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“Fisheries in the AdriatIc Region - a Shared Ecosystem Approach”

D4.7.1 – Calibrated Ecopath with Ecosim model for the Adriatic and Ionian region

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Calibrated Ecopath with Ecosim model for the Adriatic and Ionian region

FAIRSEA – Fisheries in the Adriatic Region – a shared Ecosystem Approach

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Contents

List of Acronyms used

CFP	Common Fisheries Policy
EAF	Ecosystem Approach to Fisheries
EAFM	Ecosystem Approach to Fisheries Management
EwE	Ecopath with Ecosim
FAIRSEA	Fisheries in the AdrIatic Region – a Shared Ecosystem Approach
FG	Functional Group
TL	Trophic level
GSA	FAO Geographical Sub Areas
LOA	Length OverAll
MEDITS	International Bottom Trawl Survey in the Mediterranean
SOLEMON	Sole Monitoring beam trawl survey
OTB	Bottom Otter trawl
DCRF	Data Collection Reference Framework
STECF	Scientific, Technical and Economic Committee for Fisheries
GFCM	General Fisheries Commission for the Mediterranean and Black Sea

1 INTRODUCTION

The FAIRSEA project aims at enhancing transnational capacity and cooperation in the field of an ecosystem approach to fisheries in the Adriatic region by exchanging knowledge and sharing good practices among partners. The complementary expertise of the partners is shared, interlinked and integrated, considering also challenges and opportunities identified by stakeholders. The best way to reach sustainability, in fact, is to ensure stakeholders' participation in the process that requires time, trust, transparency and efficient steering.

> **Ecosystem approach to fisheries:** *"an extension of conventional fisheries management recognizing more explicitly the interdependence between human well-being and ecosystem health and the need to maintain ecosystems productivity for present and future generations"* (Garcia et al., 2003)

The efforts are embedded in a **spatially explicit management platform** that will allow to share expertise, create a common pool of knowledge, boost the operational application of the ecosystem approach to fisheries, enhance the competence in complex system dynamics, and foster a consensus on the state of the environment and fisheries in the region.

The collective development of the integrated platform will enhance partners' expertise on an approach seldom carried out in the Mediterranean Sea. The platform will result in a spatially explicit dynamic tool, integrating cornerstone elements for an ecosystem approach to fisheries that are: water masses circulation and connectivity (module HYDRO), biogeochemical planktonic processes (BGC), distribution of resources (BSTAT), catch and fleet statistics (FSTAT), effort distribution (EFFORT), bioeconomic responses (BIOECO) and food web dynamics (FWM). The attention to the spatial components in the distribution of the resources, the variability of the oceanographic condition, the management policies and the socio-economic impact is a particularly innovative and extremely valuable aspect. The shared integrated platform will be used as a planning tool to implement demonstrative testing of applicable fisheries policies both at local (subareas) and whole Adriatic scales. It will provide a scientific basis to formulate and evaluate shared management advice in the local and international participatory processes, answering to the need of reference points knowledge for the optimisation between ecological and socio-economical sustainability.

The process developed in FAIRSEA will provide an opportunity to describe best practices and define guidelines for a sustainable fishery management. The integrated platform will result in a product that constitutes the basis for a science-based decision support tool and a preliminary step towards the future development of multiannual fishery management plans.

1.1 Fitting with the specific objectives of FAIRSEA

This deliverable concerns the the calibrated food web model developed in the Activity 4.7 "FWM – Food web modelling" of the WP 4.

The development of the food web model required considering a very broad and multidisciplinary set of ecological information, quantitative and qualitative data. Thus the development fo the food web model involved several expertise and disciplines from marine ecology to fisheries technology, from plankton dynamics to fish biology, from physical oceanography to socio-economic aspects of fisheries. This multidisciplinary work for the first time was carried out in an integrated manner by involving scientists from both sides of the Adriatic Sea, integrating competences and expertise. The food web model development, therefore, contributed to the **FAIRSEA specific objective 1: Enhance transboundary integrated competence in the field of ecosystem approach to fisheries.** The interdisciplinary work for developing the food web model and its successive use contribute to enhance the transnational competencies and skills in the field of EAF in the partnership.

Furthermore, the food web model is a cornerstone element of the integrated platform. At its maximum development (spatial dynamics) will include elements of most of the other modules (HYDRO, BGC, BSTAT, FSTAT and EFFORT) by integrating existing information and numerical approaches applied in the Adriatic basin (GSA17, GSA18 ad GSA19). The multitarget and multigear model developed in this Activity 4.7, therefore, contribute also to the **FAIRSEA specific objective 2: Implement a shared "state of the art" integrated platform for the region, by** integrating dynamics of primary production, of target marine species and their food, dynamics of fisheries and their landings. The food web model is developed into a territorially integrated conceptualization of the EAF beyond existing boundaries as a decision support tool useful in the framework of the Common Fisheries Policy (CFP).

The food web mdoel will permit testing different policies that will be analysed and presented to stakeholders and policy makers for a joint discussion. The food web model represents an integrated tool enabling quantitative application of an ecosystem approach to fisheries through scenario analysis and the insights obtained from pilot applications that will be shared in participatory approaches and technical meetings. In this way this activity will contribute to the **FAIRSEA specific objective 3: Share benefits and challenges of ecosystem approach to facilitate the achievement of CFP objectives.** The food web model will constitute a tool used to enhance processes for a collaborative and participated definition of policies to be tested. Given the complexity of the matter, the potentialities and the difficulties of food web model application for fisheries management support will be clarified, in order to increase awareness and facilitate comprehension of robustness of results. The food web model is anyway a continuously growing and improving tool: its further development in the region and outside the region is foreseen by the project itself.

1.2 A cornerstone element of the decision support tool for EAF

The integrated decision support tool is developed in FAIRSEA by including a series of aspects and disciplines. The platform represets an application of a transboundary and transdisciplinary approach that integrates physical, biochemical and biological processes. At the basis of the approach is the consideration **of trophic and technical direct and indirect interactions through a multispecies and multigear quantitative description**. This is pursued since an harmonized management can be achieved by going beyond single species and single gear approaches, and at the same time moving beyond boundaries. Given the importance for management the socioeconomic drivers and the fisheries displacement are included in the platform. Overall FAIRSEA would move toward an operational application of the ecosystem approach to fisheries useful for providing advice for the development next generation management plans.

According to original project objectives, "*elements are integrated into a dynamic spatially explicit tool, whenever possible by using a two-ways coupling, in order to represent at best spatial dynamics observed in the past 10-20 years (according to data). The integrated platform will be developed by the technical partners also considering issues, criteria, and management actions that are foreseen in the region as emerging from technical meetings (WP3) and stakeholder engagement (WP5). The platform is then used as a demonstrative and applied tool to highlight potentialities of the EAF at different target groups. A simplified version containing some scenarios will be used as a demo for dissemination (WP2). Some of its results and controlled simulations will be used for an efficient communication with stakeholders of the Adriatic Region and simulation of alternative local management actions will result in pilot applications (WP5).*"

The ecosystem food web modelling work done in this activity fullfill these original objectives. The food web model for the Adriatic-Northern Ionian shelf and upper slope is developed using Ecopath with Ecosim software platform. **Food web models developed for sub-areas of the region are calibrated with available data.** These local subregional applications will serve as a basis for a definition of an Ecopath with Ecosim model for the entire region embedded in the integrated platform. **The models represent main dynamics and interactions among main target species (with a focus on demersal and small pelagics indicated also in regulatios for the region) and their food sources, driven by dynamics of primary production and by the dynamics of the different fishing fleets.**

2 Ecosystem model development

The food web model for the Adriatic-Ionian region is developed considering the need for fisheries management. Fishing in the area is carried out through a wide series of gears and targeting several fish species (FAO GFCM, 2020). The food web model, therefore, needs to describe not only the priority species indicated by management bodies, but also considering the importance of species in the landings of the region (see also the deliverable D4.4.1 “Catches and fishing capacity by fleet segment and port” produced in the Activity 4.4). It is also important to consider direct trophic interactions among species (e.g., European hake and anchovy are predator and prey; Riccioni et al., 2018) or non trophic direct interactions (es., the habitat forming species beneficial to other fish species).

According to FAIRSEA aims it was necessary to develop a modelling tool comprehensive of the description of different fishing gears operating in the area allows considering the technical interactions that inhevitably occur but are seldom considered (e.g., fishing mortality induced by one gear on a non target species can affect another fishing gear; Agnetta et al., 2019).

Furthermore the food web model can be forced by environmental and anthropogenic drivers, which are tpically the primary production and the fishing effort, respectively. Thus the “food web” model can be refer more comprehensively and accurately as an “ecosystem food web model”, that was developed using the software package Ecopath with Ecosim (www.ecopath.org; Christensen et al., 2008) which is a flexible tool largely used wordwide and that embeds a series of approaches and diagnostics that facilitate its application (Heymans et al., 2014).

2.1 The Ecopath with Ecosim approach

The Ecopath with Ecosim (EwE) modelling approach (Christensen et al. 2008) was used to describe the energy balance of the food web models developed for the Adriatic-Ionian region. Food webs are described by means of compartments representing species, an ontogenetic phase of a species or groups of species with ecological significance and functional to the aims of the model and thereafter called Functional Groups (FGs). The FGs in the food web can represent consumers, autotrophs and non-living compartments, such as forms of organic matter, and links between FGs are formally described by a set of linear equations, one for each FG, representing the balance of energy and matter expressed as:

$$B_i \cdot \left(\frac{P}{B}\right)_i * EE_i - \sum_{j=1}^{n} B_j * \left(\frac{Q}{B}\right)_j * DC_{ij} - Y_i - E_i - BA_i = 0 \qquad \text{(Eq. 1)}$$

where B_i is the biomass of group (i), $(P/B)_i$ is the production of (i) per unit of biomass; the consumption i by the other FGs of the food web is then represented through $(Q/B)_j$ the consumption per unit of biomass of all j predators the proportion of (i) in the diet composition of predator (j) in terms of biomass (DC_{ij}); other losses on group i are represented by fishery catches, Y_i, the net migration rate E_i and eventually the biomass accumulation BA_i. The parameter EE_i represents the ecotrophic efficiency, i.e., the proportion of the production of group (i) which is utilized within the system modelled (Christensen and Walters 2004). Energy balance for each group is also ensured by equating its consumption (Q/B_i) with the sum of production (P/B_i), respiration (R/B_i) and unassimilated food (U/Q x Q/Bi). The system of equations is solved according to several ecological constrains by providing EwE with diet composition, the unassimilated food, the catches, the exports for each group and three of the basic parameters B_i, $(P/B)_i$, $(Q/B)_i$ and EE_i (Christensen et al. 2008). The solution provides a snapshot of the trophic flows within the ecosystem (further details on EwE modelling approach can be found in review literature: Christensen and Walters 2004; Heymans et al. 2014).

2.2 Topographic, oceanographic and administrative features of the region

The FAIRSEA project area of work is the Adriatic Sea and the Nothern Ionian sea. The inclusion of the Northern Ionian was done by considering the enormous relathionships and exchanges of water masses and species among the Otranto Strait. Notably, in fact, the circulation of the Ionian Sea and the Adriatic sea are deeply interconnected and several long term changes in the biological communities might be explained by large circulation changes (Civitarese et al., 2010).

The area of work of the Adriatic Sea and of the Northern Ionia Sea is divided by the GFCM in three subareas, GSA 17, 18 and 19 (see Figure 1) that were defined on the basis of ecological features, considering the admistrative boundaries and data collection.

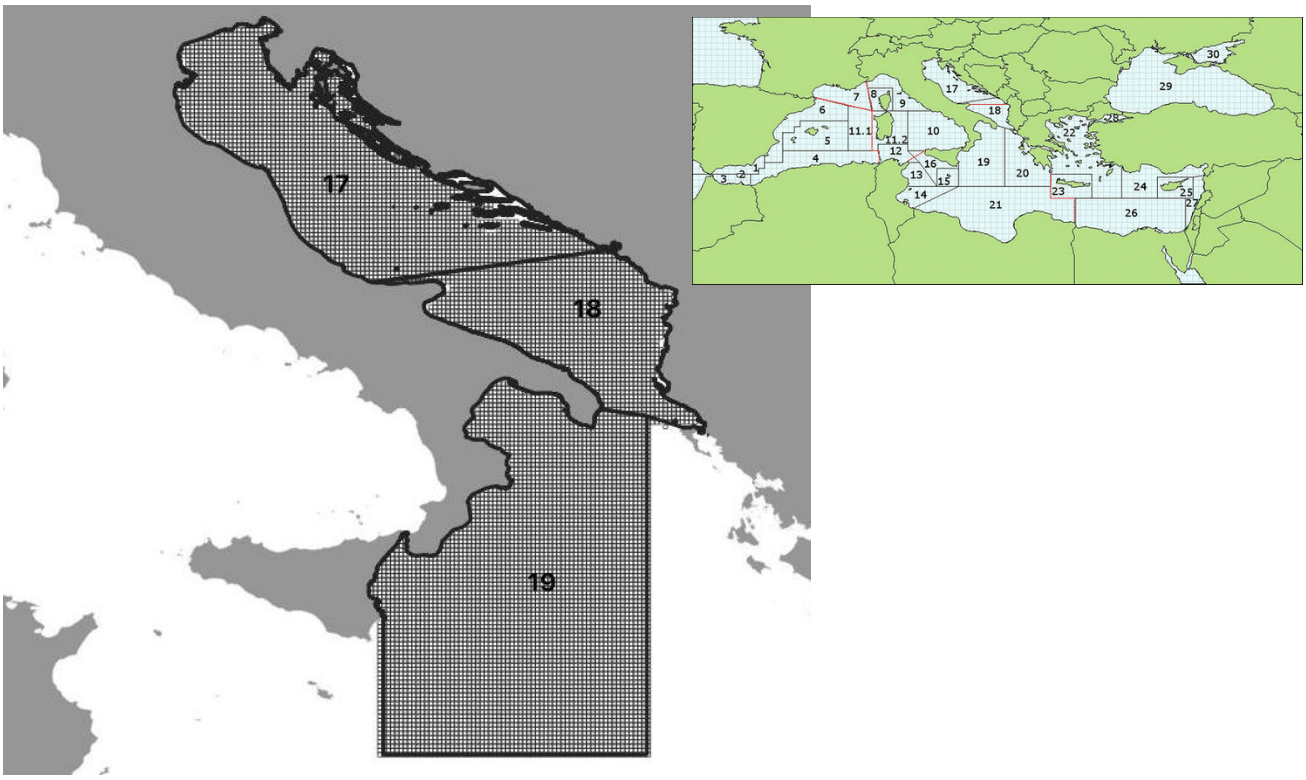


Figure 1. Study area and its subdivision into the FAO GFCM Geographic Sub-areas 17, 18 and 19.

The proper Adriatic Sea is a semi-enclosed basin that extends over 138000 and is characterised by the largest shelf area of the Mediterranean. The Northern and Central parts of the Adriatic Sea are very shallow with a large continental shelf of depths lower than 100 m. The Central part of the Adriatic Sea (GDA17) has the deepest are in the Pomo/Jabuka Pit (200-260 m). The Eastern and Western coasts are very different; the former is high, rocky and articulated with many islands, the Western coast is flat and alluvial with raised terraces in some areas. The basin of the Southern Adriatic Sea (GSA 18) is connected to the Northern Ionian Sea through the Otranto Channel, which represents the area in which an annual mass flow of water for 35 million m3 is conveyed. The Southern Adriatic has a relatively narrow continental shelf and a marked, steep slope; it reaches the maximum depth of 1223 m. The hydrography of the Adriatic Sea region is characterized by water inflow from the Eastern Mediterranean (entering from the Otranto channel along the Eastern Adriatic coast) and freshwater runoff from Italian rivers. These features seasonally produce both latitudinal and longitudinal gradients in hydrographic characteristics along the basin (Mannini and Massa, 2000). The North Western Ionian Sea corresponds to the GSA 19 and extends from Cape Otranto to Cape Passero along a coastline of about 1000 km. This GSA cover a very wide area reaching very deep zones (up to 4000 m depth). The North-western Ionian is divided by the Taranto Valley into an eastern sector represented by a broad continental shelf and a south-western one where the shelf is generally very limited and many submarine canyons are located along the coasts (Rossi and Gabbianelli 1978).

The circulation of water masses in the Adriatic sea is typically cyclonic (Artegiani et al. 1997). The Dense Waters of the Northern Adriatic (NADW), the Deep Waters of the Adriatic (ADW) and the intermediate Levantine Waters (LIW) flow into the basin. The NADW Dense Waters (cold waters) flow from north to south along the western continental shelf, the Deep Waters originate in the pit of the lower Adriatic Sea, while the Levantine Intermediate Waters, warmer and saltier, enter from the northern Ionian Sea through the Canale d'Otranto and flow in a south-north direction along the eastern coasts of the Adriatic (Manca et al. 2001). These masses of water make the bottoms of the eastern part of the southern basin characterized by higher alino and thermal regimes than in the western part (Artegiani et al. 1997). These salt concentrations determine an oligotrophic condition and the chlorophyll-a concentration is estimated to be 0.5-1.5 μg / 1 (Rizzi et al. 1994). Concerning the geomorphology and bathymetry of the area, the maximum depth of the Lower Adriatic is 1233 m in the so-called “Fossa di Bari”. This depression has rather asymmetrical contours with the steeper eastern escarpment. The western area shows substantial differences in the two northern and southern portions; the first, where the Gulf of Manfredonia is located, has a wide continental shelf (distance between the coast line and 200 m depth of 45 nautical miles) and a slightly steep escarpment; the second instead has islands of close depth, so much so that the 200 m can be reached about 8 miles from Capo Otranto. From a hydrographic point of view, the Ionian Sea is characterized by a complex system of water circulation in superficial and deep layers (Civitarese et al. 2010 and references therein), showing a general cyclonic circulation markedly influenced by the cold dense deep-water masses of the Adriatic Sea in flowing through the Otranto Channel. Hydrographic observations and current measurements performed in the 1990s revealed strong modifications in the dynamics of the entire water column termed the Eastern Mediterranean Transient (EMT) which at present seems to have concluded (Klein et al. 1999).

The presence and distribution of marine flora and fauna, as well as the main ecological characteristics of the basin are linked to environmental and morphological differences in the whole Adriatic-Ionian basins (Marano et al., 1998). In the Adriatic Sea all types of bottom sediments are found, muddy bottoms are mostly below a depth of 100 m, while in the Central and Northern Adriatic the shallower sea bed is characterized by relict sand. The area includes a complex set of habitats going from the large shallow trawleable area in the North and Central Adriatic Sea exploited since centuries (Jukic-Peladic et al., 2001) to deeper areas of the Southern Adriatic Sea and Northern Ionian hosting important demersal fishery resources (Maiorano et al. 2010, Carlucci et al. 2016, Russo et al. 2017). The area also include several hot spots of biodiversity such as rocky outcropts in the Northern Adriatic (Guidetti et al., 2005), Cold Water Coral habitats at the interface between Adriatic and Ionian Seas (D'Onghia et al., 2011, 2012b, 2016) and submarine canyons in the Ionian Sea (Capezzuto et al. 2010, Vassallo et al. 2016).

From an administrative point of view, on the shores of the North and Central Adriatic Sea (GSA 17) there are the countries: Croatia, Bosnia-Herzegovina, Italy and Slovenia. For the southern Adriatic Sea (GSA 18) the countries involved are Italy, Albania and Montenegro. The Pomo/Jabuka pit area comprises three depressions (> 200 m depth) in the middle of the Adriatic Sea, covering an area of approximately 2000 km2 (Russo et al., 2018).

The modelling development considered only areas up to depths of 800m (thus excluding deeper areas), because this is the limit of i) scientific trawl survey used for monitoring demersal species; ii) the limit of most of the exploitations going on in the area (fishing at depths > 1000 m is forbidden in the Mediterranean sea and only few vessels can fish at depths >500m).

2.3 Fisheries in the Adriatic Ionian region

In the Northern and Central Adriatic Sea, the dominant fish species in terms of biomass are the red mullet (*Mullus barbatus*), poor cod (*Trisopterus minutus*), various species of triglids, sole (*Solea solea*), various species of flatfishes, gobies and pandoras (*Pagellus* spp.) On the continental shelf from 10-50 m depth (UNEP, 2014). In addition, the anglerfish (*Lophius* spp.), European hake (*Merluccius merluccius*), greater forkbeard (*Phycis blennoides*) are also abundant, as well as blue whiting (*Micromesistius poutassou*) at 100 to 200 m deep. The continental shelf of the Adriatic Sea is also rich in invertebrate fauna, where some of the most abundant species are cuttlefish (*Sepia officinalis* and *S. elegans*), octopuses (*Eledone moschata*, *E. cirrhosa* and *Octopus vulgaris*), squids (Loligo vulgaris and Alloteuthis media), mantis shrimps (Squilla mantis), rose shrimp (*Parapenaeus longirostris*), Norway lobster (*Nephrops norvegicus*) and scallops (*Pecten jacobaeus* and *Chlamys opercularis*). In addition , the presence of the Well-Sorted Fine Sand biocenosis provided suitable conditions for the occurrence of the striped venus clam (*Chamelea gallina*), which is exploited by dredges. The main small pelagic species are sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*), horse mackerel (*Trachurus* spp.) and mackerel (*Scomber* spp.). In the northern 5 area, sprat (*Sprattus sprattus*) is found, although it was more abundant during the 1960s and 1970s than nowadays.

In the GSA 18, the demersal species landed on both the western and eastern sides of the basin with a respective distribution of 97% and 3% (Massa & Mannini 2000). Concerning the trawling, hake (*Merluccius merluccius*) represents 20%, while the species Norway lobster (*Nephrops norvegicus*), pink shrimp (*Parapenaeus longirostris*), mullet (*Mullus barbatus*), suri (*Trachurus* spp.) and dormouse (*Eledone* spp.) contribute 5-10% each (Ungaro et al. 2002). The area potentially exploited by the trawlers is equal to 15,000-17,000 km2 (70% on the western side, 30% on the eastern side).

In the Northern Ionian Sea, fishing exploitation occurs from coastal waters up to 800 m depth. The trawl fleet is characterized by vessels with a length-over-all (LOA) of 12–18 m and it mainly exploits the shelf break and slope grounds (Maiorano et al., 2010; Russo et al., 2017; Carlucci et al., 2018). Trawlers represent about 21% in number, 64% in gross tonnage and 56% in engine power with respect to the whole Northern Ionian Sea fleet (Maiorano et al. 2010). Most of the boats are registered as polyvalent fishing vessels because they often change type of gear, according to the season and sea/weather conditions, as well as the variable availability of resources and market demand. Considering the effect of trawling, and to a lesser extent of other fishing gears, the General

Fishery Commission for the Mediterranean (GFCM FAO) created a new Fishery Restricted Area (FRA) on the Santa Maria di Leuca cold-water corals (SML CWC) recommending the prohibition of towed gears (D'Onghia et al., 2016; Capezzuto et al. 2018). The most important demersal resources in the north-western Ionian Sea are represented by the red mullet (*M. barbatus*) on the continental shelf, hake (*M. merluccius*), rose shrimp (*P. longirostris*) and Norway lobster (*N. norvegicus*) over a wide bathymetric range and the deep-water red shrimps (*Ariste antennatus* and *A. foliacea*) on the slope.

3 Structuring the food web model of the Adriatic-Ionian Region

The ecosystem food web model(s) are developed following criteria of ecological accuracy and fisheries relevance: two concepts that are fundamental for an appropriate EAF. The models were developed for multiple areas as described in the project proposal.

I spite of the ecological differences within the domain of the FAIRSEA project, it is important to highlight that **the same structure was used to develop the models, by considering the same functional groups and fisheries fleets**. In fact, despite local differences both in ecological (e.g. relevance of river in the north Adriatic), biological (e.g., absence of relevant stocks of clams in the Northern Ionian) and fishing terms (e.g., lack of deep shrimp fisheries in northern Adriatic Sea) a common structure was used for all the models developed. This is an essential requirement for facilitating comparison, integration and merging of the models.

3.1 Domain of the ecosystem models developed

As indicated previously, the models represent areas up to 800 m depths, that implies full representation of the GSA17, representation of most of the GSA18 surface, but consideration of only a narrow area of the GSA19, which is dominated by large deeper areas. Thus the modelled areas in GSA 17 extends for a total of 92,261 km^2, followed by the GSA 18 with 29,008 km^2 and lastly, the GSA 19 with 16,347 km^2. The Ionian region has been modelled from Otranto to Capo Passero (Sicily). Each modelled area is ranged between 10 and 800 meters of depth because this space represents the area maily exploited by the fisheries in all GSAs.

The Adriatic region (GSA17 and 18) has been modelled as a unique area (total modelled surface of 120000 km2) dominated by the shelf grounds in the northern and central zones. Differently, the southern area is characterized by the occurrence of both shelf and slope grounds up to 1000 m in the Otranto channel.

3.2 Ecological structure of the models: defining functional groups

In order to build the structure of the food web for Adriatic EwE models, a total of 1067 taxa, with 405 taxa only in the benthic domain, were listed after checking their presence in biomass or catches related databases. Biomass related data come from the international research project "MEDiterranean International Trawl Survey' (MEDITS) (Anonymus, 2017), SOLEMON for the benthic assemblage in the Central North Adriatic Sea, the OBIS Sea Map database for the cetaceans and turtles, along a time series 1995-2019. Moreover, after collection of diet data (see dedicated section) further taxa were added in the list, when missing from the biomass databases.

The species/taxon'list was aggregated in a total of 73 functional groups (FGs), which describe the basic biological compartments of the food webs in the 3 GSAs (Tab. FGs). In particular, the clustering of species in the FGs followed several criteria:

- the trophic similarity among the species
- the life-history traits of the species
- the ecological importance in the food web (e.g. large top predators)
- the commercial interest for the fishery in the modelled areas

The choice of groups were based on the biological background and modeling experience of researchers from a side and the maximum capability of the model on the other side. Moreover great attention was paid on the distribution of the species along the investigated bathymetric gradient. Thus, the groups' nomenclature stresses the belonging to the shelf (h) or slope (s) grounds. Some species of commercial interest were detailed in the food web model by means of the splitting of the juvenile (0) and adult (1) and (2) components represented using the Ecopath multi-stanza routine (Christensen and Walters, 2004). These divisions of the components allow to represent the life-cycle of these valuable species, which will be useful in the spatial management scenarios developed by Ecospace module. In addition, for the hake and the common sole were adopted a total of 3 multi-stanza, where the third represents the individuals which become liable to contact (recruited) with the fishing gear.

Table 1. Functional groups (FGs) represented in the model their short name used in the graphs and in the following.

Functional Group name	Short name	Functional Group name	Short name
Seabirds	G01_SBR	Hake (age 1)	G38_HKE1
Marine turtles	G02_TTL	Hake (age 2+)	G39_HKE2
Mid-large odontocets	G03_ODO	Other cephalopods (Slope)	G40_CPXs
Common Bottlenose Dolphin	G04_DBO	Other cephalopods (Shelf)	G41_CPXh
Striped Dolphin	G05_DST	Squids	G42_SQD
Fin whale	G06_FIW	Common cuttlefish	G43_CTC
Rays skates (Slope)	G07_BATs	Musky-Horned octopus	G44_OCM
Rays skates (Shelf)	G08_BATh	Mantis shrimp (age 0)	G45_MTS0
Sharks (Slope)	G09_SELs	Mantis shrimp (age 1+)	G46_MTS1
Sharks (Shelf)	G10_SELh	Norway lobster (age 0)	G47_NEP0
Blackmouth catshark	G11_SHO	Norway lobster (age 1+)	G48_NEP1
Large pelagics fish	G12_PLS	Blue and Red Shrimp	G49_ARA
Medium pelagics fish	G13_PMS	Red Giant Shrimp	G50_ARS
Demersal piscivorous fish (Slope)	G14_DPSs	Deep-water Rose Shrimp (age 0)	G51_DPS0
Demersal piscivorous fish (Shelf)	G15_DPSh	Deep-water Rose Shrimp (age 1+)	G52_DPS1
Epipelagic fish	G16_EPI	Caramote prawn	G53_TGS
Mesopelagic crustacean feeding	G17_MCF	Decapods_Reptantia (Slope)	G54_REPs
Zooplancton jellyfish feeding fish	G18_ZJF	Decapods_Reptantia (Shelf)	G55_REPh
Demersal fish (Slope)	G19_DEMs	Decapods_Natantia (Slope)	G56_NATs
Demersal fish (Shelf)	G20_DEMh	Decapods_Natantia (Shelf)	G57_NATh
Other flatfishes	G21_FLX	Peracarida (suprabenthos)	G58_PER
Turbot and brill	G22_FTB	Clams	G59_CLM
Gurnads	G23_GUR	Scallops	G60_SCL
Other gadids	G24_GDX	Other Benthic invertebrates	G61_BIX
Other small pelagics	G25_SPX	Seagrasses	G62_SGR
Mackarels	G26_MCK	Seaweeds	G63_SWD
Anglers	G27_LOP	Jellyfish	G64_JLY
Sardine (age 0)	G28_PIL0	Macrozooplankton &Euphasiacea	G65_ZMA
Sardine (age 1+)	G29_PIL1	Mesozooplankton	G66_ZME
Anchovy (age 0)	G30_ANE0	Microzooplankton	G67_ZMI
Anchovy (age 1+)	G31_ANE1	Bacterioplankton	G68_BPL
Solea (age 0)	G32_SOL0	Phytoplankton - diatoms	G69_PDM
Solea (age 1)	G33_SOL1	Phytoplankton - dinoflagellates	G70_PDF
Solea (age 2+)	G34_SOL2	Discards, carrion	G71_DSC
Red mullet (age 0)	G35_MUT0	Suspended detritus	G72_POM
Red mullet (age 1+)	G36_MUT1	Bottom detritus	G73_BTD
Hake (age 0)	G37_HKE0		

3.3 Placing fisheries in the ecosystem context: defining fleet structure

The main relevant fishing gears operating in the Adriatic and Northern Ionian Sea were described in the model using "fleets" desctription that combine gear used and dimension of the segment based on the lenght out all (LOA) of the vessels. The fishing fleets definition was based on knowledge of importance in the area, taking care of features ad main target species that might require separation among fleets. Also importance in terms of landings and management measures were considered for definig the fleets that were represented in the model as in Table 2.

Table 2. Fleets used to describe the fisheries in the food web model. The fleets results from a combination of gear and size category (based on the LOA) also considering importance for the area and available information on landings, capacity ad effort.

Fishing gear	**Gear code**	**Vessel length segment (LOA)**
Boat dredges	DRB	all vessels (VL-ONE)
Set nets	GNX	all vessels (VL-ONE)
Longlines	LLX	all vessels (VL-ONE)
Small scale fishery, pots, beach seine and other gears	MIX	all vessels (VL-ONE)
Bottom otter trawlers	OTB	smaller than 18 meters (VL—18) between 18 and 24 meters (VL1824) larger than 24 meters (VL24++)
Mid-water pair pelagic trawlers	PTM	smaller than 18 meters (VL—18) between 18 and 24 meters (VL1824) larger than 24 meters (VL24++)
Purse seines	PS	smaller than 18 meters (VL—18) larger than 18 meters (VL18++)
Rapido trawlers	TBB	smaller than 18 meters (VL—18) larger than 18 meters (VL18++)

The fleets were defined in the food web models also considering available data in terms of landing, capacity and effort measures. Therefore, the definition of fleets as in table 2 represent a compromise between perceived ecological and fisheries importance and availability of data.

Several official datasets and other information were used for the scope that include: socio-economic data from Economic Analysis from STECF and Data Collection Reference Framework (DCRF) from FAO GFCM as provided by the Italian and Croatian Ministries of agriculture; Socio-economic information obtained from Mably Scarl (external service of the LP-OGS); furthermore some additional information were retrieved from websites of officials statistics and reports: the Report on status of resources and productive structures in the Italian seas; Croatian Bureau of Statistics consulted online; BiosWeb - Biological database of the Fisheries Research Institute of Slovenia, Albanian Ministry of Agriculuture and Rural Development reports. Finally the definition of fleets considered landings and catches as reported in the deliverable D4.4.1 "Catches and fishing capacity by fleet segment and port" and effort information as described in D4.5.1 "Fishing effort map distribution".

4 Parametrization of the Ecopath models

4.1 Food web initial conditions: Ecopath

The Ecopath models were implemented considering data for a reference period of 3 years (2004–2006), that was chosen to facilitate future successive steps of time-dynamic model analysis by means of the Ecosim routine (Christensen et al., 2008). The start year was chosen considering the extension and the best overlap of time series of available biomass and catch data. Biomass time series started in 1995, while the first complete and reliable data series of fishing catches was available since 2004.

All data (biomass, parameters, landings and discards, diets) were gathered by species or at the lowest taxomical level possivle and successively data were aggregated according to respective functional groups assignment (see Libralato et al., 2010).

4.2 Biomasses for plankton groups

The outputs of the biogeochemical model (BGC) developed in the Activities 4.1 and 4.2 were used to describe the phytoplankton (diatoms, dinoflagellates), zooplankton (microzooplankton and mesozooplankton), bacterioplankton and detritus groups (suspended detritus and bottom detritus). There were 16 variables covering a spatial distribution of the FAIRSEA study area (Table x). Each variable variable has five depth layers (0-50, 50-100, 100-200, 200-500 and 500-800).

Table 3. List of the available variables from the biogeochemical model.

Code	Unit	Variable Name
O2	mmol O_2 m^{-3}	Dissolved oxygen
T	°C	Temperature
S	PSU	Salinity
B1	mg C m^{-3}	Pelagic Bacteria
P1	mg C m^{-3}	Diatoms
P2	mg C m^{-3}	Nano Flagellates
P3	mg C m^{-3}	Picophytoplankton
P4	mg C m^{-3}	Large phytoplankton
Z3	mg C m^{-3}	Carnivorous Mesozooplankton
Z4	mg C m^{-3}	Omnivorous Mesozooplankton
Z5	mg C m^{-3}	Microzooplankton
Z6	mg C m^{-3}	Heterotrophic Flagellates
R1	mg C m^{-3}	Labile Dissolved Organic Matter
R2	mg C m^{-3}	Semi-labile Dissolved Organic Carbon
R6	mg C m^{-3}	Semi-refractory Dissolved Organic Carbon
R7	mg C m^{-3}	Particulate Organic Detritus

The synthesis of the data was conducted maintaining the monthly temporal resolution, while the data were spatially divided into the GFCM Geographical sub-areas (GSA): north and central Adriatic (GSA 17), southern Adriatic (GSA 18) and northern Ionian sea (GSA 19). We selected and used only data for bacteria (B1), phytoplancton (P1, P2, P3, P4), zooplankton (Z3, Z4, Z5, Z6) and organic and detrital mater (R1, R2, R6, R7).

The same procedure was for each value. Biomass of each volume unit was calculated by multiplying the density (mg C/m^3) by the height of the depth level (m) and its surface area (m^2). Average density per surface unit was obtained by dividing the sum of biomasses at different depth strata by the surface area of the cells. The average biomass density was calculated by averaging the density of all spatial cells. Wet weigth biomass was obtained converting the acctual biomass expressed in carbon (mg C/ m^3) by multiplying by a conversion factor of 12.5.

4.3 Biomasses of fish and large invertebrate species

Biomasses for several fish and invertebrates species were estimated using data from trawl surveys conducted in the Adriatic Sea and North Western Ionian Sea, i.e., in the geographical sub-areas (GSAs) 17, 18 and 19 as defined by the FAO-GFCM (General Fisheries Commission for the Mediterranean Sea). Moreover, for species with available stock assessment data, such as sardine (Sardina pilchardus), anchovy (Engraulis encrasicolus), common sole (Solea solea), red mullet (Mullus barbatus), hake (Merluccius merluccius), cuttlefish (Sepia officinalis) mantis shrimp (Squilla mantis), norway lobster (Nephrops norvegicus), deep rose shrimp (Parapenaues longirostris) and karamonte prawn (Melicertus kerathurus), biomass estimates from assessment model were used instead of survey data.

Biomass of demersal and benthic species

Biomass estimates of demersal and benthic species are based on data available from the scientific surveys MEDITS and SOLEMON.

MEDITS survey

The Mediterranean International Trawl Survey (MEDITS; Spedicato et al., 2019a) is a bottom trawl survey conducted up to 800 m depth from 1994 to 2018. The dataset consists on average 326 sampling sites (hauls) per year in the Adriatic and Northern Ionian Sea covering the shelf and upper slope of the three GSAs. Indices of demersal species biomass (kg/km2), retrieved from the MEDITS dataset, were calculated using the equation proposed by Souplet (1996)

$$I = \sum_{i=1}^{n} W_i \, \underline{x}_i$$

where I is the index, Wi is the weight of the stratum i, and xi is given by:

$$\underline{x} = \frac{\sum_{i=1}^{ni} x_{i,j}}{\sum_{i=1}^{ni} A_{i,j}}$$

where $x_{i,j}$ is the weight of the individuals in the haul j of the stratum i and Ai,j is the area trawled in the haul j of the stratum i; ni is the number of hauls in the stratum i. The stratum considered for the biomass standardization was 10-800 m.

The biomass indices derived from the MEDITS trawl surveys do not account for the catchability of the fishing gear, and thus, a catchability factor by species (q_i) was used to convert indices into biomass at sea. These catchability indices were obtained from the literature whenever possible (Fiorentino et al., 2013; Fraser, Greenstreet, & Piet, 2007). In some instances, catchability by species for demersal species was evaluated by comparison of MEDITS estimates with other data (e.g., benthic samples, other fishing gears, stock assessments) in order to determine more accurate absolute densities at sea: although this implies great uncertainty, it is a necessary step which is not always explicit in EwE modeling (see for example Arreguin-Sanchez, 1996).

SOLEMON survey

The Sole Monitoring (SOLEMON; Scarcella G., 2011, Grati et al., 2013) trawl survey is carried out with a modified beam (rapido). This trawl survey is conducted in the north and central Adriatic Sea (mainly in GSA17, with some hauls in GSA18). In 2007 a larger survey was conducted including the whole southern Adriatic Sea (GSA 18) in Montenegro, Albania and along the coast of Apulia in Italy. On average 70 sampling (hauls) per year were retrieved from 2005 to 2018; hauls were done up to a depth of 100 m. The common sole (*Solea solea*) is the target specie, but also all other benthic species were considered, such as shellfish and cephalopod and other flatfish. For this survey no catchability correction was applied, assuming that the fishing gear is specific for benthic species.

In this analysis we assumed that each of the two surveys is more specific for a certain group of species, while the other is less relevant. Therefore we summed the obtained species densities from the two surveys, assuming that one of them is more dominant than the other, and by doing this we included as much detail is available from the surveys.

Stock assessments

For the multi-stanza groups, biomasses were obtained by Stock Assessment reports (SA) of STECF and/or GFCM when available. SA reports provide information on the several biological parameters used in Ecopath multistanza such as total mortality by age, natural mortality, average growth rate, ratio between weight at first maturity and weight at infinity (see also Chrisetnsen et al., 2008 for inputs required for multistanza groups).

The representation of species into multi-stanzas (Ahrens et al., 2013) is very useful to parameterising species juvenile and adult components, either older than one year (age-1+), or two years (age-2+), as required by the multi-stanza setting in Ecopath. For the GSA 19, two SA were available for the red mullet and the deep water rose shrimp. Differently in GSAs 17-18, SA reports were collected for the European hake, red mullet, deep-water rose shrimp, sole, mantis shrimp, cuttlefish, caramote prawn, Norway lobster, sardine and anchovy. Biomass estimates from stock assessments were used for parameterising the multi-stanza species and, in Ecosim, stock assessment time-series were used as "absolute biomass" for the fitting procedures.

4.4 Biomass of cetaceans

Biomass data of cetaceans and marine turtles were derived from abundance data (N·km^{-2}) collected from OBIS Sea Map database (Halpin et al., 2009) for the Adriatic and Ionian Sea and values of mean individual weight (Piroddi et al., 2010; Carlucci et al., 2020). Moreover for the Northern ionian region, additional density data was acquired through monitoring surveys carried out by Jonian Dolphin Conservation and Department of Biology (Univ. Bari) in the Gulf of Taranto since 2009.

4.5 Basic parameters and diet composition

The Production and Consumption rates were collected for a total of 304 taxa drawing from data used in other models developed in our GSAs or calculated by empirical equations. The P/B rate under most conditions corresponds to the total mortality rate (Z, see Allen, 1971), commonly estimated in fishery stock assessments as the sum of fishing and natural mortality. The available stock assessment reports provided by STECF or GFCM were used for the species multi-stanza parameterization. Differently, Q/B rates were estimated by empirical equations available on Fishbase based on the life-history traits and feeding behaviour of the consumer. Diet information (expressed in weight proportions) were collected for a total of 240 taxa acquiring the data form Fishbase (Froese and Pauly, 2019) and literature available.

Basic parameters and diet proportions of functional groups were weighted by species biomass contribution within each group (see also Libralato et al, 2010). Only the species that contribute to a 90% cumulative proportion were designated as major contributors to the group's characteristics. P/B and Q/B parameter and diet values were inferred from species with similar ecology when species-specific data were not found. A two steps procedure was carried out in order to calculate the input parameters. Firstly, basic parameters and diet compositions of the major species contributors within a group were weighted by species biomass contribution. Secondly, the residual contribution of minor species to the group's biomass (less than 10%) was averaged and weighted cumulatively. This procedure allowed to calculate different input parameters and diet matrix characterising each group by their composition per Geographic sub-area (GSA).

4.6 Rapresenting species into multi-stanza groups

In Ecopath, multi-stanza allows representing species splitted into age classes in a way similar to what is conducted in stok assessment models (Ahres et al., 2013). This was considered for all the most important priority species for which a stock assessment was available, i.e., for anchovy, sardine, hake, red mullet, mantis shrimp, norway lobster, common sole and depp water shrimp. The setting required consumption over biomass ratio (Q/B) of adults and total fishing mortalities (Z) for all stages. Biomasses at age+ were then used with adult Q/B ratio and total fishing mortalities to estimate biomasses and Q/B of the juvenile stages (Table 3).

Table 4. Multistanza groups and their parameters

	Group name	Age, start (months)	Biomass (t/km²)	Tot. mort. (/year)	Consumption / biomass (/year)
GSA 17 & 18	G28_PIL0	0	0.1819	1.193	25.970
	G29_PIL1	12	1.7350	1.302	10.658
	G30_ANE0	0	0.4295	2.400	30.964
	G31_ANE1	12	1.8700	1.363	13.500
	G32_SOL0	0	0.0041	1.773	24.296
	G33_SOL1	12	0.0104	1.820	12.615
	G34_SOL2	24	0.0145	1.078	7.715
	G35_MUT0	0	0.0191	1.410	16.989
	G36_MUT1	12	0.1169	1.810	7.050
	G37_HKE0	0	0.0063	1.459	16.764
	G38_HKE1	12	0.0289	1.298	8.000
	G39_HKE2	24	0.0809	1.167	4.149
	G45_MTS0	0	0.0070	1.206	13.478
	G46_MTS1	12	0.0449	1.459	6.168
	G47_NEP0	0	0.0025	1.513	21.613
	G48_NEP1	12	0.0466	0.866	7.565
	G51_DPS0	0	0.0268	3.470	23.439
	G52_DPS1	12	0.0302	2.484	10.975
GSA 19	G28_PIL0	0	0.0451	1.193	25.970
	G29_PIL1	12	0.4300	1.302	10.658
	G30_ANE0	0	0.2443	2.400	30.964
	G31_ANE1	12	1.0636	1.363	13.500
	G32_SOL0	0	0.0017	1.773	26.015
	G33_SOL1	12	0.0044	1.820	13.507
	G34_SOL2	24	0.0061	1.078	8.261
	G35_MUT0	0	0.0065	1.410	16.989
	G36_MUT1	12	0.0397	1.810	7.050
	G37_HKE0	0	0.0067	2.000	17.345
	G38_HKE1	12	0.0253	1.400	8.000
	G39_HKE2	24	0.0658	1.200	4.123
	G45_MTS0	0	0.0016	1.206	13.478
	G46_MTS1	12	0.0100	1.459	6.168
	G47_NEP0	0	0.0011	1.315	21.484
	G48_NEP1	12	0.0237	0.850	7.565
	G51_DPS0	0	0.0611	3.470	23.439
	G52_DPS1	12	0.0690	2.484	10.975

4.7 Landings

Landing data were obtained from different data sources, both from data calls, official reports and data present on national or institutional repositories (Table).

Table 5 . List of available data sources for landing data.

Source code	Descrition
FSJ	FAO FishStatJ - Software for Fishery and Aquaculture Statistical Time Series http://www.fao.org/fishery/statistics/software/fishstatj/en
FAO	FAO GFCM data collection
EUR	EU Eurostat's database for Landings of fishery products (fish_Id) https://ec.europa.eu/eurostat/web/fisheries/data/database
FDI	Fishery Dependent Information data
DZS	Croatian Bureau of Statistic (Državni zavod za statistiku) https://www.dzs.hr/
IZR	Institute of Oceanography and Fisheries database (IOF) (Institut za oceanografiju i ribarstvo, baza podataka i pokazatelja stanja morskog okoliša, marikulture i ribarstva) http://baltazar.izor.hr/azopub/bindex
MBL1	Mably 1st data call
MBL2	Mably 2nd data call
ANN	Report on status of resources and productive structure in the Italian seas (Maiorano P., Sabatella R.F., Marzocchi B.M. (eds) (2019) – Annuario sullo stato delle risorse e sulle strutture produttive dei mari italiani. 432 pp.)
BIW	BiosWeb - Biological database of the Fisheries Research Institute of Slovenia http://www.biosweb.org/?task=stat#tabs-year
FSR	Reconstructed data of FishStatJ (FSJ) landings for Croatia
MBLR	Reviewed data of 2nd MABLY data call.
MAR	Albanian Ministry of Agriculuture and Rural Development http://www.instat.gov.al/en/themes/agriculture-and-fishery/fishery/#tab1

Different sources had different spatial and temporal resolutions, therefore the first step was to compare the total landings of the group, divided by area, state and source. Each of the data were converted into a common format, where country, area, fishing gear and length segments were unified. All fishing gears assigned as not known (NK) are assigned as mixed fishing gears (MIX).

Landing data from FAO FishStatJ for Croatia need integrations and corrections, since these data displayed a different species resolution in time. The beginning of the landing time series in 2004 has a lower number of taxa as some species were probably aggregated under the same taxa. More detailed information on landing composition were available in the same period when Croatia became a member of the European Union. Therefore we adopted a backward reconstruction procedure, where more recent landing composition was used to split older aggregated landing data into different taxa. This new dataset was called Reconstructed data of FishStatJ (FSJ) landings for Croatia (FSR).

Further integrations and corrections were carried to all data. Correction procedure involved the reconstruction of landings of some species with a discontinued time series. For this purpose another reference time series is identified as a guiding series, whose trend will be translated to the reconstructing series. An overlapping point in time is identified between the two series, and the ratio between the landings is multiplied to the guiding time series to obtain the reconstructed one.

The validation and correction of landings data are fully reported in the deliverable D4.4.1 "Catches and fishing capacity by fleet segment and port". The processes including considering outliers ad extremes in the time series. The analysis of landing data also showed that different sources for a specific country and group can change considerably (Appendix A2). Since landing data might have problems due to underreporting of landings or different reporting methods, we decided to select the ecological worst case scenario and use the maximum landing values between different sources per country, per area and per group. Still, we assumed that there is some kind of fishing activity when there is even some reported value between 2004 and 2018. Often such values are very low, indicating occasional landings, and might happen that landings are unreported or the reporting wasn't detailed in certain timeframes. However, correct simulations in Ecosim requires that a functional group should be present in its initial conditions in Ecopath. For this purpose, we completed the time series of groups where some landings are reported, if necessary assigning missing initial or ending values and further interpolating the gaps.

Disaggregation of landings by fishing gear

The selected yearly total landings of groups per country and area (CAYG format, i.e. country, area, year, group) are disaggregated by adding details of fishing gear (F) and length segment (L). Details of proportions by fishing gear and length segment (CAFLYG format) are taken from additional datasets reported above. The disaggregation process followed a two step procedure since the reference disaggregated time series (CAFLYG format) do not have the same timeframe as the group's total landings per area, country and gear (CAYG format, 2004-2008). In the first step there are available data with corresponding years between yearly total landings (CAYG format) and disaggregated landing data in the CAFLYG format. In this case the same yearly proportions found in the disaggregated data are used to split the yearly total landing in the CAYG format. The second step deals when there is no correspondence between yearly total landings (CAYG format) and disaggregated landing data in the CAFLYG format, therefore no proportions are available for those years. In this case we used the whole dataset's average proportions of landings split by fishing gear and length segment and used the remaining years of yearly total landings (CAYG format) series. This completes the preparation of landings time series disaggregated by country, area, fishing gear, length segment year and group.

4.8 Discards

Discards were estimated using the available most recent declared discards in catch data (FDI, DCRF datasets), estimations from scientific surveys (MEDITS and SOLEMON) and discard estimates from field studies of commercial fishing activities in north Adriatic (SOSPECO project, Raicevich 2008) and commercial dredge of marine clams in Marche region, Italy (Morello et al., 2005). Reference landing data of each fleet segment (CAFLYG format) are provided from previous estimates, detailed by country, area, fishing gear, year and group (CAFYGx format). Time series of landing, discard and survey data between 2004 and 2018 are used for estimating discards.

Estimated discards (D_i) of each group coinsists of discard practices because of legal constrains (i.e., TL < MRCS) or because of non commercial value. In cases where the literature or data provided an estimate of discard ratio by gear and species (DLratio) the discards are calculated by multiplying the DL by the available estimates of landings by gear and species.

Discard ratios of both commercial and non-commercial species are estimated using the country, area, fishing gear, year and group resolution. We had detailed discard informations only for Italy and Croatia. However, there are no discard / landings ratios available for all countries or at CAFY resolution; therefore, the missing ratios are assigned from available D/L ratios. Specifically, Croatia's TBB fleet D/L ratios are taken from Croatia's DRB fleet. In Slovenia, in GNX, LLX, MIX, OTB, PS fleets D/L ratios are equivalent to Croatia's corresponding fleets, while the PTM fleet's D/L ratios are the same as Italy's PTM fleet. Discards ratio of the unique Bosnia and Hercegovina's fleet are assumed to be similar as discards of Croatian set net fleet (GNX). For Albania and Montenegro's unique fleets we assumed that their discards are similar to a combination of Croatia's otter trawler (OTB), set net (GNX) and long line (LLX) fisheries. The derived hybrid (HYB) discard ratios sums the the individual discard ratios of the three fleets weighted by their contribution to the cumulative landings.

Estimating discards for commercial species

Different sources are available for estimating the discards of commercial species: FDI, JRC and SOSPECO project (Raicevich et al., 2005). Catch series of FDI and JRC reported landings and discards per specie, fleet segment and year of Italy and Croatia. The logic behind the reconstruction of discards was to use as much as possible the official discard data reported in catch records, and integrate with other sources only when these data are not available.

A preliminary analysis of reported discards data highlights that Croatia's catch records mostly contain discard data, while Italian records are mostly not available or zero. A further analysis between FDI and JRC reported discards shows that for Italy JRC discards are generally lower than FDI and they match only in the most recent years (2016-2018). Contrary to Italy, the same analysis indicates the two sources generally show similar discard values for Croatia. Therefore, the discard estimates are done using the FDI reported catches as the basis for estimating commercial discards. Once reconstructed discards from 2015 to 2018 are further used to estimate the group's average discard to landing ratio used from 2004 to 2014.

The reconstruction of each country's discard during 2015-2018 is done using primarily their own data and using the discards that are reported. For all other missing data a stepwise procedure is adopted, using from the most detailed data to averages by year and area. The SOSPECO project discard estimates per specie or per group fill other missing data. Italy has more missing discard data than Croatia, therefore, to fill the discard ratios only Italian fleets within SOSPECO project are used. The Italian discard estimates are detailed for otter trawlers (OTB, 9 hauls), rapido trawlers targeting scallops and soles (TBB, 8 and 6 hauls respectively), mid-pelagic pair trawlers (PTM, 7 hauls) and hydraulic dredges (DRB, 4 hauls). From these data were estimated the discards for the moat important fleets represented in the model.

Discards for OTB for non-commercial species are estimated on the basis of general information on total discards (SOMFI,2020) combined with information on non commercial catches from scientific traw surveys (MEDITS and SOLEMON) and discard observations of commercial fishing (SOSPECO project, Raicevich et al., 2005; Morello et al. 2005).

For species with existing stock assessment (sardine, anchovy, sole, red mullet, hake, cuttlefish, mantis shrimp, Norway lobster, deep rose shrimp and caramonte prawn) the discards were considered from the data used in the stock assessment ad splitted into multistanza according to information on selectivity and catches.

For all functional groups we applied the discard mortality as in Table.

Table 6. Discard mortality rates by FG applied to the model.

Group	Discard mortality	Group	Discard mortality	Group	Discard mortality
G01_SBR	1	G27_LOP	1	G52_DPS1	1
G02_TTL	1	G28_PIL0	1	G53_TGS	1
G03_ODO	1	G29_PIL1	1	G54_REPs	0.5
G04_DBO	1	G30_ANE0	1	G55_REPh	0.5
G05_DST	1	G31_ANE1	1	G56_NATs	1
G06_FIW	1	G32_SOL0	1	G57_NATh	1
G07_BATs	0.25	G33_SOL1	0.9	G58_SBT	1
G08_BATh	0.25	G34_SOL2	0.9	G59_CLM	0.005
G09_SELs	0.25	G35_MUT0	1	G60_SCL	1
G10_SELh	0.25	G36_MUT1	1	G61_BIX	0.5
G11_SHO	0.25	G37_HKE0	1	G62_SGR	1
G12_PLS	1	G38_HKE1	1	G63_SWD	1
G13_PMS	1	G39_HKE2	1	G64_JLY	1
G14_DPSs	1	G40_CPXs	1	G65_ZMA	1
G15_DPSh	1	G41_CPXh	1	G66_ZME	1
G16_EPI	1	G42_SQD	1	G67_ZMI	1
G17_MCF	1	G43_CTC	1	G68_BPL	1
G18_ZJF	1	G44_OCM	1	G69_PDM	1
G19_DEMs	1	G45_MTS0	1	G70_PDF	1
G20_DEMh	1	G46_MTS1	1	G71_DSC	1
G21_FLX	0.9	G47_NEP0	1	G72_POM	1
G22_FTB	0.9	G48_NEP1	1	G73_BTD	1
G23_GUR	1	G49_ARA	1		
G24_GDX	1	G50_ARS	1		
G25_SPX	1	G51_DPS0	1		

5 Balancing and Adjustments and PREBAL diagnostic

Initially, the Adriatic and Ionian models were not balanced mostly due to several EE values higher than 1 in different FGs. The models were manually balanced adopting a top–down approach (Mackinson & Daskalov, 2007) consisting of slight modifications to the production and consumption rates following the accepted range for the net food conversion efficiencies (production/consumption (P/Q) [0.05–0.3] for all finfish and <1 for all functional groups), respiration/assimilation (R/A [<1]), and production/respiration (P/R [<1]) ratios (Christensen et al., 2008), the slope of the biomass (on a log scale) should be in an order of approximately 5-10% decline with increasing trophic level, production/biomass (P/B) and consumption/biomass (Q/B) should also decline with increasing trophic levels (with exclusion of homeotherms) (Heymans et al., 2016).

Successively, a check of biomass values were carried out on the biomass data sources and catchability values. When the F mortality estimated for a group resulted higher than its P/B value, the biomass, landings and discard data were checked and adjusted to balance the group. Similarly, the excess of Predation mortalities on the P/B of a group were balanced by the correction of the diet values. The pre-balancing analysis (PREBAL, Link, 2010) was carried out to assess the coherence of the input data with the basic thermodynamic laws, rules, and principles of ecosystem ecology at the system level (Heymans et al., 2016).

Multiple groups showed variance from the trendline, whilst the mammals and seabirds show the largest divergence, their biological and behavioural differences as homeotherms tend to exempt them from many of the PREBAL ecological rules of thumb (Link, 2010). Seabirds showed noticeably biomass below the slope line due to their relatively light body mass.

The models were built using the same structure (same functional groups) in order to compare them and combined them to represent the entire Adriatic Sea. Therefore, in both GSAs there are functional groups that are not well represented in this ecosystem. These groups, indicated in the PREBAL figures, showed low biomasses in the PREBAL diagnostic (GSA 19: G22_FTB, G32_SOL0, G33_SOL1, G34_SOL2, G45_MTS0, G46_MTS1, G47_NEP0, G48_NEP1, G53_TGS – Figure?; GSA 1718: G02_TTL, G03_ODO, G05_DST, G06_FIW, G49_ARA – Figure ?).

Biomasses spanned over 7 and 8 orders of magnitude in GSA 17&18 and GSA 19 respectively. Biomass, on a logarithmic scale, declines over five trophic levels within the suggested ecological range (Link, 2010) by 6.9% in GSA1718 and 8.4% in GSA19 (Figures).

Production rates (P/B), on a logarithmic scale, showed decreasing trends below the ranges suggested (Link, 2010) for GSA 17&18 with declines of 3.9% whilst P/B declined of 5% in GSA 19.

Consumption rates (Q/B), on a logarithmic scale, showed decreasing trends below the ranges suggested for GSAs with declines of 2.9% and 3.3% for GSA 1718 and GSA 19 respectively.

On the balanced model, model production over consumption ratios (P/Q) and of course Ecotrophic efficiencies (EEs) met the criteria (Table). Top-predators had very little predation mortality and showed low EE. Low EE were also observed for phytoplankton groups as part of the production might be dispersed outside of the model domain and not consumed by zooplankton predation. Jellyfish feeding fish (G18_ZJF) in GSA 19 have a low EE as little is known regarding their predators. Similarly, for jellyfish (G64_JLY) in GSA17&18 low consumption by predators determined a low EE. The scallops (G60_SCL) in GSA17&18 also have low EEs as little is known regarding their predators.

When the model was balanced across all functional groups, a further correction was applied in order to balance the fluxes to detritus. In order to avoid overaccumulation of detritus or to represent exaggerated export of bottom detritus as leakage or outflow, the export of part of the plankton production was proferred. This was carried out setting emigration rates for the low trophic level groups (from pico-phytoplankton to large-zooplankton). The rates were calculated offline in order to balance the excess of fluxes to detritus by these low trophic level groups. The exports were set in order to achieve a balance between flows to detritus groups and consumption flows from detritus groups.

Table 7. PREBAL criteria used in the balancing of the models for the GSA17-18 and GSA19.

PREBAL criteria	GSA 1718	GSA19
The range of biomass should span 5-7 orders of magnitude.	Biomass range spans 7 orders of magnitude.	Biomass range spans 8 orders of magnitude.
The slope of biomass (on a log scale) should be in the order of approx. 5-10% decline with increasing trophic level.	6.9 % decline (Figure?) Groups excluded from the slope calculation as not represented in GSA 1718: G02_TTL, G03_ODO, G05_DST, G06_FIW, G49_ARA).	8.4% decline (Figure?) Seabirds (G01_SBR) and turtles (G02_TTL) have biomass below the expected trends. Groups excluded from the slope calculation as not represented in GSA 19: G22_FTB, G32_SOL0, G33_SOL2, G34_SOL2, G45_MTS0, G46_MTS1, G47_NEP0, G48_NEP1, G53_TGS, G59_CLM, G60_SCL.
P/B ratio should decline with increasing trophic level (this rule excludes homeotherms).	3.9% decline (Figure?) Excluding homeotherm top-predators odontocetes (G03_ODO), common bottlenose dolphin (G04_DBO), striped dolphin (G05_DST), fin whale (G06_FIW) and turtles (G02_TTL), that are also groups little represented in the GSA1718. G59_CLM and G60_SCL also showed lowed P/B values than expected. Zooplankton (G65_ZMA, G66_ZME and G67_ZMI) and jellyfish (G64_JLY) showed higher P/B than expected.	5% decline (Figure?) Excluding homeotherm top-predators odontocetes (G03_ODO), common bottlenose dolphin (G04_DBO), fin whale (G06_FIW), striped dolphin (G05_DST) and turtles (G02_TTL), only zooplankton (G65_ZMA, G66_ZME and G67_ZMI) and jellyfish (G64_JLY) showed higher P/B than expected.

PREBAL criteria	GSA 1718	GSA19
Q/B should decline with increasing trophic level (this rule excludes homeotherms).	2.9% decline; see figure The slope is smaller than expected due to low Q/B of G59_CLM and G60_SCL. Primary consumers jellyfish (G64_JLY) and zooplankton (G65_ZMA, G66_ZME and G67_ZMI) also showed high Q/B values and a large number of groups showed high variability above and below the expected ranges.	3.3% decline (Figure?) The slope is smaller than expected due to high Q/B odontocetes (G03_ODO), common bottlenose dolphin (G04_DBO) and striped dolphin (G05_DST). Primary consumers jellyfish (G64_JLY) and zooplankton (G65_ZMA, G66_ZME and G67_ZMI) also showed high Q/B values and a large number of groups showed high variability above and below the expected ranges.
P/Q should fall between 0.1 and 0.3 for all finfish and <1 for all functional groups.	Criteria met (Figure?) Top-predators that showed P/Q values <0.1 (Seabirds (G01_SBR), turtles (G02_TTL), odontocetes (G03_ODO), common bottlenose dolphin (G04_DBO), striped dolphin (G05_DST)) there are also some juvenile groups that showed lower values than expected indicating the necessity of better assessing the stanza-groups. *Galeus melastomus* (G11_ SHO) also showed P/Q values <0.1.	Criteria met (Figure?) Top-predators that showed P/Q values <0.1 (Seabirds (G01_SBR), turtles (G02_TTL), odontocetes (G03_ODO), common bottlenose dolphin (G04_DBO), striped dolphin (G05_DST)) there are also some juvenile groups that showed lower values than expected indicating the necessity of better assessing the stanza-groups.
EE should be <1 for all functional groups	Criteria met (Figure?)	Criteria met (Figure?)

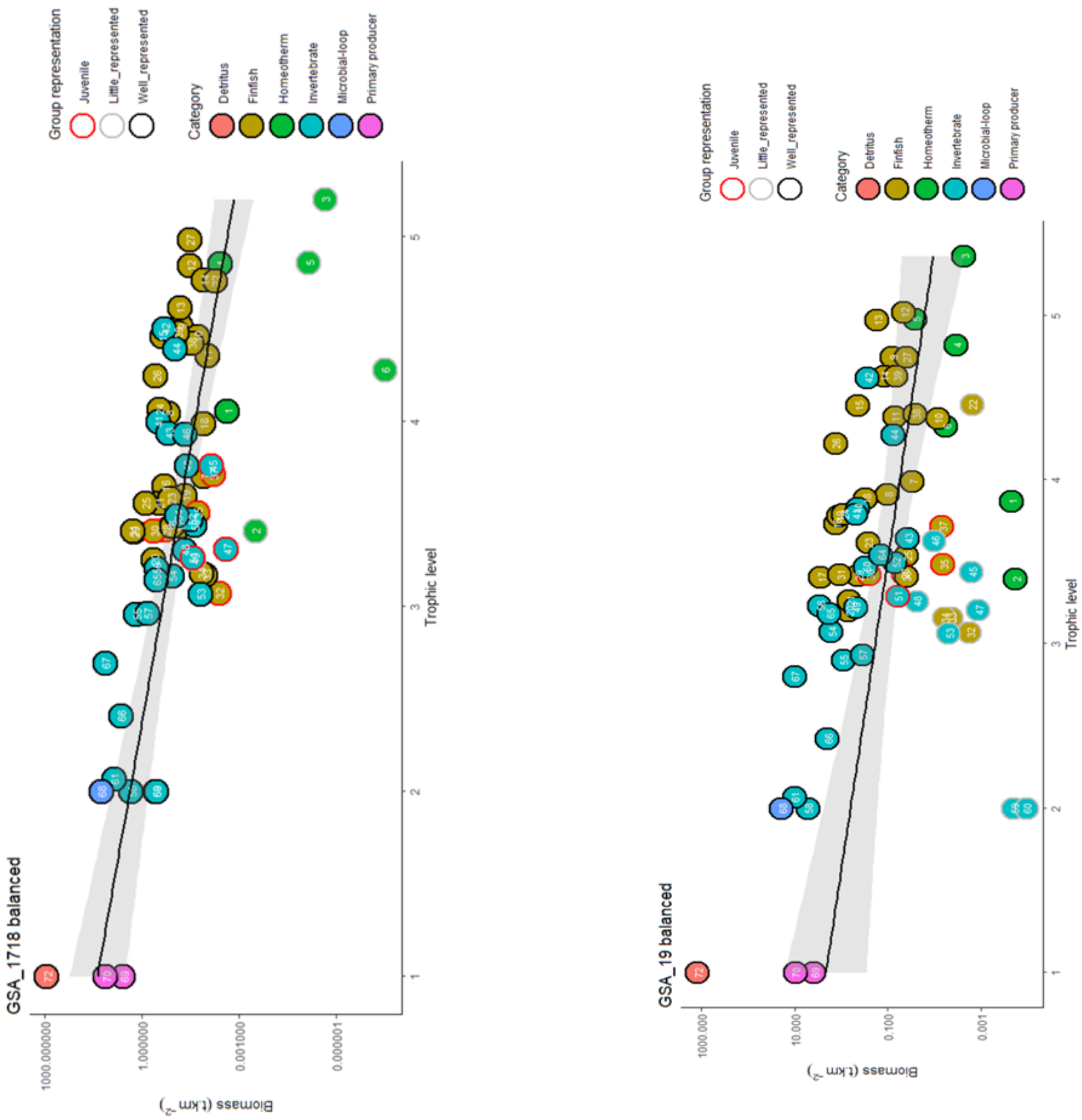


Figure 2. Declining biomass with increasing trophic level. Line is linear regression of biomass and trophic level, grey bands represent S.E. Numbers indicated functional group ID, circles with black outline represent functional groups "well represented", grey outline "little represented" and red outline "juvenile stages". Colours represent groups categories.

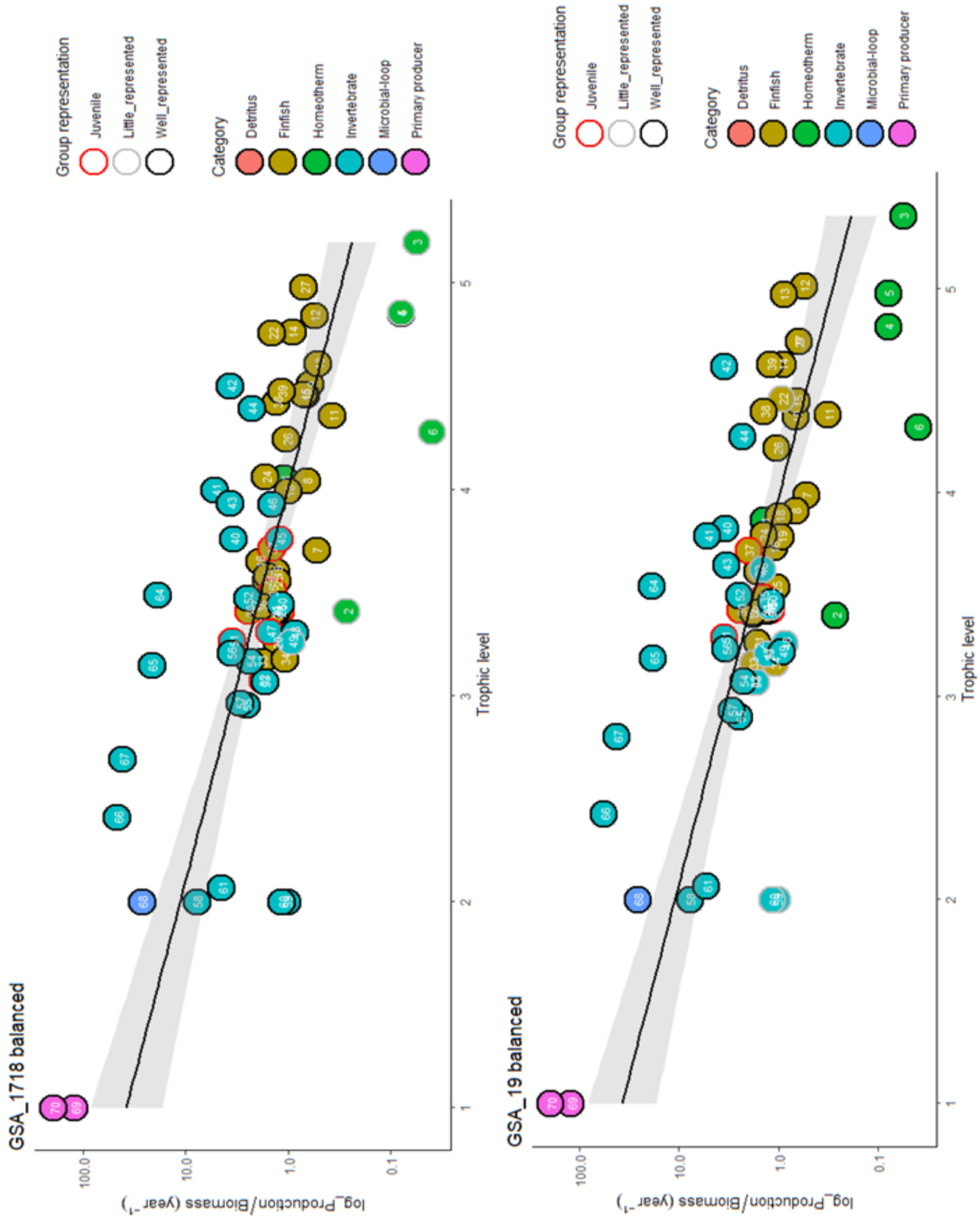


Figure 3. Declining production/biomass ratio (P/B) with increasing trophic level. Line is linear regression of P/B and trophic level, grey bands represent S.E. Numbers indicated functional group ID, circles with black outline represent functional groups "well represented", grey outline "little represented"and red outline "juvenile stages". Colours represent groups categories.

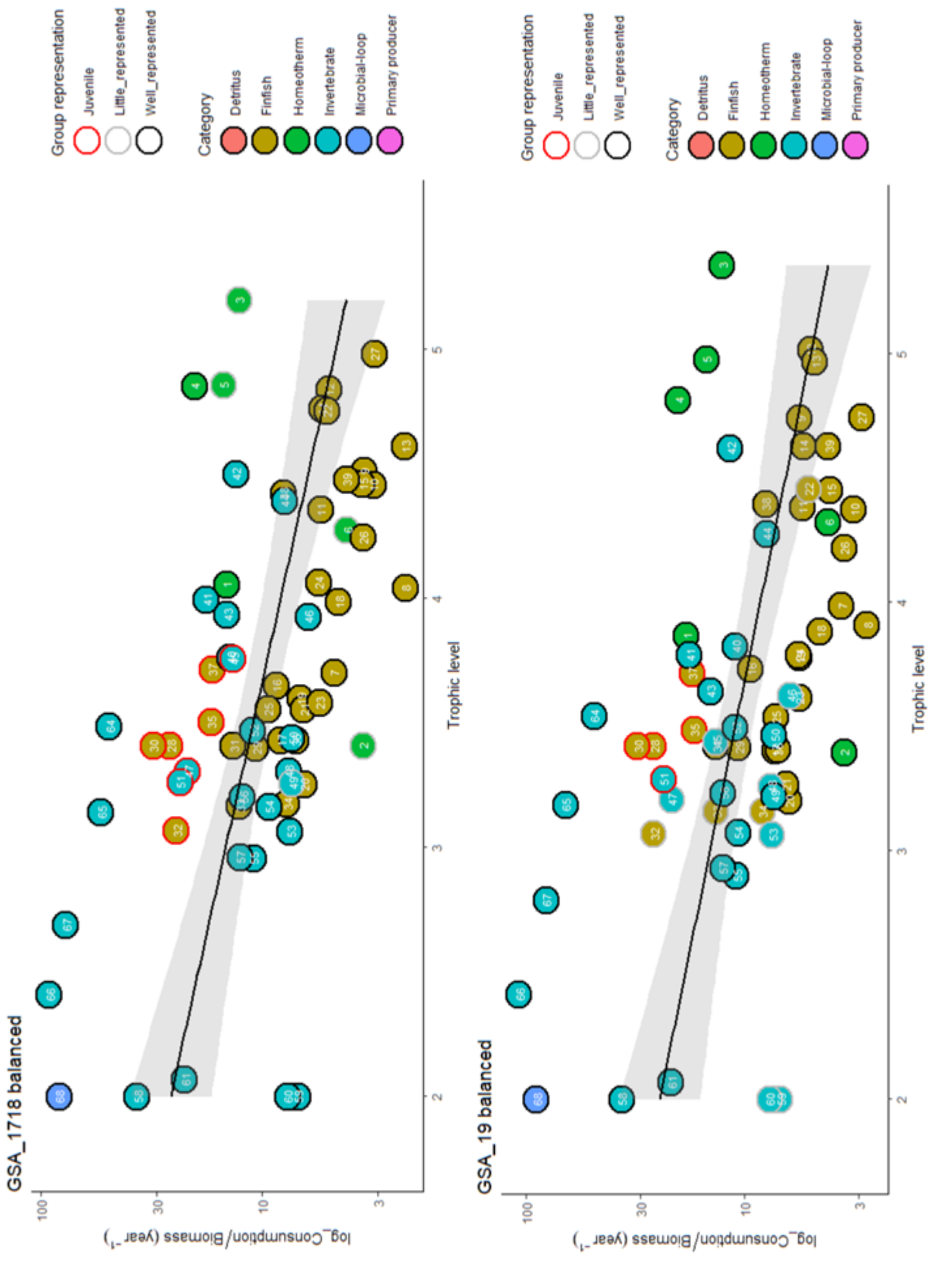


Figure 4. Declining consumption/biomass ratio (Q/B) with increasing trophic level. Line is linear regression of Q/B and trophic level, grey bands represent S.E. Numbers indicated functional group ID, circles with black outline represent functional groups "well represented", grey outline "little represented" and red outline "juvenile stages". Colours represent groups categories.

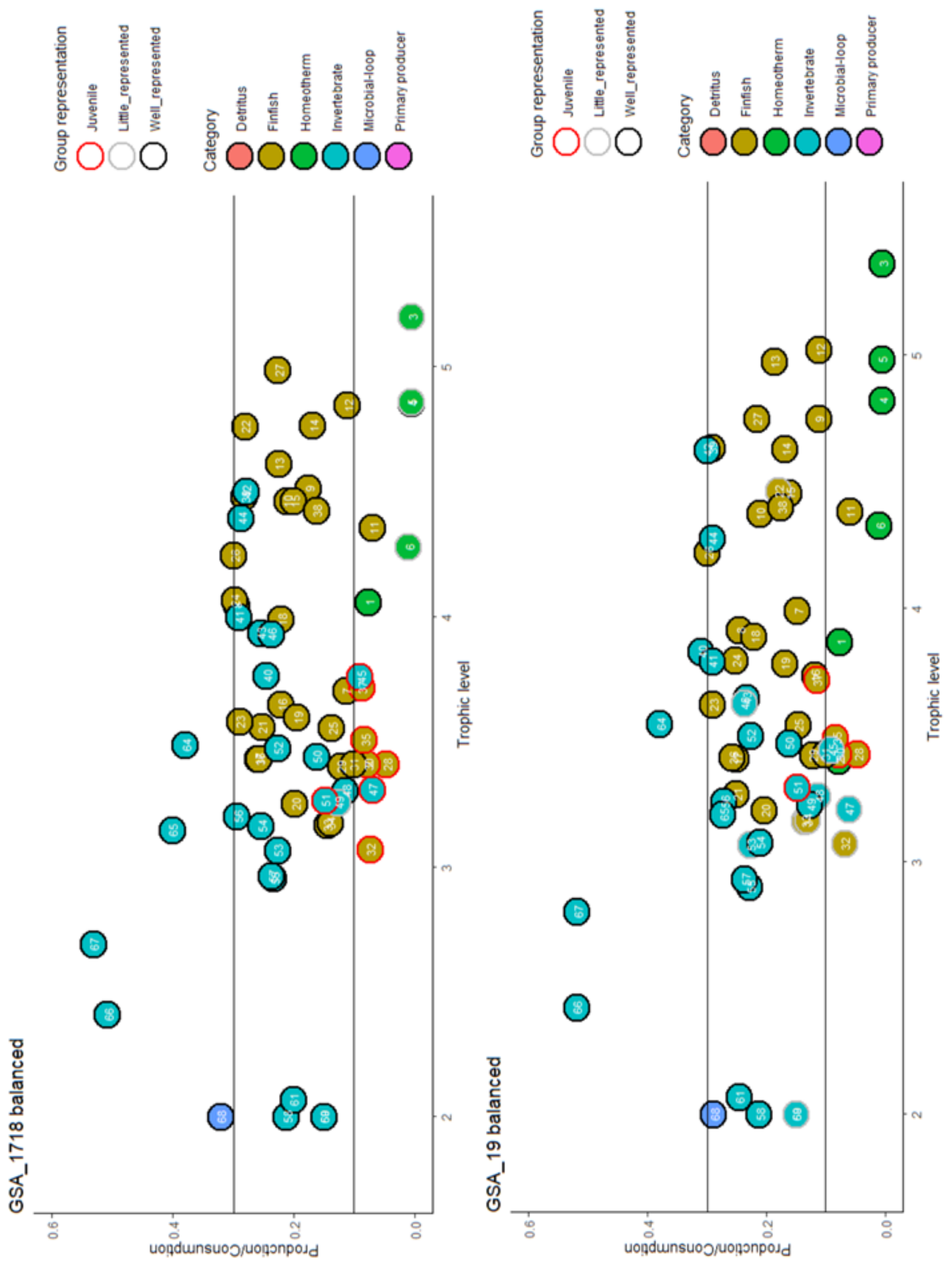


Figure 5. Production/consumption (P/Q) values with increasing trophic level. Horizontal lines represent the advised ecological limits of P/Q. Numbers indicated functional group ID, circles with black outline represent functional groups "well represented", grey outline "little represented" and red outline "juvenile stages". Colours represent groups categories.

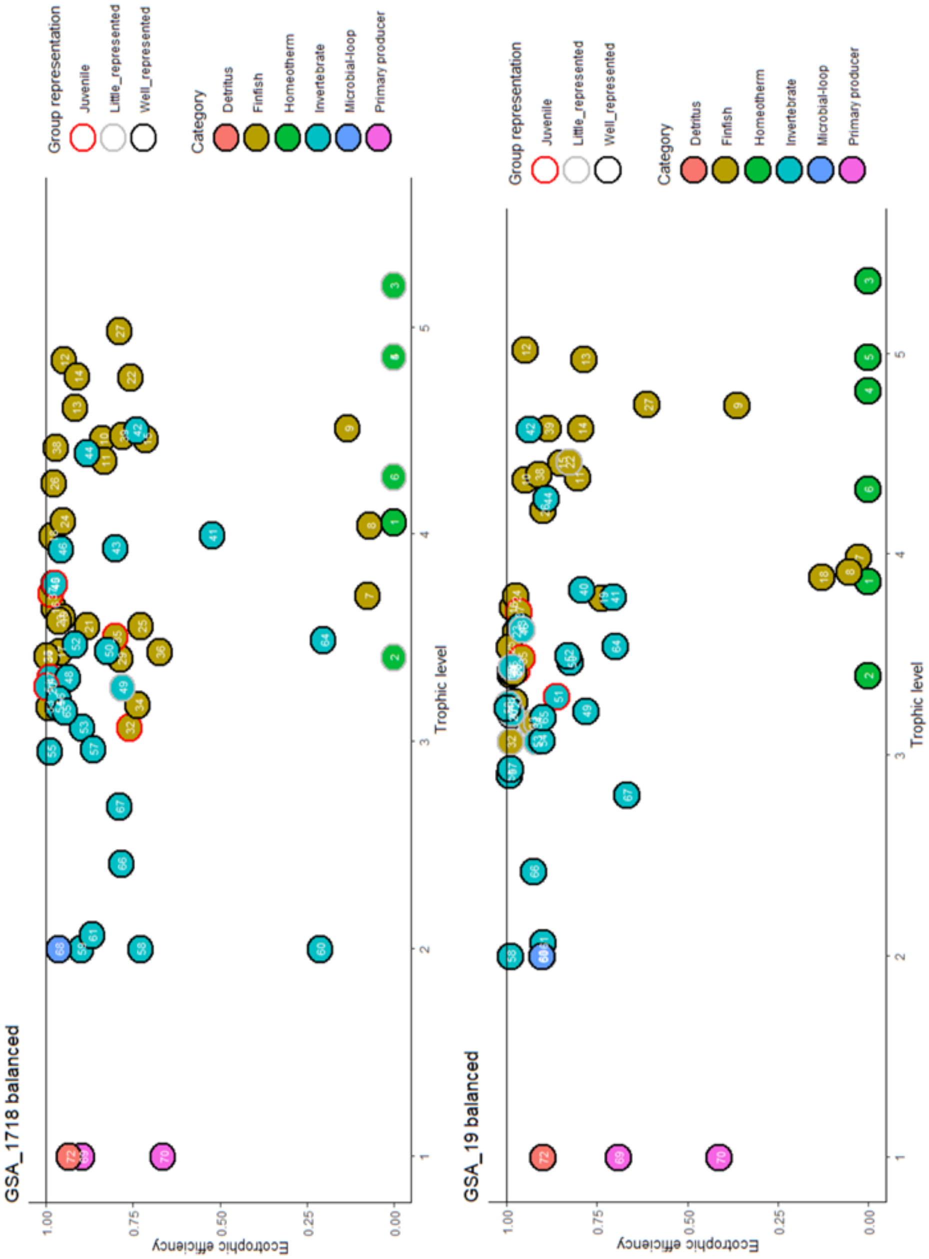


Figure 6. Ecotrophic efficiency (EE) values of the balanced model all below 1 (horizontal line) for all trophic levels. Numbers indicated functional group ID, circles with black outline represent functional groups "well represented", grey outline "little represented" and red outline "juvenile stages". Colours represent groups categories.

6 Fitting Ecosim models

6.1 Dynamic Food web modellig: Ecosim

Ecosim simulates the temporal changes of several Ecoptah parameters such as biomasses, catches, discards, predation mortalities, species consumptions etc. driven by a temporal ecosystem drivers that can be represented by fishing activities and environmental changes such as primary productivity and water temperature.

The ecosystem model describes the time course of state variables (Table X) based on the assumptions commonly made using the Ecopath with Ecosim software (EwE v6.6.5; www.ecopath.org; Christensen et al., 2008). The 73 state variables represent biomasses (in wet weigh, t km-2) of 66 consumers (eq. 2), 4 primary producers (eq. 3) and 3 non-living compartments (eq. 4) that include fishery discards (in t km-2 y-1).

Table x. Equations of the state variables of the time dynamic model for consumers (eq.2), producers (eq. 3) and non-living/detritus groups (eq. 4).

(2)	$\frac{dB_i(t)}{dt} = \gamma_i \cdot \sum_{j=1}^{N} Q_{ji}(t) - \sum_{j=1}^{N} Q_{ij}(t) + I_i - (M_i + e_i) \cdot B_i(t) - \sum_{g=1}^{G} \left[F_{ig}^{m}(t) + F_{ig}^{d}(t)\right] \cdot B_i(t)$
(3)	$\frac{dB_i(t)}{dt} = PP_i(t) \cdot B_i(t) - \sum_{j=1}^{N} Q_{ij}(t) + I_i - (M_i + e_i) \cdot B_i(t)$
(4)	$\frac{dD_i(t)}{dt} = \sum_{j=1}^{N} \left[\delta_{ji} \cdot \left(M_j \cdot B_j(t) + u_j \sum_{k=1}^{N} Q_{kj}(t)\right)\right] + \sum_{g=1}^{G} \left(\delta_{gi} \cdot \sum_{j=1}^{N} F_{jg}^{d}(t) \cdot B_j(t)\right) - \sum_{j=1}^{N} Q_{ij}(t)$

B_i	Biomass of functional group *i*.
D_i	Mass of detritus compartment of group *i*. Might be used by the scavengers of the food web.
Υ_i	Growth efficiency, $\Upsilon_i=1-(r+u)$, where *r* is the respiration rate and *u* the unassimilation of food.
Q_{ji}	Consumptions of group *i* over all of its preys *j*.
Q_{ij}	Predation on group *i* by all of its predators *j*.
I_i	Immigration.
M_i	Non-predatory natural mortality.
e_i	Emigration rate of group *i*.
F_{ig}	Fisheries mortality induced by each gear *g* through marketable catches ($C^m{}_i = F^m{}_{ig} B_i$) and discards ($C^d{}_i = F^d{}_{ig} B_i$).
PP_i	Primary production rate for autotroph group *i*.
δ_{ji}	Detritus fate parameter, the flow of detritus produced by a consumer group *j* (unassimilated food $u_i \sum Q_{ji}$ and natural mortalities $M_i B_i$) to detritus group *i*.
δ_{gi}	Discard fate parameter, the flow of dead discards by gear *g* to detritus group *i*.

6.2 Ecosystem drivers: primary productivities and fishing efforts

6.2.1 Primary productivity by phytoplankton

In the model phytoplankton primary producers were represented by diatoms (functional group G69_PDM) and dinoflagellates (functional group G70_PDF). Monthly biomasses of these groups were extracted from Copernicus biogeochemical model (deliverable D4.2.1 “Production patterns in the Adriatic Sea”) for the same temporal and spatial domains and used to calculate forcing functions to drive the ecosystem primary productivity in Ecosim. Annual averages forcing functions were also calculated and used for driving ecosystem productivity over time.

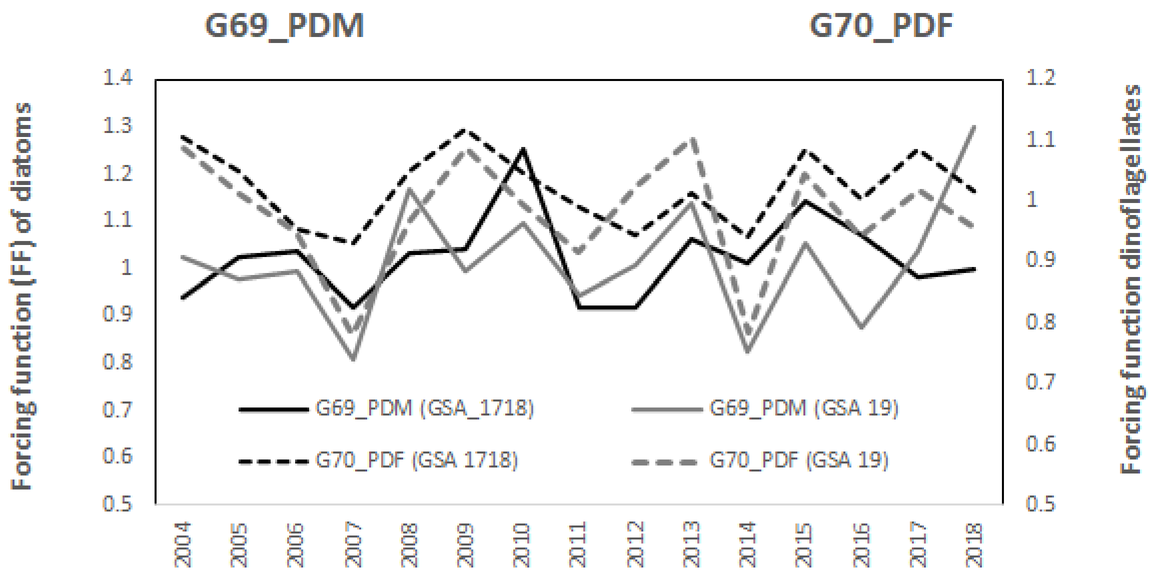


Figure 7. Changes in the primary production used in the two food web model developed.

6.2.2 Fishing effort

The fishing effort is a measure of the amount of fishing fleet’s activity exerted I a certain amount of time. In several instances, the catches are assumed to be linearly dependent from biomass at sea of the exploited species and the effort exerted to catch them, i.e., catches are proportional to its fishing effort . Fishing effort, as a forcing driver, is applied relatively indicating the relative fishing activity compared to the effort at the beginning of the simulation. The time series of the fishing effort cover the whole duration of the simulations (2004-2018).

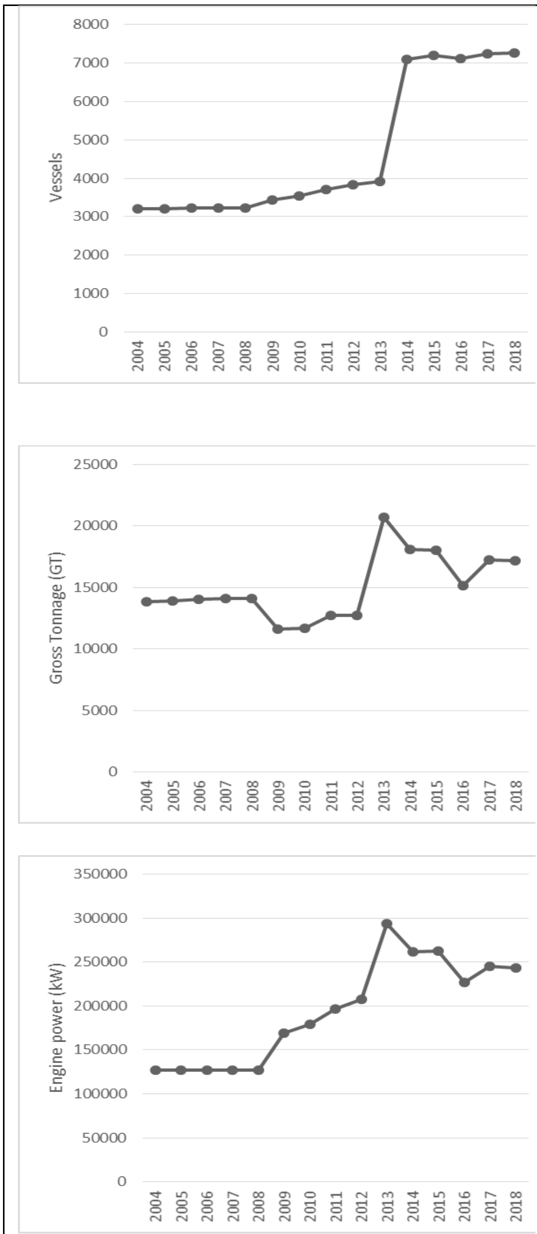
Obtaining an exhaustive time series for fishing effort is not a straightforward task, as there are different sources for this driver that can be used as a proxy (total fishing days, total engine power, total number of vessels, overall vessel length and satellite-based Vessel Monitoring System (*VMS*)): within these sources data may be unavailable, showing gaps and inconsistencies in time series. Therefore a combination of data across different sources might be used to create the forcing function of fishing effort. The differences in fishing fleets, the properties of the gears used and their management need to be considered in order to build a time series of fishing effort that can be used as a temporal driver in Ecosim.

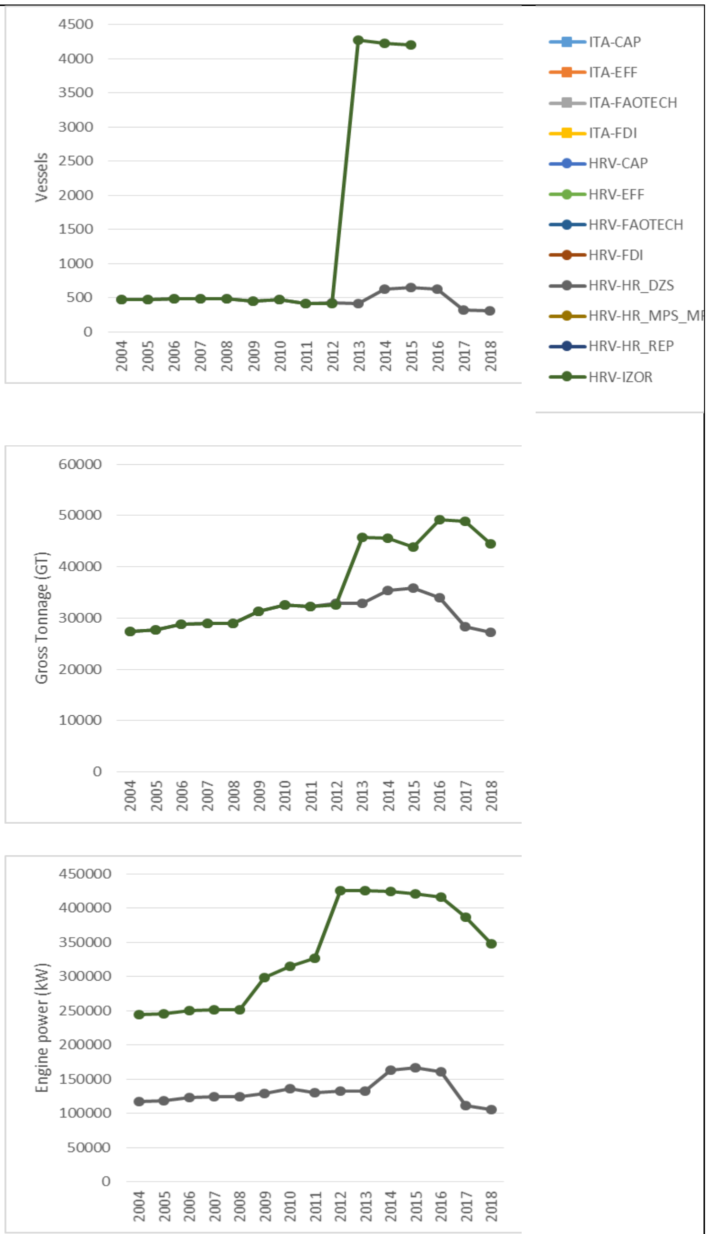
Italy (ITA) and Croatia (HRV) have the largest and most relevant fishing fleets in the Adriatic Sea and have been given a focus when analysing the fishing capacity and fishing effort. Available sources for Italy's fishing fleet came from Mably and Fisher Dependent Information data call (Table). Several data sources were used for Croatia's fleet capacity and effort data calls, FAO's spatial effort data, Croatian Bureau of Statistic, Croatian Ministry of Agriculture fishery management plans, annual fleet report for EU and repository available at the Institute of Oceanography and Fisheries (Table). An additional fishing effort measure comes from Vessel Monitoring System (VMS) analysis conducted in FAIRSEA activity 4.5 (Deliverable 4.5.1).

An exploratory analysis by fishing gear and country was conducted for Italy and Croatia to compare the trends of the fishing capacity and effort. Among different measures of fishing capacity we selected four: number of vessels, total gross tonnage (GT), total engine power (kW) and a displacement index (LOA^3), and one measure for fishing effort: fishing days (FD). The individual detailed fleet we grouped by fishing gear according to the fleet grouping specifications of the model. Further the different fleet length segments were grouped according to fleet specifications of the models.

In the Adriatic sea (GSA17 & 18) the results indicate a general reduction trend of the fishing fleet capacity (Figures). According to the data, Italy has a marked reduction of its fishing fleet, while Croatia's fleet shows some mixed trends. The dredge boats fleet (DRB) in Italy maintained a similar number of fishing vessels and other capacity indicators as in 2004 and had only a reduction of the fishing effort (Figure). In Croatia, on the contrary, there is an increase of all indicators from 2012 to 2015, followed by a decrease (Figure). All passive gears in Italy, namely set nets (GNX), long lines (LLX) and mixed and other fishing gears (MIX), show a reduction in both fishing capacity and effort (Figure). The trend of passive gears in Croatia is not clearly identifiable, showing stable values between 2012 and 2018 (Figure). Otter trawlers (OTB) show a constant trend of decreasing the fishing fleet and halving its fishing effort In Italy. Although indicators of capacity and effort for otter trawlers in Croatia are discontinued between the different sources, they seem to indicate a relatively stable fishing fleet (Figure). The purse seines (PS) in Italy show the biggest reduction of the fishing effort although the capacity indicators show a stable situation, with a short increase observed between 2004 and 2009. Croatian purse seiners seem to show a trend of increase in number of vessels between 2008 and 2012, followed by a stable fleet and a reduction in 2016-18. However the fishing effort of Croatian purse seines indicate a relatively similar level of fishing effort, with its minimum in 2015, and a constant reduction since 2015 (Figure). Mid-water pair pelagic trawlers (PTM) are only present in Italy, and both the fishing capacity and the effort show a constant decreasing trend (Figure). A decreasing trend of both fishing capacity The fleet of rapido trawlers (TBB) in Italy has a decreasing trend of fishing capacity indicators until 2014, followed by a recovery in following years and a final increase in 2018 (Figure).

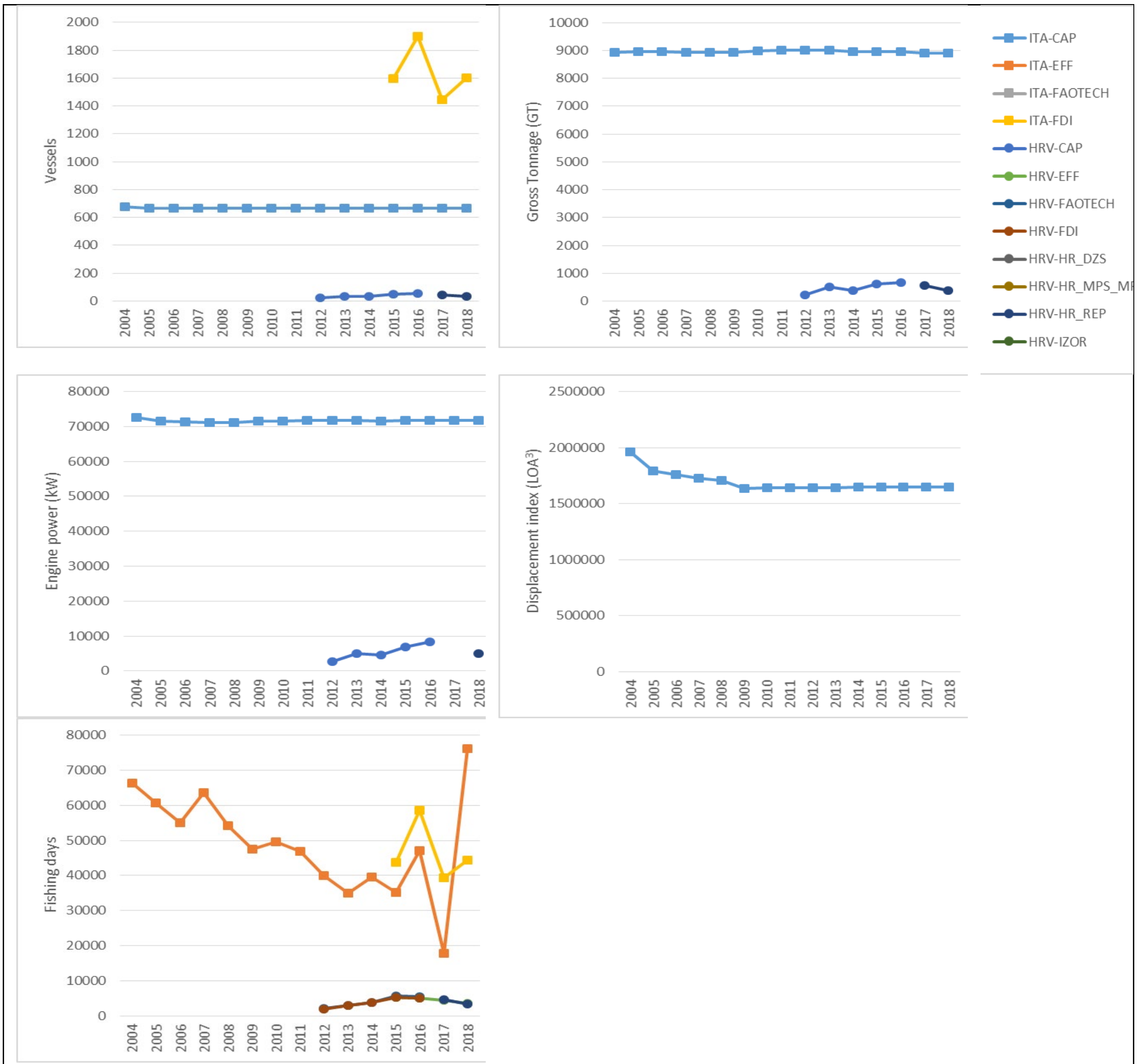
The analysis of fishing effort based on VMS data indicates a completely different trend of the different fleets activity when compared to reported data of fishing capacity and fishing effort. There is a general increasing trend of measured fishing effort from 2008 on, and only in the last three years (2016-18) stabilizes at a certain level.



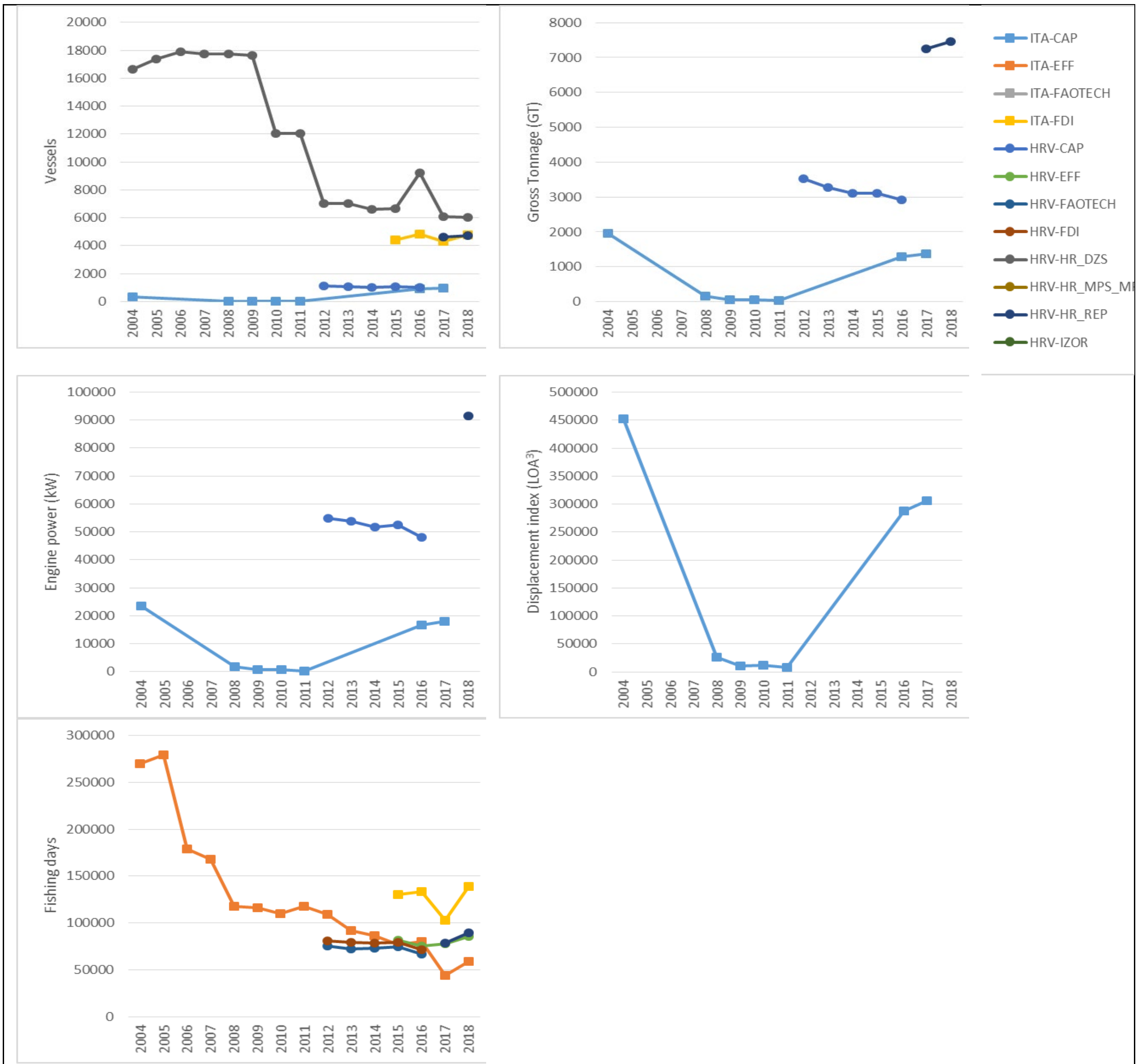


Croatian total fleet smaller than 15 m LOA (VL—15)

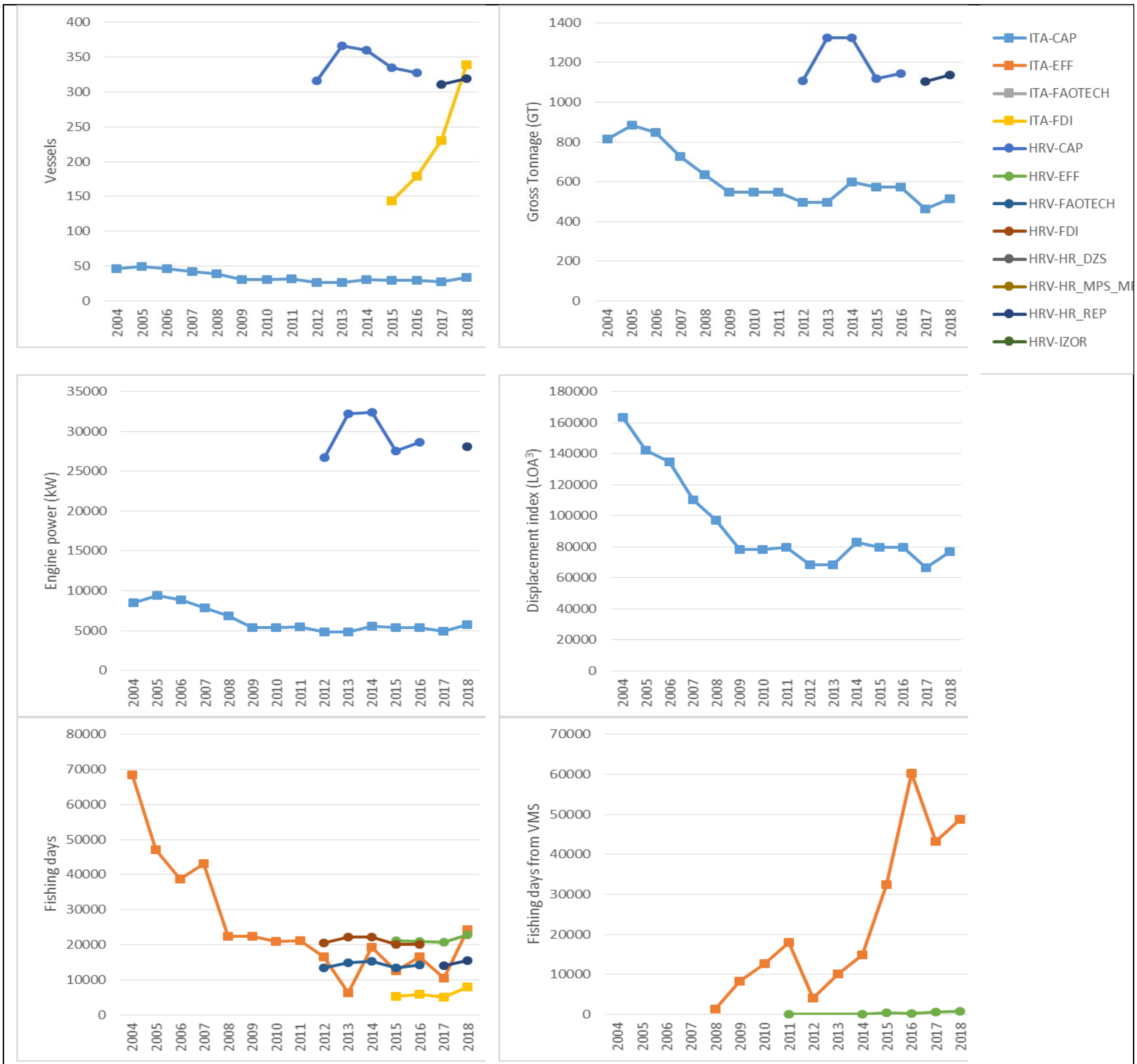
Croatian total fleet larger than 15 m LOA (VL15++)



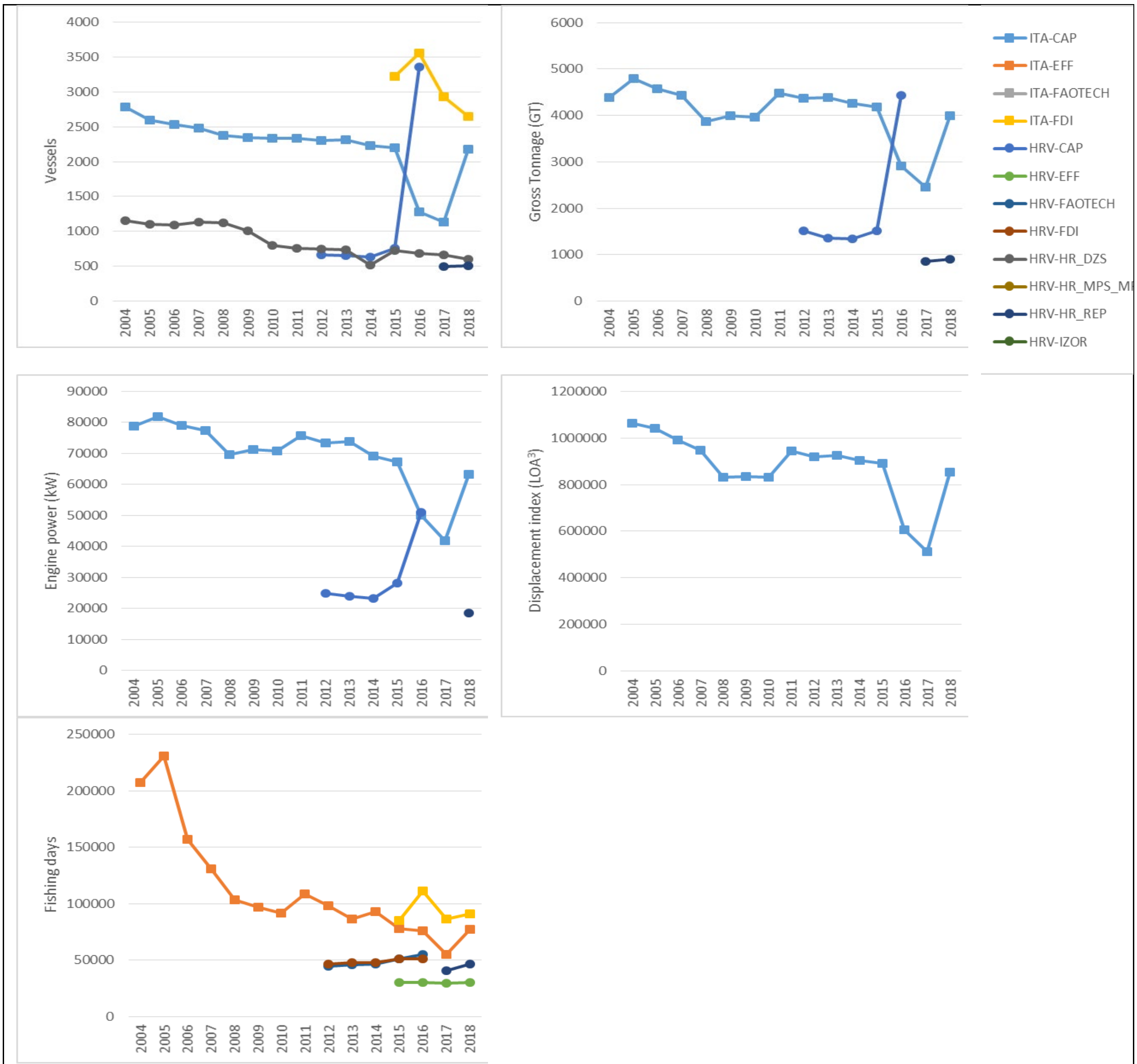
Trend of fishing capacity and fishing effort of dredge boats (DRB) for Italy (ITA) and Croatia (HRV) in GSA 17 & 18. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA³); Fishing effort: fishing days from reports. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call, HRV-CAP – Croatian capacity data call, HRV-EFF – Croatian fishing effort data call and VMS data, HRV-FAOTECH – Croatian FAO spatial effort data, ITA-FDI – Croatian FDI data call, HRV-HR_DZS – Croatian department of statistics (DZS), HRV-HR_MPS_MP – Croatian Ministry of Agriculture (MPS) fishery management plans, HRV-HR_REP – Croatian annual EU fleet report, HRV-IZOR – Data from IZOR repository (http://baltazar.izor.hr/azopub/bindex).



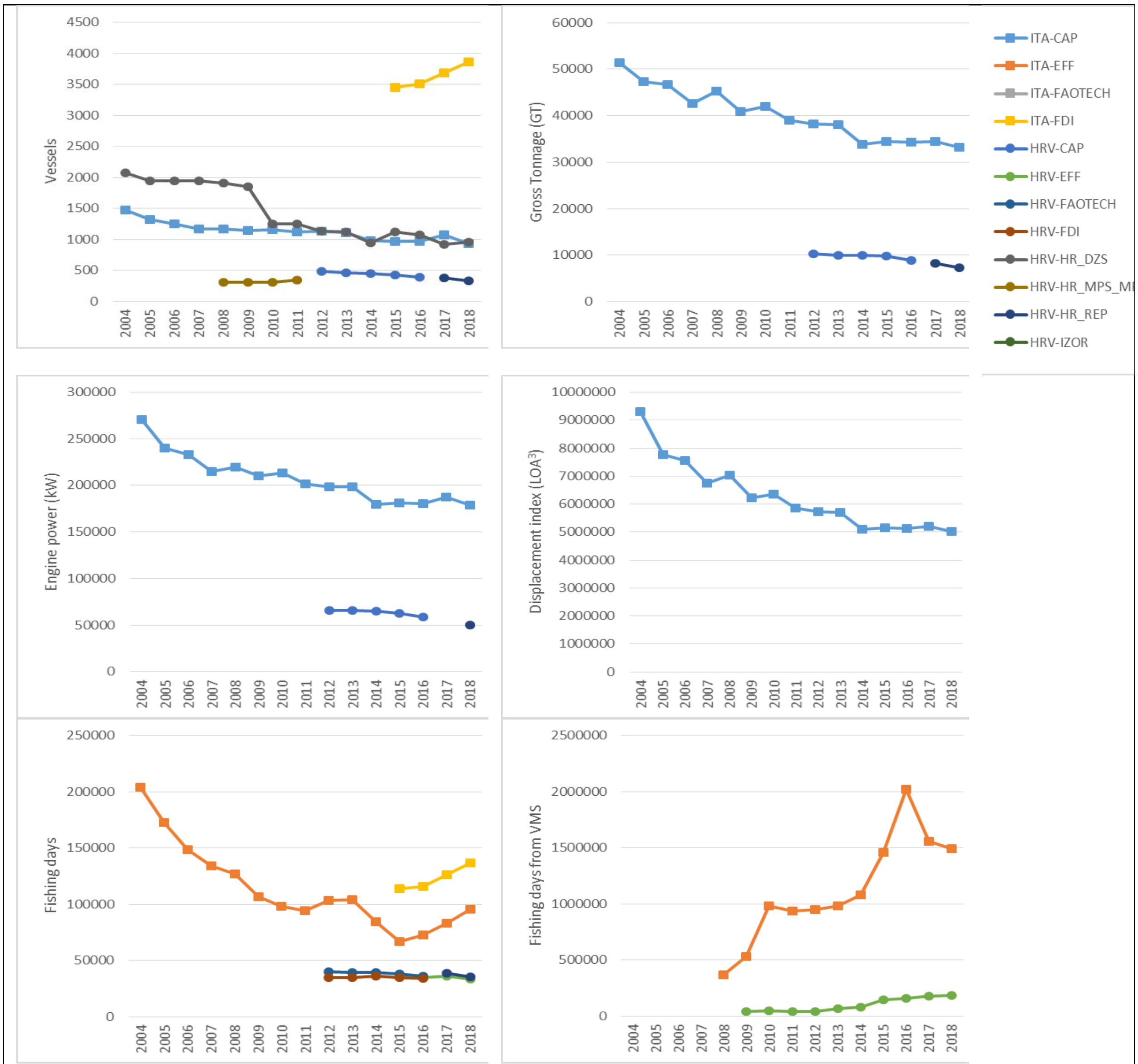
Trend of fishing capacity and fishing effort of set nets (GNX) for Italy (ITA) and Croatia (HRV) in GSA 17 & 18. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA³); Fishing effort: fishing days from reports. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call, HRV-CAP – Croatian capacity data call, HRV-EFF – Croatian fishing effort data call and VMS data, HRV-FAOTECH – Croatian FAO spatial effort data, ITA-FDI – Croatian FDI data call, HRV-HR_DZS – Croatian department of statistics (DZS), HRV-HR_MPS_MP – Croatian Ministry of Agriculture (MPS) fishery management plans, HRV-HR_REP – Croatian annual EU fleet report, HRV-IZOR – Data from IZOR repository (http://baltazar.izor.hr/azopub/bindex).



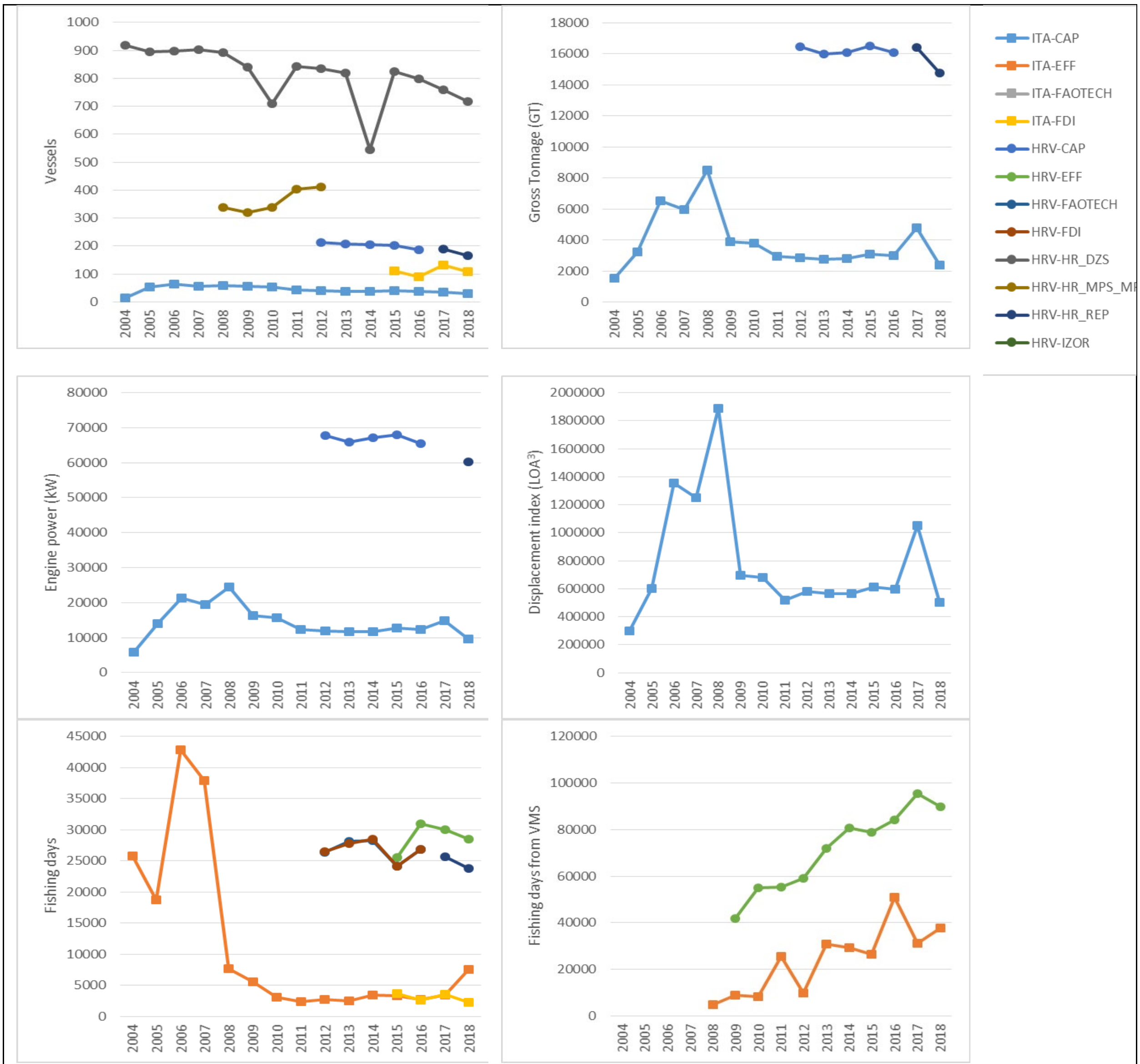
Trend of fishing capacity and fishing effort of long lines (LLX) for Italy (ITA) and Croatia (HRV) in GSA 17 & 18. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA³); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call, HRV-CAP – Croatian capacity data call, HRV-EFF – Croatian fishing effort data call and VMS data, HRV-FAOTECH – Croatian FAO spatial effort data, ITA-FDI – Croatian FDI data call, HRV-HR_DZS – Croatian department of statistics (DZS), HRV-HR_MPS_MP – Croatian Ministry of Agriculture (MPS) fishery management plans, HRV-HR_REP – Croatian annual EU fleet report, HRV-IZOR – Data from IZOR repository (http://baltazar.izor.hr/azopub/bindex).



Trend of fishing capacity and fishing effort of mixed and other fishing gears (MIX) for Italy (ITA) and Croatia (HRV) in GSA 17 & 18. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA³); Fishing effort: fishing days from reports. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call, HRV-CAP – Croatian capacity data call, HRV-EFF – Croatian fishing effort data call and VMS data, HRV-FAOTECH – Croatian FAO spatial effort data, ITA-FDI – Croatian FDI data call, HRV-HR_DZS – Croatian department of statistics (DZS), HRV-HR_MPS_MP – Croatian Ministry of Agriculture (MPS) fishery management plans, HRV-HR_REP – Croatian annual EU fleet report, HRV-IZOR – Data from IZOR repository (http://baltazar.izor.hr/azopub/bindex).

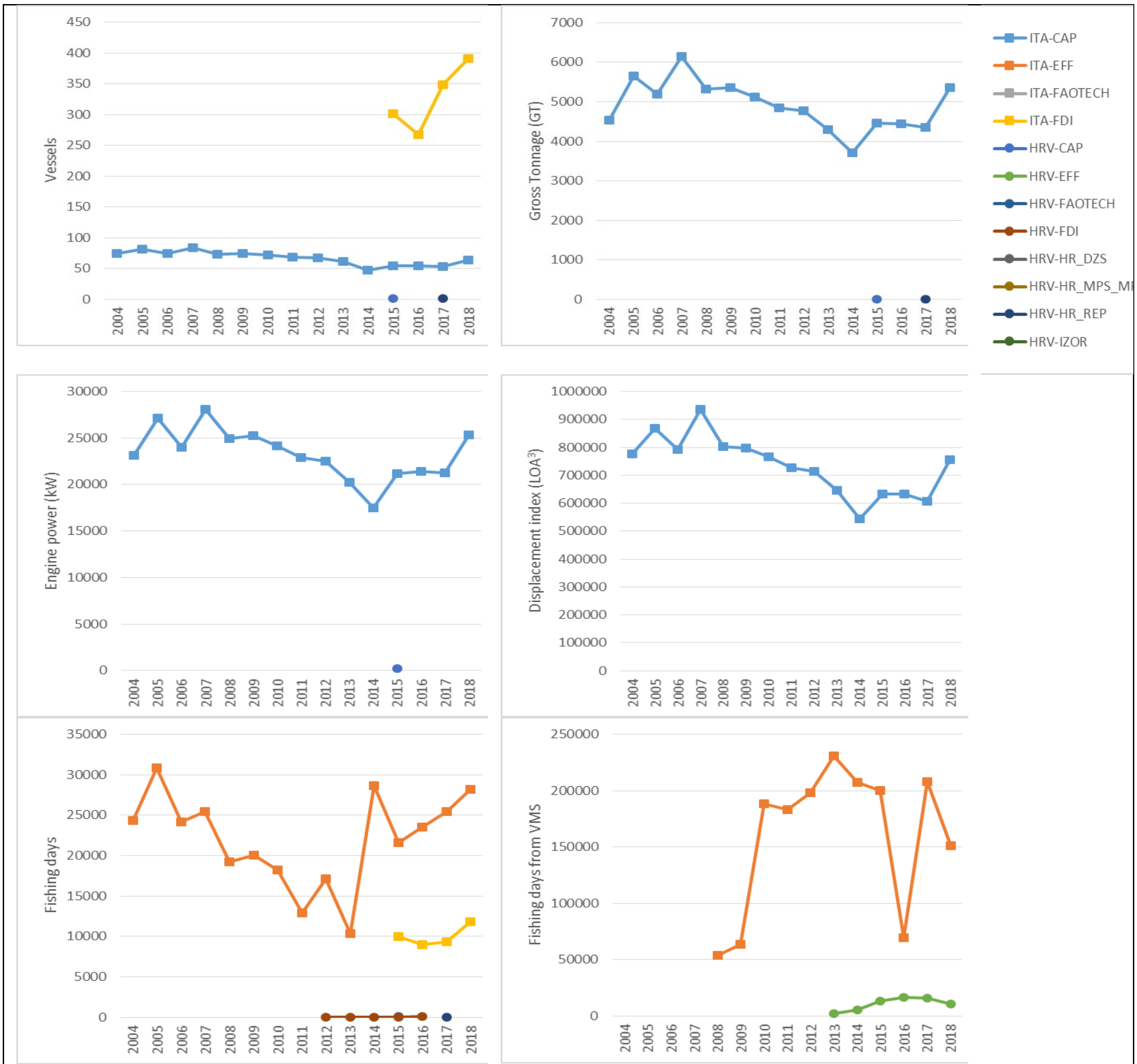


Trend of fishing capacity and fishing effort of otter trawlers (OTB) for Italy (ITA) and Croatia (HRV) in GSA 17 & 18. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA^3); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call, HRV-CAP – Croatian capacity data call, HRV-EFF – Croatian fishing effort data call and VMS data, HRV-FAOTECH – Croatian FAO spatial effort data, ITA-FDI – Croatian FDI data call, HRV-HR_DZS – Croatian department of statistics (DZS), HRV-HR_MPS_MP – Croatian Ministry of Agriculture (MPS) fishery management plans, HRV-HR_REP – Croatian annual EU fleet report, HRV-IZOR – Data from IZOR repository (http://baltazar.izor.hr/azopub/bindex).



Trend of fishing capacity and fishing effort of purse seines (PS) for Italy (ITA) and Croatia (HRV) in GSA 17 & 18. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA³); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call, HRV-CAP – Croatian capacity data call, HRV-EFF – Croatian fishing effort data call and VMS data, HRV-FAOTECH – Croatian FAO spatial effort data, ITA-FDI – Croatian FDI data call, HRV-HR_DZS – Croatian department of statistics (DZS), HRV-HR_MPS_MP – Croatian Ministry of Agriculture (MPS) fishery management plans, HRV-HR_REP – Croatian annual EU fleet report, HRV-IZOR – Data from IZOR repository (http://baltazar.izor.hr/azopub/bindex).

Trend of fishing capacity and fishing effort of mid-water pair pelagic trawlers (PTM) for Italy (ITA) and Croatia (HRV) in GSA 17 & 18. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA^3); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call, HRV-CAP – Croatian capacity data call, HRV-EFF – Croatian fishing effort data call and VMS data, HRV-FAOTECH – Croatian FAO spatial effort data, ITA-FDI – Croatian FDI data call, HRV-HR_DZS – Croatian department of statistics (DZS), HRV-HR_MPS_MP – Croatian Ministry of Agriculture (MPS) fishery management plans, HRV-HR_REP – Croatian annual EU fleet report, HRV-IZOR – Data from IZOR repository (http://baltazar.izor.hr/azopub/bindex).

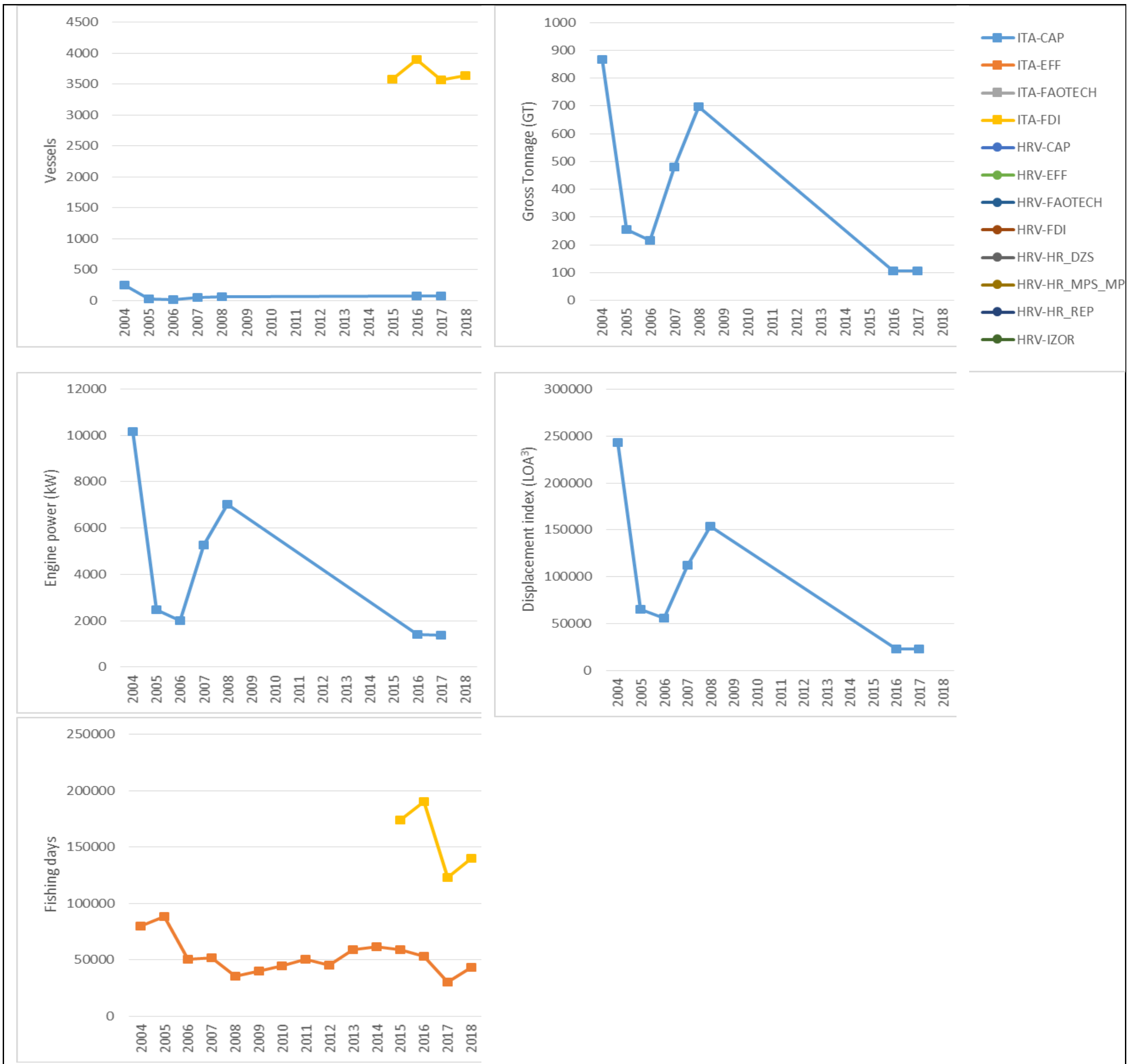


Trend of fishing capacity and fishing effort of rapido trawlers (TBB) for Italy (ITA) and Croatia (HRV) in GSA 17 & 18. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA³); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call, HRV-CAP – Croatian capacity data call, HRV-EFF – Croatian fishing effort data call and VMS data, HRV-FAOTECH – Croatian FAO spatial effort data, ITA-FDI – Croatian FDI data call, HRV-HR_DZS – Croatian department of statistics (DZS), HRV-HR_MPS_MP – Croatian Ministry of Agriculture (MPS) fishery management plans, HRV-HR_REP – Croatian annual EU fleet report, HRV-IZOR – Data from IZOR repository (http://baltazar.izor.hr/azopub/bindex).

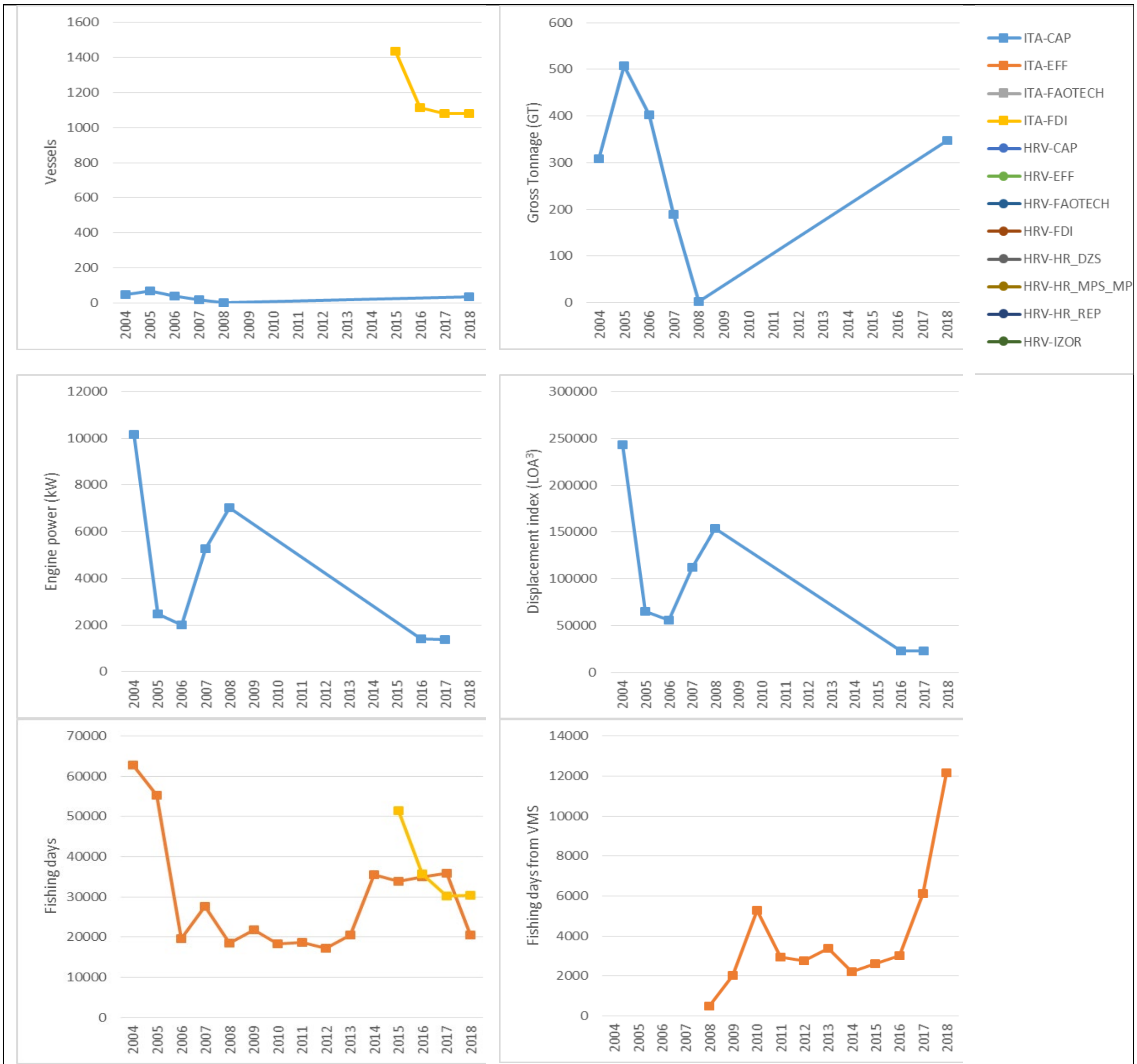
Ionian Sea (GSA 19)

In the Ionian sea (GSA 19) the fleet indicators show a similar trend of the italian fishing fleet as in the Adriatic sea. Dredge boats (DRB) were only registered in 2018 (Figure). The set nets (GNX) and long lines (LLX) present discontinuous fleet capacity data but with an apparent decreasing trend that could find support in the decreasing effort data (Figure). Mixed fisheries (MIX) have a relatively stable level of fishing vessels, while other capacity indicators show an increase until 2009 and a following decrease, observable also in the fishing effort (Figure). Otter trawlers (OTB) have a gradual decrease of both the fishing fleet capacity and effort throughout the time series (Figure). A decreasing trend is also observed for purse seines (PS), both in capacity and effort, showing an increase in the last two years (2017-18) (Figure).

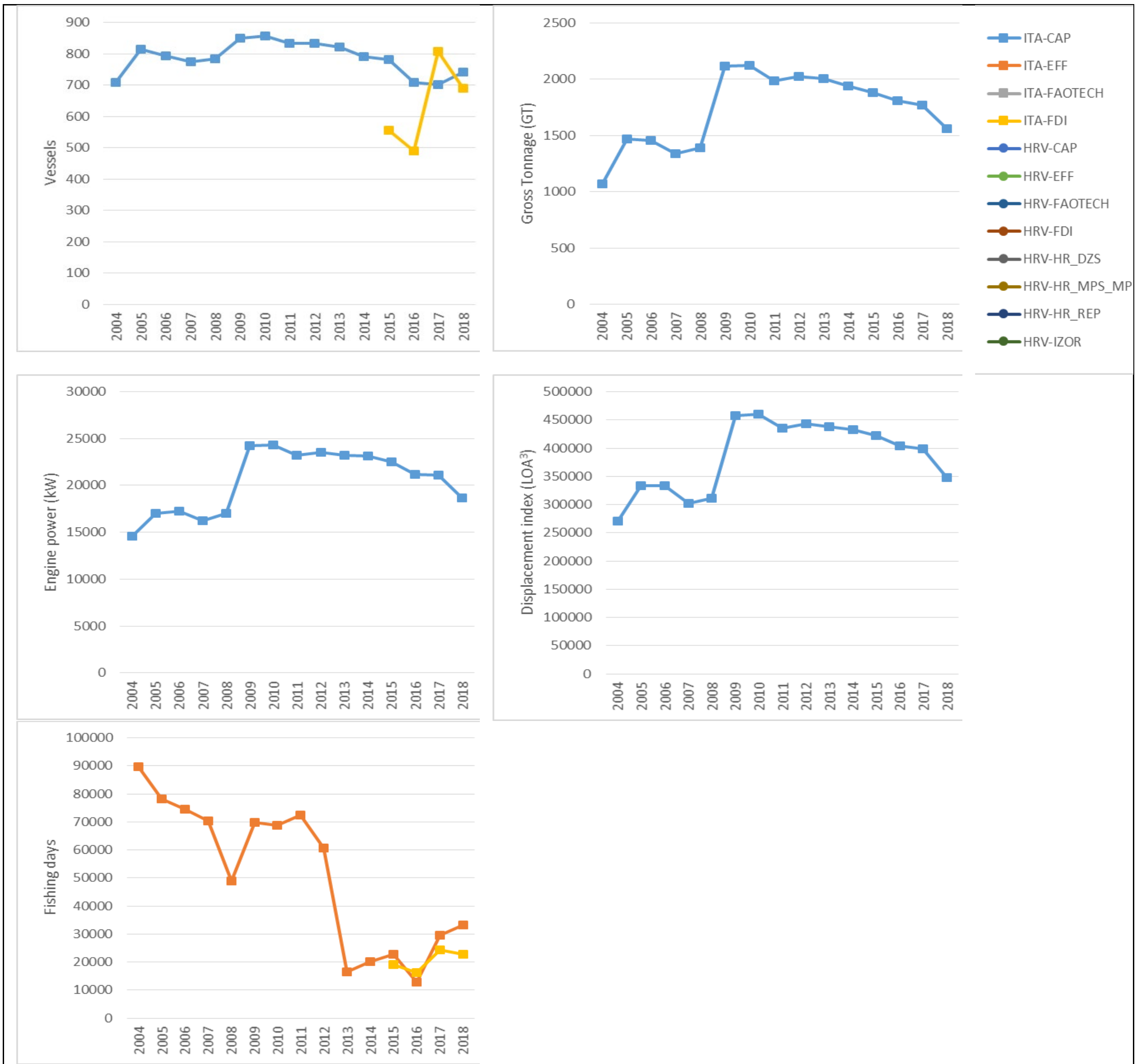
The indicators of the fishing effort measured with VMS in the Ionian fleet show a general increasing trend, contrary to all other indicators, exhibiting the same behaviour as in the Adriatic sea (Figure).



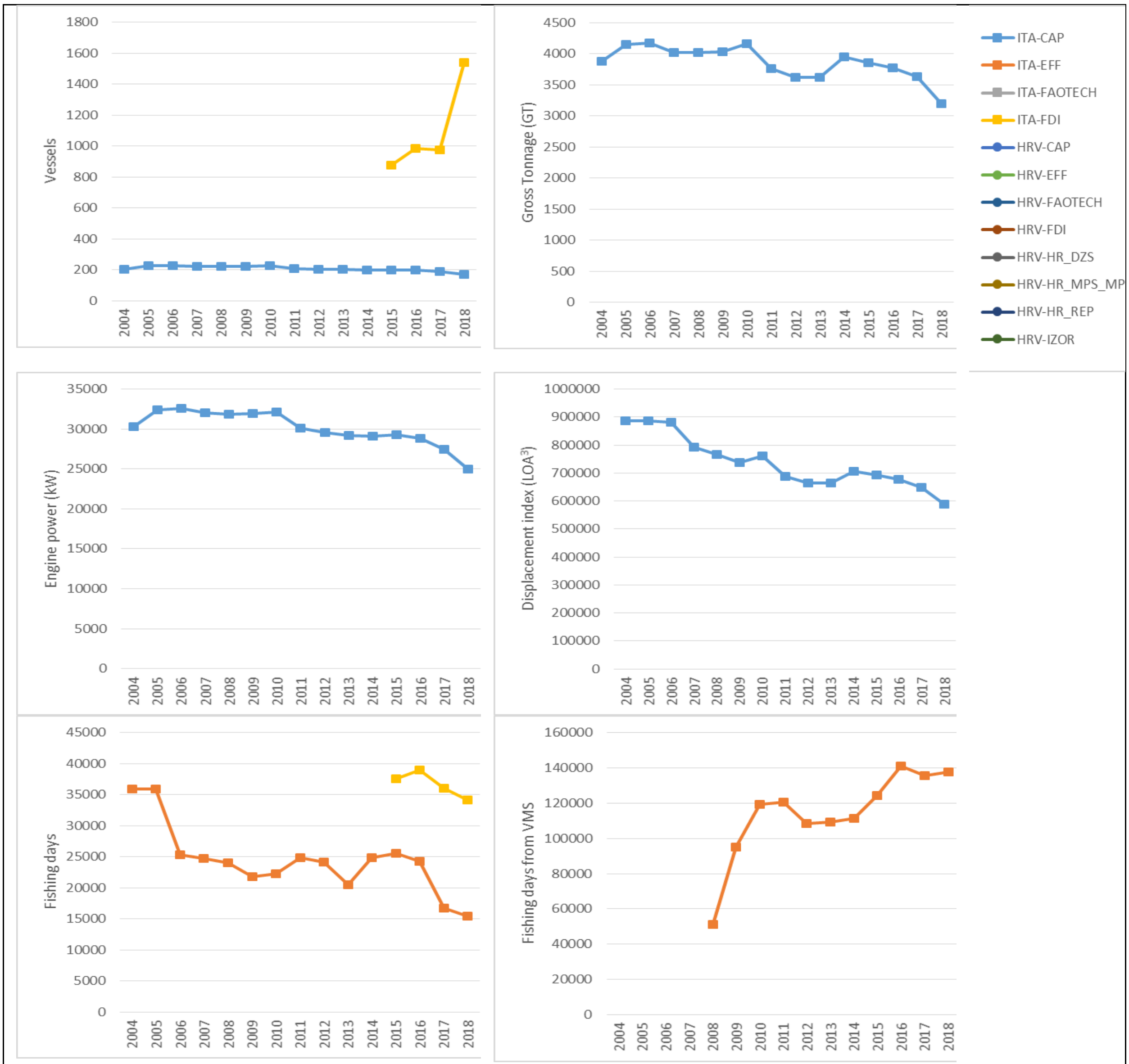
Trend of fishing capacity and fishing effort of set nets (GNX) for Italy (ITA) in GSA 19. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA^3); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call.



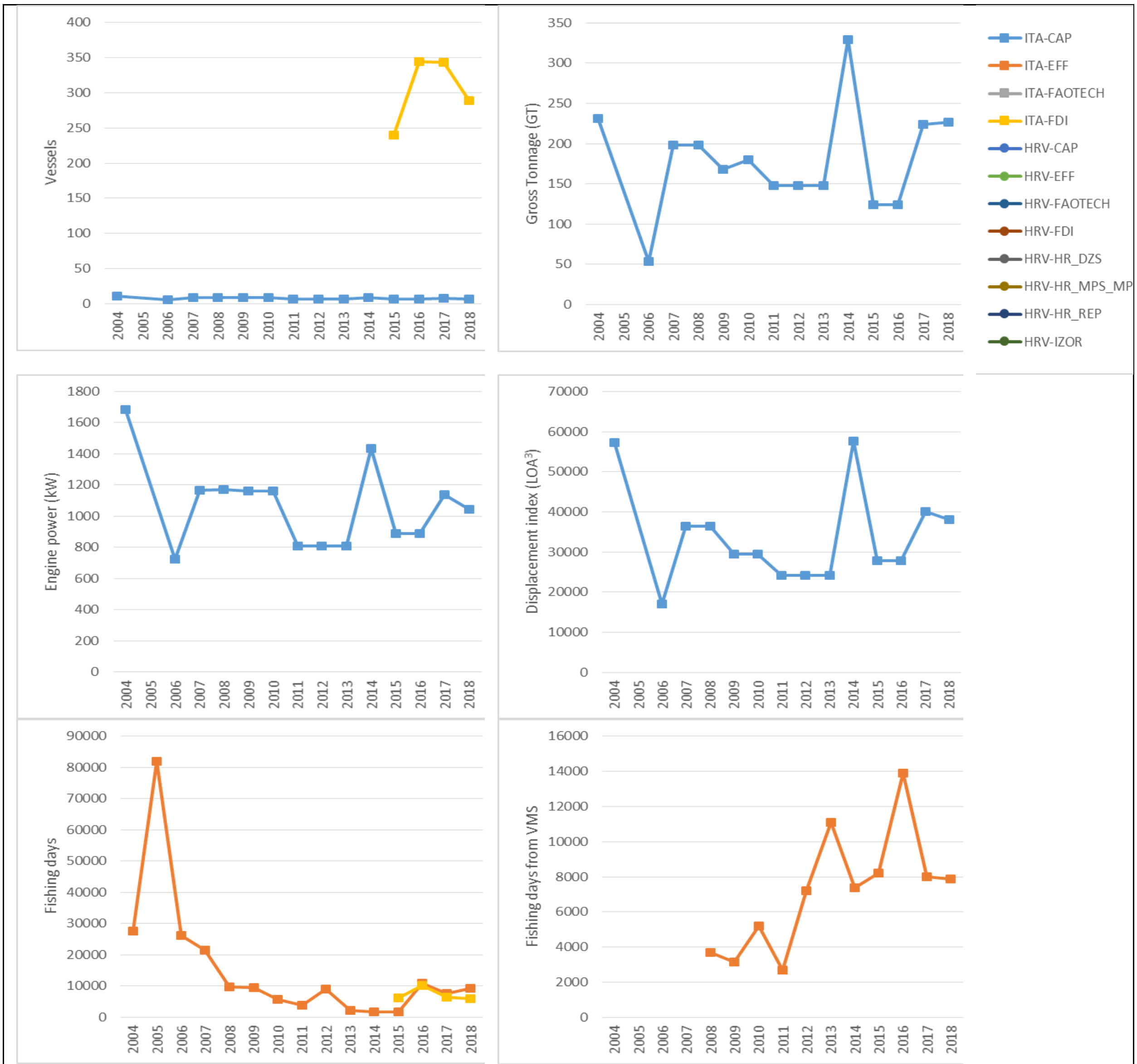
Trend of fishing capacity and fishing effort of long lines (LLX) for Italy (ITA) in GSA 19. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA^3); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call.



Trend of fishing capacity and fishing effort of mixed and other gear fisheries (MIX) for Italy (ITA) in GSA 19. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA^3); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call.



Trend of fishing capacity and fishing effort of otter trawlers (OTB) for Italy (ITA) in GSA 19. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA^3); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call.



Trend of fishing capacity and fishing effort of purse seine (PS) for Italy (ITA) in GSA 19. Plots: Fishing capacity: number of total vessels, total gross tonnage (GT), total engine power (kW) and displacement index (LOA³); Fishing effort: fishing days from reports, fishing days from VMS data. Legend: ITA-CAP – Italian fishing capacity from Mably, ITA-EFF – Italian fishing effort from Mably landing data and VMS data, ITA-FDI – Italian FDI data call.

Effort forcings time series for Adriatic sea (GSA 17 & 18)

The observations of fishing capacity and effort indicators show difficulties in collecting and comparing this type of data. The VMS data show an increasing trend, contrary to the rest of the indicators, and further analysis needs to be conducted to explain this behavior. Where possible we preferred using fishing effort data for simulations of the fishing activity in the model (Table), and in some cases we applied interpolations to remove outliers from the trend. For Italy's Adriatic mid-water pair pelagic trawlers (PTM) the fishing effort trends per LOA segment (VL--18, VL1824, VL24++) showed erratic behavior (not shown in the plots) difficult to explain, and therefore we preferred to use a much more stable index of displacement (LOA3) as a proxy for fishing effort. Similar erratic behavior of fishing effort is also observed for Adriatic beam trawlers (TBB, VL--18, VL18++) and we choose the total engine power (kW) as proxy for these fleets. The creation of effort time series for Croatia's fishing effort required creating hybrid time series by combining and scaling different series and values. When possible we preferred using the reported fishing effort, but it also required combining series from the Croatian Bureau of Statistic, Croatian Ministry of Agriculture fishery management plans, annual fleet report for EU and repository available at the Institute of Oceanography and Fisheries (Table).

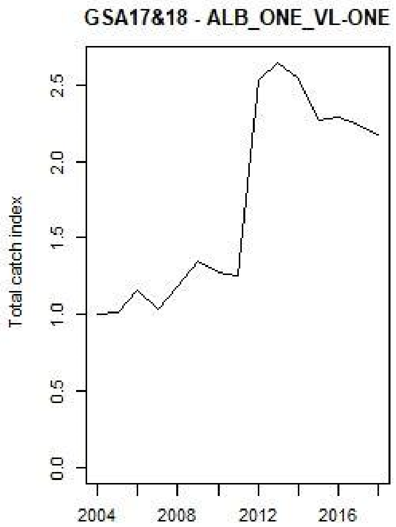
For Slovenia (SLO) we used the fishing capacity data based on EU Fleet Register records available in the North-East Adriatic Sea (NEAS) model (Celić et al. 2018). For passive gears, like the small scale fishery (SSF) we used the number of vessels as a proxy for the fishing effort of Slovenia's set nets (GNX), long lines (LLX) and mixed and other fishing gear (MIX) (Table). The number of fishing vessels was chosen assuming that these fishing gears are similar between them and are not proportional to the size of the vessels. For active gears, such as otter trawlers (OTB), mid-water pair pelagic trawlers (PTM), and purse seines (PS), the displacement index (cubic LOA, LOA^3) was selected as a proxy of the fishing capacity of the vessel, assuming that engine power and sea handling capabilities (i.e. possibility to fish in bad weather conditions) are proportional to the vessels displacement (Table).

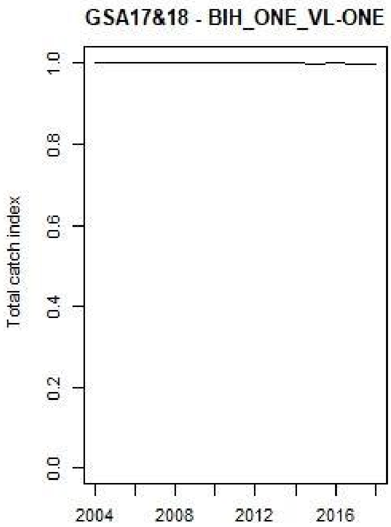
For Albania (ALB), Bosnia and Herzegovina (BIH) and Montenegro (MNT) we didn't have either fishing fleet capacity or effort indicators. We used the relative total catch index as a proxy for fishing effort, obtained by dividing the total catch time series by the total catch in 2004 (Table).

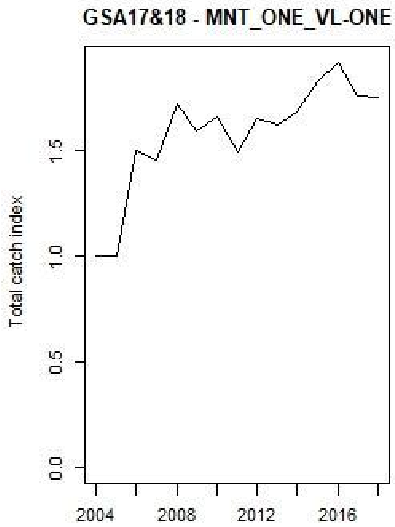
Table: Specification of reference time series data used for simulating the fishing effort of Adriatic fishing fleets (GSA 17 & 18). Fishing fleets: ONE - all fishing gears, DRB – dredge boats, GNX – set nets, LLX – long lines, MIX – mixed and other fishing gears, OTB – otter trawlers, PS – purse seine, PTM – mid-water pair pelagic trawl, TBB – rapido trawl. Fleet length over all (LOA) segments: VL-ONE – all vessel sizes, V--18 – vessel smaller than 18 meters, VL18++ – vessel larger than 18 meters, VL1824 – vessel between 18 and 24 meters, VL24++ – vessel larger than 24 meters. Other abbreviations: GT – gross tonnage, FD – fishing days, N – number of vessels.

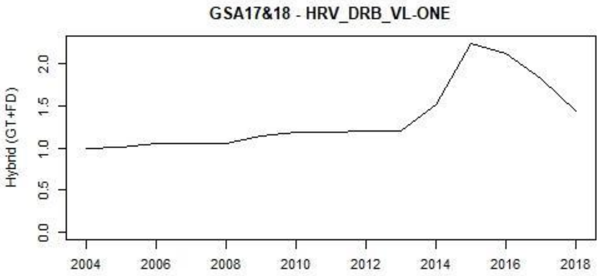
Country	Fleet	LOA segment	Value	Description
Albania	ONE	VL-ONE	Total catch index	Index of Relative total catch
BiH	ONE	VL-ONE	Total catch index	Index of Relative total catch
Croatia	DRB	VL-ONE	Hybrid (GT+FD) (FD equivalent)	GT VL_15++ scaled to FD 2013 (2004-12), FD_max (2013-18)
Croatia	GNX	VL-ONE	Hybrid (GT+FD) (FD equivalent)	GT VL_--15 scaled to FD 2012 (2004-11), FD_max (2012-18)
Croatia	LLX	VL-ONE	Hybrid (GT+FD) (FD equivalent)	GT VL_--15 scaled to FD 2012 (2004-11), FD_max (2012-18)
Croatia	MIX	VL-ONE	Hybrid (GT+FD) (FD equivalent)	GT VL_--15 scaled to FD_max 2012 (2004-11), FD_max (2012-16), FDI FD scaled to FD_max 2016 (2017-18)
Croatia	OTB	VL—18	Hybrid (GT+N+FD) (FD equivalent)	GT VL_15++ scaled to Vessels in OTB management plan 2008 (2004-07), Vessels in OTB management plan scaled to Vessels OTB statistics 2011 (2008-10), Vessels OTB statistics scaled to FD 2012 (2011), FD (2012-18)
Croatia	OTB	VL1824	Hybrid (GT+N+FD) (FD equivalent)	GT VL_15++ scaled to Vessels in OTB management plan 2008 (2004-07), Vessels in OTB management plan scaled to Vessels OTB statistics 2011 (2008-10), Vessels OTB statistics scaled to FD 2012 (2011), FD (2012-18)
Croatia	OTB	VL24++	Hybrid (GT+N+FD) (FD equivalent)	GT VL_15++ scaled to Vessels in OTB management plan 2008 (2004-07), Vessels in OTB management plan scaled to Vessels OTB statistics 2011 (2008-10), Vessels OTB statistics scaled to FD 2012 (2011), FD (2012-18)
Croatia	PS	VL—18	Hybrid (GT+N+FD) (FD equivalent)	GT VL_15++ scaled to Vessels in PS management plan 2008 (2004-07), Vessels in PS management plan scaled to FD 2012 (2008-11), FD (2012-18)
Croatia	PS	VL18++	Hybrid (GT+N+FD) (FD equivalent)	GT VL_15++ scaled to Vessels in PS management plan 2008 (2004-07), Vessels in PS management plan scaled to FD 2012 (2008-11), FD (2012-18)

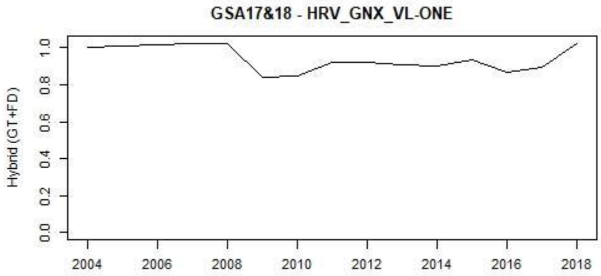
Croatia	TBB	VL—18	Hybrid (GT+FD) (FD equivalent)	GT VL_15++ scaled to FD 2013 (2004-13), FD (2014-18)
Italy	DRB	VL-ONE	FishingDays	Mably FD (04-15), FDI FD scaled to Mably FD 2015 (16-18)
Italy	GNX	VL-ONE	FishingDays	Mably FD (2004-18)
Italy	LLX	VL-ONE	FishingDays	Mably FD (2004-18)
Italy	MIX	VL-ONE	FishingDays	Mably FD (2004-18)
Italy	OTB	VL—18	FishingDays	Mably FD (2004-18)
Italy	OTB	VL1824	FishingDays	Mably FD (2004-18) with interpolation (2014-16)
Italy	OTB	VL24++	FishingDays	Mably FD (2004-18)
Italy	PS	VL—18	FishingDays	Mably FD (2004-18) with interpolation (2006-07)
Italy	PS	VL18++	FishingDays	Mably FD (2004-18)
Italy	PTM	VL—18	Displacement	Capacity from Mably LOA^3 (2004-18)
Italy	PTM	VL1824	Displacement	Capacity from Mably LOA^3 (2004-18)
Italy	PTM	VL24++	Displacement	Capacity from Mably LOA^3 (2004-18)
Italy	TBB	VL—18	EnginePower	Capacity from Mably kW (2004-18)
Italy	TBB	VL18++	EnginePower	Capacity from Mably kW (2004-18)
Montenegro	ONE	VL-ONE	Total catch index	Index of Relative total catch
Slovenia	GNX	VL-ONE	Vessel number	From Fleet register vessel number (Celić et al. 2018)
Slovenia	LLX	VL-ONE	Vessel number	From Fleet register vessel number (Celić et al. 2018)
Slovenia	MIX	VL-ONE	Vessel number	From Fleet register vessel number (Celić et al. 2018)
Slovenia	OTB	VL-ONE	Displacement	From Fleet register vessel LOA (Celić et al. 2018)
Slovenia	PS	VL-ONE	Displacement	From Fleet register vessel LOA (Celić et al. 2018)
Slovenia	PTM	VL-ONE	Displacement	From Fleet register vessel LOA (Celić et al. 2018)

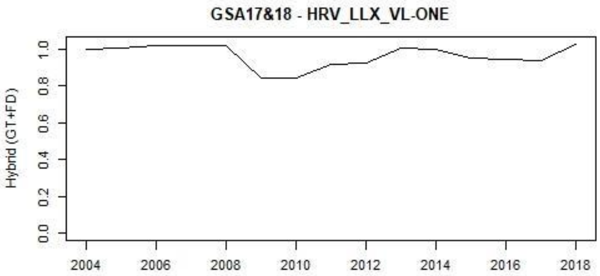

GSA17&18 - ALB_ONE_VL-ONE
Total catch index
0.0
0.5
1.0
1.5
2.0
2.5
2004
2008
2012
2016

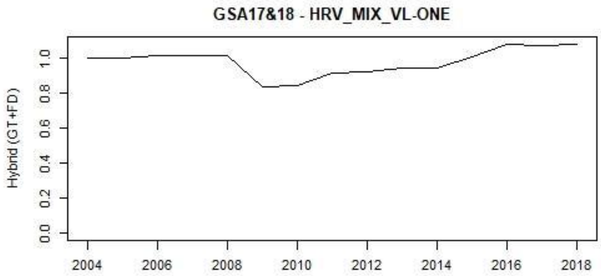

GSA17&18 - BIH_ONE_VL-ONE
Total catch index
0.0
0.2
0.4
0.6
0.8
1.0
2004
2008
2012
2016

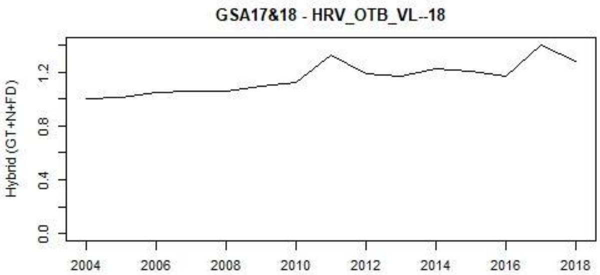

GSA17&18 - MNT_ONE_VL-ONE
Total catch index
0.0
0.5
1.0
1.5
2004
2008
2012
2016

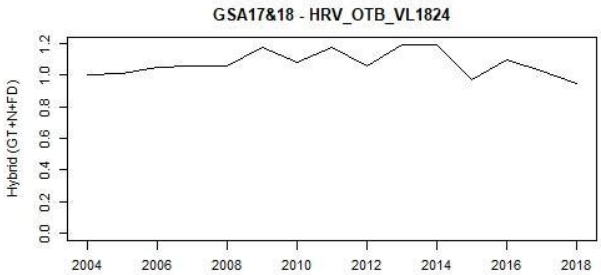

GSA17&18 - HRV_DRB_VL-ONE
Hybrid (GT+FD)

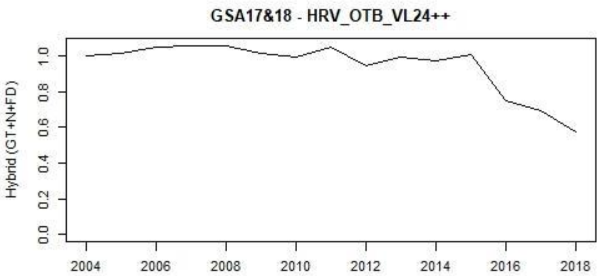

GSA17&18 - HRV_GNX_VL-ONE
Hybrid (GT+FD)

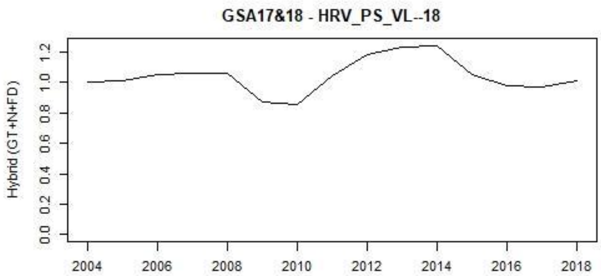

GSA17&18 - HRV_LLX_VL-ONE
Hybrid (GT+FD)

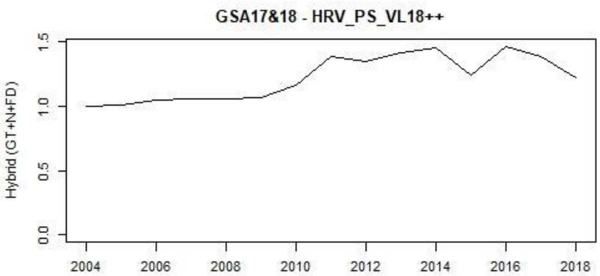

GSA17&18 - HRV_MIX_VL-ONE
Hybrid (GT+FD)

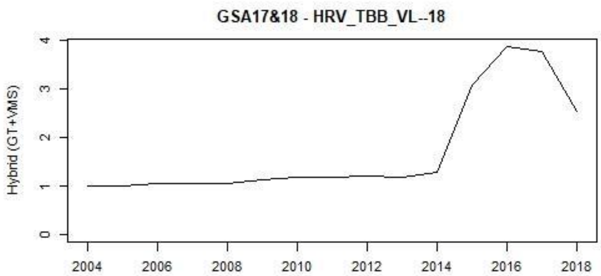

GSA17&18 - HRV_OTB_VL--18
Hybrid (GT+N+FD)

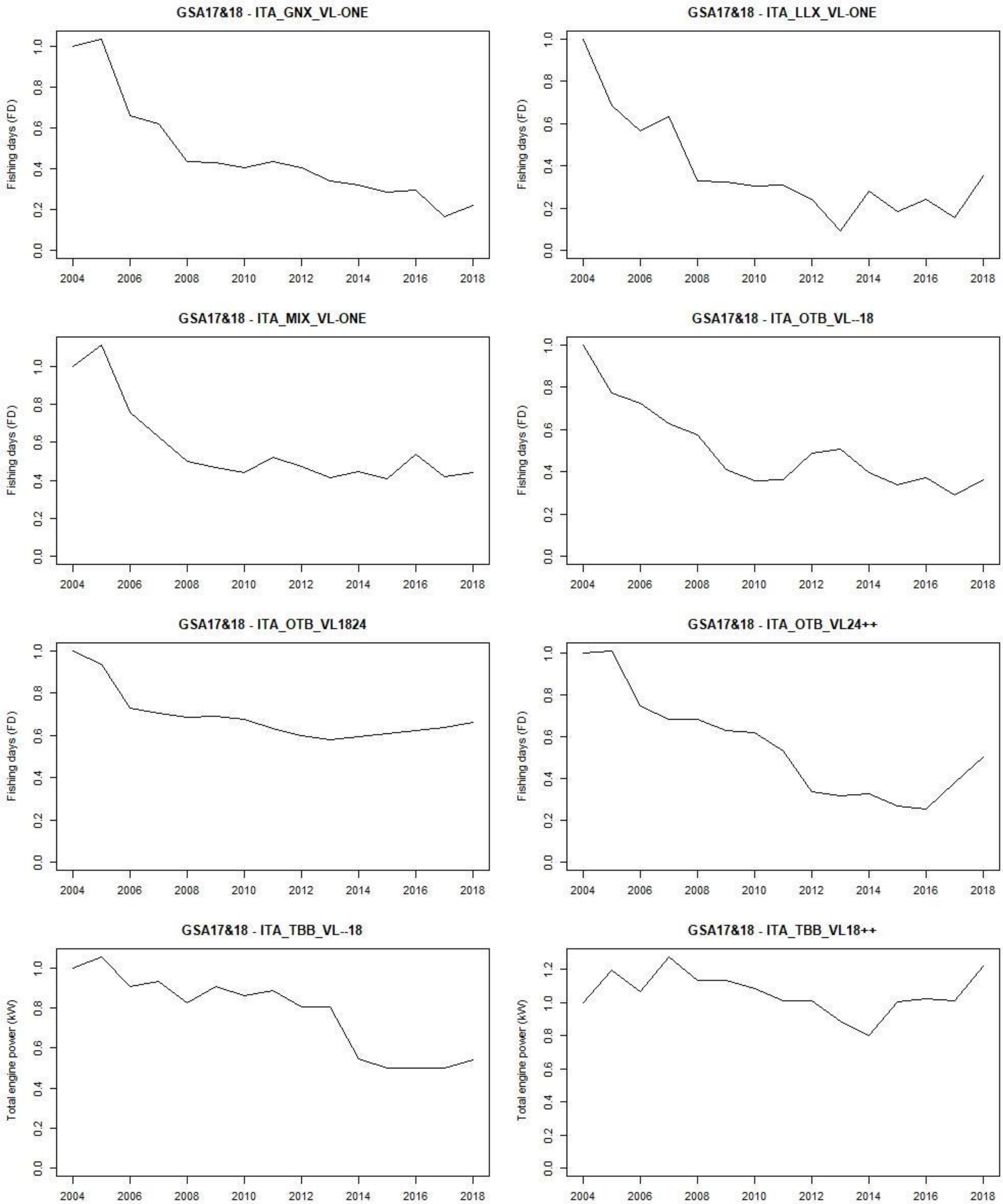

GSA17&18 - HRV_OTB_VL1824
Hybrid (GT+N+FD)

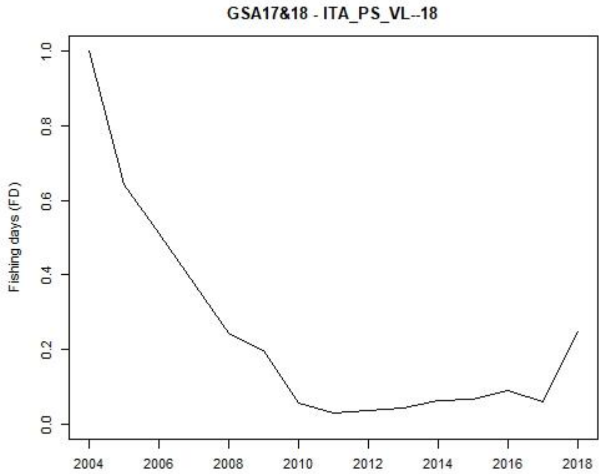

GSA17&18 - HRV_OTB_VL24++
Hybrid (GT+N+FD)

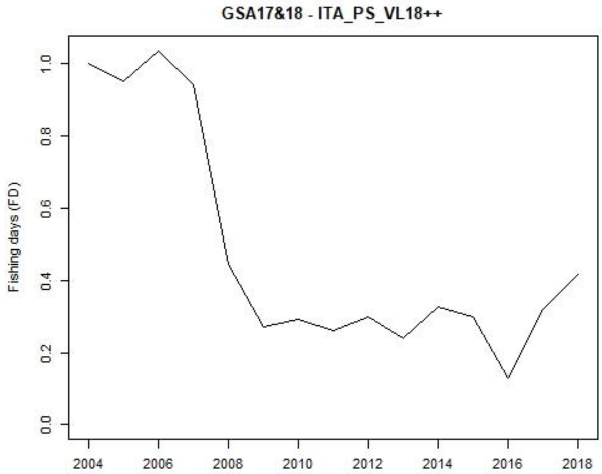

GSA17&18 - HRV_PS_VL--18
Hybrid (GT+N+FD)

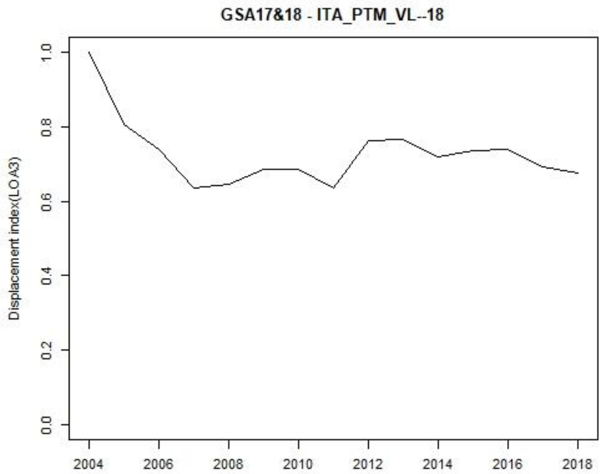

GSA17&18 - HRV_PS_VL18++
Hybrid (GT+N+FD)

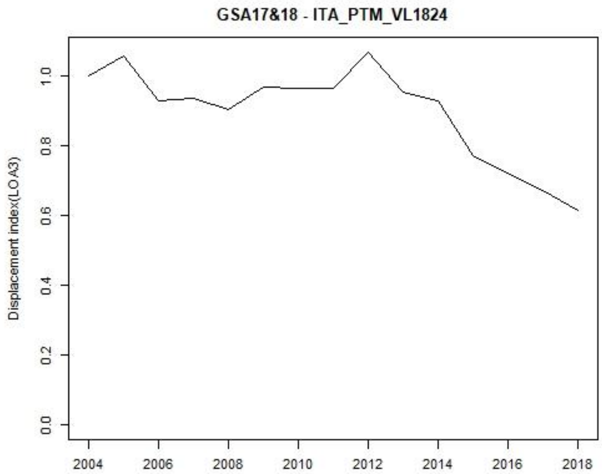

GSA17&18 - HRV_TBB_VL--18
Hybrid (GT+VMS)

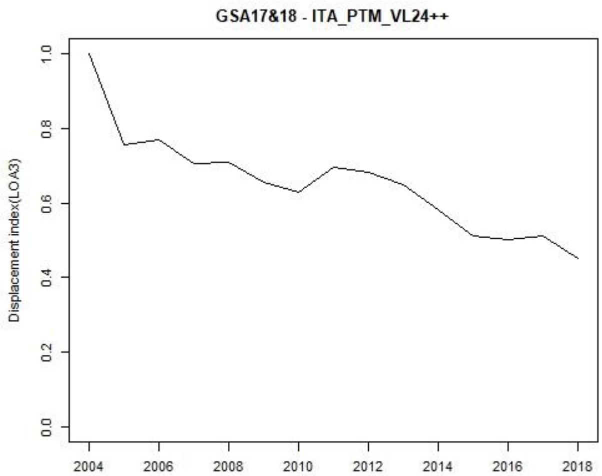

GSA17&18 - ITA_GNX_VL-ONE
GSA17&18 - ITA_LLX_VL-ONE
GSA17&18 - ITA_MIX_VL-ONE
GSA17&18 - ITA_OTB_VL--18
GSA17&18 - ITA_OTB_VL1824
GSA17&18 - ITA_OTB_VL24++
GSA17&18 - ITA_TBB_VL--18
GSA17&18 - ITA_TBB_VL18++
Fishing days (FD)
Total engine power (kW)

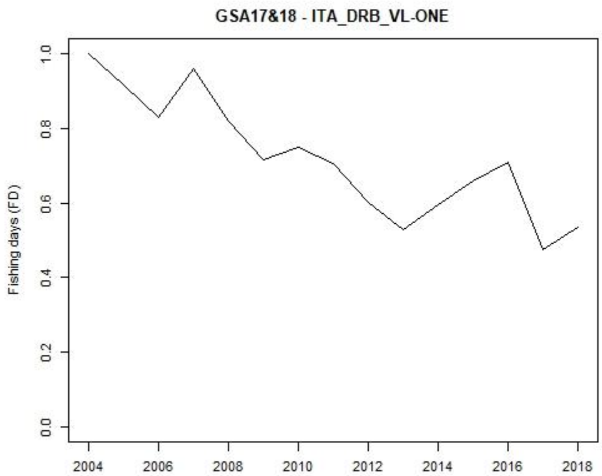

GSA17&18 - ITA_PS_VL--18
Fishing days (FD)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018

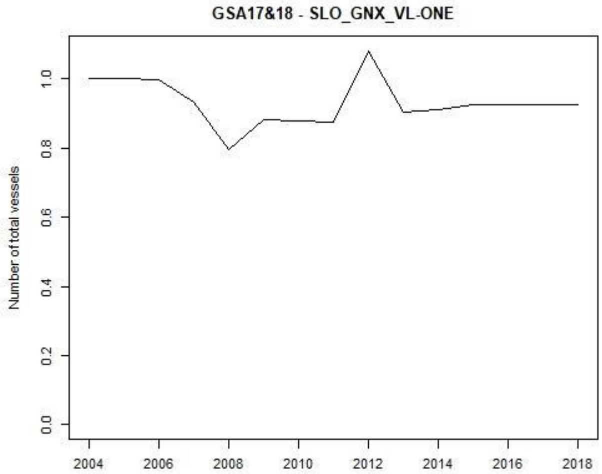

GSA17&18 - ITA_PS_VL18++
Fishing days (FD)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018

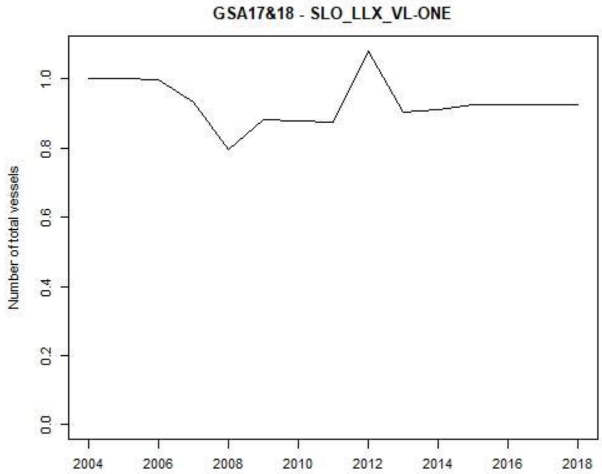

GSA17&18 - ITA_PTM_VL--18
Displacement index(LOA3)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018

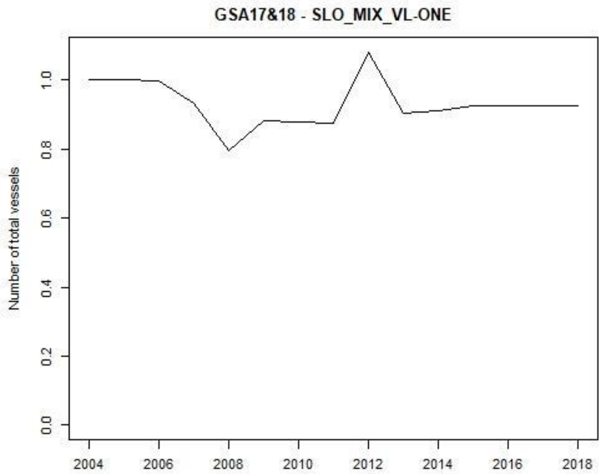

GSA17&18 - ITA_PTM_VL1824
Displacement index(LOA3)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018

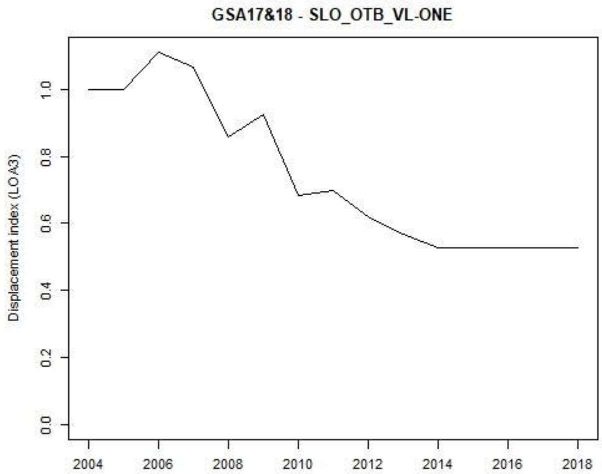

GSA17&18 - ITA_PTM_VL24++
Displacement index(LOA3)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018

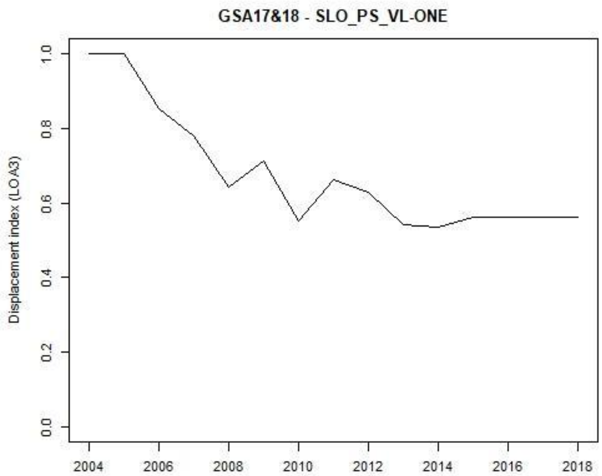

GSA17&18 - ITA_DRB_VL-ONE
Fishing days (FD)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018

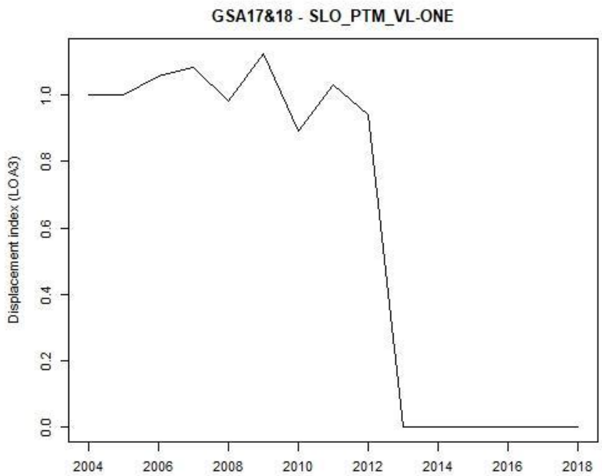

GSA17&18 - SLO_GNX_VL-ONE
Number of total vessels
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018


GSA17&18 - SLO_LLX_VL-ONE
Number of total vessels
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018


GSA17&18 - SLO_MIX_VL-ONE
Number of total vessels
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018


GSA17&18 - SLO_OTB_VL-ONE
Displacement index (LOA3)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018


GSA17&18 - SLO_PS_VL-ONE
Displacement index (LOA3)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018

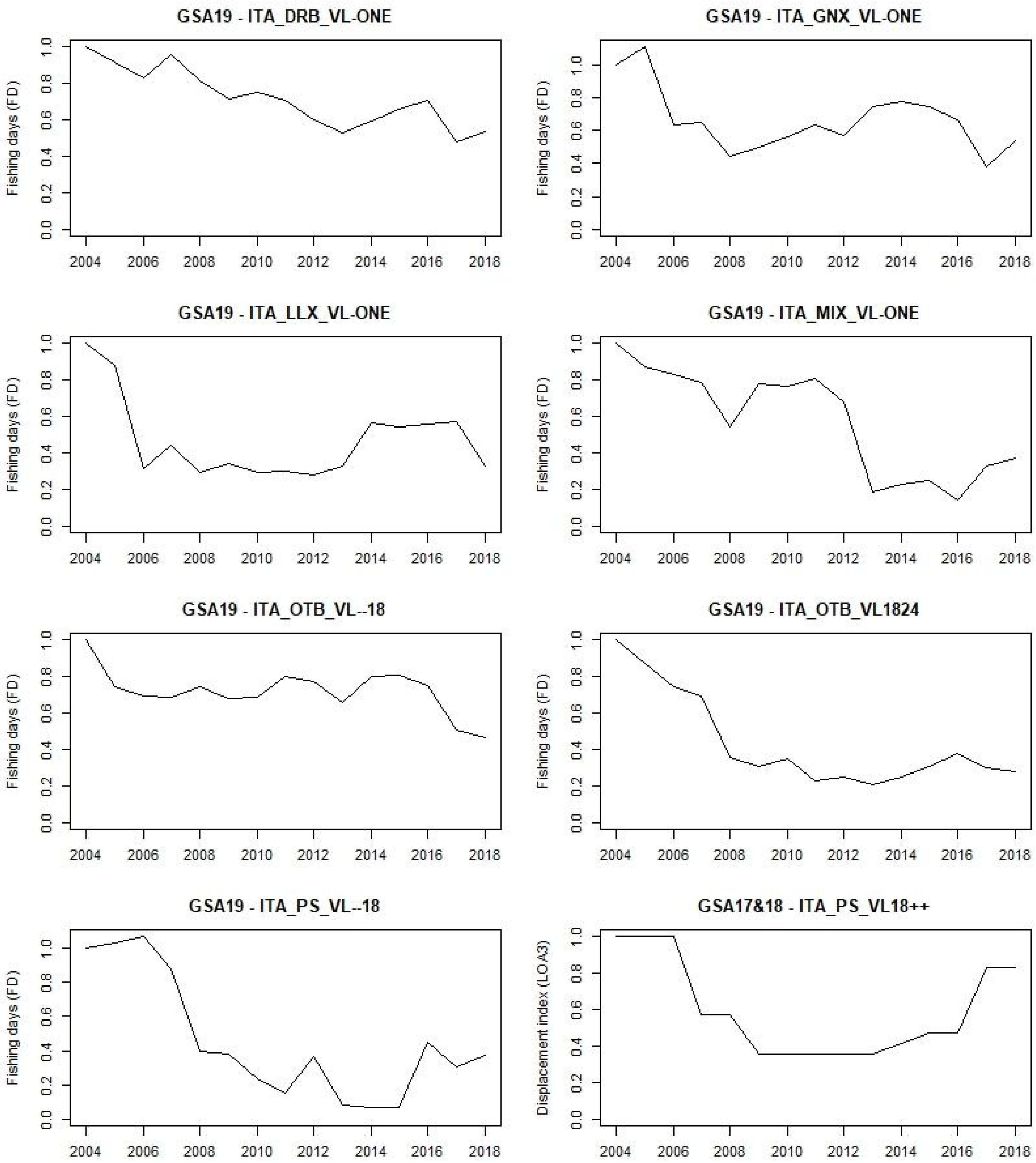

GSA17&18 - SLO_PTM_VL-ONE
Displacement index (LOA3)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018

Effort forcings time series for Ionian sea (GSA 19)

For Ionian sea fishing effort available in MABLY data call was prefered as effort forcing time series, requiring few interpolations for otter trawlers (VL1824) and purse seine (VL--18) (Table). In case of purse seines larger than 18 meters the available effort data was poor and discontinuous, therefore we used the displacement index based on cubic LOA from MABLY capacity data. The dredge boats (DRB) in the Ionian sea resulted having some reported landings but no relevant data on fishing effort were available, therefore we choose to use as proxy the same fishing effort as in the Adriatic sea.

Table: Specification of reference time series data used for simulating the fishing effort of Ionian fishing fleets (GSA 19). Fishing fleets: ONE - all fishing gears, DRB – dredge boats, GNX – set nets, LLX – long lines, MIX – mixed and other fishing gears, OTB – otter trawlers, PS – purse seine,. Fleet length over all (LOA) segments: VL-ONE – all vessel sizes, V--18 – vessel smaller than 18 meters, VL18++ – vessel larger than 18 meters, VL1824 – vessel between 18 and 24 meters, VL24++ – vessel larger than 24 meters. Other abbreviations: GT – gross tonnage, FD – fishing days, N – number of vessels.

Country	Fleet	LOA segment	Value	Description
Italy	DRB	VL-ONE	FishingDays	DRB FD time series from GSA 17&18
Italy	GNX	VL-ONE	FishingDays	Mably FD (2004-18)
Italy	LLX	VL-ONE	FishingDays	Mably FD (2004-18)
Italy	MIX	VL-ONE	FishingDays	Mably FD (2004-18)
Italy	OTB	VL—18	FishingDays	Mably FD (2004-18)
Italy	OTB	VL1824	FishingDays	Mably FD (2004-18), with interpolation (2005)
Italy	PS	VL—18	FishingDays	Mably FD (2004-18), with interpolation (2005)
Italy	PS	VL18++	Displacement	Capacity from Mably LOA^3 (2004-18), with interpolation (2005-06, 2014)


GSA19 - ITA_DRB_VL-ONE
GSA19 - ITA_GNX_VL-ONE
GSA19 - ITA_LLX_VL-ONE
GSA19 - ITA_MIX_VL-ONE
GSA19 - ITA_OTB_VL--18
GSA19 - ITA_OTB_VL1824
GSA19 - ITA_PS_VL--18
GSA17&18 - ITA_PS_VL18++
Fishing days (FD)
Displacement index (LOA3)
0.0
0.2
0.4
0.6
0.8
1.0
2004
2006
2008
2010
2012
2014
2016
2018

6.3 Time series of biomasses and catches for calibration

Time-series of biomasses and catches were analysed using box-plots in order to identify differences in magnitude across species and potential outliers. Within the identified outliers (1.5 times the interquartile range, i.e., the 25th and 75th percentiles of the boxplot) only a few were considered “true” outliers assessing the time-series one a time considering ecological aspects of the functional group (e.g. pelagic groups are expecting higher variations than demersal groups).

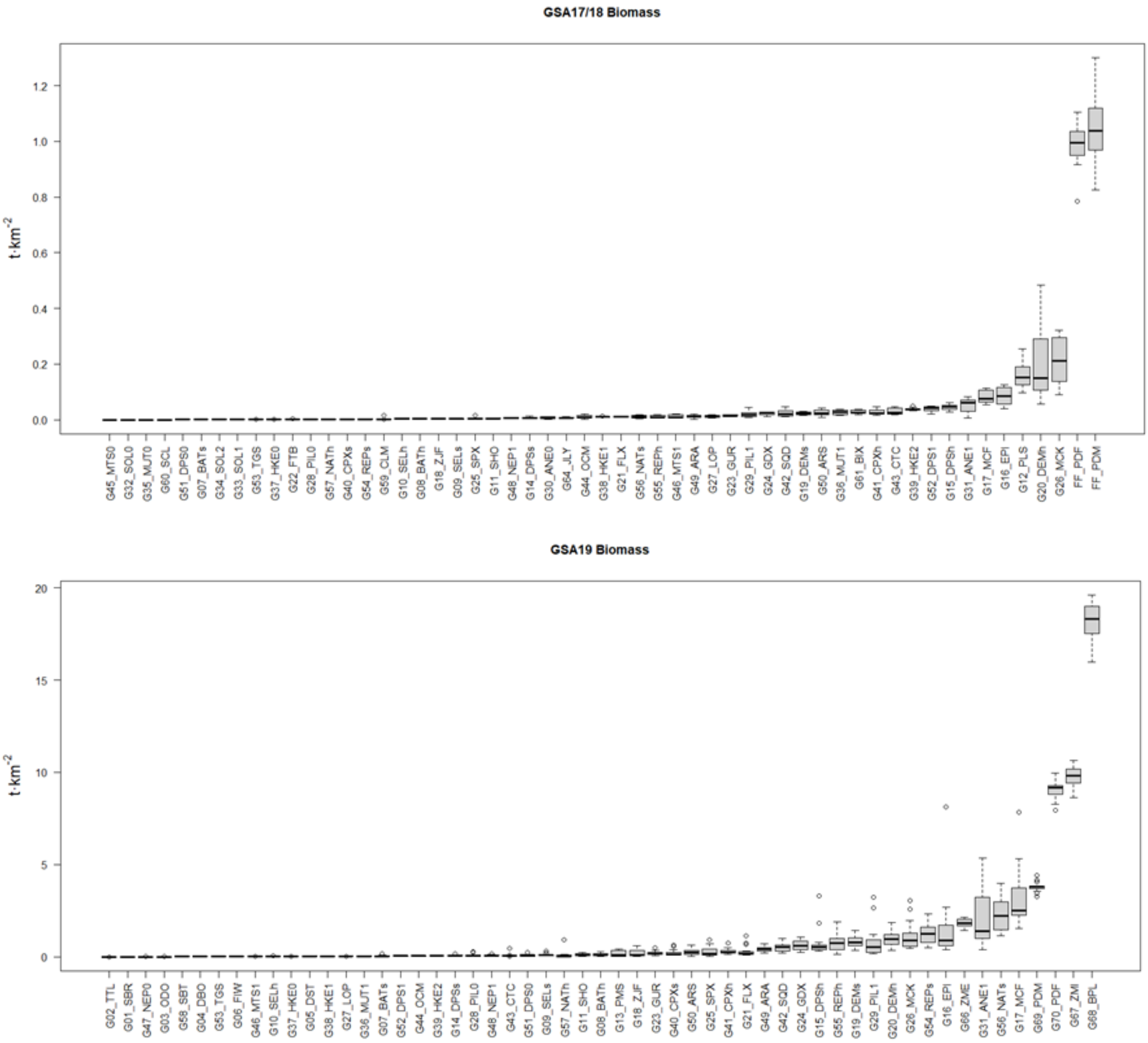


Figure 8. Box plots of biomass time-series for both GSAs ranked from order of magnitude.

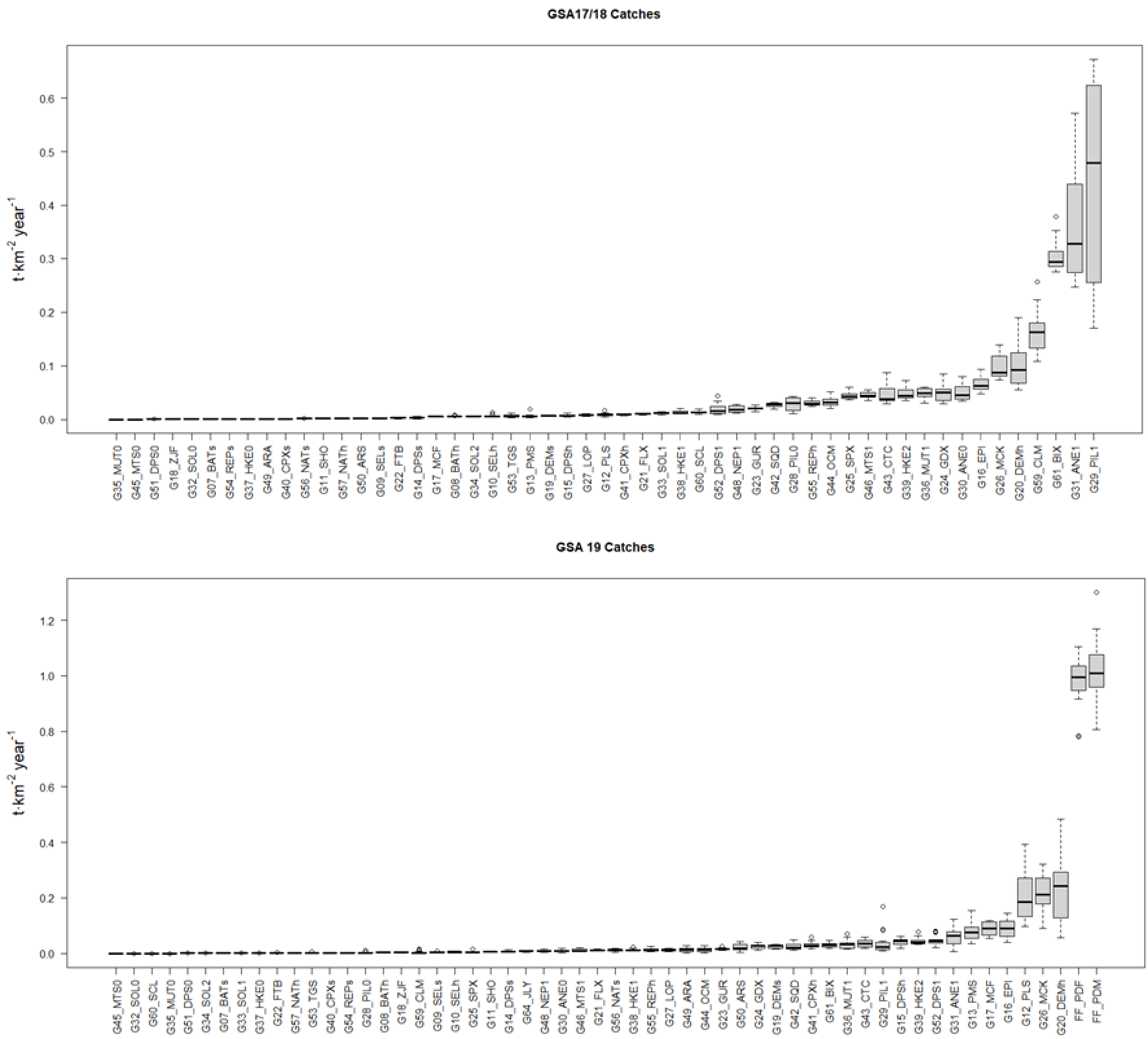


Figure 9. Box plots of catches time-series for both GSAs ranked from order of magnitude.

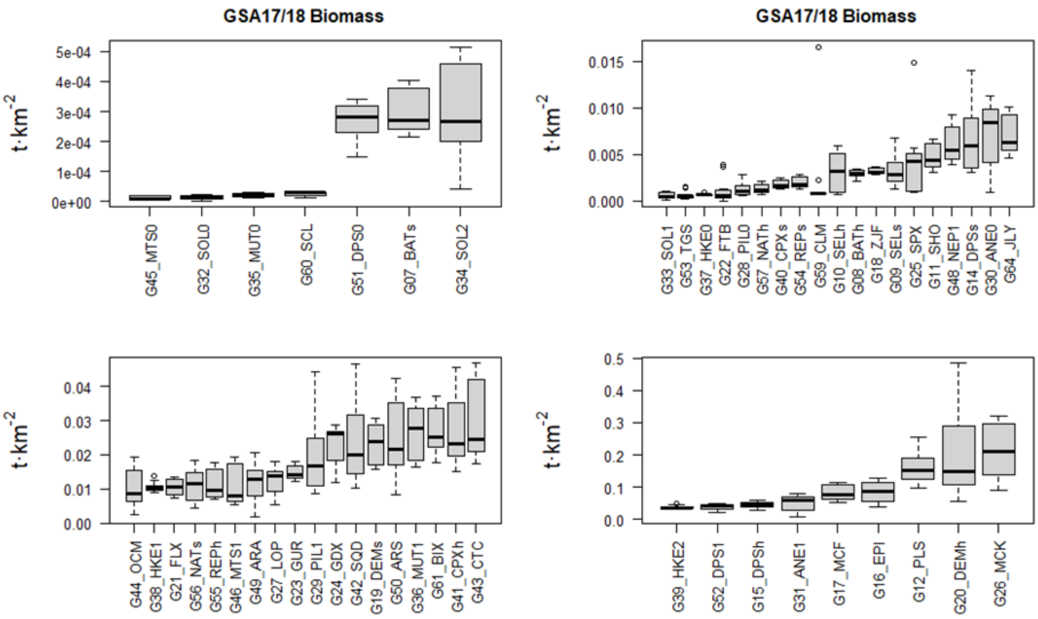


Figure 10. Whisker plots of biomass time-series per functional group for GSA 17&18

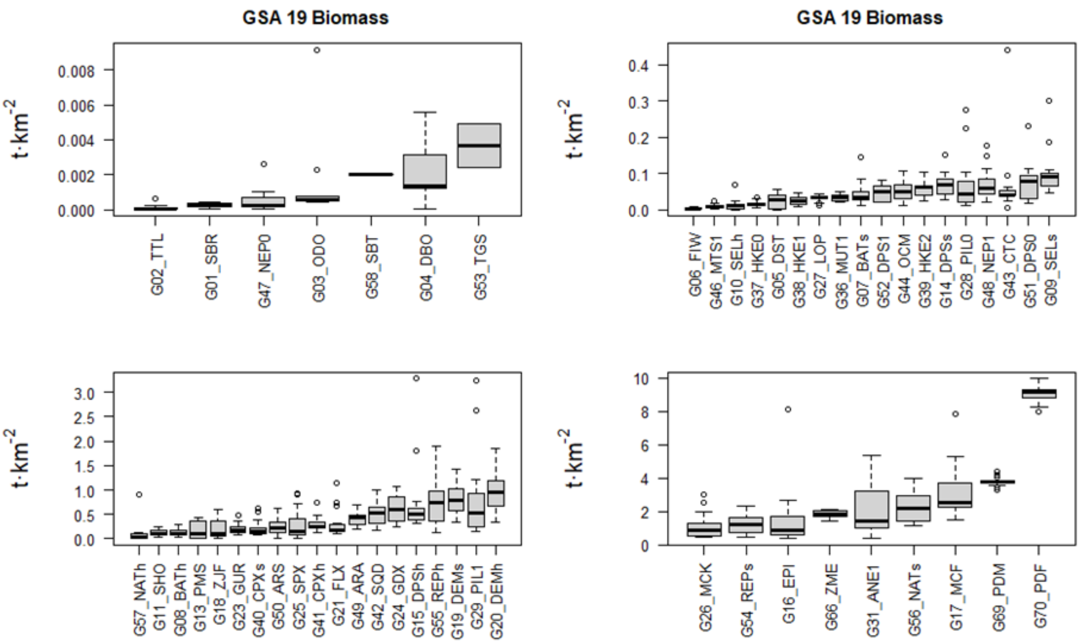


Figure 11. Whisker plots of biomass time-series per functional group for GSA 19

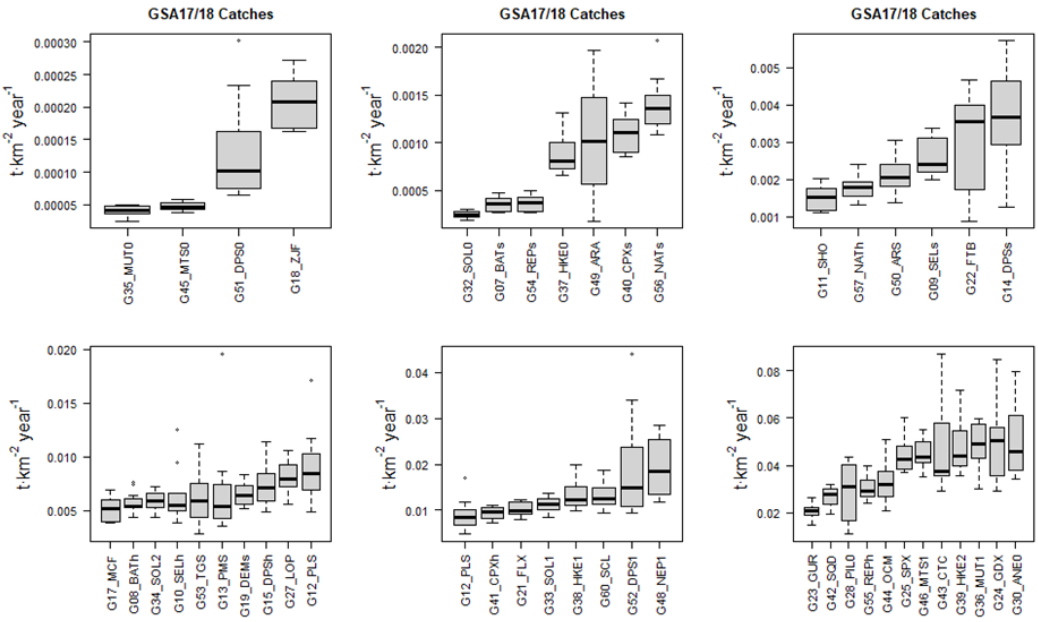


Figure 12 Whisker plots of catches time-series per functional group for GSA 17&18

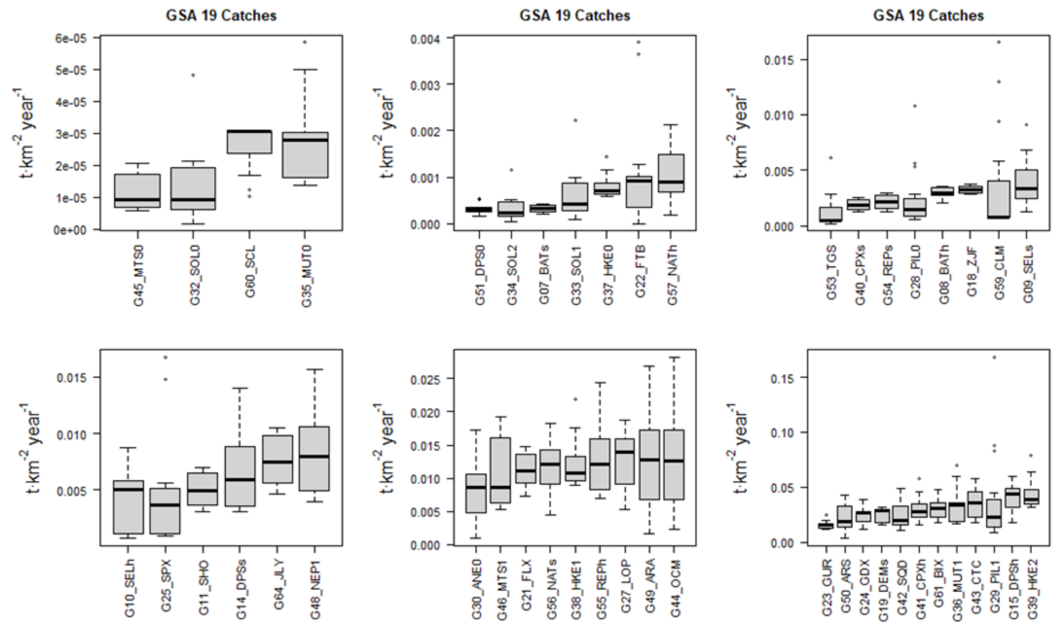


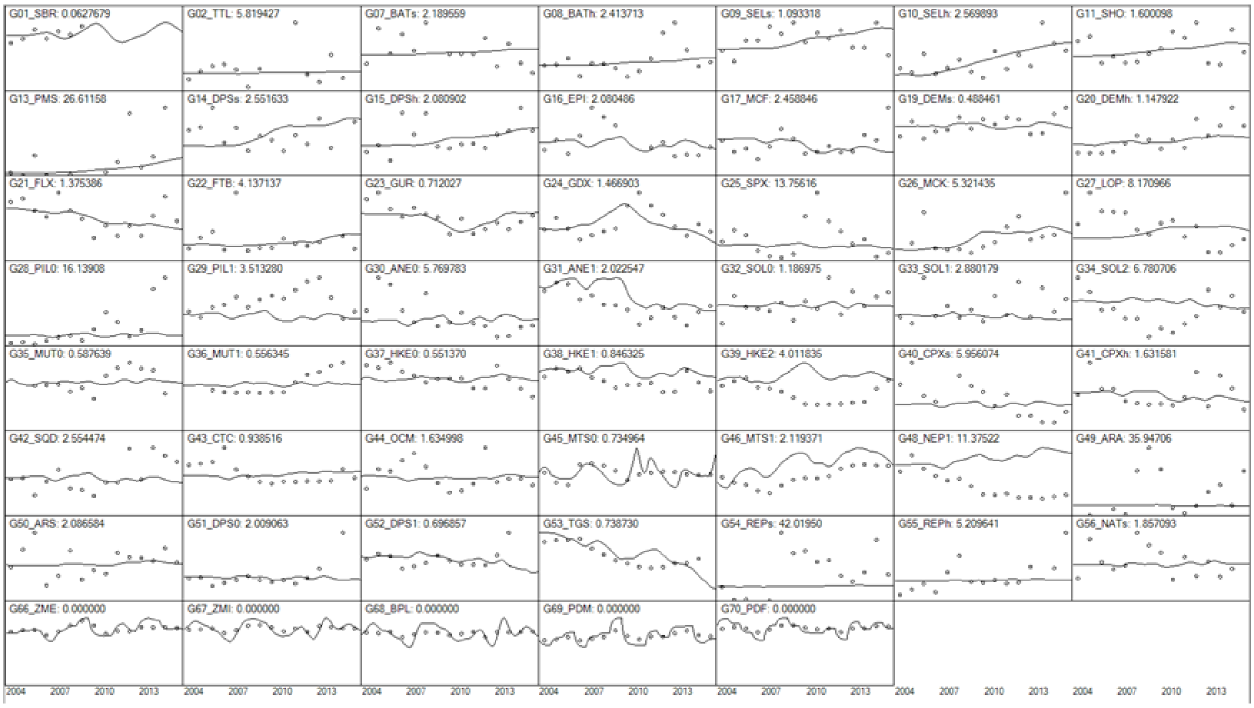
Figure 13. Whisker plots of catches time-series per functional group for GSA 19

7 Fitting strategy: preliminary testing results

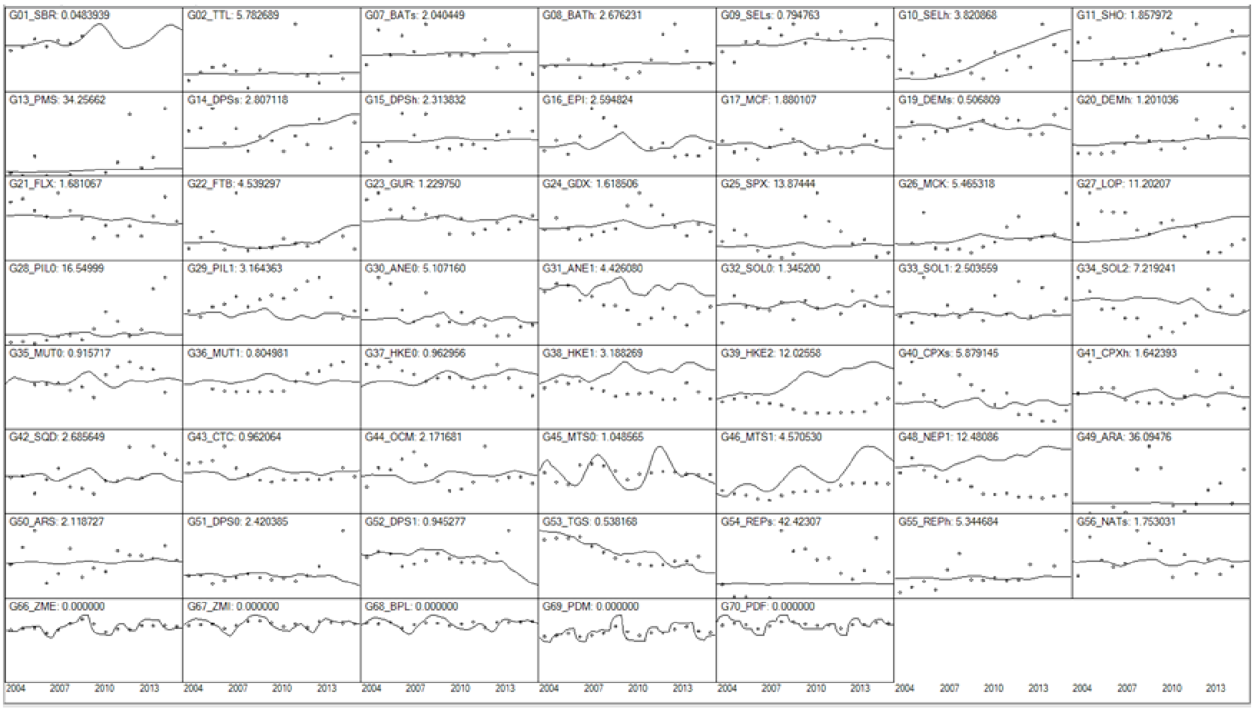
Only time series of groups well represented in the specific GSA were used for the fitting.

GSA 1718. Firstly the model was fitted using relative biomasses (type=0) and observed biomasses for stock assessment data (type=1) and catches as temporal drivers (forced catches, type -6). Manually fitting 48 parameters (49 time series of biomasses).

- Fitting by predator SS=561.9 → 258.7

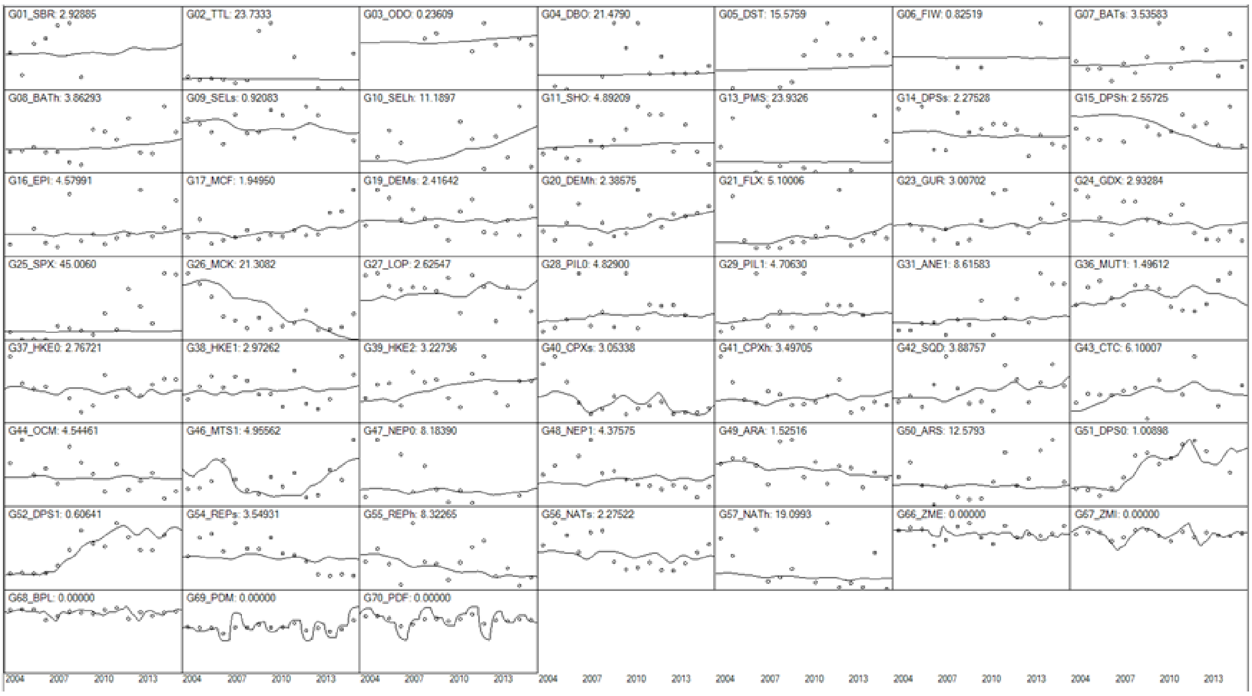


- Fitting by predator/prey SS=561.9 → 291.3

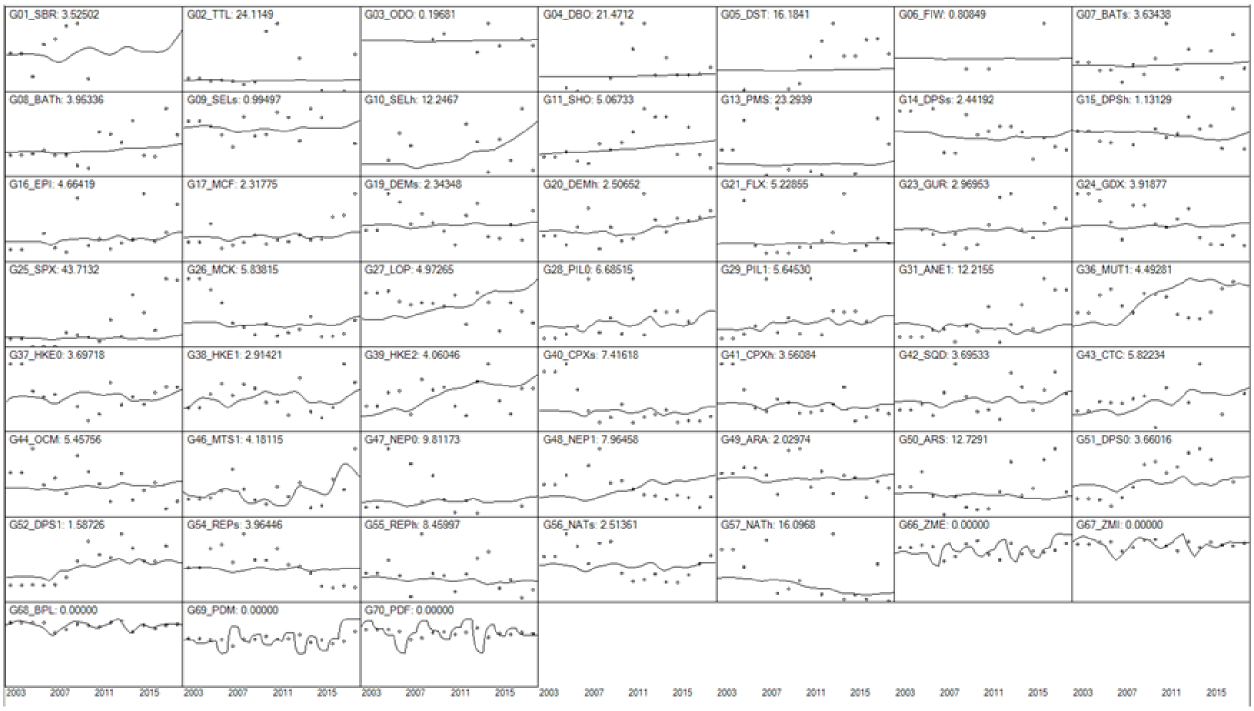


GSA 19. Firstly the model was fitted using relative biomasses (type=0) and catches as temporal drivers (forced catches, type -6). Manually fitting 46 parameters (47 time series of biomasses).

- Fitting by predator SS=607.3 → 319.9



- Fitting by predator/prey SS= 607.3 → 339.8



- For GSA19 different fitting were tested also with the stepwise plug-in using effort as temporal driver (total fishing days). We used a simplified time-series (only groups strongly represented in the GSA 19), and we tested different weightings:
  - All series with weight=1, BEST fitting by predator/prey AICc= -985.5 →-1002.7 (Fishing + 5 Vs)
  - Modified weight (10) for SHO, DEMh, GDX, DPS1, MUT1, CPXs, CPXh, OCM, ARS, REPs. BEST fitting by predator/prey AICc= 264.17 →-255.55 (Fishing + 7 Vs)
  - All weighting were standardised across time-series based on number of time-series availability per group (e.g. seabirds weight= 1 as only biomass available; *Lophius* spp. weight =0.5 for biomass and catches; sardine weight= 0.25 as two series of biomasses and two for catches were available (juvenile-adults). BEST fitting by predator/prey AICc= -1902 →-1920.6 (Fishing + 7 Vs)

This time-series did not perform well on replicating declining trends for important groups such as gadoids (G24_GDX), mackerel (G26_MCK), *Lophius* spp. (G27_LOP), shelf- and slope-cephalopods (G40_CPXh and G41_CPXs) and Eledone spp. (G44_OCM). Negative biomass accumulations (BAs) were added in Ecopath in order to force the model to hindcasting higher biomasses at the beginning of the time-series.

Negative biomass accumulation added:

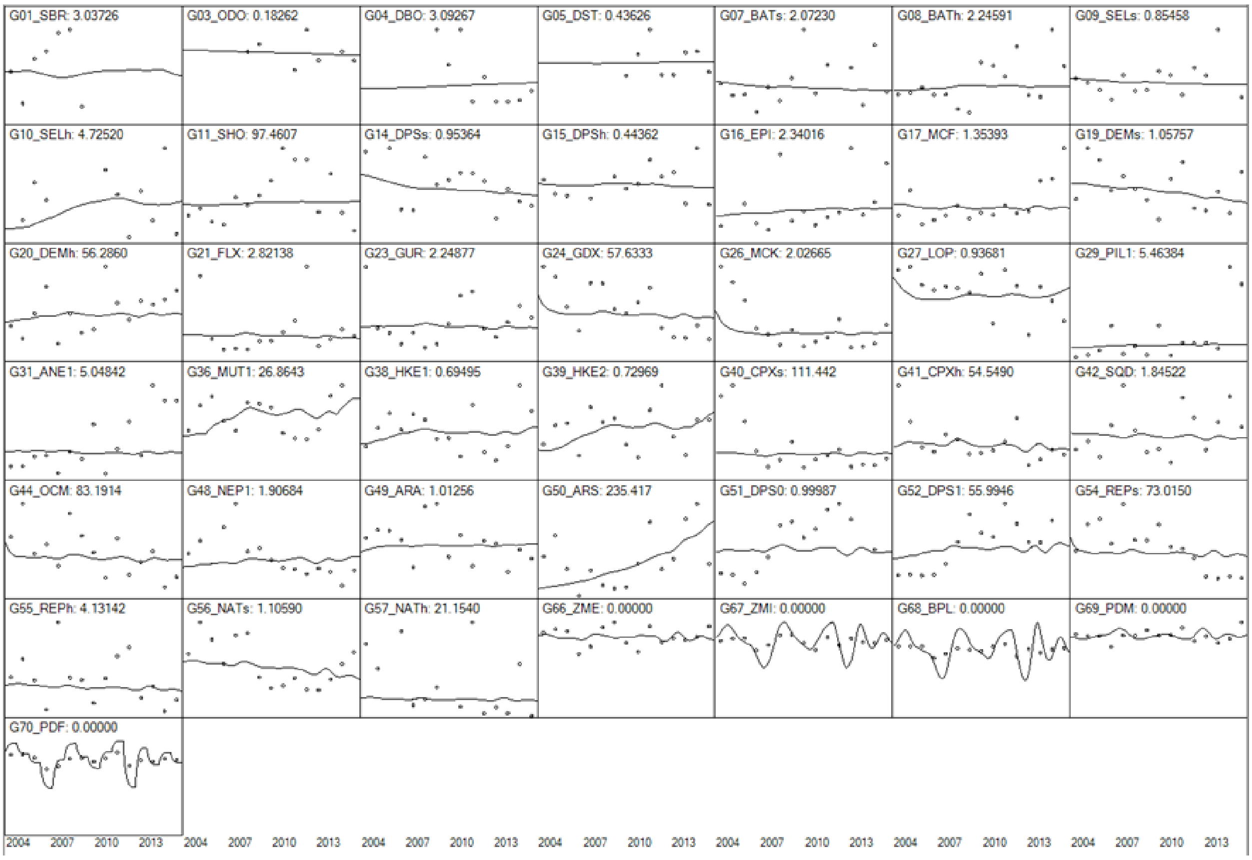
G24_GDX (-0.5 t/km2), G26_MCK (-0.9 t/km2), G27_LOP (-0.008 t/km2), G40_CPXh (-0.99 t/km2), G41_CPXs (-0.99 t/km2), G44_OCM (-0.06 t/km2).

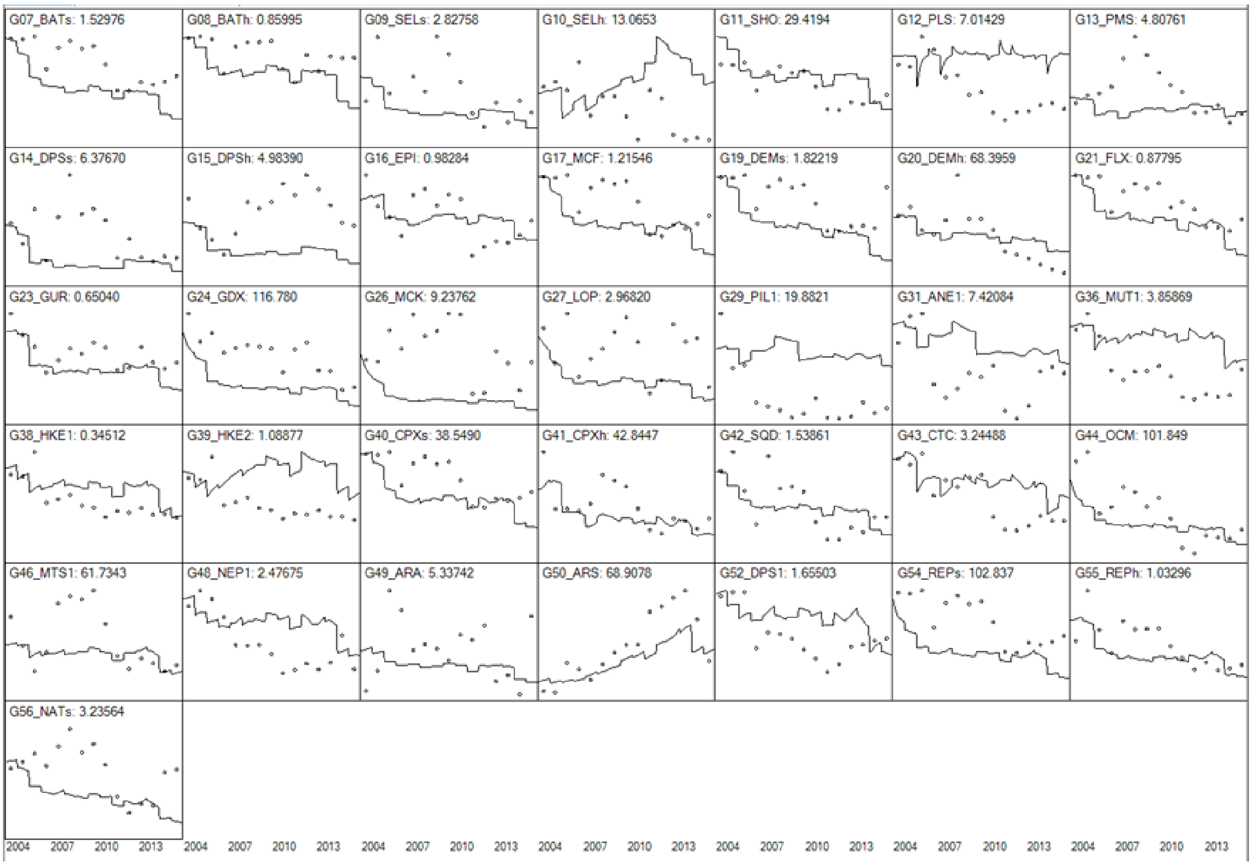
o All weighting were standardised across time-series, with added negative BAs. BEST fitting by predator/prey AICc= -1506.2 →-1607.2 (Fishing + 29 Vs)

Negative BAs for shelf- and slope-cephalopods (G40_CPXh and G41_CPXs) did not improve the fitting and was removed. Negative BA was added for slope decapods reptantia (G54_REPs, BA= -1.5 t/km2) and positive BA was added for Aristeomorpha foliacea (G50_ARS, BA= 0.05 t/km2) that showed increasing temporal observed trends.

o All weighting were standardised across time-series, with added the updated BAs. BEST fitting by predator/prey AICc= -1586.5 →-1680.7 (Fishing + 29 Vs)

o Weighting standardised across time-series and modified weight (20) for SHO, DEMh, GDX, DPS1, MUT1, CPXs, CPXh, OCM, ARS, REPs. BEST fitting by predator/prey AICc= 918.7 →568.9 (Fishing + 41 Vs).


G01_SBR: 3.03726
G03_ODO: 0.18262
G04_DBO: 3.09267
G05_DST: 0.43626
G07_BATs: 2.07230
G08_BATh: 2.24591
G09_SELs: 0.85458
G10_SELh: 4.72520
G11_SHO: 97.4607
G14_DPSs: 0.95364
G15_DPSh: 0.44362
G16_EPI: 2.34016
G17_MCF: 1.35393
G19_DEMs: 1.05757
G20_DEMh: 56.2860
G21_FLX: 2.82138
G23_GUR: 2.24877
G24_GDX: 57.6333
G26_MCK: 2.02665
G27_LOP: 0.93681
G29_PIL1: 5.46384
G31_ANE1: 5.04842
G36_MUT1: 26.8643
G38_HKE1: 0.69495
G39_HKE2: 0.72969
G40_CPXs: 111.442
G41_CPXh: 54.5490
G42_SQD: 1.84522
G44_OCM: 83.1914
G48_NEP1: 1.90684
G49_ARA: 1.01256
G50_ARS: 235.417
G51_DPS0: 0.99987
G52_DPS1: 55.9946
G54_REPs: 73.0150
G55_REPh: 4.13142
G56_NATs: 1.10590
G57_NATh: 21.1540
G66_ZME: 0.00000
G67_ZMI: 0.00000
G68_BPL: 0.00000
G69_PDM: 0.00000
G70_PDF: 0.00000
2004
2007
2010
2013


G07_BATs: 1.52976
G08_BATh: 0.85995
G09_SELs: 2.82758
G10_SELh: 13.0653
G11_SHO: 29.4194
G12_PLS: 7.01429
G13_PMS: 4.80761
G14_DPSs: 6.37670
G15_DPSh: 4.98390
G16_EPI: 0.98284
G17_MCF: 1.21546
G19_DEMs: 1.82219
G20_DEMh: 68.3959
G21_FLX: 0.87795
G23_GUR: 0.65040
G24_GDX: 116.780
G26_MCK: 9.23762
G27_LOP: 2.96820
G29_PIL1: 19.8821
G31_ANE1: 7.42084
G36_MUT1: 3.85869
G38_HKE1: 0.34512
G39_HKE2: 1.08877
G40_CPXs: 38.5490
G41_CPXh: 42.8447
G42_SQD: 1.53861
G43_CTC: 3.24488
G44_OCM: 101.849
G46_MTS1: 61.7343
G48_NEP1: 2.47675
G49_ARA: 5.33742
G50_ARS: 68.9078
G52_DPS1: 1.65503
G54_REPs: 102.837
G55_REPh: 1.03296
G56_NATs: 3.23564
2004 2007 2010 2013

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9 ANNEXES

9.1 A1 Input data and data sources of the Adriatic and Ionian Sea models

FG, input parameter	Source	Taxa/Notes
1. Seabirds		*Gelochelidon nilotica, Larus* spp., *Mergus serrator, Phalacrocorax carbo, Podiceps spp., Puffinus yelkouan, Sterna* spp.
Bi (t km^{-1} y^{-1})	Zenatello et al., 2014	
P/B (y^{-1})	Ristow et al., 1990; Brando et al., 2004	
Q/B (y^{-1})	Nagy, 1878	
Diet	Fasola et al., 1989; Agnetta et al., 2019; Ricci et al., 2019; Coll et al., 2007	
2. Marine turtles		*Caretta caretta.*
Bi (t km^{-1} y^{-1})	OBIS Sea Map (Halpin et al. 2009; Deflorio et al., 2005	Abundance data transformed by means mean individual weight (Deflorio et al. 2005; Casale et al., 2012))
P/B (y^{-1})	Casale et al., 2007	
Q/B (y^{-1})	Ricci et al., 2019	
Diet	Tomas et al., 2001; Casale et al., 2008	
3. Mid-large odontocetes		*Grampus griseus, Physeter macrocephalus, Ziphius cavirostris*
Bi (t km^{-1} y^{-1})	Maglietta et al., 2018	Monitoring surveys Jonian Dolphin Conservation in the Gulf of Taranto; Abundance data transformed by means mean individual weight (Piroddi et al. 2010)
P/B (y^{-1})	Mackinson and Daskalov, 2007; Coll et al., 2007;	
Q/B (y^{-1})	Trites and Pauly, 1998; Laran et al., 2010	
Diet	Milani et al., 2017; Blanco et al., 2006; Roberts, 2003; Garibaldi and Podestà, 2014	
4. Common Bottlenose dolphin		*Tursiops truncatus*
Bi (t km^{-1} y^{-1})	Carlucci et al., 2018	Monitoring surveys Jonian Dolphin Conservation in the Gulf of Taranto; Abundance data

FG, input parameter	Source	Taxa/Notes
		transformed by means mean individual weight (Piroddi et al. 2010; Ricci et al., 2020)
P/B (y^{-1})	Mackinson and Daskalov, 2007; Coll et al., 2007	
Q/B (y^{-1})	Trites and Pauly, 1998; Laran et al. 2010	
Diet	Milani et al., 2017; Blanco et al., 2001	
5. Striped dolphin		*Stenella coeruleoalba*
Bi (t km^{-1} y^{-1})	Carlucci et al., 2018	Monitoring surveys Jonian Dolphin Conservation in the Gulf of Taranto; Abundance data transformed by means mean individual weight (Piroddi et al. 2010; Ricci et al., 2020)
P/B (y^{-1})	Mackinson and Daskalov, 2007; Coll et al., 2007	
Q/B (y^{-1})	Trites and Pauly, 1998; Laran et al., 2010	
Diet	Milani et al., 2017; Bello, 1993; Würtz and Marrale, 1993	
6. Fin whale		*Balaenoptera physalus*
Bi (t km^{-1} y^{-1})	OBIS Sea Map (Halpin et al., 2009)	Abundance data transformed by means mean individual weight (Piroddi et al. 2010)
P/B (y^{-1})	Coll et al., 2007	
Q/B (y^{-1})	Trites and Pauly, 1998; Laran et al., 2010	
Diet	Pauly et al., 1998; Piroddi et al., 2017	
7. Demersal rays & skates_Slope		*Chimaera monstrosa, Dipturus oxyrinchus, Leucoraja circularis, Leucoraja fullonica, Leucoraja melitensis, Mobula mobular, Rhinoptera marginata, Torpedo nobiliana*
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B (y^{-1})	Pauly, 1980; Lopez, 2013	Z=F+M Empirical equation
Q/B (y^{-1})	Froese and Pauly, 2008; Lopez 2013	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Macpherson, 1979, 1981; Yıgın and Ismen, 2010; Barrìa et al., 2015; Mulas et al., 2015	
8.		*Dasyatis centroura, Dasyatis marmorata, Dasyatis pastinaca, Dasyatis* spp., *Gymnura altavela,*

FG, input parameter	Source	Taxa/Notes
Demersal rays-skates Shelf		*Myliobatis aquila, Pteromylaeus bovinus, Pteroplatytrygon violacea, Raja alba, Raja asterias, Raja batis, Raja brachyura, Raja clavata, Raja miraletus, Raja montagui, Raja ocellata, Raja polystigma, Raja radiata, Raja radula, Raja* spp., *Raja undulata, Squatina squatina, Torpedo marmorata, Torpedo torpedo, Torpedo* spp.
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B (y^{-1})	Pauly, 1980	Z=F+M Empirical equation
Q/B (y^{-1})	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Morte et al., 1997; Cortes, 1999; Romanelli et al., 2006; Vannucci et al., 2006, Yeldan et al., 2009; Follesa et al., 2010; Kadri et al., 2013; Navarro et al., 2013; Barrìa et al., 2015; Mulas et al., 2019	
9. Demersal sharks Slope		*Carcharhinus plumbeus, Centrophorus granulosus, Dalatias licha, Etmopterus spinax, Galeorhinus galeus, Heptranchias perlo, Hexanchus griseus, Isurus oxyrinchus, Oxynotus centrina, Scyliorhinus canicula, Squalus blainvillei*
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B (y^{-1})	Pauly 1980; Lopez, 2013	Z=F+M Empirical equation
Q/B (y^{-1})	Pauly et al., 1990; Froese and Pauly, 2008; Madurell and Cartes, 2005; Merz and Myers, 1998; Martinho et al., 2012; Barrìa et al., 2015	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Macpherson, 1981; Smale, 1996; Belluscio, et al. 2000; Madurell and Cartes, 2005; Megalofonu and Chatzispyrou, 2006; Fanelli et al., 2009a	
10. Demersal sharks Shelf		*Alopias vulpinus, Centrophorus uyato, Mustelus asterias, Mustelus mustelus, Mustelus punctulatus, Mustelus* spp., *Prionace glauca, Scyliorhinus* spp., *Scyliorhinus stellaris, Squalus acanthias, Squalus* spp., *Squatina aculeata, Squatina oculata, Sphyrna* spp.

FG, input parameter	Source	Taxa/Notes
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS) (ADR); Estimated (ION)	Average biomass 2004-2006; EE=0.95 in Ionian Sea
P/B (y^{-1})	Pauly, 1980	Z=F+M Empirical equation
Q/B (y^{-1})	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Morte et al., 1997; Cortes, 1999; Romanelli et al., 2006; Yeldan et al., 2009; Mulas et al., 2019	
11. Blackmouth catshark		*Galeus melastomus*
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B (y^{-1})	Pauly, 1980	Z=F+M Empirical equation
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Macpherson, 1979; Cortes, 1999; Fanelli et al., 2009a	
12. Large pelagics		*Istiophoridae, Katsuwonus pelamis, Tetrapturus belone, Thunnus alalunga, Thunnus albacares, Thunnus obesus, Thunnus thynnus, Xiphias gladius* ION: EE fixed 0.95; Other Production – Immigration = 0.300 t km^{-2} y^{-1}
Bi (t km^{-1} y^{-1})	ICCAT 2020	
P/B	Piroddi et al., 2015	
Q/B	Piroddi et al., 2015, 2017; Moutopoulos et al., 2013	
Diet	Bello, 1991; Karakulak et al., 2009; Battaglia et al., 2013	
13. Medium pelagics		*Auxis rochei, Auxis* spp., *Brama brama, Coryphaena hippurus, Euthynnus alletteratus, Lichia amia, Pomatomus saltatrix, Sarda sarda, Seriola dumerili, Seriola fasciata, Sphyraena sphyraena, Sphyraena* spp., *Trachinotus ovatus*
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980	Z=F+M Empirical equation, www.fishbase.org
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Akadje et al., 2013; Campo et al., 2006	
14. Demersal piscivorous Slope		*Chauliodus sloani, Conger conger, Evermannella balbo, Molva dipterygia, Molva molva, Polyprion americanus, Stomias boa, Sudis hyalina,*

FG, input parameter	Source	Taxa/Notes
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980; Merz and Myers, 1998, Guènette and Morato, 2001	Z=F+M Empirical equation, www.fishbase.org
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Morato et al., 1999; Butler et al., 2001, O'Sullivan et al., 2004	
15. Demersal piscivorous Shelf		*Dentex dentex, Dentex gibbosus, Dentex macrophthalmus, Dentex maroccanus, Dentex* spp.*, Dicentrarchus labrax, Epinephelus aeneus, Epinephelus alexandrinus, Gymnothorax unicolor, Lepidopus caudatus, Muraena helena, Scorpaena elongata, Scorpaena porcus, Scorpaena scrofa, Scorpaena* spp.*, Synodus saurus, Trachinus araneus, Trachinus draco, Trachinus* spp.*, Trachinus vipera, Uranoscopus scaber, Zeus faber,*
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980	Z=F+M Empirical equation, www.fishbase.org
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Sanz, 1985; Abdelkader and Ktari, 1986; Bradai and Bouain, 1990; Stergiou and Fourtouni, 1991; Arculeo et al., 1993 ; D'Onghia et al., 2000; Morte et al., 1999a, 2001; Renones et al., 2002; Soares et al., 2003; Samir, 2008; Başçınar and Sağlam, 2009	
16. Epipelagic fish		*Aphia minuta, Atherina boyeri, Atherinidae, Belone belone, Boops boops, Chelon labrosus, Chromis chromis, Liza aurata, Liza ramada, Liza saliens, Liza* spp.*, Mola mola. Mugil cephalus, Mugil* spp.*, Spicara flexuosa, Spicara maena, Spicara smaris, Spicara* spp.
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Brando et al., 2004;	Z=F+M Empirical equation, www.fishbase.org

FG, input parameter	Source	Taxa/Notes
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Moreno and Castro, 1995, Derbal and Kara, 2008; Milisenda et al., 2014	
17. Mesopelagic fish crustacean feeders		*Arctozenus risso, Argentina sphyraena, Argyropelecus hemigymnus, Benthocometes robustus, Benthosema glaciale, Capros aper, Ceratoscopelus maderensis, Chlorophthalmus agassizi, Cyclothone spp., Diaphus holti, Diaphus metopoclampus, Diaphus rafinesquii, Diaphus spp., Electrona rissoi, Epigonus constanciae, Glossanodon leioglossus, Gonichthys coccoi, Gonostoma denudatum, Hygophum benoiti, Hygophum hygomii, Hygophum spp., Hymenocephalus italicus, Ichthyococcus ovatus, Lampanyctus crocodilus, Lampanyctus spp., Lampris guttatus, Lestidiops spp., Lobianchia dofleini, Lobianchia gemellarii, Macroramphosus scolopax, Maurolicus muelleri, Microichthys coccoi, Myctophum punctatum, Myctophidae, Nansenia oblita, Nemichthys scolopaceus, Nettastoma melanurum, Nezumia aequalis, Nezumia sclerorhynchus, Notacanthus bonapartei, Notolepis rissoi, Notoscopelus bolini, Notoscopelus elongatus, Notoscopelus spp., Paralepis coregonoides, Paralepis speciosa, Symbolophorus veranyi, Trachipterus trachypterus, Vinciguerria attenuata*
Bi (t km^{-1} y^{-1})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Tsarin, 1994; Arreguín-Sánchez et al., 2002; Stanford et al., 2002; Heymans 2005; Rosas-Luis et al. 2009; Pauly 1980; Silvestre et al. 1993; Vega-Cendejas et al. 1993; Merz and Myers 1998; Guènette et al. 2002; Heymans, 2005; Anastasopoulou et al., 2006, Rosas-Luis et al., 2009	Z=F+M Empirical equation, www.fishbase.org

FG, input parameter	Source	Taxa/Notes
Q/B	Childress et al., 1980; Pakhomov et al., 1996; Pauly et al., 1990; Madurell and Cartes, 2005; Froese and Pauly, 2008	www.fishbase.org; estimated on average local biomass of the species group using empirical equation
Diet	Podrazhanskaya 1993; Pakhomov et al. 1996; Macpherson 1981; Hopkins et al. 1985, 1996; Stefanescu and Cartes,1992; Gorelova and Krasil'nikova, 1990; Longo et al., 2005; D'Onghia et al., 2006; Anastasopoulou and Kapiris, 2008; Carpentieri et al., 2006, 2007, 2016	
<u>18.</u> **Fish zooplancton-jelly feeders**		*Centrolophus niger, Cubiceps gracilis, Schedophilus ovalis, Stromateus fiatola*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Agnetta et al., 2019	
Q/B	Froese and Pauly, 2008; Agnetta et al., 2019	www.fishbase.org; estimated on average local biomass of the species group using empirical equation
Diet	Battaglia et al., 2014	
<u>19.</u> **<u>Demersal fish_Slope</u>**		*Aulopus filamentosus, Bathophilus nigerrimus, Bathypterois dubius, Caelorhynchus caelorhynchus, Callanthias ruber, Cataetyx alleni, Chlopsis bicolor, Dysomma brevirostre, Echiodon dentatus, Epigonus denticulatus, Epigonus telescopus, Gnathophis mystax, Helicolenus dactylopterus, Hoplostethus mediterraneus, Lepidion lepidion, Macrouridae, Ophisurus serpens, Pagellus bogaraveo, Synchiropus phaeton, Trachyrhynchus scabrus*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980	Z=F+M Empirical equation, www.fishbase.org
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Macpherson, 1979; Casadevall and Matallanas, 1990; Meyer and Smale, 1991; Morato et al., 2001;	

FG, input parameter	Source	Taxa/Notes
	Carrassón et al., 2002; Madurell and Cartes, 2005; Carpentieri et al., 2007; Tuncay et al., 2008; Consoli et al., 2010; Capezzuto et al., 2020	
20. Demersal fish_Shelf		*Acantholabrus palloni, Ammodytes* spp.*, Anguilla Anguilla, Anthias anthias, Apogon imberbis, Ariosoma balearicum, Balistes carolinensis , Bellottia apoda, Blenniidae, Blennius ocellaris, Callionymus fasciatus, Callionymus lyra, Callionymus maculatus, Callionymus risso, Callionymus spp., Carapus acus, Centracanthus cirrus, Cepola macrophthalma, Coris julis, Dalophis imberbis, Deltentosteus quadrimaculatus, Diplodus annularis, Diplodus puntazzo, Diplodus sargus, Diplodus* spp.*, Diplodus vulgaris, Echelus myrus, Gobius geniporus, Gobius niger, Gobius spp., Gymnammodytes cicerellus, Hippocampus guttulatus, Hippocampus hippocampus, Hippocampus* spp.*, Labridae, Labrus merula, Labrus mixtus, Lappanella fasciata, Lepadogaster lepadogaster, Lesueurigobius friesii, Lesueurigobius sanzi, Lesueurigobius suerii, Lithognathus mormyrus, Mullus surmuletus, Nerophis ophidion, Oblada melanura, Ophichthus rufus, Ophidion barbatum, Pagellus acarne, Pagellus erythrinus, Pagellus* spp.*, Pagrus caeruleostictus, Pagrus pagrus, Parablennius gattorugine, Parablennius tentacularis, Pomatoschistus marmoratus, Pomatoschistus minutus, Pomatoschistus* spp.*, Salaria pavo, Sarpa salpa, Sciaena umbra, Scorpaena notata, Serranus atricauda, Serranus cabrilla, Serranus hepatus, Serranus scriba, Sparisoma cretense, Sparus aurata, Sphoeroides pachygaster, Spondyliosoma cantharus, Symphodus cinereus, Symphodus mediterraneus, Symphodus ocellatus, Symphodus* spp.*, Syngnathus acus, Syngnathus tenuirostris, Syngnathus spp., Syngnathus typhle, Thalasoma pavo, Umbrina cirrosa, Xyrichtys novacula, Zosterisessor ophiocephalus*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980	Z=F+M Empirical equation, www.fishbase.org

FG, input parameter	Source	Taxa/Notes
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Jukic, 1972; Khoury C (1984); Rosecchi, 1987; Arculeo et al., 1993; Stergiou, 1993; Casadevall et al., 1994; Sala and Ballesteros, 1997; Cardinale et al., 1997; Bradai et al., 1998; Fabi et al., 1998; Morte et al., 2001; Filiz and Toğulga 2009, Ouannes-Ghorbel et al., 2005; Kitsos et al., 2008a; Šantić, 2010; Tuncay et al., 2010; Fanelli et al., 2011,	
<u>21 Other flatfishes</u>		*Argyrosomus regius, Arnoglossus imperialis, Arnoglosuss kessleri, Arnoglossus laterna, Arnoglossus rueppelii, Arnoglossus spp., Arnoglossus thori, Bothus podas, Buglossidium luteum, Citharus linguatula, Dicologlossa cuneata, Lepidorhombus boscii, Lepidorhombus spp., Lepidorhombus whiffiagonis, Microchirus boscanion, Microchirus ocellatus, Microchirus variegatus, Monochirus hispidus, Pegusa impar, Pegusa lascaris, Platichthys flesus, Pleuronectiformes nd, Solea aegyptiaca, Solea lascaris, Synapturichthys kleinii, Symphurus ligulatus, Symphurus nigrescens, Symphurus* spp., *Zeugopterus regius,*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980	Z=F+M Empirical equation, www.fishbase.org
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Macpherson, 1981; Morte et al., 1999b; Cabral et al., 2002; Fanelli et al., 2009b	
<u>22. Turbot and brill</u>		*Psetta maxima, Scophthalmus rhombus*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980	Z=F+M Empirical equation, www.fishbase.org

FG, input parameter	Source	Taxa/Notes
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Vinagre et al., 2011	
23. Gurnards		*Aspitrigla cuculus, Chelidonichthys lucerna, Chelidonichthys obscurus, Dactylopterus volitans, Eutrigla gurnardus, Lepidotrigla cavillone, Lepidotrigla dieuzeidei, Peristedion cataphractum, Trigla lyra, Trigla* spp.*, Trigloporus lastoviza,*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980	Z=F+M Empirical equation, www.fishbase.org
Q/B	Colloca et al., 1997; Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Moreno-Amich, 1992, 1994; Labropoulou and Machias, 1998; Terrats et al., 1999; Boudaya et al., 2007; Stagioni, 2012	
24. Other gadids		*Antonogadus* spp.*, Gadella maraldi, Gadiculus argenteus, Gaidropsarus biscayensis, Gaidropsarus mediterraneus, Gaidropsarus* spp.*, Merlangius merlangus, Micromesistius poutassou, Mora moro, Phycis blennoides, Phycis phycis, Trisopterus minutus capelanus,*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980	Z=F+M Empirical equation, www.fishbase.org
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Macpherson, 1981; Bergstad 1991; Olaso et al., 1995; Carrassón et al., 1997; Morato et al., 1999; Cabral and Murta, 2002; Morte et al., 2002; Milic et al., 2012	
25. Other small pelagics		*Alosa alosa, Alosa fallax, Alosa* spp.*, Clupeidae, Naucrates ductor, Sardinella aurita, Sprattus sprattus*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980;	Z=F+M Empirical equation, www.fishbase.org

FG, input parameter	Source	Taxa/Notes
Q/B	Pauly et al., 1990; Froese and Pauly, 2008; Tudela and Palomera, 1995	www.fishbase.org, estimated on average local biomass of the species group using empircal equation
Diet	Sirotenko and Sorokalit, 1979, Lomiri et al., 2008; Morote et al., 2008	
26. Mackarels		*Carangidae, Scomber colias, Scomber scombrus, Scomber* spp., *Trachurus mediterraneus, Trachurus picturatus, Trachurus trachurus, Trachurus* spp.
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Pauly, 1980	Z=F+M Empirical equation, www.fishbase.org
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Castro and Hernandez-Garcìa, 1995; Šantić et al., 200, 2005; Jardas et al., 2004; Sever et al., 2006	
27. Anglers		*Lophius budegassa, Lophius piscatorius*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Carlucci et al., 2009; Maiorano et al., 2010	Z=M+F Empirical equation, www.fishbase.org
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Stagioni, 2013	
28. Sardine 0		*Sardina pilchardus* (age 0)
Bi (t km^{-2} y^{-1})	Estimated	Multi-stanza routine
P/B	WGSASP-GFCM, 2019	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Nikolioudakis et al., 2012; Borme et al., 2013	
29. Sardine 1+		*Sardina pilchardus* (age 1+)
Bi (t km^{-2} y^{-1})	WGSASP-GFCM, 2019 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	WGSASP-GFCM, 2019	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Nikolioudakis et al., 2012; Borme et al., 2013	

FG, input parameter	Source	Taxa/Notes
30. Anchovy 0		*Engraulis encrasicolus* (age 0)
Bi	Estimated	Multi-stanza routine
P/B	WGSASP-GFCM, 2019	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Borme et al., 2009	Integrate with Tudela and Palomera, 1995; Bacha et al. 2010
31. Anchovy 1+		*Engraulis encrasicolus* (age 1+)
Bi	WGSASP-GFCM, 2019 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	WGSASP-GFCM, 2019	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Borme et al., 2009	Integrate with Tudela and Palomera, 1995; Bacha et al. 2010
32. Sole 0		*Solea solea* (age 0)
Bi (t km^{-2} y^{-1})	Estimated	Multi-stanza routine
P/B	STECF, 20-15, GSA 17	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Costa, 1988	
33. Sole 1		*Solea solea* (age 1)
Bi (t km^{-2} y^{-1})	STECF, 20-15, GSA 17 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	STECF, 20-15, GSA 17	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Cabral, 2000	
34. Sole 2+		*Solea solea* (age 2+)
Bi (t km^{-1} $y^{-1)}$	STECF, 20-15, GSA 17 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	STECF, 20-15, GSA 17	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Molinero and Flos, 1991	
35. Red Mullet 0		*Mullus barbatus* (0)
Bi (t km^{-1} $y^{-1)}$	Estimated	Multi-stanza routine

FG, input parameter	Source	Taxa/Notes
P/B	STECF, 20-15, GSA 17-18 (ADR); Maiorano et al. 2010, Ricci et al., 2019	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Jukic, 1972; Froglia, 1988	
36. Red Mullet 1+		*Mullus barbatus* (1+)
Bi (t km^{-1} y^{-1})	STECF, 20-15, GSA 17-18 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	STECF, 20-15, GSA 17-18 (ADR); Maiorano et al. 2010, Ricci et al., 2019	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Jukic, 1972; Labropoulou and Eleftheriou, 1997	
37. Hake 0		*Merluccius merluccius* (0)
Bi (t km^{-1} y^{-})	Estimated	Multi-stanza routine
P/B	STECF, 20-15, GSA 17-18	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Jukic, 1972; Froglia, 1973; Bozzano et al., 1997; Stagioni et al., 2010	
38. Hake 1		*Merluccius merluccius* (1)
Bi (t km^{-1} y^{-})	STECF, 20-15, GSA 17-18 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	STECF, 20-15, GSA 17-18 (ADR); Maiorano et al., 2010 (ION)	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Jukic, 1972; Froglia, 1973; Bozzano et al., 1997; Stagioni et al., 2010	
39. Hake 2+		*Merluccius merluccius* (2+)
Bi (t km^{-1} y^{-})	STECF, 20-15, GSA 17-18 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006

FG, input parameter	Source	Taxa/Notes
P/B	STECF, 20-15, GSA 17-18 (ADR); Maiorano et al., 2010 (ION)	Z= weighted average by age biomass (F+M)
Q/B	Froese and Pauly, 2008	www.fishbase.org, estimated on average local biomass of the species group using empirical equation
Diet	Jukic, 1972; Froglia, 1973; Bozzano et al., 1997; Stagioni et al., 2010	
<u>40. Other cephalopods Slope</u>		*Abralia verany, Abraliopsis morisii, Ancistrocheirus lesueurii, Ancistroteuthis lichtensteinii, Bathypolypus sponsalis, Brachioteuthis riisei, Callistoctopus Macropus, Chtenopteryx sicula, Chiroteuthis veranii, Heteroteuthis dispar, Macrotritopus defilippi, Neorossia caroli, Octopoteuthis sicula, Octopus salutii, Ommastrephidae, Onychoteuthis banksii, Pteroctopus tetracirrhus, Pyroteuthis margaritifera, Rondeletiola minor, Rossia macrosoma, Sepietta oweniana, Sepietta* spp., *Thysanoteuthis rhombus*
Bi	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Brey, 2001	Empirical equation
Q/B	Boyle 1990, Wells and Clarke 1996; Cammen, 1980	Empirical equation
Diet	Bergstrom, 1985; Quetglas et al., 2001, 2005, 2009	
<u>41. Other cephalopods Shelf</u>		*Alloteuthis media, Alloteuthis subulata, Alloteuthis* spp., *Argonauta argo, Octopus* spp., *Octopus vulgaris, Scaeurgus unicirrhus, Sepia elegans, Sepia orbignyana, Sepia spp., Sepietta obscura, Sepietta neglecta, Sepiola affinis, Sepiola intermedia, Sepiola robusta, Sepiola rondeletii, Sepiola* spp.
Bi (t km^{-1} y^{-})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Brey, 2001	Empirical equation
Q/B	Cammen, 1980; Boyle, 1990; Wells and Clarke, 1996	Empirical equation
Diet	Castro and Guerra, 1990; Quetglas et al., 1998; Zghidi et al., 2003; Rosa et al., 2004	

FG, input parameter	Source	Taxa/Notes
42. Squids		*Histioteuthis bonnellii, Histioteuthis reversa, Histioteuthis* spp., *Illex coindetii, Illex* spp., *Loligo forbesi, Loligo vulgaris, Loligo* spp., *Todarodes sagittatus, Todaropsis eblanae,*
Bi (t km^{-1} y^{-})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Brey, 2001	Empirical equation
Q/B	Cammen, 1980; Wells and Clarke, 1996	Empirical equation
Diet	Pierce et al., 1994, Castro and Hernandez-Garcìa, 1995; Coelho et al., 1996; Rasero et al., 1996; Quetglas et al., 1999, 2010; Lelli et al., 2005	
43. Common cuttlefish		*Sepia officinalis*
Bi (t km^{-2} y^{-1})	STECF, 20-15, GSA 17 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	Brey, 2001	Empirical equation
Q/B	Cammen, 1980; Wells and Clarke, 1996	Empirical equation
Diet	Castro and Guerra, 1990	
44. Musky-horned octopus		*Eledone cirrhosa, Eledone moschata*
Bi (t km^{-1} y^{-})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Brey, 2001	Empirical equation
Q/B	Cammen, 1980; Wells and Clarke, 1996	Empirical equation
Diet	Sifner and Vrgoc, 2009	
45. Mantis shrimp 0		*Squilla mantis* (0)
Bi (t km^{-1} y^{-})	Estimated	Multi-stanza routine
P/B	STECF, 20-15, GSA 17 (ADR)	Z= weighted average by age biomass (F+M)
Q/B	Cammen, 1980	Empirical equation
Diet	Mili et al., 2013	
46. Mantis shrimp 1+		*Squilla mantis* (1+)
Bi (t km^{-1} y^{-})	STECF, 20-15, GSA 17 (ADR), Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	STECF, 20-15, GSA 17	Z= weighted average by age biomass (F+M)
Q/B	Cammen, 1980	Empirical equation
Diet	Froglia and Giannini, 1989; Mili et al., 2013	
47. Norway lobster 0		*Nephrops norvegicus* (0)
Bi (t km^{-1} y^{-})	Estimated	Multi-stanza routine

FG, input parameter	Source	Taxa/Notes
P/B	STECF, 20-15, GSA 17	Z= weighted average by age biomass (F+M)
Q/B	Cammen 1980; Maynou and Cartes, 1998	Empirical equation
Diet	Cristo and Cartes, 1998	
48. Norway lobster 1+		*Nephrops norvegicus* (1+)
Bi (t km^{-1} y^{-})	STECF, 20-15, GSA 17 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	STECF, 20-15, GSA 17 (ADR); Maioarano et al., 2010 (ION)	Z= weighted average by age biomass (F+M)
Q/B	Cammen 1980; Maynou and Cartes, 1998	Empirical equation
Diet	Cristo and Cartes, 1998	
49. Blue and Red Shrimp		*Aristeus antennatus*
Bi (t km^{-1} y^{-})	Estimated (ADR); Trawl Survey (MEDITS) (ION)	EE=0.78 (ADR); Average biomass 2004-2006
P/B	WGSAD-GFCM (2018); Maiorano et al., 2010	Z=F+M Empirical equation
Q/B	Cammen 1980; Maynou and Cartes, 1998	Empirical equation
Diet	Kapiris and Thessalou-Legaki, 2011	
50. Red Giant shrimp		*Aristaeomorpha foliacea*
Bi (t km^{-1} y^{-})	Estimated (ADR); Trawl Survey (MEDITS) (ION)	EE=0.83 (ADR); Average biomass 2004-2006 (ION)
P/B	WGSAD-GFCM (2018); Maiorano et al., 2010	Z=F+M Empirical equation
Q/B	Maynou and Cartes, 1998; Cammen 1980	Empirical equation
Diet	Kapiris et al., 2010	
51. Deep water rose shrimp 0		*Parapenaeus longirostris* (0)
Bi (t km^{-1} y^{-})	Estimated	Multi-stanza routine
P/B	STECF, 20-15 GSA 17-18-19	Z= weighted average by age biomass (F+M)
Q/B	Cammen 1980	Empirical equation
Diet	Kapiris, 2004	
52. Deep water rose shrimp 1+		*Parapenaeus longirostris* (1+)
Bi (t km^{-1} y^{-})	STECF, 20-15 GSA 17-18-19	Average biomass 2004-2006
P/B	STECF, 20-15 GSA 17-18-19	Z= weighted average by age biomass (F+M)
Q/B	Cammen, 1980	Empirical equation

FG, input parameter	Source	Taxa/Notes
Diet	Cartes 1995, Kapiris, 2004	
53. Caramote prawn		*Penaeus kerathurus*
Bi (t km^{-1} y^{-})	STECF, 20-15 GSA 17 (ADR); Trawl Survey (MEDITS) (ION)	Average biomass 2004-2006
P/B	STECF, 20-15 GSA 17	Z=M+F
Q/B	Cammen, 1980	Empirical equation
Diet	Prato et al., 2010	
54. Decapods_Reptantia_Slope		*Aegaeon lacazei, Bathynectes maravigna, Bathynectes* spp., *Calocaris macandreae, Geryon longipes, Macropipus tuberculatus, Monodaeus couchii, Munida iris, Munida perarmata, Munida tenuimana, Pagurus alatus, Paromola cuvieri, Polycheles typhlops, Rissoides desmaresti, Rissoides pallidus*
Bi (t km^{-1} y^{-})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Brey, 2001	Empirical equation
Q/B	Cammen, 1980; Maynou and Cartes, 1998	Empirical equation
Diet	Abelló, 1989; Cartes and Abelló, 1992; Cartes, 1993a, b	
55. Decapods_Reptantia_Shelf		*Aegaeon cataphractus, Alpheidae, Alpheus glaber, Alpheus* spp., *Anamathia rissoana, Anapagurus bicorniger, Anapagurus breviaculeatus, Anapagurus laevis, Anapagurus spp., Atelecyclus rotundatus, Atelecyclus* spp., *Brachynotus gemmellari, Brachynotus sexdentatus, Brachynotus spp., Calappa granulata, Calappa rissoana, Calappa tuerkayana, Callianassidae, Callinectes sapidus, Carcinus aestuarii, Corystes cassivelaunus, Crangon spp. Crangonidae, Dardanus arrosor, Dardanus calidus, Diogenes pugilator, Diogenes spp. Dromia personata, Ebalia cranchii, Ebalia edwarsi, Ebalia nux, Ebalia spp., Eriphia verrucose, Ethusa mascarpone, Eurynome aspera, Medorippe lanata, Galathea dispersa, Galathea intermedia, Galathea strigosa, Galathea spp., Goneplax rhomboides, Homarus gammarus, Homola barbata, Ilia nucleus, Inachus communissimus, Inachus dorsettensis, Inachus leptochirus, Inachus phalangium, Inachus thoracicus, Inachus spp., Jaxea nocturna, Latreillia elegans, Liocarcinus corrugatus, Liocarcinus depurator, Liocarcinus maculatus, Liocarcinus*

FG, input parameter	Source	Taxa/Notes
		spp., Liocarcinus vernalis, Lissa chiragra, Macropodia linaresi, Macropodia longipes, Macropodia longirostris Macropodia rostrata, Macropodia spp., Maja crispata, Maja goltziana, Maja squinado, Maja spp., Medorippe lanata, Munida intermedia, Munida rugosa, Munida rutllanti, Munida spp, Necora puber, Nepinnotheres pinnotheres, Paguridae, Pagurus prideaux, Pagurus spp., Palicus caroni, Palinurus elephas, Partenope angulifrons, Parthenope massena, Pilumnus hirtellus, Pilumnus spinifer, Pilumnus spp., Pilumnus villosissimus, Pinnotheres pisum, Pisa armata, Pisa muscosa, Pisa nodiopes, Pisa spp., Pisidia longicornis, Pisidia spp.*, Polybius henslowi, Porcellana platycheles, Portunus hastatus, Portunus* spp.*, Pseudosquillopsis cerisii, Pycnogonida, Scyllarus arctus, Scyllarides latus, Scyllarus pygmaeus, Scyllarus* spp.*, Spinolambrus macrochelos, Stenopus spinosus, Typton spongicola, Upogebia tipica, Upogebia* spp.*, Xantho spp.*
Bi (t km^{-1} y^{-})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Brey, 2001	Empirical equation
Q/B	Cammen 1980; Maynou and Cartes, 1998	Empirical equation
Diet	Freire, 1996; Bernardez et al., 2000	
56. Decapods_Natantia_Slope		*Acanthephyra eximia, Acanthephyra pelagica, Acanthephyra spp., Chlorotocus crassicornis, Deosergestes arachnipodus, Eusergestes arcticus, Funchalia woodwardi, Gennadas elegans, Ligur ensiferus, Nematocarcinus exilis, Pandalina profunda, Pasiphaea multidentata, Pasiphaea sivado, Pasiphaea* spp.*, Philocheras echinulatus, Philocheras* spp.*, Plesionika acanthonotus, Plesionika antigay, Plesionika edwardsii, Plesionika gigliolii, Plesionika heterocarpus, Plesionika martia, Plesionika* spp.*, Pontophilus norvegicus, Pontophilus spinosus, Pontophilus* spp.*, Processa canaliculate, Processa edulis, Processa modica, Processa nouveli, Processa spp., Sergestidae, Sergestes robustus, Solenocera membranacea,*

FG, input parameter	Source	Taxa/Notes
Bi (t km^{-1} y^{-})	Estimated (ADR); Trawl Survey (MEDITS) (ION)	EE= 0.96 (ADR); Average biomass 2004-2006 (ION)
P/B	Brey, 2001	Empirical equation
Q/B	Cammen, 1980; Maynou and Cartes, 1998	Empirical equation
Diet	Cartes, 1993c, d, 1995; Fanelli and Cartes, 2004	
57. Decapods_Natantia_Shelf		*Hippolyte* spp., *Palaemon macrodactylus, Palemon serratus, Palemon* spp., *Pandalina* spp., *Pandalus borealis, Pandalus* spp., *Plesionika narval, Sicyonia carinata*
Bi (t km^{-1} y^{-})	Trawl Survey (MEDITS)	Average biomass 2004-2006
P/B	Brey, 2001	Empirical equation
Q/B	Cammen 1980; Maynou and Cartes, 1998	Empirical equation
Diet	Guerao and Ribera, 1996; Barańska, 2008; Kitsos et al., 2008b	
58. Suprabenthic_macrocrustaceans		Amphipods, Isopods, Misidiaceans, Cumaceans, Ostracoda, Tanaidacea
Bi (t km^{-1} y^{-})	SOLEMON Survey (ADR); Estimated in ION	EE=0.99 (ION)
P/B	Ricci et al., 2019 (ION)	
Q/B	Ricci et al., 2019 (ION)	
Diet	Greze et al., 1968; Fanelli et al. 2009c, Polunin et al. 2001	
59. Clams		*Chamelea gallina, Callista chione, Ruditapes decussatus, Venerupis aurea, Venus verrucosa, Venus* spp.
Bi (t km^{-1} y^{-1})	DRES survey (ADR); Estimated (ION)	Average 2004-2006 (ADR); EE=0.90 and P/Q=0.15 (ION)
P/B	Coll et al., 2007; FAO EastMed, 2014	
Q/B	Coll et al., 2007	
Diet	Coll et al., 2007	
60. Scallops		*Aequipecten opercularis, Pecten jacobeus, Pecten* spp.,
Bi (t km^{-1} y^{-1})	SOLEMON Survey (ADR); Estimated in ION	Average biomass 2005-2006 (ADR); EE=0.90 and P/Q=0.15 (ION)
P/B		
Q/B		
Diet		

FG, input parameter	Source	Taxa/Notes
61. Other benthic invertebrates		405 taxa: mega-macro, Echinoderms, Molluscs, Poriferas, Sessile tunicates, Anthozoans
Bi (t km^{-1} y^{-})	SOLEMON Survey (ADR); Estimated in ION	Average biomass 2005-2006 (ADR); EE=0.90 (ION)
P/B	Coll et al., 2007 (ADR); Ricci et al., 2019 (ION)	
Q/B	Coll et al., 2007 (ADR); Ricci et al., 2019 (ION)	
Diet	Fauchald and Jumars, 1979; Pearson and Gage 1984; Berthon, 1987; Frantzis et al., 1988; Coma et al., 1995; Opitz, 1996; Ribes et al., 1999; Agnetta et al., 2013; Lopez et al., 2013	
62. Seagrasses		*Posidonia oceanica, Cymodocea nodosa*
Bi (t km^{-1} y^{-})	Estimated in ION	EE=0.50 (ION)
P/B	Buia and Marzocchi 1995; Banaru et al. 2013; Agnetta et al. 2019; Ricci et al. 2019	
63. Seaweeds		Benthic macroalgae, Chlorophyta nd, *Codium* spp., *Cystoseira* spp., Dictyotales, Phaeophyta nd, Rhodophyta nd, *Ulva* spp., Vegetalia
Bi (t km^{-1} y^{-})	Estimated in ION	EE=0.50 (ION)
P/B	Buia and Marzocchi 1995; Banaru et al. 2013; Agnetta et al. 2019; Ricci et al. 2019	
64. Jellyfish		*Pelagia noctiluca*, *Pyrosoma atlanticum*, *Rhizostoma pulmo,* Salpidae, Scyphozoa, Siphonophora, *Thalia democratica*, Thaliacea,
Bi (t km^{-1} y^{-})	Estimated in (ION)	EE=0.70 (ION)
P/B	(ADR); Ricci et al., 2019 (ION)	
Q/B	(ADR); Ricci et al., 2019 (ION)	
Diet	Malej, 1989; Sabatés et al., 2010; Tecchio et al. 2013; Canepa et al., 2014	
65. Macrozooplankton & Euphasiacea		Chaetognatha, Copepoda, *Cymbulia peronii*, Euphasiacea, Macrozooplankton, Pteropoda
Bi (t km^{-1} y^{-1})	BFM?? (ADR); Estimated in (ION)	EE=0.90 (ION)
P/B		
Q/B		

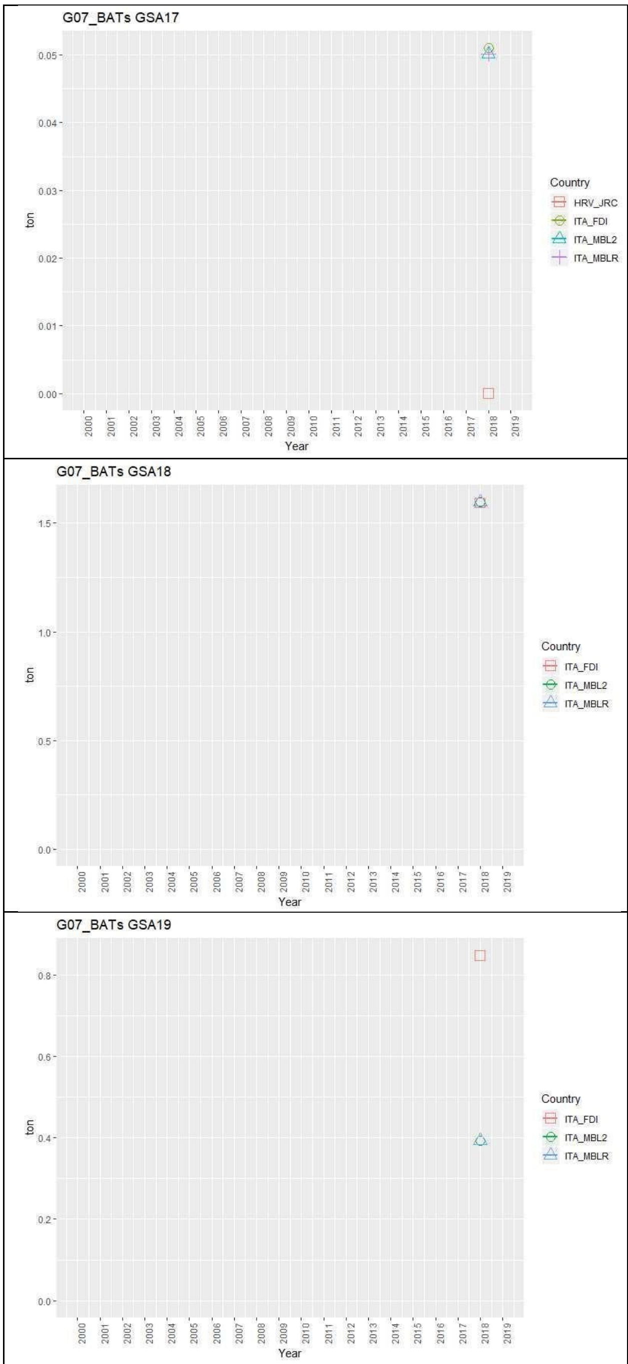
FG, input parameter	Source	Taxa/Notes
Diet	Tecchio et al. 2013; Agnetta et al., 2019; Ricci et al., 2019	
<u>66. Mesozooplankton</u>		Mesozooplankton, Larval stages
Bi (t km^{-1} y^{-})	FAIRSEA WP4.2 - Deliverable D 4.2.1 – Production patterns in the Adriatic Sea	
P/B		
Q/B		
Diet	Agnetta et al., 2019; Ricci et al., 2019	
<u>67. Microzooplankton</u>		Cladocera, Foraminifera, Microzooplankton
Bi (t km^{-1} y^{-})	FAIRSEA WP4.2 - Deliverable D 4.2.1 – Production patterns in the Adriatic Sea	
P/B		
Q/B		
Diet	Agnetta et al., 2019; Ricci et al., 2019	
<u>68. Bacterioplankton</u>		Bacteria
Bi (t km^{-1} y^{-})		
P/B	FAIRSEA D 4.2.1– Production patterns in the Adriatic Sea	
Q/B		
Diet	Agnetta et al., 2019; Danovaro, 1998; Mirto et al., 2004	
<u>69. Phytoplankton</u>		Diatoms
Bi (t km^{-1} y^{-})	FAIRSEA D 4.2.1– Production patterns in the Adriatic Sea	
P/B		
<u>70. Picophytoplankton</u>		Dinoflagellates
Bi (t km^{-1} y^{-})	FAIRSEA WP4.2 - Deliverable D 4.2.1 – Production patterns in the Adriatic Sea	
P/B		
<u>71. Discards</u>		
Bi (t km^{-1} y^{-})		
<u>72. Suspended detritus</u>		

FG, input parameter	Source	Taxa/Notes
Bi (t km^{-1} y^{-})	FAIRSEA WP4.2 - Deliverable D 4.2.1 – Production patterns in the Adriatic Sea	
73. Bottom detritus		
Bi (t km^{-1} y^{-})	FAIRSEA D 4.2.1– Production patterns in the Adriatic Sea	

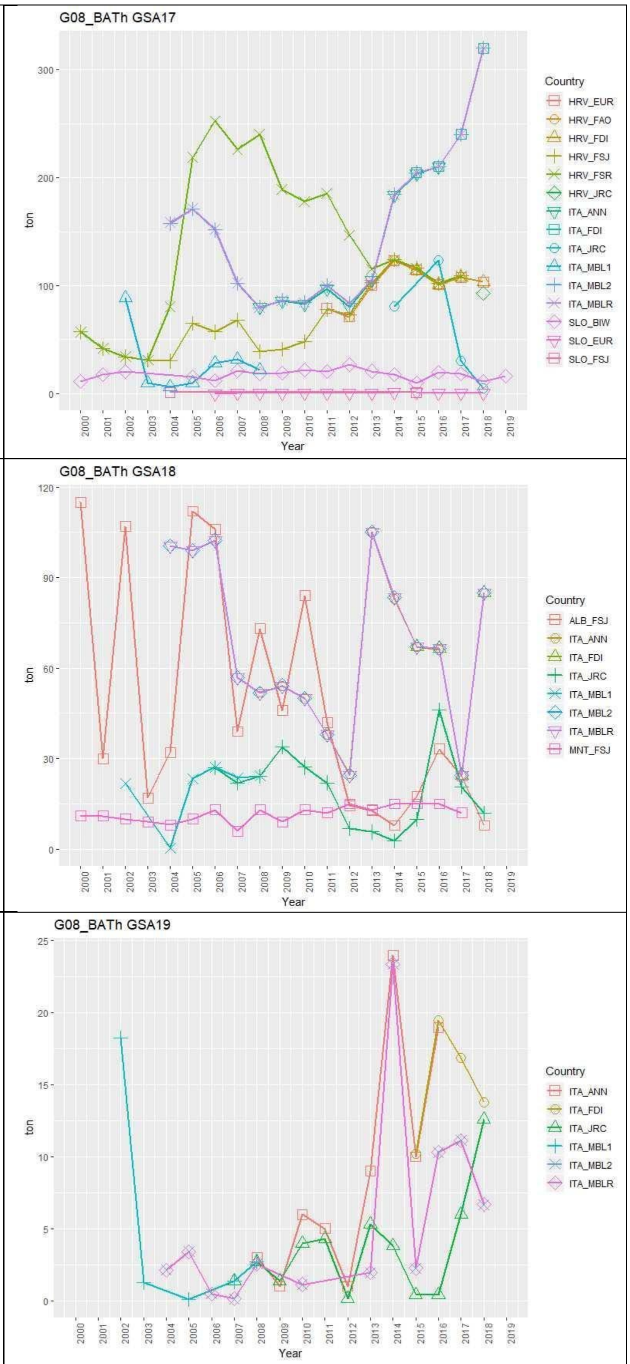
9.2 Landing data treatment

The plots represent the available data of landings collected from different sources in the three Geographical Sub Areas (GSAs) included in the FAIRSEA framework, north and central Adriatic Sea (GSA 17), southern Adriatic Sea (GSA18) and Ionian Sea (GSA 19). All data are represented as total landings in tons per group and per country, disregarding the division by fleet segment. The time series from available sources are visualized on the same plot for the sake of comparing and inspecting the data.

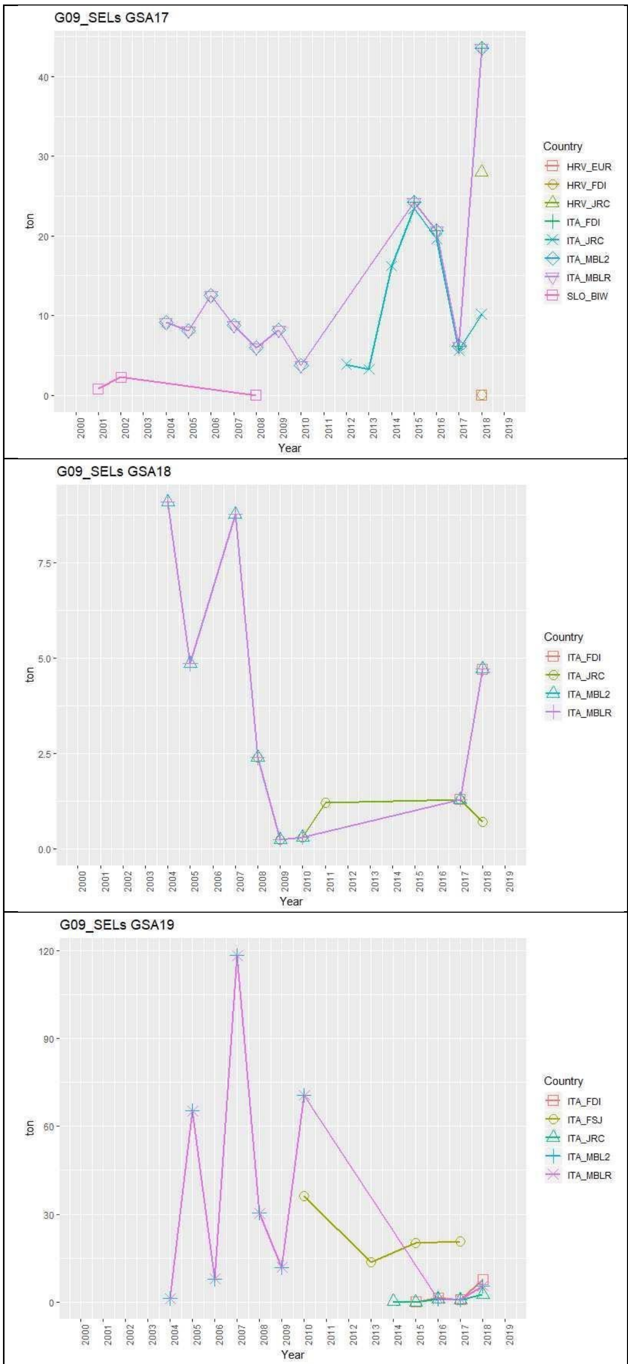
Source code	Descrition
FSJ	FAO FishStatJ - Software for Fishery and Aquaculture Statistical Time Series http://www.fao.org/fishery/statistics/software/fishstatj/en
FAO	FAO GFCM data collection
EUR	EU Eurostat's database for Landings of fishery products (fish_Id) https://ec.europa.eu/eurostat/web/fisheries/data/database
FDI	Fishery Dependent Information data
DZS	Croatian Bureau of Statistic (Državni zavod za statistiku) https://www.dzs.hr/
IZR	Institute of Oceanography and Fisheries database (IOF) (Institut za oceanografiju i ribarstvo, baza podataka i pokazatelja stanja morskog okoliša, marikulture i ribarstva) http://baltazar.izor.hr/azopub/bindex
MBL1	Mably 1st data call
MBL2	Mably 2nd data call
ANN	Report on status of resources and productive structure in the Italian seas (Maiorano P., Sabatella R.F., Marzocchi B.M. (eds) (2019) – Annuario sullo stato delle risorse e sulle strutture produttive dei mari italiani. 432 pp.)
BIW	BiosWeb - Biological database of the Fisheries Research Institute of Slovenia http://www.biosweb.org/?task=stat#tabs-year
FSR	Reconstructed data of FishStatJ (FSJ) landings for Croatia
MBLR	Reviewed data of 2nd MABLY data call.
MAR	Albanian Ministry of Agriculuture and Rural Development http://www.instat.gov.al/en/themes/agriculture-and-fishery/fishery/#tab1



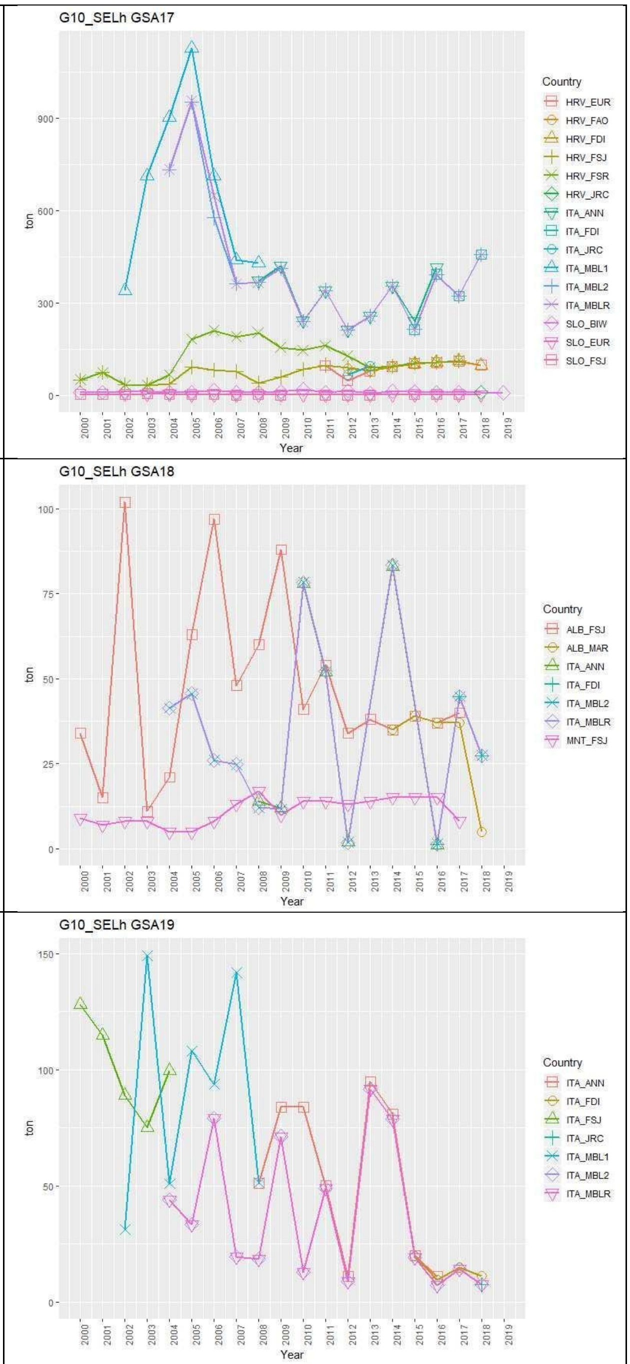
Trend of landings of demersal rays and skates of slope (BATs) in three GSAs.



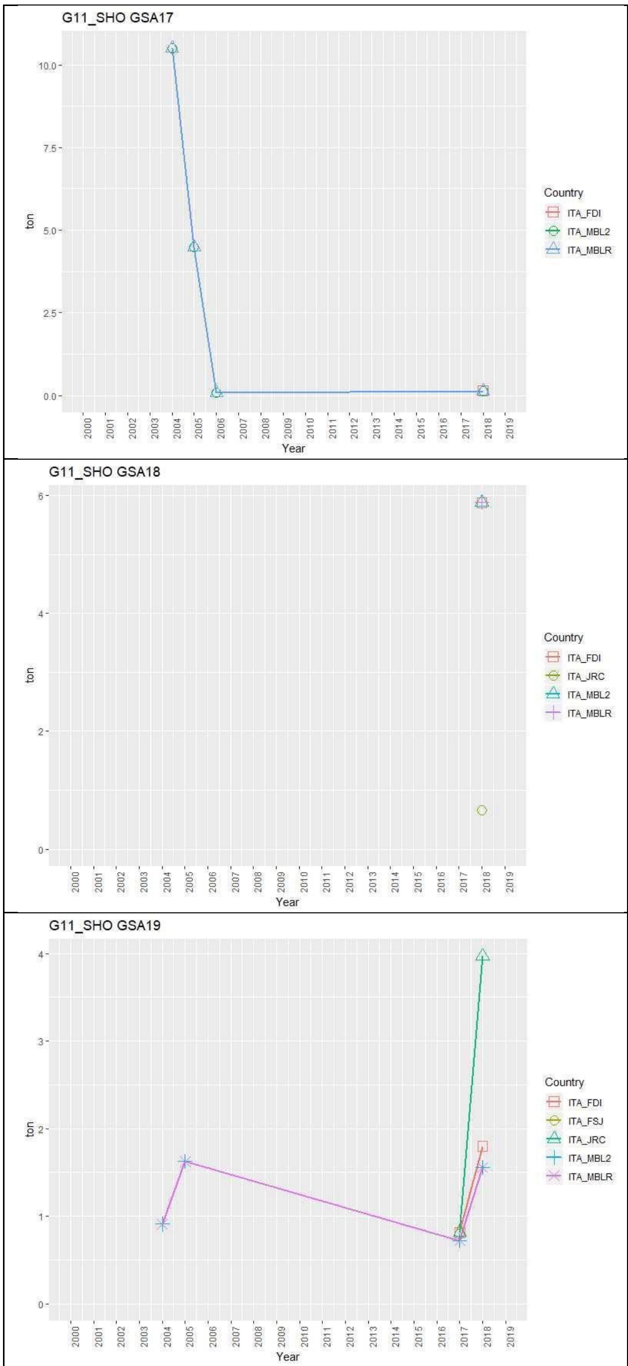
Trend of landings of demersal rays and skates of shelf (BATh) in three GSAs.



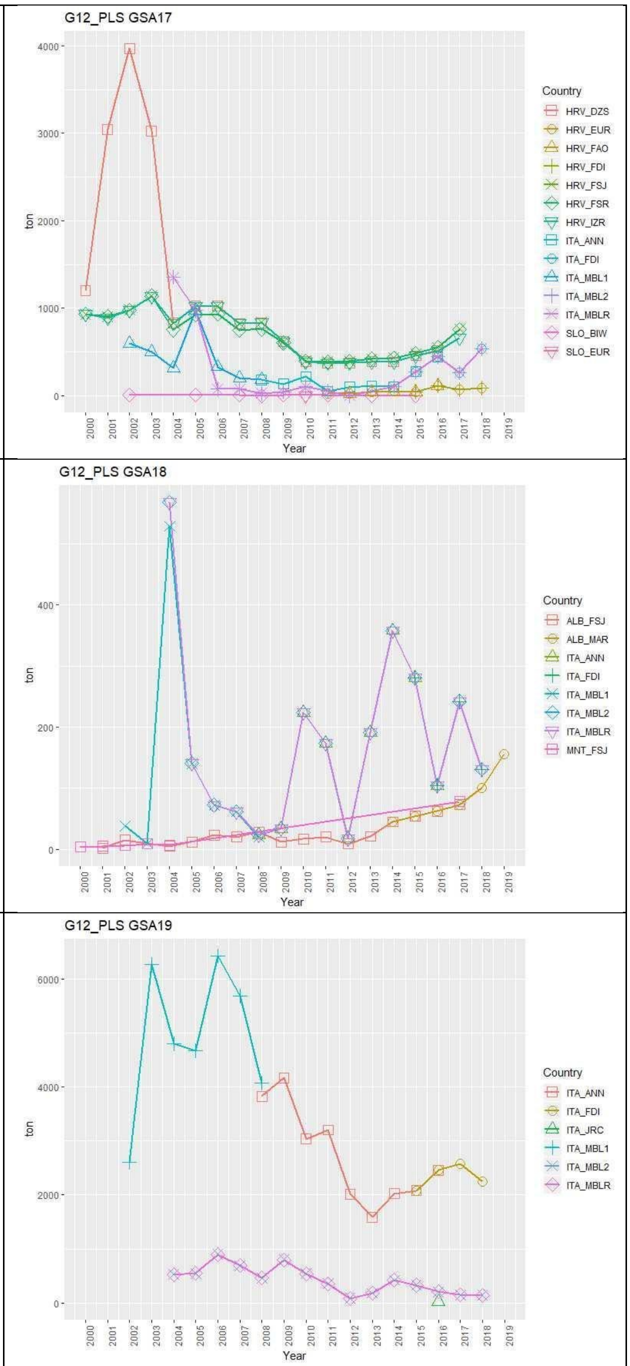
Trend of landings of demersal sharks of slope (SELs) in three GSAs.



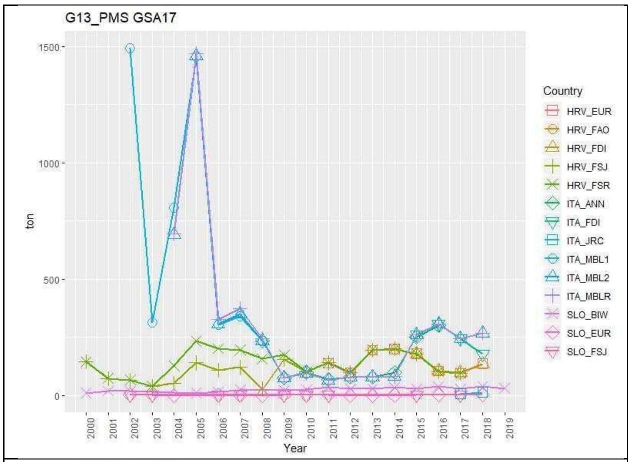
Trend of landings of demersal sharks of shelf (SELh) in three GSAs.

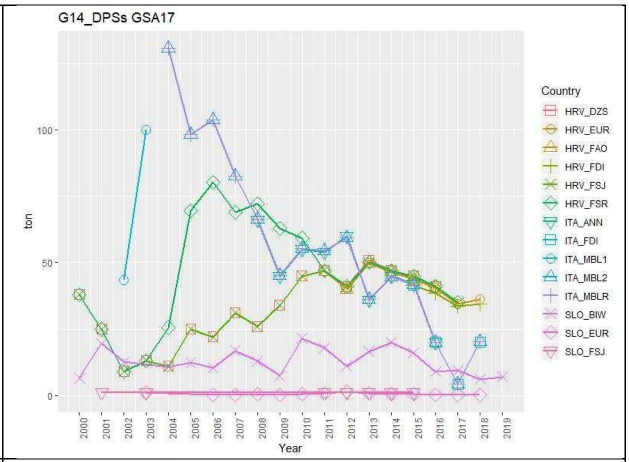


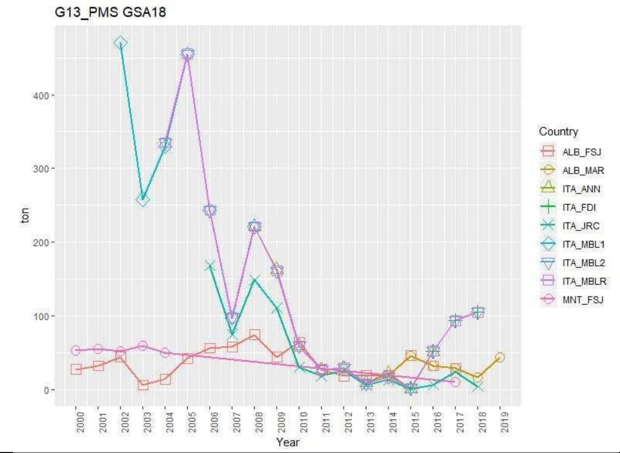
Trend of landings of blackmouth catshark (SHO) in three GSAs.

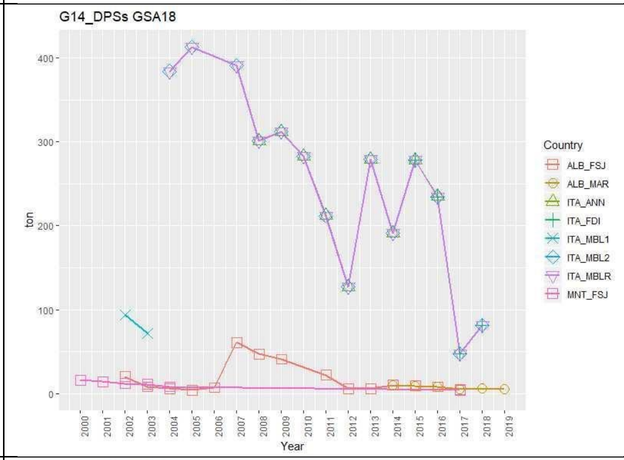


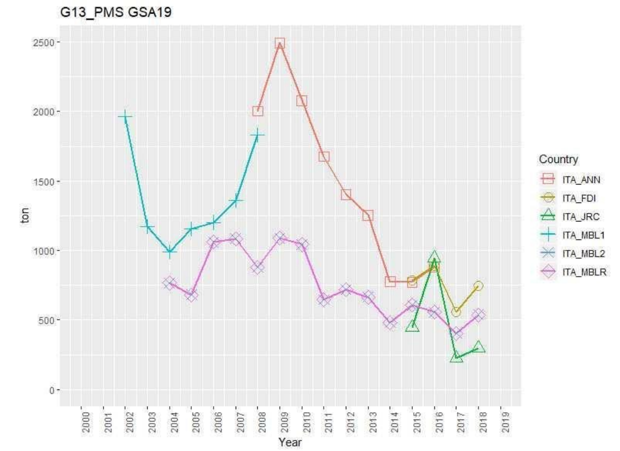
Trend of landings of large pelagic fish (PLS) in three GSAs.

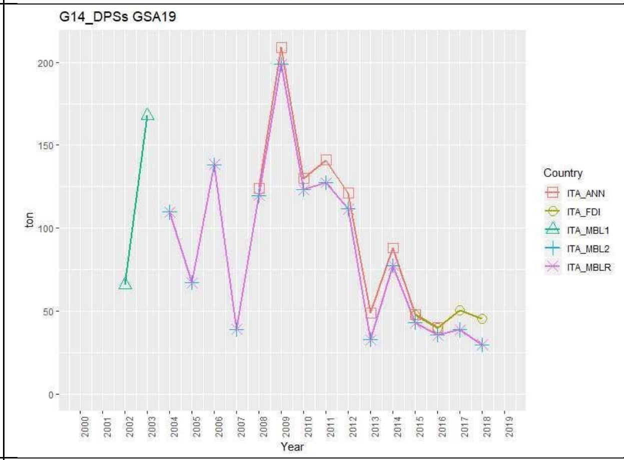






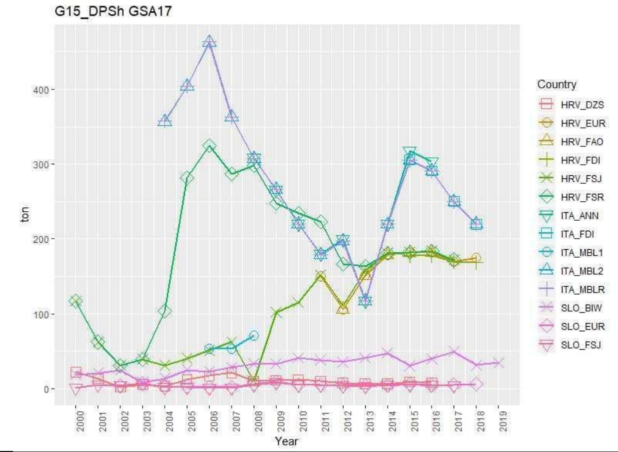


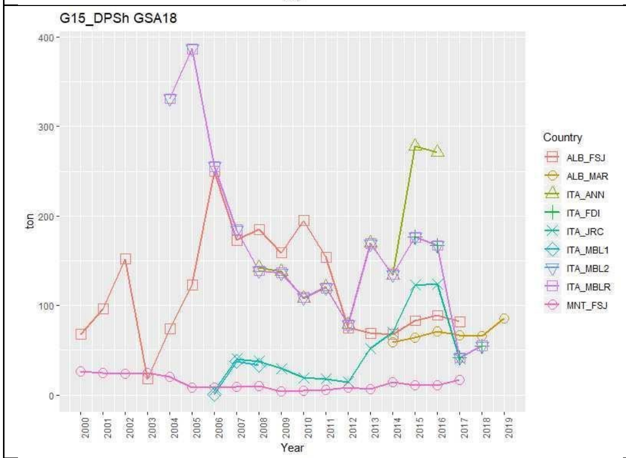


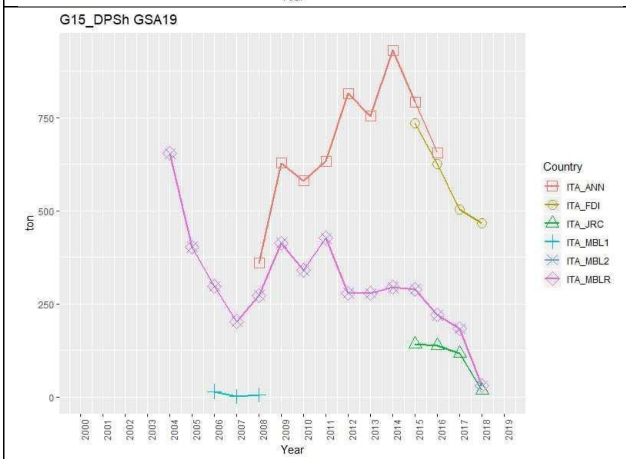


Trend of landings of medium pelagic fish (PMS) in three GSAs.

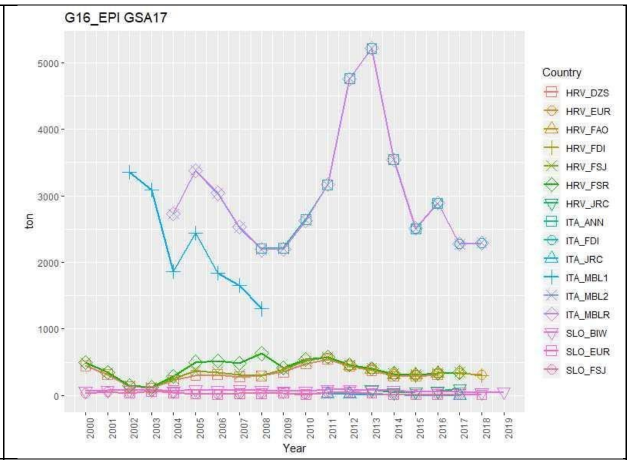
Trend of landings of demersal piscivorous fish of slope (DPSs) in three GSAs.

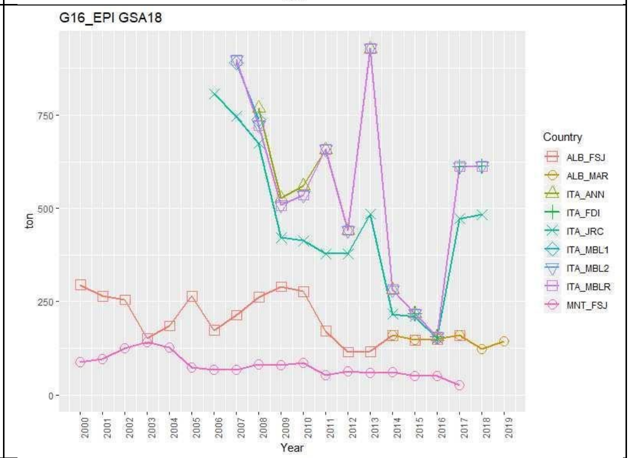


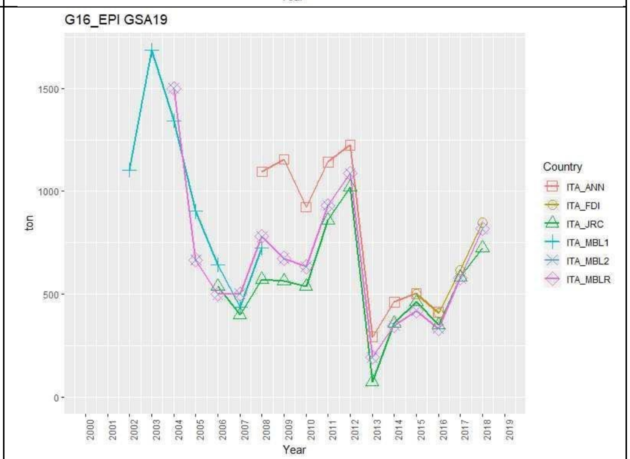




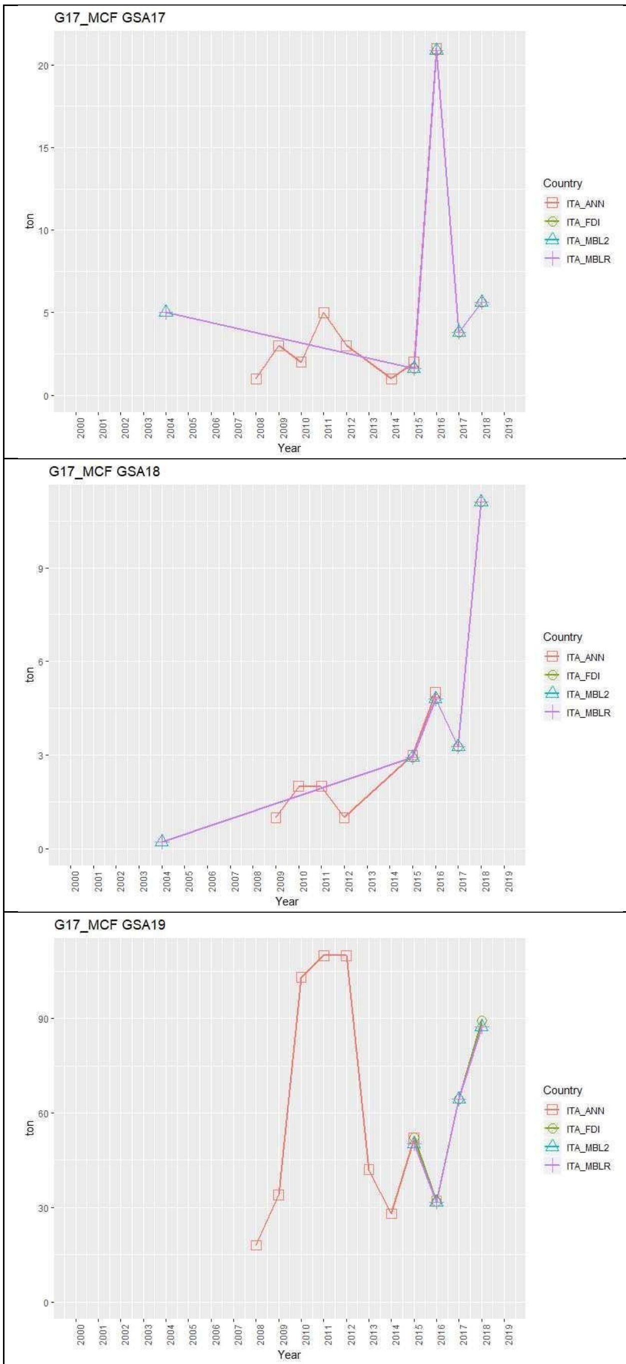
Trend of landings of demersal piscivorous fish of shelf (DPSh) in three GSAs.



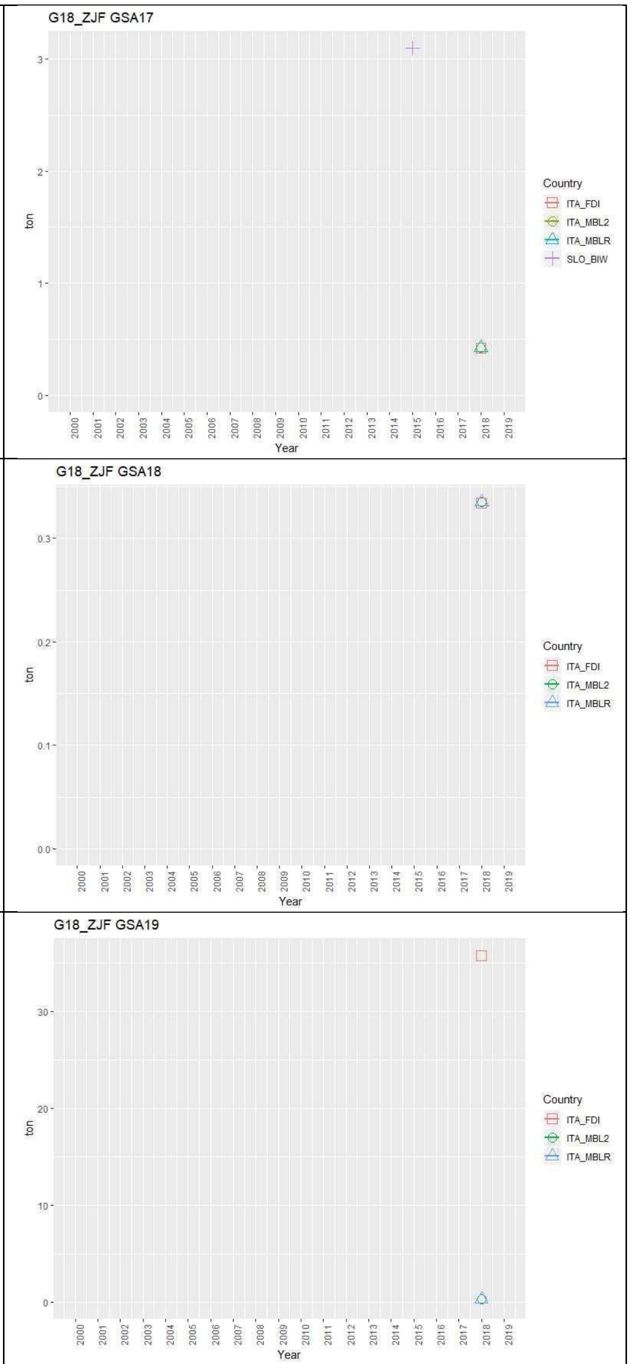




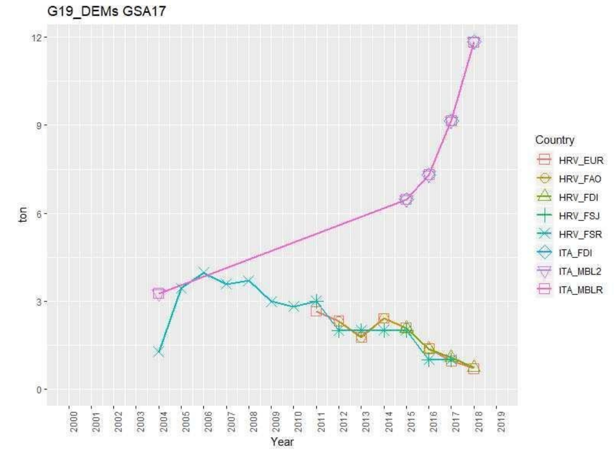
Trend of landings of epipelagic fish (EPI) in three GSAs.

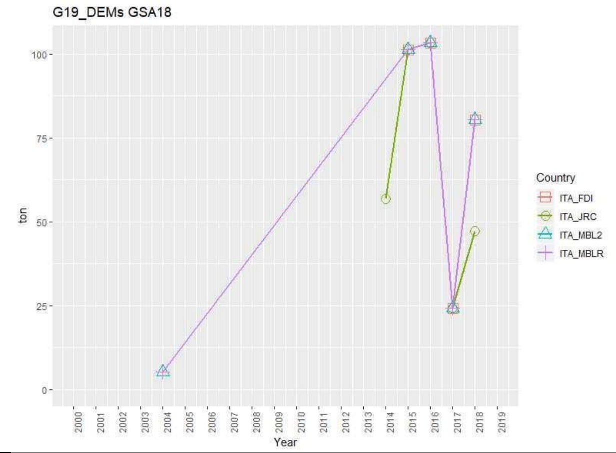


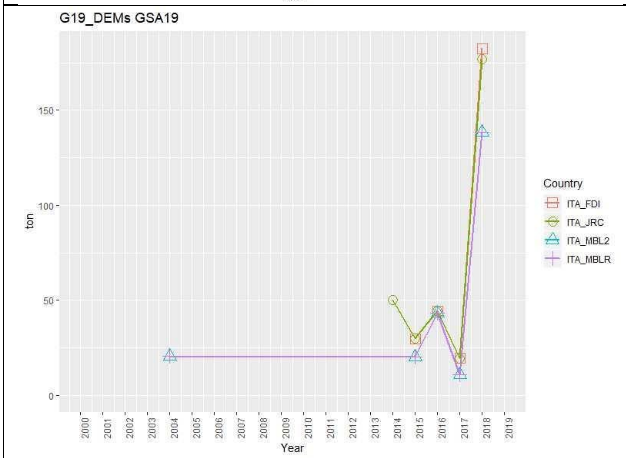
Trend of landings of mesopelagic crustacean feeding fish (MCF) in three GSAs.



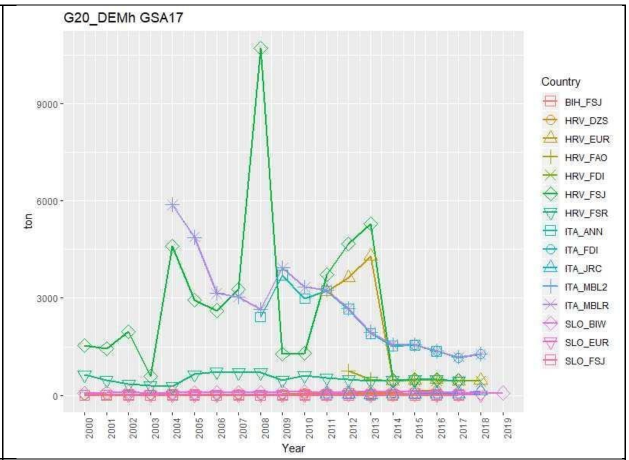
Trend of landings of zooplancton-jelly feeding fish (ZJF) in three GSAs.

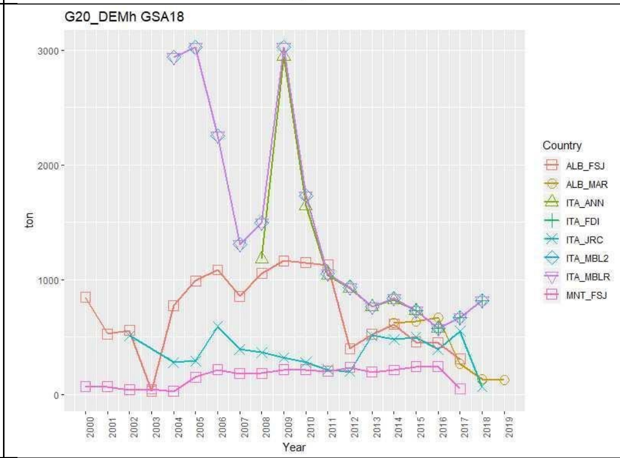


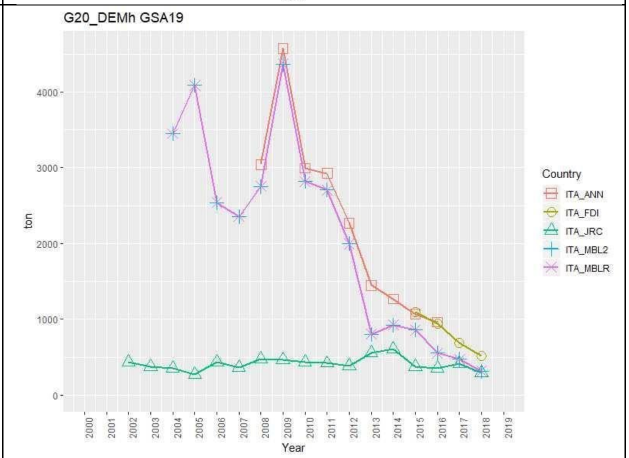




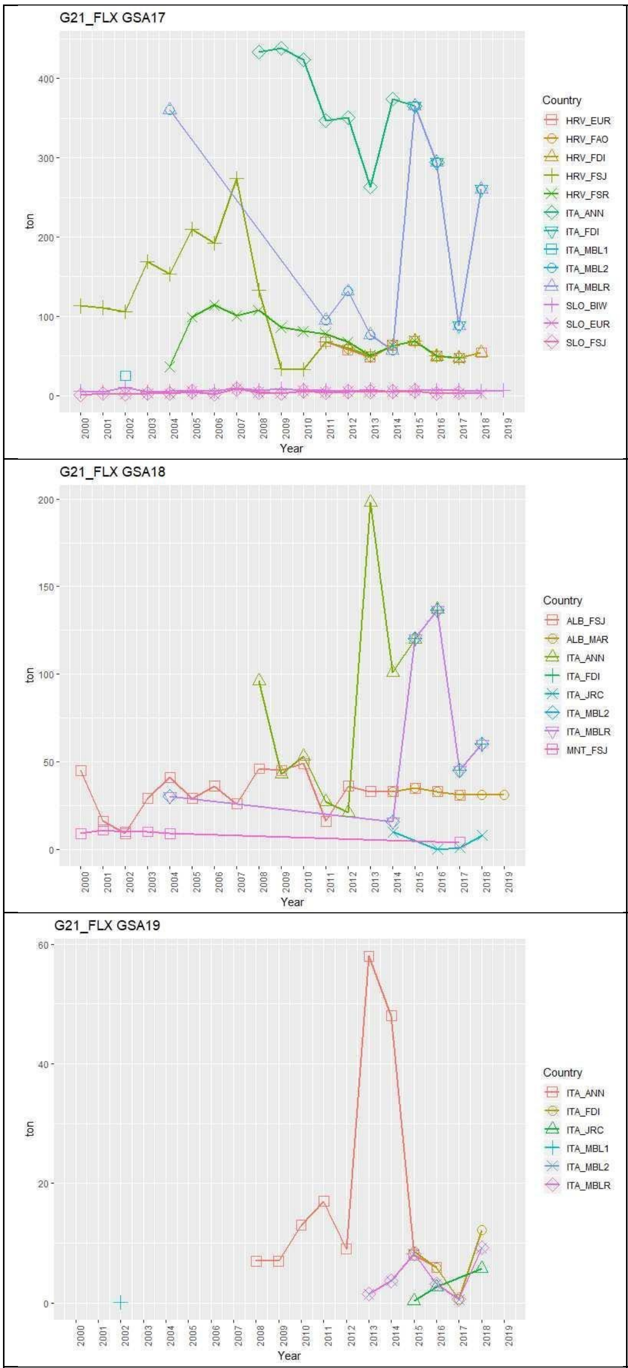
Trend of landings of demersal fish of slope (DEMs) in three GSAs.



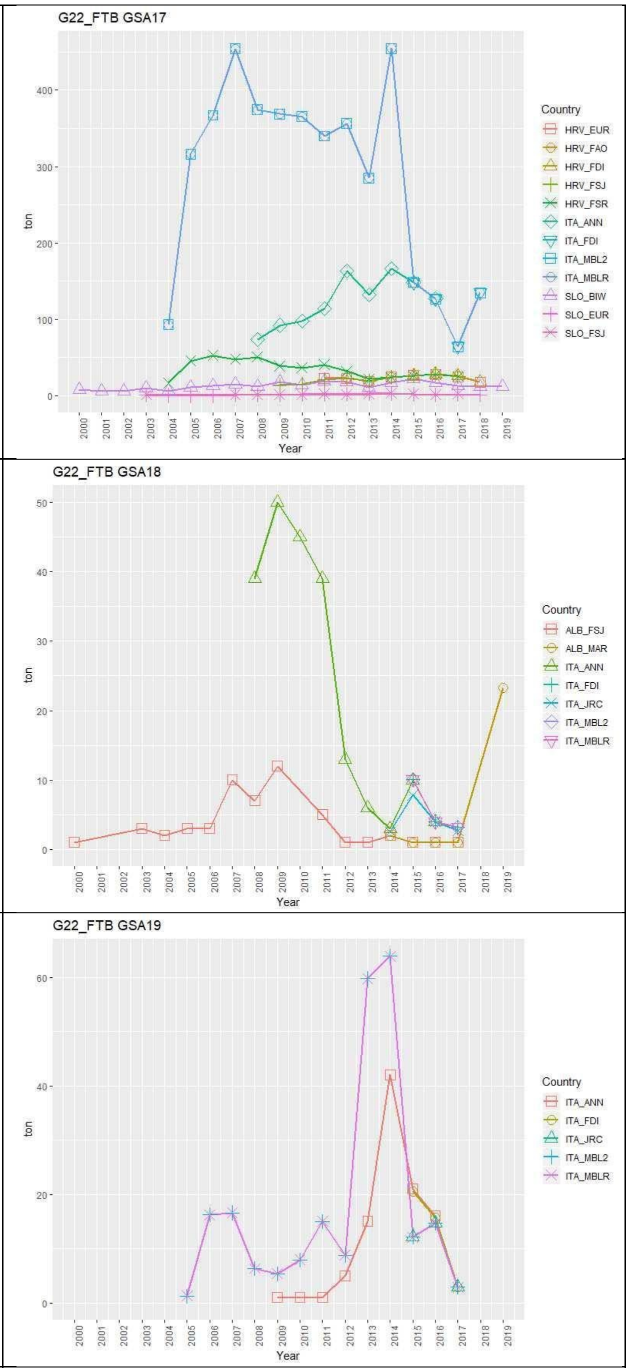




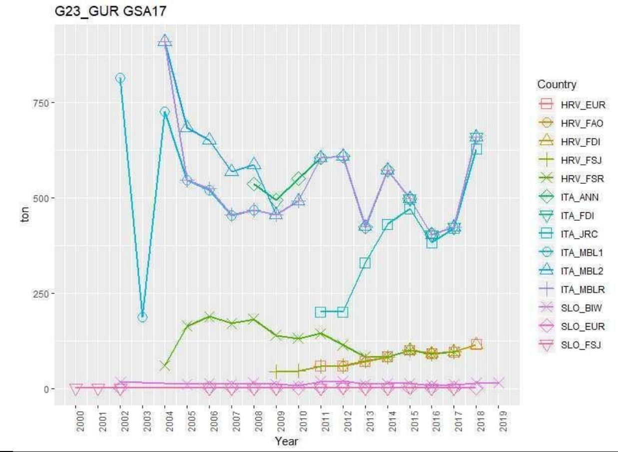
Trend of landings of demersal fish of shelf (DEMh) in three GSAs.

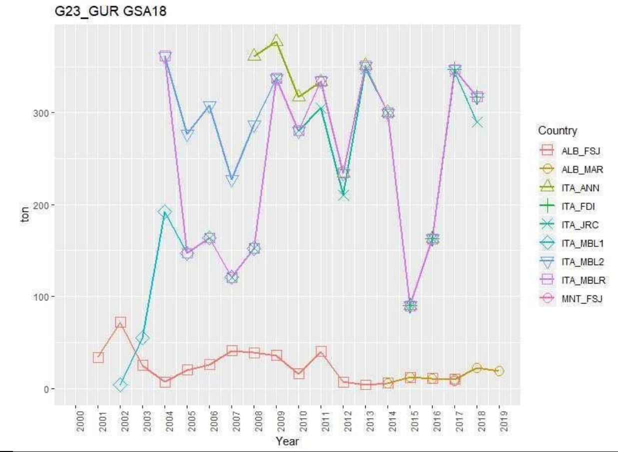


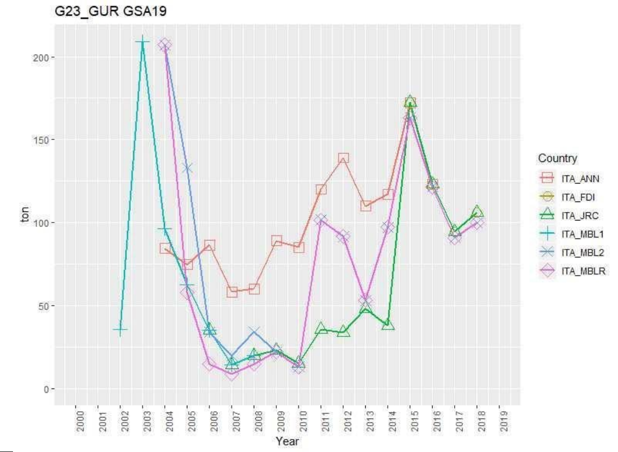
Trend of landings of flatfish (FLX) in three GSAs



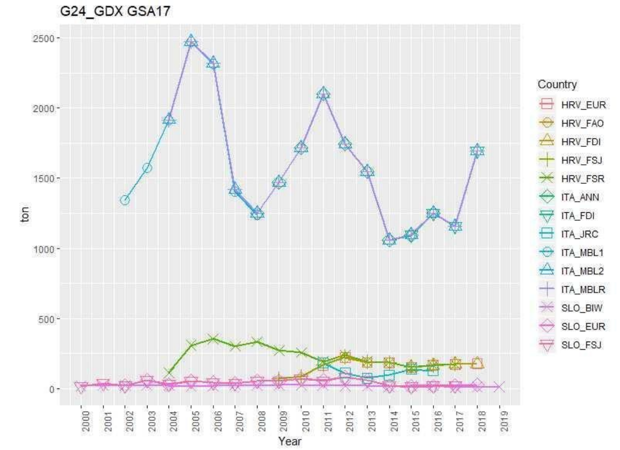
Trend of landings of turbot and brill (FTB) in three GSAs.

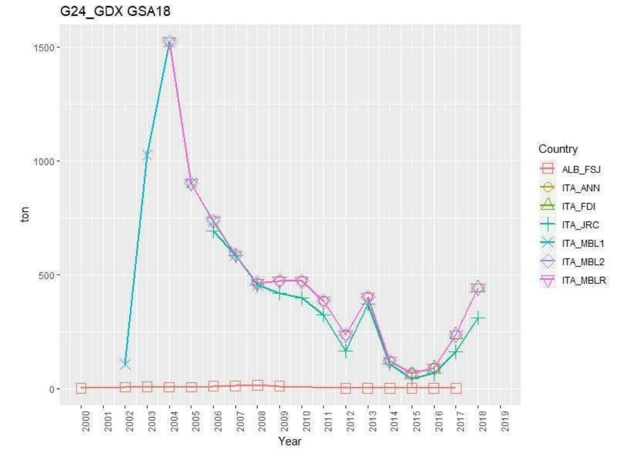


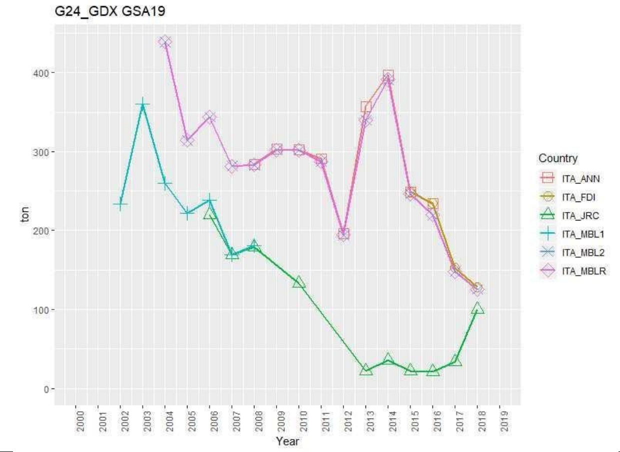




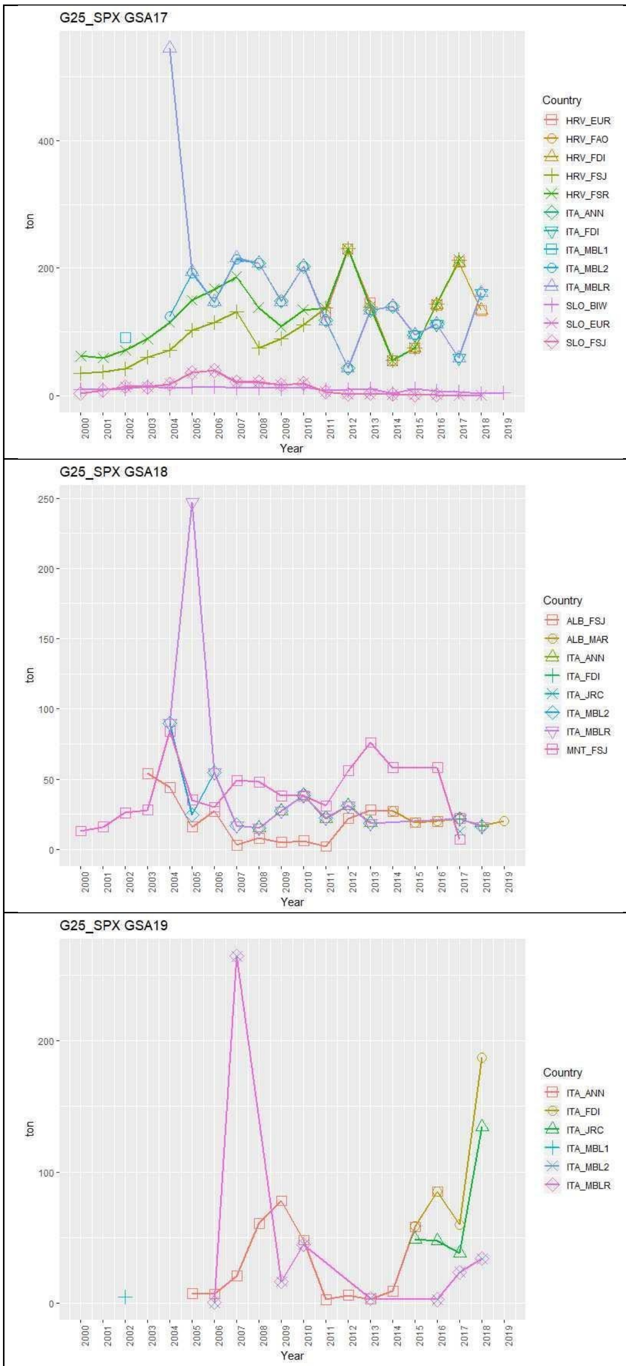
Trend of landings of gurnards (GUR) in three GSAs.



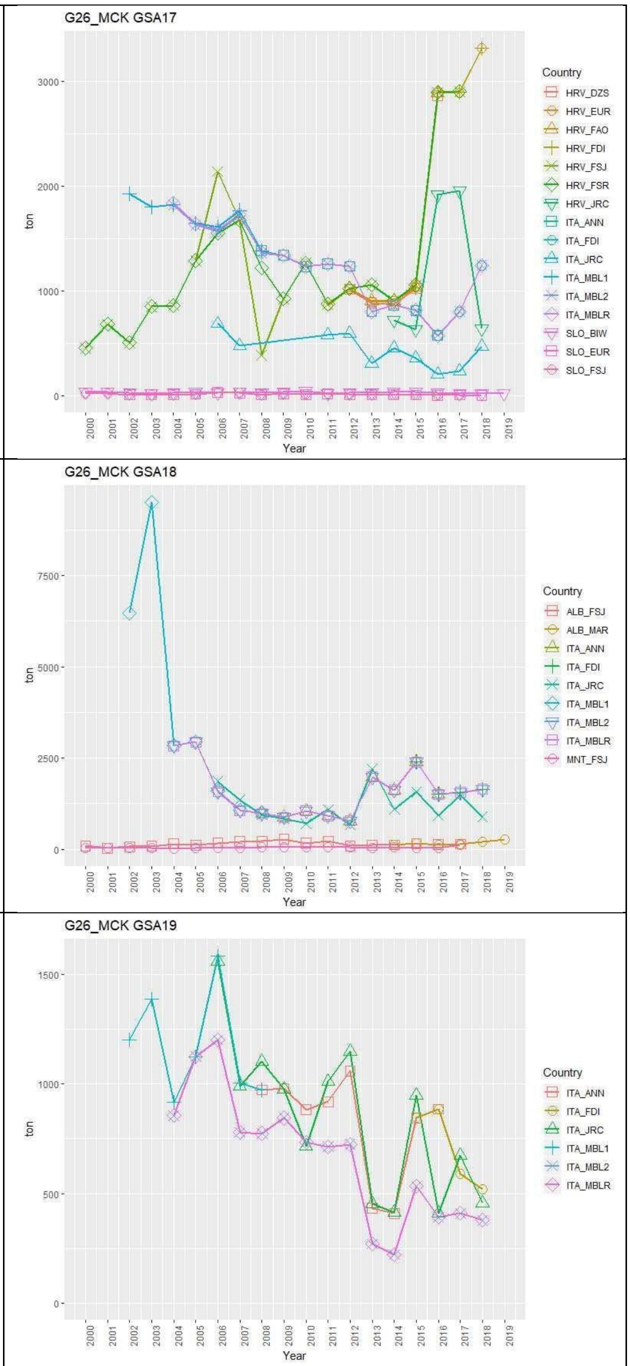




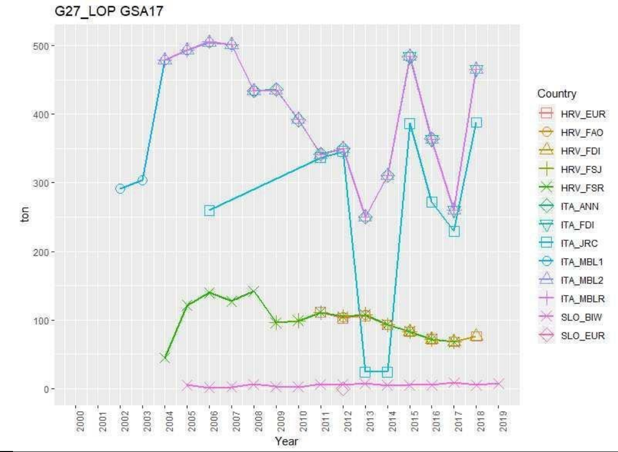
Trend of landings of other gadids (GDX) in three GSAs.

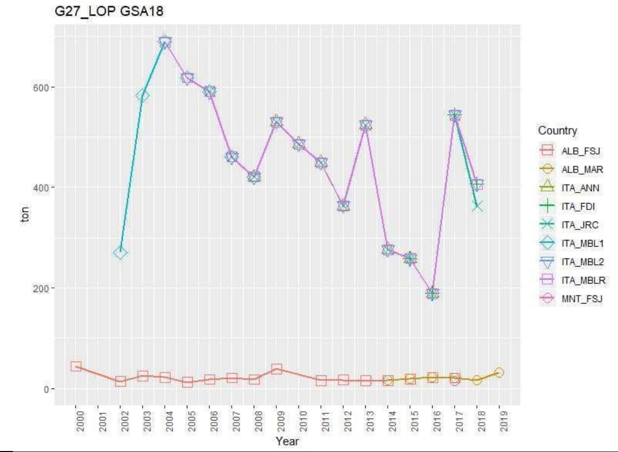


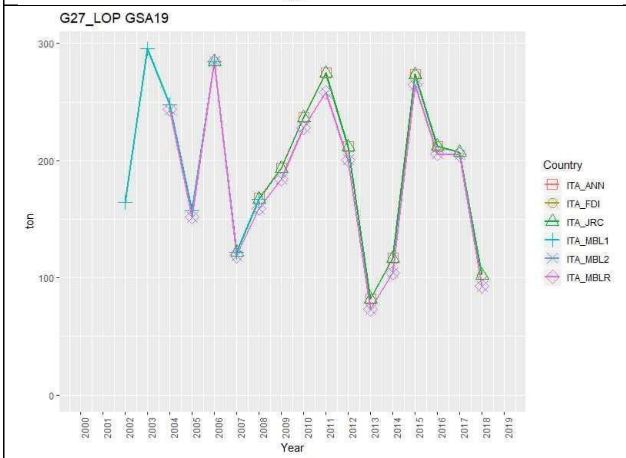
Trend of landings of other small pelagic fish (SPX) in three GSAs.



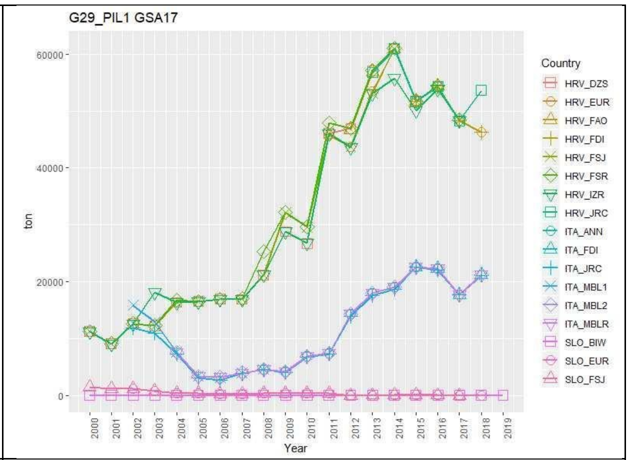
Trend of landings of mackerels (MCK) in three GSAs.

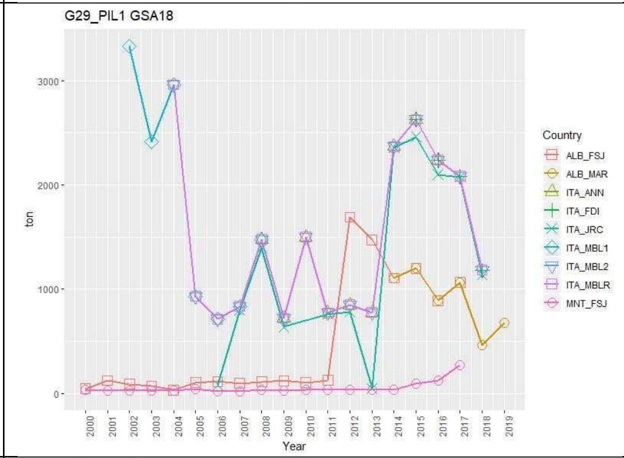


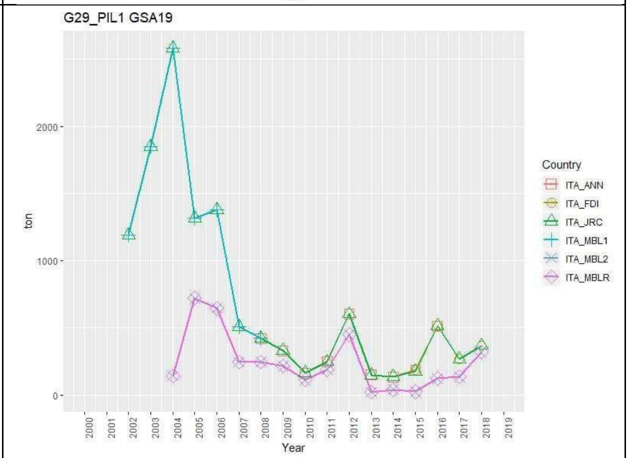




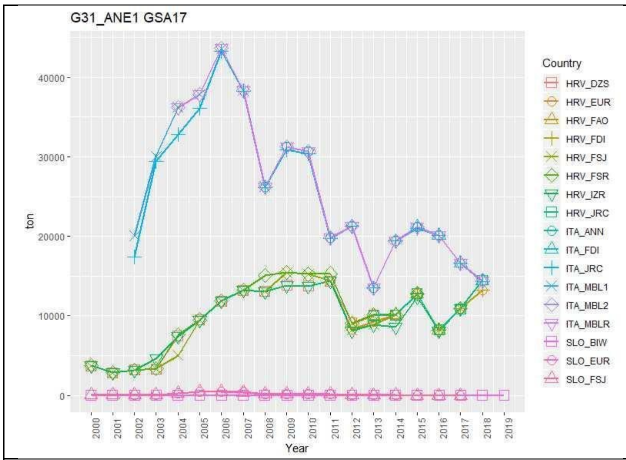
Trend of landings of anglers (LOP) in three GSAs.

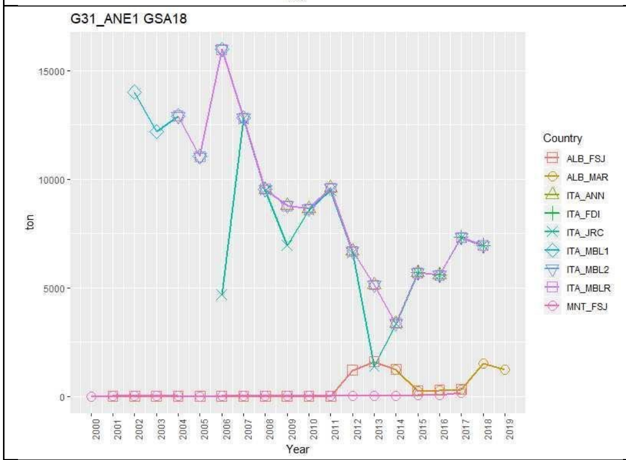


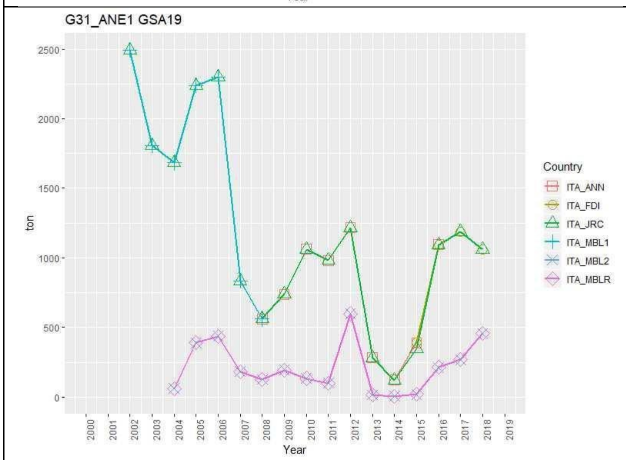




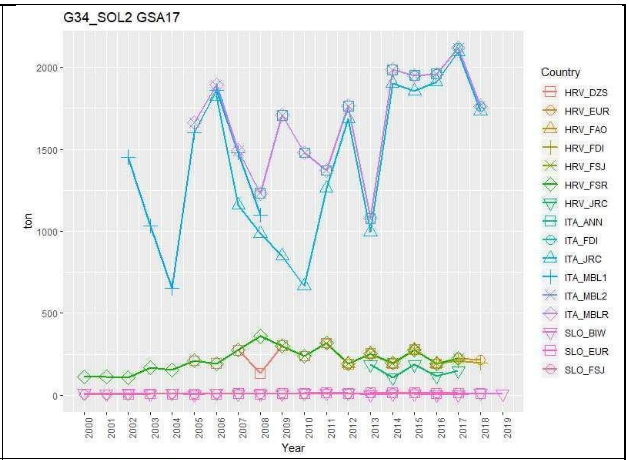
Trend of landings of pilchards (PIL) in three GSAs.

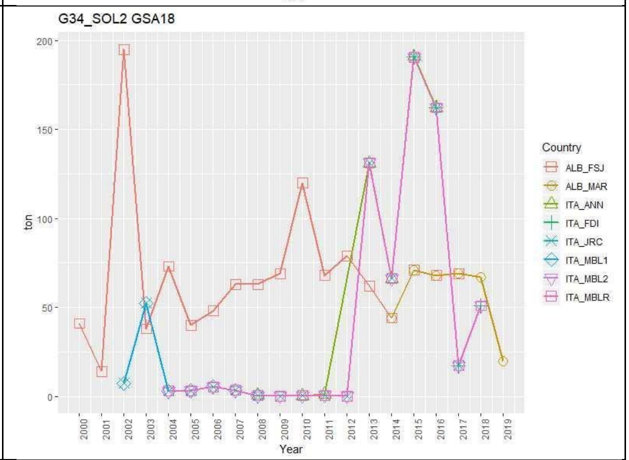


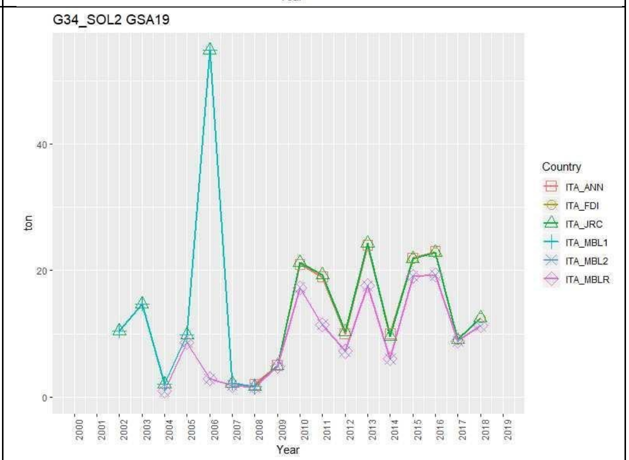




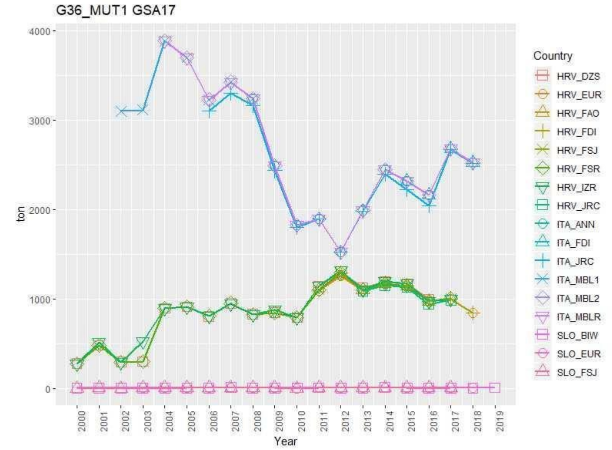
Trend of landings of anchovies (ANE) in three GSAs.

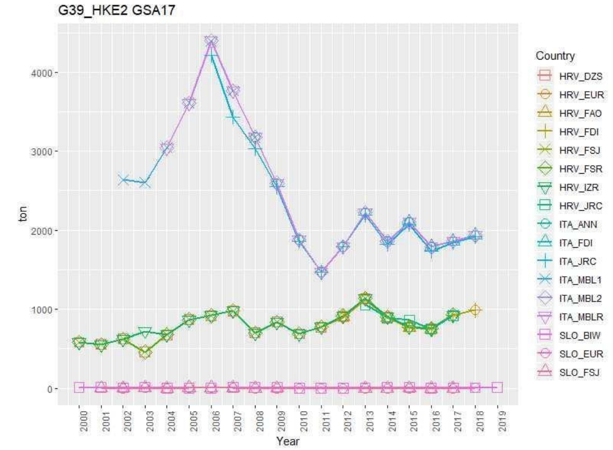


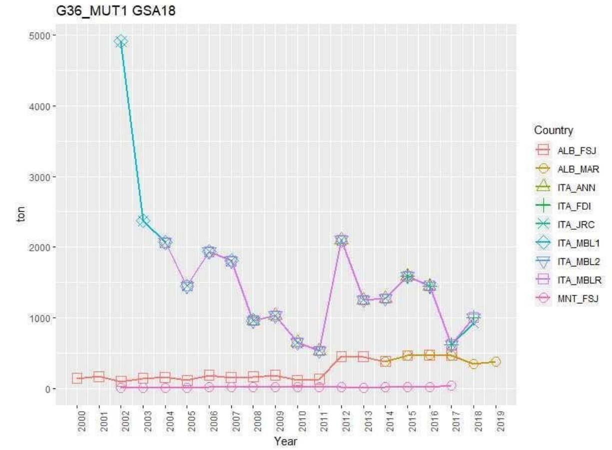


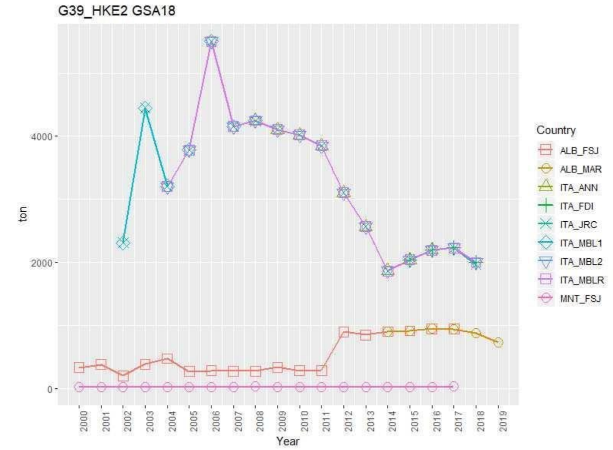


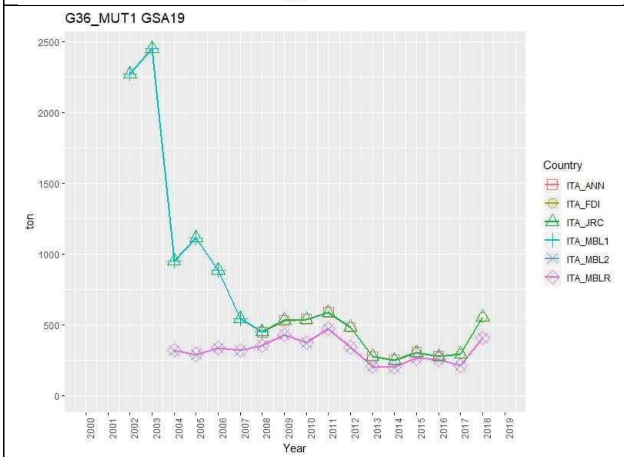
Trend of landings of soles (SOL) in three GSAs.

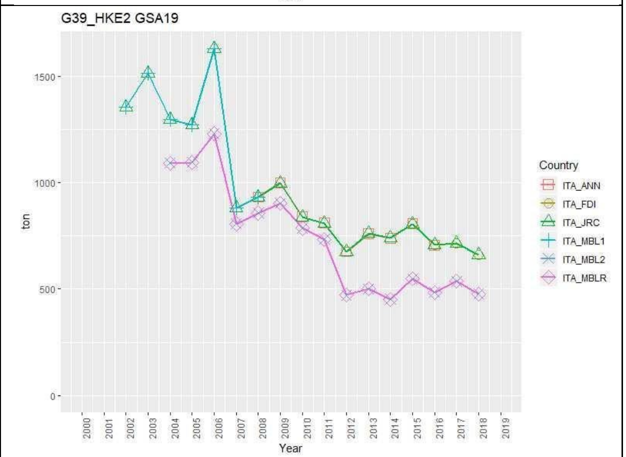




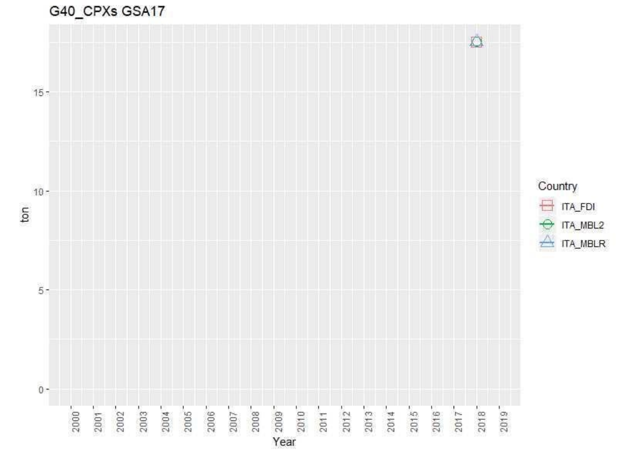
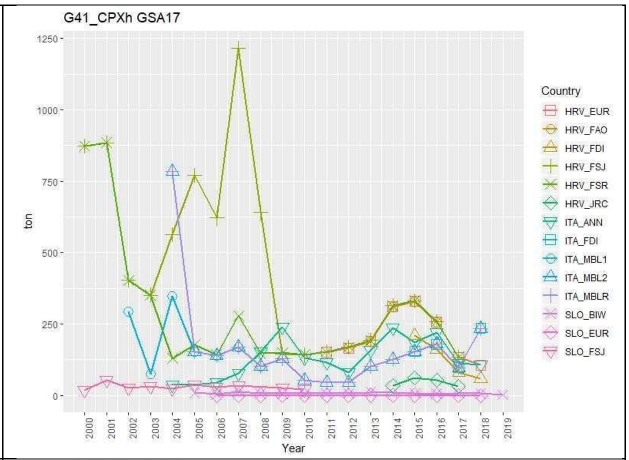
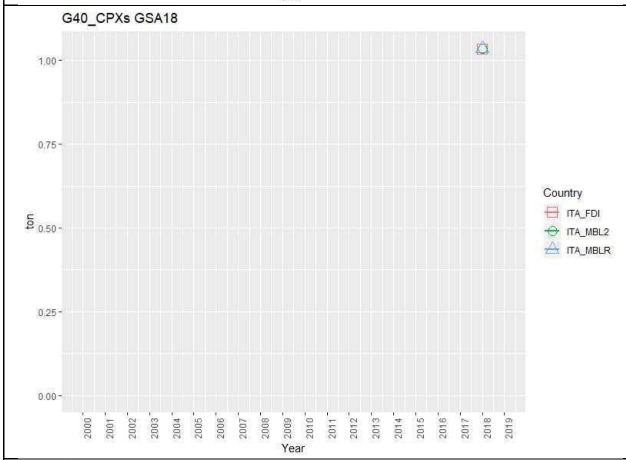
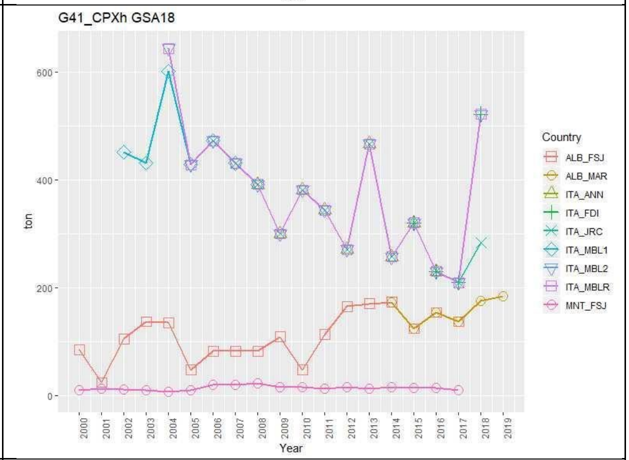
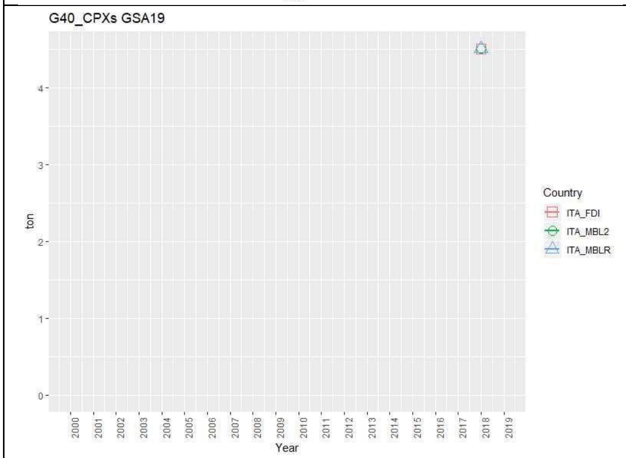
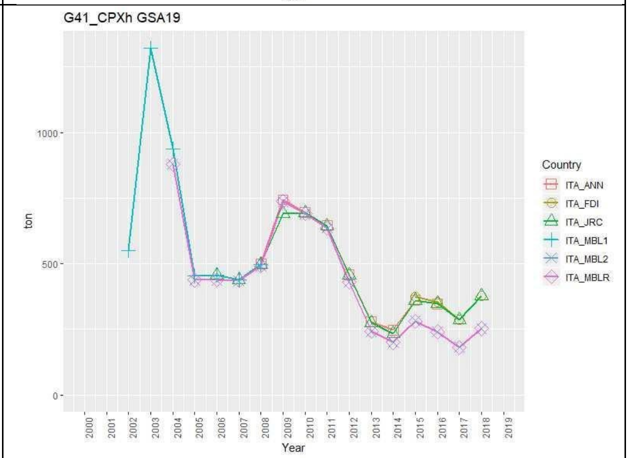


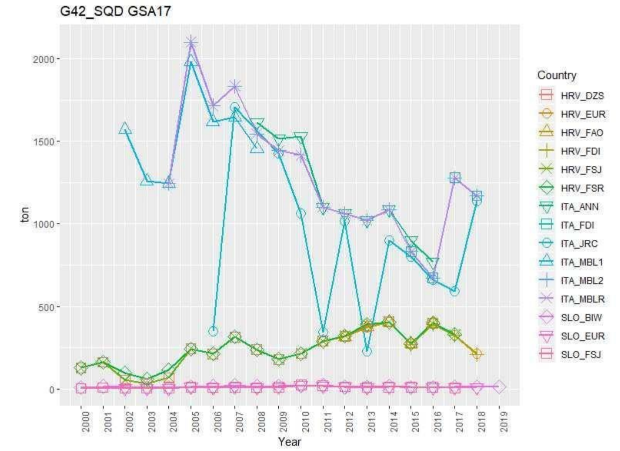


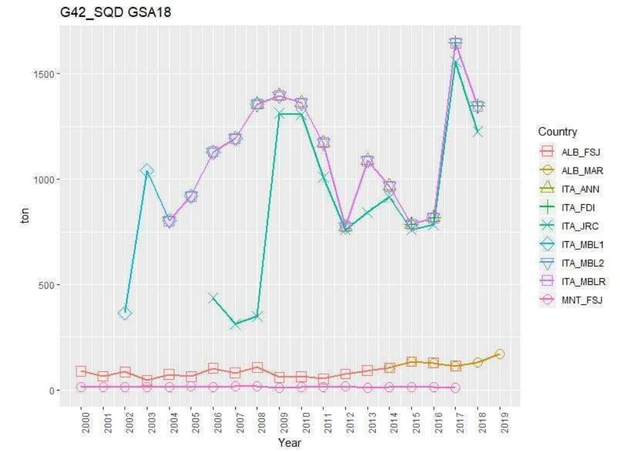


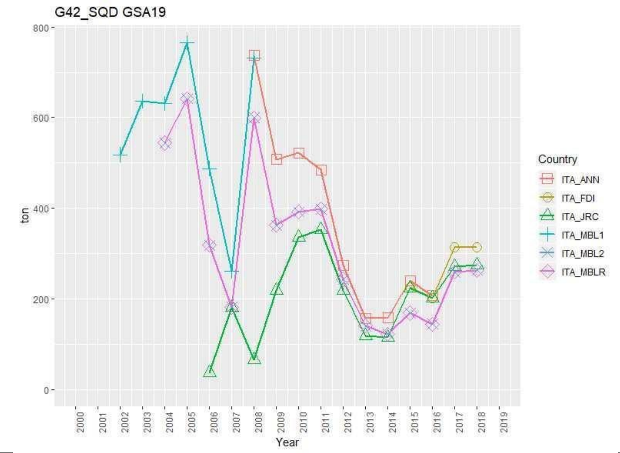


Trend of landings of red mullet (MUT) in three GSAs.	Trend of landings of hake (HKE) in three GSAs.

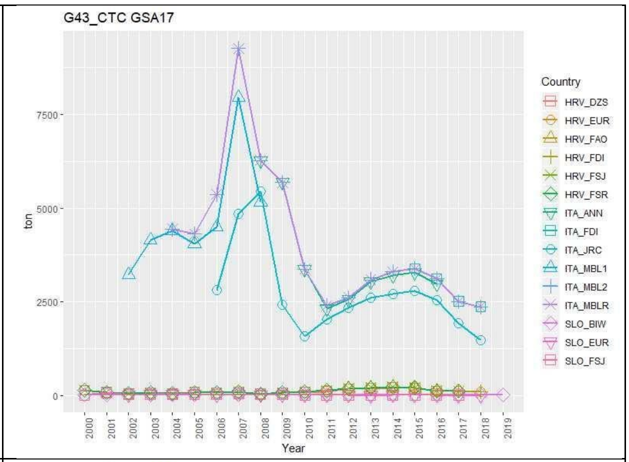
	
	
	
Trend of landings of other cephalopods of slope (CPXs) in three GSAs.	Trend of landings of other cephalopods of shelf (CPXh) in three GSAs.

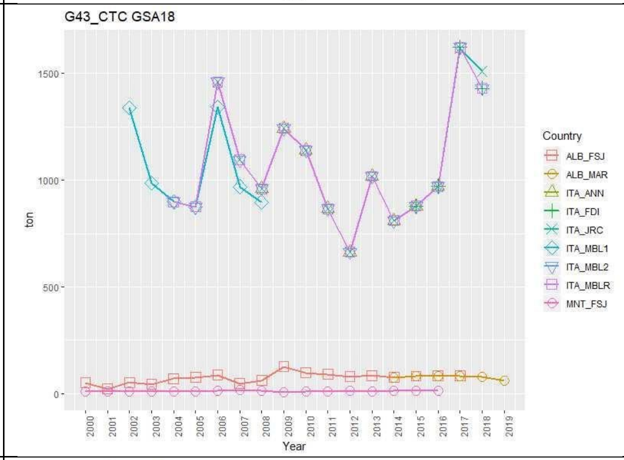


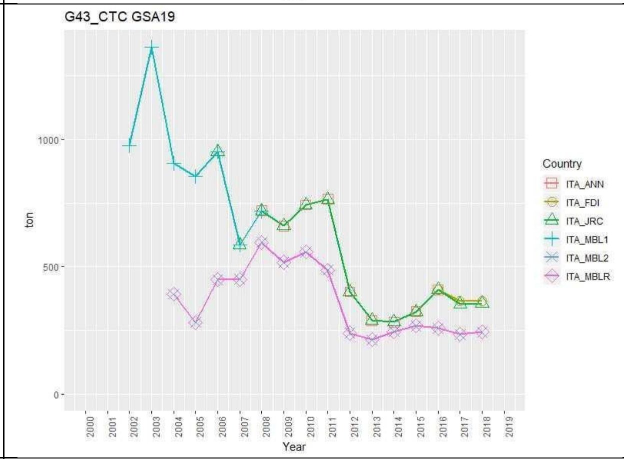




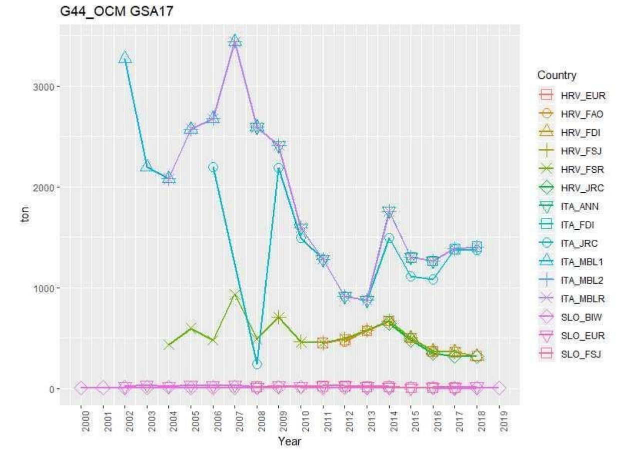
Trend of landings of squids (SQD) in three GSAs.

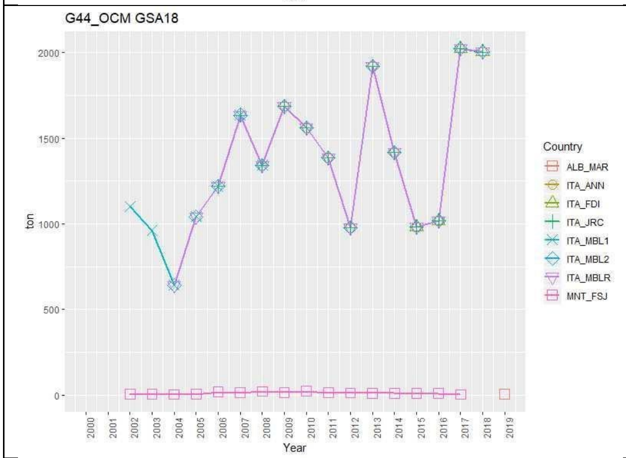


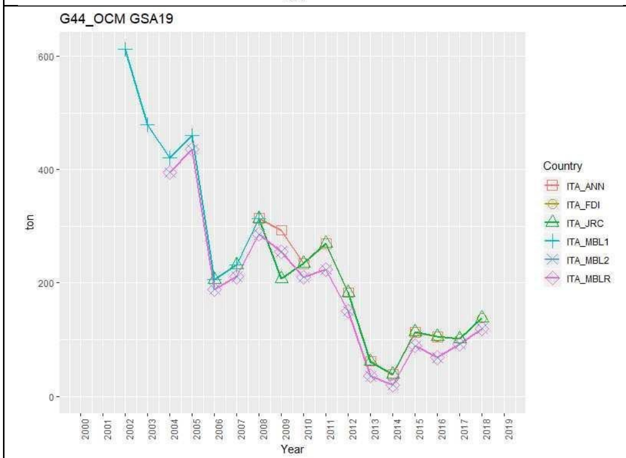




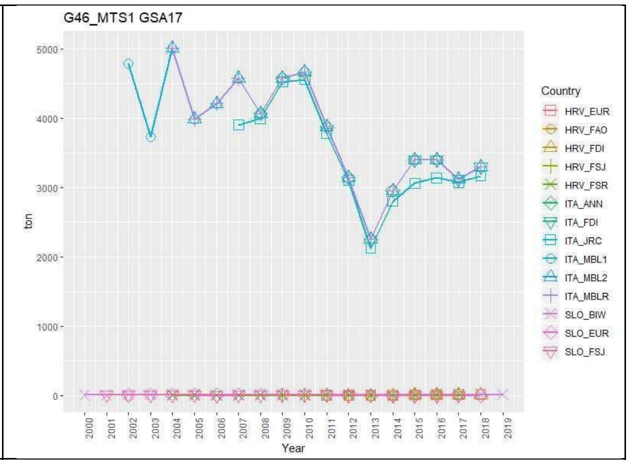
Trend of landings of common cuttlefish (CTC) in three GSAs.

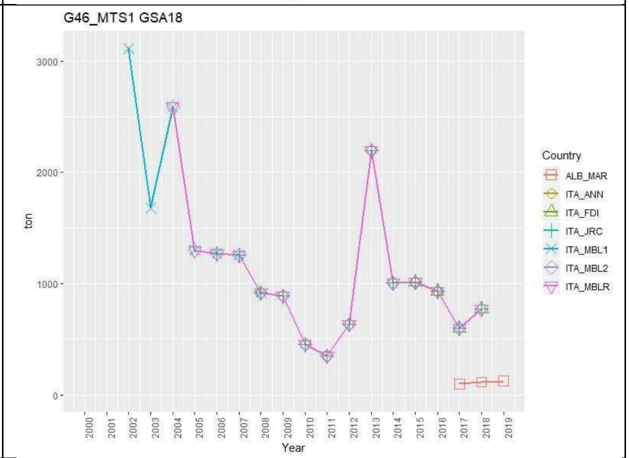


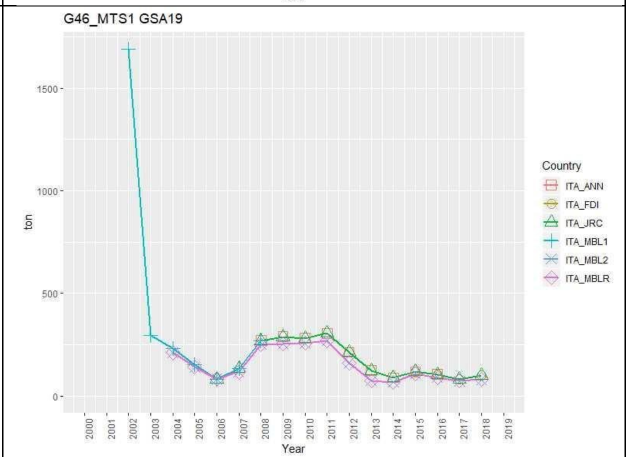




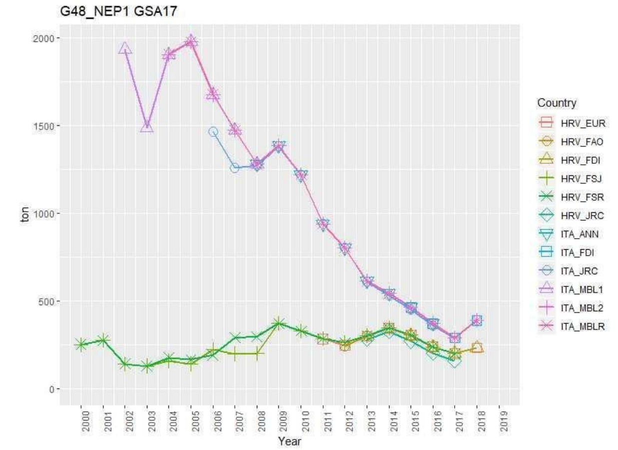
Trend of landings of musky and horned octopus (OCM) in three GSAs.

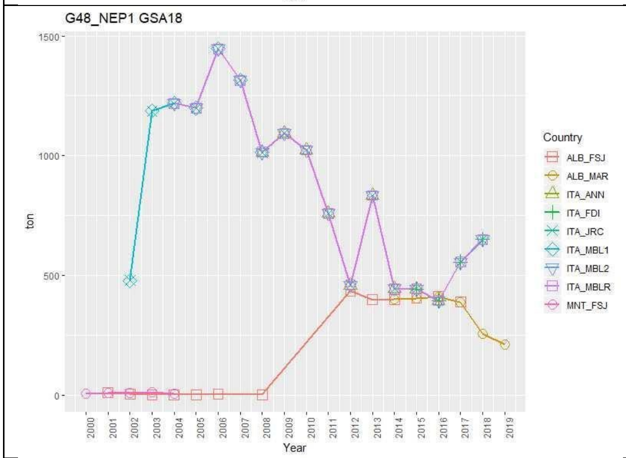


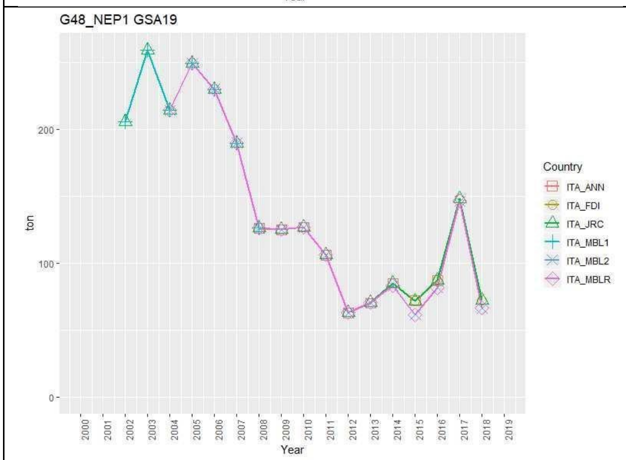




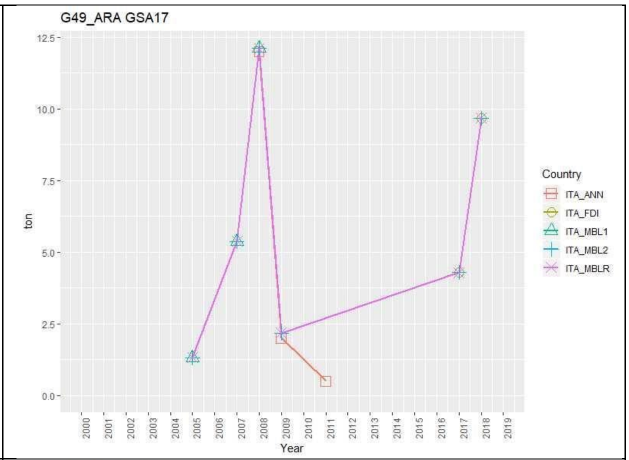
Trend of landings of mantis shrimp (MTS) in three GSAs.

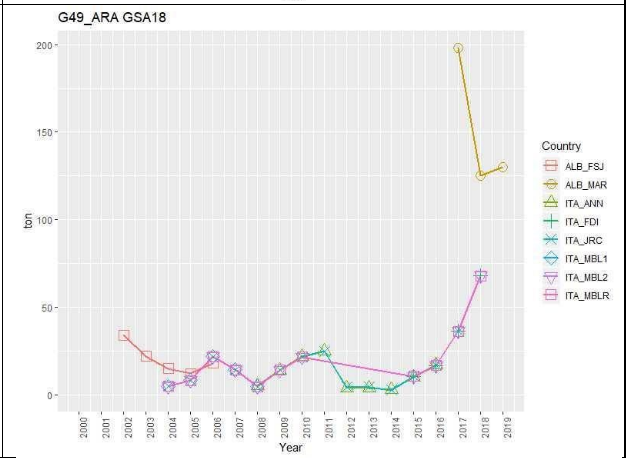


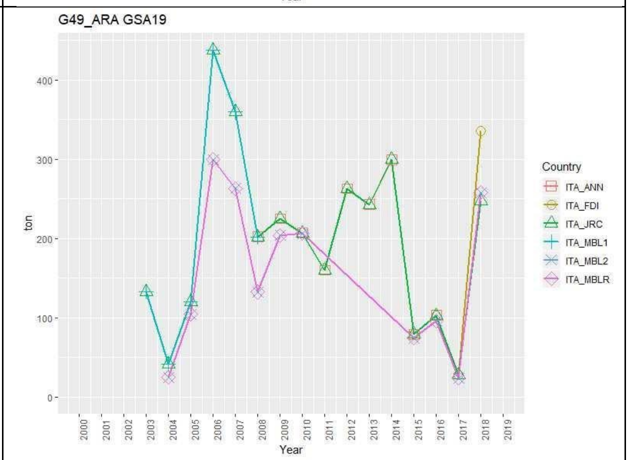




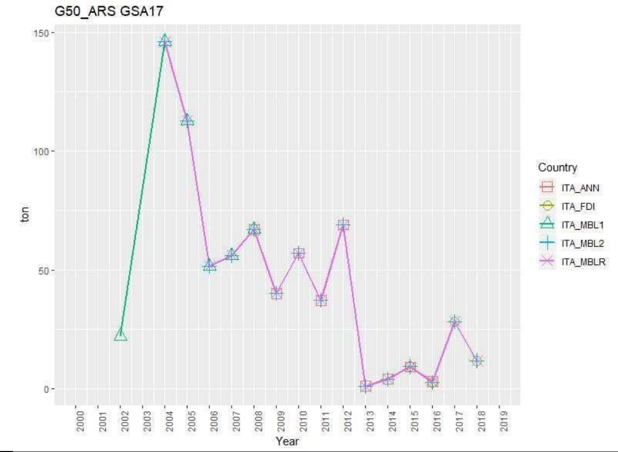
Trend of landings of norway lobster (NEP) in three GSAs.

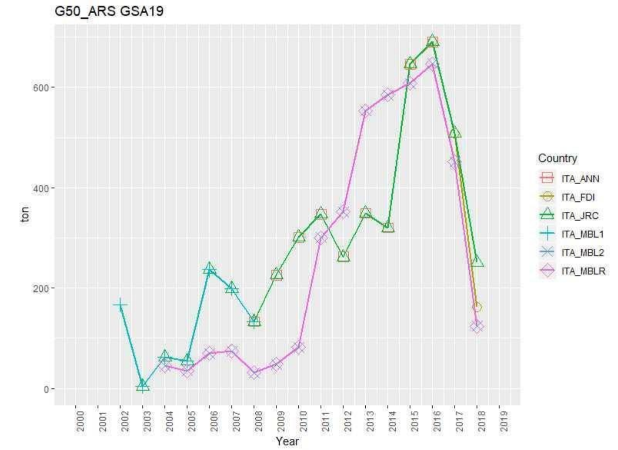




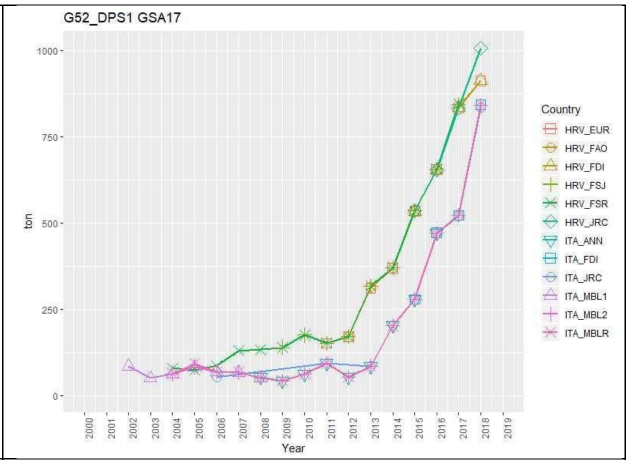


Trend of landings of blue and red shrimp (ARA) in the three GSAs.

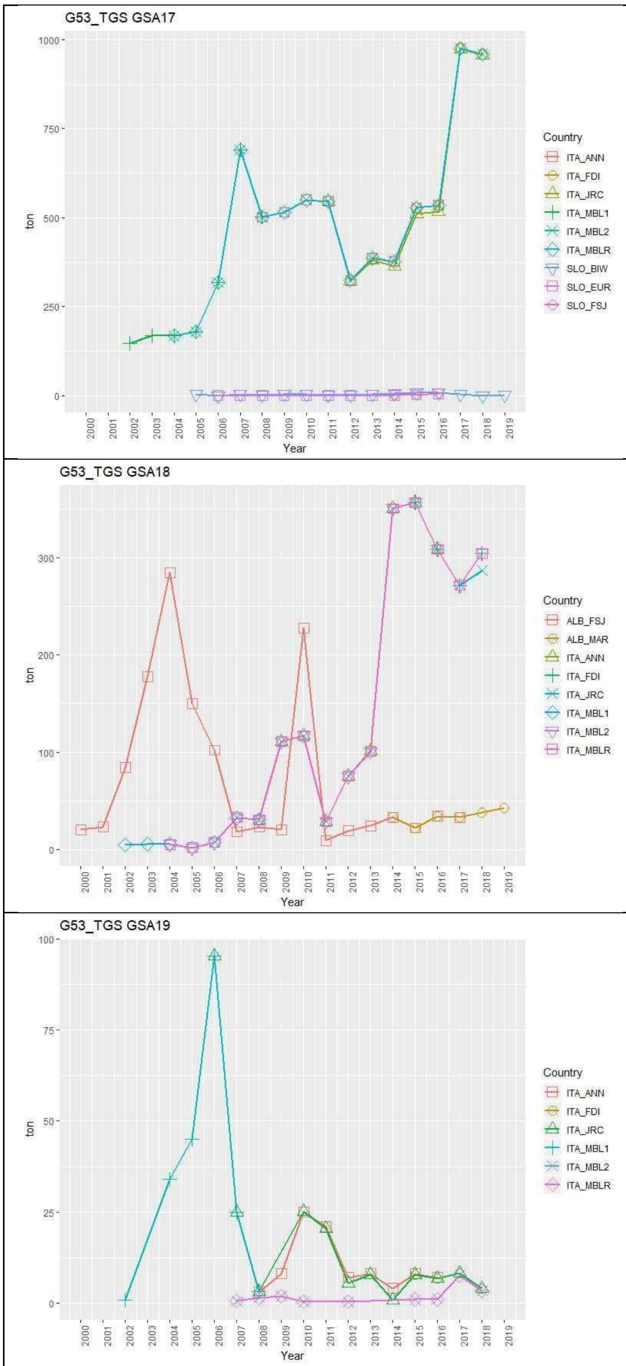




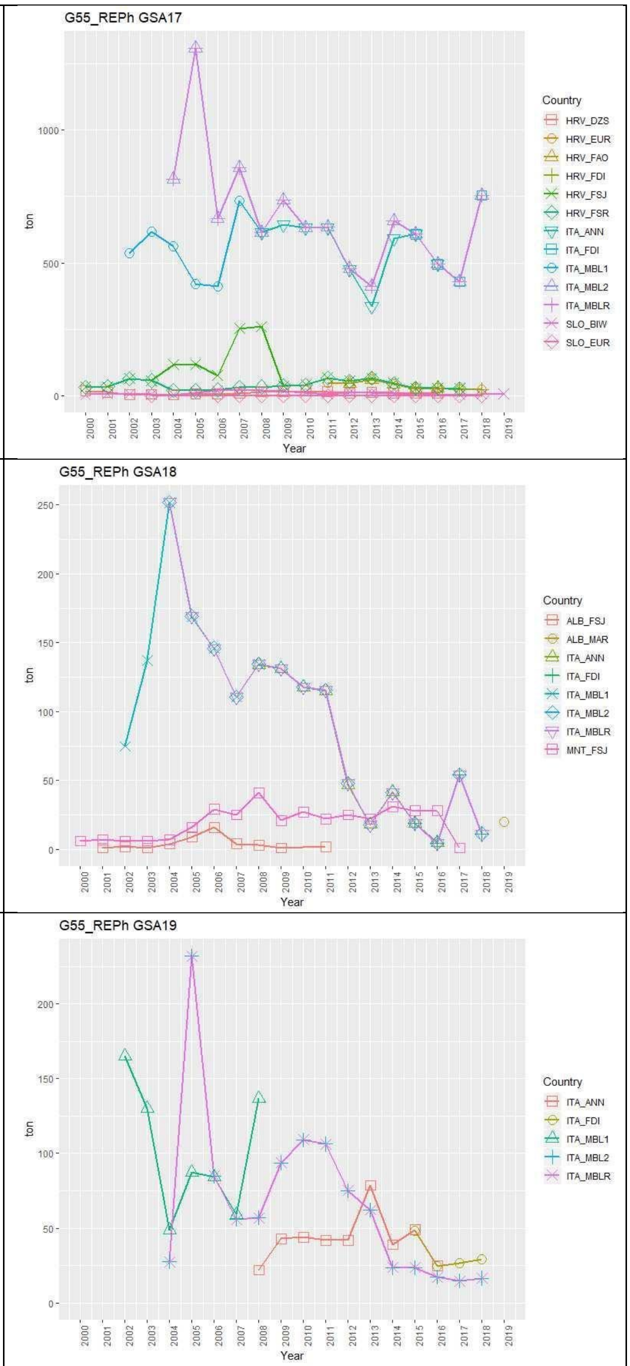
Trend of landings of red giant shrimp (ARS) in three GSAs.



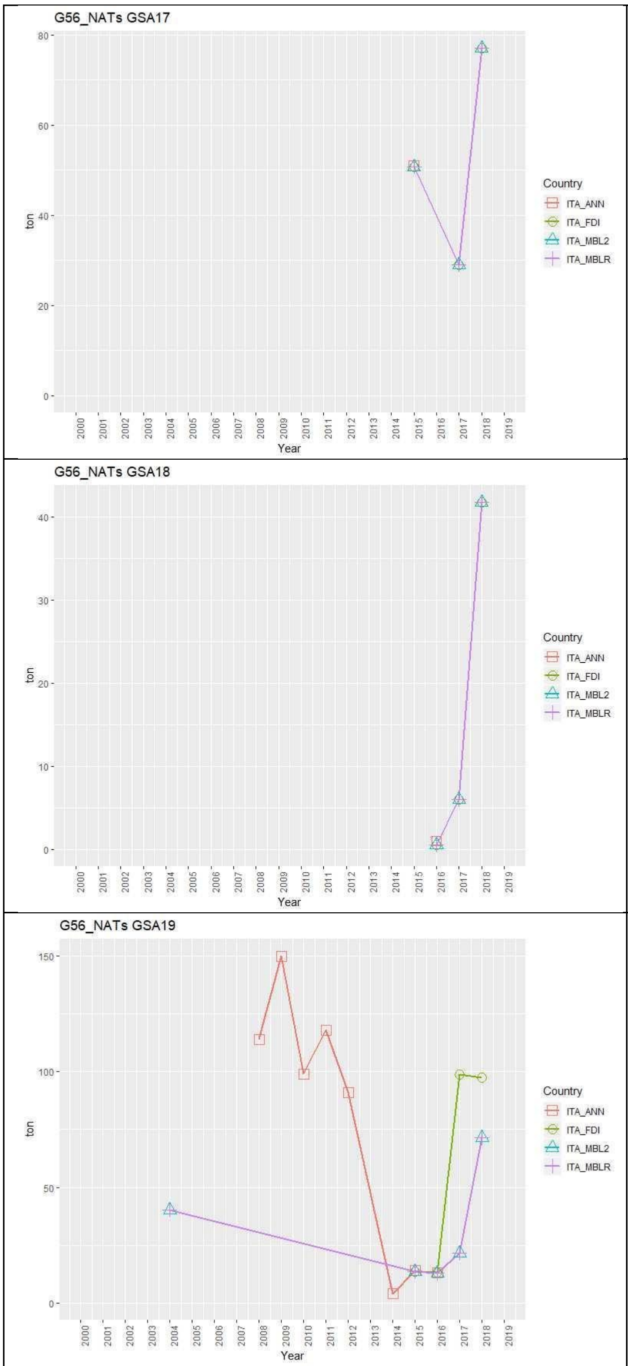
Trend of landings of deep-water rose shrimp (DPS) in three GSAs.



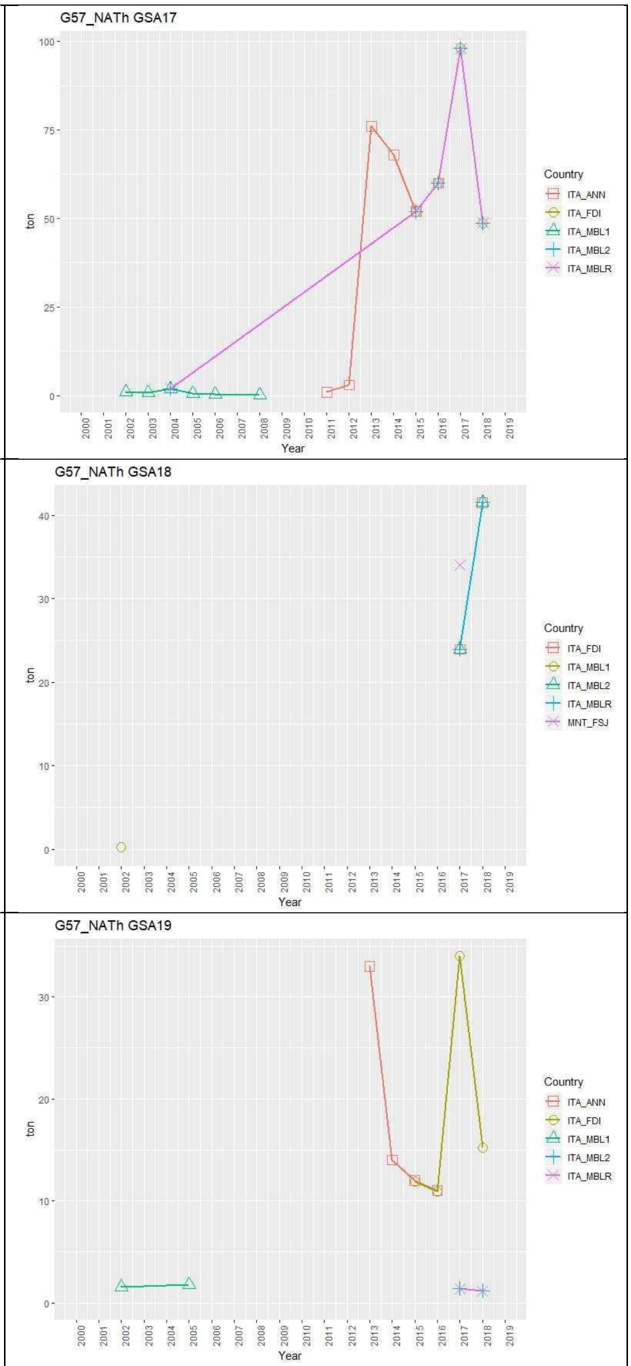
Trend of landings of caramote prawn (TGS) in three GSAs.



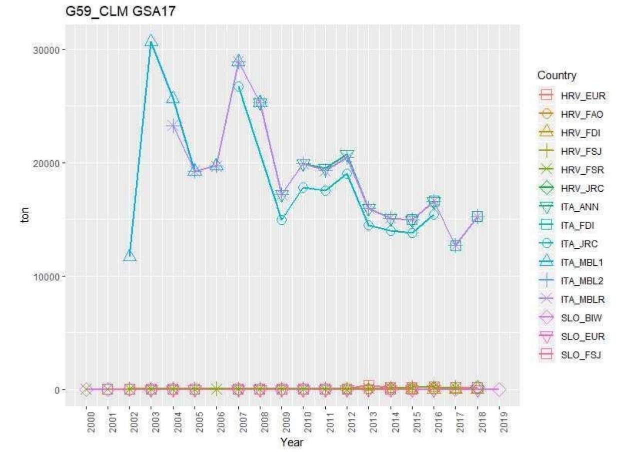
Trend of landings of reptantia decapods of shelf (REPh) in three GSAs.

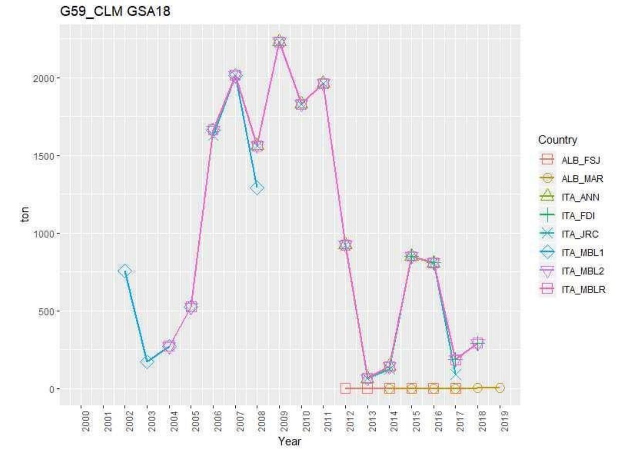


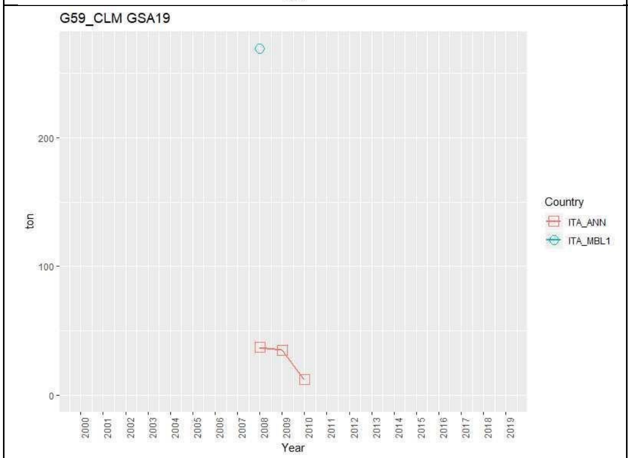
Trend of landings of natantia decapods of slope (NATs) in three GSAs.



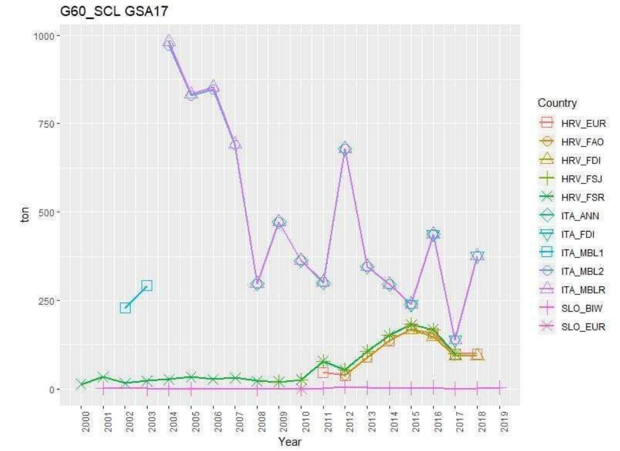
Trend of landings of natantia decapods of shelf (NATh) in three GSAs.

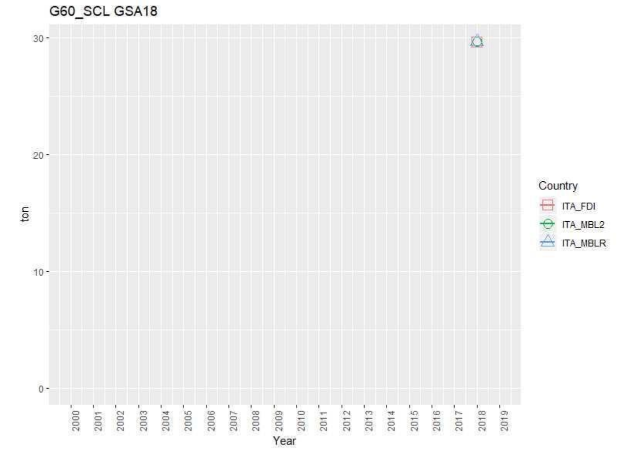


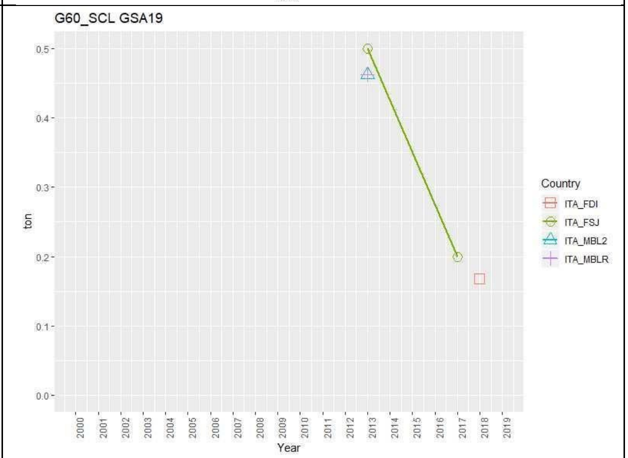




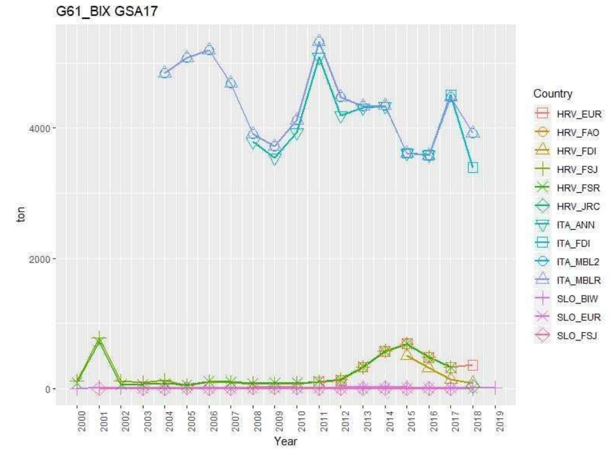
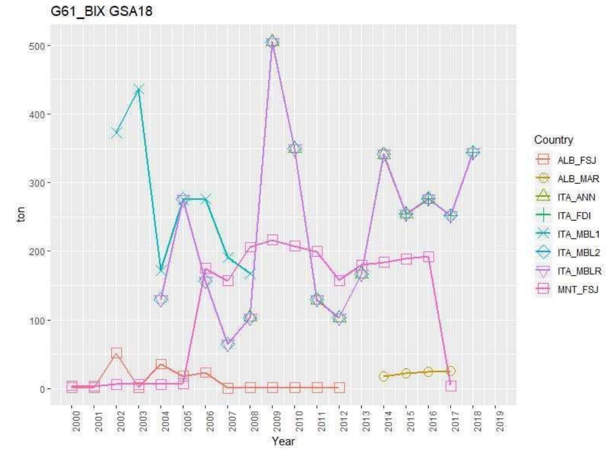
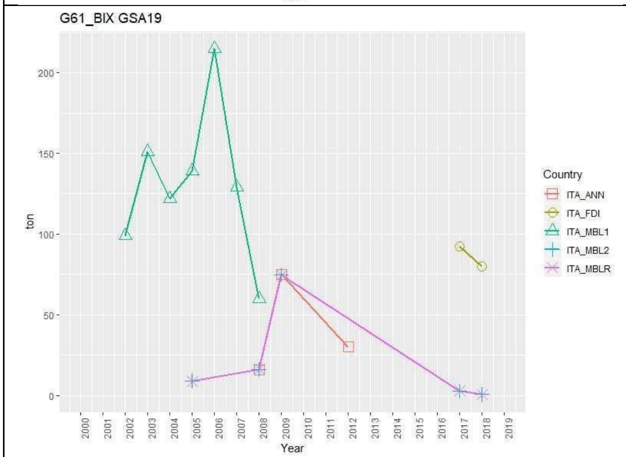
Trend of landings of venerid clams (CLM) in three GSAs.







Trend of landings of scallops (SCL) in three GSAs.

	
	
	
Trend of landings of other benthic invertebrates (BIX) in three GSAs.	