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Where not to fish – reviewing and mapping fisheries restricted areas in the Aegean Sea

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Abstract

An up-to-date systematic review and unofficial codification of the national fisheries legislation was conducted, along with an up-to-date systematic review of environmental, archaeological and maritime legislation, about spatio-temporal restrictions of fishing activities, by all fishing gears, in the Aegean Sea. Spatio-temporal restrictions established by the European Union and the General Fisheries Commission for the Mediterranean were also reviewed. A database was built, including detailed information on the identified Fisheries Restricted Areas (FRAs). All FRAs were mapped, as polygons in Geographic Information System shapefiles. The national fisheries, environmental, archaeological and maritime legal framework comprises 32, 2, 37 and 43 legal acts respectively; EU and GFCM legislation consists of one Regulation and one Recommendation, respectively. A total of 521 FRAs were identified in the study area, out of which 511 are national (254 established by fisheries, 21 by environmental, 85 by archaeological and 151 by maritime legislation), 6 are EU and 4 are international FRAs. 85.2% are located in the Aegean Sea and 14.8% in Crete. Towed or mobile gears are restricted in 88.5% of the FRAs, while static gears are restricted in only 10.2% of the FRAs. Fish stocks and *Posidonia oceanica* beds protection are the most common reasons for regulating fishing activities (25.3% and 25.0% respectively). Most of the FRAs (85.4%) impose permanent closures. National fisheries, environmental, archaeological, maritime, EU and international FRAs cover 25.8%, 1.0%, 1.1%, 0.4%, 13.5% and 22.6% of the study area, respectively. This study provides valuable information for Maritime Spatial Planning in the Aegean Sea.

Keywords: FRA mapping, fisheries legislation, environmental legislation, archaeological legislation, maritime legislation, fisheries management, maritime spatial planning.

Abbreviations

EU, European Union; FRA, Fisheries Restricted Area; euFRA, FRA established by the EU; intFRA, FRA established by international fisheries organizations; nFRA, national FRA; n_aFRA, nFRA established by legislation for the protection of underwater archaeological heritage (hereafter: archaeological legislation); n_eFRA, nFRA established by environmental legislation; n_fFRA, nFRA established by fisheries legislation in territorial waters; n_{if}FRA, nFRA established by fisheries legislation in international waters; n_mFRA, nFRA established by maritime legislation; GFCM, General Fisheries Commission for the Mediterranean; GG, Government Gazette; GGI, Government Gazette Issue; GIS, Geographic Information System; GSA, Geographical Sub-Areas (in the GFCM context); JMD, Joint Ministerial Decision; MD, Ministerial Decision; PD, Presidential Decree; RD, Royal Decree; RFMO, Regional Fisheries Management Organization.

Introduction

Historically, overfishing has substantially reduced fish biomass and caused significant ecological changes in the global ocean (Jackson *et al.*, 2001; Pauly & Zeller, 2016). In recent years, increasing efforts to restore marine ecosystems and rebuild fisheries have succeeded in improving the state of fisheries resources in some regions (Worm *et al.*, 2009). However, the situation in the Mediterranean Sea has worsened as exploitation rate is increasing steadily (Colloca *et al.*, 2013), fishing gear selectivity has not achieved the expected results and seems inadequate (Vasilakopoulos *et al.*, 2014), and stocks are in decline (Cardinale & Osio, 2013; Tsikliras *et al.*, 2015).

Spatio-temporal restrictions of fishing activities and technical measures are the main tools used in the Medi-

terranean Sea for the management of fish stocks (Colloca *et al*., 2013). Yet, the multitude of legislative instruments with diverse objectives often complicates management, surveillance, and the assessment of the efficiency of spatial restrictions (Cacaud, 2005; Damalas *et al.*, 2015). In many Mediterranean countries, a thorough compilation and mapping of all spatial restrictions pertaining to fishing is lacking and, thus, their extent and large-scale efficiency remains unknown.

At national level, Greek legislation on spatio-temporal restrictions of fishing activities is remarkably complex and characterized by extensive multi-regulation (Kapantagakis, 2007). A large number of Fisheries Restricted Areas[1] (FRAs) have been established mainly under the fisheries legal framework, but also the provisions of archaeological and maritime legislation. Therefore, the identification and mapping of national FRAs is an extremely demanding procedure. The lack of official codification[2] of national legislation by the competent authorities renders the procedures even more complicated. On the contrary, few spatio-temporal restrictions of fishing activities are issued at European and international level with respect to Greek territorial waters and the legal framework is well-defined. Thus, the identification and mapping procedure is far less demanding.

Argyrakopoulos (2006) has published a useful guidebook/tool for fisheries sector stakeholders, i.e. professional and recreational fishers, port authorities and administration officers etc., which includes a thorough compilation of national fisheries and underwater archaeological legislation. Unofficial codification of legal acts concerning all issues of fishing activities (i.e. not only spatio-temporal restrictions), has been carried out, based on a historical review of each legal act and the amendments that have been implemented over the years. This guidebook also includes descriptive maps (as images) of most of the fisheries and archaeological FRAs established at the time.

In the context of the IMAS-Fish project 2003-2006 (Kavadas *et al.*, 2013), a Greek national and EU fisheries legislation archive was built within the multidisciplinary database management system that was developed, containing fragmentary information and GIS maps for specific regulations, decisions, directives or decrees. However, due to restricted access for authorized users, it is not publically accessible.

An attempt to review, identify and map existing FRAs in the Mediterranean was made within the framework of the MEDISEH project (Giannoulaki *et al*., 2013). The review of existing information was based on reports, grey literature and maps, with or without georeferenced information. Some of the major difficulties encountered by MEDISEH concerning the identification and mapping of FRAs, included the problematic definition of locations, gears and some regionally adopted measures, mainly due to the fact that many national measures are described in laws without accompanying maps, or proper geographical or geospatial information. Thus, in the FRAs database created within the framework of the aforementioned project, although almost all FRA entries included some form of spatial information, there were some cases where mapping was not possible. According to the MEDISEH experts' team, after completion of the project, a large number of fisheries measures were still largely unrecorded, and it was proposed that it would be worthwhile for the FRAs database to be updated and enriched in the future (Papadopoulou *et al.*, 2013). Furthermore, many new FRAs have been established after 2013, mainly for the protection of *Posidonia oceanica* meadows.

Although many attempts have been made to compile, review and map legislation concerning spatio-temporal restrictions in the Aegean Sea, only patchy and difficult to combine information has been produced so far. Hence, the "where not to fish?" issue remains unclear and underlines the need for an integrated approach to obtain a complete spatio-temporal restrictions database that is suitable for analyses and mapping.

In the context of the current study, an up-to-date systematic review and unofficial codification of national fisheries legislation, along with an up-to-date systematic review of environmental, archaeological and maritime legislation, on all spatio-temporal restrictions of fishing activities concerning all types of fishing gears, was performed from scratch for the Aegean Sea. In addition, the FRAs established by the European Union and international fisheries organizations were identified. A database was built, with detailed information for each FRA. Finally, all FRAs were mapped, as polygons in Geographic Information System (GIS) shapefiles and were incorporated in the database. The process was supported by the Greek Competent Authorities for Fisheries Policy and Control, i.e. the Directorate General for Sustainable Fisheries, Ministry of Rural Development and Food and the Directorate for Fisheries Control of the Hellenic Coast Guard, Ministry of Shipping and Island Policy, in order to achieve common acceptance of the current study's outcomes.

The overall goal of this study was to identify and map the current distribution of spatio-temporal restrictions on fishing activities in the Aegean Sea, and to provide scientific documentation for fisheries policy research, decision making, as well as monitoring, control and enforcement. In addition, the national fisheries legal framework concerning these restrictions is critically examined, and its weaknesses are identified and discussed. The information will help fisheries managers in the area to reconsider the establishment of spatio-temporal restrictions on fishing activities, in line with

1 A Fisheries Restricted Area is a geographically-defined area, in which all or certain fishing activities are temporally or permanently banned or restricted, in order to improve the exploitation and conservation of harvested living aquatic resources or the protection of marine ecosystems (GFCM e-Glossary, 2016).

2 Codification is the process of officially bringing together a legislative act and all its amendments in a single new act (EC Legal Service, 2016).

the provisions of the Common Fisheries Policy and the EU framework for Maritime Spatial Planning.

Materials and Methods

Study area

The study area consists of the General Fisheries Commission for the Mediterranean (GFCM) Geographic Sub-Areas (GSAs) "22-Aegean Sea" and "23-Crete", partly modified, to adapt to the needs of this study. In particular, the study area is defined as followed: the western and northern borders coincide with the coastline of Greece, the eastern border coincides with the marine border between Greece and Turkey, the southern border coincides with the simplified, smoothed 2,000 m bathymetric contour line, while in the south-eastern region, a small part (2,336 km^2) of GSA "24-North Levantine" is joined to the study area, in order to include Kastellorizo Island. Hereafter, reference to GSA22 and GSA23 shall refer to the relevant modified GFCM GSAs, as described above. Both Greek territorial and international waters are included in the study area.

Review of Legislation and Identification of FRAs

To delineate the national FRAs (nFRAs) established by fisheries legislation in the study area, a systematic review of the national fisheries legal framework, concerning spatio-temporal restrictions of fishing activities in territorial (n_tFRAs) and international waters (n_{it}FRAs), was performed. All legislative acts, i.e. Royal Decrees (RD), Presidential Decrees (PD), Ministerial Decisions (MD) and Joint Ministerial Decisions (JMD), for the establishment of spatio-temporal restrictions in the study area were retrieved through the official website of the Greek National Printing Office (National Printing Office, 2016) and arranged in chronological order.

Due to the fact that the national fisheries legislation in force concerning spatio-temporal restrictions of fishing activities dates back to the 1940s, and that since then many legal acts have been corrected, amended or repealed, it was decided that the national fisheries legislation should be unofficially codified, in order to identify the provisions that are currently in force. Thus, unofficial codification was performed for all legislative acts concerning the establishment of n_tFRAs.

For the identification of the FRAs established by national environmental legislation (n_eFRAs), i.e. the FRAs established within Marine Protected Areas (MPAs), information was retrieved from the List of Nationally Designated MPAs of Greece, provided by the Ministry of Environment and Energy (Protected Areas of Greece, 2016). The legal acts concerning the protection and management of these MPAs were retrieved from the National Printing Office, in order to compile detailed information on the n_eFRAs.

The necessary data for the review and identification of the FRAs established by national legislation relating to archaeology (n_aFRAs) was retrieved from the Standing List of Designated Archaeological Sites and Monuments of Greece, provided by the Directorate of Monument Archives of the Hellenic Ministry of Culture and Sports. As stated by the Directorate of Monument Archives (Listed Monuments, 2016), the list is informative and only the texts of the legislative acts, as published in the Government Gazette (GG) have legal force. Hence, in all cases where a n_aFRA was identified in the List, the relevant GG was retrieved from the National Printing Office, in order to cross-check the information provided by the list.

For the nFRAs established by maritime legislation (n_mFRAs), the list provided by the Directorate for Fisheries Control of the Hellenic Coast Guard concerning the restriction of fishing activities in ports, beaches, underwater cable/pipe areas, effluent sites, navigation channels, military areas and other sites, was used (DFC-HCG, 2016). Cross-checks with the relevant legal acts (i.e. MDs concerning General and Specific Port Regulations) as published in the GG, were also performed in the cases of n_mFRA identifications.

National environmental, archaeological and maritime legal acts were not unofficially codified. The procedure to determine the provisions in force has already been followed by the competent authorities and thus only these provisions are included in the above mentioned lists.

The FRAs established by the European Union (euFRAs) were identified by reviewing EU fisheries legislation. The official website of European Union Law was accessed (EUR-Lex, 2016) in order to retrieve the relevant legal acts. Identification of the FRAs established by international fisheries organizations (intFRAs) and specifically by the Regional Fisheries Management Organization (RFMO) General Fisheries Commission for the Mediterranean (GFCM), was based on the information provided by the Compendium of Decisions of the GFCM (GFCM Decision Compendium, 2016).

It was decided that each spatio-temporal restrictions on certain fishing gears constitutes a unique FRA. An FRA code was attributed to each FRA. In cases where spatio-temporal restrictions for different types of fishing gear apply to a given area, an FRA with a distinct code was considered for each gear. A database of all FRAs was then built in Excel, containing detailed information for each FRA, organized in separate fields (Table S1).

The FRAs identified in the study area were classified according to (i) FRA type, i.e. n_tFRA, n_{it}FRA, n_eFRA, n_aFRA, n_mFRA, euFRA, intFRA; (ii) marine area, according to the National Statistical Service of Greece (NSSG), i.e. 7-Gulf of Lakonia, 8- Gulf of Argolida and Saronikos Gulf, 10- Gulf of South and North Evia - Gulf of Lamia, 11- Pagassitikos Gulf, 12- Eastern coasts of Evia and Sporades Islands, 13- Thermaikos Gulf and Gulf of Chalkidiki, 14- Strimonikos, Kavala, Thassos, Thracian Sea, 15- Islands of Lesvos, Chios, Samos and Ikaria, 16-Dodekanissos, 17- Kyklades and 18-Kriti (Fig. S1); (iii) geographic region, according to the official European Commission nomenclature of terrestrial units (NUTS) for

Statistics[3], i.e. EL30 Attica, EL64 Central Greece, EL52 Central Macedonia, EL5 Eastern Macedonia & Thrace, EL41 North Aegean, EL65 Peloponnese, EL42 South Aegean, EL61 Thessaly and EL43 Crete (Fig. S1); (iv) GFCM geographic sub-region, i.e. Aegean Sea-GSA 22 and Crete-GSA 23; (v) restricted gear type, i.e. towed, mobile, static or their combinations[4]; (vi) purpose of establishment, i.e. stock protection, *Posidonia oceanica* beds protection, artificial reefs, nature reserve area, archaeological site protection, port restrictions etc. and (vii) closure type, i.e. permanent or seasonal. The number (n), total number (N) and total percentage (%) of the FRAs identified per category was estimated.

FRAs mapping

The spatial information for each FRA was included in a unified Geographic Information System, using the ESRI ArcGIS 10.1 software package (ESRI, 2011). The Lambert Azimuthal equal-area projection was used for map projection. Polygons in shapefile format for each FRA were created from scratch, using the information obtained from the relevant legal acts.

In cases where available information on the delimitation of the FRAs was insufficient (e.g. unknown locations, capes, beacons etc.), the contribution of the competent authorities, mainly the Coast Guard Services, was requested. The use of grey literature (e.g. Argyrakopoulos, 2006) and of supplementary material (e.g. navigation maps, travel maps etc.) was also helpful in some cases. Bathymetric contours, based on the bathymetry by Manoutsoglou (2016), were used for the delimitation of FRAs, when such contours were stated in the legislation.

The polygons in shapefile format, which correspond to the n_fFRAs for otter bottom trawls, were kindly provided by the Directorate for Fisheries Control of the Hellenic Coast Guard. These files were checked, corrected (where needed), modified, and re-projected using the Lambert Azimuthal equal-area projection. Furthermore, adjustments were made in order for the polygons to be fitted to the coastline used.

The mapped polygons were grouped in different shapefiles, according to FRA type. Number (n), area (in km^2), net area (in km^2) and net area percentage (%) per FRA type, GSA and type of closure were estimated.

The area of each FRA and of FRA type per GSA and type of closure was estimated, using ArcGIS tools. The total area of the seven FRA types was estimated by summing up the respective values. The net area (i.e. the remaining area after polygon overlaps were considered) of each FRA type per GSA and closure type, and the total net area of the seven FRA types were estimated by merging polygons and shapefiles, respectively, using ArcGIS software.

Results

The national fisheries legal framework concerning spatio-temporal restrictions of fishing activities in the study area comprises of a set of 32 legal acts, namely three Ministerial Decisions (MDs), 10 Royal Decrees (RDs) and 19 Presidential Decrees (PDs). The national environmental legal framework concerning the spatio-temporal restrictions of fishing activities within the designated MPAs, consists of two legal acts, one Joint Ministerial Decision (JMD) and one PD. The spatio-temporal restrictions of fishing activities in the study area established by the national legal framework for the protection of underwater archaeological heritage comprises of a set of 37 legal acts, six JMDs and 31 MDs, while national maritime legislation consists of 43 legal acts, all MDs (Table S3). The EU and GFCM legal framework concerning the establishment of spatio-temporal restrictions of fishing activities in the study area consists of one Regulation (EU Council Regulation (EC) No 1967/2006) and one Recommendation (GFCM Recommendation 29/2005/1), respectively.

The review of national fisheries, environmental, archaeological and maritime legislation concerning the spatio-temporal restrictions of fishing activities in the study area, revealed a total of 521 FRAs; specifically, 511 nFRAs (253 n_tFRAs, 1 n_{tt}FRA, 21 n_eFRAs, 85 n_aFRAs and 151 n_mFRAs), 6 euFRAs and 4 intFRAs. For each FRA, a wealth of detailed information was compiled (Table S3).

The FRAs identified are distributed throughout the NSSG marine areas of the study area. Most FRAs are located in NSSG marine areas 15- Islands of Lesvos, Chios, Samos and Ikaria (14.78%), 18-Kriti (13.82%) and 12-Eastern coasts of Evia and Sporades Islands. Regarding the geographic region of FRAs, the majority correspond to EL42-South Aegean (18.8%), EL-43 Crete (14.8%), EL41-North Aegean (14.0%) and EL64-Central Greece (12.3%). Overall, 85.2% of the FRAs are located in the Aegean Sea and 14.8% in Crete. In most of the FRAs (88.5%), towed or mobile gears are restricted, while static gears are only restricted in 10.2% of the FRAs and recreational fishing activity is only restricted in 1.3% of the FRAs. In terms of purpose of establishment, stock protection and *Posidonia oceanica* beds protection are the most common reasons for restricting fishing activities (25.3 and 25.0%, respectively). Most of the FRAs (85.4%) impose permanent closures (Table 1).

3 The FRAs identified in the study area are attributed to the corresponding terrestrial geographic region/s for management purposes, i.e. in order to determine the corresponding Regional Fisheries Department/s, that is/are the competent authority/ies for the implementation and monitoring of the legal provisions on FRAs at regional level.

4 The fishing gear categories used to classify FRAs are in line with the provisions of EU Commission Regulation (EC) No1799/2006, amending Regulation (EC) No 26/2004 on the Community fishing fleet register (EU Commission, 2006) (Table S2).

Table 1. Categorization of the 521 Fisheries Restricted Areas (FRAs) identified in the study area (Aegean Sea-GSA22 and Crete-GSA23) per FRA type, marine areas according to the National Statistical Service of Greece (NSSG), geographic region according to the official European Commission nomenclature of terrestrial units (NUTS) for Statistics, GFCM geographic sub-region (GSA), restricted gear type, establishment purpose and closure type. Number (n), total number (N) and total percentage (%) of FRAs classified in each category. euFRA, FRA established by the EU; intFRA, FRA established by international fisheries organizations; nFRA, national FRA; n_aFRA, nFRA established by legislation for the protection of the underwater archaeological heritage; n_eFRA, nFRA established by environmental legislation; n_fFRA, nFRA established by fisheries legislation in territorial waters; n_{if}FRA, nFRA established by fisheries legislation in international waters; n_mFRA, nFRA established by maritime legislation.

FRA TYPE	nFRA				n_{fi}FRA	euFRA	intFRA	TOTAL (N)	TOTAL (%)
	n_fFRA	n_eFRA	n_aFRA	n_mFRA					
N	**253**	**21**	**85**	**151**	**1**	**6**	**4**	**521**	**100%**
NSSG MARINE AREA									
GSA 22 - Aegean Sea									
7- Gulf of Lakonia	1	0	1	0	0	0	0	**2**	**0.38%**
8- Gulf of Argolida and Saronikos Gulf	25	0	6	22	0	0	0	**53**	**10.17%**
10- Gulf of South and North Evia - Gulf of Lamia	30	1	0	12	0	0	0	**43**	**8.25%**
11- Pagassitikos Gulf	4	0	0	14	0	0	0	**18**	**3.45%**
12- Eastern coasts of Evia and Sporades Islands	14	20	4	26	0	0	0	**64**	**12.28%**
13- Thermaikos Gulf and Gulf of Chalkidiki	39	0	2	4	0	0	0	**45**	**8.64%**
14- Strimonikos, Kavala, Thassos, Thracian Sea	24	0	0	13	0	0	0	**37**	**7.10%**
15- Islands of Lesvos, Chios, Samos and Ikaria	31	0	27	19	0	0	0	**77**	**14.78%**
16- Dodekanissos	25	0	9	8	0	0	0	**42**	**8.06%**
17- Kyklades	34	0	2	17	0	0	0	**53**	**10.17%**
multi-NSSG marine areas*	3	0	0	1	1	3	2	**10**	**1.92%**
GSA 23 - Crete									
18- Kriti	23	0	34	15	0	0	0	**72**	**13.82%**
multi-NSSG marine areas*	0	0	0	0	0	3	2	**5**	**0.96%**
NUTS GEOGRAPHIC REGION									
GSA 22 - Aegean Sea									
EL30 Attica	13	1	2	17	0	0	0	**33**	**6.3%**
EL64 Central Greece	33	0	0	31	0	0	0	**64**	**12.3%**
EL52 Central Macedonia	48	0	2	4	0	0	0	**54**	**10.4%**
EL51 Eastern Macedonia and Thrace	19	0	0	12	0	0	0	**31**	**6.0%**
EL41 North Aegean	31	0	23	19	0	0	0	**73**	**14.0%**
EL65 Peloponnese	16	0	5	7	0	0	0	**28**	**5.4%**
EL42 South Aegean	59	0	15	24	0	0	0	**98**	**18.8%**
EL61 Thessaly	11	20	4	22	0	0	0	**57**	**10.9%**

(continued)

Table 1. *(continued)*

multi-NUTS geographic regions**	0	0	0	0	1	3	2	**6**	**1.2%**
GSA 23 - Crete									
EL 43 Crete	23	0	34	15	0	3	2	**77**	**14.8%**
RESTRICTED GEAR TYPE									
towed	61	7	4	2	1	4	4	**83**	**15.9%**
mobile	28	6	0	0	0	2	0	**36**	**6.9%**
static	27	3	0	23	0	0	0	**53**	**10.2%**
recreational	0	2	1	4	0	0	0	**7**	**1.3%**
towed, mobile	130	0	18	1	0	0	0	**149**	**28.6%**
towed, mobile, static	7	1	61	121	0	0	0	**190**	**36.5%**
towed, mobile, recreational	0	1	0	0	0	0	0	**1**	**0.2%**
towed, recreational	0	0	1	0	0	0	0	**1**	**0.2%**
mobile, recreational	0	1	0	0	0	0	0	**1**	**0.2%**
ESTABLISHMENT PURPOSE									
stock protection	121	0	0	0	1	6	4	**132**	**25.3%**
Posidonia oceanica beds protection	130	0	0	0	0	0	0	**130**	**25.0%**
artificial reefs	2	0	0	0	0	0	0	**2**	**0.4%**
nature reserve areas	0	21	0	0	0	0	0	**21**	**4.0%**
archaeological sites	0	0	85	0	0	0	0	**85**	**16.3%**
beaches	0	0	0	40	0	0	0	**40**	**7.7%**
cables, pipes	0	0	0	16	0	0	0	**16**	**3.1%**
channels	0	0	0	4	0	0	0	**4**	**0.8%**
military facilities	0	0	0	5	0	0	0	**5**	**1.0%**
ports	0	0	0	47	0	0	0	**47**	**9.0%**
waste effluent	0	0	0	8	0	0	0	**8**	**1.5%**
other***	0	0	0	31	0	0	0	**31**	**6.0%**
CLOSURE TYPE									
permanent	213	20	85	117	0	6	4	**445**	**85.4%**
seasonal	40	1	0	34	1	0	0	**76**	**14.6%**

* FRAs which are extended at more than one NSSG marine areas are classified in this category.
** FRAs which correspond to more than one NUTS geographic regions are classified in this category.
*** FRAs which are established for purposes other than those mentioned above are classified in this category. Details on their specific establishment purpose can be found in Table S3.

Table 2. Grouping of the 516 Fisheries Restricted Areas (FRAs) mapped in the study area (Aegean Sea-GSA22 and Crete-GSA 23) per FRA type. Number (n), Area (in km^2), Net Area* (in km^2) and Net Area Percentage** (%) of FRAs per GSA and type of closure (permanent or seasonal). euFRA, FRA established by the EU; intFRA, FRA established by international fisheries organizations; nFRA, national FRA; n_aFRA, nFRA established by legislation for the protection of the underwater archaeological heritage; n_eFRA, nFRA established by environmental legislation; n_fFRA, nFRA established by fisheries legislation in territorial waters; n_{if}FRA, nFRA established by fisheries legislation in international waters; n_mFRA, nFRA established by maritime legislation.

		Permanent				Seasonal				Total			
FRA Type	**GSA**	**n**	**Area (km^2)**	**Net Area (km^2)**	**Net Area Percentage (%)**	**n**	**Area (km^2)**	**Net Area (km^2)**	**Net Area Percentage (%)**	**n**	**Area (km^2)**	**Net Area (km^2)**	**Net Area Percentage (%)**
National Fisheries Legislation FRAs in territorial waters, n_{ft}FRAs	**22**	187	15,918	8,221	4.6%	38	32,140	12,049	6.8%	225	48,058	14,544	8.2%
	23	21	459	415	1.2%	2	8,477	8,287	23.3%	23	8,936	8318	23.4%
	22+23	**208**	**16,377**	**8,635**	**4.1%**	**40**	**40,617**	**20,336**	**9.5%**	**248**	**56,994**	**22,862**	**10.7%**
National Fisheries Legislation FRAs in international waters, n_{if}FRAs	**22**	0	0	0	0.0%	1	38,007	38,007	21.4%	1	38,007	38,007	21.4%
	23	0	0	0	0.0%	0	0	0	0.0%	0	0	0	0.0%
	22+23	**0**	**0**	**0**	**0.0%**	**1**	**38,007**	**38,007**	**17.8%**	**1**	**38,007**	**38,007**	**17.8%**
National Environmental Legislation FRAs, n_eFRAs	**22**	20	3,466	1,833	1.0%	1	2172	2,172	1.2%	21	5,637	2,176	1.2%
	23	0	0	0	0.0%	0	0	0	0.0%	0	0	0	0.0%
	22+23	**20**	**3,466**	**1,833**	**0.9%**	**1**	**2,172**	**2,172**	**1.0%**	**21**	**5,637**	**2,176**	**1.0%**
National Archaeological Legislation FRAs, n_aFRAs	**22**	51	2,307	2,307	1.3%	0	0	0	0.0%	51	2,307	2,307	1.3%
	23	34	52	52	0.1%	0	0	0	0.0%	34	52	52	0.1%
	22+23	**85**	**2,359**	**2,359**	**1.1%**	**0**	**0**	**0**	**0.0%**	**85**	**2,359**	**2,359**	**1.1%**
National Maritime Legislation FRAs, n_mFRAs	**22**	103	432	431	0.2%	33	252	252	0.1%	136	683	680	0.4%
	23	14	51	51	0.1%	1	29	29	0.1%	15	81	81	0.2%
	22+23	**117**	**483**	**482**	**0.2%**	**34**	**281**	**281**	**0.1%**	**151**	**764**	**761**	**0.4%**
European Union Legislation FRAs, euFRAs	**22**	3	39,579	25,553	14.4%	0	0	0	0.0%	3	39,579	25,553	14.4%
	23	3	4,901	3246	9.1%	0	0	0	0.0%	3	4,901	3,246	9.1%
	22+23	**6**	**44,480**	**28,799**	**13.5%**	**0**	**0**	**0**	**0.0%**	**6**	**44,480**	**28,799**	**13.5%**
International Organizations' Decisions FRAs, intFRAs	**22**	2	59,938	29,969	16,9%	0	0	0	0.0%	2	59,938	29,969	16.9%
	23	2	36,285	18,143	51.1%	0	0	0	0.0%	2	36,285	18,143	51.1%
	22+23	**4**	**96,223**	**48,112**	**22.6%**	**0**	**0**	**0**	**0.0%**	**4**	**96,223**	**48,112**	**22.6%**
	Total	**440**	**163,388**	**80,943**	**38.0%**	**76**	**81,077**	**58,915**	**27.6%**	**516**	**244,465**	**119,832**	**56.2%**

* Net area is the remaining area after polygon overlaps have been considered. Net areas have been estimated by merging respective polygons and shapefiles using ArcGIS software.
** The total area of the study area was calculated using ArcGIS software and found equal to 213,168 km^2 (177,644 km^2 for the part of the study area included in GSA 22 and 35,524 km^2 for that included in GSA 23).

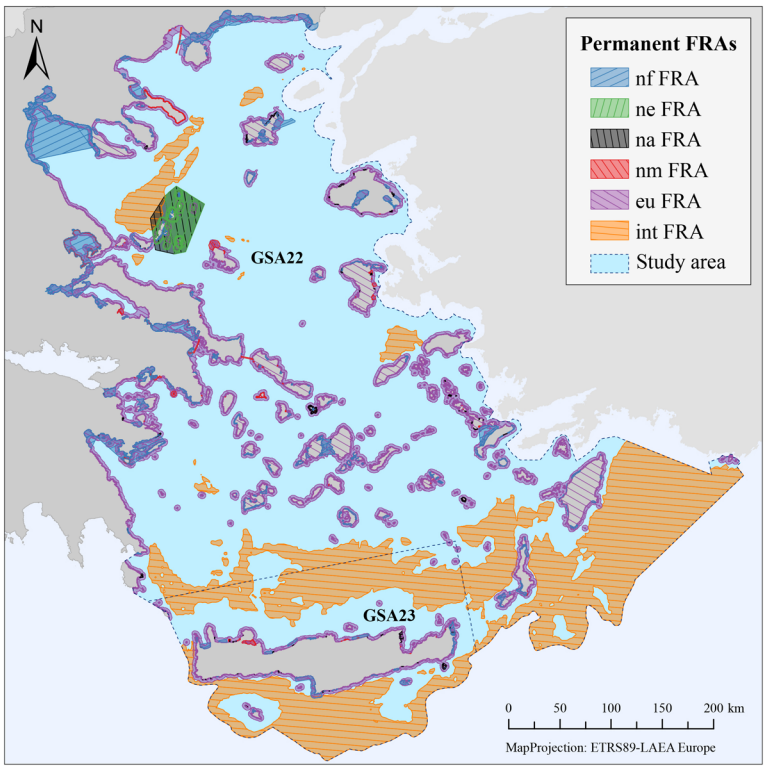

Fig. 1: Map of the 440 permanent Fisheries Restricted Areas (FRAs) identified in the study area (Aegean Sea-GSA 22 and Crete-GSA 23) per FRA type, i.e. 208 national fisheries legislation FRAs in territorial waters (n_iFRAs), 20 national environmental legislation FRAs (n_eFRAs), 85 national archaeological legislation FRAs (n_aFRAs), 117 national maritime legislation FRAs (n_mFRAs), 6 European Union legislation FRAs (euFRAs) and 4 General Fisheries Commission for the Mediterranean (GFCM) Decisions' FRAs (intFRAs).

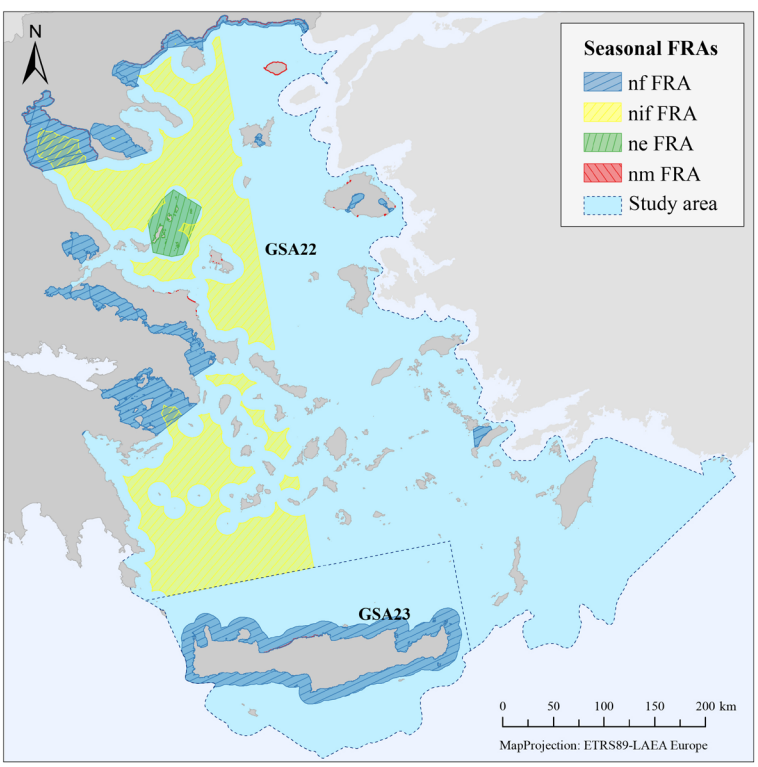

Fig. 2: Map of the 76 seasonal Fisheries Restricted Areas (FRAs) identified in the study area (Aegean Sea-GSA22 and Crete-GSA23) per FRA type, i.e. 40 national fisheries legislation FRAs in territorial waters (n_iFRAs), 1 national fisheries legislation FRA in international waters (n_{if}FRA), 1 national environmental legislation FRA (n_eFRA) and 34 national maritime legislation FRAs (n_mFRAs).

The final component of the FRAs mapping procedure was a total of 516 polygons in shapefile format, of which 484 were created from scratch, while 32 were kindly provided by the Directorate of Fisheries Control of the Hellenic Coast Guard. It was not possible to create polygons for five FRAs, due to the lack of the very shallow two-metre contour (four cases) or due to the lack of information on the exact location of fish farms (one case).

The 516 polygons mapped were grouped according to GSA, FRA type and type of closure (permanent or seasonal) (Table 2, Figs 1 and 2). In terms of number, most of the FRAs identified and mapped in the study area (248 out of 516 FRAs) have been established by the provisions of national fisheries legislation in territorial waters (n_tFRAs) and cover 10.7% of the study area (Table 2, Figs S2 & S3). One FRA has been established by national fisheries legislation in international waters (n_{it}FRA) and covers 17.8% of the study area (Table 2, Fig. S4). The contribution of national maritime, archaeological and environmental legislation to the FRAs established in the study area, is substantial in terms of numbers (151 n_mFRAs, 85 n_aFRAs and 21 out of 516 FRAs), but in terms of area coverage, their contribution is low (0.4%, 1.1% and 1.0% of the study area, respectively) (Table 2, Figs S5-S9). The number of FRAs established at European (euFRAs) and international (intFRAs) level in the study area is smaller than at national level (6 and 4 out of 516, respectively), but they are the most significant ones in terms of area, as they cover 13.5% and 22.6% of the study area, respectively (Table 2, Figs S10-S13). It is worth mentioning that all FRAs identified and mapped in the study area cover approximately 56.2% of the study area; 38.0% of the study area is covered by permanent and 27.6% by seasonal FRAs (Table 2, Figs 1 and 2).

In most of the FRAs mapped in the study area, restrictions on fishing activities concern the use of towed and mobile gears (in 423 and 376 out of the 516 FRAs, respectively), while the use of static gears is restricted in approximately half of the FRAs identified (in 238 out of 516 FRAs). It was estimated that towed, mobile and static gears are permanently prohibited in 38.0%, 3.2% and 2.4% of the study area, respectively (Table 3).

Discussion

The national legal framework concerning spatial and temporal restrictions on fishing activities in the Aegean Sea is remarkably complex, as it consists of numerous provisions, enabled by many legal acts (which in many cases have also been amended), issued by various management bodies, aiming to regulate different and usually conflicting activities in the marine environment. The national FRAs identified in the study area are enabled by legal acts issued mainly by the Ministry of Rural Development and Food within the context of national fisheries legislation, but also by the Ministry of Environment and Energy, the Ministry of Culture and Sports and the Ministry of Shipping and Island Policy within the context of national environmental, archaeological and maritime legislation, respectively.

On the contrary, the European and international legal frameworks concerning spatio-temporal restrictions on fishing activities in the study area are clear and definite. They both consist of a single legal act, i.e. a Regulation issued by the Council of the European Union and a Recommendation issued by the GFCM, respectively. These frameworks have not been amended since they entered into force.

The national restrictions on fishing activities, issued by virtue of fisheries legislation (i.e. n_tFRAs), are established typically as conventional fishery management measures, e.g. in order to limit the harvest of specific life stages, to protect depleted stocks and their habitats during the rebuilding phase of a fishery, to protect genetic reservoirs, to protect habitat that is critical for the sustainability of harvested resources or to restrain excess fleet capacity and optimize the value of catches (Hall, 2002). The restrictions on fishing activities within the nationally designated MPAs according to the environmental legal framework (n_eFRAs) are imposed as wider conservation measures, to conserve nature and protect habitats. The FRAs designated according to the national maritime (i.e. n_mFRAs) and archaeology (i.e. n_aFRAs) legislation, although irrelevant to fisheries management, as they are measures established in order to regulate maritime activities and to protect underwater archaeological heritage, also contribute to some degree to the protection of fisheries resources and the conservation of the marine environment. Spatial and temporal closures, established at European and international level in the study area, are issued as wider conservation measures rather than conventional fisheries management measures, as they are established not only for the sustainability of fisheries resources, but also for the protection of demersal and deep-water habitats and species.

The complexity of the national legal framework on spatio-temporal restrictions of fishing activities in the study area could be attributed, to some extent, to the fact that the coastal and marine area of the Aegean Sea is a valuable natural resource, where many profitable economic activities take place by different stakeholders (Stergiou *et al*., 2016). In such cases, the different (and usually incompatible) activities should be strictly and clearly regulated in order to resolve conflicts over multiple-use of areas or resources, including conflicts of marine users with conservation (Hall, 2002; Katsanevakis *et al*., 2011).

Indeed, the study area has unique characteristics, in terms of geomorphology, which also formulate many of the activities that take place in the area. The Aegean Sea covers an area of approximately 200,000 km^2 (which corresponds to nearly 7% of the total Mediterranean Sea area); it has a lengthy coastline of approximately 12,000

Table 3. Grouping of the 516 Fisheries Restricted Areas (FRAs) mapped in the study area (Aegean Sea-GSA22 and Crete-GSA23) per restricted gear type. Number (n), Area (in km^2), Net Area* (in km^2) and Net Area Percentage** (%) of FRAs per GSA and type of closure (permanent or seasonal).

		Permanent				Seasonal				Total			
Restricted Gear Type	**GSA**	**n**	**Area (km^2)**	**Net Area (km^2)**	**Net Area Percentage (%)**	**n**	**Area (km^2)**	**Net Area (km^2)**	**Net Area Percentage (%)**	**n**	**Area (km^2)**	**Net Area (km^2)**	**Net Area Percentage (%)**
Towed	**22**	306	110,609	59,495	33.5%	50	50,987	47,207	26.6%	356	161,596	93,646	52.7%
	23	66	41,377	21,412	60.3%	1	190	190	0.5%	67	41,567	21,471	60.4%
	22+23	**372**	**151,986**	**80,907**	**38.0%**	**51**	**51,177**	**47,397**	**22.2%**	**423**	**203,163**	**115,117**	**54.0%**
Mobile	**22**	275	8,043	6,313	3.6%	41	8,319	7,591	4.3%	316	16,362	12,718	7.2%
	23	59	626	559	1.6%	1	8,287	8,287	23.3%	60	8,913	8,340	23.5%
	22+23	**334**	**8,670**	**6,872**	**3.2%**	**42**	**16,606**	**15,878**	**7.4%**	**376**	**25,276**	**21,058**	**9.9%**
Static	**22**	145	6,055	5,106	2.9%	45	16,365	6,951	3.9%	190	22,419	7,536	4.2%
	23	47	103	103	0.3%	1	29	29	0.1%	48	132	131	0.4%
	22+23	**192**	**6,158**	**5,209**	**2.4%**	**46**	**16,394**	**6,980**	**3.3%**	**238**	**22,552**	**7,667**	**3.6%**
Recreational	**22**	8	2,253	2,179	1.2%	1	0.028	0.030	0.0%	9	2,253	2,179	1.2%
	23	1	0.195	0.190	0.0%	0	0	0	0.0%	1	0.195	0.195	0.0%
	22+23	**9**	**2,253**	**2,179**	**1.0%**	**1**	**0**	**0**	**0.0%**	**10**	**2,253**	**2,179**	**1.0%**

* Net area is the remaining area after polygon overlaps have been considered. Net areas have been estimated by merging respective polygons and shapefiles using ArcGIS software.
** The total area of the study area was calculated using ArcGIS software and found equal to 213,168 km^2 (177,644 km2 for the part of the study area included in GSA 22 and 35,524 km2 for that included in GSA 23).

km and includes numerous islands and islets. Thus, the Aegean Sea has a long-standing tradition and history in the fisheries and maritime sector. Indeed, fisheries represent a primary sector of significant socio-economic importance, particularly in coastal, traditionally fisheries-dependent, areas. The maritime sector is also significant in the area, as it provides the exclusive means of transportation between the islands and the mainland, and also because the Aegean Sea is at the crossroads of three continents (Asia, Africa and Europe) with significant cargo vessel traffic. Archaeology is also important, due to the rich history of Greece. In the coastal part of the study area, in particular, many antiquities are underwater and close to the coast (with the exception of offshore archaeological shipwreck sites), requiring protection especially from towed fishing gears.

A more detailed look at the fisheries sector in the study area reveals that, in terms of number of vessels, the Greek fishing fleet[5] is the largest in the European Union, (EC, 2016). Small-scale coastal fishing vessels constitute the largest part of the Greek fishing fleet (Stergiou *et al.*, 2007 a, b) as they correspond to 96% of the total fleet (National Fleet Register, 2016).

The complex and multi-regulated legal framework concerning the FRAs in the study area, along with its unique geomorphological features (long coastline, large area, numerous islands, large fishing fleet) and the multi-gear and multi-species character of Greek fisheries (mainly performed by small-scale vessels: Stergiou *et al.*, 2007 a, b) make monitoring, surveillance, control and enforcement of management measures an extremely challenging procedure.

Apart from its complexity, the national legal framework on spatio-temporal restrictions of fishing activities in the study area is considerably old, especially in the case of national fisheries legislation. Indeed, the first FRA in the Aegean Sea dates back to the early 1940s, when it was established by the provisions of the RD of 1940 (GG243A), concerning the permanent closure of a specific area in Evoikos gulf for the traditional small-scale fishing method called "volasma"[6], using trammel nets.

It is estimated that approximately one fourth of the total national fisheries FRAs were established between the early 1940s and the early 1970s (62 out of a total of 254 FRAs, by the provisions of 8 out of a total of 32 legal acts). This period is characterized as the "growth phase" of Greek fisheries (Moutopoulos & Stergiou, 2011), during which they started to modernize and expand to fishing grounds not previously exploited. In the mid-1960s, fisheries monitoring, research and legislation started to be organized in parallel with the development of a well-organized transportation system, through the establishment of wholesale fish markets throughout Greece (Ananiadis, 1968; Moutopoulos & Stergiou, 2011). During the following period, from the 1970s to the mid-1990s (1970-1994), when 26 more FRAs were established by the provisions of 17 legal acts, Greek fisheries passed through a "fully to over-exploited phase", as a consequence of the modernization observed during the previous period, and also participation in a series of development programs, as a result of Greece's accession to the European Union in 1981 (Moutopoulos & Stergiou, 2011).

Thus, it could be hypothesized that the FRAs established during the "growth phase" and the "fully to over-exploited phase" of the Greek fisheries sector, were designated as a means to resolve equity issues. There are cases worldwide where a fishery manager might choose to adopt an area or time closure to resolve conflicts of interests between different stakeholders in the area rather than to provide fisheries management measures or even conservation measures in a wider sense (Hall, 2002). This hypothesis is based on the fact that, during the "growth phase", no systematically collected fisheries data and relevant documentation were available to fisheries managers for them to impose fisheries management measures. On the other hand, during the "fully to over-exploited phase", fisheries focused on the development of a strong and profitable sector and little or even no attention was paid to the impacts of intensive fishing of natural resources.

From 1995 to 2007, Greek fisheries passed through a "decaying phase" (1995-2007), when the overexploitation of fisheries resources resulted in a considerable decline in Greek fisheries landings, clearly showing that fisheries resources were not sustainably harvested (Stergiou *et al*., 1997; 2007a; 2007b; Moutopoulos & Stergiou, 2011). During this period, 57 FRAs were established by the provisions of 3 legal acts, which were issued at the very end of this period (specifically in 2006 and 2007, while from 1995 to 2005 no FRAs were established). It is probable that these are the first attempts of Greek fisheries managers to impose spatio-temporal restrictions of fishing activities as fisheries management measures, because they had started to become familiar with the concepts of overexploitation of fisheries resources and the need for sustainable exploitation in the future.

Indeed, since the mid-1990s, the concept of the Ecosystem Approach to Fisheries Management was highlighted in fisheries management literature (FAO, 1995; Christensen *et al.*, 1996; Pitcher & Pauly, 1998; Sinclair *et al.*, 2002; FAO, 2003; Garcia, 2003; Sutinen & Soboil, 2003; Garcia & Cochrane, 2005). Also, in the early 2000s, the

5 According to the EU Fishing Fleet Register (situation as in September 2015), the Greek fishing fleet comprised of 15,638 vessels (18.4% of the total EU fleet), with a combined gross tonnage of 76,573 GT (4.7% of the total EU gross tonnage) and a total engine power of 449,534 kW (6.9% of the EU total engine power) (EC, 2016)

6 "volasma" refers to a fishing method aiming to create sounds that scare fish and consequently leads them towards the set nets (Andrianos, 1987)

Common Fisheries Policy of the EU was reformed[7], since it was realized that the measures introduced so far, were not sufficiently effective to halt overfishing, and thus the depletion of many fish stocks continued at an increasingly faster pace. Moreover, in year 2000, an EU framework for the collection and management of fisheries data was established, by Council Regulation (EC) No 1543/ 2000, setting precise rules and practices commonly implemented by all Member States for the collection, management and distribution of fisheries data, needed for scientific advice, by fisheries managers. Finally, during the same period, EU and International FRAs were established in the area (in 2006 and 2005 respectively), which emphasizes the fact that the problem of overexploitation of fisheries resources and the urgent need to address it adequately, was also indisputable at European and International level.

The results of the current study provide scientific documentation to support (a) fishers: both the reviewing and mapping results of the study clarify the issue of where, when, by which gear and which legal act has imposed prohibitions on fishing activities; (b) fisheries policy: the identification of the current spatio-temporal distribution of fishing restrictions sets the basis for fisheries policy decision-making in the future; (c) fisheries control: the GIS mapping of the FRAs could optimize surveillance, as it can be incorporated in the national Fisheries Monitoring Centre in order to provide real-time infringement detection; and (d) scientific research: the GIS mapping of the FRAs is a necessary tool to estimate fishing effort (Kavadas *et al*., 2015) and to identify fishing grounds (Maina *et al.*, 2016) that can be used in modelling population dynamics.

In a wider context, the mapping of FRAs in the study area provides useful documentation for the establishment and implementation of maritime spatial planning, under the provisions of Directive 2014/89/EU. The overall aim of maritime spatial planning is to ensure the sustainability of marine ecosystems and the services provided to humans, and to deal with conflicts among various users of the seas (Katsanevakis *et al*., 2011); to that end, mapping the spatial distribution of human activities and of existing management measures is a necessary initial step (Stelzenmuller *et al*., 2013). Besides, the results of this study could be used to identify FRAs that could either meet the IUCN definition of a protected area or could be considered as other effective area-based conservation measures, and thus could contribute to the attainment of Aichi Biodiversity Target 11 of the Strategic Plan for Biodiversity 2011-2020 adopted by the Parties to the Convention on Biological Diversity. According to the above strategic plan "by 2020 (…) at least 10 per cent of coastal and marine areas (…) are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures".

Finally, this study is the first step for future assessment of the effectiveness of the current legal framework on the spatio-temporal restrictions on fishing activities. A comprehensive national evaluation of the effectiveness of spatio-temporal restrictions has not yet been performed in the Aegean Sea. Such an evaluation should be viewed as a necessity within the framework of the Common Fisheries Policy, and for efficient management of marine space, in accordance with the principles of Maritime Spatial Planning and adaptive management.

7 Regulation (EC) No 2371/2002 on the conservation and sustainable exploitation of fisheries resources repealing Regulations (EEC) No 3760/92 and (EEC) No 101/76 (EU Parliament & Council, 2013).

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