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Research Article

Otter trawls in Greece: Landing profiles and potential métiers

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Abstract

A fleet of 326 bottom trawlers operate in Greek Seas and their landings represent approximately 27% of the total fish production in Greece. In this study, otter trawl landing data were analyzed in order to identify potential métiers. Landing data between 2002 and 2006 were used, collected from 42 ports in the Aegean and East Ionian Sea. A three-step procedure was applied to identify potential métiers: the first step involved a factorial analysis of the log-transformed landing profiles, the second step a classification of the factorial coordinates, and the third step a further aggregation of clusters based on expert knowledge. In all, six potential métiers were identified in the Aegean Sea, and five in the Ionian Sea. The most important target species were European hake (*Merluccius merluccius*), deepwater pink shrimp (*Parapenaeus longirostris*), red mullet (*Mullus barbatus*), caramote prawn (*Melicertus kerathurus*), picarel (*Spicara smaris*), cephalopods, bogue (*Boops boops*), anglers (*Lophius* spp.), and Norway lobster (*Nephrops norvegicus*). Otter trawls in Greece use more or less the same gear with minor modifications, and métier selection is basically reflected as a choice of geographical sub-area and hauling depth. The limitations of using landing profiles to identify métiers and the need for further verification are discussed.

Keywords: Aegean; Ionian; Landings; Otter trawl; Métier; Target species.

Introduction

Based on 2008 data, a fleet of 326 bottom trawlers operate in Greek Seas, of which 291 are registered in ports of the Aegean Sea (Geographical Sub-Areas [GSA] 22 and 23 according to the General Fisheries Commission for the Mediterranean [GFSM]) and 35 in ports of the Ionian Sea (GFCM-GSA 20) (IMAS-FISH, 2009). The size of the fleet has been steadily decreasing over the last 18 years from 422 vessels in 1991 (Fig. 1). The current active fleet has an average age of 22 years and an average length of 25 m, which has increased from 22 m in 1991 (Fig. 1). Although trawlers represent only the 1.9% of the 17920 fishing vessels of the Greek fleet, their landings constitute approximately 27% of the total landings and thus trawlers have a significant socio-eco-

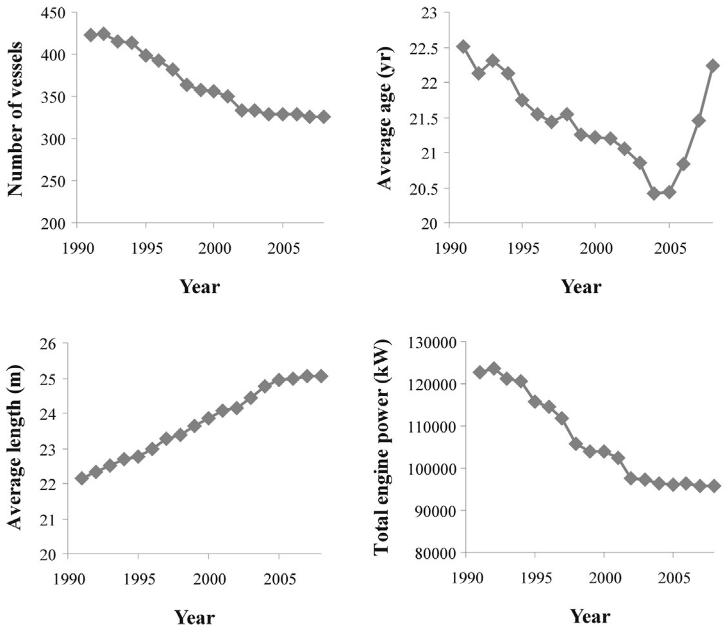

Fig. 1: Time series of the number of trawlers operating in Greece, their average age, average length, and total engine power of the trawler fleet, from 1991 to 2008 (Source: IMAS-FISH, 2009).

nomic role in the fishing industry of Greece (IMAS-FISH, 2009).

The gear used is more or less the same (otter trawls with 40 mm mesh size) irrespective of the target species, with only minor modifications (ADAMIDOU, 2007). The Hellenic fisheries, similar to most Mediterranean fisheries, are managed through effort control rules and technical measures, such as closed seasons, limited issue of new licenses, minimum legal landing sizes and mesh size regulations. RD 917/1966 is the principal law regulating the operation of trawlers. Although this law is still in effect, it has been superseded by EC Regulation 1626/1994, and its replacement Regulation 1967/2006. The main restrictions established by national and European legislation are: (1) establishment of a total exclusion zone one and a half miles from the coastline, (2) a total fishing ban from the 1st of June till the end of September, (3) in the zone three miles from the coastline, trawling is prohibited at depths shallower than 50 m, (4) minimum cod-end mesh size is 40 mm (EC regulation 1967/2006); from 1 July 2008, the net should be replaced by a square-meshed net of 40 mm at the cod-end or, at the duly justified request of the shipowner, by a diamond meshed net of 50 mm. There are also some local restrictions mostly concerning closed gulfs where bottom trawling is either totally forbidden (all year) or the fishing period is shorter than in the rest of the country.

Mediterranean fisheries have an essentially multispecies nature with upward of 100 species in some fisheries (CADDY, 2009). Bottom trawler fisheries, in particular, target a species complex and not just one species. Additionally, there is high interaction with other gear and fleet segments since many of the trawler target species are also targeted by different fishing techniques or strategies, each often concentrating on individuals of different sizes (CADDY, 2009). Coastal fisheries using nets, longlines, and boat seines also pursue the main target species of trawlers (STERGIOU *et al.,* 2002; TZANATOS *et al.,* 2005; POLITOU, 2007; KATSANEVAKIS *et al.,* 2010a,b). Conventional single species theory for stock assessment and management applied to multispecies fisheries has long been recognized as ineffective and problematic (PELLETIER & FERRARIS, 2000; CADDY, 2009). When more than one species is exploited simultaneously, management of each stock affects the management of all other target (and non-target) stocks. Additionally, when managing fleets that apply various fishing practices targeting more than one species assemblage, the relationship between total fleet effort and fishing mortality is not straightforward. One of the key concepts in reducing the fishing mortality of a species through effort control is to ensure that the effort parameters that are controlled are relevant to the fishing mortality of the particular species.

To provide a multi-species, multi-fisheries, multi-fleet advice, fisheries scientists have to better understand the behavior of fishers and assess the flexibility of fishing practices, which may vary depending on market conditions, season, management regulations and the skipper's empirical knowledge (HILBORN & LEDBETTER, 1985; PELLETIER & FERRARIS, 2000; MARCHAL *et al.,* 2006). Each fishing practice is likely to impact on exploited stocks in a particular way; to assess the relationship between the total fishing effort of the fleet and the resulting fishing mortalities of the exploited stocks a separate evaluation for each fishing practice is necessary (PELLETIER & FERRARIS, 2000).

A first step would be to define the fishing practices of each fleet segment by reducing the description of the variety of fishing trips to a single categorical variable that summarizes its main characteristics, i.e. the gear used, the fishing ground, and the target species (PELLETIER & FERRARIS, 2000; ULRICH & ANDERSEN, 2004). Such a variable has been referred to in the literature using a wide variety of terms such as 'métier', 'fishery', 'directed fishery', 'fishery management unit', 'fishing trip type', 'fishing strategy', or 'fishing tactic' (PELLETIER & FERRARIS, 2000 and literature therein; ULRICH *et al.,* 2001; PECH *et al.,* 2001; SILVA *et al.,* 2002; MAYNOU *et al.,* 2003; ULRICH & ANDERSEN, 2004; JIMÉNEZ *et al.,* 2004). The term 'métier' is used in the present study.

Despite the high economic importance of trawlers in the fishing industry of Greece, an identification of métiers on a national level is lacking. The aim of this study was to analyze landing profiles and to make an identification of potential bottom trawler métiers, based on a large sample of landings from all over Greece. The identification of métiers is important in mixed fisheries management, to better understand the response of fishers to management and to improve the design of stratified data collection in order to achieve better performance in the estimates of species-specific production.

Materials and Methods

Study area

The study area included all of Greek territorial coastal waters, i.e., most of the Aegean Sea (GFSM 37.3.1, GSAs 22 & 23) and the eastern Ionian Sea (GFCM 37.2.2, GSA 20) (Fig. 2). The sea floor of the Greek

Seas displays a complex geomorphology, reflecting a complexity of geological and geodynamic processes (SAKELLARIOU & ALEXANDRI, 2007). The Aegean Sea has an extended length of coastline (~16000 km), complex bathymetry, and approximately 2000 small islands. The Aegean has a generally narrow continental shelf with the exception of the northern part and the Kyklades Plateau. The Greek part of the Ionian Sea has a narrower continental shelf than in the Aegean Sea, and hosts the deepest basins of the Mediterranean Sea. Both the Aegean and the Ionian offshore waters are oligotrophic, with the exception of some coastal areas (mostly enclosed gulfs) that are mesotrophic or even eutrophic (GOTSIS-SKRETAS & IGNATIADES, 2007; SIOKOU-FRANGOU *et al.,* 2005). The Greek Seas are characterized by clear, temperate waters, high species diversity, low biomass, and the distribution of temperate sea grasses that act as major nursery areas for many species; detailed descriptions of the pelagic and benthic ecosystems in Hellenic Seas are given in SoHelMe (2005) and SoHelFi (2007). For the present analysis, the Aegean Sea was divided into five subareas (North Aegean, South Aegean, Evvoikos Gulf, Argosaronikos Gulf, and Crete) and the Ionian Sea into two sub-areas (Central-South Ionian and North Ionian), based on their distinctive geomorphological characteristics (Fig. 2).

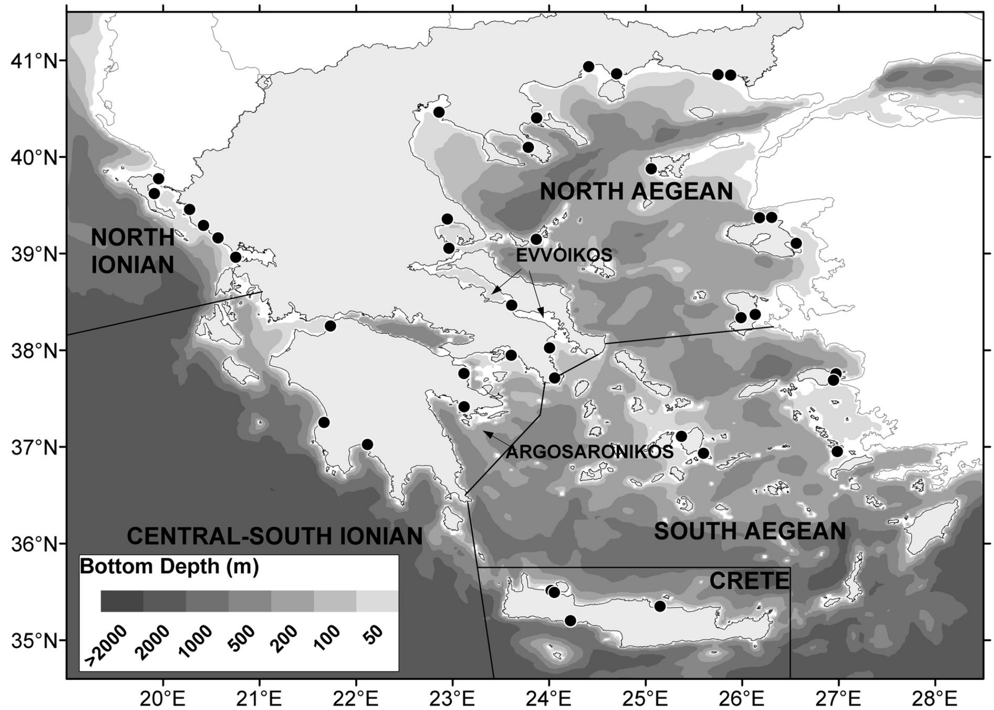

Fig. 2: Map of Greece, with the main areas mentioned in the text. The sampling ports are marked with white bullets.

Data

Logbooks in the Mediterranean are not compulsory except for a selected segment of the fleet targeting large pelagic species. Additionally, due to limited and intermittent financing and manpower constraints, there is a shortage of landing data in Greece, and assessment of fisheries is based on a small sample of total landings. Under the Data Collection Regulation framework (EC 1543/2000; EC 1639/2001), data on effort and landings have been collected in Greece since 2002; no data were collected in 2007 for administrative reasons. Effort and landing data for trawlers were collected from 42 landing sites (33 in the Aegean Sea and 9 in the Ionian Sea) (Fig. 2). From each site, species-specific landing data were gathered by local correspondents (mainly the Prefecture's Fisheries Inspectors) on a monthly basis, according to a systematic sampling procedure (details are given in BAZIGOS & KAVADAS, 2007). Specifically, each month the local correspondents visited a predefined number of landing ports in their site of responsibility and collected landing data from arriving vessels. From this dataset (2002–2006), records of landings from trawlers were used to identify landing profiles and potential métiers in the Aegean and the Ionian Seas.

Only fishing trips with non-zero landings were considered, i.e. 3558 trips for the Aegean Sea and 384 trips for the Ionian Sea (only two trips in the Aegean Sea had zero landings and were excluded). Rare species, i.e. caught in less than 0.5% of the trips, were excluded from the analysis.

Multivariate analysis

Separate analyses were conducted for the Aegean and the Ionian Seas. First a data matrix A with fishing trips as individuals (n rows) and landings per species as variables (p columns) was constructed for each area. For each trip, the absolute weight of the landings was transformed into a landing profile, i.e. a relative species composition, by dividing the weight of the landings per species by the total weight of the landings of the fishing trip. This removed the differences in the level of the landings, which are often linked to various factors such as the total effort, the time of the year, and the weather conditions. Data were then log-transformed to symmetrize their distribution. A three-step multivariate approach was used to identify potential métiers. The first step involved a factorial analysis of the log-transformed landings profiles, the second step a classification of the factorial coordinates, and the third step a further aggregation of clusters based on the expert knowledge of fisheries scientists.

Specifically, a non-normalized PCA (Principal Components Analysis) based on the covariance matrix was performed in order to produce a convenient lower dimensional summary of the original variables, which accounts for a substantial proportion of the total variation of the initial data. The principal components are derived in decreasing order of importance in terms of their contribution in the total variation of the original data, and taken together explain all the variation. The general scope of PCA is that the first few components will account for a substantial proportion of the variation in the original variables and can be used to provide a convenient lower dimensional summary of these variables. Furthermore, PCA provides a geometric description of the individuals, the variables, and the relationships between them, which is helpful to explore the structure of the data set, and individuals are more easily allocated to a cluster through their factorial coordinates (PELLETIER & FERRARIS, 2000). The number of principal components selected was based on the scree diagram, which is a plot of the eigenvalues λ_i of the covariance matrix against the rank i of the eigenvalues. The number of components selected is the value of i corresponding to an 'elbow' in the curve, which is considered to be where 'large' eigenvalues (i.e. accounting for a large proportion of the total variation of the original data) cease and 'small' eigenvalues begin (e.g., EVERITT, 2005).

A hierarchical agglomerative cluster (HAC) analysis, based on Euclidean distances and applying Ward's minimum variance criterion (WARD, 1963), was conducted using the retained principal components. The HAC analysis of the fishing trips led to the identification of homogenous groups (clusters), representing different landing profiles. The choice of the number of clusters was based on expert knowledge and on several trials with different choices of dissimilarity threshold in the resulting dendrogram. Potential métiers were defined after an additional aggregation of these clusters, based on expert knowledge.

Results

European hake (*Merluccius merluccius*), deepwater pink shrimp (*Parapenaeus longirostris*), red mullet (*Mullus barbatus*), and caramote prawn (*Melicertus kerathurus*) made up the largest contribution in trawler landings in the Aegean Sea (44.4%). European hake, red mullet, deepwater pink shrimp, and European squid (*Loligo vulgaris*) were the top species in trawler landings (64.2%) in the Ionian Sea. Most taxa were recorded at species level except for *Lophius* spp., *Trachurus* spp., *Eledone* spp., Rajiformes, crabs (*Maja* spp. and *Portunus* spp.), and sharks.

A total of 79 taxa were recorded in the sample from the Aegean Sea, of which 59 were retained in the analysis after the removal of rare species. For the fishing trips in the Aegean Sea, seven principal components were retained based on the scree diagram (not shown) and on the contribution of each component to the total variance. These seven components accounted for 56% of the total variation of the original data. The HAC analysis of the fishing trips based on the seven principal components led to the identification of 8 clusters (A – H) (Fig. 3). These 8 clusters had different average landing profiles (Table 1) and different geographical distribution among the 5 main sub-areas of the Aegean (Table 2).

A total of 80 taxa were recorded in the sample hauls from the Ionian Sea, of which 40 were retained in the analysis after the removal of rare species. For the fishing trips in the Ionian Sea, seven principal components were retained based on the scree diagram (not shown) and on the contribution of each component to the total variance. These seven components accounted for 66% of the total variation of the original data. The HAC analysis of the fishing trips based on the seven principal components led to the identification of six clusters (I to N) (Fig. 4). The identified clusters had different landing profiles (Table 3) and different geographical distribution among the main sub-areas of the Ionian Sea (Table 4).

Clusters C, D, and E were aggregated to a single métier (AEG-OTB-3; Table 5) as they all had European hake and deepwater pink shrimp as the main target species, and their differences in the landings' composition were mostly in the relative percentages of some species or in the presence/absence of some non-primary target species. For example, red mullet had a higher contribution in landings of cluster D than in the landings of the other two clusters, which might be incidental or due to hauls

Table 1

Average landing profiles of the eight clusters identified in the Aegean Sea (Fig. 3), given as a proportion (%) of the landings of each species to the total landings of each cluster. The most important species of each profile are given in bold.

	Landing profiles								
	A	B	C	D	E	F	G	H	Total
Merluccius merluccius	**10.7**	**16.7**	**20.0**	**23.0**	**17.0**	**16.6**	1.5	**12.8**	15.2
Parapenaeus longirostris	6.4	**14.4**	**33.3**	**12.7**	**25.0**	1.2	0.0	8.6	13.3
Mullus barbatus	**19.3**	**9.5**	2.1	**11.6**	3.8	4.1	11.8	8.0	8.5
Melicertus kerathurus	**10.7**	0.3	0.3	0.2	7.6	**37.1**	0.0	1.3	7.4
Spicara smaris	0.3	4.6	0.1	0.6	0.0	0.6	0.3	**25.3**	5.8
Illex coindeti	0.8	0.4	**8.9**	**8.0**	3.4	7.3	**9.6**	3.7	4.8
Lophius spp.	1.8	0.6	2.2	5.4	**10.4**	3.5	**10.0**	1.6	4.1
Boops boops	1.7	**18.6**	0.5	2.0	0.1	0.6	0.2	6.7	3.8
Nephrops norvegicus	0.1	0.4	2.5	3.1	3.6	4.2	**24.4**	0.5	3.4
Trachurus spp.	0.9	1.0	**11.8**	4.3	0.2	4.3	0.3	3.3	3.3
Eledone spp.	**8.9**	0.4	1.5	2.0	4.3	1.9	0.3	4.1	3.3
Octopus vulgaris	**12.3**	1.3	0.4	0.7	1.2	1.2	3.7	1.4	2.8
Micromesistius poutassou	0.4	0.9	3.1	1.6	0.3	6.9	**14.6**	0.8	2.7
Mullus surmuletus	1.4	5.2	0.9	2.1	0.3	0.3	0.1	5.1	2.2
Loligo vulgaris	1.9	1.6	0.3	0.6	1.2	0.9	2.7	2.8	1.5
Maja spp., *Portunus* spp.	0.1	0.0	0.1	0.1	0.1	0.1	**11.0**	0.0	0.8
Other species	22.4	24.0	12.2	22.1	21.6	9.1	9.4	14.0	17.0

Table 2

Percentage distribution of the recorded fishing trips of the eight identified landing profiles in each main geographical sub-area of the Aegean Sea. For each area, the landing profiles with a contribution >15% are given in bold.

Cluster	Argosaronikos	N Aegean	Evvoikos	Crete	S Aegean
A	2.7	**22.6**	6.9	7.7	4.6
B	3.9	8.8	2.2	14.3	**40.7**
C	**32.7**	8.8	0.2	0.5	2.4
D	9.1	**15.4**	2.0	1.1	2.4
E	7.3	**25.9**	2.8	1.1	0.0
F	6.2	14.3	**27.5**	0.5	0.0
G	0.1	0.7	**47.9**	0.0	0.0
H	**38.0**	3.6	10.4	**74.7**	**49.8**
Sampled trips	822	1766	461	182	327

in shallower areas. Similarly, *Trachurus* spp. which are not primary target species had a high contribution in landings of cluster C and substantially less in the other two clusters. However, such differences most probably reflected underlying differences in fish assemblages and not divergence in fisher's intentions and fishing strategy. Thus, combining these clusters to a single métier seems reasonable.

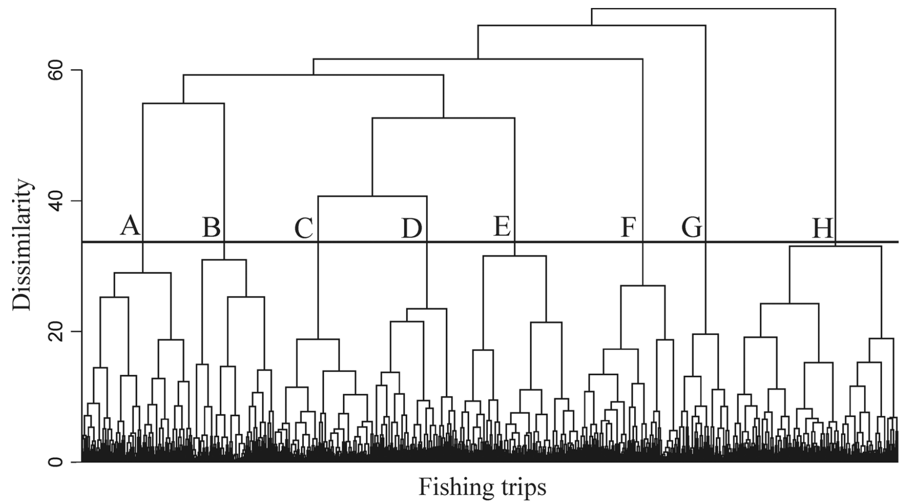

Fig. 3: Dendrogram of the bottom trawl fishing trips in the Aegean Sea, based on the log-transformed landing profiles.

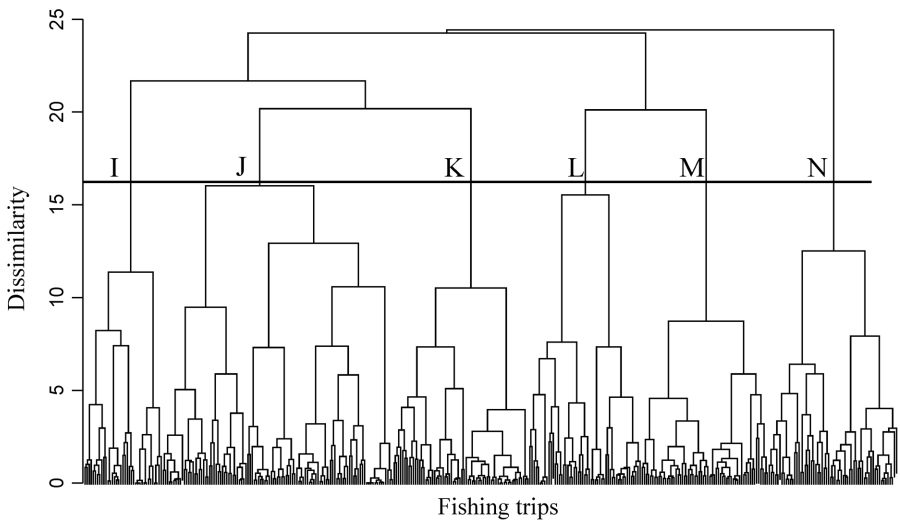

Fig. 4: Dendrogram of the bottom trawl fishing trips in the Ionian Sea, based on the log-transformed landing profiles.

Similarly clusters L and M in the Ionian Sea were aggregated to a single métier (ION-OTB-4; Table 5) targeting European hake, red mullet, bogue, and cephalopods. Again in this case, one of the main differences between the two clusters was the high

Table 3
Average landing profiles of the six clusters identified in the Ionian Sea (Fig. 4), given as a proportion (%) of the landings of each species to the total landings of each cluster. The most important species of each profile are given in bold.

	Landing profiles						
	I	J	K	L	M	N	Total
Merluccius merluccius	**34.3**	**34.0**	**25.6**	**23.6**	**25.3**	**23.5**	28.2
Mullus barbatus	6.3	**23.3**	1.1	11.1	**20.1**	**14.1**	14.3
Parapenaeus longirostris	1.7	**13.6**	**49.9**	8.4	0.0	4.8	14.3
Loligo vulgaris	6.0	7.6	3.0	7.3	**13.0**	7.2	7.4
Boops boops	1.5	0.9	1.1	**21.2**	**16.7**	1.7	6.4
Spicara smaris	0.0	0.5	0.1	4.6	0.1	**29.3**	5.5
Melicertus kerathurus	**28.3**	0.1	0.0	1.5	0.0	0.0	2.9
Lophius spp.	0.6	1.8	4.0	0.4	1.5	4.5	2.2
Micromesistius poutassou	5.6	0.4	3.4	3.4	0.3	0.4	1.8
Octopus vulgaris	0.1	1.8	0.2	0.8	5.2	1.6	1.7
Trachurus spp.	0.0	0.4	0.0	9.5	0.1	0.6	1.5
Eledone spp.	0.0	0.7	0.3	0.8	4.0	0.3	1.0
Illex coindeti	1.3	2.0	0.6	1.3	0.0	0.3	1.0
Nephrops norvegicus	0.3	0.2	2.5	0.0	0.1	0.2	0.6
Mullus surmuletus	0.0	0.4	0.0	0.4	0.7	0.8	0.4
Other species	14.0	12.2	8.3	5.8	12.8	10.8	10.7

Table 4
Percentage distribution of the recorded fishing trips of the six identified landing profiles in each main geographical sub-area of the Ionian Sea. For each area, the landing profiles with a contribution >15% are given in bold.

Cluster	C-S Ionian	N Ionian
I	13	2
J	29	26
K	22	2
L	13	17
M	3	49
N	20	5
Sampled trips	276	108

Table 5
Description of the identified bottom trawl landing profiles and potential métiers.

Cluster	Cluster size	Fishery characterization	Main species	Typical fishing locations	Potential métier (% contribution)
Aegean Sea					
A	482	Octopods - Red mullet	*Octopodidae* (21.2%) *Mullus barbatus* (19.3%) *Merluccius merluccius* (10.7%) *Melicertus kerathurus* (10.7%)	N Aegean	AEG-OTB-1 (13.5%)
B	356	Bogue - European hake	*Boops boops* (18.6%) *Merluccius merluccius* (16.7%) *Parapenaeus longirostris* (14.4%)	S Aegean, Crete, N Aegean	AEG-OTB-2 (10.0%)
C	434	Deepwater pink shrimp - European hake	*Parapenaeus longirostris* (33.3%) *Merluccius merluccius* (20.0%) *Trachurus* spp. (11.8%) *Illex coindeti* (8.9%)	Argosaronikos	AEG-OTB-3 (37.4%)
D	366	European hake	*Merluccius merluccius* (23.0%) *Parapenaeus longirostris* (12.7%) *Mullus barbatus* (11.6%) *Illex coindeti* (8.0%)	N Aegean	
E	532	Deepwater pink shrimp - European hake - Anglers	*Parapenaeus longirostris* (25.0%) *Merluccius merluccius* (17.0%) *Lophius* spp. (10.4%)	N Aegean	
F	432	Caramote prawn	*Melicertus kerathurus* (37.1%) *Merluccius merluccius* (16.6%)	Evvoikos, N Aegean	AEG-OTB-4 (12.1%)
G	234	Norway lobster	*Nephrops norvegicus* (24.4%) *Micromesistius poutassou* (14.6%)	Evvoikos	AEG-OTB-5

(continued)

Table 5 (continued)

			Micromesistius poutassou (14.6%) *Mullus barbatus* (11.8%) *Crabs* (11.0%)		AEG-OTB-5 (6.6%)
H	722	Picarel - European hake	*Spicara smaris* (25.3%) *Merluccius merluccius* (12.8%)	Crete, S Aegean, Argosaronikos	AEG-OTB-6 (20.3%)
Ionian Sea					
I	37	European hake - Caramote prawn	*Merluccius merluccius* (34.3%) *Melicertus kerathurus* (28.3%)	C-S Ionian	ION-OTB-1 (9.6%)
J	109	European hake - Red mullet	*Merluccius merluccius* (34.0%) *Mullus barbatus* (23.3%) *Parapenaeus longirostris* (13.6%)	whole Ionian Sea	ION-OTB-2 (28.2%)
K	64	Deepwater pink shrimp - European	*Parapenaeus longirostris* (49.9%) *Merluccius merluccius* (25.6%)	C-S Ionian	ION-OTB-3 (16.5%)
L	53	European hake - Bogue	*Merluccius merluccius* (23.6%) *Boops boops* (21.2%) *Mullus barbatus* (11.1%)	whole Ionian Sea	ION-OTB-4 (29.2%)
M	60	Mixed (European hake - Red mullet - Bogue - European squid - Common octopus)	*Merluccius merluccius* (25.3%) *Mullus barbatus* (20.1%) *Boops boops* (16.7%) *Loligo vulgaris* (13.0%) *Octopus vulgaris* (5.2%)	N Ionian	
N	64	Picarel - European hake	*Spicara smaris* (29.3%) *Merluccius merluccius* (23.5%) *Mullus barbatus* (14.1%)	C-S Ionian	ION-OTB-5 (16.5%)

contribution of *Trachurus* spp. in cluster L (9.5%) contrary to cluster M (0.1%). A similar métier in the Aegean was AEG-OTB-2, with bogue and European hake having the largest contribution in the landings.

Octopods (*Octopus vulgaris* and *Eledone* spp.) were represented in the landing profiles almost exclusively in métier AEG-OTB-1. *Octopus vulgaris* landings accounted for 12.3% of the total landings, while in all other landing profiles the common octopus contributed <3.8%. Similarly, landings of Eledone spp. made up 8.9% of the total landings in AEG-OTB-1, while in all other landing profiles they contributed to <4.3% of the landings. AEG-OTB-1 was mainly practised in the North Aegean Sea.

The Norway lobster métier (AEG-OTB-5) was almost exclusively operated in the Evvoikos Gulf. The proportion of Norway lobster landings in the total landings of this métier was 24.4%, while in all other Aegean and Ionian métiers it was <4.2%. No similar métier targeting Norway lobster was observed in the Ionian Sea.

Two métiers targeted caramote prawn and European hake, one in the Aegean (AEG-OTB-4) and one in the Ionian Sea (ION-OTB-1). Caramote prawn and European hake accounted for 54% and 63% of the landings in AEG-OTB-4 and ION-OTB-1 respectively. Caramote prawn also contributed a non-negligible percentage of the landings of AEG-OTB-1 (10.7%), while in all other métiers its contribution was negligible.

Two métiers targeting picarel and European hake were identified in the Aegean (AEG-OTB-6) and in the Ionian Sea (ION-OTB-5). A métier targeting European hake and red mullet (ION-OTB-2) and another targeting deepwater pink shrimp and European hake (ION-OTB-3) were also identified in the Ionian Sea. ION-OTB-3 was similar to the AEG-OTB-3 in the Aegean Sea.

Discussion

Octopods have generally greater densities in the Aegean than in the Ionian (BELCARI *et al.,* 2000a; 2000b), and production of octopods from the North Aegean represent 66% of the total octopods production in the Greek Seas (based on 2007 data; IMAS-FISH, 2009). The lower abundance of octopods in the Ionian Sea partly explains why a similar métier targeting octopods was absent from the Ionian. *Octopus vulgaris* is a coastal and sedentary species living mostly between 0 and 100 m depth; it is scarce at depths between 100 and 200 m and is only occasionally found at greater depths (GUERRA, 1981; BELCARI *et al.,* 2002a; KATSANEVAKIS & VERRIOPOULOS, 2004). In the Aegean Sea, *Eledone moschata* is mostly restricted to the continental shelf, especially at depths of <100 m, while *Eledone cirrhosa* has a wider bathymetric distribution and although mostly found on the continental shelf (<200 m) it is also abundant on the upper slope (200–500 m) (BELCARI *et al.,* 2002b). Other species caught by AEG-OTB-1 such as *Mullus barbatus* and *Melicertus kerathurus* are also mostly distributed in the upper continental shelf (<100 m). Thus, based on the composition of the landings, AEG-OTB-1 may be characterized as a generally shallow métier operated mostly on the upper continental shelf.

AEG-OTB-3 and ION-OTB-3 are mostly targeting deepwater pink shrimp and European hake. Anglers (*Lophius budegassa* and *Lophius pescatorius*), blue whiting (*Micromesistius poutassou*), and Norway lobster were also landed in these métiers. AEG-OTB-3 was the most frequent métier in the sample, representing 37% of the fishing trips in the Aegean. The species assemblages of the landings suggested that these métiers operate at relatively deep waters on the lower continental shelf and the continental slope (at depths >100 m).

On the other hand métiers AEG-OTB-2, ION-OTB-2, and ION-OTB-4 are relative shallow, as deduced by the high percentage in the landing profiles of species that mostly thrive in the upper part of the continental shelf (<100 m), such as bogue, red mullet, common octopus, picarel (KALLIANIOTIS *et al.,* 2000; DEMESTRE *et al.,* 2000; KATSANEVAKIS & VERRIOPOULOS, 2004; LABROPOULOU, 2007; KATSANEVAKIS & MARAVELIAS, 2009).

Métiers AEG-OTB-6 and ION-OTB-6 targeting picarel and European hake are relative shallow métiers operating on the upper part of the continental shelf. These two métiers mostly operate in the southern regions of the Aegean and Ionian Sea (Tables 2 and 4). Boat seine is the main gear for picarel, especially for small individuals, which are in the highest demand (KATSANEVAKIS *et al.,* 2010a), and supplies ~48% of total picarel landings, based on 2007 data of the National Statistical Service of Greece (IMAS-FISH, 2009). However, otter trawls also make an important contribution (~27%) to the total landings of picarel. Although, picarel has low market value compared to European hake, red mullet, Norway lobster, deepwater pink shrimp and other target species of trawlers, it contributes substantially to the total value of the landings of métiers AEG-OTB-6 and ION-OTB-6.

There are two identified métiers, one in the Aegean (AEG-OTB-4) and one in the Ionian Sea (ION-OTB-1) targeting caramote prawn. Caramote prawn lives on muddy sands or sands of coastal marine or brackish waters and is typically recorded at depths between 0.5 and 90 m and more commonly between 5 and 50 m (THESSALOU-LEGAKI, 2007; KEVREKIDIS & THESSALOU-LEGAKI, 2006). It prefers areas in the vicinity of estuaries, where its nursery grounds are located (such as Amvrakikos Gulf and many estuarine coastal areas of the North Aegean or Central Ionian) (THESSALOU-LEGAKI, 2007). Trawlers targeting caramote prawn usually conduct 1-day-trips, on the fishing ground from dawn until dusk, and mostly operate at depths of between 35 and 70 m (KEVREKIDIS & THESSALOU-LEGAKI, 2006). Catches of caramote prawn generally decrease with depth and thus fishers tend to prefer shallow fishing grounds (KEVREKIDIS & THESSALOU-LEGAKI, 2006). Hence, AEG-OTB-4 and ION-OTB-1 should be considered as very shallow métiers restricted to specific geographical areas, mostly near estuaries.

The highest abundance of Norway lobster occurs in the upper continental slope (200-500 m depth), although in the North Aegean Sea there is a fair proportion of occurrences on the lower shelf (100-200 m) (ABELLÓ *et al.,* 2002). The catch assemblage of the identified Norway lobster métier AEG-OTB-5 (cluster G in Table 1) indicates a deepwater operation on the lower shelf and the upper continental slope (mainly 100–400 m depth) (ABELLÓ *et al.,* 2002; KATSANEVAKIS & MARAVELIAS, 2009). Based on 2007 data from the National Statistical Service of Greece, the highest Norway lobster landings occurred in the Evvoikos Gulf (20% of total national landings), in the North Aegean sub-area (48.6% of total national landings), and in the Pagassitikos Gulf (10% of total national landings; trawling is prohibited in the Pagassitikos Gulf, where Norway lobster is mainly caught with traps and nets) (IMAS-FISH, 2009). Although almost half of the Norway lobster production comes from the North Aegean sub-area, in the present study no métier targeting specifically Norway lobster was identified in the North Aegean, but the species appeared rather as an incidental target species in other métiers.

Fisher's intentions may not be strictly reflected in the landing profiles. Fishers choose the fishing ground, the timing, and the depth of their hauls, and make appropriate modifications to their gear, targeting specific species. However, there is always uncertainty about the outcome, and the fisher's expectations may be not be fulfilled. Additionally, trawlers may combine several métiers in a single fishing trip, e.g. by conducting a few shallow hauls and a few deeper hauls in adjacent areas, and thus the landings of a fishing trip may not represent a single métier but more than one. This will give intermediate landing profiles from which it is difficult to reveal the component métiers. Even when a single métier is practised in each fishing trip, a clear distinction between two profiles of landings, i.e. two groups of target species, is not always easy and a smooth transition between clusters may occur. Defining the threshold in a cluster analysis of fishing trips in order to group the trips into homogenous clusters is not straightforward and may be variable both in time and space, as species assemblages vary according to stock distribution and dynamics. However, in the absence of records at a haul level, landing profiles are an inexpensive and readily available (through the Data Collection Regulation) source of data to define métiers. Identifying métiers from landing profiles needs caution, and expert knowledge is often necessary to decide upon the final level of aggregation of the landing profiles.

The use of values of landed species instead of their weight might prove to be an improvement in the methodology for métier identification, as the target species and thus métier choice are mostly dependent on market value. Species with a relatively low proportion in total catches but with high market values might be the actual target species instead of the most abundant species in the catches. However, such values of landings were not collected on a trip-by-trip basis under the framework of DCR, in order to apply such an approach. Using average annual or seasonal values would not be an adequate alternative, because there is substantial spatial and temporal variation of market values.

Although landing profiles have been extensively used in the literature to define métiers, the fisheries scientists have not agreed upon a unique multivariate method for métier definition and several approaches have been followed (LEWY & VINTHER, 1994; HE *et al.,* 1997; PELLETIER & FERRARIS, 2000; ALEMANY & ÁLVAREZ, 2003; CAMPOS *et al.,* 2007; MARCHAL, 2008; KATSANEVAKIS *et al.,* 2010 a,b). Depending on the multivariate approach, data transformation, dissimilarity measure and linkage type in cluster analysis, decision criteria for the choice of dissimilarity threshold in the resulting dendrogram, and other choices when analyzing fishing trip data, different conclusions may be reached.

For all the above reasons, the métiers identified in this study were characterized as 'potential' in the sense that further verification based on carefully designed interviews with fishermen on a national scale would be desirable to finalize métier identification and use of such classification of trawler operations for management purposes. Understanding how the fishing effort of otter trawls is distributed among the various métiers and the specific details of each one (target species, geographical location, depths etc) is valuable for the management of fisheries. This information is necessary in order to adopt measures with specific objectives for a species or species assemblage and to predict the consequences of redistributing fishing effort among métiers. Unexpected outcomes of management measures have been observed in the past, e.g. closures leading to undesirable effort redistribution, mainly because managers lacked knowledge of the fishing practices. Improved knowledge of the otter trawl métiers could prove useful in understanding how fishers will adapt their behaviour and survival strategies under various management systems and incentives.

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