table S1. Range Silhouette Class (SC) and the interpretation, Figure S1. Clusters using quantity (kg) from landings data for the Algarve coastal multi-gear fishing fleet. FAO codes are defined in Annex Table S2, Figure S2. Clusters using quantity (kg) from landings data for the Algarve coastal multi-gear fishing fleet per year from 2012 to 2016. FAO codes are defined in Annex Table S2. The class, family, species (SPP), FAO codes (CodFAO) and the quantity (t) and value (10^5 €) per year, Figure S3. Clusters using quantity (kg) from landings data for the Algarve coastal multi-gear fishing fleet per year for winter, spring, summer and fall. FAO codes are defined in Annex Table S3. The class, family, species (SPP), FAO codes (CodFAO) and the quantity (q) and value (v) per season. (Win = winter; Spr = spring; Sum = summer; fall).

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