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Deliverable D5.1

Description of a conceptual model of food web for each case study area, including the identification of key species, processes, and functional groups, environmental and human (socio-economic) drivers

August, 2014

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Executive Summary

MareFrame Deliverable 5.1 on "the description of a conceptual model of food web for each case study area",, summarizes results on characterisation of ecosystem structures and identification of fisheries management issues. It is the first deliverable of WP5 "Apply new methods in case studies" and will apply the modelling approaches developed in WP4 on marine ecosystems. MareFrame Case studies (CSs) represent different types of European seas and the Chatham Rise east of New Zealand, characterized by different geological, oceanlogical and ecosystem structures (i.e. open marine waters or semi-enclosed seas) and cover a wide range of ecosystem types, biological complexity (e.g. Baltic/Mediterranean Sea/North Sea), ecological knowledge (e.g. data-poor/data rich areas) and a large array of management practices, issues and priorities. The main management issues and priorities were first identified in the co-creational way with stakeholders that formed the basis for the development of management scenarios. The conceptual models are then used by scientists for the development of management scenarios. For all CSs, the descriptive conceptual models cover all trophic levels, from primary producers up to top predators, but with special focus on the intermediate trophic level, where target species/functional groups are located. The conceptual food web models for case studies must encapsulate the prey-predator relationships between the numerous species present within their ecosystem. To do so, it is important to ensure that each model employed represents the food web structure (key/chock/keystone species) well and is correctly parameterised in order to efficiently capture the dynamic processes. Most of case studies represent various types of ecosystems, with specific ecological processes and a stochastic interplay of forcing factors. The most common processes recognized for most of the CSs to be modelled are: fishing exploitation pattern, recruitment, prey-predator interactions, density-dependence etc. Common set of model based indicators are suggested. The main common management issues and priorities were recognized for each ecosystem during case study meetings with stakeholders that are organized in cooperation with WP1 on "co-creation & pathways for implementation". Most of the proposed modelling work focus on exploitable stocks recovery, implementation of an ecosystem approach to fisheries management that accounts for species interactions and environmental factors, identification of maximum sustainable/maximum economic yields (MSY/MEY) within a multispecies context, effect of different management measures on the ecosystems using GES indicators (e.g. Descriptor 3 of the Marine Strategy, criterion 3.1. and 3.2, Commission Decision 2010/477/EU). In addition MAREFRAME represents an opportunity to explore the likely ecosystem effect of the discard ban introduced by the new Common Fisheries Policy.

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Introduction

Deliverable 5.1 summarize results obtained for Task 5.1. This was aimed at characterising ecosystem structure and identifying fisheries management issues. For each case study this task involves the development, with stakeholders, of a conceptual model of food web, including the identification of key species, processes, and functional groups, environmental and human (socio-economic) drivers to investigate in each area. The main management issues and priorities were identified during stakeholders meetings held in each case study area (WP1 – Task 1.5) as input for WP1 and base for development of management scenarios in T5.3.

The ecosystems included in the case studies are the followings: 1. Baltic Sea, 2 North Sea, 3 Iceland, 4 Northern waters; 5 Southern Western Waters (Iberian Peninsula), 6 Mediterranean-Strait of Sicily, 7 Black Sea. They cover a wide range of ecosystem types, biological complexity (e.g. Baltic/Mediterranean Sea), ecological knowledge (e.g. data-poor/data rich areas) and a large array of management practices, issues and priorities.

I. Baltic Sea case study

1. Oceanography-water circulation pattern and environmental features

Bottom topography, substrates and circulation

The Baltic Sea is one of the largest brackish areas in the world. It receives freshwater from a number of larger and smaller rivers while saltwater enters from the North Sea along the bottom of the narrow straits between Denmark and Sweden. This creates a salinity gradient from southwest to northeast and a water circulation characterised by the inflow of saline bottom water and a surface current of brackish water flowing out of the area.

The Baltic Sea is characterised by large areas (ca 30%) that are less than 25 m deep interspersed by a number of deeper basins with a maximum depth of 459 m (Fig. 1.1). The Gulf of Bothnia and the Gulf of Riga are internal fjords, while the Baltic Proper and the Gulf of Finland feature several deep basins separated by sills. The western and northern parts of the Baltic have rocky bottoms and extended archipelagos, while the bottom in the central, southern and eastern parts consists mostly of sandy or muddy sediment.

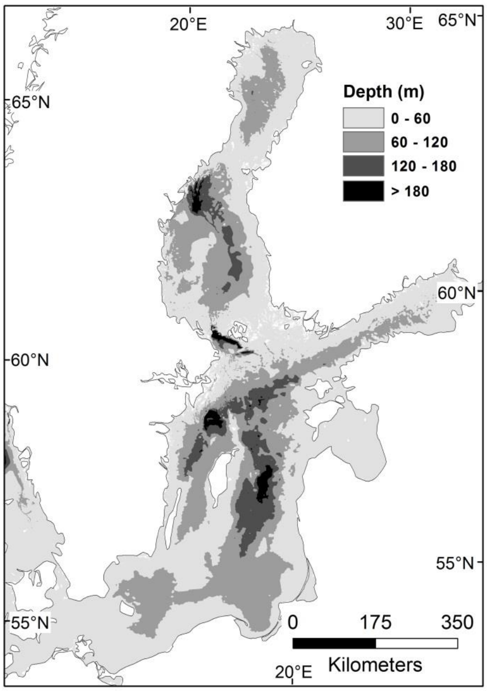

Figure 1.1. Baltic Sea bathymetry.

Physical and Chemical Oceanography

The water column in the open Baltic is permanently stratified with a top layer of brackish water separated from a deeper layer of saline water. This separation limits the transport of oxygen from the surface and as a result the oxygen in the deeper layer can become depleted due to breakdown of organic matter.

A strong inflow of new saline and oxygen rich water from the North Sea can lead to a renewal of the oxygen depleted bottom water. Strong inflows can occur when a high air pressure over the Baltic is followed by a steep air pressure gradient across the transition area between the North Sea and the Baltic. Such situations typically occur in winter. Strong inflows were frequent prior to mid-1970's, but have since become rarer and as a result salinity has decreased over the last 25 years. Major inflows occurred, however, in 1976, 1983, and 1993. In 2003 an inflow of medium size (200 km^3, ICES 2004) introduced salty, cold and well-oxygenated water into all main basins of the Baltic Sea, including the Gotland Deep.

Broad scale climate and oceanographic features and drivers

The 2007 HELCOM report states: "In summary, a climate warming is reflected in time series data on the maximum annual extent of sea ice and the length of the ice season in the Baltic Sea. On the basis of the ice extent, the shift towards a warmer climate took place in the latter half of the 19th century. During the past ten years, all ice winters have been average, mild, or extremely mild. The length of the ice season showed a decreasing trend by 14–44 days during the 20th century, the exact number depending on the location around the Baltic Sea. The ice extent, the date of ice break-up, and the length of the ice season show a correlation with the NAO index".

The oceanographic conditions in the Baltic are very much driven by meteorological forcing influencing inflow from the North Sea. Significant correlations have been demonstrated between the NAO and total freshwater runoff, westerly winds and salinity (Häninnen et al. 2000), ice conditions (Koslowski & Loewe 1994) as well as local circulation and upwelling (Lehmann et al. 2002). Climate variability has been shown to affect the dynamics of many of the components of the Baltic ecosystem (Hagen & Feistel 2005).

Surface salinities in the Central Baltic have been increasing since the beginning of the 2000s (Fig. 1.2, bottom left). In the halocline region (80–100 m depth) salinities have values close to the data series maximum (Fig. 1.2, bottom right) (ICES 2012).

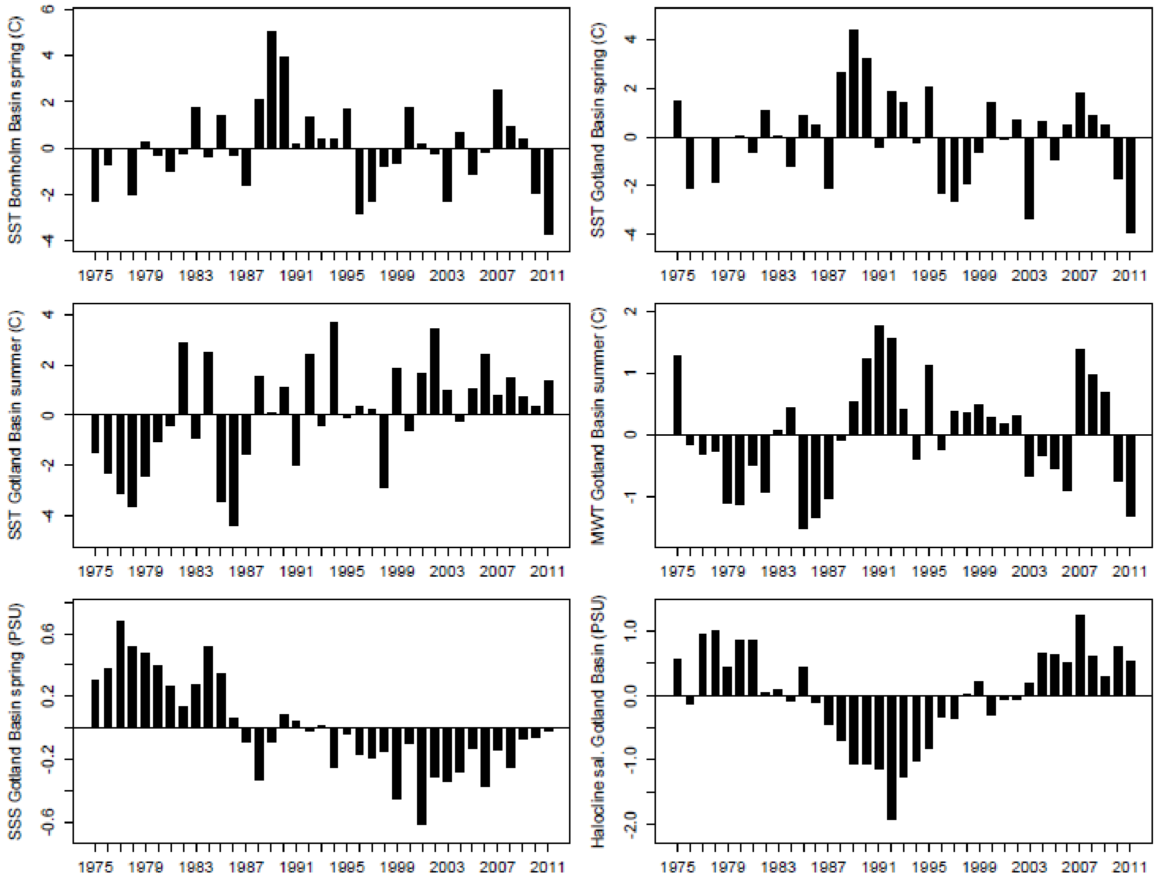

Figure 1.2. Temperature and salinity in the Central Baltic. Anomaly plots show surface water temperatures in May in the Bornholm Basin (top left, mean = 5.87 C) and the Gotland Basin (top right, mean = 5.27 C) as well as surface (middle left, mean = 15.16 C) and midwater temperatures (40–60 m, middle right, mean = 3.38 C) in summer in the Gotland Basin. Bottom row depicts surface salinity in May in the Gotland Basin (bottom left, mean = 7.13 PSU) and salinity at 80–100 m depth in the Gotland Basin in summer (bottom right, mean = 9.81 PSU). (ICES 2012).

While saltwater inflows have almost restored the salinity conditions in the Central Baltic after the stagnation period at the end of the 1980s, bottom water oxygen conditions have continued to deteriorate (Fig. 1.3, top left). Since 2003 only warm baroclinic inflows have occurred that were not dense enough to reach deep water layers and contained comparatively little oxygen (Hansson et al., 2011) (ICES 2012).

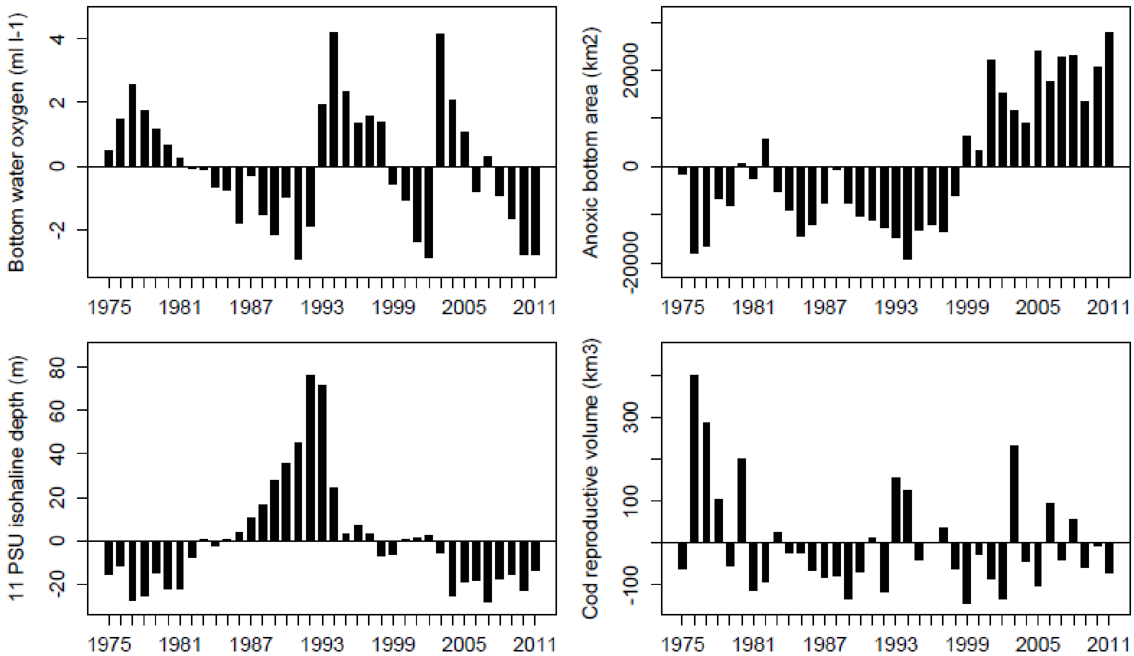

Figure 1.3. Oxygen conditions in the central Baltic Sea. Anomaly plots show oxygen concentra- tions at 200–220 m depth in the Gotland deep (top left, mean = -1.25 ml l^{-1}, anoxic bottom area in the Baltic Proper, Gulf of Finland and Gulf of Riga (top right, mean = 22 018 km^2), depth of the 11 PSU isohaline (bottom left, mean = 122 m) and cod reproductive volume (bottom right, mean = 177 km^3, (ICES 2012).

Nutrients, primary production, eutrophication, hypoxia (anoxia)

The Baltic receives nutrients and industrial waste from rivers, and airborne substances from the atmosphere. As a result the Baltic has become eutrophic during the 20th century. In general, nutrient concentrations in the Baltic Sea have not decreased since the mid-1990s. Low oxygen conditions in deep water affect the amounts of nutrients in the water. Phosphorus is easily released from sediments under anoxic conditions. Nitrogen cycles in deep water layers also change in anoxic conditions: mineralization eventually produces ammonium, and no oxidation occurs to form nitrates. Consequently, the process of denitrification, which needs oxygen from nitrates, will not occur. The resulting nutrient surplus in the deep water layers is a potential source of nutrients for the surface layers, where primary production may be further increased (Helcom 2003). This effect may counterbalance the decrease in nutrient input into some parts of the Baltic Sea. In addition, a long-term decrease in silicate concentrations is apparent in most parts of the Baltic, and silicate has recently been limiting growth of diatoms in the Gulf of Riga in spring. Silicate limitation changes the structure of the phytoplankton community rather than limiting the total production (Helcom 2002).

Winter surface water nutrient concentrations show similar trends in the Bornholm and Gotland Basins (Fig. 1.4 top and middle). Deep water nutrient concentrations in the Gotland Basin reflect the water renewal pattern in the basin (Fig. 1.4, bottom) and presently deep water DIN and DIP concentrations are above their long-term average.

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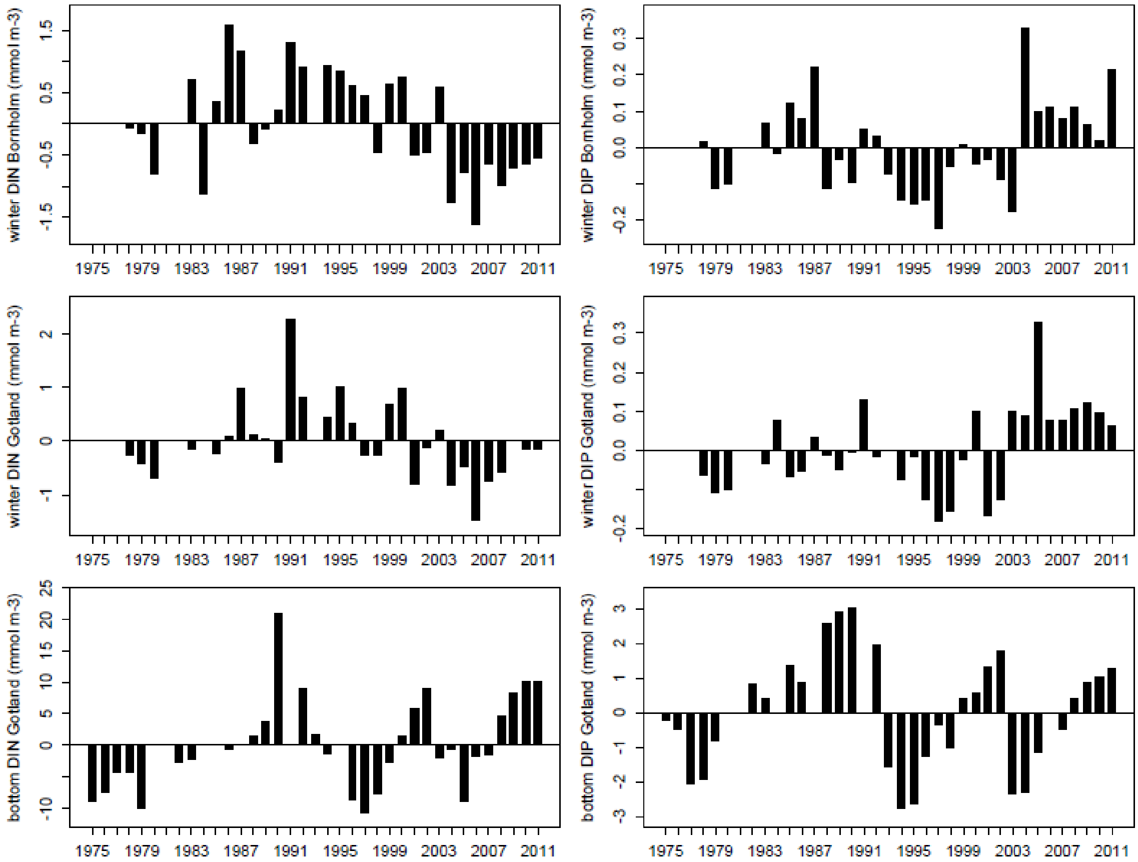

Figure 1.4. Nutrient conditions in the central Baltic Sea. Anomaly plots show surface winter DIN and DIP concentrations in the Bornholm Basin (top row, means 3.57 mmol m^{-3} DIN and 0.64 mmol m^{-3} DIP) and the Gotland Basin (middle, means 3.67 mmol m^{-3} DIN and 0.55 mmol m^{-3} DIP). Bottom row shows deep water (200–220 m) nutrient concentrations in the Gotland Basin (mean 11.14 mmol m^{-3} DIN and 4.36 mmol m^{-3} DIP) (ICES 2012).

Increased stratification, combined with low supply of oxygen to bottom waters and most likely high sediment oxygen consumption (see e.g. Meier et al., 2011), have caused anoxic bottom waters to expand quickly between 1993 and 2001 and to remain on a record high level until present (Hansson et al. 2011, Fig. 1.3 top right). The low oxygen concentrations have negative effects on the reproductive habitat for cod (i.e., cod reproductive volume). While in 2008–2010 part of the Gotland Basin was suitable for cod reproduction, oxygen conditions suggest that in 2011 cod reproduction was limited to the Bornholm Basin (ICES 2012).

A historical analysis has recently shown that hypoxic areas have 10-folds increase during the last century (Castenesen et al., 2014; Fig.1.5).

Figure 1.5. The extent of hypoxic and anoxic areas in the Baltic Sea in 1906, 1955 and 2012 is shown in red and black, respectively.

2. Baltic Sea Food- web

Food-web – general overview, main processes

The Baltic Sea food-web shows a relatively low species diversity, compared to fully marine systems (Sandberg et al. 2000), but includes all trophic levels from primary producers to marine mammals as top predators (Harvey et al. 1997, Jarre-Teichmann 1995). The lowest trophic levels are occupied by primary producers (phytoplankton, and\or macrophytes in coastal areas). The intermediate trophic levels (2 – 2.8 TL) is covered by Micro- and Mesozooplankton as well as benthic fauna. Fish (demersal and pelagic) as well as carnivore invertebrates occupy the trophic levels from 3.4 to 3.7 (Sandberg et al. 2000). Marine mammals (seals and harbour porpoises) form the highest trophic levels.

Despite the spatial environmental gradients, the classical food web structure is fairly similar across the basin, however the estimated primary production varied significantly between basins (Sandberg 2007). The overall carbon flows are highest in the Baltic proper, somewhat lower in the Bothnian Sea and much lower in Bothnian Bay. Some difference could be found in the average trophic levels in the food web between basins. The average trophic level was lower for demersal fish in the Bothnian Sea and higher for macrofauna in the Bothnian Bay, compared to the other basins (Sandberg et al. 2000).

As described by Harvey et al. (1997), biomass changes at higher trophic levels caused either by fishing, trophic interactions, and/or variable recruitment also influence lower trophic levels. Also Osterbloom et al. (2006, 2007), confirm that cascading effects in the Baltic food web and fish population dynamics are related to a combination of fishing effects and changes in the level of productivity of the system.

The south-eastern Baltic coastal ecosystems are highly productive, channelling a large proportion of their primary production into exploitable fishery resources. Local nutrient sources influence phytoplankton primary production, but retention of primary production in sheltered areas with favourable hydrographical conditions is the most important factor determining food availability to the pelagic and benthic food web (Tomczak et al. 2009).

In the late 1980s, an ecosystem regime shift was described for the Baltic Proper (BP) (Alheit et al., 2005; Möllmann et al., 2009). The BP is the central basin of the brackish, semi-enclosed Baltic Sea. The regime shift in the BP was associated with pronounced changes and reorganisations within and across the trophic levels of zooplankton and fish (Alheit et al., 2005; Möllmann et al., 2009). In particular, the zooplankton community changed from the dominance of the copepod *Pseudocalanus* sp. to *Temora* sp. and *Acartia* spp., most probably due to climate-related effects (Möllmann et al., 2003). Further, changes in the hydrography and fishing pressure affected the reproductive success and abundance of the major fish species, resulting in a change of dominance from piscivorous cod (*Gadus morhua*) to planktivorous sprat (*Sprattus sprattus*) (Köster et al., 2003). This caused a further decrease in the biomass of the sprat prey *Pseudocalanus* sp. Möllmann et al. (2009) suggest that internal predator-to-prey (P2P) feedback-loops possibly stabilized the new regime (Fig. 1.6).

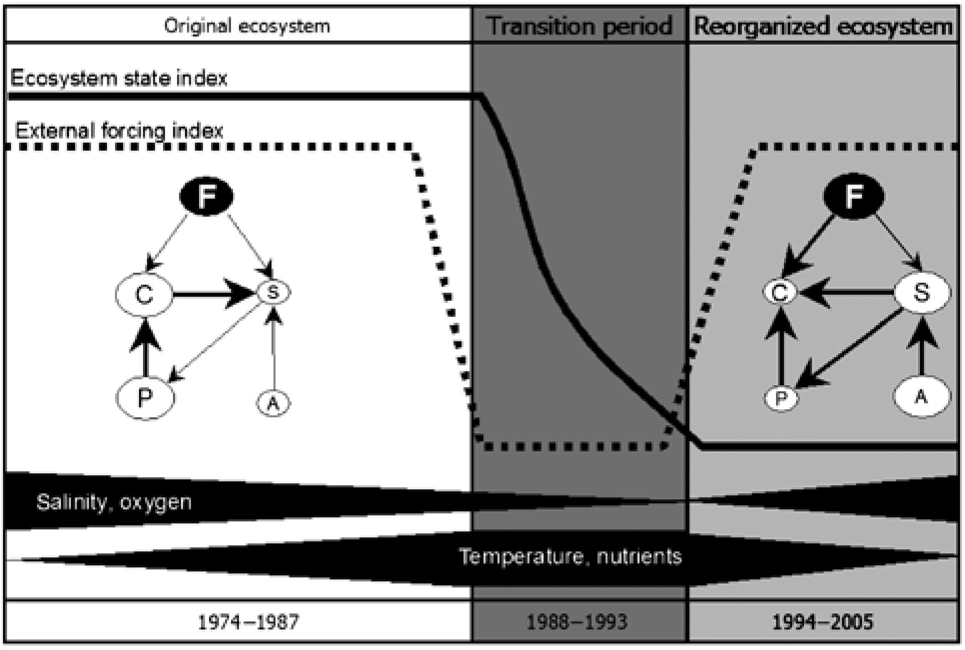

Figure 1.6. Conceptual diagram displaying the changes in the Baltic Sea ecosystem; F, fishing pressure; C, cod; S, sprat; P, Pseudocalanus acuspes and A, Acartia spp.; arrows represent direction and strength of a control.

The dramatic increase of sprat has had a negative effect not only on the growth and abundance of predators and zooplanktivores (cod, sprat and herring; Cardinale & Arrhenius 2000; Cardinale et al. 2002; Casini et al. 2006) and the breeding success of fish-eating birds such as the common guillemot (Österblom et al. 2006), but has also had cascading effects on zooplankton (Casini et al. 2006) and phytoplankton (Casini et al. 2009.).

Key species, ecological functional groups and fishing fleets

Phytoplankton

The species composition of the phytoplankton depends on local nutrients and salinity and thus changes gradually from the southwest to the northeast. Primary production exhibits large seasonal and interannual variability (Helcom 2002,). Normally, an intense spring bloom starts in March in the western Baltic, but only in May-June in the Gulf of Bothnia. In the southern and western parts the spring bloom is dominated by diatoms, whereas it is dominated by dinoflagellates in the central and northern parts. Over the period from 1979 to 1999 downward trends were found for diatoms in

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spring and summer, whereas dinoflagellates generally increased in the Baltic proper, but decreased in the Kattegat. Chlorophyll a, a proxy indicator for total phytoplankton biomass, also increased in the Baltic proper (Wasmund and Uhlig 2003).

Summer blooms of nitrogen-fixing cyanobacteria ("blue-green algae") are normal in the central Baltic, Bothnian Sea, Gulf of Finland and Gulf of Riga. Such blooms have occurred in the Baltic Sea for at least 7,000 years, but their frequency and intensity seem to have increased since the 1960s. Mass occurrences of blue-green algae are often made up of several species. Since 1992 the relative abundance of the most common species has shown a clear trend in the Arkona Basin (southern Baltic) and in the northern Baltic Sea: the toxin-producing species *Nodularia spumigena* has become more abundant compared to the non-toxic Aphanizomenon flos-aquae. Red tides (dinoflagellate blooms) are regularly observed, including blooms of the toxic *Gymnodinium mikimotoi* (Helcom 2002, 2003). The spring bloom was higher in 2007 than in the previous year in the Gulf of Finland, the Northern Baltic Proper and Arkona Basin. No rising trend can be detected from 1992 to 2007 in the Gulf of Finland, the Northern Baltic Proper or the Arkona Basin (Helcom 2007).

As reported by WGIAB (ICES 2012). Recent publications have shown shifts and alternating oscillations between diatom and dinoflagellate during spring in the Central Baltic, with diatom dominated spring blooms in the 1980s and since 2000, whereas dinoflagellates were most abundant during the 1990s (Klais et al. 2011; Wasmund et al. 2011). During summer, data show fluctuating phytoplankton concentrations in the Bornholm Basin and a steady increase in summer chlorophyll a in the Gotland Sea (Fig. 1.7). A pronounced chlorophyll a maximum was observed in 2008 probably result of large cyanobacteria surface accumulations
(http://www.helcom.fi/BSAP_assessment/ifs/ifs2011/en_GB/Cyanobacterialblooms2011).

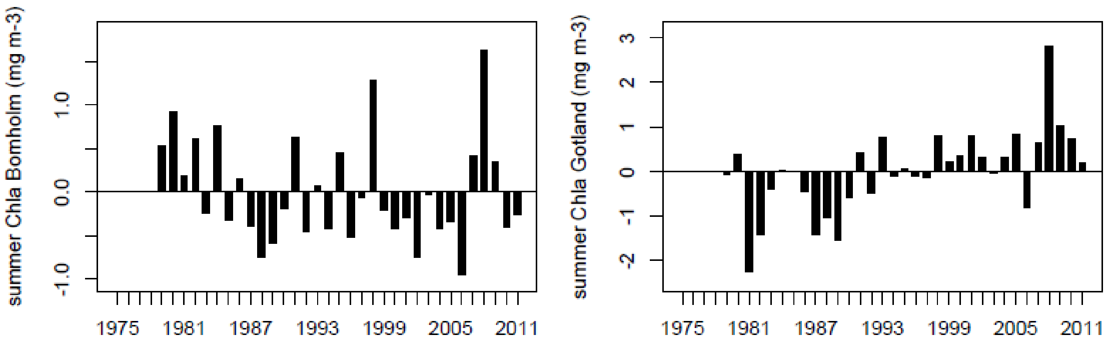

Figure 1.7. Summer chlorophyll a concentrations in the Central Baltic Sea. Anomaly plots show chlorophyll a concentrations in the Bornholm (left, mean = 2.12 mg m-3) and Gotland (right, mean = 2.44 mg m-3) basin (ICES 2012).

Zooplankton

In terms of biomass the zooplankton of the Baltic Sea is dominated by calanoid copepod and cladocerans. The species composition is influenced by the salinity gradient. Generally marine species (e.g. *Pseudocalanus* sp.) prevail in the southern more saline part, while brackish species (e.g. *Eurytemora affinis* and *Bosmina longispina maritima*) dominate in the northern areas. Changes in the species composition of the zooplankton have been linked to changes in salinity and temperature. For the shallower northern areas of the Baltic Sea a decline of large neritic copepods and an increase of

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species with freshwater origin, i.e. cladocerans has been related to a reduction of salinity caused by increased river runoff (Viitasalo et al. 1995, Vuorinen et al. 1998, Ojaveer et al. 1998). In the Central Baltic deep basins the abundance and biomass of *Pseudocalanus* sp. has declined since the 1980s, whereas the abundance of *Temora longicornis* and *Acartia* spp. increased (Fig. 1.8). The decrease in *Pseudocalanus* sp. is correlated to the decrease in deep water salinity resulting from the reduced frequency of inflow events (Möllmann et al. 2000, 2003 a). Recent investigations indicate that the combination of low salinity and oxygen conditions in the halocline of the deep basins, might have a detrimental effect on the viability of *Pseudocalanus* sp. eggs and nauplii (Schmidt et al. 2003, Renz and Hirche 2005). The increase in *Acartia* spp. and *T. longicornis* during the 1990s is correlated with temperature (Möllmann et al. 2000, 2003 a), a result of the persistently strong positive state of the NAO (Alheit et al. 2005, Möllmann et al. 2005). Recent investigations indicate that temperature-dependent resting egg activation is the responsible process behind the temperature-*Acartia* spp. relationship (Alheit et al. 2005). *Acartia* spp. and *Temora longicornis* (Fig. 1.8, ICES WGIAB 2012), the dominating copepods above the halocline in the Central Baltic, have clearly benefitted from warmer water temperatures in spring. During summer both species show slightly differing trends. While *Acartia* spp. biomass declines again after a maximum in the mid 1990s, *Temora longicornis* shows strong fluctuations with an increasing trend throughout the entire time-series. In contrast to *Acartia* spp. and *Temora longicornis*, *Pseudocalanus acuspes* is primarily distributed in the halocline region of the Central Baltic. Its biomass has declined since the beginning of the 1990s and has remained low since then (Fig. 1.8).

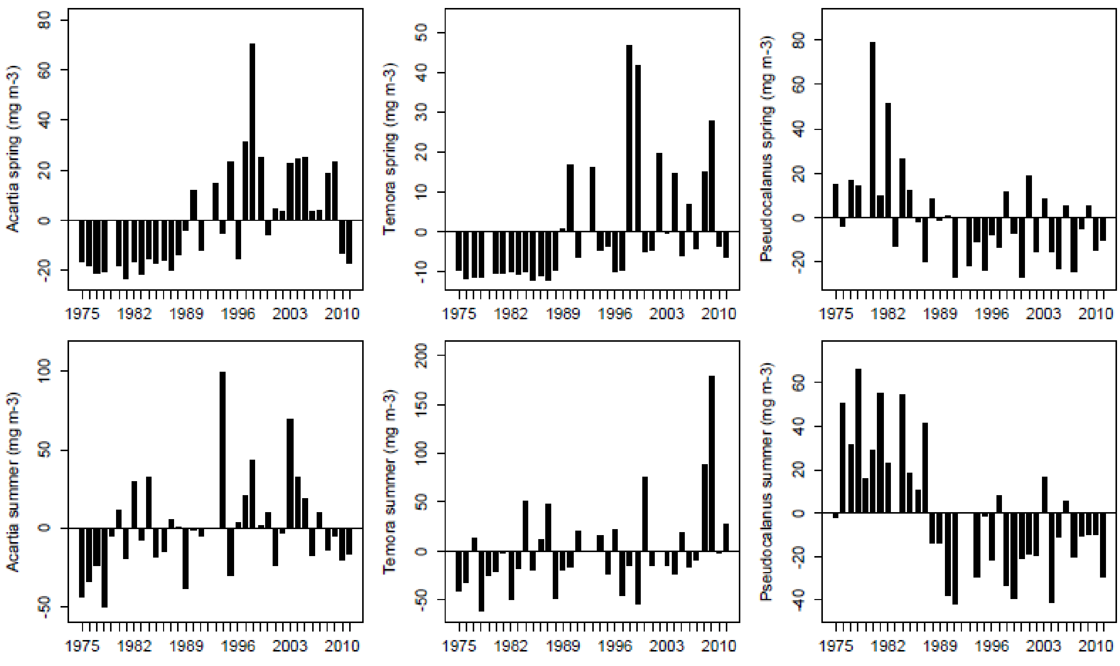

Figure 1.8. Zooplankton biomass in the Central Baltic Sea. Anomaly plots show biomass in spring (top row) and summer (bottom row) for Acartia spp. (left, means 24.7 mg m^{-3} and 61.2 mg m^{-3}), Temora spp. (left, means 13.0 mg m^{-3} and 73.7 mg m^{-3}) and Pseudocalanus spp. (right, means34.3 mg m^{-3} and 55.2 mg m^{-3}) (ICES 2012).

Benthos

The composition of the benthos depends both on the sediment type and salinity, with suspension feeding mussels being important on hard substrate while deposit feeders and burrowing forms dominate on soft bottoms. The species richness of the zoobenthos is generally poor and declines from the southwest towards the north due to the drop in salinity. However, species poor areas and low benthos biomasses are also found in the deep basins in the central Baltic due to the low oxygen content of the bottom water. After major inflows a colonisation of these areas can, however, be seen.

In the south-western part of the Baltic the bivalve *Macoma balthica* characterises the community found on shallow soft bottoms while a community characterised by the bivalves *Abra alba* and *Arctica islandica* are found in the deeper parts. East of the Dars sill various polychaetes become important in the deeper parts. In the central areas the major parts of the hard bottoms are inhabited by communities of *Fucus vesiculosus* and *Mytilus edulis*, while the fauna of the main part of the soft bottoms has been classified as a Macoma community (Voipio, 1981). In the Bothnian Bay and the central part of the Bothnian Sea the isopod *Saduria entomon* and the amphipod *Pontoporeia* spp. dominate the zoobenthos (Laine 2003). In shallow areas seaweed and seagrass form important habitats (including nursery grounds) for many animals. The distribution of seaweed and seagrass has changed over time, in some cases in response to eutrophication (Helcom 2003).

Fish

The distribution of the roughly 100 fish species inhabiting the Baltic is largely governed by salinity. Marine species (some 70 species) dominate in the Baltic Proper, while freshwater species (some 30-40 species) occur in coastal areas and in the innermost parts (Nellen and Thiel 1996, cited in Helcom 2002). Cod, sea and sprat comprise the large majority of the fish community in both biomass and numbers. Commercially important marine species are sprat, herring, cod, flounder, plaice, turbot, and salmon. Sea trout and eel, once abundant, are of very low population sizes. Sturgeons, once common in the Baltic Sea and its large rivers are now extinct from the area. Recruitment failures of coastal fish, e.g. perch (*Perca fluviatilis*) and pike (*Esox lucius*) in Sweden have been observed along the Swedish Baltic coast (Nilsson et al. 2004, Sandström and Karås 2002).

Cod is the main predator on herring and sprat, and there is also some cannibalism on small cod (Köster et al. 2003). Herring and sprat prey on cod eggs, and sprat are cannibalistic on their eggs, although there is seasonal and inter-annual variation in these effects (Köster and Möllmann 2000a). The trophic interactions between cod, herring and sprat may periodically exert a strong influence on the state of the fish stocks in the Baltic. Due to the coastal spawning of herring, it is also subject to interactions with freshwater species in the coastal zone. For example, pikeperch predation on young herring can decrease local herring production considerably (Hansson et al. 1997). Immature cod are also commonly found in shallower areas (Baranova 1995), but the relative importance of its interactions with coastal dwelling species remains unclear.

Climate driven changes in the salinity, temperature and oxygen content of the water affect the recruitment and growth of cod, herring and sprat. The reduction in salinity and oxygen and the increase in temperature caused by the high NAO index in the 1990s resulted in a reduction of the growth rate of herring, and sprat growth declined during the 1980s and 1990s, probably due to changes in the zooplankton composition and abundance (Rönkkonen et al. 2004, Möllmann et al.

2005) and as a result of increases in food competition (Casini et al. 2006), while the recruitment of herring in the Gulf of Riga and sprat in the entire Baltic increased during the 1990s (MacKenzie and Köster 2004).

In the past the eastern cod stock spawned in the Bornholm, Gdansk, and Gotland Deeps, but in the later years the salinity and oxygen conditions have only allowed successful spawning, egg fertilisation and egg development in the Bornholm Deep (Köster et al. 2005). Cod eggs can only develop successfully if oxygen concentration is larger than $2ml*l^{-1}$ and salinity is higher than 11 psu, and the volume of water where this is fulfilled, the so-called "reproductive volume", has generally been very low or zero since the mid-1980s in the Gotland and Gdansk Deeps (MacKenzie et al. 2000).

Egg predation intensity by clupeids depends on ambient hydrographic conditions. In stagnation periods, when oxygen and salinity are low, the vertical overlap between predator and prey is high, while opposite conditions release cod eggs from clupeid predation (Köster et al. 2005). Furthermore, egg predation pressure depends on predator abundance. Herring stock sizes declined throughout the 1980s and 1990s (Köster et al. 2003), while sprat stock size increased to the highest levels on record in the mid-1990s, mainly because of favourable thermal conditions for reproduction (MacKenzie and Köster 2004). Timing of cod spawning determines the relative strength of predation by herring and sprat, i.e. late spawning enhancing the horizontal overlap with herring, but releasing predation pressure by sprat. The shift of the cod spawning season to summer during the first half of the 1990s has thus been an advantage for cod reproductive success (Köster et al. 2005).

In the Central Baltic, cod and sprat spawn in the same deep basins and have partly overlapping spawning seasons. Hydrographic-climatic variability (i.e., low frequency of inflows from the North Sea, warm temperatures) and heavy fishing during the past three decades have led to a shift in the fish community from cod to clupeids (herring, sprat) by weakening cod recruitment and subsequently generating favourable recruitment conditions for sprat (Köster and Möllman, 2000, Köster et al, 2003; MacKenzie and Köster 2004). Reducing the fishing mortality of cod has initiated a recovery of the cod stock to average SSB for the time period 1975–2010, despite low recruitment (WGIAB, Fig. 1.9, left). Also the sprat stock is currently at its time-series average, after record high biomasses in the mid 1990s. Recruitment conditions continue to be favourable for sprat, but fishing mortality for the stock is relatively high (Fig. 9A, right). Central Baltic Sea herring has stabilized on a low level. Recruitment has been low since the mid-1980s and despite lowering the fishing mortality after the end of the 1990s, the stock has only recovered slightly (Fig. 1.9, middle).

The drastic reduction of the cod population abundance since the late 1980s resulted in a contraction of it distribution towards the south-western Baltic Proper (ICES 2013). A combination of climatic, intra- and inter-specific density dependent factors have been suggested as drivers of the changes in the spatial distribution and condition of herring and sprat in the central Baltic Sea during the last two decades. In particular, from mid 1990s sprat densities increase towards the north-eastern of the Baltic Proper likely as a consequence of both increase water temperature and release of cod predation which contracted its distribution progressively south-westward (Casini et al. 2014). For both herring and sprat, condition was high and similar in all areas of the Baltic Proper until the early 1990s, coincident with low sprat densities. Afterwards, a drop in condition occurred and a pronounced north-south gradient emerged. The drop in condition after the early 1990s was stronger in the northern areas, where sprat population increased mostly (Casini et al. 2011).

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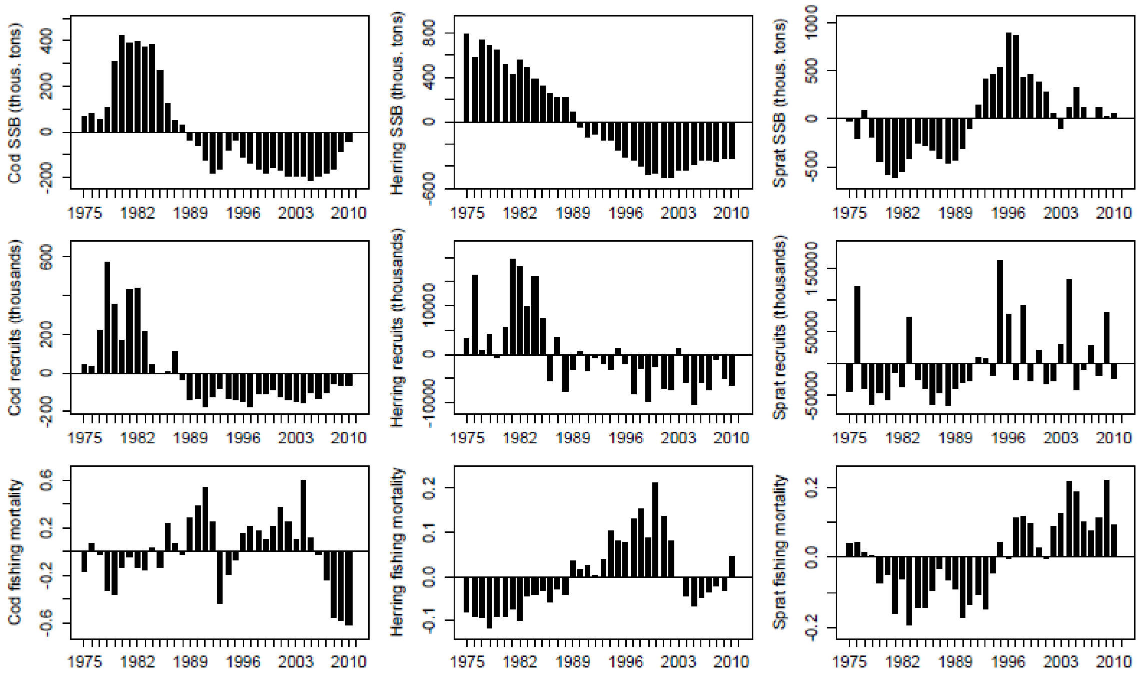

FFigure 1.9. Fish and fishery indicators for the Central Baltic Sea. Anomaly plots show spawning stock biomasses of cod, herring and sprat (top row, means 274*10^3 tons, 864*10^3 tons, 259*10^3 tons), recruitment (middle, means cod recruits at age 2 = 258*10^3, herring recruits at age 1 = 17.3*10^6 tons, sprat recruits at age 1 = 79.0*10^6) and fishing mortality F (bottom, means 0.86, 0–27, 0.31 ICES 2012).

Birds and mammals

The marine mammals in the Baltic consist of grey (*Halichoerus grypus*), ringed (*Phoca hispida*), and harbour seals (*Phoca vitulina*), and a small population of harbour porpoise (*Phocoena phocoena*). Seals and harbour porpoise were much more abundant in the early 1900s than they are today (Elmgren 1989; Harding and Härkönen 1999) where their fish consumption may have been an important regulating factor for the abundance of fish (MacKenzie et al., 2002; Österblom et al. 2007). Baltic seal populations – harbour seals, grey seals and ringed seals – are generally increasing. Little is known about recent changes in the abundance of the harbour porpoise (Helcom 2001).

The seabirds in the Baltic Sea comprise pelagic species like divers, gulls and auks, as well as benthic feeding species like dabbling ducks, sea ducks, mergansers and coots (ICES 2003). The Baltic Sea is more important for wintering (c.10 million) than for breeding (c.0.5 million) seabirds and sea ducks. The common eider exploits marine waters throughout the annual cycle, but ranges from being highly migratory (e.g., in Finland) to being more sedentary (e.g., in Denmark).

Population trends for seabirds breeding within the different countries of the Baltic Sea show an overall decrease for nine of the 19 breeding seabird species. Black-headed gulls are assessed as decreasing throughout the Baltic Sea, whereas the eight other species are considered decreasing in parts of the Baltic Sea. The status of other species, which predominantly breed in the archipelago areas, like common eider, arctic skua, Caspian tern and black guillemot, is uncertain, and populations of these species may be decreasing in parts of the archipelago areas (ICES 2003).

Multiple pressures can be identified as playing an important (either negative or positive) role in the development of populations and distributions of most species of waterbirds (Skov et al. 2011):

- climate change: ubiquitous north-ward shifts in the distribution of wintering waterbirds have taken place over the last 15 years. The majority of northward distribution shifts may be coupled to reductions in ecosystem capacity in the southern Baltic as well as to increases in water temperature and the related increased availability of open water areas.
- eutrophication: the long-term reduction in loads of nitrogen and phosphorous in the southern and central Baltic may be coupled to wide-spread declines since 1993 in almost all species feeding on benthic invertebrates and fish in sublittoral environments. Results stress the importance of eutrophication as a key driving factor for the spatiotemporal variability in food supply for an abundance of bivalve-eating seaducks and fish-eating mergansers in the Baltic Sea.
- oil pollution/shipping: illegal discharges of oil pollution from ship traffic introduce significant extra mortality to wintering waterbirds in offshore Baltic waters.
- by-catch: all diving species today experience extra-mortality due to by-catches in gill-nets. Interactions between fisheries and seabirds are frequent and widespread leading to levels of incidental seabird mortality which pose a serious threat to many seabird populations. The EU Commission introduced the Action Plan for reducing incidental catches of seabirds in fishing Gears (COM(2012) 665 final) recently.

Main fisheries (fleets/metiers), target species and catch composition, seasonality and main spatial patterns in the fisheries

The main target species in the Baltic commercial fisheries are cod, herring and sprat, which account for approx. 95% of the total catch. A number of other fish species have local economic importance as salmon, plaice, flounder, dab, brill, turbot, pike-perch, pike, perch, vendace, whitefish, turbot, eel and sea-trout.

Demersal trawls, pelagic trawls and gillnets are the main fisheries targeting cod in the Baltic. The cod fishery was intensified in the early 1980s when the stock biomass substantially increased due to favourable reproductive conditions. The landings increased in the mid 1980s as a consequence of the large year classes of the 1976, 1977 and 1980. During this period a considerable part of the catch was taken in the subdivisions 28-32. In the 1990s the stock had a progressive decline which resulted in overall lower catches, but the high proportion of old cod in that period promoted an expansion of the gillnet fishery. Further change in the stock composition towards younger fish during the late 1990s and early 2000s generated a reduction of gillnet and an increase in demersal trawlers. During the recent two decades, the cod catches were largely taken in subdivisions 25-26 with approximately 30-40% being taken by gillnets. The importance of longlines has increased recently, probably due to cheaper running-costs of vessels involved in this fishery, and mostly at the expense of the gillnet fishery. In the last 5 years the use of passive gears has generally increased in relation to trawls, which is probably a reflection of the rising fuel prices.

Pelagic trawlers catching a mixture of herring and sprat dominate the pelagic fisheries in the Baltic. The proportion of the two species in the catches varies according to area and season. To a minor extent, a predominantly herring fishery is carried out with trap-nets/pound-nets and gill nets in coastal areas as well as with bottom trawls. The catches of the pelagic species are used for human consumption, reduction to oil and meal, and to animal fodder. The allocation of the catches into these categories differs not only by country, but also over time, mostly driven by market demand. Approximately 2/3 of the central Baltic herring landings are evenly distributed between subdivisions 25,26,29. In recent years landings of herring are increased in subdivisions 25-26, decreased in subdivision 27 and 28.2, and unchanged in SD 29 and 32. Baltic sprat landings are reported from all the whole Baltic, SD22-32. However, landings are largely represented by catches in subdivision 25, 26 and 28 followed in order of importance by SD 29, 27 and 32. During the 2000s it has been observed a progressive decrease in landings from SD25 and increase in SD28.

Coastal fisheries are conducted along the entire Baltic coastline. The coastal fisheries target a variety of marine, freshwater and migratory species with a mixture of active (i.e., Danish seines) and passive gears (i.e., gill, pound and trap nets, and weirs). Trawling is forbidden in coastal waters in most Baltic countries, though some demersal trawling activities for herring, cod and flatfishes occur in some coastal waters.

3. Ecosystem models and species considered

Ecopath with Ecosim – Central Baltic Sea

The mass-balance trophic model by Tomczak et al., 2012 describes the annual conditions in the Baltic Proper ecosystem since 1974 based on a large amount of available historical information. The new Baltic Proper (BP) food-Web model (BaltProWeb) includes 22 functional groups (Fig. 1.10) with trophic components from primary producers to top predators. It further includes two detritus groups, i.e., sediment and water column detritus. Primary producers are represented by three functional groups – cyanobacteria, spring phytoplankton and other phytoplankton that mainly represent summer and autumn species. Microzooplankton was included to represent an important component of the microbial loop. Mesozooplankton was divided into four functional taxa-related groups: *Pseudocalanus*, *Acartia*, *Temora*, and other mesozooplankton, which consists of other copepods and cladocerans. Mysids, an important food item of fishes, were included as a single group. The benthic community was split into two groups, i.e., meio- and macrozoobenthos. There are three functional groups of fish – sprat, herring and cod, as these are the dominating fish species in the BP. Top predators are represented by grey seals. The human impact was indicated by using one fishing fleet for each fish species.

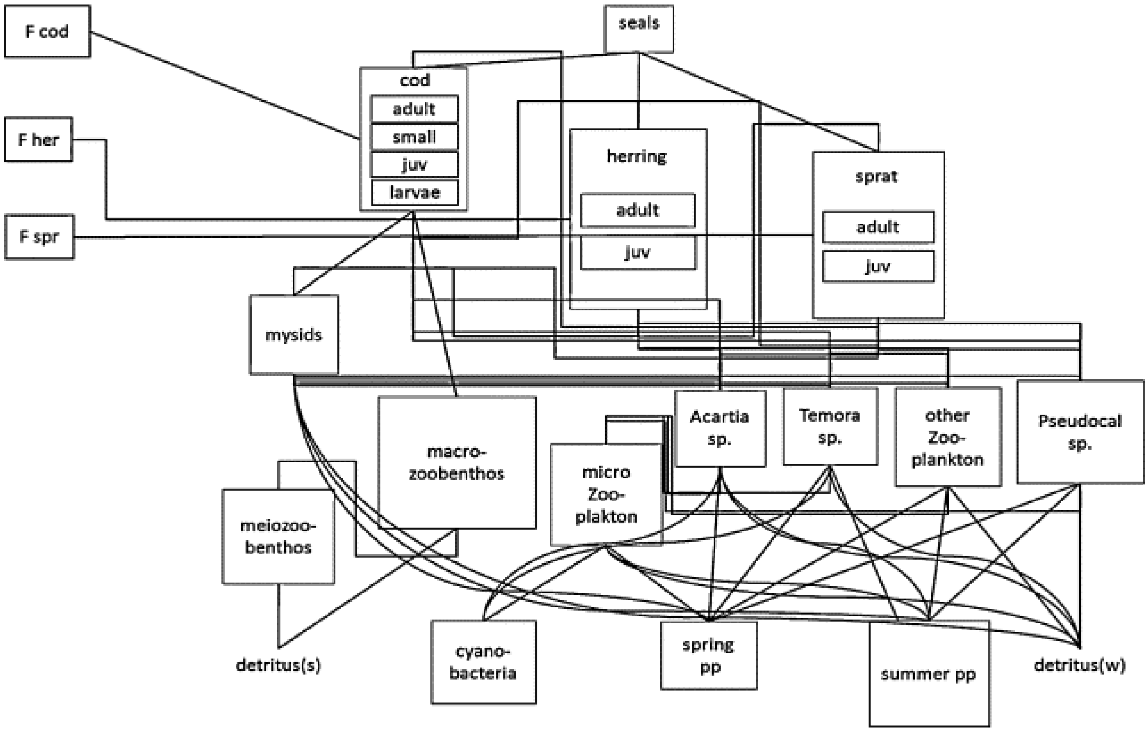

Figure 1.10. The structure of the BaltProWeb model. Where F represent respective fisheries, pp – primary producers, juv – juvenile stanza of given fish species. Detritus pool is divided into two groups: detritus on the sediment (detritus (s)) and water-column (de)) – Tomczak et al., 2012.

Multispecies Stock Production Model

The multispecies stock-production model (Horbowy 1996, 2005) is a multispecies simplification of the age-structured multispecies model of Andersen and Ursin (1977). The model development bases on Andersen and Ursin equations describing dynamics in natural mortality (which is dependent on state of predator populations) and dynamics in growth (which is dependent on food availability and population density). The biomass *B* of the age group *a* is $B_a(t)=N_a(t)w_a(t)$. Taking derivatives one gets

$$\frac{dB_a}{dt} = N_a \frac{dw_a}{dt} + w_a \frac{dN_a}{dt}$$

and substituting dN/dt and dw/dt by equations from Andersen and Ursin (1977) model, doing summation over ages and some averaging, the change of biomass of population *s* is

$$\frac{dB_s}{dt} = (v_s h_s w_s^{-1/3} - k_s - q_s E_s - M1_s - \sum_{r=1}^{n} h_r w_r^{-1/3} \frac{G_r^s B_r}{\sum_{j=1}^{n} G_r^j B_j + OT})B_s \qquad (1)$$

Where:

v, h, k = parameters of the von Bertalanffy growth equation generalised by Andersen and Ursin (1977), v is the fraction of eaten food assimilated for growth,

E = fishing effort,

q = catchability coefficient,

M1 = residual natural mortality,

w = mean weight of fish in the population,

G_r^s = suitability of prey s to predator r,

OT = "other food"

s, r, j = populations,

n = number of populations.

The last expression in the brackets (starting with first summation symbol) represents predation mortality. Assuming that the term in brackets is constant or has low variability in a time interval [t, t + dt], model (1) can be approximated by

$$B_s(t+dt) = B_s(t)\exp[a_s(t)dt] \ , \qquad (2)$$

where a_s is term in brackets in eq. 1.

If recruitment takes place at time t+dt, equation (2) will take the following form

$$B_s(t+dt) = B_s(t)\exp[a_s(t)dt] + R_s \qquad (3)$$

where R is the biomass of the year-class recruited to the population.

Input data to the model include growth parameters, residual natural mortality, total catches, fishing effort and/or survey indices of stock size. The model may be fitted to survey and/or catch data.

GADGET

Gadget - Globally applicable Area Disaggregated General Ecosystem Toolbox - is a flexible and generic modeling framework that has been developed to model marine ecosystems, including both the impact of the interactions between species and the impact of fisheries harvesting the species (Begley and Howell 2004). Gadget implements age-length structured models as forward simulation models. Many parameters describe the modelled ecosystem, and then the output from the model is compared to observed measurements to get a likelihood score (Stefansson 2003). The model ecosystem parameters are then be adjusted, and the model re-run, until an optimum is found, which corresponds to the model with the lowest likelihood score. This iterative, computationally intensive process is handled within Gadget, using a set of robust minimisation algorithms (also optimized for parallel minimisation on a network). Gadget has successfully been used to investigate the population dynamics of single stocks and stock complexes in a number of different ecosystems (i.e., Icelandic waters, the Barents Sea, the North Sea, the Irish and Celtic Seas, the Bay of Biscay, and the Mediterranean Sea), but to our knowledge it has never be applied to the Baltic Sea ecosystem.

Multi-fleet and multi-area single species models can be initially parametrized with main focus on the central Baltic herring, the eastern Baltic cod and the Baltic sprat stocks. The concept of sub-basin will be implemented within the models and tested for both seasonal and ontogenetic movements, and for the effect of long-term changes in the spatial distribution. Within these single species models, the effect of multiple fishing fleets will be included via fleet specific selection curves which can be parametrized within Gadget. Additional levels of complexity (e.g., ontogenetic stages) and relevant sub-processes (e.g., maturation, reproduction, movement, and for cod also cannibalism) can be included and tested within single species models. Selected single species Gadget models can be linked by predation of cod on both herring and sprat. Feedback effect of this trophic interaction on cod growth can also be tested.

4. Other effects of human use of the ecosystem

Human society uses the Baltic for many purposes including shipping, tourism, sand and gravel extraction, wind farms, gas and oils extraction, and mariculture. Overviews are given in Helcom (2002, 2003, 2007) and Frid et al. (2003). Shipping may pose threats due to transport and release of hazardous substances (e.g., oil) and non-indigenous organisms. The former would likely have only relatively short-term effects (e.g., direct mortality of individuals in a restricted time and area), whereas the latter are more likely to have longer-term and more widespread effects (e.g., influences on energy flows or species interactions in food webs.

Introduction of non-native species

The current status of being a non-native species refers to a position in evolutionary history but does not qualify as an ecological category with distinct and consistent properties. However, the next invasion by a non-native species may be the first with profound consequences on the ecosystems affected and therefore, precautionary measures should be taken to avoid any introduction (Reise et al. 2006). The American comb jellyfish *Mnemiopsis leidyi* was first recorded in the Baltic Sea in 2006 (Javidpour et al. 2006). In the Black Sea, *M. leidyi* showed to be a dangerous invader, feeding intensively on early life stages of commercial important pelagic fish species, thus impacting on fish stocks as well as causing dramatic cascading effects on the whole food-web (Shiganova et al. 2001). In a recent investigation, Haslob et al. (2007) investigated the potential consequences for fish stock recruitment in the Baltic Sea, focussing on the Bornholm Basin, which serves as the major spawning ground for cod and sprat. It could be shown that the diet of *M. leidyi* is composed of fish eggs. The vertical overlap coefficient with cod eggs was more than 4 times higher than with sprat eggs. Based on an observed temporal and spatial overlap with cod eggs, *M. leidyi* should be considered a potentially important predator of cod (Haslob et al. 2007). However, based on the recent information on the reproduction limits and data on hydrodynamic drift modelling (Lehtiniemi et al. 2012) of *M. leidyi* in the Baltic it is concluded that *M. leidyi* will not form a permanent population in the central and northern areas of the Baltic Sea.

Contaminants

The Baltic Sea is severely contaminated, and contamination status is regularly assessed through Helcom (e.g., Helcom 2002, 2003), where details are available. Whereas DDT pollution has decreased substantially, the decline of PCB and Dioxin concentrations continues, but at a slow rate, suggesting that some input of these compounds continue (Helcom 2002, 2006). Annual emissions of dioxins and furans in HELCOM countries have decreased during the period from 1990 to 2005 by 24% (Helcom 2007).

Pollution of the Baltic Sea includes POPs, such as PCBs and other organochlorines e.g. dioxins are efficiently transferred through trophic levels which often results in higher concentrations in top consumers and fat rich species e.g. sprat, herring and salmon. Contaminant levels in northern Baltic herring and salmon are so high that consumption is being regulated (Helcom 2002, 2004). Concentrations of PCBs in fish vary between years and species. In herring muscle concentrations were high in the late 1960s to early 1970s and have declined since that time. Similarly, in cod liver the concentrations have declined by 4-5 fold during the 1980s to 1990s. However, after the early 1990s the levels have remained stable or risen slightly. These trends mirrors the ban of PCBs but also indicates that PCBs are still available and cycled through trophic levels despite the ban and much lowered supply to the Baltic from direct emissions and other processes such as riverine input and deposition. The largest pool of PCBs in the Baltic Sea is in the sediment which also acts as an important source for PCB in biota (Wania et al. 2001). MacKenzie et al. (2004) showed that the standing stock of the most important fish species in the Baltic Sea is an important sink for PCBs that, through fisheries, removes a significant part in comparison to other budget components. The study highlights that fisheries has a role in the recycling of contaminants and suggests that banning the discard of contaminated organs such as cod liver could be part of pollution management (MacKenzie et al. 2004).

5. Commercial species and reference points (F_{msy}, B_{msy})

Only five species are commercially exploited at the higher scale in the Baltic. These are: cod, herring, sprat, flounder, and salmon. The precautionary reference points are applied for evaluating if stock has full reproductive capacity and if its exploitation is sustainable (Table 1.1). The stock is within precautionary limits if its biomass is higher than B_{lim} and its fishing mortality is lower than F_{lim}. However, as both biomass and fishing mortality estimates are subject to errors the buffers are added to B_{lim} and F_{lim} and reference points with such buffers are referred to as B_{pa} and F_{pa}. The stock is within precautionary limits with high probability if its biomass is higher than B_{pa} and its fishing mortality is lower than F_{pa}.

Catch quotas for both cod stocks have been set on the basis of the management plans, which have been evaluated by ICES as precautionary. At present, taking into account dramatic changes in cod growth and the behaviour of assessments, ICES does not consider the cod management plans as precautionary. For other stocks catch limits are set using fishing mortality which leads to maximum sustainable yield (F_{msy}), if F_{msy} has been estimated. In addition to single species F_{msy} the multispecies F_{msy} has been estimated and it is usually presented as range of values.

Table 1.1. Reference points for all the cod, herring and sprat stocks (biomass in 10^ tons) inhabiting the Baltic Sea.

Stock	B_{lim}	B_{pa}	$B_{trigger}$	F_{lim}	F_{pa}	F_{mp}	F_{msy}	Multispecies F_{msy} (range)
cod 22-24	26	36.4	36.4	nd	nd	0.6	0.26	
cod 25-32	63	88	88	nd	nd	0.3	0.46	0.4 - 0.6
herring 20-24	90	110	110	nd	nd	no plan	0.28	
herring 25-29,32	430	600	600	0.52	0.41	no plan	0.26	0.25 - 0.35
herring GoR	nd	nd	60	nd	0.4	no plan	0.35	
herring 30	nd	nd	316	nd	nd	no plan	0.15	
herring 31	nd	nd	nd	nd	nd	no plan	nd	
sprat 22-32	410	570	570	0.39	0.32	no plan	0.29	0.25 - 0.35

nd=not defined

mp= management plan

6. Socio-economic indicators (performance)

The Baltic Sea supports important commercial and recreational fisheries. The volume and value of commercial landings are evaluated and recorded by national statistics agencies in a reasonably uniform manner, but there are differences among countries with respect to evaluation of recreational fisheries. Although there are some confrontations between these fisheries sectors, in this Baltic Sea case study review we focus on the socioeconomic indicators of commercial fishers' society.

Member states compile statistics of some socioeconomic indicators on annual basis. Despite the economic database possessed by EuroStat(http://epp.eurostat.ec.europa.eu/portal/page/portal/fisheries/data/database) and JRC (https://fishreg.jrc.ec.europa.eu/web/datadissemination/home), it appears that holistic analysis of the potential usefulness of these data is yet to be commenced.

It is known from previous research that Baltic fisheries are dynamic systems driven by market demand and resource supply (Stephenson et al. 2001). Also STECF (2012) addresses that the economic performance of fleets is usually affected more by external factors, like fuel prices and fish prises, which are driven mostly by overall price levels and consumption, than by biological factors. Therefore, socioeconomic should be valuable for any evaluations of EAFM.

Much of the current knowledge is mostly qualitative. STECF (2012), for instance, forecasts that economic performance of the Baltic Sea commercial fishing fleets is likely to be more affected by external factors as global fuel prices, fish meal and fish oil prices, and competition between Asian and

European production. They also anticipate that increase of stock abundance and catchability could increase volume and value of catch per fishing effort, leading to the improvement of economic situation of the fleet. Also, "the overall quality (and thus attractiveness) of jobs depends among others on stability (part time vs full time/full season) and remuneration. The management plan affects not only current employment, but also employments expectations."

Evaluations and forecasts of alternative management strategies seem to be lacking from the literature with respect to the Baltic Sea fisheries. There are time series of some socioeconomic indicators available, but these are judged to include shortcomings. These issues include short length of the data series, lack of updated data, limitations on FTE, engaged crew and number of vessels data availability (affecting in various ways all indicators), and the effect of data allocation influencing mainly the indicators for the demersal trawlers (STECF 2012). In an earlier project, it was observed that fishing cost data, in particular, is very often not available for science (Rahikainen et al. 2009). The general problem is that available economic data are aggregated to on national and gear type level, but these attributes do not allow taking into account the true mosaic in the fleet structure and dynamics. MacKenzie at al. (2007) synthesize that there are many complexities and uncertainties in understanding how industry and fishing communities will respond to changing environment.

As an overview, there are economic data available, referenced in the MareFrame deliverable D2.1, currently including variables such as capacity (avg. vessel age, avg. length, engine power, total number of vessels, tonnage); economic performance (avg. wage, capital productivity, profit, employment, fuel efficiency, GVA, revenue, etc.). These variables are then used to calculate some social indicators, called balance indicators, such as fleet overcapacity and current revenue to break even revenue. The challenge is the high level of aggregation in these data making all segment –based forecasts about potential trade-offs very difficult.

There are available some project based works related to socioeconomic issues in the Baltic Sea. As an example, an earlier project, COEXIST, has identified that conservation of fish-eating animal species, particularly the grey seal and the cormorant, and has aroused conflicts. The basis for these conflicts is the damage induced by the seals and cormorants to fishing livelihood and aquaculture. Grey seals are commonly regarded as the main threat in Finnish coastal fisheries and there are persistent discussions about options for mitigating cormorant-induced damages in fisheries. The seals and cormorants eat fish completely or partly from fishing gear, making commercial use of landings impossible. The animals also break the fishing gear. Moreover, fishermen claim that seals scare fishes away from the fishing sites. The problem is seen differently by the fisheries and hunting groups on one hand and nature protection NGOs and environmental administrators on the other.

7. Governance and management rules enforced (fisheries management, MPA, others that can affect fisheries and ecosystem)

Governance of maritime ecosystem and fisheries is sectored at the national level, also with respect to science and management advice. In Finland, for instance, fish stock assessment is assigned to Finnish Game and Fisheries Research Institute; environmental monitoring to Finnish Environment Institute; updating and development of fisheries and environmental statistics is assigned to Statistics Finland; and monitoring contaminants of sea food and carrying out risk analysis for human health is assigned to the Finnish Food Safety Authority. These national sectorial institutions cooperate with, and to some extent are coordinated by intergovernmental organizations such as ICES, HELCOM, and STECF to produce holistic scientific synthesis and management advice at larger geographic areas for shared fish stocks and other natural resources.

Regulations – time, effort, gears

See cod recovery plan.

Total Allowable Catch (TAC)

Fishery in the Baltic is regulated mainly by TACs. ICES is main external advisory body on stock management while STECF provides internal advice and evaluations. For stocks for which analytical assessment exists ICES advises TACs using the following hierarchy of options:

- TAC resulting from management plan, if such plan exists and has been evaluated by ICES as precautionary
- TAC resulting from MSY approach, i.e. TAC determined by Fmsy
- TAC resulting from precautionary approach, i.e. TAC determined by Fpa or TAC under which SSB is expected to be above Bpa, if fishing at Fpa leads to lower biomass than Bpa.

If analytical stock assessment is not available for given stock (e.g. most of flatfishes) the advice is based on methods for Data Limited Stocks. The change in biomass index (taken as survey and/or commercial CPUE) is estimated as the ratio of mean biomass in recent two years to mean biomass in three preceding years and taking into account this change, trends in fishing effort, and recent catches the quota to be advised is determined.

Catch quotas for both cod stocks have been set on the basis of the management plans, which have been evaluated by ICES as precautionary. In 2014, taking into account dramatic changes in cod growth and the behaviour of the assessments, ICES has not provided advice using the cod management plans, as in present situation the plans may be not precautionary. For other stocks catch limits are set using MSY approach, if Fmsy has been estimated. In addition to single species Fmsy the multispecies Fmsy has been estimated and it is usually presented as range of values.

Cod recovery plan

EU has agreed on a multiannual plan for cod in the Baltic Sea in 2007 (EC, 2007). ICES has evaluated the management plan in 2009 and considered it to be in accordance with the precautionary approach. Cod management plan consists of the following main elements:

- Target fishing mortality set at 0.3 for eastern stock and 0.6 for the western stock
- Yearly reduction of fishing mortality by 10% until target levels are achieved
- Limits in annual changes of catch quota set at +/- 15% (the limits are not applied if their application would lead to fishing mortality higher than F of 0.6 for eastern stock or F of 1.0 for western stock)

In addition to the rules presented above some limitation on fishing effort were imposed:

- Closure of fishery from 1 July to 31 August for eastern stock and from 1 to 30 April for western stock
- Yearly decrease of fishing days by 10% until difference between current and target F is lower than 10%
- Areas closed for any fishing activity from 1 May to 31 October were established on spawning grounds (Bornholm Basin, Gdańsk Deep, Gotland Deep).

The implementation of the plan for eastern cod stock and increased recruitment to the stock has led to substantial decline in fishing mortality to levels close to target F of 0.3.

The agreed multi-annual plan was developed under the assumption of unchanged growth. However, the cod growth rate declined dramatically in recent years, thus this assumption is no longer valid. It is one of the reasons, that ICES has not used the EU-agreed multiannual plan as the basis for advice in 2014 (ICES, 2014).

Multispecies management plan

Cod multispecies management plan has not been developed so far, although multispecies simulations showing effect of cod biomass on clupeids mortality and effect of clupeids biomass on cod cannibalism (decline in clupeids biomass may lead to higher cod cannibalism) have been conducted using SMS (Stochastic Multispecies Simulations) or stock-production models. Simulations indicate that yield of cod as a function of fishing mortality is relatively flat for range of Fs from 0.4 to 0.6 but effect of such Fs on cod biomass is substantial. Thus, one option for setting the fishing mortality on cod and clupeids in multispecies context could be to have relatively high F on cod to keep bigger clupeids biomass and have higher catches of herring and sprat. Many other options for Fs in multispecies context are possible and they would depend on decision what we intend to maximize/optimize (e.g. sum of catches, sum of catches weighted by specific weights for cod, herring and sprat).

The above simulations assume that there is full spatial overlap between cod, herring and sprat in the central Baltic. However, at present cod is mainly distributed in southern areas (sub-divisions 25 and 26) while clupeids extend also to northern areas (sub-divisions 27 and 32). This lack of full overlap should be considered in management advice and the tools for spatial management should be developed.

The multispecies effects are to some extent included in Baltic stocks management as assessment and catch projection for herring and sprat use variable natural mortality dependent on cod biomass and provided by multispecies model (SMS).

8. Conservation priorities (protected habitats, species, etc.)

Bycatch of fish

The total by-catch of fish in the Baltic fisheries is presently unknown. The EU has supported several studies of by-catch, the results of which have been compiled by ICES (2000c). These studies primarily concern the major fisheries for cod, herring and sprat and these have low by-catches. The less important smaller fisheries can have a high proportion of by-catch (Helcom 2002).

The occurrence of lost net have been surveyed in areas where gillnet fishing are practiced and lost nets are frequent (compiled in Brown & Macfadyen 2007. Lost gillnets in the Baltic cod fishery are most likely of concern for cod fishing mortality since 30-50% of the landings originate from the net fishery. Experiments show that during the first 3 months, the relative catching efficiency of "lost" nets decrease by around 80%, thereafter stabilising around 5–6% of the initial level (Tschernij and Larsson 2003).

Bycatch of seabirds and mammals

Fishing nets, in particular set nets, have caused considerable mortality for long-tailed ducks (*Clangula hyemalis*), velvet scoters (*Melanitta fusca*), eiders (*Somateria mollissima*) and black scoters (*Melanitta nigra*). There are also reports of guillemot and razorbill (*Alca torda*) mortality in the driftnet fishery for salmon (Helcom 2003).

Reports suggest that fisheries by-catches amount to 0.5–0.8% of the porpoise population in the south-western part of the Baltic Marine Area each year, as well as 1.2% of the porpoise population in the Kiel and Mecklenburg Bays and inner Danish waters (Kock and Behnke 1996). Estimates of the harbour porpoise population are uncertain, however, and the number of porpoises by-caught in fisheries is probably underestimated. The loss of porpoises to fishery in the Baltic Marine Area may be too high to sustain the population (ICES, 1997).

Seals have been recorded caught in fyke nets, set nets and salmon driftnets, but although the recorded data almost certainly underestimate the total number of by-caught seals, the added mortality does not appear to restrain the seal populations from increasing (Helander and Härkönen, 1997).

Fishing activities will also affect the seabird community through the discarding of unwanted catch and fish offal. Studies indicate, for example, that over 50% of the offal discarded in the Baltic Marine Area will be consumed by seabirds (ICES, 2000c).

9. Management priorities and possible scenarios (input from case study meetings).

A list of fisheries management priorities as recognised during a workshop organized on 26th May 2014 with representative stakeholders from the fishing industry (i.e., Baltic Sea RAC) and relevant national authorities (i.e., Swedish Agency for Marine and Water Management, SWAM) include:

- Poor condition and growth of eastern Baltic cod
- Competition and conflict between seals and fisheries
- Identification of maximum sustainable yields in an EBFM*
- Implications of landings obligations
- Influence of contaminants on fish populations, food quality and security

  * selected as management issue focus of the case study

The implementation of an ecosystem approach to fisheries management that accounts for species interactions and environmental factors is an overarching management priority for the Baltic as well as in the rest of Europe. The moderate species diversity, the relatively good knowledge of species interactions and the low number of species exploited by the fishery (i.e., cod, herring and sprat make most of the harvested biomass in the central Baltic) make the Baltic Sea as one of the main regions where such implementation is seen as feasible in Europe. Because in a multispecies perspective the dynamics of different fish stocks are linked to each other, their response to a complex of harvesting rates (i.e., multiple fleets) is not a trivial issue to be resolved. From a management perspective a core issue, as also recognised during the workshop with stakeholders, is represented by the identification of maximum sustainable yields (MSY) within a multispecies context, and the need to investigate scenarios where fishing mortality is allowed to vary among the species.

II. North Sea case study

1. Oceanography-water circulation pattern and environmental features

A detailed overview of the North Sea abiotic system is to be found in ICES, 2007, and the reader is referred to this for more detail. This may be briefly summarized as follows:

Bottom topography and circulation

The North Sea may be viewed a rectangle whose longer sides trend roughly NNW. These are bounded by the UK coast to the west and by Jutland, the Skagerrak and effectively by the deeper Norwegian trench to the east. Note however, that the ICES definition of the North Sea includes the trench and the Norwegian coast south of 62.5°N. The shorter SSE boundary is formed by the northern extremity of the French coast, the Belgium and Netherlands coasts and part of the Coast of Germany. The Northern Boundary is the open deep water of the Norwegian Sea. The southern third of the North Sea is shallow but the waters deepen sharply to the north of the Dogger Bank. Sediment types also vary between north and south, tending to be muddier in the deeper northern area. Water is exchanged with other regions at the open northern and north-eastern boundaries, with the Baltic and with the Eastern English Channel via the Straight of Dover. Figure 2.1 shows its Bathymetry, while figure 2.2 shows the main water currents in the North Sea

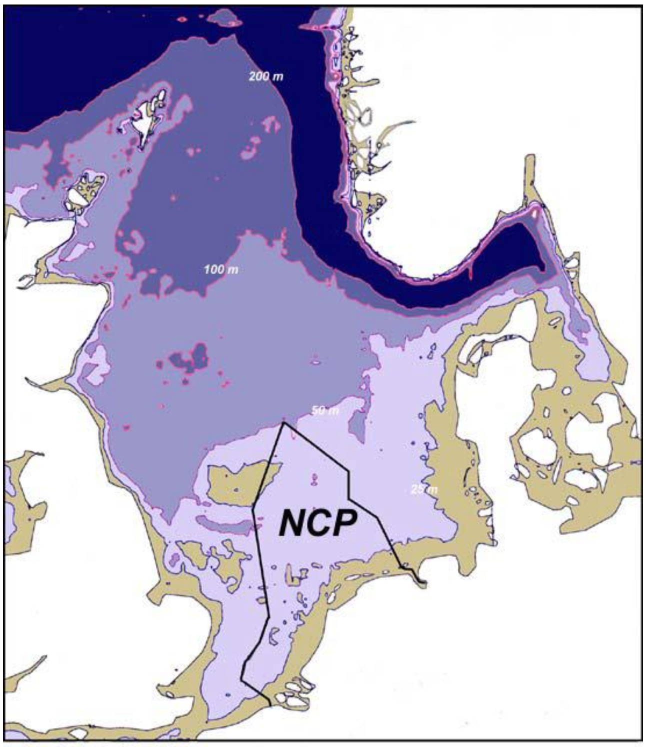

Figure 2.1 (from ICES 2007) Bathymetry of the North Sea together with the Netherlands EEZ (source RIVO - via ICES).

The water circulation is also influenced by wind forcing and the southern North Sea is an area of strong tidal streams. North of the Dogger Bank waters are mostly stratified while to the south they are mixed.

The variation in bathymetry, sediments and water types makes the North Sea a biologically complex area with some species largely confined to specific regions and or habitats. It is also politically complex with 8 coastal nations (here Scotland is best regarded as a nation) each with its distinctive but overlapping fisheries. These are based historically upon the fish stocks most available to each. Ideally modelling of the North Sea needs to embrace this complexity.

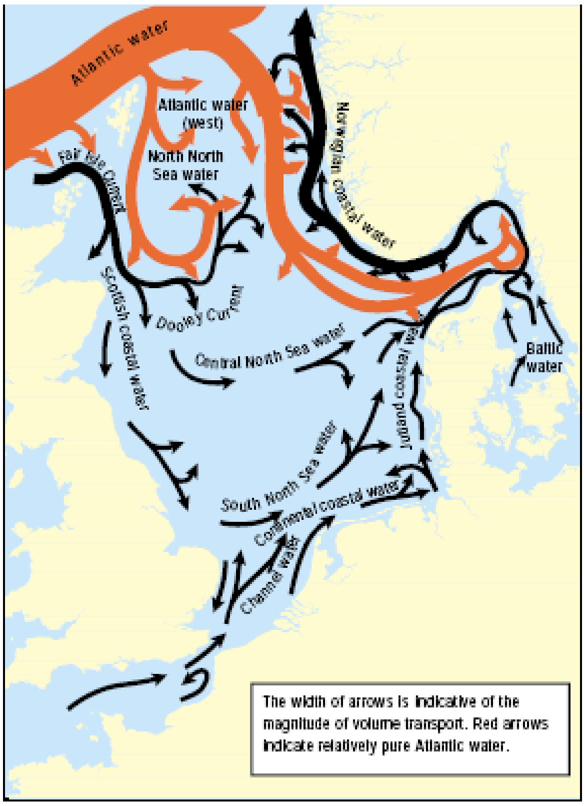

Figure 2.2 (From ICES 2007) General circulation pattern in the North Sea. Copied from Regional QSR II (after Turrell *et al.*, 1992).

Broad scale climate and oceanographic features and drivers

ICES (2007) also provides a broad description of the climatic and oceanographic features and drivers to which the reader is referred to for more detail. Briefly, situated in the temperate zone the North Sea ocean climate is naturally dominated by the annual cycle of light, wind and temperature that this implies. It is also strongly influenced on a multiannual scale by the North Atlantic Oscillation (NAO). Consequently oceanic inflows and also atmospheric conditions affecting wind, insolation etc. vary both interannually and on longer time scales. Temperatures and salinity both show some episodic features which doubtless influence the North Sea ecosystem though typically in non obvious ways. Underlying this all, a gradual trend due to global warming must doubtless be anticipated. Thus, annual, episodic and trend changes are all potentially important features to consider in models of the North Sea ecosystem.

Nutrients, eutrophication, hypoxia (anoxia)

Nutrients in the North Sea respond to the strong annual production cycle. ICES , 2007, summarizes work on regional nutrient distributions shown in figures 2.3 and 2.4. These figures again illustrate the strong regional differences to be found in the North Sea.

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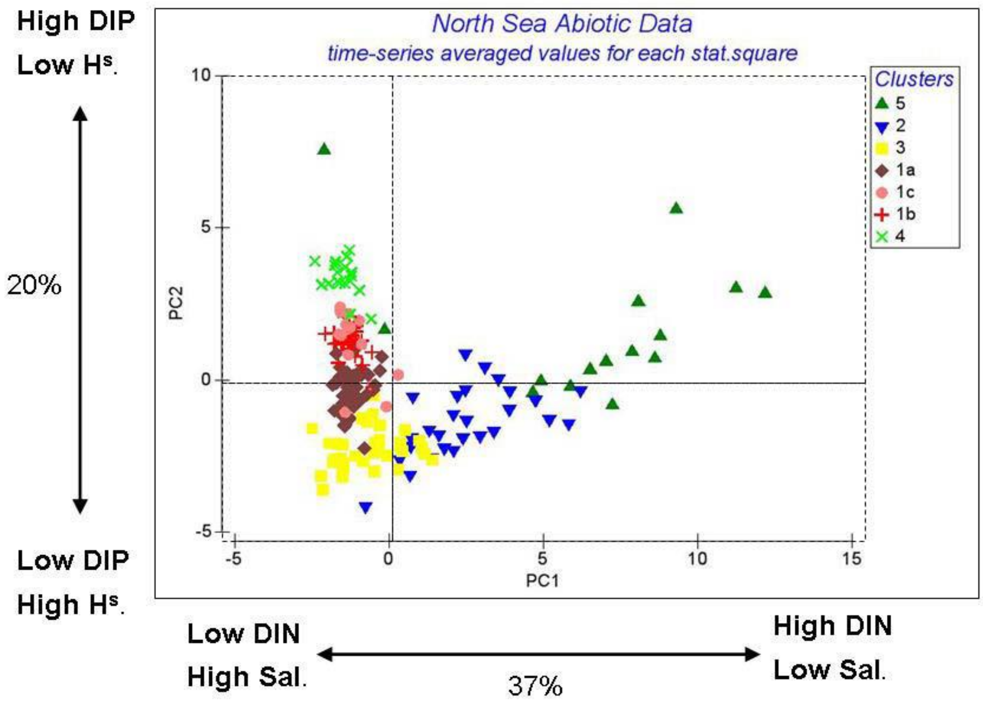

Figure 2.3 (from ICES 2007) Spatial gradients in the North Sea physical/chemical characteristics based upon 13 variables averaged between 1973 and 2004 (REGNS, 2006; Kenny *et al.*, 2006). The variables explaining most of the variation are; Dissolved Inorganic Phosphate (DIP), Dissolved Inorganic Nitrogen (DIN), nearbed wave stress (Hs), and salinity (Sal). Each symbol represents the abiotic status of a single ICES statistical rectangle in the North Sea (about 200 statistical rectangles have been used in the present analysis to describe the North Sea) and these have been coloured according to their respective clusters based upon hierarchical cluster analysis at a significance level of >p = 0.05, (REGNS, 2006).

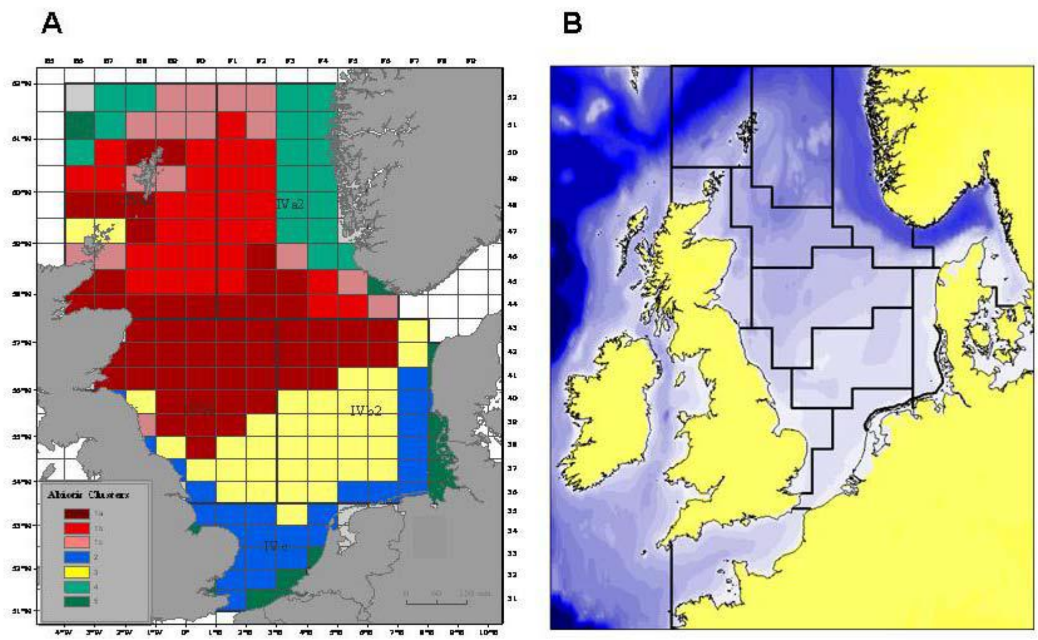

Figure 2.4 (from ICES 2007) A) Spatial representation of physical/chemical status of ICES statistical rectangles based upon the analysis presented in Figure 3; B) Subdivisions of the North Sea based upon a study of hydrodynamic properties undertaken by ICES (ICES, 1983).

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There are seasonal periods of anoxia often associated with red tides at the land margins of the North Sea particularly the Waddenzee and Jutland areas. These may be of significance because these are some of the prime nursery areas for young demersal fish. Additionally, there is variation in the abiotic environment between years on a variety of time scales. Figure 2.5 (ICES, 2007) illustrates this interannual variation. Clearly, management models of the North Sea must anticipate non stationary behaviours in key features of production.

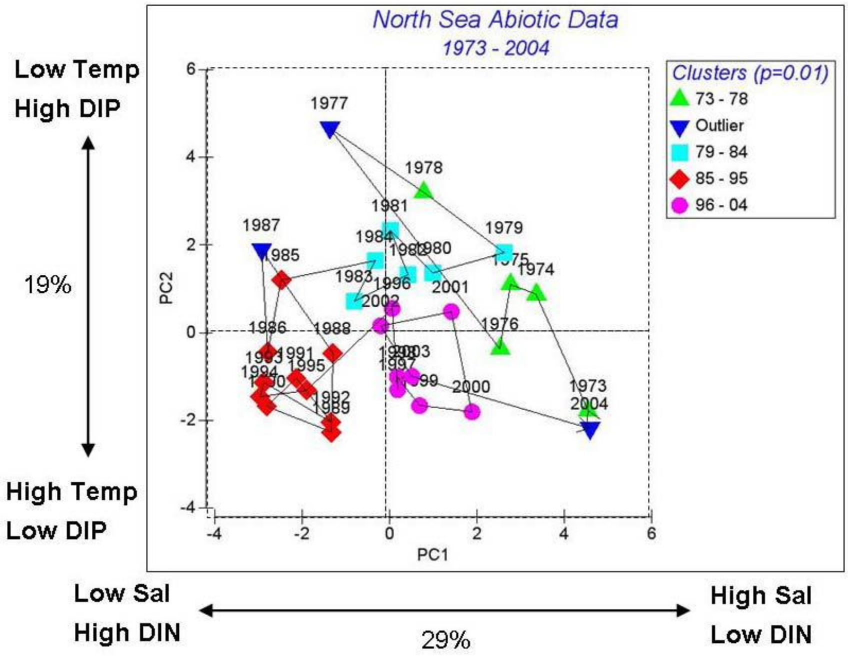

Figure 2.5 (From ICES 2007). Changes in the abiotic state of the North Sea between 1973 and 2004, highlighting the importance of salinity, temperature, and dissolved inorganic nutrients in explaining the trends over this period. Each symbol represents the average abiotic state in a specific year with groups of years coloured according to their corresponding cluster after hierarchical cluster analysis at a significance level of >p = 0.05.

2. Food- web description, key species, ecological functional groups and fleets

Food-web – general overview, main processes

Primary Production (phytoplankton, benthic primary production…)

According to ICES, 2007,"Primary productivity is dominated by diatoms and dinoflagellates. Up to the 1970s primary production classically followed a spring/autumn bloom pattern. This is borne out by Continuous Plankton Recorder (CPR) "greenness" values. Since the 1970s this separation has become increasingly blurred and primary production has been continuous over much of the year, also over a longer period (Hughes and Lavin, 2004). This longer and less bipolar productivity has led to a much greater primary production in all recent years, associated with a reduction in diatom production and an increase in dinoflagellates. Both trends appear to be continuing in the most recent years. Theoretically this should provide more food at the base of the food web (SAHFOS, 2003). After the recent changes, the primary productivity in the North Sea can be considered as stronger and lasting longer than in adjacent Atlantic waters."

Zooplankton

Again according to ICES, 2007, Zooplankton production is dominated by copepods and euphasids. Patterns of abundance have changed through time and in particular there has been a decline in the production of *Calanus finmarchicus* with some replacement by C. helgolandicus. These changes are thought to be associated with the NAO and Eastern Atlantic oceanographic changes rather than being derived from population processes in the North Sea. Thus they should be regarded as external drivers of production and fish recruitment. Figure 2.6, ICES, 2007, illustrates these changes.

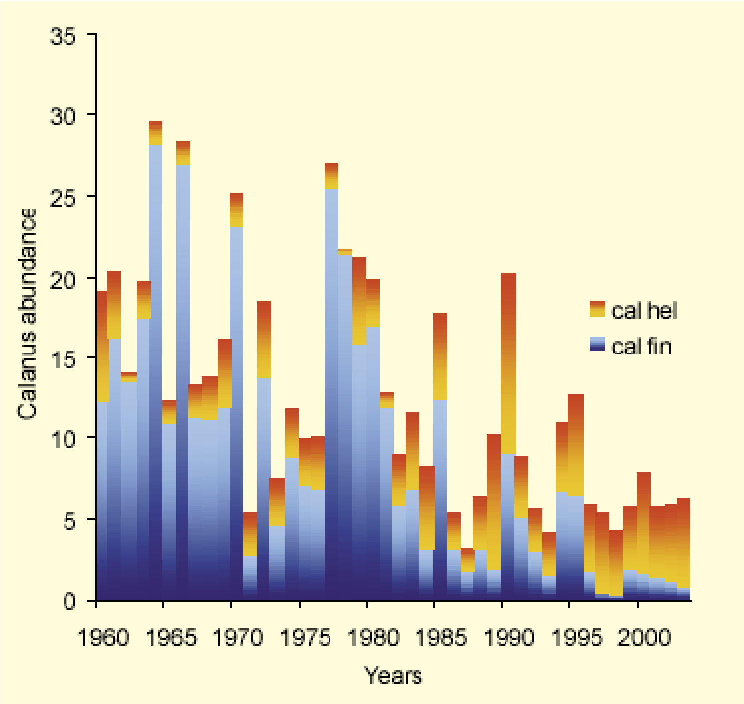

Figure 2.6 (From ICES 2007) The abundance of *Calanus* populations in the North Sea from 1960 to 2003. The percentage ratio of *Calanus finmarchicus* (blue) and *Calanus helgolandicus* (red) are shown in relation to total *Calanus* abundance in each annual bar. From www.sahfos.org, Ecological Status 2004/5.

ICES 2007a also illustrates changes in the timing and type of the zooplankton production cycle and indicates these may be linked to fish recruitment processes.

Benthos

Benthos varies in type between the shallow and deeper regions of the North Sea and is also affected by sediment type. It is directly affected, though to an unknown extent, by bottom trawling. Important directed trawl fisheries exist for *Nephrops norvegicus, Pandalus borealis*, and brown shrimp *Crangon crangon*.

Fish

A long list of species have been recorded from the North Sea but the total biomass of North Sea fish is dominated (ICES, 2007) by relatively few species. These are the pelagic species herring *Clupea harengus*. Mackerel *Scomber scombrus* and horse mackerel *Trachurus trachurus* the latter two being mostly summer migrants from other areas, the gadoid species cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, whiting *Merlangius merlangus*, and saithe *Pollachius virens,* the main flatfish species, common dab *Limanda limanda*, plaice *Pleuronectes platessa*, long rough dab *Hippoglossoides platessoides*, lemon sole *Microstomus kitt*, and sole *Solea vulgaris and by the* forage fish species, sandeels *Ammodytes marinus*, Norway pout *Trisopterus esmarki*, and sprat *Sprattus sprattus.* These dominate both the biomass flow through the fish system and the commercial landings. The contribution from the various species has however varied notably during the period of the gadoid outburst from late 1960s up to the early 1980s when gadoid species were abundant while herring and mackerel biomass were low. Recent years have seen an influx of more southerly species such as red mullet as sea temperatures have warmed.

A compelling feature of the North Sea Fish ecosystem is its regular size spectra (Dann et al, 2005). Theoretical considerations (Pope et al, 2003) suggest that the size spectrum slope is a strong indicator of overall fishing pressure and that the size spectra of all fish caught in routine surveys may be a predictable emergent property of the system. A corollary of this is that as fishing pressure has increased, since the onset of fishing, larger species have tended to come under pressure and some have become very rare.

Birds and mammals

ICES 2007 states that: "About 2.5 million pairs of seabirds breed around the coasts of the North Sea, encompassing some 28 species. While most species breed in dense colonies along the coast, they make a very different use of the marine ecosystem, During the breeding season, some species depend on local feeding conditions within tens of km around their colony, while others may cover several hundreds of km during their foraging trips."

ICES, 2007 further notes that "seabirds do not represent a single homogeneous group that responds to fisheries in some uniform way. A few species profit directly from human consumption fisheries, either discards or offal, e.g. fulmars and gulls."

Such species have increased markedly in abundance over the past 100 years. On the other hand, ICES 2007, further notes that "Local breeding success of some species has been low in some recent years. This been related to a local shortage of forage fish. Although the industrial sandeel fishery has been blamed by some for this failure, there is only limited evidence to support this."

Harbour seals *Phoca vitulina* and grey seals *Halichoerus grypus are* the resident North Sea pinniped species. In the recent past their populations have fluctuated in the North Sea mostly due to periodic outbreaks of phocine distemper virus. The dominating cetacean species (ICES, 2007) are minke whales, harbour porpoises and whitebeaked dolphins.. Population estimates derived from surveys made in 1994 are available for harbour porpoise *Phocoena phocoena* (about 340 000), white-beaked dolphin *Lagenorhynchus albirostris* (7900) and minke whale *Balaenoptera acutorostrata* (7300). All these marine mammals consume fish while Harbour porpoise in particular suffer from by-catch in gill net fisheries.

3. Ecosystem models and species considered

Figure 2.7 illustrates the links between the higher trophic levels of the North Sea Food Web.

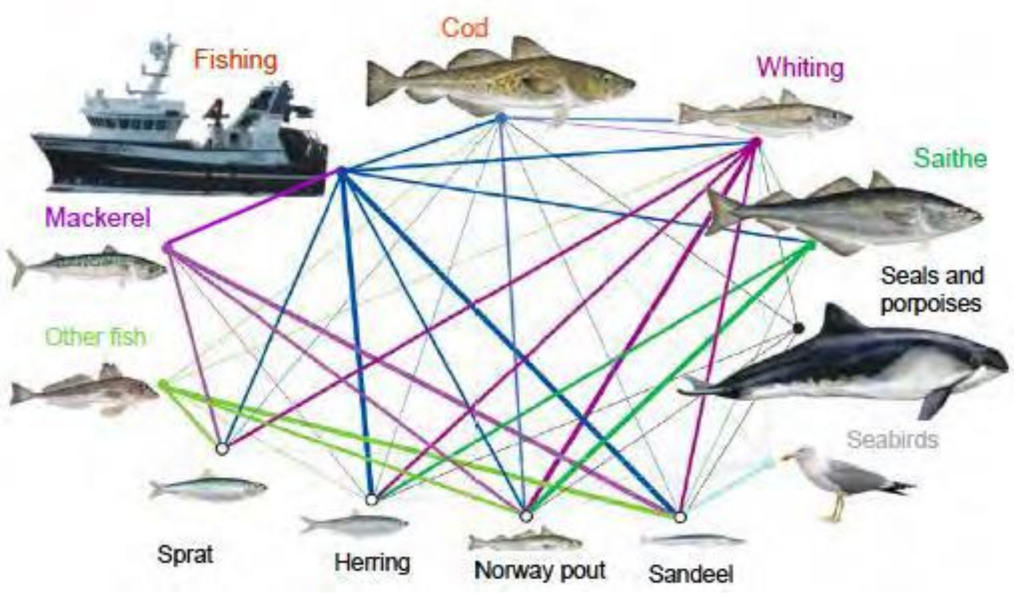

Figure 2.7 (from Rindorf et al, 2013) Feeding links in the Higher trophic levels of the North Sea. Note: Other fish include grey gurnard, Horse mackerel and starry ray. Seabirds include fulmar, gannet, great black backed gull, guillemot, herring gull, kittiwake, puffin and razorbill and seals and porpoises include grey seal and harbour porpoise. Colour of the lines indicates which predator the species is eaten by, the thickness of the lines indicates the biomass removed in this interaction (average from 1963–2010) (ICES 2012).

As far as is practical, these species together with the inclusion of phytoplankton, zooplankton and benthic groups and species will be the main focus for all of the models planned. But with the following caveats

Simple Size Based Models

These will consolidate species in figure 2.7 into Linf and possibly food size preference trait groups. The advisability of including phytoplankton and zooplankton will be considered.

GADGET and/or MSVPA like models.

These will focus on the fish species relationships shown in figure 2.7 and possibly include Nehrops. Changes in the productivity of lower tropic levels will be dealt with only through changes in recruitment to the key species.

Multispecies Stock Production Model

These will summarize the model(s) above and will focus mostly on providing a stakeholder friendly interface to more complex models.

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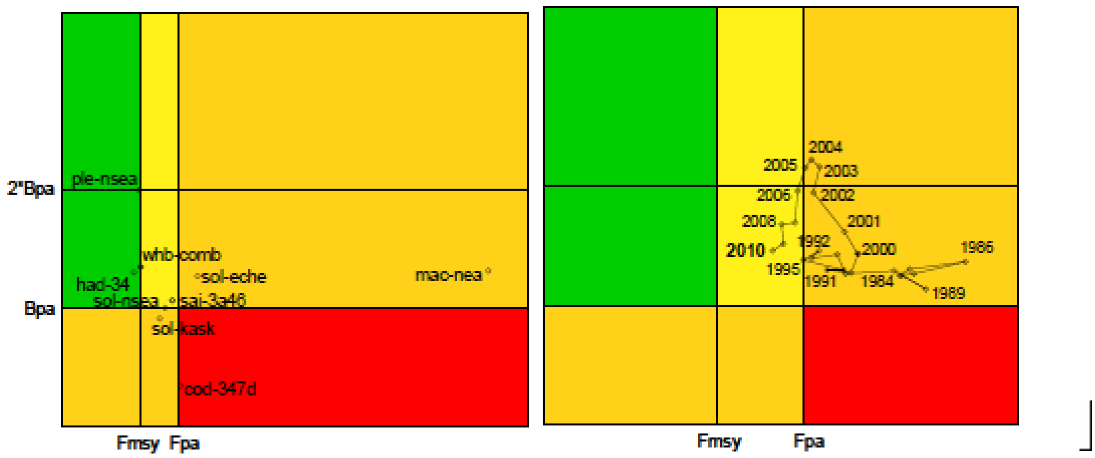
Ecopath with Ecosim

These are intended for comparative purposes only. They will include phytoplankton, zooplankton and benthic groups but it is suspected that given the changing patterns of phytoplankton production resulting from processes outside the North Sea (see section above) that these results may be only broadly indicative.

4. Other effects of human use of the ecosystem

Commercial species and reference points (F_{msy}, B_{msy})

Figure 2.8 (STECF 2012) shows plots of the status of the important North Sea species. Relative to Fmsy and Bmsy and a consolidated trajectory of combined species. However, it is important to recognise that these Fmsy and Bmsy figures are single species constructs and therefore likely to change if multispecies considerations are included. Table 2.1 below which gives Fmsy, Bmsy and multispecies equivalent Fmsy for some North Sea species illustrates this point.



approach (pa) and MSY reference points. Left: current state (last assessment for 9 stocks) – Right: mean trajectory from 1983 to 2010 (mackerel excluded, cf. § 4.3) (STECF, 2012e).

It is also probable that even on a single species basis these reference points may change as a result of any changes in selection consequent upon the progressive implementation of the Landings Obligation (i.e. discard ban) or due to changes in fleet structure.

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Table 2.1 from ICES 2012. Fmsy, Bmsy and multispecies equivalent Fmsy for some North Sea species.

Estimates of yield and SSB for F_{MSY} with fixed target F = 0.5 for cod, fixed target F = 0.45 for saithe, and fixed target F = 0.30 for whiting. Realized F, MSY, and SSB at F_{MSY} values represent the average value over the time period 2016–2070.

	Single-species	Multispecies					
	F_{MSY}	F_{MSY} (target F above B_{pa})	B_{lim}/Lower trigger biomass (thousand tonnes)	B_{pa}/Higher trigger biomass (thousand tonnes)	Average realized F	Maximum Sustainable Yield (thousand tonnes)	Average SSB at F_{MSY} (thousand tonnes)
Cod	0.19	0.50	70	150	0.45	91	168
Whiting		0.30	(200)	(250)	0.07	8	150
Haddock	0.3	0.35	100	140	0.14	22	128
Saithe	0.3	0.45	106	200	0.40	132	207
Herring	0.24-0.3	0.55	800	1000	0.40	561	1303
Sandeel*		0.55	(787)	(1098)	0.48	616	859
Norway pout*		0.60	(263)	(440)	0.22	82	130
Sprat*		0.55	(157)	(213)	0.43	151	221

* Trigger biomass refers to total stock biomass (TSB). Simulations indicate that an HCR based on TSB performs better than using SSB.
Values in brackets indicate that a single-species reference point does not exist or is not useful in multispecies context.

Main fisheries (fleets/metiers), target species and catch composition, seasonality and main spatial patterns in the fisheries

The following information is taken from STECF, 2012.

Figure 2.9 shows the percentage national shares (excluding Norway) of North Sea catch values.

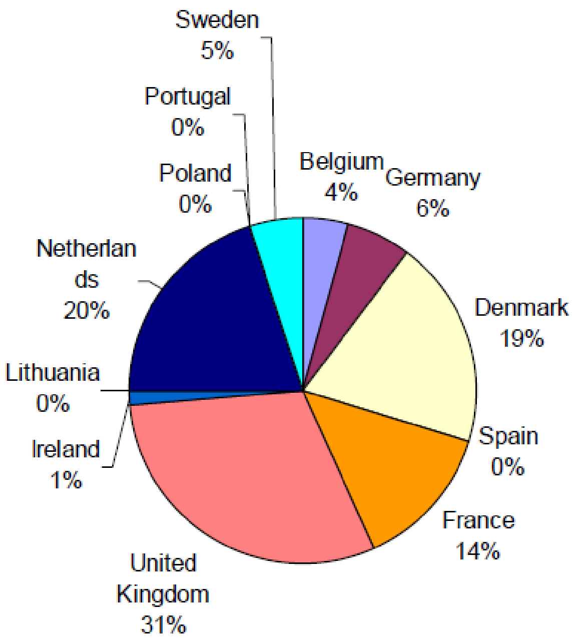

Figure 2.9. National percentage catch values (excluding Norway).

Table 2.2. below shows the main gear types used in the North Sea from 2006 to 2010. These are dominated by the mobile fishing gears, i.e. demersal trawls, pelagic trawls and beam trawls.

Gear type	2006		2007		2008		2009		2010	
	Volume (tons)	Value (€ 1000)	Volume (tons)	Value (€ 1000)	Volume (tons)	Value (€ 1000)	Volume (tons)	Value (€ 1000)	Volume (tons)	Value (€ 1000)
Drift and fixed nets	3,2	17,5	3,5	18,5	4,2	12,8	11,3	48,5	4,6	16,4
Dredges	62,6	27,6	66,1	33,7	49,2	34,7	61,6	72,0	41,3	42,7
Demersal trawl / seine	234,3	397,3	205,6	421,8	200,7	354,8	272,5	373,3	221,8	355,6
Fixed pots and traps	12,4	33,6	13,0	39,9	18,3	48,6	19,5	42,7	17,8	41,1
Gears using hooks	1,4	2,6	1,4	3,5	1,8	4,7	4,3	11,0	2,1	5,9
Other mobile gears	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Polyvalent mobile gears	0,5	1,3	0,5	1,4	0,3	0,7	8,0	18,3	0,8	1,8
Passive gears	1,6	7,5	1,5	8,9	3,1	14,5	2,8	12,0	3,7	16,1
Other passive gears	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Polyvalent passive gears	20,8	58,2	45,0	63,8	13,2	28,2	10,3	25,3	12,9	28,6
Polyvalent mobile & passive gears	18,2	26,4	14,2	27,0	7,9	16,6	8,2	15,0	8,2	15,5
Purse seine	0,0	0,0	0,0	0,0	79,1	67,1	89,2	70,6	86,0	70,5
Pelagic trawl / seine	994,0	355,9	763,1	309,1	0,0	0,0	0,0	0,0	0,0	0,0
Beam trawl	120,2	352,4	121,4	383,3	101,5	345,7	107,1	296,8	116,0	324,9
Pelagic trawl	0,0	0,0	0,0	0,0	575,0	211,6	643,7	199,8	586,6	212,5
Clustered gears	0,5	3,3	0,5	2,7	6,4	25,2	2,6	13,6	35,5	32,8
All gear types	**1469,5**	**1283,7**	**1235,8**	**1313,5**	**1060,8**	**1165,2**	**1241,2**	**1198,9**	**1137,3**	**1164,4**

Landings volume and value per gear type in the North Sea

Table 2.3 shows the 10 most important EU fleets that fish the North Sea. Together these fleets take more than 50% of the landings value.

Table 2.3. The 10 most important EU fleets fishing the North Sea based upon 2009 statistics.

Country	Gear	Vessel length	Total Landings value (1000 €)	%
DNK	TM	VL 40XX	139521	12,0%
NLD	TBB	VL 40XX	121385	10,4%
GBR	DTS	VL 1824	81875	7,0%
GBR	PS	VL 40XX	69627	6,0%
DNK	TM	VL 2440	51826	4,5%
NLD	TBB	VL 1824	46327	4,0%
DNK	DTS	VL 1824	39539	3,4%
DNK	DTS	VL 1218	31294	2,7%
BEL	TBB	VL 2440	28287	2,4%
GBR	FPO	VL 0010	24415	2,1%
Others	segments		530283	45,5%
Total			1164379	100,0%

These have very varied fishing patterns. This may be judged from the partial fishing mortalities these fleets generate on the main North Sea species. These are shown in Figure 2.10. This shows that Fleets 1, 9 and 10 fish predominantly for flatfish, Fleets 2 through 5 fish industrial (forage fish) species though also catch other species as well. Fleet 6 catches demersals and Nephrops. Fleet 7 catches shellfish and Fleet 8 catches pelagic species.

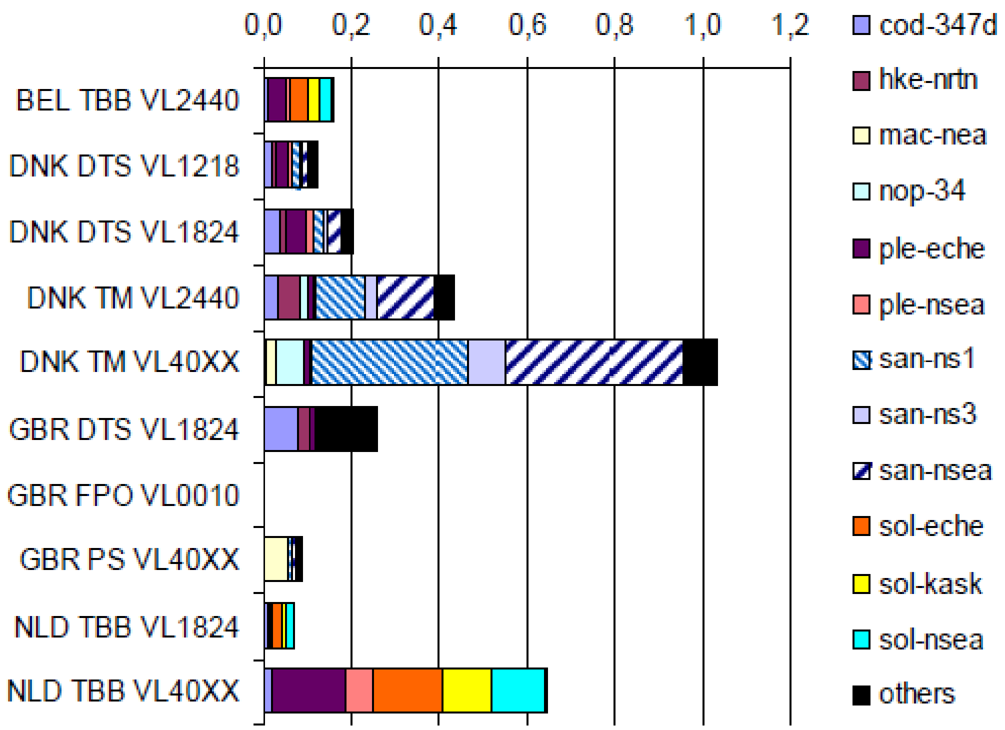

Figure 2.10. Partial Fishing Mortality Rates as assessed by ICES generated by the 10 most important EU fleets.

Some of these fleets are extremely seasonal in their activities. For example the sandeel season is typically in the summer months. Similarly spatial distributions of fishing can vary widely. Some fishing activities are largely confined to the northern area e.g. haddock fishing while others are confined to the more southerly areas e.g. sole fishing. Some are confined to specific localised substrates e.g. Nephrops fishing. It is impossible to depict these distributions in this report but figure 2.11 shows aggregate fishing intensity by statistical rectangle. More detailed fishing distributions by gear type can be seen in Nielsen et al, 2013.

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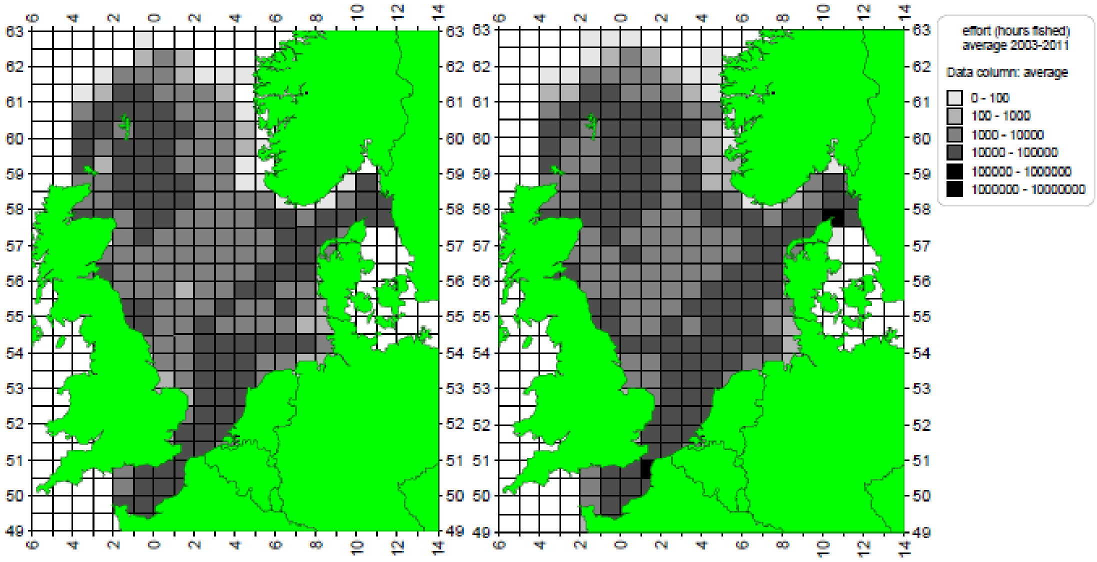

Figure 2.11 from Nielsen et al 2013 shows annual fishing effort (hours fished) of effort regulated gear groups per rectangle in 2011 (left panel) and averaged for the period 2003-2011 (right panel).

Figure 2.11 indicates that while fishing effort is widespread there are nevertheless some hot spots. These tend to tie in with the differences in rectangle size spectra shown by Dann et al 2005.

5. Socio-economic indicators (performance)

In recent years fishing effort in the North Sea has decreased, employment in the fishing industry has declined and the profitability of the fleets has generally increased. Table 2.4 from STECF 2012 gives some key social economic indicators.

STECF, 2012, also shows equivalent social economic data for the North Sea EU fishing Fleets that catch over 60% of the catch by volume.

Table 2.4

Economic indicators of the 10 selected fleet segments with the highest landings value in the North Sea (from the 2011 Annual Economic Report, AER 2011)

FLEET SEGMENT	Number of vessels	FTEs	Energy consump-tion	North Sea days at sea	North Sea days at Sea as % of total	North Sea volume landed (Tons)	% of total volume landed	North Sea Value landed (€ 1000)	% of total value landed
BEL TBB VL2440	40	210	40 912	5 577	60%	8 849	70%	29 491	64%
DNK DTS VL1218	177	269	10 965	15 467	70%	32 436	61%	25 457	72%
DNK DTS VL1824	77	226	12 588	11 022	89%	48 104	89%	32 240	89%
DNK TM VL2440	46	260	24 469	9 657	91%	117 367	86%	46 354	90%
DNK TM VL40XX	32	209	30 794	4 198	74%	373 731	84%	77 321	81%
GBR DTS VL1824	221	1 143	50 671	26 097	66%	42 468	79%	75 009	78%
GBR FPO VL0010		1 013	16 908	71 482	51%	9 079	48%	23 319	46%
GBR PS VL40XX	31	231	50 100	648	32%	88 398	33%	69 192	34%
NLD TBB VL1824	173	453	23 213	19 360	100%	18 931	100%	43 982	100%
NLD TBB VL40XX	64	392	86 809	12 434	100%	32 378	100%	109 650	100%

FLEET SEGMENT	Direct subsidies (€1000)	Total income (€1000)	Crew wages (€1000)	Gross value added (GVA) (€1000)	Operating cash flow (OCF) (€1000)	Profit / Loss (€1000)	Average wage per FTE
BEL TBB VL2440	728	48 630	14 813	18 509	4 423	-4 296	70 538
DNK DTS VL1218	15	37 663	8 362	19 487	11 141	-7 559	31 081
DNK DTS VL1824	5	38 613	10 573	20 790	10 222	-3 837	46 714
DNK TM VL2440	0	52 628	13 768	27 953	14 185	-2 186	52 874
DNK TM VL40XX	0	98 730	20 863	64 729	43 865	277	99 834
GBR DTS VL1824	6 142	108 373	23 880	38 912	21 174	7 551	20 888
GBR FPO VL0010	2 050	58 294	13 596	36 358	24 811	9 454	13 415
GBR PS VL40XX	5 567	159 268	34 200	92 020	63 387	7 833	148 052
NLD TBB VL1824	0	47 930	12 453	21 668	9 215	-791	27 477
NLD TBB VL40XX	0	112 742	23 459	55 984	32 524	19 977	59 797

6. Governance and management rules enforced (fisheries management, MPA, others that can affect fisheries and ecosystem)

Fisheries in the EU part of the North Sea are governed by a wide range of direct conservation measures and technical conservation measures. Total allowable catches are the key direct measure intended to limit fishing mortality on individual species and also serve as the cornerstone of the principle of relative stability that dictates national catch allocations. In the past restrictive TACs have led to excessive discarding of fish. So TACs are backed up by restrictions on the fishing effort of the various fleet sectors. There are also a bewildering range of technical measures such as mesh restrictions and derogations, closed areas etc. that are intended to improve selection patterns. of specific fleets or to discourage harmful practices. Moreover, the landings obligation (a ban on discarding) will be rolled out progressively. The NATURA 2000 closed areas determined by the habitats directive will also be further imposed. Currently these do not much impact on the main trawl fisheries with existing closures designed to reduce by catch of Harbour Porpoise in gill net fisheries.

TACs are agreed between the EU and Norway but other measures can vary between the Norwegian and EU EEZs. There are agreed detailed recovery/long term management plans agreed between the

EU and Norway for cod, haddock, whiting saithe, plaice and sole. These involve quite detailed rules for setting the TACs for these species and taken in isolation they are designed to be precautionary. However, they do not take full account of the multispecies/mixed fishery nature of many of the North Sea fisheries. In addition to the North Sea wide regulations, individual nations also have national regulations that affect fisheries. For example *de Jure* and *de facto* ITQ systems have been adopted by many of the North Sea countries.

The North Sea management system is certainly complex and overlapping. It might be argued that there is a strong need for a rationalisation of North Sea management measures designed to work more with the grain of the fisheries and in the spirit of EAFM to encourage more responsible fishing and to discourage serious ecosystem effects of fishing.

7. Other effects of human use of the ecosystem - drivers

Non-native species

Currently this is not a serious problem in the North Sea. Increases in global warming will likely lead to range extensions of more southerly species into the North Sea and perhaps to the demise of some native species.

Contaminants

This is most likely a problem of localised inshore region. In the North Sea it is not a problem of the scale seen for example in the Baltic.

Other…

Oil and gas installations and their removal are potential issues. Oil and gas exploration has also been a concern. Wind and Tidal energy Installations may have effects on local fisheries access and effects on the wider ecosystem.

8. Conservation priorities (protected habitats, species, etc.);

By-catch of fish

The main issues are with large species particularly elasmobranchs.

By-catch of seabirds and mammals

By catch of Harbour Porpoise remains a problem

Other

Disturbance of sediment and impact on the food chain are two of the major impacts of fisheries on the wider ecosystem. Figure 2.12 from STECF 2012 provides indications of the scale of these two impacts for the 10 most important fleets detailed in tables 3 and 4.

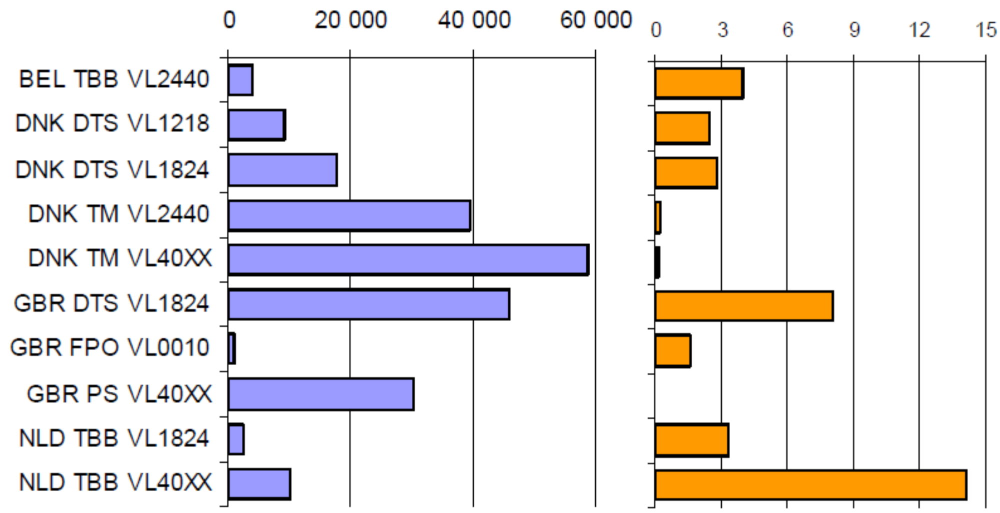

Figure 2.12. Ecological index for the main fleet segments operating in the North Sea. Left: food web impact index (Primary Production required, 10^6wet tons/year); Right, habitat impact index

9. Management priorities and possible scenarios (input from case study meetings).

The MAREFRAME North Sea Stakeholder meeting agreed that the most important scenario to study involved the North Sea multispecies system. The pelagic fisheries might perhaps additionally be considered as a segment to study in greater detail. The essence of the study would be to explore ways of achieving EAFM that worked with the grain of the fisheries and encouraged responsible and law abiding fisheries. As part of this there is a need for identifying current combinations of regulation that act against these aims. Central to this will be providing a simplified form of the proposed models that stakeholders can use as a tool to explore various management options and see the EAFM consequences of various alternative approaches.

III. Northern & Western Waters – Iceland Waters case study

1. Oceanography-water circulation pattern and environmental features

Bottom topography and circulation

The marine ecosystem around Iceland is open compared to for example the Barents or North Sea. The Icelandic shelf is relatively narrow with a steep or moderately steep slope region and deep water beyond. The ocean topography of the area is shown in figure 3.1.

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 613571

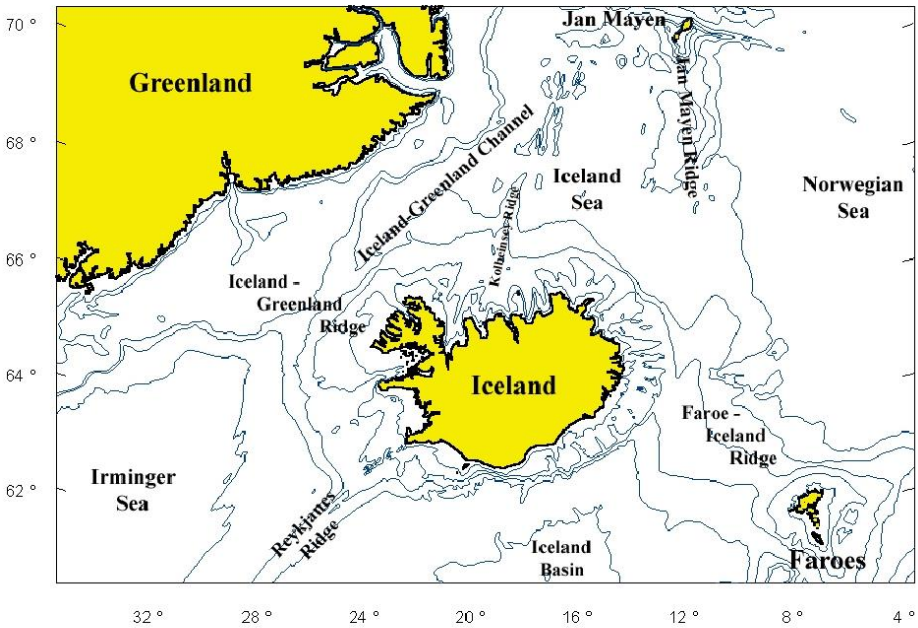

Figure 3.1. Topography of Icelandic waters. Grey lines represent, 200 500, 1000 and 2000 m depth contours.

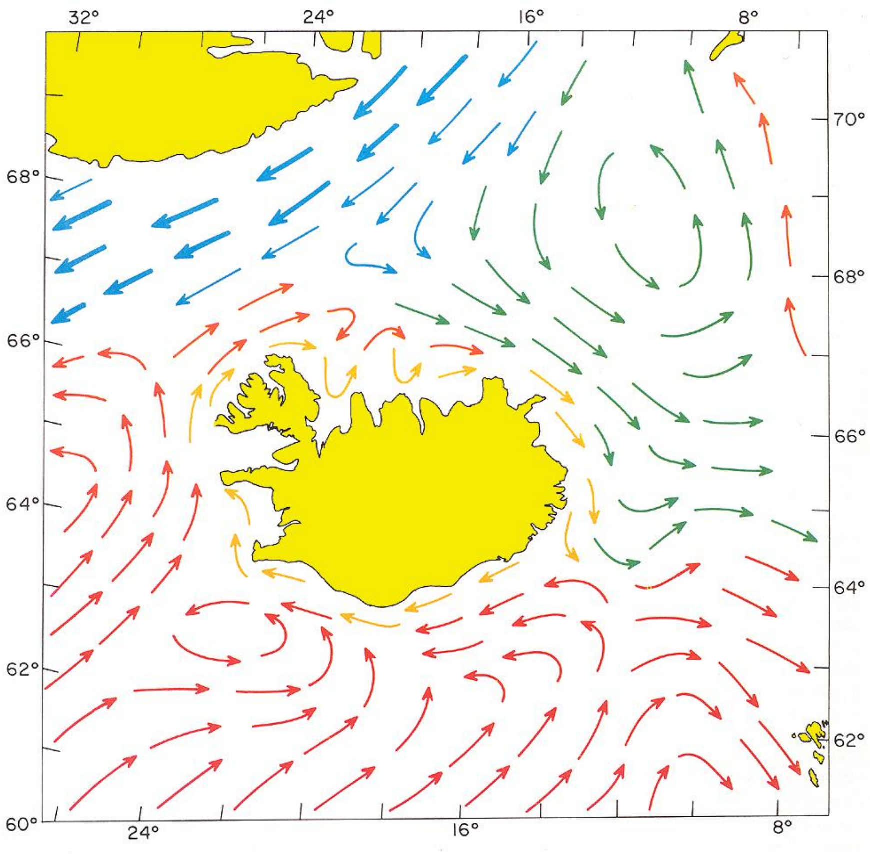

Figure 3.2. Ocean currents around Iceland. Red arrows: Atlantic water. Blue arrows: Polar water. Green: Arctic water, Yellow: Icelandic coastal water (Stefánsson and Ólafsson, 1991).

The areas of the south and west coasts of Iceland receive relatively warm and saline Atlantic water from the Irminger Current. Topography has quite important role with respect to the water circulation around Iceland. The ridge that runs between Iceland and Greenland splits the Irminger Current into two parts (Figure 3.1). One branch swings to the west and southwest and forms a cyclonic eddy in the Irminger Sea (Figure 3.2). The other, the North Icelandic Irminger current, follows the Icelandic shelf area and continues eastwards along the north coast. There it mixes with the colder arctic waters of the East Icelandic Current and at times with the polar water or the East-Greenland Current. The East-Greenland Current transports cold low salinity water to the south and crosses the Iceland-Greenland Ridge (Stefánsson and Ólafsson, 1991).

The East Icelandic Current, formed by south flowing Arctic water and often mixed to a varying degree with polar water from the East-Greenland Current, flows southwards along the east Icelandic continental slope and turns to the southeast at the Faeroe-Iceland Ridge. Thus transport out of the coastal area mainly takes place in two regions, at the northwest and at the southeast cost of Iceland (Figure 3.2). In addition to these two main system of ocean currents a lower salinity coastal current, driven by gravity forces, runs in a clockwise direction around Iceland (Figure 3.2) (Stefánsson and Ólafsson, 1991).

Broad scale climate and oceanographic features and drivers

Year to year changes are relatively small in the area south and southwest of Iceland but the north and northeast part of the Icelandic shelf is marked with large environmental variation due to the wind regime and the distribution of polar water (Stefánsson 1962, 1969). Such changes affect primary, secondary productivity and biological conditions in general (Stefánsson and Jakobsson 1989).

During the first decades of the last century there was a significant increase in temperature in northern waters which among other things led to a retreat of polar ice in the Icelandic Sea (Vilhjálmsson, 1994). The period between 1933 and 1964 was particularly warm in North Icelandic waters. After 1964 a sharp downward trend in water temperature and salinity in both the surface and intermediate layers occurred in all of the years between 1965 and 1971. This was related to the widening of the ice belt, increased admixture of low salinity polar water in the surface layers and as a result, increased stratification in the southern and eastern Iceland Sea (Vilhjálmsson, 1994). Measurements of temperature and salinity at Siglunes station no. 3 at 50 m have been used as an index on the volume of Atlantic water flowing into the region north of Iceland, (Malmberg and Kristmannsson, 1992). These measurements reveal large inter-annual variations in the shelf area (Figure 3.3). During the period between 1965 and 1971 the whole of the north Icelandic shelf area was characterized by negligible inflow of Atlantic water as polar water dominated the water mass. Since 1972 cold and mild years have alternated and ice conditions generally improved from the 1965-71 period (Stefánsson, 1969; Malmberg, 1984; Stefánsson and Jakobsson, 1989).

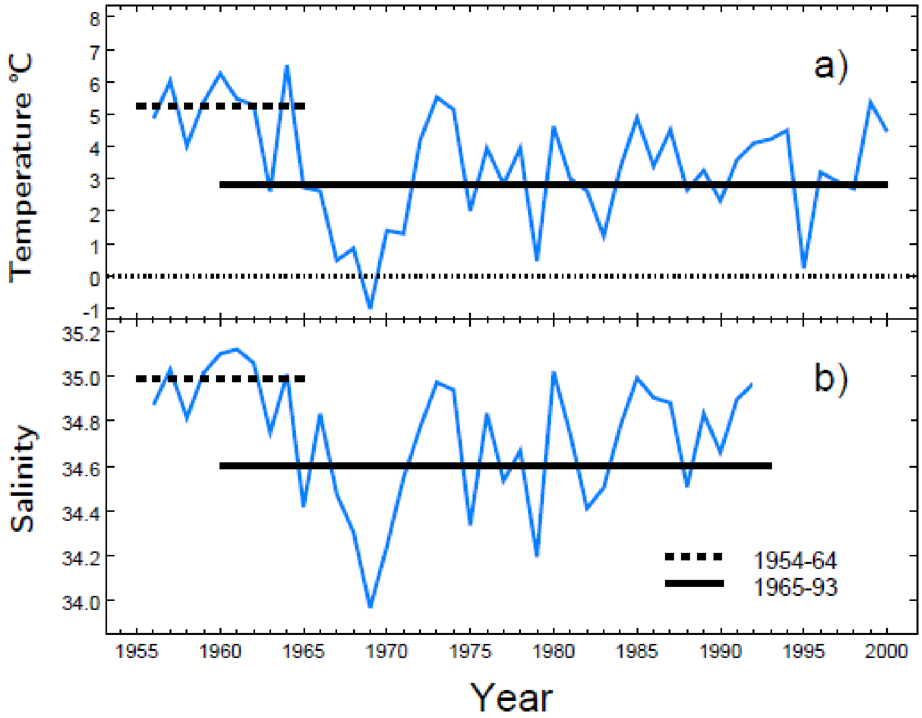

Figure 3.3. Measurements of a) temperature and b) salinity (grey line) at 50 m from station 3 on the Siglunes section (N-Iceland). Black dotted line represents mean values from 1954-1964 and black whole line represents mean values from 1965-1993. Redrawn from Malmberg & Kristmannsson (1992) with additional data from the Marine Research Institute, Iceland.

In general the fluctuations described above can be related to large-scale changes in the atmospheric circulation in the arctic regions during the preceding decades (Rhodewald, 1972; Dickson *et al.*, 1975; Malmberg & Svansson, 1982). On a smaller scale local conditions seem to depend on meteorological conditions much closer in time. This can be seen by the close connection between oceanographic variables (temperature and salinity) on the northeast Icelandic shelf and meteorological conditions (wind speed and direction) a few months earlier off the west and northwest coast of Iceland. Therefore it can be said that meteorological factors control, to some degree, the inflow of Atlantic water to the north Icelandic shelf area (Stefánsson, 1962; Stefánsson & Guðmundsson, 1969).

Nutrients, primary production, eutrophication, hypoxia (anoxia)

Measurements of nutrient levels in Icelandic waters have revealed that the effect of freshwater runoff on the nutrient content of the surface layers is insignificant for both phosphate and nitrate except close to shore. On the other hand freshwater runoff has significant effect on silicate levels to such an extent that it might prolong the growth of diatoms (Stefánsson & Ólafsson, 1991). The freshwater runoff also has an important role for the forming of stratification. Therefore the uptake of nutrients in the Faxafloi region in spring begins about two months earlier at stations near-shore than in deeper waters farther ashore.

In general there is a stronger stratification and lower nutrient levels in the north Icelandic shelf area than on the south and west shelf. The main reason for this is the mixture of low salinity polar water in the north. In late May and beginning of June (at the time of the environmental survey) a typical distribution of nutrients is a tongue of relatively high concentrations in the outer part of the shelf region along the northwest peninsula of Iceland (Vestfirdir). This tongue is associated with the current of Atlantic water from the shelf area west of Iceland. In the eastern part the nutrients level are generally low and these low nutrient levels extend south along the east coast.

Atlantic water is therefore of major importance as a source of nutrients to the north shelf area, both directly because of high concentrations and indirectly because of much more efficient renewal in the surface layers, because of eddy diffusion, than in the stratified polar waters.

Year to year variations in nutrient levels can be quite dramatic on the north shelf. In the period between 1954 and 1964 the nutrients level were quite high which can be related to strong influx of Atlantic water to the north shelf during this period. In the cold years between 1965 and 1971 the nutrients level were extremely low. Since then high and low levels have interchanged (Vilhjálmsson, 1994).

Primary production has been measured in Icelandic waters since the late 1950s using the C^{14} method. These measurements have revealed that compared to other areas Icelandic waters are on average relatively productive. In the Atlantic waters of the south and west coast primary production is high whereas in the polar and mixed waters north and east of Iceland the mean productivity is relatively low. There seems also to be a marked decrease in production from west to east along the north Icelandic shelf as influence of Atlantic water decreases (Fig 3.4). Primary production at the northeast corner of Iceland is therefore four times lower than where it is highest along the southwest coast (Vilhjálmsson, 1994).

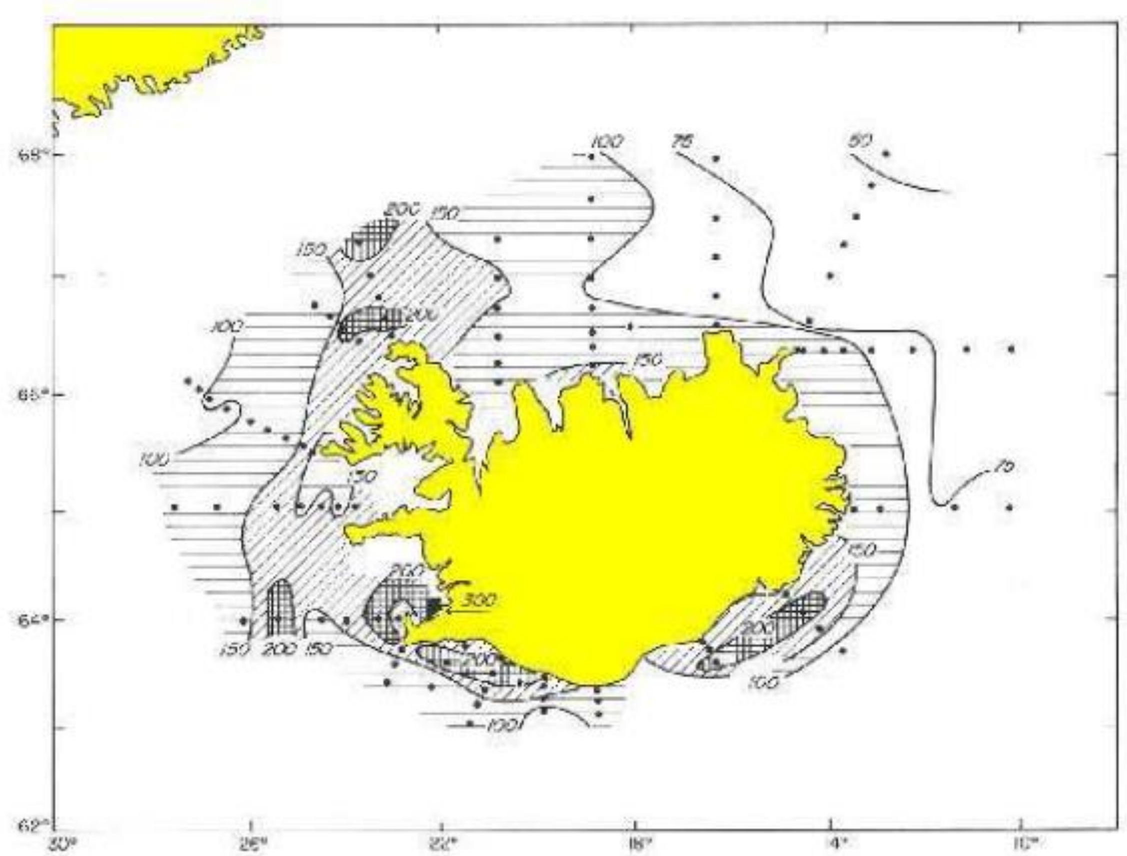

Figure 3.4. Mean contours of annual primary production measured as the amount of carbon per square meter per year (*g*C*m*2*/yr)* in Icelandic waters for the period 1958-1982. Black points represent stations occupied during the annual spring survey from Vilhjálmsson (1994).

Primary production year to year variations are also high in Icelandic waters. This is most apparent in the colder regions in contrast to the more stable production in the warmer regions in the southwest. As an example of these variations the measured values from the warm years of 1974, 1976, 1978 and 1980 from the north shelf are up to 30 times higher than in the same region during the exceptionally cold years of 1965, 1967, 1968 and 1969 (Thordardottir, 1977, 1984).

These variations in primary production have little to do with temperature as such but much more to do with the influx of Atlantic water or the absence of it (Vilhjálmsson 1994). Another important point is also the difference between sea and air temperature as this difference is greater in the warmer areas in the south and southwest than in the colder areas in the north and northeast (Stefánsson, 1969). In June when the sea temperature is higher than the air temperature along the south coast temperature is lost from the sea but the opposite holds at the north shelf. Because of this heating of sea water is more rapid in the north area leading to a steeper temperature gradient which in turn produces a stronger pycnocline (Stefánsson & Ólafsson, 1991).

Studies on seasonal primary production have revealed that the spring bloom of phytoplankton normally starts in the near shore waters and is delayed with increasing distance from the shore. In the shallower inner region of Faxaflói at the SW-coast of Iceland the bloom normally starts in late March but maximum bloom is in the beginning of May (Figure 3.4). In the deeper and farther ashore part of Faxaflói the uptake of nutrients does not start until the middle of May. The growth period is also longest inside Faxaflói and west of the Reykjanes peninsula (Thordardottir & Stefánsson, 1977, Thordardottir, 1986; Stefánsson *et al.*, 1987).

Little data exist on the timing of blooming of phytoplankton on the north shelf but existing data indicates that it does not start later than middle of May and reaches a maximum in the middle or later half of the same month (Thordardottir, 1977). The reason for earlier phytoplankton growth in the northern and eastern areas than in the areas deep of the west coast is mainly due to lowered salinity in the surface layer. The inflow of Atlantic water therefore promotes a continued algal growth in the waters north and later east of Iceland.

Similar data series for zooplankton are available for Icelandic waters as for phytoplankton. Average zooplankton densities were calculated for the period 1961-1992 (Astthorsson *et al.*, 1983; Astthorsson & Gislason, 1993) and following is a brief summary of these findings for the Siglunes and Selvogsbanki sections (Fig 3.5) as they are quite representative for the north and south area respectively (Vilhjálmsson 1994).

In the period 1965-1969 there was a large drop in the zooplankton volume (ml/21m^3) measured in the late spring survey in the north section (Siglunes). This associates with the drastically reduced inflow of Atlantic water during this period and strong influence of polar water at that time. Recovery followed this decline but was only partial. This can be seen clearly by the fact that zooplankton volume of pre 1965 levels has not been measured after 1969 with the exception of 1971 and 1977. Zooplankton levels have remained relatively low to moderate (Fig 3.5). Similar trends were observed at sections along the east and west coast as on Siglunes-section. Data series for the north-eastern and eastern part do not go as far back as for the northern area and the variation in the zooplankton index there is somewhat different but the general picture should be similar (Vilhjálmsson 1994).

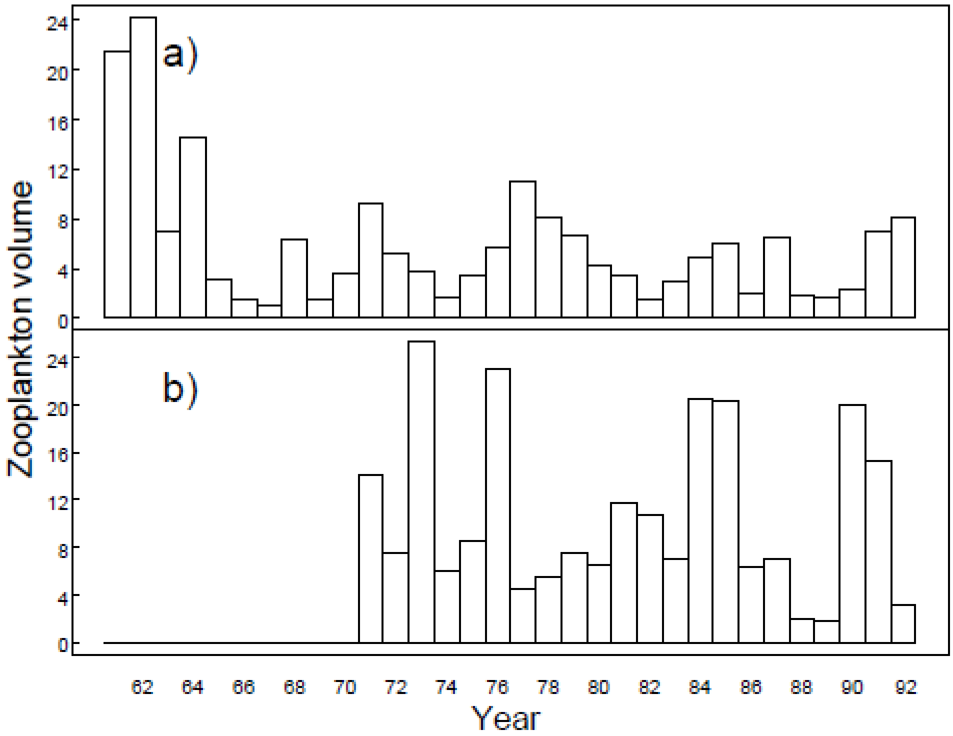

Figure 3.5. Variations in the average volume of zooplankton (ml/21m³) on Siglunes section a) in the years 1961-1992 and from Selvogsbanki section b) from 1971-1992. Redrawn from Astthorsson & Gislason (1993).

At stations farthest offshore in the north Icelandic area zooplankton densities remains almost the same during the period 1961-1982. That far north arctic species dominate in the samples opposed to samples from stations closer to shore. It seems therefore that the negative effects of lesser influx of Atlantic water had less effect on the arctic species than the more temperate ones. This resulted in their abundance being relatively stable (Astthorsson *et al.,* 1983). It is however clear that the variations in temperature and salinity over the shelf north of Iceland have been greater than in those areas further north (Vilhjálmsson 1994).

2. Food- web description, key species, ecological functional groups and fleets

Food-web – general overview, main processes

In Icelandic waters most fish species spawn in the warmer Atlantic waters along the south and southwest coast. The young then drift with the surface currents to the north and east of Iceland where they spend most of their juvenile life. Under normal feeding conditions these are also the main feeding grounds in the summer. Because Icelandic waters are open, in some years there can be a significant amount of fish larvae such as capelin, cod and haddock that drift to the west towards Greenland. Depending on oceanographic conditions these larvae sometime grow up and migrate back into Icelandic waters (Vilhjálmsson 1994).

There are two main pelagic species of importance in Icelandic waters, herring and capelin. There are three main stocks of herring, spring spawning, summer spawning and the Norwegian spring spawning stock. The spring spawning herring mainly spawn around Selvogsbanki at depth of 75-150 m in

March and April. The summer spawning stock on the other hand spawns at similar depth all along the south and south west coast (Jónsson, 1992).

Capelin is a key species in Icelandic water as it is a major prey for most of the ground fish stocks. Capelin generally spawn along the southeast, south and west coast in the period February till April, starting in the east and migrating to the west. Most of the spawning stock dies after spawning. Capelin larvae hatch after approximately three weeks and drift to the west and north part of the shelf. Then capelin migrate to the north and north-west of Iceland where during summer it spends most of its time. During summer adult capelin migrate north to Jan Mayen and in the autumn they migrate back to Icelandic waters (Jónsson, 1992). Both herring and capelin support fisheries. Herring was heavily exploited until the early sixties when the stock collapsed. By that time exploitation of capelin had started.

As noted earlier capelin is of great importance as prey for the ground fish stocks. This can be seen by the close relationship between changes in capelin biomass and weight of six year old cod (Vilhjálmsson, 1997). Haddock also feeds on capelin but mainly during spring when it is readily available. For haddock of 40-80 cm capelin can be from 60-80% of the weight of its diet in March (Einarsson 1997).

Cod (*Gadus morhua*) is the largest demersal fish stock in Icelandic waters and has been heavily exploited during the last century. The main spawning grounds for cod are at Selvogsbanki but the larvae and juveniles grow in the colder waters of the north coast. Mature cod migrate to the south-west coast to spawn in spring. Cod main prey species is capelin but shrimp is also of importance especially for younger cod (Jónsson, 1992; Schopka, 1994; Vilhjálmsson, 1997). Haddock is a much smaller stock but is also of great economic importance.

Apart from these two stocks saithe (*Pollachius virens*), redfish (*Sebastes marinus*), wolffish (*Anarhichas lupus*) and various flatfish species such as halibut (*Hippoglossus hippoglossus*), plaice (*Plauronectes platessa*), dab (*Limanda limanda*), witch (*Glyptocephalus cynoglossus*), lemon sole (*Microstomus kitt*) and long rough dab (*Hippoglossoides platessoides*) are well represented in Icelandic waters and support to a varying extend fisheries.

Food consumption of whales has been estimated as 4.5 million tonnes of which approximately quarter is fish. Most of the fish whales prey on is capelin, herring and sand eel (Sigurjónsson & Víkingsson, 1992, Víkingsson *et al.,* 2003; Jónasson, 2004). However recent studies into the feeding ecology of minke whales indicate a shift in consumption toward larger gadoid species (Víkingsson et al. 2013).

Two species of seals breed along the Icelandic coast, harbour seal and grey seal. Hauksson (1997) estimated that grey seals consume 30 thousand tonnes of fish annually. Since his survey in 1995 grey seals numbers have decreased from 8000 to probably less than 5000 seals. Harbour seals where estimated to consume about 28 thousand tonnes annually, since that survey numbers have remained stable at around 15 thousand seals (Bogason, 1997).

Seabirds are numerous all around Iceland. Lillendahl & Sólmundsson (1997) estimated the consumption of six largest seabird populations, during summer, as around 100 thousand tonnes of capelin and sandeel.

Food web functional groups included to the model(s)

The main focus of the modelling effort within the Northern waters case study will be on cod on the Icelandic continental shelf and its significant interactions to other species. In Icelandic waters multispecies interactions between shrimp, capelin and cod have received considerable attention as all the species are commercially exploited (Pálsson 1983, Stefánsson et al. 1994, Björnsson et al. 1997). Predictions from a multispecies model indicate that it would be economically feasible to reduce the shrimp fishery by half in order to increase the biomass of cod (Stefánsson et al. 1994). Similar models also indicate that minke and fin whales can have a significant impact on the cod stock but lesser impact on capelin. The uncertainty in these models though is quite large (Stefánsson et al. 1997).

3. Commercial species and reference points (i.e F_{msy}, B_{msy})

The main demersal stocks (cod, haddock, saithe and golden redfish) in Icelandic waters are now harvested according to harvest control rules that have been evaluated by ICES as to confirm with the MSY framework. Similarly herring has been managed in a similar framework. Capelin has been managed with a constant escapement strategy and its HCR is under evaluation.

4. Main fisheries (fleets/metiers), target species and catch composition, seasonality and main spatial patterns in the fisheries

The Icelandic fishing fleet can be characterised as users of the most sophisticated technological equipment available in this field. This applies to navigational techniques and fish-detection instruments as well as the development of more effective fishing gear. The most significant development in recent years is the increasing size of pelagic trawls and with increasing engine power the ability to catch pelagic fishes at greater depths than previously possible. There have also been substantial improvements in recent decades with respect to technological aspects of other gears such as bottom trawl, longline and handline. Each fishery uses a variety of gears and some vessels frequently shift from one gear to another within each year. The most common demersal fishing gear are otter trawls, longlines, seines, gillnets and jiggers while the pelagic fisheries use pelagic trawls and purse seines. The total recorded landings of the Icelandic fleets in 2010 amounted to around 1 million tonnes where pelagic fishes amounted to 0.5 million tonnes.

A simple categorization of boats among the different fisheries types is impossible as many change gear depending on fish availability in relation to season, quota status of the individual companies, fish availability both in nature and on the quota exchange market, market price, etc. E.g. larger trawl vessels may operate both on demersal species using bottom trawls as well as using purse seine and pelagic trawls on pelagic species. Total number of vessels within each fleet category in 2010 is thus limited to the broad categories given in Table 3.1.

Table 3.1. Total number of vessels within each fleet category in 2010 is thus limited to the broad categories.

Type	No. vessels[1)]	Gear type used
Trawlers	57	Pelagic and bottom trawl
Vessels > 100 t	140	Purse seine, longline, trawl, gillnet
Vessels < 100 t	621	Gillnet, longline, danish seine, trawl, jiggers
Open boats	807	Jiggers, longliners (including recreational fishers)
Total	1625	

[1)]*Source: Statistic Iceland - http://www.statice.is/*

The demersal fisheries take place all around Iceland including variety of gears and boats of all sizes. The most important fleets targeting them are:

- Large and small trawlers using demersal trawl. This fleet is the most important one fishing cod, haddock, saithe, redfish as well as a number of other species. This fleet is operating year around; mostly outside 12 nautical miles from the shore.
- Boats (< 300 GRT) using gillnet. These boats are mostly targeting cod but haddock and a number of other species are also target. This fleet is mostly operating close to the shore.
- Boats using longlines. These boats are both small boats (< 10 GRT) operating in shallow waters as well as much larger vessels operating in deeper waters. Cod and haddock are the main target species of this fleet but a number other species are also caught, some of them in directed fisheries.
- Boats using jiggers. These are small boats (<10 GRT). Cod is the most important target species of this fleet with saithe of secondary importance.
- Boats using Danish seine. (20-300 GRT) Cod, haddock and variety of flatfishes, e.g. plaice, dab, lemon sole and witch are the target species of this fleet.

Although different fleets may be targeting the main species the spatial distribution of effort may different. In general it can be observed that the bottom trawl fleet is fishing in deeper waters than the long line fleet.

The pelagic fisheries targeting capelin, herring, blue whiting and mackerel is almost exclusively carried out by larger vessels. The fisheries in Icelandic waters for capelin and herring are carried out using both purse seine and pelagic trawl while that of blue whiting and mackerel is exclusively carried out with pelagic trawl. Additionally a significant part of the pelagic fisheries of the Icelandic fleet is caught outside the Icelandic EEZ, both on the Atlanto-Scandian herring and on blue whiting.

5. Socio-economic indicators (performance)

NA.

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6. Governance and management rules enforced (fisheries management, MPA, others that can affect fisheries and ecosystem)

The Ministry of Fisheries is responsible for management of the Icelandic fisheries and implementation of the legislation. The Ministry issues regulations for commercial fishing for each fishing year, including an allocation of the TAC for each of the stocks subject to such limitations. Below is a short account of the main feature of the management system.

A system of transferable boat quotas was introduced in 1984. The agreed quotas were based on the Marine Research Institute's TAC recommendations, taking some socio-economic effects into account. Until 1990, the quota year corresponded to the calendar year but since then the quota, or fishing year, starts on September 1 and ends on August 31 the following year. This was done to meet the needs of the fishing industry. In 1990, an individual transferable quota (ITQ) system was established for the fisheries and they were subject to vessel catch quotas. Since 2006/2007 fishing season, all boats operate under the TAC system.

With some minor exceptions it is required by law to land all catches. Consequently, no minimum landing size is in force. To prevent fishing of small fish various measures such as mesh size regulation and closure of fishing areas are in place (see below).

Within this system individual boat owners have substantial flexibility in exchanging quota, both among vessels within an individual company as well as among different companies. The latter can be done via temporary or permanent transfer of quota. In addition, some flexibility is allowed by individual boats with regard to transfer allowable catch of one species to another. These measures, which can be acted on more or less instantaneously, are likely to result in lesser initiative to discards and misreporting than can be expected if individual boats are restricted by strict TAC measures alone. They may however result in fishing pressures of individual species to be different than intended under the single species TAC allocation.

With the extension of the fisheries jurisdiction to 200 miles in 1975, Iceland introduced new measures to protect juvenile fish. The mesh size in trawls was increased from 120 mm to 155 mm in 1977. Mesh size of 135 mm was only allowed in the fisheries for redfish in certain areas. Since 1998 a minimum mesh size of 135 is allowed in the codend in all trawl fisheries not using "Polish cover" and in the Danish seine fisheries. For the gillnet fishery both minimum and maximum mesh-sizes are restricted. Since autumn 2004 the maximum allowed mesh-size in the gillnet fishery is 8 inches. The objective of this measure is to decrease the effort directed towards bigger spawners.

A quick closure system has been in force since 1976 with the objective to protect juvenile fish. Fishing is prohibited for at least two weeks in areas where the number of small fish in the catches has been observed by inspectors to exceed certain percentage (25% or more of <55 cm cod and saithe, 25% or more of <45 cm haddock and 20% or more of <33 cm redfish). If, in a given area, there are several consecutive quick closures the Minister of Fisheries can with regulations close the area for a longer time forcing the fleet to operate in other areas. Inspectors from the Directorate of Fisheries supervise these closures in collaboration with the Marine Research Institute. In 2010, 113 such closures took place:

In addition to allocating quotas on each species, there are other measures in place to protect fish stocks. Based on knowledge on the biology of various stocks, many areas have been closed temporarily or permanently aiming at protect juveniles. Some of them are temporarily, but others have been closed to fishery for decades.

The major spawning grounds of cod, plaice and wolfish are closed during the main spawning period of these species. The general objectives of these measures, which were in part initiated by the fishermen, are to reduce fishing during the spawning activity of these species.

Discarding measurements have been carried out in Icelandic fisheries since 2001, based on extensive data collection and length based analysis of the data (Pálsson 2003). The data collection is mainly directed towards main fisheries for cod and haddock and towards saithe and golden redfish fisheries in demersal trawl and plaice in Danish seine. Sampling for other species is not sufficient to warrant a satisfactory estimation of discarding. The discard rate for cod has been in the range of 0.2-2.2% of the reported landings over the time investigated. The discard estimates for haddock are somewhat higher ranging between 0.7-5.0% annually. Discarding of saithe and golden redfish has been negligible over time period of investigation. Relatively low discard rates compared to what is generally assumed to be a side effect of a TAC system may be a result of the various measures, including the flexibility within the Icelandic ITQ system (see above). Since the time series of discards is relatively short it is not included in the assessments.

All catch that is brought ashore must by law be weighted by a licensed body. The monitoring and enforcement is under the realm of the Directorate of Fisheries. Under the TAC system there are known incentives for misreporting, both with regards to the actual landings statistics as well as with regards to the species recorded. This results in bias in the landings data but detailed quantitative estimates of how large the bias may be. Unpublished report from the Directorate of Fisheries, partly based on investigation comparing export from fish processing plants with the amount of fish weighted in the landing process indicate that this bias may be of the order of single digit percentages.

7. Other effects of human use of the ecosystem

Non native species

With the increase in global oceanic trade the establishment of non-indigenous marine organisms has become a major environmental and economic problem worldwide. The oceanic island of Iceland has apparently not received many non-indigenous marine invertebrate species during the last decades. (Gíslason et. al 2013). Recently however, the Atlantic rock crab (*Cancer irroratus*) was reported in Icelandic waters, Eastern North Atlantic. The crab was most likely transferred to Iceland as larvae in ballast water and has successfully established a reproducing population in Icelandic waters. The species is distributed along the southwestern- and western-coast of Iceland. Adult specimens are now common in Faxaflói Bay, Southwest Iceland, but with sporadic occurrences in western and northwestern Icelandic waters.

Contaminants

In 2003, the Icelandic Ministry of Fisheries, now the Ministry of Industries and Innovation, initiated a project aimed at screening for undesirable substances in the edible portion of marine catches, as well as in fish meal and fish oil for feed, captured in Icelandic waters. Matis was assigned the responsibility of carrying out the surveillance programme, which has now been on-going for ten consecutive years. The goal of the surveillance programme is to gather information and evaluate the status of Icelandic seafood products regarding undesirable substances and is funded by the Ministry of Industries and Innovation in Iceland. The project includes measurements on various undesirable substances in a number of economically important marine species from Icelandic fishing grounds. This monitoring has indicated that the Icelandic seafood products contain negligible amounts of persistent organic pollutants (POPs) such as dioxins, dioxin like PCBs, pesticides and PBDEs (Jensen et. al 2013). The marine biosphere around Iceland is also monitored for fluctuations in contaminant levels (Jörundsdóttir et. al 2013). In addition to the monitoring Matís participates in several national and international research projects as well as coordinating national and international research projects, focusing on investigating the pollution in the marine environment (Jörundsdóttir et al., 2013; Jörundsdóttir et al., 2014; Sturludóttir et al., 2014).

Conservation priorities (protected habitats, species, etc.)

See 6: Governance

8. Management priorities and possible scenarios (input from case study meetings).

The initial meeting of the stakeholders in the Northern waters case-study was held on the 10th of June in Reykjavík, Iceland. The meeting was held with participants from the Ministry of fisheries, Directorate of fisheries, Marine research institute, University of Iceland, Federation of Icelandic fishing vessel owners, Coalition of small vessel owners and other select representatives from the industry. The stakeholders indicated that their main interest would be on a stable and strong cod fishery in Icelandic waters.

On the economic side, relevant questions to the stakeholders are how quota is assigned within the industry and what factors should be considered. These include:

- Should quota consolidation barriers be removed, currently it is at 12% of total allowable catch.
- Effects of municipality controlled quota, quota assigned to the municipality when
- Aggregation of small and large type fishing vessels. Currently small type vessels are treated separately.
- Should the industry to take into account socio-economic factors.

IV. Northern Waters - West Scotland case study

1. Oceanography and water circulation

Bottom topography and circulation

The West of Scotland Ecosystem comprises the shelf area west of Scotland (ICES subarea VIa) which covers inshore and offshore waters from the west coast of Scotland to 12°W of longitude (Fig. 4.1).

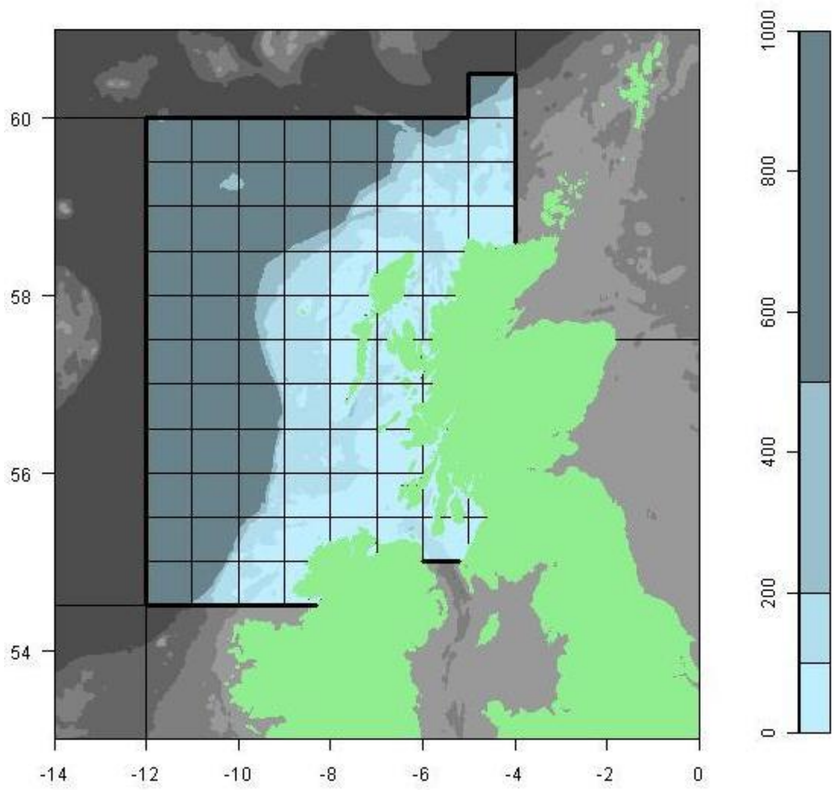

Figure 4.1. Shelf area west of Scotland with ICES subarea VI (lighter colors) and corresponding bathymetry (grey scale).

The geomorphology of the area is complex with the coastline including beaches, fjords and numerous islands. The seabed generally consists of extensive areas of sand and muddy-sand interspersed with rocky outcrops, reefs, shelves and seamounts. From east to west water depths range from the Malin and Hebrides Shelves which are shallower than 250m to the Rockall Trough where depth can excess 2500 m (ICES, 2011). The oceanography in subarea VIa is strongly influenced by the North Atlantic Current (NAC) which is partially responsible for the temperate climate experienced west of Scotland when compared with other regions at similar latitudes (Rahmstorf, 2003). The main oceanographic front in the area is the Irish Shelf Front that occurs to the south and west of Ireland (at 11°W), and exists all year-round. This front marks the boundary between waters of the shelf (often mixed vertically by the tide) and offshore North Atlantic waters. The turbulence caused by the front introduces nutrients from deeper water to the surface where they promote the growth of phytoplankton. These are in turn fed on by zooplankton and associated with fish aggregations (Reid et al., 2001).

Water circulation on the shelf follows the poleward flowing slope current which is stronger in summer (Huthnance, 1986). The Rockall Trough is an important pathway by which North Atlantic surface waters reach the Norwegian Sea. Along the eastern edge of the Rockall Trough, this flow of water is also known as the European Slope Current (ESC) which is a persistent feature active from the south of the Porcupine Seabight to the north of the Shetland Islands. Over the Rockall plateau, domes of cold water indicate retentive circulation (ICES, 2012). Closer inshore the Scottish Coastal Current (SCC) flows northwards carrying a mix of Irish and Clyde sea water from the North Channel. As it flows north the SCC mixes with fresh water from the Scottish Highlands. Water in the SCC takes around 4-6 months to move from the North Channel to Cape Wrath (Inall et al., 2009). When coupled with ocean currents and tides the complex geomorphology of the region produces a wide variety of oceanographic features including tidal jets, density-driven recirculation gyres and Taylor columns as well as partially isolated fjordic systems with periodic overturning (Inall and Sherwin, 2006).

Broad scale climate and oceanographic features and drivers

Temperature and salinity

From the 1960s to the 1990s surface, mid and deep waters across the northeast Atlantic have been relatively cold but from the early 1990s there has been a period of warming and increasing salinity. This is reflected by the winter North Atlantic Oscillation (NAO) index which experienced a negative phase in the 1960s but became more positive in the late 1980s and early 1990s. The winter NAO index was negative from 1996 to 2004, but became positive again in 2005. In 2006, the warm and saline conditions persisted in the upper ocean of the Rockall Trough, though salinity has been decreasing since a peak in 2003. The concomitant increase in salinity suggests that the increase in temperature is mainly due to Atlantic water flowing onto the shelf area in division VIa. The main impacts of the inter-annual and inter-seasonal variability in ocean currents are on water temperature and salinity and on the input of nutrients from the Atlantic into the shelf and inshore waters. Inshore waters off the west of Scotland have also continued to warm, consistent with open-ocean conditions. Sea surface temperatures measured in coastal stations northwest of Ireland since the 1960s show a trend of sustained positive temperature anomalies from 1990 (Nolan and Lyons, 2006). At Millport, where monitoring has been conducted since 1953, gradual warming is apparent, and a more rapid warming that has taken place since the mid-1990s (Bailey et al., 2011). In-situ data suggests that coastal waters off the west coast of Scotland are currently (i.e. 1982-2008) warming at a rate twice that of North Sea coastal waters (0.6°C decade-1 compared to 0.3°C decade-1) (Bailey et al., 2011).

Input of fresh water

Because of the complex fjordic nature of the western coast of Scotland there is also a substantial fresh-water input from the numerous sea-lochs, notably the Firth of Lorne sea loch system (Nolan and Lyons, 2006).

Nutrients, primary production, eutraphication, hypoxia (anoxia)

The concentration of nutrients introduced from deeper water generally declines through the spring due to biological production (Colebrook, 1986). The phytoplankton productivity is reasonably strong on the shelf but drops rapidly west of the shelf break. The Continuous Plankton Recording (CPR) greenness records for area VIa show that the phytoplankton spring bloom occurs between April and October, although in recent years it has lasted until December. This change in phenology is likely due to warmer temperatures. CPR data also suggest that there has been a steady increase in phytoplankton colour index across the whole area over at least the past 20 years.

In contrast, the overall abundance of zooplankton in this region has declined in recent years. CPR data show a substantial drop in Calanus species abundance and these are now below the long-term average. In 2005, major changes in the zooplankton composition were reported. Not only has the rank order of the top ten species changed, but new groups (i.e. Echinoderm larvae, Noctiluca scintillans, Siphonophores, and C. Helgolandicus) appeared in the dominant species for the first time (ICES, 2012). In addition, Ps. elongatus, which was the most abundant species during the 1988-2004 period when it contributed nearly 12% of the total zooplankton abundance, represented only 2.3% of the zooplankton community in 2005. Ps. elongatus abundance in 2005 is the lowest abundance ever observed. The West of Scotland ecosystem is characterized as a spawning area for a number of key wide-ranging migratory species. Thus, zooplankton species have a key role as they constitute the main source of food that fish larvae feed upon.

2. The West of Scotland food-web

Food-web – general overview, main processes

Conceptual model

The conceptual food web model for the West coast of Scotland case study must encapsulate the prey-predator relationships between the numerous species present within this ecosystem. To do so, it is important to ensure that the model employed is correctly parameterised in order to efficiently capture the dynamic processes. This ensures that the modelling tool reproduces the dynamics happening in the wild as good as possible. A schematic diagram of the conceptual model and the prey-predator relationships to be modelled is given in Figure 4.2.

The key species included in this model are: cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), saithe (*Pollachius virens*), hake (*Merluccius merluccius*), herring (*Clupea harengus*), mackerel (*Scomber scombrus*), Norway pout (*Trisopterus esmarkii*), Sandeel (*Ammodytes marinus*), Norway lobster (*Nephrops norvegicus*), anglerfish (*Lophius piscatorius*), megrim(*Lepidorhombus whiffiagonis*), blue whiting (*Micromesistius poutassou*), grey gurnard (*Eutrigla gurnadus*), poor cod (*Trisopterus minutus*), spurdog (*Squalus acanthias*), and lesser spotted dogfish (*Scyliorhinus canicula*). These species includes the main commercial species of the West coast of Scotland fisheries as well as the key prey and predator species of the West coast of Scotland ecosystem.

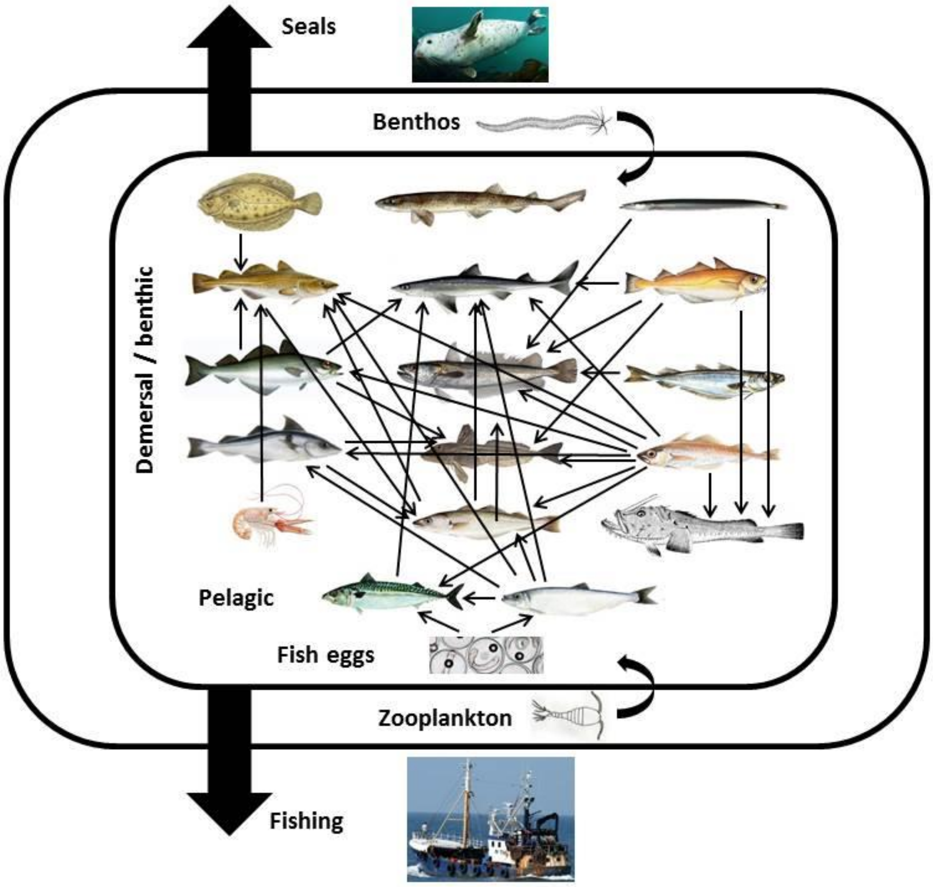

Figure 4.2. Conceptual model of the West coast of Scotland (ICES area VIa) case study ecosystem to be parameterise for the MareFrame project.

The processes to be modelled are:

(i) Fishing exploitation: The species in the model are subject to various levels of fishing mortalities which will impact the overall mortality of these species and their abundance and subsequent recruitment success.
(ii) Seal predation: The gadoid species in the model are subject to seal predation which, like fishing, will impact the overall mortality. The seal population can be modelled as a fishing fleet with a different selectivity and which does not achieve any landings and profit.
(iii) Prey-predator interactions: This is a key process to be captured in an ecosystem model, albeit difficult to parameterise accurately. A high predators' abundance will negatively impact the abundance of preys while a high abundance of preys may, depending on the fishing pressure applied on the predator species, positively impact the abundance of predators. This can in turn impact landings and associated profits.
(iv) Density-dependence: For certain species, density –dependence process can have a large impact on species' abundance.

The biological and ecosystem indicators to be generated from the model and investigated include:

- Biomass levels in comparison to biological reference points
- Fishing mortalities in comparison to biological reference points
- Large Fish Indicator (proportion of fish with length above 40 cm)
- Change in species composition

The economic and social indicators which could be investigated include:

- EBITDA (Earnings Before Income Tax, Depreciation and Amortisement) as an indicator of the economic performance of the considered fisheries
- Change in fleet sizes as an indicator of employment
-

Key species, ecological functional groups and fishing fleets

Fish community and main commercial species

Gadoids

Atlantic cod *Gadus morhua* has a wide distribution in the northeast Atlantic stretching from the Celtic Sea to the Barents Sea (Froese and Pauly, 2010). On the west coast of Scotland juveniles are frequently found in coastline shallow waters and sea lochs and generally spend the first winter close inshore (Magill and Sayer, 2004). As they reach maturity they move off into deeper water to join adult stocks, although Hawkins et al. (1985) reported that cod up to 4 years old may remain localised in shallow Scottish sea lochs. Cod west of Scotland are believed to comprise of at least two subpopulations of cod that remain geographically separate throughout the year. The southern component is characterized by coastal groups with a tendency towards year-round residency, while the northern component appears to inter-mix with cod in the North Sea (ICES, 2012).

Haddock *Melanogrammus aeglefinus* is a highly commercial gadoid species which is widely distributed around the west coast of Scotland and can be caught in most areas within the 200m depth contour (ICES, 2012). It is found up to a depth of 300m close to the bottom (Wheeler 1978). Juvenile haddock are found in shallower water. The west of Scotland haddock stock on the continental shelf (IVa) is an entirely separate stock from the one at Rockall (Newton et al., 2008).

Whiting *Merlangius merlangus* occur throughout the northeast Atlantic waters in a wide range of depths from shallow inshore waters down to 200m. Adult whiting are widespread throughout division VIa, while large numbers of juvenile fish occur in inshore areas (ICES, 2012). The species is associated with shallow seas, particularly the juveniles that settle into shallow water and sea lochs close to the shore (Wheeler, 1978). Historically, whiting has been a key commercial species in the west coast of Scotland (Gordon and De Silva, 1980).

European hake *Merluccius merluccius* is widely spread in the northeast Atlantic with a distribution ranging from the tropical western coast of North Africa to the cold waters of the western coast of Norway (Casey and Pereiro, 1995). Hake is found in high abundance in the west of the British Isles including division VIa, especially during summer as the species migrate northwards throughout the year. Hake is a demersal and benthopelagic species which is found mostly between 70 and 370m although it is found in both shallower and deeper waters, from coastal waters (30m) to 1000m (Lloris et al., 2003). Hake has experienced a tremendous increase in abundance in the 2000s, especially in the northern areas of its distribution such as the West of Scotland and the North Sea. Hake assessment is carried annually for the northern stock ranging from the south of the Bay of Biscay to the northern North Sea.

Other large gadoid species occurring west of Scotland are pollock *Pollachius pollachius* and saithe Pollachius virens. Pollock are often associated with harder rocky ground and can be found from surface waters to a depth of 200 m (Wheeler 1978). Saithe are associated with surface and mid water where they can aggregate into dense shoals (Wheeler, 1978). Both species are abundant in British waters around the UK (Gordon and De Silva, 1980). However, saithe is much more abundant than Pollock in the west of Scotland.

Small gadoid species include Norway pout *Trisopterus esmarkii* and poor cod *Trisopterus minutus*. Norway pout is a small benthopelagic gadoid occurring in area VIa. It is found mainly over muddy seabed between 100 and 200 m, although the species is also caught in shallower water. The Norway pout stock is not assessed on the West of Scotland, unlike in the North Sea. Poor cod is a small benthopelagic gadoid found in coastal waters of the north east Atlantic (Wheeler 1978). It can be found in schools close to the sea bed.

Anglerfish

Anglerfish occur in a wide range of depths, from shallow inshore waters down to at least 1000m. Two species of anglerfish are caught off the west coast of Scotland, the monkfish *Lophius piscatorius* and the black bellied angler fish *Lophius budegassa*. Monkfish can grow up to 2m in length and are the larger and more common of the two anglerfish species. They can be found from shallow water down on to the continental slope (Wheeler, 1978). Black bellied anglerfish are less common and are generally found between at depths between 100 and 300m.

Other demersal species

Other demersal species include John Dory *Zeus faber*, blue-mouth *Helicolenus dactylopterus*, and ling M*olva molva*. A number of species of gurnards are also found in the waters off the west coast of Scotland. However, only grey gurnard *Eutrigla gurnardus* and red gurnard *Aspitrigla cuculus* contribute significantly to West of Scotland demersal group, with grey gurnard being the most abundant of the two. Both these species are usually associated with sandy bottoms, but are regularly found on rocky and muddy ground.

Benthopelagic species

Four species of sand eel are prevalent in the waters off the west coast of Scotland: sand eel *Ammodytes marinus*, smoothed sand eel *Gymnammodytes semisquamatus*, greater sand eel *Hyperoplus lanceolatus*, and Corbins sand eel *Hyperoplus immaculatus*. They are found in burrows in sand beds but can also be found schooling in the water column (Wheeler 1978). The sand eel species are known to be a major prey item for many fish species as well as sea-birds such as puffins, thus playing a large role in the West of Scotland ecosystem.

A large number of flatfish species are present on the west coast of Scotland. The main species are lemon sole *Microstimus kitt,* plaice *Pleuronectes platessa*, dab *limanda limanda* and megrim *lepidorhombus whiffiagonis.*

Pelagic species

Sprat, *Sprattus sprattus* is small pelagic clupeoid fish abundant in inshore waters and estuaries off the Scottish west coast particularly during the summer months when they spend their time in shallower water (Wheeler 1978). The sprat stock is not assessed on the West of Scotland.

Mackerel *Scomber scombrus* is a highly commercial species with an annual value of £64 million for the Scottish fishing fleet (Bailey et al., 2011). It is a migratory fish and individuals only spend part of the year in area VIa. After spawning this species migrate towards their main feeding grounds in the Norwegian Sea. An annual mackerel stock assessment is carried out for the whole of the northeast Atlantic population.

Horse mackerel *Trachurus trachurus* is a migratory pelagic fish. The western population spawns in the Bay of Biscay and west of the British Isles early in the year before migrating to feed in the Norwegian and North Seas in the latter half of the year (Froese and Pauly, 2010). The western horse mackerel stock is assessed annually by ICES (ICES, 2010).

Blue whiting *Micromesistius poutassou*, is a pelagic gadoid species that is found on the continental shelf and slope at depths between 150 and 3000m (Froese and Pauly, 2010). They are a migratory species and the main stock off the west coast of Europe passes through the waters of area VIa as part of their annual migration towards the Norwegian Sea (Reid, 2001).

Herring *Clupea harengus* are distributed throughout the north east Atlantic and from the English Channel to as far north as the Arctic Ocean. Herring has been a key fishery species in the waters around Scotland, particularly during the 19th and early 20th century (Smylie, 2004). However the fishery has seen a dramatic decline, largely as a result of overfishing. Most herring populations spawn in autumn. Larvae from the spawning grounds off the west and north coast of Scotland are known to feed into the nursery grounds in the North Sea (MSS 2009). Some of the larvae remain on the west coast where the juveniles can be found in inshore waters and sea lochs. Eventually the juveniles join the adult stocks which are found in the deeper waters of the continental shelf.

Other pelagic species that are found in area VIa include sardines *Sardina pilchardus* and anchovy *Engraulis encrasicolus*.

Nephrops

The Norway lobster *Nephrops norvegicus* distribution is limited to muddy habitat as this crustacean species requires sediment with a minimum of 10% of silt and clay content to excavate its burrows. Thus, the Nephrops distribution matches the distribution of suitable sediment. Adult Nephrops only undertake small-scale movements of a few hundred meters but in some areas larval transfer may occur between separate mud patches (ICES, 2012). On the West Coast of Scotland Nephrops is assessed in three Functional Units: the Firth of Clyde and the North and South Minches. Although Nephrops do occur elsewhere within area VIa, including on the shelf edge, the vast majority of the biomass is believed to be accounted for by these functional units. The assessment has been carried out since 1995 using an Underwater TV Survey. The density of burrows is calculated and this is scaled to give an abundance estimate.

Elasmobranchs

A large number of species of rays and skates are present on the west coast of Scotland. However, the most abundant species are the homelyn ray *Raja montagui*, the cuckoo ray *Leucoraja circularis*, the thornback ray *Raja clavata* and the blue skate *Dipturus batis*. The two shark species that are commonly found west of Scotland are the small spotted catchark *Scyliorhinus canicula* and the piked dogfish *Squalus acanthias*. These two species account for the vast majority of sharks that occur VIa. The abundance of piked dogfish has decreased over time while the abundance of small spotted catshark has increased.

Marine mammals

Grey seals

Grey seals *Halichoerus grypus* are abundant around Scotland. A pup count of is carried out annually (SCOS, 2008). This count is estimated to be accurate to within ±13%. The pup count has been linked to total population size using various models of which the outputs vary considerably (SCOS 2008). Estimates of the total abundance of the grey seal population are thus associated with high uncertainty. According to Trites and Pauly (1998), the mean weight of a male grey seal is estimated to be 168kg while the mean weight of a female is estimated to be 152kg. The food requirements of grey seals depend on the oiliness of the prey. For an average seal daily consumption estimates are 7kg of cod or 4kg of sand eel (SCOS, 2008). Hammond and Harris (2006) conducted analysis of scat samples to estimate that grey seals in the Hebrides consumed on average 4.99kg of fish per day. According to Trites and Pauly (1998), the mean daily ration R of a marine mammal as a percentage of body weight W is:

R=0.1W0.8.

Harbour seals

Harbour seals *Phoca vitulina* are commonly found on the west coast of Scotland. Numbers of harbour seals are estimated from counts at haul out sites. The Sea Mammal Research Unit (SMRU) carry out a survey every five years only for practical reasons (SCOS 2008). Survey data for harbour seals extends back as far as1992 for the Outer Hebrides and 1994 for the Scottish Highlands. It is estimated that 30 to 40% of the seals are not counted during the surveys due to individuals being underwater and abundance estimates should account for this. The average weight of adult harbour seals is estimated at 63.6kg (Trites and Pauly, 1998). The daily harbour seal ration is considered to be 3kg of oily fish or 5kg of gadoids (SCOS 2008).

Main fisheries (fleets/metiers), tagert species and catch composition

West of Scotland fisheries

The West of Scotland (area VIa) supports important commercial fisheries for Nephrops, gadoids species, anglerfish species and a number of flatfish species. UK, Ireland and France are the most important exploiters of the demersal fisheries (ICES, 2012). The demersal fisheries in area VIa are predominantly conducted by otter trawlers fishing for Nephrops, gadoids (cod, haddock, hake, saithe, and whiting), anglerfish, and megrim (flatfish). Other flatfish species (lemon sole, plaice, halibut, turbot) as well as witch, red mullet and pollock form a proportionally small but valuable part of the catch (ICES, 2012). Trawlers may target a particular species assemblage in particular areas, but invariably catch a mixture of species. Generally, three main fisheries can be considered in area VIa:

- an inshore fishery targeting Nephrops (with by-catches of gadoids)
- a shelf fishery targeting gadoids
- a fishery on the shelf edge targeting anglerfish and megrim

Inshore Nephrops fisheries

The Nephrops fisheries are exploited throughout the year, with the highest landings usually made in spring and summer. In the Minch (functional units 11 and 12) fisheries are predominantly exploited by Nephrops trawlers using single rig gear with a 70mm mesh, although about 15% of landings are currently made by creel vessels. About 135 trawlers contribute to the landings, 75% of which are local. The mean engine power is around 200 kW, and the mean vessel length is around 15 m.

The Firth of Clyde Nephrops fishery is predominantly exploited by a dedicated Nephrops trawler fleet of approximately 120 vessels, with less than 2–3 % of the landings made by creel vessels. The 90 resident Clyde trawlers make about 90% of the Nephrops landings. The regular fleet is comprised of Scottish vessels, but some catches are taken by Northern Ireland and Republic of Ireland vessels. The trawler fleet that fishes the Firth of Clyde mostly consists of vessels between 10 and 20 m in length (mean overall length 14 m), with a mean engine power of 185 kW.

Most vessels use single otter trawls with a 70mm mesh codend and just under a third of Nephrops landings are taken by vessels using twin- rig trawls with an 80mm mesh codend, which is still a smaller mesh size than the 120mm mandatory for fisheries targeting cod (ICES, 2012). As a result bycatches of cod are made by Nephrops fisheries. Bycatches of whiting are also made in the Firth of Clyde.

Gadoid fisheries

The gadoid fisheries on the shelf (< 200m) are exploited throughout the year, with the highest landings usually made in spring (ICES, 2012). Since 2009, these fisheries are predominantly exploited by trawlers using single trawls with 120mm mesh, although pair trawling, twin trawling and seine nets are also used. Recent increases in the price of fuel have led to a reduction in twin trawling and renewed interest in seine netting. About 120 trawlers from the west of Scotland contribute to the fishery but Ireland, Northern Ireland, England, France, Spain and Germany also participate in these fisheries (ICES, 2012). The minimum landing size for cod, haddock and whiting in VIa are 35 cm, 30 cm and 27 cm respectively.

In 2009, the Council regulation (EC) No 1342\2008 introduced a cod long-term management plan. The objective of the plan is to ensure the sustainable exploitation of the cod stock on the basis of maximum sustainable yield while maintaining a fishing mortality of 0.4. Since 2012, all fisheries are restricted to landings of cod through bycatch only as the council regulation (EU) No 43/2012 set a zero TAC for cod in VIa. Bycatches of cod covered by this TAC may be landed provided that it does not comprise more than 1,5% of the live weight of the total catch retained on board per fishing trip. (ICES, 2012). Cod is believed to be no longer targeted in any fisheries now operating in ICES Division VIa.

The shelf edge fishery

The anglerfish fishery in Division VIa is exploited mainly by UK and France, followed by Ireland. The Scottish fishery for anglerfish comprises two main fleets targeting mixed roundfish. The Scottish Light Trawl Fleet (<27 m) takes around 60% of landings and the Scottish Heavy Trawl Fleet (>27 m) over 20%. The development of a fishery targeting anglerfish has led to changes in the distribution of fishing effort: effort shifted away from traditional inshore roundfish fisheries to offshore areas and deeper waters. The expansion in area and depth range fished has been accompanied by the development of specific trawls and vessels to exploit the stock. There has been an almost linear increase in landings from Division VIa since the start of the anglerfish fishery until 1996 which has been followed by a very severe decline, suggesting that the previous increase was due to the expansion and increase in efficiency of the fishery (ICES, 2012).

The French vessels catching anglerfish may be targeting saithe and other demersal species or fishing in deep water for roundnose grenadier, blue ling or orange roughy. The Irish fleet which takes around 15–20% of the total Division VIa landings is a light trawl fleet targeting anglerfish, hake, megrim and other gadoids on the Stanton Bank and on the slope northwest of Ireland. This fleet uses a mesh size of 80 mm or greater. Spanish gillnetters and longliners, many of them operating under the UK flag, work along the shelf edge targeting anglerfish, hake and ling.

3. Ecosystem models

Ecopath with Ecosim (EwE)

Ecopath with Ecosim (EwE) is a production model used to analyse aquatic ecosystems. It combines software for ecosystem trophic mass balance analysis (Ecopath) with a dynamic modelling capability (Ecosim) (Christensen et al., 2005). The ecosystem as modelled is represented by functional groups (i), which can be composed of species, groups of species with ecological similarities or ontogenetic fractions of a species. Ecopath uses two equations to parameterize models: one for the energy balance of each group and one to describe the production (Christensen et al., 2005). EwE has been parameterised for the West of Scotland (area VIa) and used to study the implementation of ecosystem-based fisheries management (Heymans et al., 2011).

FishSUMS

FishSUMS (Speirs et al., 2010) is a length-structured partial ecosystem model in which the species of interest are modelled with full length structure from egg to adult together with a highly simplified representation of the rest of the ecosystem (hence the name partial ecosystem model) in three components: zooplankton, benthos and other fish. Unlike EwE, FishSUMS is not a production model but a mortality model: food requirements for growth,
maintenance and reproduction, together with a length-based prey preferences, are used to calculate predation mortalities on the prey. FishSUMS has originally been developed for the North Sea ecosystem (Speirs et al., 2010) and is currently being parameterised for the West of Scotland ecosystem by the Marine Population Modelling group of Strathclyde University.

Available data

Biological data

Fisheries data are available for commercial species managed by ICES such as in area VIa. These data include commercial data and scientific surveys data. From commercial data are obtained catches, landings and discards, both in weight and numbers. From surveys are obtained abundance indices, distribution, age-length keys, sex ratios and maturity estimates.

Stomach content data are extremely useful for ecosystem models parameterisation and are often unavailable due to the extensive sampling required to obtain them. Two sources of stomach data are available for the Celtic and Irish seas which encompass area VIa (Pinnegar, 2003). UK researchers collected stomachs for 66 species during annual groundfish surveys from 1986 to1994, while French researchers sampled stomachs of seven species aboard commercial fishing vessels from 1977 to 1992.

Physical data

Several temperature datasets covering area VIa are available. Gridded sea surface temperature (SST) datasets are derived from a combination of satellite and in-situ observations interpolated to provide global coverage. Such data are available for download from the National Oceanic and Atmospheric (NOAA) website at: http://www.emc.ncep.noaa.gov/research/cmb/sst_analysis/. Similar data exist also for salinity and can be accessed via: http://www.nodc.noaa.gov/General/salinity.html.

Locally, other datasets exist regarding area VIa. The ICES Annual Ocean Climate Status Summary (IAOCSS) provides long-term time-series for temperature and salinity anomalies from the Rockall Trough situated west of Britain and Ireland dating back to 1975. Long term oceanographic observations are available for Ellett Line and the Tiree Passage Mooring as well as a number of inshore recording stations (maintained by the Scottish Association for Marine Science http://www.sams.ac.uk/). A few temperature record datasets for inshore waters of the Scottish west coast are also available from Scottish monitoring stations located in Loch Maddy (North Uist), Loch Ewe, Mallaig and Millport. The Millport time series is the longest and goes back to 1953 while other datasets only go back to 1999. These datasets are available for download as daily averages from www.marine-scotland.ac.uk.

Production data

Global estimates of primary production based on estimated chlorophyll from remote sensing are available from the ocean productivity group at Oregon University (http://www.science.oregonstate.edu/ocean.productivity/).
The Continuous Plankton Recorder (CPR) also provides a measure of phytoplankton concentrations (Batten et al., 2003). The CPR is towed behind ships of opportunity and collects plankton samples which are subsequently analysed at the Sir Alister Hardy Foundation for Ocean Science (Plymouth, UK). In the northeast Atlantic the CPR has been operated since the 1940s and it now comprises the largest marine ecological monitoring dataset in existence.

Climatic indices

Several indices exist to quantify large-scale atmospheric circulation over the Northern Hemisphere such as the North Atlantic Oscillation (NAO) and the East Atlantic pattern (EA). NAO and EA data are

available for download on a monthly basis from:
ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/tele_index.nh.

Another mode of variability occurring in the North Atlantic Ocean is the Atlantic Multidecadal Oscillation (AMO). It is defined as sea surface temperature anomaly from detrended mean global warming value. Monthly means of this parameter are available from the Physical Science Division of NOAA (www.esrl.noaa.gov).

The Gulf Stream index (GSNW) is a measure of the latitudinal position of the north wall of the Gulf Stream where it breaks away from the east coast of North America. Positive values of this index are indicative of a displacement to the north of the long-term mean location of the Gulf Stream, while negative values indicate a southward movement (Nunn et al., 2007). GSNW data are available from the website of the Plymouth Marine Laboratory at www.pmlgulfstream.org.uk.

Ekman wind transport data in kg.m-1.s-1 in both north-south and east-west directions are available for the northeast Atlantic shelf. These datasets can be downloaded as 1ºx1º grids
On daily intervals at: www.las.pfeg.noaa.gov.

Other effects of human use of the ecosystem

NA

Comercial species and reference points

See point - The West of Scotland food-web

4. Socio-economic indicators (performance)

NA

5. Governance

NA

6. Conservation priorities

NA

7. Management priorities and possible scenarios (input from case study meetings).

Whitefish stock recovery

A major concern for stakeholders of the West of Scotland gadoid fisheries is the low biomass of the cod and whiting stocks. As a result, effort should be made to investigate what are the possible management strategies that would allow these stocks to recover.

Seal predation

One of the main hypotheses to explain decline in cod, haddock and whiting stocks is increased predation from grey seals (SCOS, 2008). It is well established that grey seal numbers around much of the British coastline, including the Inner and Outer Hebrides of Scotland, have been on the increase. Fishermen argue that the increased predation associated with this rise in seal numbers is sufficient to suppress fish stocks, and cod in particular. However, the real impact of seal populations of whitefish stocks remains to be quantified.

Bycatches of juvenile fish by the Nephrops fishery

In recent years the Nephrops fishery has become an increasingly important fishery for Scottish fleets. This fishery operates in areas that are important grounds for juvenile gadoids. Nephrops trawlers use a smaller mesh size than the 120 mm mandatory for cod targeted fisheries. As a result, bycatches of juvenile fish are important, and the Nephrops fishery discards large amounts of juvenile cod, haddock and whiting. This pressure on juvenile fish could be sufficient to impede future stock rebuilding (ICES, 2012). Stakeholders expressed interest towards investigating the effects of new selectivity from alternative Nephrops trawler gears on whitefish stocks.

Maximum economic yield

A major interest for stakeholders is the management strategy which would allow the Maximum Economic Yield (MEY) to be reached. Finding MEY requires investigating different combination of fishing mortalities applied to the species involved in the fishery to determine the multispecies MEY. Regarding the West coast of Scotland, MEY could be estimated, for example, by finding the optimum balance between the whitefish and Nephrops fisheries. Other potential issues to address include identifying the optimum fleet size which would allow maximising profit while sustaining employment.

Choke species

A choke species is a species with a relatively low quota compared to other commercial species of a mixed fishery which may, under a discard ban, lead to a premature closeure of the entire mixed fishery (Baudron & Fernandes, 2014). This management issue ought to be investigated for the West coast of Scotland fisheries in order to identify (i) what would be the choke species and (ii) what impact would it have on the fishery i.e. when would the fishery close and what are the associated losses.

Trawling impact on seabed

Trawl fishing is known to damage the seabed. This issue is of high importance in Division VIa which includes the Darwin Mounds, a globally unique site holding the coldwater coral *Lophelia pertusa*. Although located at 1000 m depth and 150 km northwest of the Outer Hebrides, these are susceptible to damage by trawling. In 2003, the Darwin Mounds were given emergency protection through the CFP which banned demersal fishing in that area. This protection was made permanent in August 2004. It is however unclear how the trawling impact on seabed can be included in an ecosystem model.

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Climate change

In addition to top-down explanations for low levels of cod, haddock and whiting abundance, climate change could also affect abundance bottom-up controls (Cook and Heath, 2005; Brunel and Boucher 2007; Heath and Lough 2007). Climate change is associated with changes in ocean currents and nutrient levels which in turns impact primary and secondary production. As gadoid larvae feed on phytoplankton and zooplankton, a change in production is likely to affect gadoid stocks recruitment

V. South West Waters case study(s)

The present CS encompasess an approach a two scales, a general analysis of trophic interaction between small cetaceans and fisheries in the ICES Divisions VIIIc and IXa and a strong focus on the connection between small pelagic and environments in the Gulf of Cádiz (IXa south) (Figure 5.1).The present document responds to this different intensity of analysis with an introduction to the physical, biological and socioeconomic environment in the Gulf of Cádiz and a more general description of the trophic interactions between small cetaceans and fisheries in the whole of the ICES Divisions VIIIc and IXa.

Figure 5.1. ICES Divisions VIIIc and IXa.

Subcase I: The Gulf Of Cádiz

1. Oceanography-water circulation pattern and environmental features

Overall Boundaries

The Gulf of Cádiz (Figure 5.2) is the basin that connects the North Atlantic Ocean and the Mediterranean Sea. The north, east and south boundaries of the basin are the Iberian Peninsula and Northwest African coasts whereas the west boundary is not well defined. The 9oW meridian running through Cape San Vicente would be a good choice for delimiting the Gulf of Cádiz to the west. Cape San Vicente is a sharp topographic feature where the shoreline changes orientation from north to east at almost right angle, separating the oceanographic regime west of Portugal from the more peculiar regime of the Gulf of Cádiz. The prominent cape Beddouzza, close to Cape San Vicente longitude, could be considered a nominal southern limit. In addition to Cape San Vicente, this area has two other noticeable capes, Santa María and Trafalgar. Cape Santa María is an abrupt break off where continental shelf hardly exists. The continental shelf extends offshore to depths of around 100 m where the shelf slopes down and the continental slope begins. It is divided by Cape Santa María in two different portions with distinct characteristics. West of the cape, the continental shelf is narrow (around 15 km), it is cut by the pronounced Portimao submarine canyon and there are hardly any inputs of continental freshwater. East of the cape, on the contrary, the shelf widens (around 50 km) and important rivers like Guadiana, Guadalquivir, Tinto and Odiel feed it with freshwater and other dissolved or suspended substances from the continent. East of Cape Trafalgar the shelf narrows again as the Gulf of Cádiz faces its eastern limit at the strait of Gibraltar.

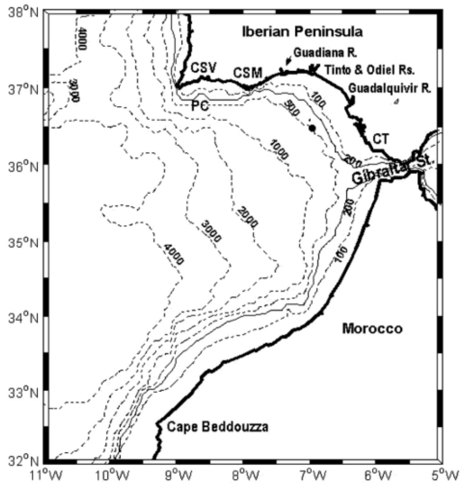

Figure 5.2. CSV, CSM and CT stands respectively for capes San Vicente, Santa María and Trafalgar. PC stands for Portimao Canyon.

Climate

Seasonality

In broad terms the climate in the Gulf of Cádiz follows the Mediterranean pattern with hot and dry summers and mild and rainy winters. Nevertheless, the Atlantic influence softens this pattern towards milder and less dry summer and more rainy winters. Figure 5.3 shows this seasonal signal for historical data (from 1971 to present) at the meteorological station in Jerez airport.

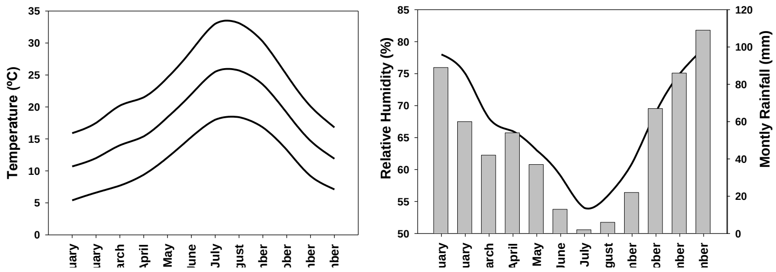

Figure 5.3. On the left are the climatological mean and the mean of maxima and minima monthly temperatures at Jerez airport. To the left the monthly rainfall (bars) and the mean of relative humidity (line).

Climatic oscillations

The mid-latitude and eastern Atlantic location of the Gulf of Cádiz makes this basin very sensitive to the North Atlantic Oscillation (NAO). NAO conditions the precipitation in the region (Figure 5.4) and, therefore, the river run off with its subsequent impacts on the circulation, fertilization and nursery dynamics of the basin.

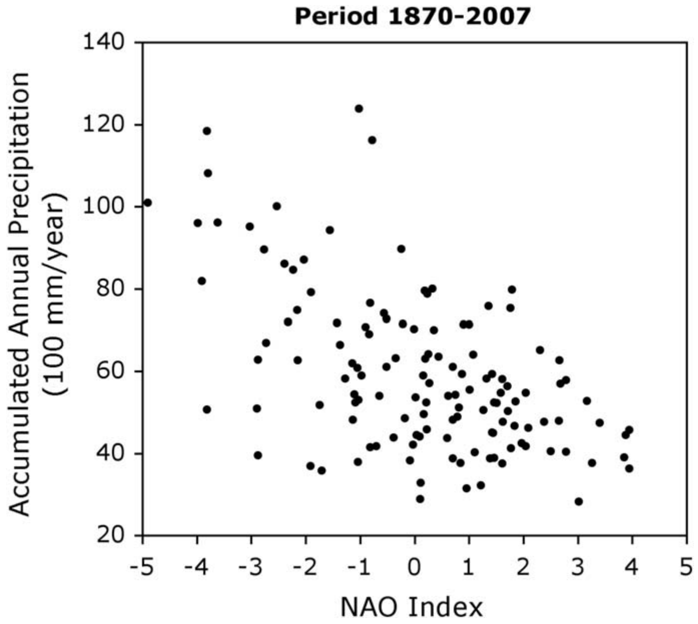

Figure 5.4. Relation between the NAO index and the annual accumulated precipitation (mm/year) in the area of the Gulf of Cadiz for the period 1870–2007. The precipitation data were registered in the Real Observatorio de la Armada (ROA), situated in San Fernando (Cadiz,Spain). From Prieto et al. (2009).

The Strait of Gibraltar influence

Wind regime at the Gulf of Cádiz seems less connected to NAO and more influenced by the local control exerted by the strait of Gibraltar. An increasing zonal component and stronger winds are observed as we approach the Strait as exemplified by the probability density of winds at the meteorological stations of Huelva and Cádiz (Figure 5.5). The magnifying effect of the strait on the wind regime is more clearly seen on the power spectra of the wind velocity (Figure 5.65). Wind variance in Huelva noticeably accumulates at annual frequencies, corresponding to the seasonal cycle, whereas variances at frequencies in the interval between 1 week and 1 month (synoptic winds) are much lower. In contrast, the seasonal cycle signal in Cadiz is lower compared to Huelva and the accumulated variance corresponding to synoptic winds is remarkably high. This amplified effect has a significant effect on the coastal circulation and production of the basin, particularly at the shelf east of Cape Santa María.

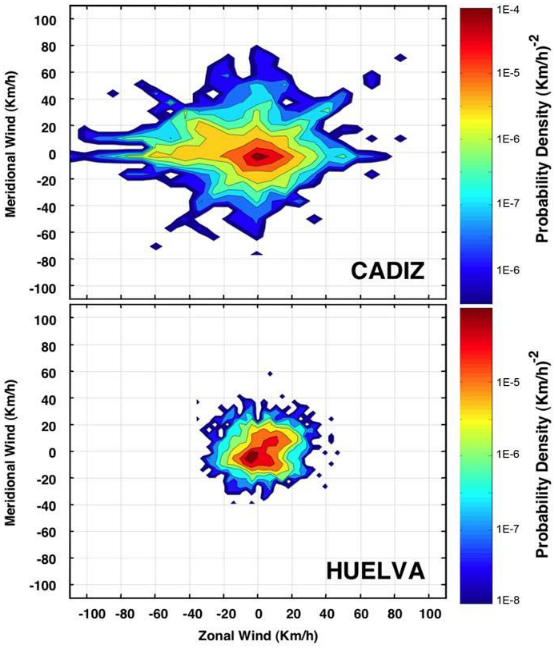

Figure 5.5. Probability density of winds at Cádiz and Huelva meteorological stations. Cádiz is located east of Huelva and much closer to the Strait of Gibraltar. From Prieto et al. (2009).

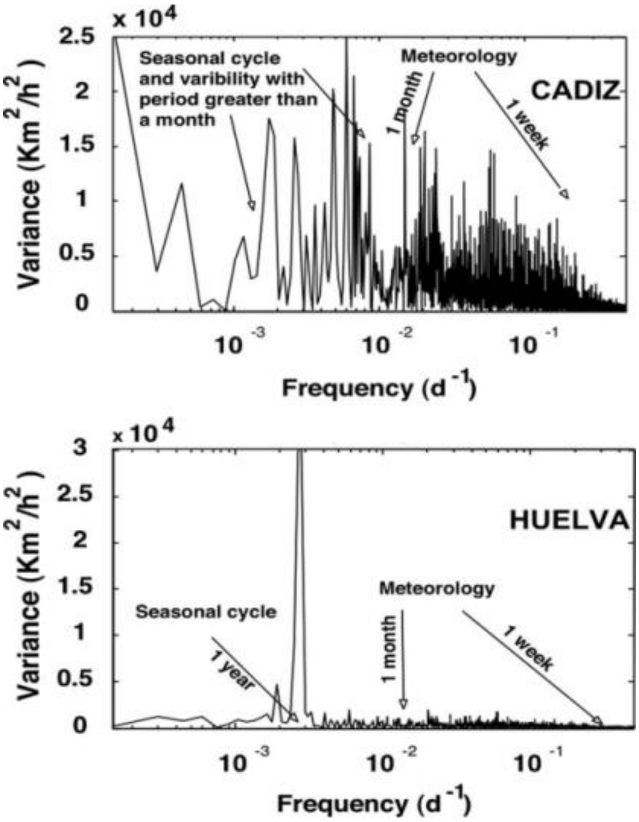

Figure 5.6. Power spectra for the distribution of variance in different time scales in the wind recorded at the Cadiz (upper) and Huelva (lower) meteorological stations. In both figures is displayed the different significance of seasonal versus synoptic (of days to weeks). From Prieto et al. (2009).

Bathymetry and substrates

Although the Gulf of Cádiz continental margin is located within the context of the eastern sector of the central North Atlantic (Figure 5.7), it shows unique morphological, structural and sedimentary features. The presence of unstable substrata and the predominance of along-shore processes have resulted in a distinctive broad slope and slope terrace morphology (Hernández-Molina et al., 2006). Following the overall highly dynamical nature of a basin that connects two seas (Atlantic and Mediterranean) and two continents (Africa and Europe), the sedimentary system has generated a highly heterogeneous and complex pattern as can be seen in Figure 5.8. A very singular feature of the Gulf of Cádiz bottoms is the abundance of mud volcanoes at the continental margin (Figure 5.9), that are receiving increasing environmental focus owing to the need for protecting such singular ecosystems from deep-sea trawling activities.

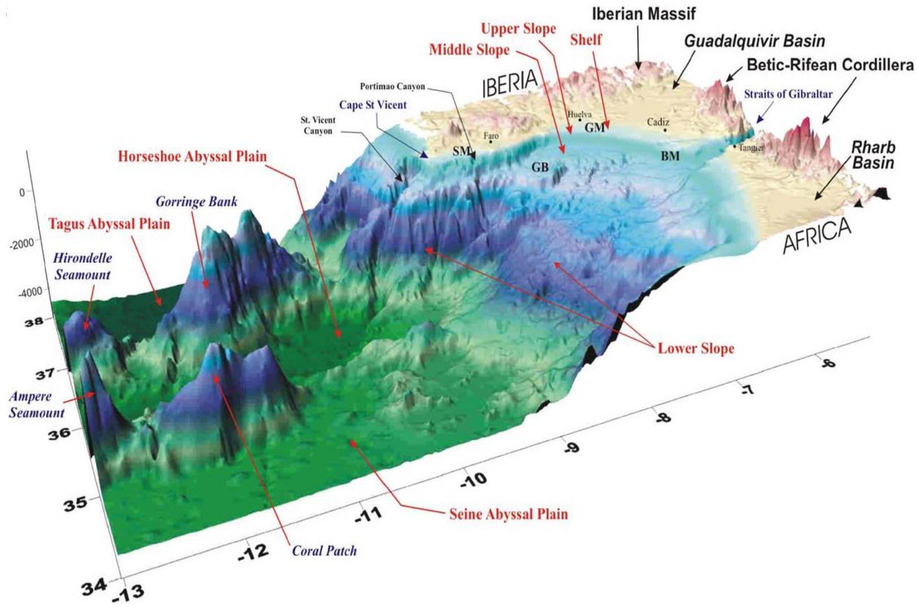

Figure 5.7. regional bathymetric map. Legend of the physiographic reference points, in alphabetical order: ASM = Ampere Seamount; BH = Barbate high; DSM = Dragon Seamount; GB = Guadalquivir Bank; JSM = Josephine Seamount; HSM = Hirondelle Seamount; LSM = Lion Seamount; MTR = Madeira Torre Rise; SSM = Sea Seamount; USM = Unicorn Seamount. Legend of the morphostructural zones: SM = Sudiberic Margin; GM = Guadalquivir Margin, BM = Betic domain Margin. From Hernández-Molina et al. (2006).

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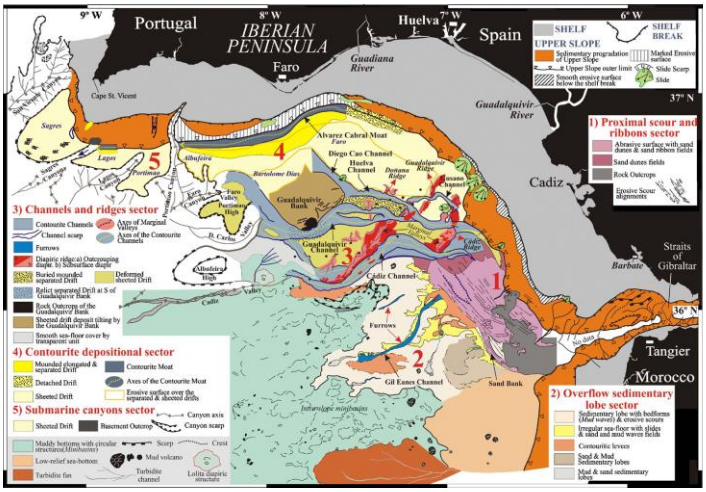

Figure 5.8. Morphosedimentary map of the Contourite Depositional System of the Gulf of Cádiz. From Hernández-Molina et al (2006).

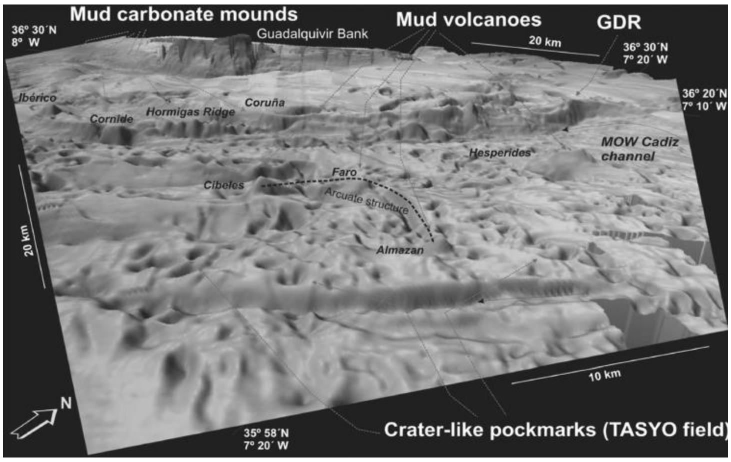

Figure 5.9. 3D multi-beam bathymetric image of the Gulf of Cádiz with structures related to gas seepages: numerous crater-like pockmarks, mud volcanoes and carbonate mounds. From Leon et al. (2006).

Hydrography and circulation

The surface circulation in the Gulf of Cádiz is affected by the seasonal fluctuations of the North Atlantic subtropical gyre. The size and position of this gyre follows the displacements of the Azores atmospheric high, which extends northwards in summer and reduces its size in winter. Following these fluctuations, the eastward-flowing Azores current flows at a latitude greater than the Gulf of Cádiz latitude when the North Atlantic subtropical gyre is large, whereas it is displaced to the south when the subtropical gyre diminishes the size. This seasonality is mirrored by the circulation along the eastern boundary of the mid-latitude North Atlantic. An example is the winter appearance of the Poleward Current flowing northwards at the surface along the Portuguese coast (Frouin et al., 1990; Haynes and Barton, 1990), which is replaced by the equatorward upwelling jet during the upwelling season from May to October (Wooster et al., 1976; Fiúza et al., 1982; Haynes et al., 1990; Peliz and Fiúza, 1999).

The Gulf of Cádiz circulation is sensitive to these large-scale variations. Relvas and Barton (2002) suggest that, when the upwelling jet formed in summer reaches Cape San Vicente, it spreads preferably to the east along the shelf break and slope of the northern part of the Gulf of Cádiz, providing a generalized anticyclonic circulation in the basin. Figure 5.10 shows an acoustic Doppler snapshot of this situation as diagnosed in May 2001 (García-Lafuente and Ruiz, 2007). The figure shows a pattern of the large scale circulation in the Gulf of Cádiz that seems to be anticyclonic in summer, a pattern that might switch to cyclonic in winter according to García-Lafuente and Ruiz (2007). As figure 5.10 already suggests this overall pattern is modified at its northern shelf by smaller (mesoscale) features generated by the influence of the capes and the run off of major rivers. The schematic circulation model for the area by García-Lafuente and Ruiz (2007) is shown in figure 5.11. It comprises the overall anticyclonic circulation of the basin plus two mesoscale cyclonic features at the shelf east and west of Cape Santa Maria.

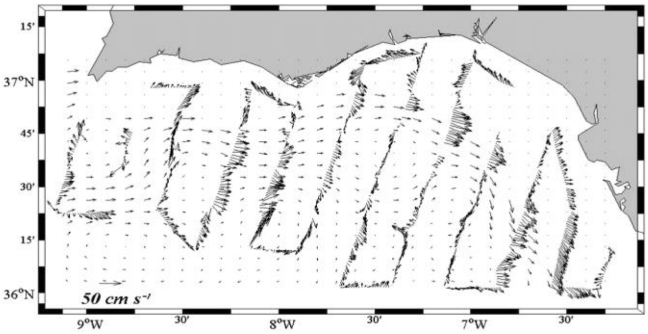

Figure 5.10. Summer overall circulation at the Gulf of Cádiz. Acoustic doppler current profiler (ADCP) velocities at 18 m depth during May 2001 (from García-Lafuente and Ruiz, 2007).

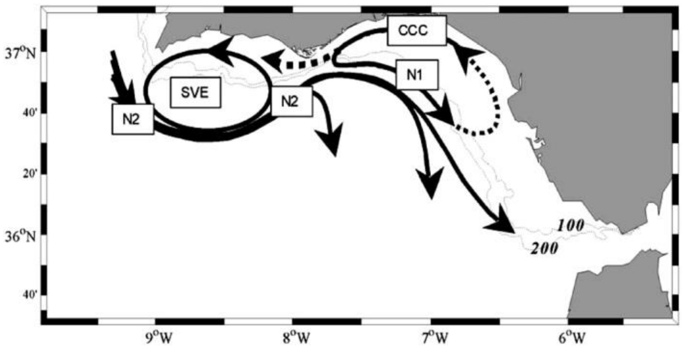

Figure 5.11. Schematic circulation features at the Gulf of Cádiz. N1 and N2 stand for eastward circulation currents whereas CCC and SVE for a coastal counter current and a cyclonic gyre. From García-Lafuente and Ruiz. (2007).

Physical Environment Sub-Regions

Both from a geographic and a circulation standpoint, the information presented above indicates two distinct sub regions in the northern shelf of the Gulf of Cadiz, delimited by the Cape of Santa María. The western shelf is narrow and dynamically controlled by features associated to the boundary current of the eastern Atlantic in its interaction with the Portuguese coast. The eastern shelf is wide and with a dynamics which is mainly connected to the impact exerted on it by the Guadiana and Guadalquivir rivers, the major freshwater sources at the southern Iberian Peninsula, discharges as well as heavily influenced by the strong winds nearby the Strait of Gibraltar. Both of these areas are under the influence of cyclonic gyres (isolated from each other by Cape Santa Maria) differentiated from the overall anticyclonic circulation of the basin.

2. Food- web description, key species, ecological functional groups and fleets

Food-web – general overview, main processes

Nutrients, Primary Production and Phytoplankton

An exhaustive regionalization of the Gulf of Cádiz through the use of color signals from SeaWiFS also differentiates these two shelf sections among the different eco-regions of the Gulf of Cádiz (Navarro and Ruiz, 2006). The different regions recognized by Empirical Orthogonal Decomposition of SeaWiFS data for the area identified a close connection between the physical forcings and the biological responses for the ecological units at the Gulf of Cádiz. The set of regions are presented in Figure 5.12. The open ocean (deep blue in Figure 5.12) occupies an area of a bathymetry deeper than 1000 m; thereby the topography factor is not expected to greatly influence the physical and biological features. It shows the occurrence of only one winter chlorophyll maxima in its monthly climatology (Figure 5.13). Shelf waters west of Cape Santa María (light blue in Figure 5.12) have temperatures and chlorophyll values that are remarkably different to the oceanic zone. Monthly thermal variations are not as smooth and anomalies are higher owing to the influence of oceanographic instabilities in a narrow shelf with a square angle shape (Figure 5.14). Minimum and maximum values of temperature are reached during the same months as in open waters although the magnitude of the maxima is lower. Thermal anomalies are particular high during summer time, when the presence of the upwelling in Cape San Vicente injects cold waters to the surface (Fiúza, 1983). Chlorophyll climatology has two maxima throughout the year. The first one in spring is related to the development of spring blooms in these latitudes (Navarro and Ruiz, 2006). However, the highest chlorophyll values are found for the second peak in summer. The fact that the highest chlorophyll concentrations occur in summer, when the radiation is maximal, indicates that this zone is not strongly limited by nutrients during this period of the annual cycle. Therefore, due to the upwelling occurring in the zone, nutrients do not limit the production during the months of maximum stratification and minimum production in the deep waters. Oceanographic instabilities associated to the sharp slope of Cape Santa María (traditionally known as the Huelva Front, green color in Figure 5.12). Monthly climatologies (Figure 5.15) result in a thermal regime whose maxima are intermediate between the values observed in deep waters and in Cape San Vicente area. Chlorophyll peaks in February, and a second maximum of a smaller intensity appears in September, although the

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interannual variability of the maximum in winter is very high. The shelf east of Cape Santa María (marked red in Figure 5.12) shows the highest climatological values of temperature of all the areas (August in Figure 5.16). In addition, it also shows the lowest temperature value compared to the other regions (January in Figure 5.16). In contrast to this large rage of variation, anomalies are comparatively low. Both elements evidence a persistent forcing connected with the influence exerted by land on these waters, mainly through Guadalquivir river estuary (Prieto et al., 2009). Guadalquivir influence is also very neat on the chlorophyll concentrations whose maxima are reached in April and have the highest records of all regions. A second phytoplankton bloom in fall coincides with the relaxation of thermal stratification in October. Chlorophyll anomalies are a high proportion of the average value of chlorophyll (>30%), which indicates a high interannual variability. This variability is tightly connected to Guadalquivir forcing as manifested by both the time coherence of chlorophyll and runoff signals (see for instance Navarro and Ruiz, 2006) as well as by the spatial distribution of nutrients in the shelf (Figure 5.17). Climatologies at Cape Trafalgar (marked yellow in Figure 5.12) are conditioned by vertical mixing nearby the Strait of Gibraltar where sharp changes of batimetry occur (García-Lafuente et al.,2007). Thermal and chlorophyll patterns are similar to the Huelva front or the shelf west of Cape Santa María whose climatologies are also driven by oceanographic instabilities (Figure 5.18).

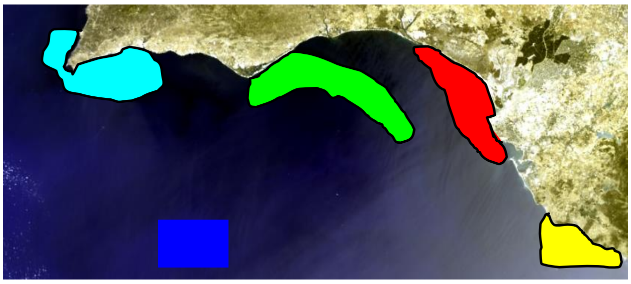

Figure 5.12. Gulf of Cadiz Eco-Regions. Regionalization based on EOF analysis of color satellite imagery (modified from Navarro and Ruiz, DSR-II 2006). Light blue: Cape San Vicente region. Green: Huelva Front region. Red: continental shelf under the Guadalquivir influence. Yellow: Cape Trafalgar region. Dark blue: open sea region. From Navarro and Ruiz (2006).

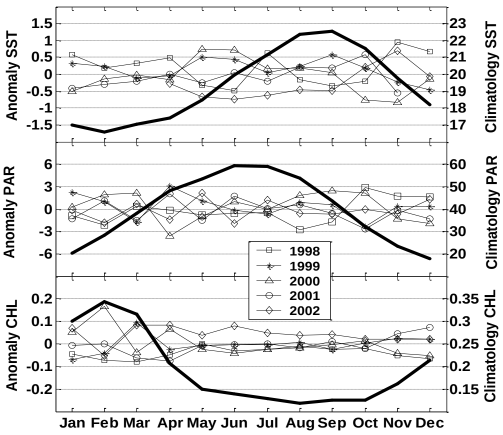

Figure 5.13. Monthly averages and anomalies of sea surface temperature (SST), photosynthetic available radiation (PAR) and satellite chlorophyll (CHL) for open ocean waters in the Gulf of Cádiz. From Navarro and Ruiz (2006).

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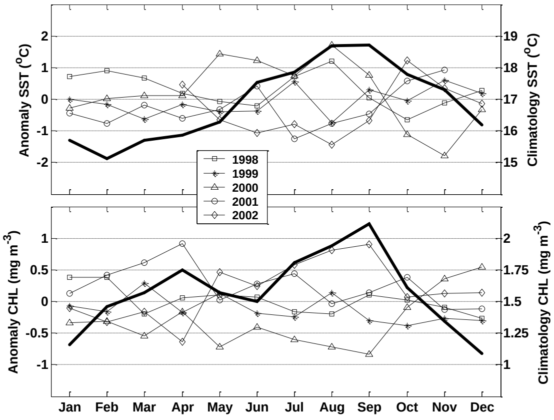

Figure 5.14. Monthly averages and anomalies of sea surface temperature (SST) and satellite chlorophyll (CHL) for the shelf west of Cape Santa Maria in the Gulf of Cádiz. From Navarro and Ruiz (2006).

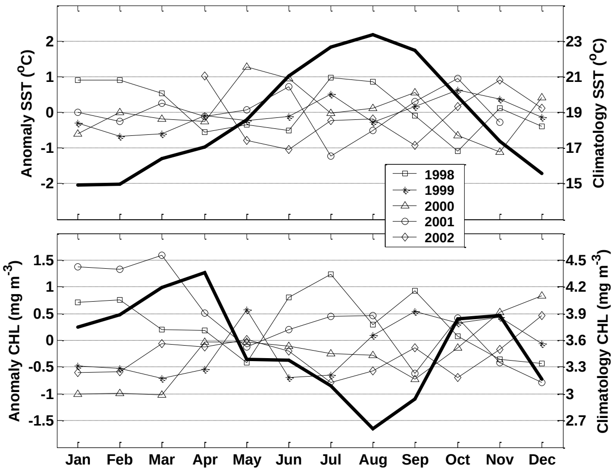

Figure 5.15. Monthly averages and anomalies of sea surface temperature (SST) and satellite chlorophyll (CHL) for slope waters (Huelva front) in the Gulf of Cádiz. From Navarro and Ruiz (2006).

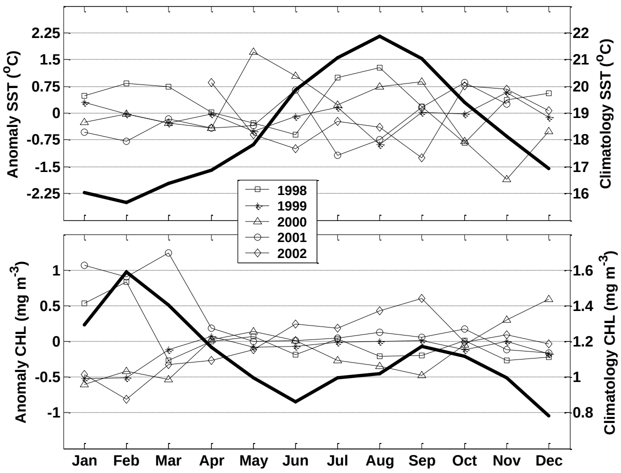

Figure 5.16. Monthly averages and anomalies of sea surface temperature (SST) and satellite chlorophyll (CHL) for the shelf east of Cape Santa Maria in the Gulf of Cádiz. From Navarro and Ruiz (2006).

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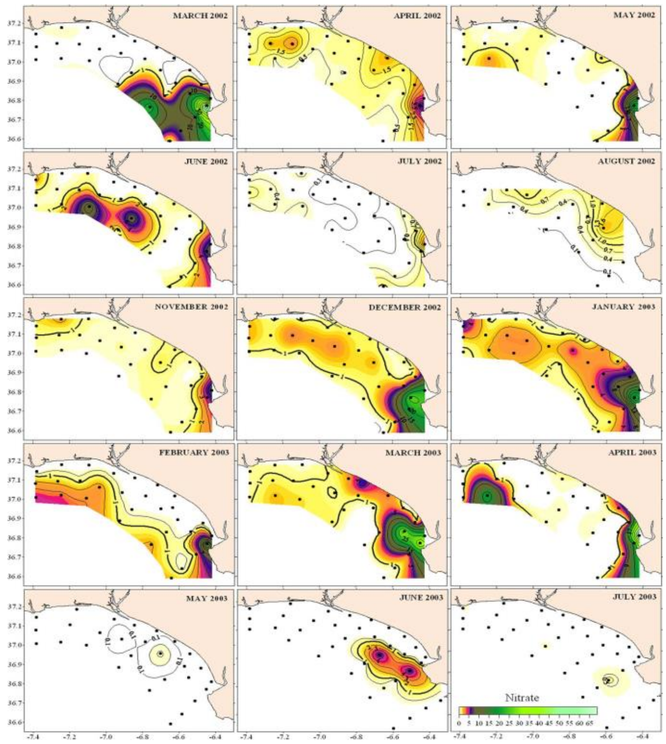

Figure 5.17. Spatial distribution of nutrients in the shelf west of Cape Santa María.

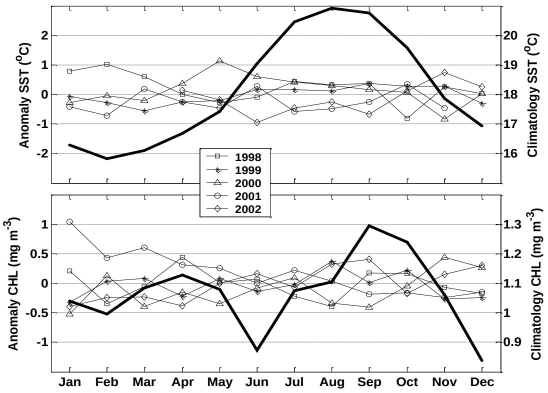

Figure 5.18. Monthly averages and anomalies of sea surface temperature (SST) and satellite chlorophyll (CHL) for Trafalgar shallows in the Gulf of Cádiz. From Navarro and Ruiz (2006).

Bacteria

Prieto et al. (1999) made a comparative analysis of bacterioplankton distribution in the Alboran Sea, Strait of Gibraltrar and GoC. They found higher bacterial abundance in productive regions while lower overall biomass was present in the open-ocean regions (Figure 5.19). In this work, a positive and significant correlation was found between bacterial abundance and chlorophyll concentration. Also, chemosynthetic bacteria have been reported to significantly contribute to the nutrition of deep-waters bivalves in the mud volcanoes of the Gulf of Cádiz (e.g., Rodrigues et al., 2010).

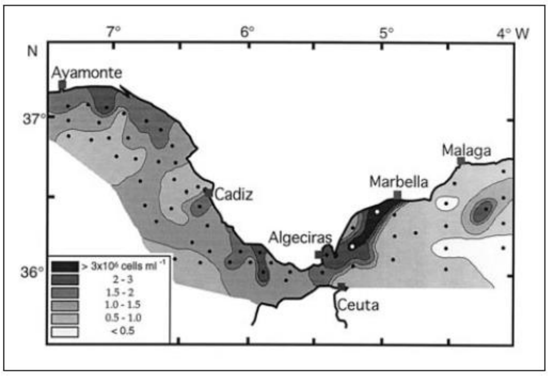

Figure 5.19. Bacterial abundances (x10^6 cells ml^{-1}) at the Deep Chlorophyll Maximum (From Prieto et al., 1999).

Zooplankton

Information on zooplankton in the Gulf of Cádiz is scarce. In the off-shore region, around the Josephine Bank (southwest off Portugal), one study on zooplankton by Vives (1970) considered that in June, the most abundant copepods species are *Calanushelgolandicus* and *Neocalanusgracilis* with the copepod community composed by around 122 species. The copepods perform vertical daily migrations and can be separated by two group of species, one group that usually lives above the 300 m depth and a second group that inhabit below the 500 m deep. The first group (e. g. *Calanushelgolandicus*, *Neocalanusgracilis*, *Euaetideusgiesbrechti*) usually ascends to the upper layers (100 m depth to surface) during the night whereas the second group (e.g. *Metridialucens*, *M. brevicauda*) do not rise above 300 m depth.

Another study on zooplankton by Vives (1972), performed during June and July that includes information on coastal and open-sea regions, has concluded that *Neocalanusgracilis*, *Nannocalanus minor* and *Calanushelgolandicus* are the most abundant copepods in that areas. He also analyzed the composition of the copepods community in the vicinity of Cape San Vincente and concluded that they are of mixed character. According to the Mediterranean water flow in the area, the composition of species are all typical from the Atlantic Ocean in the first 300 m of the water column, and never found in Mediterranean Sea, as e.g. *Chirudinastreetsi*, *Undenchaetaplumosa*, *Scaphocalanusechinatus*, *Metridialucens*, *M. venusta*, *Phyllopushelgae* and *Conacarapax*. Finally, it was considered that copepods populations in the area were mainly composed of neritic species.
The seasonal zooplankton abundance shows maximum abundances in July, August and September (Villa et al. ,1997, Figure 5.20).

The western entrance of the Strait of Gibraltar has been defined as a zooplankton 'hot-spot' by Macías et al. (2010). The primary production triggered by the mixing events and the redistribution of planktonic biomass by the concomitant mixing process create periodic accumulations of zooplankton biomass over the main sill of the Strait. Both, zooplankton community composition and size structure, seems to be controlled by the intense hydrological processes happening in this region.

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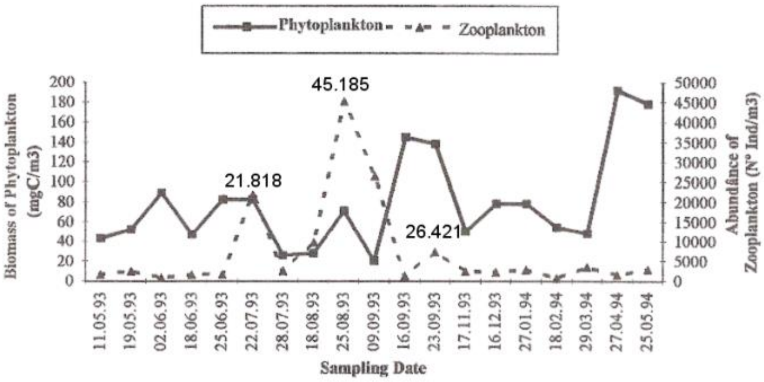


Figure 5.20. Seasonal variation of phytoplankton biomass and zooplankton abundance (from Villa et al. 1997) for the NW Gulf of Cádiz.

Fish

The analysis of 32 surveys from 1993 to 2010 (World Conference on Marine Biodiversity 2011; *Variations in the diversity of demersal fish species during the period 1993-2010 in the Gulf of Cadiz (SW Spain)*) of the trawlable bottoms of the shelf and upper-middle slope between 6º 20' W and 7º 20' W and from 15 m to 800 m depth identified for the area a total of 284 fish species belonging to 87 families. *Chondrichthyans* contributed with 43 species: 22 batoid species distributed between 4 families, with *Rajiidae* relatives being the most representative ones (15 species), and 21 selachian species, distributed between 6 families, especially outstanding *Squalidae* (12 species). In the Class *Actinopterygii* were identified 6 superorders, 19 orders, 79 families and 240 species. The most important families were *Sparidae* (23 species), *Myctophidae* (17), *Soleidae* (13) and *Gobiidae* (10).

This high diversity of fish assamblages was found by Catalan et al. (2006) to follow a strong spatial gradient related to depth, sediment type, and bottom temperature (all related to the distance from the Guadalquivir River mouth). These components were responsible for most of the explained variability in global values and demersal species structure. Theshallowest stations, also close to the Guadalquivir River mouth, showed higher numerical abundance and biomass valuesbut lower diversity and number of species. Typical or abundant species from those stations included fishes from the families Sparidae (particularly *Diplodusbellottii*), Haemulidae, Soleidae or the stomatopod *Squilla mantis*. Deeper stations were defined by higher relative densities of cephalopods and several pleuronectiform fish. Significant seasonal differences in the abundance of several species also were observed at most stations, mainly between summer and winter. Species like *Merlucciusmer luccius* were particularly abundant in winter, whereas *Arnoglossus laterna* was more abundant in summer

Small cetaceans

The Spanish Society for Marine Mamals has evidenced, through the Life program LIFE02NAT/E/8610, the presence of harbour porpoise (*Phocoena phocoena*) and the bottlenose dolphin (*Tursiopstrunctus*) in the north sector of the Gulf of Cádiz. Extensive observations have also been conducted in the context of their migration through the Strait of Gibraltar by the non-governmental organization CIRCE (http://www.circe.biz/). They evidence the significance of the Strait of Gibraltar as a migratory route as well as the threatens they face as a consequence of increasing marine traffic through the Strait. As an example, Figure 5.21 shows the great overlap between the density of fin and sperm whales (*Balaenopter aphysalus* and *Physetercatodon*) with the presence of large (cargo and ferry) vessels in the area nearby the Strait. These studies also point at the importance of the oceanographic singularities of the area for other marine mammals like killer whales (*Orcinus orca*) or common and stripped dolphins (*Delphinus delphis* and *Stenellacoeru leoalba*). These species are included in the Spanish National and the Andalusian Regional Catalogues of threaten species. In addition, bottlenose dolphin are in Annex II of the Habitat Directive whereas for killer whales both the International Union for the Conservation of Nature (IUCN) and the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS) consider this as a species under critical extinction threat.

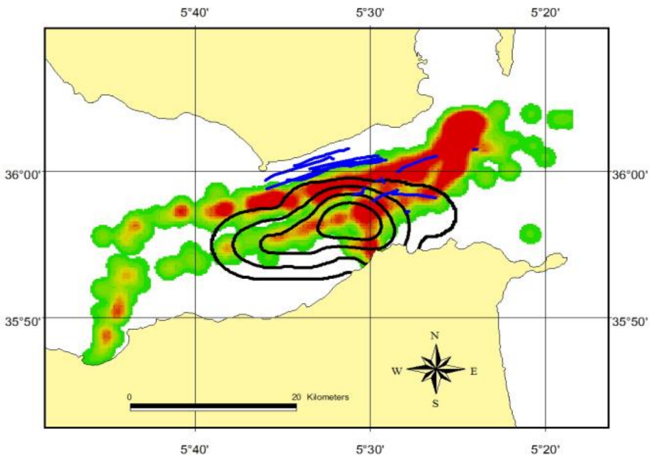


Figure 5.21. Sperm whale density (black lines) and fin whale observations (blue lines) overlapping with large vessels nearby the Strait of Gibraltar. Figure from CIRCE web page.

3. Ecosystem processes included in the model(s)

As explained above, the Gulf of Cádiz is a region of extremes in terms of its meteorology. The ecosystem processes triggered by easterly winds and rain are the main forcings of anchovy stock fluctuations (Ruiz et al., 2006).The neat transfer of these signals into recruitment fluctuations have facilitated the implementation of modeling tools (Ruiz et al., 2009) showing some predictive capacity with a time spam of several months ahead (Figure 5.22).

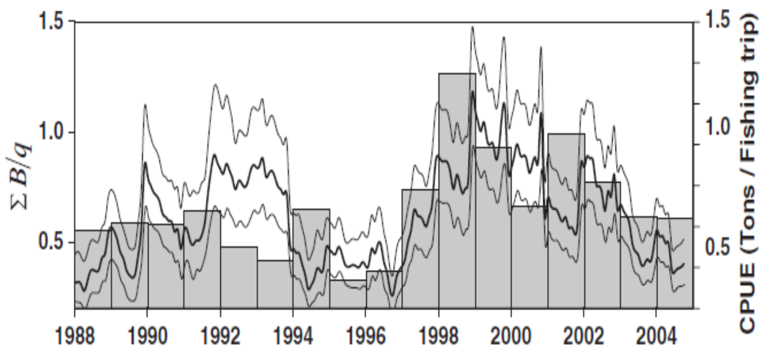


Figure 5.22. Predictive capacity of European anchovy recruitment at the Gulf of Cádiz. Bars are realized CPUE at a certain year and lines are $\sum B/q$, a proxy for CPUE. This proxy is estimated by a Bayesian model after assimilating all process and information controlling anchovy recruitment previous to the year when the prediction is made. From Ruiz et al. (2009).

The probabilistic structure of these previous models, they were constructed under the Bayesian approach, makes of Gadget a natural frame to make the present models to advance towards more evolved structures. They will include the physical component of the ecosystem since this is essential in this fishery but also the impact of the physical component in the interaction between the pelagic species (anchovy and sardine) that are the target for the pursue-seine fleet. As will be shown below, more than the trophic interactions with small cetaceans, during the first stakeholder meeting of the co-creation process these interactions were identified as the main concern of the fishery sector. Therefore, Gadget will be adapted to assimilate in its probabilistic frame the singularities of the two stocks (sardine and anchovy) as well as their interactions with the fishery sector and the environmental forcing, with small cetaceans having a lesser role than initially considered in the effort. Although not initially contemplated in the DoW for this particular CS, and to facilitate the within CS model inter-comparison of Work Package 4, alternative models to Gadget will be explored for the same porpoise. These will probably include either size-based representations of the community or the use of Bayesian frameworks with a more complex representation of the ecosystem,including the interactions of more than one single species with the environment and the fishery.

Commercial species and reference points

The Gulf of Cadiz is a highly suitable habitat for the reproduction of many commercially important marine species (e.g., Jiménez et al., 1998; Millán, 1999) being the Guadalquivir River a key player in providing suitable spawning and nursery conditions from many fish species (García-Isarch et al., 2003; Ruiz et al., 2006). The fisheries at the Gulf of Cadiz (included in ICES region IXa) have traditionally represented an important socio-economic activity for the coastal population of SW Spain. An important multispecies– multigear artisanal fishery exploits the coastal fringe of the Gulf (Sobrino et al., 1994; Silva et al., 2002), extending off-shore in the central region of the Gulf, between the Guadalquivir and Guadiana estuaries (Figure 5.23). Bottom trawling is forbidden at the first 10km offshore, which embraces a shallow area of a maximum depth of ca. 30 m.

Figure 5.23. Main fishing grounds (green areas) within the Gulf of Cádiz.

Table 5.1. Landings by species in the Gulf of Cádiz (year 2012).

Species	WEIGHT		VALUE
	(Kg.)	(% s/ total)	(Euros.)
Scomber colias	7,409,701	20.3%	3,536,869.57
Sardina pilchardus	6,099,521	16.7%	10,105,812.30
Engraulis encrasicolus	4,376,547	12.0%	11,327,942.69
Chamelea gallina	3,455,863	9.5%	7,760,527.78
Octopus vulgaris	3,223,132	8.8%	10,842,626.63
Merluccius senegalensis	2,738,629	7.5%	4,972,163.79
Parapenaeus longirostris	1,309,750	3.6%	11,372,371.71
Sepia officinalis	678,531	1.9%	3,198,846.89
Merluccius merluccius	589,961	1.6%	2,047,895.37
Trachurus trachurus	421,024	1.2%	424,250.66
TOTAL	**36,545,546**	**100.0%**	**94,778,569.35**

Species catches vary greatly in space and time in association with the highly diverse environmental traits encountered in the shelf and the species life cycles (Sobrino et al., 1994; Ramos et al., 1996). In addition to anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) as the species to focus in the modelling effort. No reference points have been set for the anchovy and sardine stocks (ICES, 2013). Some commercially important benthic and demersal species in the area include hake (*Merluccius merluccius*), several Sparidae, wedge sole (*Dicologoglossa cuneata*) cephalopods like octopus (*Octopus vulgaris*) or cuttlefish (*Sepia officinalis*), and crustaceans like *Squilla mantis* or *Melicertus kerathurus*. This fishery represents 49% of the total catches in the GoC region with hake and octopus as the main captured species.

Main fisheries (fleets/metiers), target species and catch composition , seasonality and main spatial patterns in the fisheries

Table 5.1 shows the species composition of the Andalusian regional government data compilation of landing in the Gulf of Cádiz for the year 2012 (http://ws128.juntadeandalucia.es/agriculturaypesca/portal/servicios/estadisticas/estadisticas/pesqueras/pescafres2012.html). It is manifest from the table the importance of pelagic fisheries in the landing, with *Scombercolias*, *Sardinapilchardus* and *Engraulisencrasicolus* at the top of the landings accounting in total for 49 % of the biomass fished in the region.

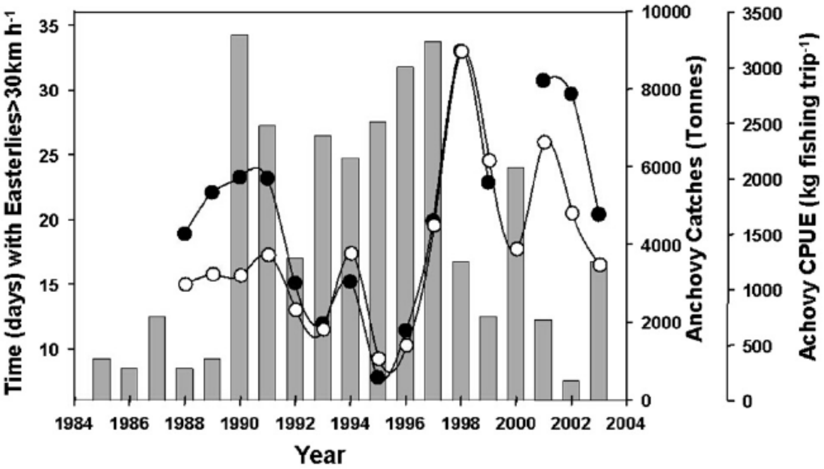


Figure 5.24 Anchovy catches (black circles) in the Gulf of Cádiz (sub-division IX.a South) and CPUE in Barbate by a single purpose pursue-seine fleet. Bars represent the cumulative sum of days from March to September with easterlies stronger than 30 km h^{-1} in Cádiz meteorological observatory. From Ruiz et al. (2006).

Although not first in the landing ranking, the main target species for the purse seine fleet to the east of Cape Santa María has traditionally been the European anchovy (*Engraulisencrasicolus*).This is the result of the traditionally high appreciation for this species in Spain. This is evident in Table I, where anchovy is second in the ranking and only surpassed by *Parapenauslongirostris* owing to the very high price per kilogram of this species. Being a short living species, anchovy recruitment and landing largely fluctuate with environmental variability (Nakata et al., 2000; Lloret et al., 2001; Erzini, 2005; Basilone et al., 2006). The sensitivity to the physical environment is particularly acute at the Gulf of Cádiz. The severe mortality imposed by the fishery impedes adults to survive from one year to the next. Without sustain of adults, the population totally relies on recruits to persist between years. Owing to the vulnerability that early stages have to ocean processes, the stock is, then, totally controlled in a BOTTOP fashion (mixed bottom-up and top-down; Ruiz et al., 2007) with the human pressure making the stock extremely exposed to environmental oscillations.

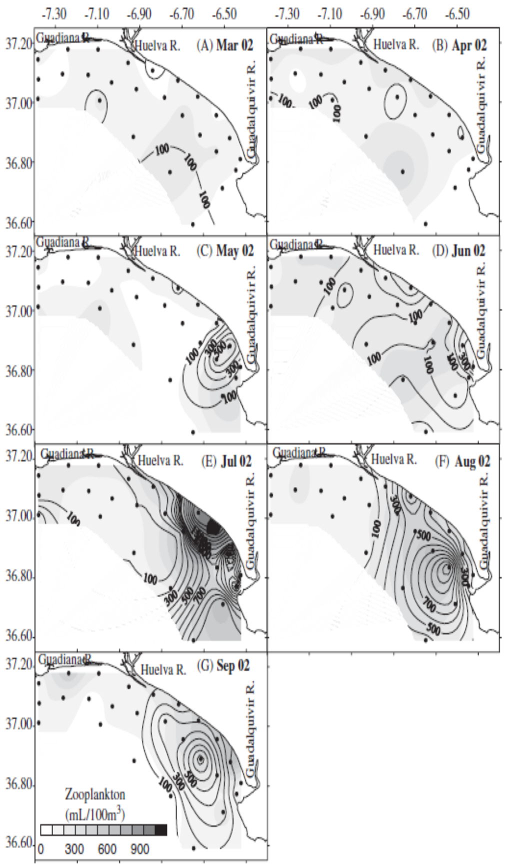


Figure 5.25 Anchovy larvae concentration (# larvae/100m³, contour lines) and zooplankton biovolume (ml/100m³) in the Gulf of Cádiz shelf to the east of Cape Santa María.

As shown above, bathymetry and coastline create a cyclonic circulation segregated from the energetic currents nearby the Strait of Gibraltar (Figure 5.11). Salt marshes and river input respectively heat and fertilize the shelf during summer, generating a large pool of warm and chlorophyll-rich water (Navarro and Ruiz, 2006; García-Lafuente and Ruiz, 2007) at that time of the year when the concentration of anchovy eggs and larvae is very high (see an example at Figure 5.24). Besides favourable conditions for planktonic stages, the shelf is connected to the lower reaches of the Guadalquivir River, a nursery area for post-larvae of anchovy (Baldó and Drake, 2002; Drake et al., 2007). Favourable conditions for anchovy recruitment are distorted under specific meteorological regimes at the southern Iberian Peninsula. Shelf currents are highly sensitive to the intense zonal winds nearby the Strait of Gibraltar (Figure 5.5). Persistent easterlies cause the offshore spilling of waters from the shelf through Capes Santa María and San Vicente (Relvas and Barton, 2002). Westward advection of fish larvae under this regime has been documented (Catalán et al., 2006a). In addition, latent heat fluxes during easterlies cool shelf waters and hamper anchovy spawning (Ruiz et al., 2006). As explained above, rain at the south of the Iberian Peninsula fertilizes the shelf through freshwater discharges from the Guadalquivir River (Navarro and Ruiz, 2006). A dam, 110 km upstream from Guadalquivir mouth, tightly regulates discharges, which are dramatically reduced during years of severe drought. Besides lowering the primary production of the shelf, the agriculture management of the dam during dry years modifies the seasonal pattern of discharges and negatively impacts the anchovy nursery within the estuary (Drake et al., 2002). Low recruitment under adverse meteorology, intense easterlies and low precipitation, can create stock collapses at the Gulf of Cádiz (see for instance Figure 25 for an example of dramatic collapse in mid-nineties).

4. Socio-economic indicators

The information of this section is extracted from the last socio-economic analysis performed by the Andalusian regional government on the fishery sector in that region (http://www.juntadeandalucia.es/agriculturaypesca/portal/servicios/estadisticas/estadisticas/pesqueras/valor_pesca_andalucia.html) for the year 2012 as well as from an specific report for the year 2010 (Galisteo-Delgado et al., 2011). Although these reports frequently aggregates the economic numbers for the Mediterranean and the Gulf of Cádiz, the later encompass the majority of the fishery economy in the Andalusian region so that they are a representative picture of his region. The fishery represents about 0.2% of a total GDP of more than 142 billion euros in the Andalusian region, with landings from regional grounds as the dominant driver of the fishery economy (Table 5.2).

The intermediate consumption was 64% at year 2009, with fuel as an important (35.3%) operational cost. In 2010 the fishery sector had 22583 employees; with a proportion of direct and indirect employment of 34.91% and 65.09% respectively (i.e. two indirect for each direct employee).Most of the direct employees (66.49%) are located in the Gulf of Cádiz. The economic numbers for landings from regional grounds show a stable or slightly decreasing tendency over recent years for all economic indicators (Table 5.3).

Table 5.2. Gross value added and proportion of GDP to the Andalusian region of the different sector of the fishery economy.

FISHERY SECTOR	GROSS VALUE ADDED 2012 (M€)	PROPORTION OF THE REGIONAL GDP
FRESH FISH AUCTION	76	0.05%
ALMADRABA	9	0.01%
FROZEN FISH	6	0.005%
AQUACULTURE	19	0.01%
FISH PROCESSING INDUSTRY	64	0.04%
WHOLESALE TRADE	118	0.08%
TOTAL	**292**	**0.20%**

Table 5.3. Evolution of economic indicators for landings at regional grounds in the Andalusian region.

YEAR	OUTPUT AT BASIC PRICE (M€)	GROSS VALUE ADDED 2012 (M€)	EMPLOYEE REMUNERATION	GROSS EXPLOITATION SURPLUS (M€)
2008	169	74	52	29
2009	158	76	53	28
2010	150	78	48	32
2011	159	76	49	25
2012	152	76	50	25

Table 5.4. Evolution of economic indicators for the pelagic fleet at regional grounds in the Andalusian region.

YEAR	OUTPUT AT BASIC PRICE (M€)	GROSS VALUE ADDED 2012 (M€)	EMPLOYEE REMUNERATION	GROSS EXPLOITATION SURPLUS (M€)
2006	34.00	21.56	19.31	3.19
2007	43.79	24.81	18.67	7.55
2008	39.89	22.96	20.32	4.71
2009	30.71	17.24	14.39	3.94
2010	30.19	18.72	13.22	5.39
2011	43.25	26.17	17.62	8.09
2012	39.79	25.09	17.26	7.51

The economic indicators for the pelagic fleet (Table 5.4) show strong inter-annual variations rather than the overall decreasing tendency for the whole of the fishery sector thus evidencing the consequences on the socioeconomic arena of the fluctuations forced by the environment in this fishery.

5. Governance and management rules enforced (fisheries management, MPA, others that can affect fisheries and ecosystem)

The higher economic value of the anchovy over other pelagic species has made of this the preferred target of pursue seine fleet in the region. The regulation of the stock is based in a quasi-fixed TAC (Figure 5.26). Owing to the strong fluctuations that the environment imposes over the stock, this kind of regulatory measures is prone to societal conflicts. As evident in the figure, the quota cannot be reached some years while in others it is surpasses thus triggering restrictive measures at the Commission level. The mismatch between regulatory measures and the underlying processes governing this fishery is a key issue to be focussed by the tools to be developed within the context of MareFrame. In addition to TAC, limitations to the size and a closure of the fishery during winter months are restrictions imposed by the regional government.

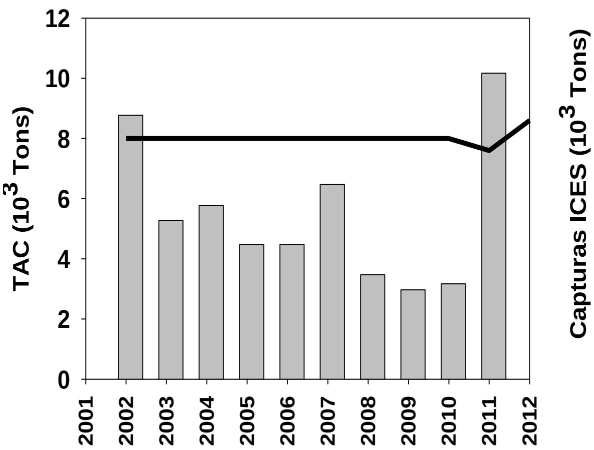


Figure 5.26 Landings and TAC for the anchovy stock in ICES IXa south.

In addition to TAC, there are other restrictions to fishery activities in the region. The value of the estuary of Guadalquivir River as a nursery ground for early stages of many commercial species brought the declaration of a fishery reserve in the area. Figure 5.27 shows the extension and the different protection levels (www.juntadeandalucia.es/agriculturaypesca/reservapesca).

Figure 5.27. Fishery protected areas nearby Guadalquivir (decresingrotection from A to D).

The estuary of Guadalquivir and the nearby coast of the Doñana National Park, a wetland considered a UNESCO-MAB Biosphere Reserve and World Heritage site. They are also SIC and IBA of the Natura 2000 network and environmental NGOs are increasingly suggesting that the sea surrounding Doñana should be declared as MPA.

6. Other effects of human use of the ecosystem - drivers

Fish at the Gulf of Cádiz critically depends on the interlink between the marshes-estuary of the Guadalquivr River and the inner shelf. These are is the nursery ground for a large number of commercial exploitable species (Baldo et al., 2006) and in particular for the anchovy stock (Ruiz et al, 2006). This natural habitat for the early stages of anchovy has, nevertheless, being highly modified by humans. The main historical driver of the habitat modifications was the pressure for agricultural land, leading to widespread drainage of the marshes and massive modifications in the fresh water regime. More than 80% of the original marsh surface, where juveniles are known to nurse, was transformed, representing one of the largest losses of marshes in Europe. In addition, the burgeoning agriculture demands led to a strong modification of fresh water inputs and the building of numerous reservoirs throughout the drainage basin. Fresh water inputs fertilize the estuary but have decreased by an average of 60% (from approximately 5000 hm^3/yr in 1931−1981 to 2000 hm^3/yr in 1981−2000) with a greater reduction in dry-years.

More recently the remaining marshes of the Doñana area were completely isolated from the estuary using dykes and floodgates (Contreras and Polo 2010). As a result of all these modifications, the estuary is now composed of a main channel with a few tidal creeks without any significant intertidal zones. This channel is periodically dredged from its mouth to where it accesses the Port of Seville in order to guarantee a minimum navigation depth of 6.5 m. The recent decision by the Port Authority of Seville to extend the program of dredging so as to significantly increase the depth of the navigational section of the estuary, triggered social alarm for the potential consequences of human actions on ecosystem services, including the provision of commercial fish.

7. Conservation priorities (protected habitats, species, etc.);

The high environmental value of the Doñana National Park and its sorrounding habitats is the constant focus of demands for protective measures. The societal sensitivity to these environments is much higher than the value the fishery sector can provide. As mentioned before, this territory is already a UNESCO-MAB Biosphere Reserve and a World Heritage site as well as SIC and IBA of the Natura 2000 network .There are increasing pressures from environmental NGOs to extend the presentvery high level of protection Doñana has to the shelf adjacent to its coast, being the presence there of small cetaceans one of the key supporting arguments. An increased protection and recovery of top predators may outcome in potential future pressures on the anchovy stock and possible negative synergies with environmental fluctuations.

8. Management priorities and possible scenarios (input from case study meetings).

The stakeholders attending the first meeting of the co-creation process included a variety of environmental and fishery actors as correspond to the singular characteristics of this CS. The elements identified above, increased habitat protections and the threat of dredging the Guadalquivir River estuary, emerged as priorities from the more environmental stakeholders. Less interest than expected was focussed on small cetaceans or other species conservation. The fishery sector made a very clear claim to MareFrame. They are perfectly aware of the intrinsic fluctuation nature of this fishery and that this has an imponderable environmental origin. They asked us to search for a tool to manage the fishery in a fashion that could help to smooth these strong fluctuations in favour of more stable incomes, including the alternance between anchovy and sardinein the catches of the pelagic fleet.

This is a very challenging request from stakeholders, and one not envisaged at the time of MareFrame writing but a natural consequence of the co-creation process this project has set up at its core. An initial feedback to stakeholders on this request was the possibility of exploring the design of an insurance scheme for the fishery (e.g. Mumford et al., 2009). The sector was particularly interested in the idea and willing to collaborate in the co-creation process of this particular idea.

Subcase II: fishery and small cetaceans in ICES VIIc and IXa

As explained above, this subcase focusses in a large-scale analysis of the interaction between small cetaceans and the fishery, with an environmental context already framed (in terms of climate and overall oceanography) in the text above or less relevant for this subcase. The text bellow thus focuses in sections two and subsequent of the reporting structure with fish (including hake as the main species in the fishery) and small cetaceans as the main target.

1. Biological diversity in the region

Biological diversity is high in the region in relation to the co-occurrence of sub-tropical, temperate and boreal species whose relative abundances follow latitudinal gradients (Sánchez et al, 2002), this increase in diversity is also important in the Cantabrian sea where several Mediterranean species are found increasing their presence in an eastern gradient, although these are more abundant in the littoral than in the shelf and also affects the invertebrate fauna (Sánchez, 1993). The main pelagic species are sardine, anchovy, mackerel, horse mackerel and blue whiting. To the south, chub mackerel (*Scomber japonicus), Me*diterranean horse mackerel (*Trachurus mediterraneus) and* blue jack mackerel (T*rachurus picturatus) are* common too. Seasonally, albacore (*Thunnus alalunga) occ*ur along the shelf break. The main commercial demersal fish species caught are hake, megrims, and anglerfishes; besides blue whiting is an important species in the catches, and also horse mackerel is an important target for these fleets. In the demersal habitats major elasmobranchs species are the rays (*Raja clavata and Raja montagui), an*d the catsharks (*Scyliorhinus canicula and Galeusmelastomus) at* the coast and on the inner and outer shelf respectively (Rodríguez-Cabello et al. 2004). Deeper, several deepwater sharks and chimaeroids are found (Sánchez and Serrano, 2003), and among the pelagic species only blue shark (*Prionace glauca) is* a target species for longliners operating in the area during the summer.

The study area is characterised by the high number of cetacean species. Twenty-four species have been recorded in the northern area (Galicia and the Cantabrian Sea), of which 8 can be considered common, five occasional and the remaining rare (MAGRAMA, 2012). In Portugal at least 13 species of cetaceans have been recorded (Brito et al, 2009) while in the Gulf of Cadiz area 12 species have been described (of which 7 are considered common and 5 occasional) (MAGRAMA, 2012). The most abundant species are the common dolphin (*Delphinus delphis*), the striped dolphin (*Stenella coeruleoalba*), the bottlenose dolphin (*Tursiops truncatus*), the harbour porpoise (*Phocoena phocoena*), the long finned pilot whale (*Globicephala melas*), the Risso´s dolphins (*Grampus griseus*) and the fin whale (*Balaenoptera physalus*). (e.g. López et al., 2002, 2004; Ruano et al., 2007; Covelo et al., 2008; SCANS-II, 2008; Brito et al., 2009; Pierce et al., 2010; MAGRAMA, 2012).

The common dolphin is frequently sighted both in offshore and shelf waters (Pierce et al., 2010; Spyrakos et al., 2011). Striped dolphin is considered an oceanic species (e.g. Aguilar, 1997; Brito et al., 2009, Llavona et al., 2011) because more sightings of this species have been recorded in oceanic waters. Bottlenose dolphins are the most frequently sighted cetacean in coastal waters in the region (e.g. López et al., 2004; Covelo et al., 2008; Pierce et al., 2010). In addition, there is a resident population of bottlenose dolphins in the southern Galician Rías (López et al., 2002; 2004). The harbour porpoise is another coastal species with most sighting recorded in shallow waters of Northwest Spain and Portugal (e.g. López et al., 2004; Ruano et al., 2007; Covelo et al., 2008; Brito et al., 2009; Pierce et al., 2010).

2. Trophic web description

There are strong relationships between the pelagic, demersal and benthic domains (Sánchez and Olaso, 2004). Zooplankton and small pelagic fish play an important role in the energy transfer from primary production to upper trophic levels. Abundant macrozooplankton (mainly euphausiids and mysids) are available to pelagic and small demersal fish species (mackerel, horse mackerel, blue whiting, Gadiculus argenteus, Capros aper).

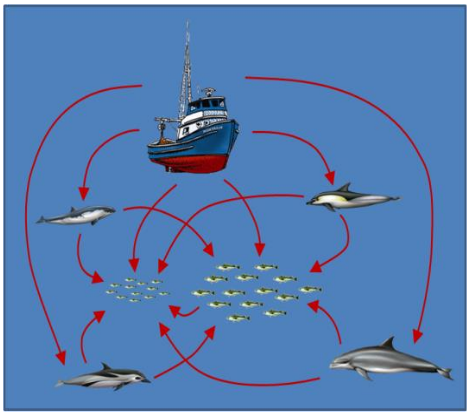
Small pelagics like blue whiting or sardine (Silva et al., 1997; Olaso et al., 1998) are an important part of the diet for some demersal fish species, cephalopods and marine mammals (Rasero et al., 1996; Santos et al., 2013b; Velasco and Olaso, 1998a,b; Preciado et al., 2008). Blue whiting is one of the most important prey for the trophic relationships between nekton and demersal communities in the southern Bay of Biscay. This is a consequence of three factors: (1) its high abundance (Sánchez et al., 2002); (2) its wide spatial and bathymetric distribution that extend from mid-shelf to the continental shelf-break (Carrera et al., 2001), and (3) its vertical migrations (Schoene, 1978; Stensholt et al., 2002). This role as prey for the demersal fish community together with its position in the marine food web as a consumer of zooplankton (mainly euphausiids and mysids) makes of blue whiting a key species in the ecosystem of the Cantabrian Sea. Hake is the most important demersal fish predator consuming pelagic fish. This is probably be related to their high motility and vertical migrations (Velasco and Olaso, 1998a, 1998b) in contrast to other specialized ichthyophagous fish.

Sardine, hake, blue whiting, anchovy, mackerel and horse mackerel have all been found in the diet of cetacean and fish species. In general, these species have a more benthophagous diet in the younger stages, changing later to more demersal and semipelagic diets, with an increase in the number and size of prey (Velasco and Olaso, 1998a and 1998b; Preciado et al. 2008). Regarding possible changes in the trophic structure, Velasco et al. (2003a) studied the prey variability of the demersal fish in the Cantabrian Sea and found no clear trends (throughout the 1990s) in the trophic level (TL) of the main fish predators. However, the decadal evolution of TL shows a clear association between years with high upwelling indices and an increase in the TL of many predators.

The diet of small cetaceans has been described from the stomach contents of animals stranded and by-caught in Galicia (NWS pain), Asturias and Portugal (Silva, 1999; Arronte et al., 2008, 2009; Santos et al.,2007, 2013a, 2013b; Santos, unpub.; Sollmann, unpub.). Results from these studies indicate that sardine was the main prey (in terms of reconstructed prey biomass) of common dolphins stranded and by-caught in Portugal and second in importance (after blue whiting, M. poutassou) in the stomachs of the Galician common dolphins. For striped dolphins, a sample of 47 animals in Galicia between 1994 and 2009 shows a diet based on blue whiting, ommastrephid squid and Trachurus spp. (Santos, unpub.). In Asturias, dietary information from a sample of 19 non-empty stomachs stranded in Asturias (northern Spain) between 1994 and 2004 show again blue whiting as the main prey, followed by the oceanic squid Gonatus (Arronte et al., 2008). Santos et al. (2007) reported blue whiting and hake to be the main prey of bottlenose dolphins after examination of a sample of 82 non-empty stomachs stranded in Galicia between 1990 and 2005. The same two main prey species were reported by Arronte et al. (2009) in a sample of 8 non-empty stomachs from bottlenose dolphins stranded in Asturias. For harbour porpoises, Trisopterus spp., blue whiting and Trachurus sp are the main prey identified from a sample of 56 individuals stranded and by-caught in Galicia between 1991 and 2010 (Read et al., 2012). No other dietary studies are available in the study area.

Multispecies model functional groups

Based on the elements described above, the ecosystem model proposed considers four main functional groups: on the top there is the fishing fleet; then the small cetaceans, then the hake and finally the small pelagic like blue whiting or sardine. The fleet acts over the other three groups; the small cetaceans predate on hake and small pelagic and finally the hake predates small pelagic.
However, to implement this model, information on population size, diet and energetic requirements or food consumption are still needed to integrate cetaceans into multispecies models. Estimates of small cetacean abundance off the Iberian Peninsula are available from the dedicated survey SCANS-II (Small Cetaceans Abundance in the North Sea and adjacent waters) carried out in 2005 that produced estimates of abundance for the most common cetacean species in shelf waters of the NE Atlantic (SCANS-II, 2008). Dietary information has been made available by the examination of the stomach contents described above. For data on energy requirements, some estimates have been published for cetaceans, based on energetic requirements or food consumption of captive animals or previously published empirical relationships between body weight and basal or resting metabolic rate (see for example Innes et al., 1987; Kastelein et al., 2000; Lockyer, 2007).



Commercial species and reference points

The Southern **European hake** stock occupies the Atlantic area of the Iberian peninsula. Hake is a demersal and benthopelagic species, found mainly between 70 and 370 m depth. The maximum length and weight of this medium-large gadoid species are about 140 cm and 15 kg, respectively. It is evaluated by ICES with length based methods (ICES, 2013). Hake is a highly ichthyophagous species. Euphausiids and decapod prawns are an important part of its diet for smaller hake (> 20 cm). Its diet at >30 cm is mainly composed mainly of blue whiting, but also of horse mackerel and clupeids. European hake presents indeterminate fecundity and asynchronous development of the oocytes (Murua et al., 1998; Domínguez-Petit, 2007; Mehault et al., 2010). It is a serial or batch spawner. Adults breed when water temperatures reach 10º or 12ºC, Hake recruitment indices have been related to environmental factors (Sanchez and Gil, 2000). High recruitments occur during intermediate oceanographic scenarios and decreasing recruitment is observed in extreme situations. Following ICES (2013) advice, fishing mortality has decreased in recent years but is well above the FMSY in 2012 (0.24). SSB has increased since 1998 and is above the average in 2012. Most recruitments since 2005 have been above the historical mean.

The Iberian sardine (*Sardina pilchardus*) is a small pelagic fish with short life span, fast growth, high fecundity and a long spawning season (e.g. Carrera and Porteiro, 2003; Stratoudakis et al. 2007). The Iberian sardine is considered to be a single stock from the Strait of Gibraltar to the border between France and Spain (ICES, 2010). Although some degree of exchange is likely to occur with other sardine populations outside the stock boundaries, there is currently no evidence that this substantially influences stock dynamics (ICES, 2010). The Iberian stock has been assessed annually since 1978 by ICES using data on Portuguese and Spanish landings and information from fishery-independent acoustic and Daily Egg Production Method surveys. ICES (2013) indicates that the biomass of age 1 and older fish has decreased since 2006 with 2012 biomass was 64% below the long-term average and that recruitment has been below the long-term average since 2005. Fishing mortality fluctuated without a clear trend, in 2010–2011 it was well above the long-term average but decreased 33% from 2011 to 2012. No reference points have been set for this stock.
The Blue whiting is a pelagic planktivorous gadoid. It is widely distributed species. The stock definition comprised all the Atlantic area of Europe. Their depth distribution ranges from 200 to 600 m. Spawning takes place in late winter and early spring west of the British Isles. Juveniles are also widely distributed being present in the Bay of Biscay and Iberian waters where trawlers fish them.

Main fisheries (fleets/metiers), target species and catch composition

Fisheries in the Iberian Peninsula (ICES divisions VIIIc and IXa) are mainly mixed fishery targeting pelagic and demersal species by the Spanish and Portuguese fleets (trawls, gillnetters, longliners and artisanal fleets). Main target species are hake, blue whiting and sardine. The Spanish fleet is mainly composed of trawlers (pair and otter trawlers), gillnetters, long-liners, purse seiners and artisanal fleet. Main target species are hake, anglerfishes, megrims, Norway lobster, blue whiting, horse mackerel, mackerel, sardine and anchovy. The artisanal fleet is very heterogeneous and uses a wide variety of gears; traps, large and small gillnet, long lines, etc. Portuguese fleet is composed of trawl, artisanal and purse seiners. It is a mixed fishery targeting hake, mackerel, anglerfish, megrim, mackerel, Spanish mackerel, blue whiting, red shrimp, rose shrimp and Norway lobster.

3. Governance and management rules enforced

Main global regulations implemented in the area are the Common Fishery Policy (CFP) and Marine Strategy Framework Directive (MSFD). Fisheries management in area is driven by EU through the CFP. Catch restrictions for the Bay of Biscay are recommended on the basis of scientific advice (ICES, STECF). Total Allowable Catches (TACs) are shared between Portugal and Spain for several species (e.g. sardine, megrims, hake, etc) for stocks occurring in ICES Sub-Areas VIIIc and IXa. Effort limitations have also been enforced since 2005. Technical measures are implemented through member states regulations. These technical measures include minimum landing size for most species, marine protected areas, mesh regulations, etc

Hake is managed by TAC, effort control and technical measures. A Recovery Plan for southern hake was enacted in 2006 (CE 2166/2005). This plan aims to rebuild the stock to within safe biological limits by decreasing fishing mortality a maximum of 10% at year with a TAC constrain of 15%. This regulation includes effort management in addition to TAC measures, set in Reg. EU Council 39/2013 (annex II-b). Technical measures applied to this stock include: (i) minimum landing size of 27 cm, (ii) protected areas, and (iii) minimum mesh size. These measures are set depending on areas and gears by several national regulations. A management plan was agreed for Blue Whiting in December 2005.

This management agreement aims to maintain the blue whiting stock at levels above 1.5 million tonnes (Blim) and the fishing mortality rates at levels of no more than 0.32 (Fpa). To achieve this, the TAC is reduced by at least 100,000 ton/year until the fishing mortality is reduced to 0.32 (Fpa). The plan states that, if Blim<2.25 million ton, actions to obtain a safe and rapid recovery to this level should be taken. There is a management plan for sardine under discussion. There is not an international TAC for this stock. Sardine is managed by Portugal and Spain through minimum landing size, maximum daily catch, days fishing limitations, and closed areas.

The Spanish Ley de Protección del Patrimonio Natural y la Biodiversidad (42/2007) cites the bottlenose dolphin and the harbor porpoise in annex II as "animal and plant species of Community interest whose conservation requires the designation of special areas of conservation" and cites all cetaceans in annex V as "animal and plant species of Community interest in need of strict protection". Law 42/2007 also created the figure of Marine Protected Area (MPA) as one of the categories of protected natural spaces and created the list of "Wild species under Special Protection" where the Spanish Catalogue of Threatened Species is included. The Real Decreto 139/2011 develops the Wild species under Special Protection list and the Spanish Catalogue of Threatened Species that includes a total of 27 cetacean species. The Spanish Ley de Proteccion del Medio Marino (41/2010), represents the transposition to the Spanish law of Directiva 2008/56/CE (The Marine Strategy Framework Directive). The Real Decreto 1727/2007 specifically establishes measures for the protection of cetaceans by incorporating general protection measures and specific measures for activities such as whale watching. Spain and Portugal are signatories to ACCOBAMS (Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area), the Berne Convention on the Conservation of European Wildlife and Natural Habitats (1979), the Bonn Convention on the Conservation of Migratory Species of Wild Animals (1979), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973) and the International Whaling Commission. In addition, Spain is also a signatory to the Barcelona Convention for the protection of the Mediterranean Sea.

VI. Mediterranean Waters - Strait of Sicily case study

1. Oceanography-water circulation pattern and environmental features

General description of the ecosystem

The Mediterranean Sea is the largest semi-enclosed basin in the world, featured by high biodiversity, habitat heterogeneity and heavy human pressure on the coastal system. The basin is subdivided into several regional seas (Fig. 6.1) based on bathymetric and morphological considerations (Bianchi and Morri, 2002, Spalding, 2007). Peculiar physical processes create a dynamic and complex system in which mesoscale, thermohaline and wind driven circulations interact at different scales, resulting in a dominant west to east surface transport partially compensated by east to west transport at intermediate depths (Pinardi and Masetti, 2000). The Strait of Sicily separates the western and eastern Mediterranean sub-basins and includes the Sicilian and Tunisian shelves. It is featured by a high primary productivity with high values of biodiversity due to the moderate depths, geographical location, peculiar hydrography and the variety of habitat types.

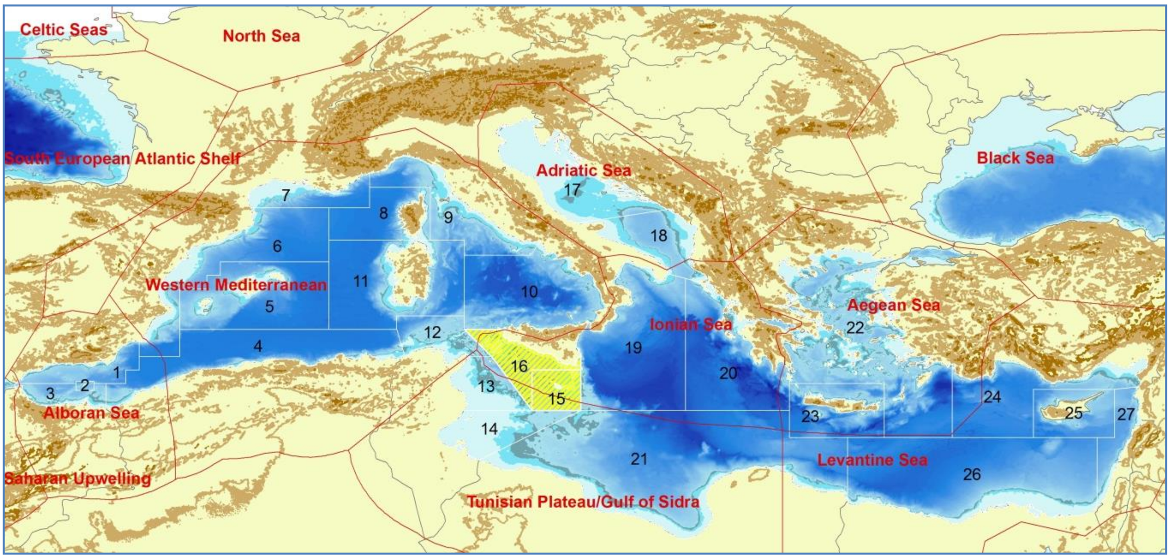


Figure 6.1. Map of Mediterranean showing the boundaries of ecoregions (red lines) according to Spalding et al. (2007), FAO-GFCM geographical sub-areas (white lines) and the case study area (yellow boxes).

The case study area corresponds to the North sector of the Strait of Sicily (Fig. 6.1) and includes the FAO-GFCM geographical sub-areas (GSAs) 15 (Malta Island) and 16 (South of Sicily). Prominent features include deep coral assemblages, cold seep communities, coralligenous habitats, rare or endemic species (such as Maltese ray), high habitat heterogeneity, spawning and nursery grounds for large pelagic fish (i.e. bluefin tuna and sword fish), persistent hotspots of diversity of demersal species, and large fluxes of Atlantic and Indo-Pacific exotic species. Most important human uses of the area are fishing, aquaculture, conservation, shipping and tourism. Other important uses are oil drilling and extraction, deployment of gas pipelines and communication cables, and construction of wind-mill farms (see MESMA project, http://www.mesma.org/default.asp?ZNT=S0T1O735P854).
The area includes the south coasts of Sicily and the Maltese waters within the FAO 37.2.2 statistical
From a biogeographic point of view the Strait of Sicily is traditionally considered as the boundary between western and eastern Mediterranean basins. A different picture was suggested by Giaccone & Sortino (1974) who, working on the algal flora, established the boundary between the western and the eastern Mediterranean in the middle of the Straits of Sicily, so that the island of Pantelleria should belong to the western Mediterranean, whereas the Pelagie islands (Lampedusa and Linosa) and Malta should belong to the eastern Mediterranean (Bianchi, 2007). In any case the nature of transitional area of the Strait of Sicily between the East and West basins is not only due to its physical position but also related to the temperature gradient across the Mediterranean with the 15 °C isotherm for February crossing the Strait of Sicily (Bianchi, 2007).

The circulation in the Strait of Sicily (SS) plays an important part of the Mediterranean thermohaline circulation (Bethoux, 1979; Astraldi et al., 1999) and is characterized by a highly dynamic circulation system that exchanges water masses between the eastern and western sub-basins. The Mediterranean ThermoHaline Circulation (MTHC) is driven by heat and water losses at the sea surface (Wüst 1961) and features an anti-estuarine circulation with fresh and warm water Atlantic Water (AW) getting into the Mediterranean Sea across the Gibraltar Strait and flowing eastward at the surface (top 200m) and saltier and colder deep Eastern Mediterranean Outflow Water (EOW), mainly composed of Levantine Intermediate Water (LIW) flowing in the opposite direction. The AW

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 613571

splits into two branches at the entrance of the Sicilian strait, one flowing into the Tyrrhenian Sea, the other into the strait. The second branch is composed by two streams, the Atlantic Ionian Stream (AIS) and the Atlantic Tunisian Current (ATC). In winter, the ATC is more pronounced. In summer, the AIS is associated with a number of well-known semi- permanent features in particular with two large cyclonic vortexes; the first one lies over the Adventure Bank and the second, over the Malta shelf, off Cape Passero (Fig. 6.2).

The circulation is driven both by Mediterranean general circulation features and local atmospheric fluxes and involves interactions of several water masses leading to substantial variability in time and space (Manzella et al., 1990; Robinson et al., 1999). For both the AIS and LIW, the averaged kinetic variability has been observed 2 to 4 times higher in winter than in summer, in response to stronger wind stress and reduced stratification (Grancini and Michelato, 1987; Manzella et al., 1988, 1990; Onken and Sellschopp, 1998). The hydrographic properties of the AIS are also known to undergo significant seasonal variations, but those of the LIW are more constant (Manzella et al., 1990; Moretti et al., 1993).

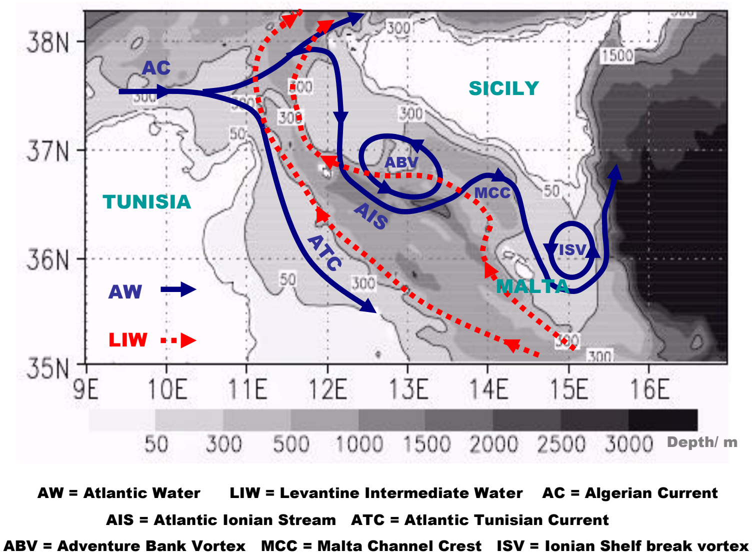


Figure 6.2 Scheme of the AW and LIW paths according to Astraldi et al. (2002) and Lermusiaux and Robinson (2001), from Drago and Sorgente, 2010.

Oceanographic features eddies, vortices and fronts

The SS is a dynamically complex area, characterized by the presence of oceanographic features vortices, upwelling areas and fronts, the intensity and position of which are mainly controlled by the variability in AIS meandering (Robinson et al., 1999; Lermusiaux and Robinson, 2001). The AIS encircles two large cyclonic vortices, one over Adventure Bank, the Adventure Bank Vortex (ABV) and a second one off Cape Passero, the Ionian Shelf-break Vortex (ISV), at the southernmost tip of Sicily (Fig.6.2). The circulation favours the establishment of "permanent" upwelling to the left of the Stream possibly reinforced by wind-induced upwelling, which may sharpen the density front due to the offshore Ekman transport (García Lafuente et al. 2002). The dynamic of these upwellings appears to be of several types (Askari, 1998). Along the Sicilian coast local wind is the driving mechanism of the sub-inertial variability of the currents and the characteristic time scale for the near-shore circulation to adjust to new local meteorological conditions is around three days (Grancini and

Michelato, 1987). By this means, nutrient rich, cold deep water (LIW) can intrude into the shelf, thereby enriching the upper water layers and allowing the production of a large quantity of organic substance, which supplies the food cycle of both the coastal benthic populations and the pelagic communities. The constant presence of a line of cold water along the Sicilian coast reported by Piccioni *et al.* (1988) is a signature of this mechanism. Another type of upwelling occurring in this area is induced by inertia of the isopycnal domes of the AIS meanders and the ABV and ISV cyclonic vortices (Robinson et al., 1999). Finally, topographically induced upwelling along the shelfbreak south of Sicily can also occur, in response to either wind driven effects, direct advection by the AIS as it rises above the along-shore relief variations (e.g. Janowitz and Pietrafesa, 1982), or localized tidal mixing as along other shallow shelf-breaks (e.g. Simpson, 1998). Dominant meanders for the AIS were reported to have time-scales of the order of 5-8 days (Manzella et al., 1988), in response to atmospheric, topographic and internal (e.g. stratification, inertia) forcing. Changes in the AIS path and its year-to-year variability have an impact on the other predominant hydrological phenomena occurring in the region, such as the extension of upwelling and the formation of frontal structures, as well as on the ecosystem and fisheries.

Bottom topography

The Strait of Sicily is characterized by a narrow continental shelf in the central part which achieve larger extensions off the eastern (Adventure bank) and western Sicilian coasts (Malta bank). The slope shape is extremely irregular, incised by many canyons, trenches and steep declines, seamounts, cut off by sub-horizontal and more accessible trawlable traits.

The shelf is characterized by the inflow of terrigenous material from the AIS that forms a wedge of well-stratified sands and silty shale varying in thickness from about 5–6 m near the coasts to almost zero at the edge of the shelf (Colantoni et al., 1985). An exception is the Adventure Bank characterized by a virtually flat surface with a mean depth of about 80–90 m. It is isolated from the inflow of terrigenous material by the strong currents and deposition is therefore biogenic: 1) carbonate sands consisting mainly of the remains of organisms (bryozoans, red algae, serpulidae, foraminiferida, gastropods and corals) living in the extensive eelgrass and seaweed meadows and 2) fragments of biogenic concretions (coraligenous) (Colantoni et al., 1985).

Past volcanic activity in the area produced several seamounts (Tetide, Anfitrite, Galatea, Cimotoe, Graham, Bannock and Nameless Bank), creating the conditions that support a diversity of important habitat types. Two of them emerge to form the Pantelleria and Linosa islands (Calanchi et al.,1989). Neogene rifting caused the development of three major depressions, the Pantelleria (1317 m depth), Linosa (1529 m depth), and Malta (1731 m depth), located in the central basin of the channel (Civile et al., 2008). The Graham Seamount is an active volcano featured of lava flows fumaroles along the north eastern flank at depths ranging from −160 m to −50 m (Civile et al.,2008).

Broad scale climate and oceanographic features and drivers

The MESMA EU project has provided an overview of the risks associated with the ongoing climate change on the Strait of Sicily ecosystem. In relation to its relatively small volume of water and the strong influence of the surrounding land masses with respect to the oceans the Mediterranean is potentially less resilient to the climatic change than the open oceans.

Oceanographic patterns that influence marine life, such as nutrient cycling, surface water circulation, vertical mixing and stratification of water masses, upwellings, concentration fronts and retention gyres, can change faster in the Mediterranean than in the oceans. This is especially the case of the

Strait of Sicily, which is strongly influenced by the energy of the water fluxes between the western and the eastern Mediterranean sub-basins. Global warming is changing the balance between those fluxes and is suspected that the oceanographic circulation pattern is already changing. Other oceanographic features could also change or become disrupted.

According to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2001), the climate over the Mediterranean basin, described as one of the main climate change hot-spots, may become warmer and drier during the twenty-first century (Giorgi, 2006). Model projections predict that the greatest contribution to the Mediterranean regional climate change will be caused by a large decrease in mean precipitation and an increase in precipitation variability during the dry (warm) season (Giorgi et al., 2001).

There is substantial evidence of changes having been occurring in Mediterranean deep water temperature in the last decades. A 30-year time series (1959–1989) of deep-water temperatures acquired in the northwestern Mediterranean evidenced a general warming trend of 0.12°C (about 0.004°C per year), as a possible result of human-induced global warming (Béthoux et al., 1990). Later data have confirmed this trend (Béthoux et al., 1999; Vargas-Yanez et al., 2008). Many authors have reported a warming and salting of the Mediterranean deep waters over the last decades (e.g. Béthoux et al. 1990) and more recently of the AW in the Atlantic Ocean close to the Gibraltar Strait (Potter and Lozier 2004) as well as far from it (Curry et al. 2003). This recent change seems to have many impacts on water mass structures and properties (Klein et al. 1999; Lascaratos et al. 1999; Manca et al. 2003) as well as on the biogeochemistry (Klein et al. 2003) and fisheries (García Lafuente et al. 2002).

The formation of sapropels is evidence that the MTHC was shutdown, or at the least very weak in the past (Béthoux 1993). Some unexpected effects on thermohaline circulation have been documented from 1987 through the 1990s; these changes have been termed the Eastern Mediterranean Transient (EMT). It seems that strong anomalies in temperature and rainfall were involved in triggering the EMT, which has dramatically changed the hydrology of the deep eastern Mediterranean (Roether et al., 2007). Temperature, salinity, stratification and circulation of water masses have been affected. Through the alteration of the carbon and nitrogen cycles, the deep-sea biota has also been negatively impacted (Danovaro et al., 2001). Observations made between 2004 and 2006 have indicated that the EMT signal has propagated to the western basin and has disrupted previous thermohaline patterns there also (Schroeder et al., 2008).

Recent modelling studies suggested that the MTHC could be strongly weakened during the 21st Century under the influence of the global climate change (Thorpe and Bigg, 2000; Somot et al., 2006). Predicted variations in MTHC stability states (deep or intermediate) are likely to affect the Sea Surface Temperature (SST) pattern and consequently the climate of the surrounding areas and the dynamics of the ecosystem, with changes in spatial distribution, metabolic habitat suitability and trophic interactions.

Essential Fish Habitats

Most of the identified nurseries of demersal species (e.g. European hake, deep-sea rose shrimp, broadtail shortfin squid) are located along the external western and eastern edges of the Adventure Bank off the south-eastern Sicilian coasts (Fortibuoni et al., 2010, Garofalo et al., 2011, Colloca et al., 2014). Here, the Atlantic Ionian Stream, generates a number of semi-permanent features such as upwellings, eddies and fronts which enhance and concentrate marine productivity (Agostini and Bakun, 2002).

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2. Food- web description, key species, ecological functional groups and fleets

Food-web – general overview, main processes

Primary Production (phytoplankton, benthic primary production…)

The main source of primary production data for the area, that will be used in Atlantis, is derived by the biogeochemical model OPATM-BFM which is composed by an advection and diffusion part (OPATM) and by a biogeochemical model (BFM), which accounts for more than fifty variables. BFM is a carbon based model and reproduces the nutrients cycles with not fixed C:N:P:Si ratios in the food web compartments. Primary producers are made up by 4 functional groups. use the Geider formulation and account for possible multi-limitation related to nutrients concentration (Lazzari et al., 2010).

The OPATM-BFM model is already applied for hindcast and operational simulations providing the Mediterranean biogeochemical products in MyOcean (Lazzari et al., 2012, http://www.myocean.eu/, Fig. 6.3).

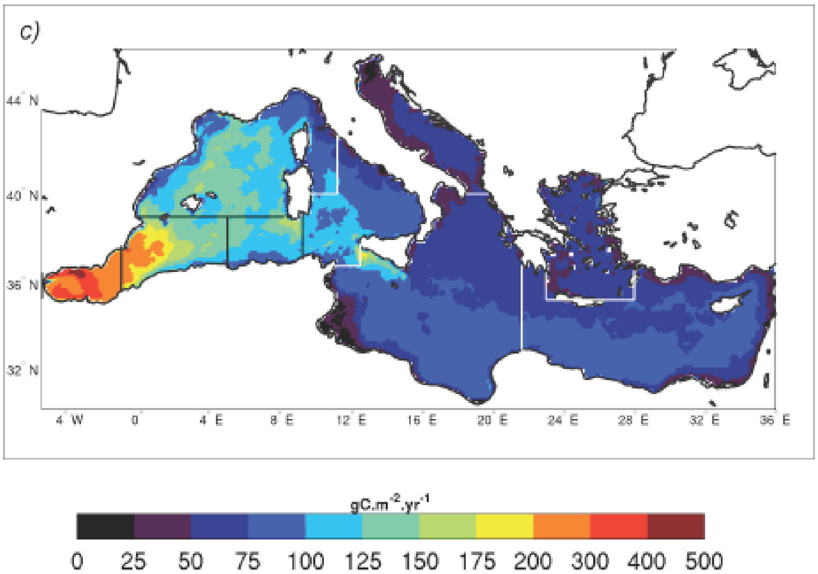

Figure 6.3 Model derived vertically integrated primary production ($mgCm^{-3}d^{-1}$) in the Mediterranean Sea from Lazzari et al., 2012.

During spring 1996 and 1998 two oceanographic cruises were conducted in order to measure fluorescence, biomass distribution and primary production in different sectors of the Strait of Sicily (Nardello et al. 2004). The chlorophyll a ranged between 14 and 60 mg/m2 in the 0-100 m depth stratum. Primary productivity was higher in the western sector of the area (Adventure bank) with values up to 524.61 mg C/m^2 day, between 0 and 20 m depth and the minimum value (218 mg C/m^2 day) in the SE sector. Primary production showed a maximum value (524.61 mg C/m^2 day) between 0 and 20 m depth and the minimum value (110.94 mg C/m^2 day) at about 60 m depth where maximum values of chlorophyll concentration were recorded. Brunet et al. (2007) in a study carried out on vertical variability and diel dynamics of picophytoplankton in the strait of Sicily showed a Deep Fluorescence Maximum (DFM) between 70 and 100 m. In the Deep Chlorophyll Maximum (DCM), a significant diel periodicity was observed for the orange fluorescence (from phycoerythrin) and for the red fluorescence (from chlorophyll). The high pigment diversity of picophytoplankton in the DCM and its elevated contribution to total chl a indicated an elevated degree of adaptation to the quantity and quality of light available. The phytoplankton community of the Sicilian Channel has been scarcely investigated up to now. Magazzù and Dicembrini (1995) reviewing the primary production, biomass and abundance of phototrophic picoplankton of the Mediterranean Sea showed as the contribution of picophytoplankton to primary production varies from 31 % in Straits of Messina to 92% in Ionian Sea; low values, instead, were found in Strait of Sicily.

Zooplankton

Data from oceanographic surveys in the Eastern Mediterranean carried out at the beginning of '90 showed an increased abundance of meso-zooplankton in the area of the Strait of Sicily (Mazzocchi et al. 1997). The mean value recorded in the Sicily Channel was almost one order of magnitude higher than in the other areas (200 ± 47 ind. m^{-3}). The zooplankton assemblage was dominated by copepods (81.83%), followed by ostracods (5.43%). More detailed data on the abundance and composition of meso-zooplanktonic organisms were provided by the MAGO project (MAGO Group 2002) at the end of '90s. In June 1999 zoo-planktonic biomass values, expressed in DW (mg m^{-3}), show a clear spatial pattern, with high density values in the western sector of the area and in correspondence of upwelling areas and frontal systems. Three peaks, respectively off Sciacca (10.16 mg m^{-3}), in front of Licata (6.38 mg m^{-3}) and off Cape Passero (10.14 mg m^{-3}), were evident (Fig. 6.3). In 2000 zooplanktonic biomass results have shown higher values (expressed in Dry Weight; DW, mg m^{-3}) in neritic stations than in pelagic and coastal waters (neritic areas: 6.08 ±5.92 mg m^{-3}; pelagic 4.35 ± 3.40 mg m^{-3}; coastal 3.30 ±1.75mg m^{-3}).

The zooplanktonic community was dominated by Copepods with 86 species found (74.8% of total zooplanktonic organisms in 1999, 388.4 ind/m^3; ±233.5; and 77.4%, 572.6; ±362.9 in 2000).
The second and third group were composed respectively by Appendicularia (9.6%; 49.8 ind/m^3; ±44.6 in 1999; 7.49%, 55.3±59.5 in 2000) and Cladocer (*Evadne spinifera* with 3.4%, 18.0 ind/m^3; ±20.9 in 1999. The Chetognata appeared more abundant in 2000 (3.7%, 27.8 ind/m^3; ±35.9).
As concerns the species, the most common Copepods were juveniles belonging to genus *Clausocalanus e Centropages*. Taking into account adult stages only, the three most abundant species in 1999 were: *Clausocalanus pergens, Centropages typicus, Paracalanus parvus, Centropages typicus* and *Oncaea curta*.

Benthos

The south coasts of Sicily are featured by a high heterogeneity in benthic communities along the continental shelf. Several biocenosis/benthic assemblage types were identified such as, SFBC (well-graded fine sand), HP (*Posidonia oceanica* meadows), VTC (coastal terrigenous mud), C (coralligenous), DC (coastal detritus), DL (open-sea detrital bottoms), VB-VSG (sandy muds with gravels), VB-C (compacted muds), VB-PSF, (soft muds with fluid surface film), DL (offshore detritic bottoms), Fig. 4.

In particular the *Posidonia* meadows along the SW sector are considered among the largest of the Mediterranean.

In a recent study was demonstrated a closer biogeographic affinity of the benthos of the Strait of Sicily with the benthos of the Tyrrhenian Sea (Massi et al., 2013).

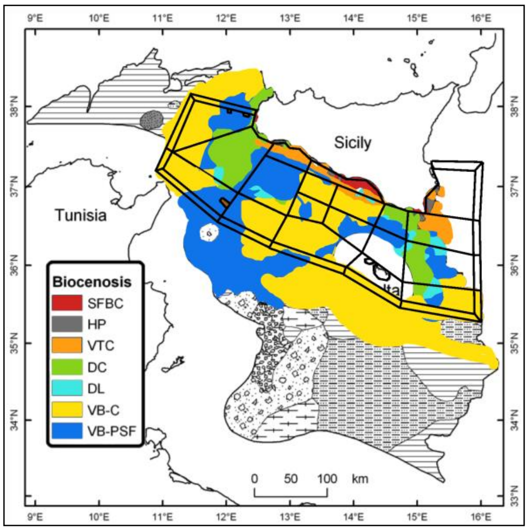

Figure 6.4 – Benthic biocenosis (redrawn from Garofalo et al, 2002). Within the Atlantis model domain 7 dominant biocenosis/facies types were identified: SFBC (well-graded fine sand), HP (*Posidonia oceanica* meadows), VTC (coastal terrigenous mud), DC (coastal detritus), DL (open-sea detrital bottoms), VB-C (compacted muds), VB-PSF (soft muds with fluid surface film).

Different studies on the benthic communities in the Strait of Sicily have shown the dominance of rheophilic species. Bottoms between 50 and 200 m are all ascribed to the "circalittoral" layer, mainly characterized by light penetration, that determines the biological aspects; the next, deeper level, generally associated with the continental slope and the deep steeps around the banks, is the "bathyal" layer. Regarding the hard substrates of the circalittoral layer, the Mediterranean shows a peculiar biocoenotic series the "coralligenous bottoms"; another circalittoral biocoenosis of the hard bottoms is that of the "off-shore rocks". The biocoenosis of the "coastal deposits" belongs to the soft bottoms.

The epi-bathyal layer extends between 200-250 m and 400-450 m, whose bottoms are generally muddy, with a consistent fraction of fine sand; their biocoenoses are poorer and less varied than those of the circalittoral. The most typical biological indicator species is the sea pen *Funiculina quadrangularis*, even if it is now quite rare especially on the trawlable grounds.

The geo-biological exploration of a pockmark field located at ca. 800m below sea level in the Gela basin (Strait of Sicily, Central Mediterranean) provided a relatively diverse chemosymbiotic community. In the Strait of Sicily, the hard bottoms of deeper bathymetric zones, those of the bathyal layer, are characterized by several huge "buildings" produced by madrepores generally forming scattered clumps, which give origin to the "white coral assemblages" biocoenosis between 300 m and 450 m.

Fish

Large pelagics

According to the results of larval campaigns, bluefin tuna spawn within a large portion of the pelagic Mediterranean environment (Piccinetti et al., 1997). Remarkable concentration of eggs and larvae occurs, off the eastern coast of Sicily. Oray et al., (2005) showed the results of a 2003 and 2004 fish egg and larval survey which encompasses the BFT spawning grounds off the southern Sicilian coasts.

Traditional fishing activities ("tonnare") have been replaced in more recent years by the use of purse seine and longlines. The fishery is regulated under a quota system, that for Italy was about 2900 tons in 2012 and 2013.

Swordfish (*Xiphias gladius*) is the other very important large pelagic species in the Mediterranean Sea. The ICCAT considers the existence of a single Mediterranean Stock. The Sicilian Channel seems to be one of the most important spawning grounds for the species (Di Natale, 2006). Driftnets ("reti derivanti") have been forbidden in the last years and replaced by the use of surface and mid-water longlines. The species is now one of the most important commercial species in the GSA 16 as total landing and commercial value.

<u>Small pelagics</u>

Anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) are the two most important species of the area. Their biomass and distribution is estimated annually through acoustic pelagic surveys (MEDIAS programme). In the Strait of Sicily both anchovy and sardine underwent large inter-annual fluctuations in GSA 16, with biomass estimates ranging from 6000 to over 36,000 tons for sardine and 7000–23,000 tons for anchovy. Fig. 6.5 shows the trend in relative biomass observed in the period 1998-2008.

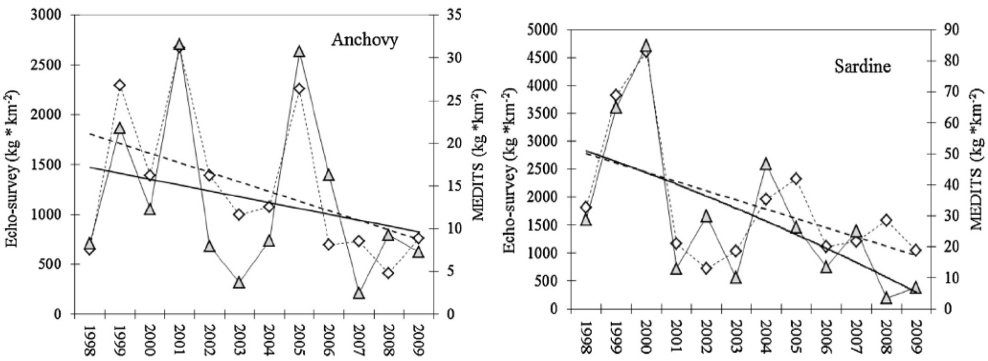

Figure 6.5 Trends in sardine and anchovy biomass in the North sector of the Strait of Sicily according to echo survey (empty diamonds) and MEDITS bottom trawl survey (filled triangles. From Fiorentino et al., 2013.

The spawning habitats of anchovy in the Strait of Sicily have been recently described by Basilone et al. (2013). Very high temperatures in some years were associated with the lowest egg densities in the Strait, and the low nutrient input associated with high salinities is a chronic condition that appears to limit productivity in the Strait. Shallow waters with upwelling (low temperature, high density, high fluorescence) and moderate current speeds may represent preferred areas for Sicilian spawning anchovy.

<u>Demersals</u>

The demersal community has been monitored with bottom trawl surveys (GRUND and MEDITS programs) since the early '80s. Data on discards and landings of the main commercial stocks are available since 2002 within the EU Data Collection Framework. A description of species assemblages can be found in Gristina et al., 2006, who also evaluated the impact of fishing on the community in terms of species composition and biomass. The area is featured by a rich community of elasmobranchs with species (*Mustelus mustelus, Raja clavata*) that are still important for demersal fisheries (Garofalo et al., 2002; Ragonese et al. 2013). The greatest diversity within the fish communities occurs at the offshore bank on the western part of the south Sicilian shelf (Adventure Bank, Garofalo et al., 2007).

The continental slope in the central Mediterranean is dominated by soft-bottom communities characterised by decapod assemblages (Ragonese et al., 2008), including species of tropical or subtropical origin (e.g. *Aristaeomorpha foliacea, Parapenaeus longirostris*). In particular, *P. longirostris* sustains one of the largest Mediterranean fisheries with 4000-10.000 t landed annually.

The dominant fish species are sharks such as *Galeus melastomus* and *Etmopterus spinax* (Stefanescu et al. 1992).

Birds, mammals, sea turtles

The Strait of Sicily area plays a fundamental role in large cetacean migration. The cetacean fauna of the area is rich. Fin whales are known to congregate in late February and early March in the coastal waters of the island of Lampedusa (Italy), Sicilian Channel, to feed on the euphausiid Nyctiphanes couchii (Canese et al., 2006.). Sperm whale (*Physeter macrocephalus*) occurs all year round. Several studies document the distribution and abundance of different cetaceans, such as the bottlenose dolphin, common dolphin and striped dolphin dolphin in the area (see UNEP-MAP-RAC/SPA. 2014, Vella and Vella, 2012).

Lampedusa and Linosa (two Natura 2000 sites) are among the last known nesting sites of Loggerhead (*Caretta caretta*) in this part of the Mediterranean where this species can lay its eggs. From 1995 Rescue Centre activity has marked more than 600 sea turtles and released in these years. During this period, it has been observed that one female turtle which was captured and marked in 1996 was observed nesting again in Linosa eight years later.

The Mediterranean hosts a resident and genetically distinct population of white shark and the Strait of Sicily is one of the most important spawning areas of the species in the region (De Maddalena and Heim, 2012; Saidi et al., 2005).

One of the most important Mediterranean pelagic birds is Cory's shearwaters (Calonectris diomedea diomedea). Particularly, Channel of Sicily hosts one of the biggest colonies of Cory's Shearwater in the Mediterranean (Brichetti and Fracasso 2003).

Main fisheries (fleets/metiers), target species and catch composition, seasonality and main spatial patterns in the fisheries

Fisheries in the North sector of the Strait of Sicily, as in other Mediterranean sectors, are mixed with a high number of stocks exploited and fishing gear used.

The composition of the Italian fishing fleet active in the GSA 16 during 2013 is showed in table 6.1.

The total number of artisanal vessels using mostly fixed nets (e.g. trammel nets) and longlines shows a clear reduction of the activity in winter summer.

The active trawlers range between 250 and 300 depending on the period of the year. Bottom trawl fishery is classified into three different metiers, according to the species assemblages exploited, for the purpose of the EU data collection framework, namely: i) demersal species (shelf and upper slope), ii) deep water species (middle slope: red shrimps), iii) mixed demersal species and deep water species.

The trawl fleet can be also subdivided in two main segments, < 24 m overall length and >24 m. The first mostly operate on short-distance fishing trips toward the outer shelf and shallow slope. The second exploits mostly international waters in a large area also covering sectors of the Eastern Mediterranean basin.

The other important fishery in the area is the pelagic fisheries to exploit small pelagic fish (anchovy and sardine) targeted by purse seiners (about 20 active vessels in spring-summer) and mid water pair trawlers (15 vessel). A seasonal fishery specifically aimed at the dolphinfish (*Coryphaena hyppurs*) using Fads, ("cannizzati") take place in September-October.

Table 6.1. Composition in number of active vessels of the Sicilian fishing fleet in 2013 in the GSA 16 by month and fishing metier (DCF data)

Fishing métier	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
Trammel nets	279	396	554	559	563	501	530	555	547	531	388	198
Hand lines									14	13	13	
Drifting longlines	28			49	24	24	24	24	32	9		26
Bottom set longlines	8	8	60	62	62	62	61	61	61	61	61	9
Miscellanea		24	24	25	25	25	25	25	25	25		
Bottom trawl (shelf and shallow slope)	142	131	120	115	123	104	92	111	138	166	154	144
Deep water bottom trawl	10	37	37	70	68	79	82	71	50	52	35	14
Mixed bottom trawl (coastal and offshore)	45	89	94	110	101	101	99	102	113	85	92	60
Midwater otter trawl	2	6	6	8	8	8	8	8	8	6	8	8
Purse seine large pelagics				2	2	4	2	2	17	16	9	
Purse seine small pelagics		7	15	22	20	22	22	20	18	22	15	4
Pelagic pair trawl	15	15	15	15	15	15	15	15	15	14	14	14

The Maltese fleet was composed in 2011 by 12 trawlers (4 of 12-24 m and 8 over 24 m), 11 of them were licensed to operate within the 25 nm Maltese Fisheries Management Zone.

Bottom trawl fishing effort exerted by Italian vessels over 24 m decreased of 40% in the period 2004-2012. Maltese vessels were only responsible for 3.5% of total trawling effort in GSAs 15 and 16 in 2012, however the total nominal effort of Maltese trawlers increased by 78% in 2005-2012 and fishing effort exerted by Maltese trawlers increased by 27% in 2011-2012. Small Italian artisanal vessels (6-12 m) fishing with trammel nets reduced their effort of 33% in the period 2004-2012, compensated however by an 42% increases of vessels measuring 12-24 m. Effort of Maltese artisanal fleet using trammel nets declined by 70% in the period 2006-2012 (STECF, 2013)

3. Food web functional groups included to the model(s)

The Strait of Sicily case of study will be based on the Atlantis (Fulton *et al*., 2004) and Gadget (Globally Applicable Disaggregated General Ecosystem Toolbox) model (Begley and Howell, 2004). Gadget is able to integrate species interaction and the impact of fisheries exploiting the stocks. As specified by Stefansson and Palsson (1998), Gadget has been developed as a forward simulation model using statistical estimation through weighted combinations of several log-likelihood criteria. Among the main advantages of Gadget respect other widely applied stock assessment methods there are its flexibility, low data-demanding, and the possibility to integrate into the same model incomplete time series of data at different aggregation levels and scales. These features make Gadget an ideal tool for modelling fish population dynamics in context with sparse and moderate amount of data such as in the Mediterranean (Bartolino et al., 2009).

Atlantis is an ecosystem box-model intended for use in Management Strategy Evaluation. The implementation of a Strait of Sicily version would provide a useful tool for identifying the interactions between natural and anthropogenic pressures, assess their effects on the ecosystem, to compare the potential consequences (biological, social and economic) and trade-offs derived from the application of alternative management scenarios.

At the core of Atlantis is a deterministic biophysical submodel that is spatially-resolved in three dimensions using a map made up of boxes and vertical layers. This model tracks the nutrient flow through the main biological groups found in the marine ecosystem of interest. The primary ecological processes considered in the model are consumption, production, waste production and cycling, migration, predation, recruitment, habitat dependency, and mortality. Atlantis treats lower (invertebrate) trophic levels as biomass pools (though cephalopods and prawns may have age structure), while the vertebrates are represented using an age- and stock-structured formulation (which tracks the condition of average individuals). The physical environment is also represented explicitly - via a set of polygons matched to the major geographical and bioregional features of the simulated marine system. Polygonal maps are used as they allow for the model to focus the spatial attention where needed, capturing the critical dynamics while still achieving computational efficiency (Fig.6.1b). Atlantis also features a detailed exploitation model. It allows for multiple fleets, each with its own technical characteristics. At its most complex it includes explicit handling of economic drivers, compliance decisions, exploratory fishing and other complicated real world concerns. The output of the assessment models are fed to the management model (typically a set of decision rules and management levers) for action. The management model in Atlantis for Strait of Sicily is currently only detailed for the fisheries sector.

The Atlantis SS community was constructed using data from the MEDITS survey programme (International bottom trawl survey in the Mediterranean, MEDITS). A total of 354 species sampled were aggregated into 45 functional groups, 19 of which vertebrates (tables 6.2-6.3), with some of the most commercially important species represented at species level (i.e. *Aristaeomorpha foliacea, Engraulis encrasicholus, Merluccius merluccius, Mullus barbatus, Parapaeneus longirostris, Sardina pilchardus*). Functional groups are spatially distributed over 7 habitat types: macroalgae, seagrass, rough, flat, mud, detritus, canyons.

The fisheries fleet, which at present has not yet been implemented, will consist of 9 vessel types: bottom trawlers, pelagic trawlers, pelagic artisanal vessels, demersal artisanal vessels, purse seine, demersal longline, pelagic longline, gillnets and trammel nets.

Table 6.2. Invertebrates, plants, detritus and nutrients.

PL - Large Phytoplankton	Diatoms
PS - Small Phytoplankton	Picophytoplankton: Synechoccus, Prochlorochoccus, picoeukariotes
DF - Dinoflagellates	Dinoflagellates
ZS - Small Zooplankton	Copepodites
ZM -Mesozooplankton	Copepods
ZL - Large Zooplankton	euphausiids and chaetognath
ZG - Gelatinous Zooplankton	Salps (pryosomes), coelenterates
Me - Medusae	*Pelagia noctiluca, Rhizostoma pulmo, Cotylorhiza tuberculata*
SU - Suprabenthos	Crustacean peracarids (mysiids, amphipods, etc.)
PB - Pelagic Bacteria	Pelagic Bacteria
CEP - Pelagic cephalopods	*Abralia veraniji, Alloteuthis media, Alloteuthis spp, Alloteuthis subulata, Ancistroteuthis lichteinsteini, Argonauta argo, Bathypolypus sponsalis, Heteroteuthis dispar, Histhioteuthis bonnellii, Histhioteuthis reversa, Histhioteuthis spp, Illex coindetii, Loligo forbesi, Loligo vulgaris, Ommastrephes bartramii, Onychoteuthis banksi, Todarodes sagittatus, Todaropsis eblanae*
BB - Sediment bacteria	Aerobic and anaerobic bacteria
BC - Carnivoruos infauna	Polychaetes
MBS - Macroepibenthos Slope	*Alpheus glaber, Anamathia rissoana, Anapagurus laevis, Crustacea, Dardanus arrosor, Goneplax rhomboides, Isopoda, Lepas anatifera, Macropodia longipes, Macropodia longirostris, Macropodia rostrata, Pagurus alatus, Parthenope macrochelos, Parthenope massena*
MBH - Macroepibenthos Shelf	*Other Crustaceans, Clibanarius erythropus, Dardanus calidus, Diogenes pugilator, Dromia personata, Ebalia deshayesi, Eriphia verrugosa, Eurynome aspera, Ilia nucleus, Inachus dorsettensis, Inachus parvirostris, Inachus spp, Inachus thoracicus, Latreillia elegans, Paguri-Anomura, Paguristes eremita, Pagurus cuanensis, Pagurus prideaux, Pagurus spp, Pilumnus hirtellus, Pinnotheres pisum, Pisa armata, Pisa nodipes, Scalpellum scalpellum*
DNS - Natant Decapods Slope	*Acanthephyra eximia, Acanthephyra purpurea, Aristeus antennatus, Chlorotocus crassicornis, Crangonidae, Gennadas elegans, Pasiphaea multidentata, Pasiphaea sivado, Plesionika acanthonotus, Plesionika antigai, Plesionika edwardsii, Plesionika gigliolii, Plesionika heterocarpus, Plesionika martia, Pontocaris cataphractus, Pontocaris lacazei, Processidae spp, Rissoides desmaresti, Rissoides pallidus, Sergestes robustus, Sergestes spp, Sicyonia carinata, Solenocera membranacea*
DRH - Reptant Decapods Shelf	*Galathea intermedia, Homarus gammarus, Liocarcinus corrugatus, Liocarcinus depurator, Maja crispata, Maja goltziana, Maja squinado, Maja verrucosa, Medorippe lanata, Palinurus elephas, Scyllarides latus, Squilla mantis*
DRS - Reptant Decapods Slope	*Bathynectes maravigna, Calappa granulata, Ethusa mascarone, Galathea dispersa, Geryon longipes, Homola barbata, Liocarcinus arcuatus, Macropipus tuberculatus, Monodaeus couchii, Munida intermedia, Munida iris, Munida spp, Nephrops norvegicus, Palinurus mauritanicus, Paromola cuvieri, Polycheles typhlops*
BO - Meiobenthos	Mainly composed of nematodes
MB - Microphytobenthos	Mainly sediment diatoms
ARF – Giant red shrimp	*Aristaeomorpha foliacea*
PWL – Deep sea pink shrimp	*Parapaeneus longirostris*
CEB -Benthic cephalopods	*Eledone cirrhosa, Eledone moschata, Neorossia caroli, Octopus defilippi, Octopus macropus, Octopus salutii, Octopus spp, Octopus vulgaris, Pteroctopus tetracirrhus, Rondeletiola minor, Rossia macrosoma, Scaeurgus unicirrhus, Sepia elegans, Sepia officinalis, Sepia orbignyana, Sepia spp, Sepietta oweniana, Sepietta spp, Sepiola affinis, Sepiola intermedia, Sepiola rondeleti, Sepiola spp, Sepiolinae*
MA - Macroalgae	*Vidalia etc.*
SG - Seagrass	*Posidonia oceanica*
DL - Labile Detritus	
DR - Refractory Detritus	
DC - Carrion	
NUTRIENTS	Dissolved organic nitrogen, Ammonia, Nitrate, Silicate, Phosphorous

Table.6.3. Vertebrates species aggregation into functional groups.

DFH - Dem fish shelf crust feed	*Scorpaena elongata*	*Diplodus vulgaris*	*Caelorhynchus caelorhynchus*
Argentina sphyraena	*Trigla lyra*	*Epinephelus aeneus*	*Capros aper*
Arnoglossus imperialis	**DSH - Dem selaceens shelf**	*Hippocampus hippocampus*	*Carapus acus*
Arnoglossus laterna	*Dasyatis pastinaca*	*Labrus mixtus*	*Ceratoscopelus maderensis*
Arnoglossus rueppelli	*Mustelus asterias*	*Liza aurata*	*Chlorophthalmus agassizi*
Arnoglossus thori	*Mustelus mustelus*	*Mugil cephalus*	*Diaphus holti*
Aspitrigla cuculus	*Mustelus punctulatus*	*Muraena helena*	*Diaphus metopoclampus*
Blennius ocellaris	*Myliobatis aquila*	*Pagrus caeruleostictus*	*Diaphus rafinesquei*
Bothus podas	*Raja alba*	*Pagrus pagrus*	*Diaphus spp*
Buglossidium luteum	*Raja asterias*	*Phycis phycis*	*Electrona rissoi*
Callionymus lyra	*Raja batis*	*Sciaena umbra*	*Epigonus denticulatus*
Callionymus maculatus	*Raja brachyura*	*Scorpaena loppei*	*Epigonus telescopus*
Callionymus risso	*Raja circularis*	*Scorpaena notata*	*Evermanella balbo*
Cepola macrophtalma	*Raja clavata*	*Scorpaena porcus*	*Facciolella oxyrhyncha*
Chelidonichthys gurnardus	*Raja fullonica*	*Scorpaena scrofa*	*Gadella maraldi*
Chelidonichthys lastoviza	*Raja melitensis*	*Scorpaena spp*	*Gadiculus argenteus*
Chelidonichthys lucerna	*Raja miraletus*	*Spondyliosoma cantharus*	*Hoplostethus mediterraneus*
Chelidonichthys obscurus	*Raja montagui*	*Umbrina canariensis*	*Hygophum benoiti*
Citharus linguatula	*Raja naevus*	**DSS - Dem selaceens slope**	*Hymenocephalus italicus*
Coris julis	*Raja oxyrinchus*	*Centrophorus granulosus*	*Lampanyctus crocodilus*
Dactylopterus volitans	*Raja polystigma*	*Centrophorus uyato*	*Lampanyctus pusillus*
Dalophis imberbis	*Raja radula*	*Chimaera monstrosa*	*Lappanella fasciata*
Deltentosteus quadrimaculatus	*Raja spp*	*Dalatias licha*	*Lepidopus caudatus*
Echelus myrus	*Torpedo marmorata*	*Etmopterus spinax*	*Lestidiops jayakari jayakari*
Gaidropsarus biscayensis	*Torpedo nobiliana*	*Galeus melastomus*	*Lobianchia dofleini*
Gaidropsaurus mediterraneus	*Torpedo torpedo*	*Heptranchias perlo*	*Macroramphousus gracilis*
Gaidropsaurus spp	**DSM - Dem fish shelf mixed**	*Hexanchus griseus*	*Macrorhamphosus scolopax*
Gnathophis mistax	*Altri Serranidi*	*Oxynotus centrina*	*Maurolicus muelleri*
Gobius cobitis	*Balistes capriscus*	*Squalus acanthias*	*Micromesistius poutassou*
Gobius cruentatus	*Hippocampus spp*	*Squalus blainvillei*	*Myctophidae spp*
Gobius niger	*Lithognathus mormyrus*	**ENG - Anchovy**	*Myctophum punctatum*
Gobius spp	*Mullus surmuletus*	*Engraulis encrasicholus*	*Nansenia oblita*
FIGLepidotrigla cavillone	*Serranus cabrilla*	**EPI - Epipelagic fish**	*Nemichthys scolopaceus*
Lepidotrigla dieuzeidei	*Solea solea*	*Anthias anthias*	*Nettastoma melanurum*
Lesueurigobius friesii	*Solea spp*	*Aphia minuta*	*Nezumia aequalis*
Lesueurigobius sanzoi	*Solea variegata*	*Boops boops*	*Nezumia sclerorhynchus*
Lesueurigobius sueri	*Sphoeroides pachygaster*	*Callanthias ruber*	*Notacanthus bonaparte*
Microchirus ocellatus	*Symbolophorus veranyi*	*Centracanthus cirrus*	*Notoscopelus elongatus*
Microchirus variegatus	*Symphodus mediterraneus*	*Glossanodon leioglossus*	*Paralepis c. coronogoides*
Ophidium barbatum	*Symphurus ligulatus*	*Scyliorhinus canicula*	*Paralepis HYA*
Pagellus acarne	*Symphurus nigrescens*	*Scyliorhinus stellaris*	*Sudis hyalina*
Pagellus erythrinus	*Symphurus spp*	*Spicara flexuosa*	**MSG - Mesop slope jelly feed**
Pomatoschistus minutus	*Syngnathus abaster*	*Spicara maena*	*Centrolophus niger*
Psetta maxima	**DSP - Dem shelf fish pisc**	*Spicara smaris*	*Cubiceps gracilis*
Serranus hepatus	*Conger conger*	**HAK - Hake**	*Ruvettus pretiosus*
Synapturichthys kleinii	*Lophius budegassa*	*Merluccius merluccius*	*Schedophilus medusofagus*
Synchiropus phaeton	*Lophius piscatorius*	**LPL - Large pelagics**	**MSP - Mesop slope fish pisc**
Triglidae	*Synodus saurus*	*Thunnus tynnus*	*Chauliodus sloani*
Trisopterus m. capelanus	*Trachinus araneus*	*Xiphias gladius*	*Stomias boa*
DFS - Dem fish slope	*Trachinus draco*	**MPL – Medium pelagics**	**MUL – Red mullet**
Helicolenus d. dactylopterus	*Trachinus radiatus*	*Naucrates ductor*	*Mullus barbatus*
Lepidorhombus boscii	*Uranoscopus scaber*	*Sphyraena sphyraena*	**SAR - Sardine**
Lepidorhombus whiffjagonis	*Zeus faber*	*Trachurus mediterraneus*	*Sardina pilchardus*
Molva dipterygia	**DSR - Dem fish shelf rocky**	*Trachurus picturatus*	**SB - Seabirds**
Molva molva	*Alepocephalus rostratus*	*Trachurus trachurus*	**SPL - Small pelagics**
Mora moro	*Dentex dentex*	**MSC - Mesop slope crust feed**	*Alosa fallax*
Ophisurus serpens	*Dentex gibbosus*	*Argyropelecus hemigymnus*	*Sardinella aurita*
Pagellus bogaraveo	*Dentex macrophthalmus*	*Bathypterois mediterraneus*	*Scomber colias*
Peristedion cataphractum	*Diplodus annularis*	*Bellottia apoda*	*Scomber scombrus*
Phycis blennoides	*Diplodus puntazzo*	*Benthocometes robustus*	*Scomber spp*
CET - Cetaceans	**CHE- Chelonia**		
Tursiops truncatus	*Caretta caretta*		
Stenella coeruleoalba			

4. Other effects of human use of the ecosystem

Maritime traffics and tourism

The Strait of Sicily is the most important traffic lane for crude oil crosses all the Mediterranean East-West and connects the Black Sea, Suez and Gibraltar, resulting the area where the concentration of this type of traffic is close to 80% of the total in the whole region (Patruno, 2008). For this reason Strait of Sicily is considered as a sea area at very high risk of pollution from ships, in a region where, between 1978 and 2003, were recorded 470 accidents with 305,000 tonnes of oil and 136,000 tonnes of various chemical products discharged at sea. Furthermore, although the Mediterranean is declared a «special area» by MARPOL Convention, where any discharge of oil or oily residues and mixtures from ships is prohibited, the so-called operational pollution, which is the marine pollution originated by routine shipping activities and voluntary discharges, became recently more and more significant (Patruno, 2008).

Tourism is one of the most important economic activities in Sicily and Malta. Coastal area are under a very high touristic pressure with increasing urbanization of the coasts (e.g. touristic resorts, marina, etc.) that in turn determine impact on coastal fragile habitats such as *Posidonia oceanica* meadows. Touristic activity in nesting sites of the sea turtle *Caretta caretta* is a big threat for the species in Sicily as well as in the rest of the Mediterranean (Giacoma and Solinas, 2001).

Non-native species

The Strait of Sicily is recognized as one of the main hotspots of introduction of alien species in Italy and small island, such as Linosa, may act as stepping stone for secondary dispersal of non-native species from west to east Mediterranean basin or vice versa (Occhipinti-Ambrogi et al ., 2011). The origin of these species is mainly the Indo-Pacific region as they have been previously reported in the eastern Mediterranean upon their entrance through the Suez Canal, whereas a few fish species of tropical Atlantic origin seem to have entered through the Strait of Gibraltar. The ongoing warming trend has substantially accelerated the acclimatization of alien thermophilic species, mainly macroalgae (e.g. *Caulerpa racemosa, Asparagopsis taxiformis*), invertebrates and fishes. *Percnon gibbesi* is an example of a very rapid and successfull colonization. The crab was found in Linosa in 1999 for the first time in the Mediterranean (Relini et al. , 2000) and it is now widespread along the Upper infralittoral fringe as reported by recent studies (Raineri et al ., 2011). Among fish, there are several Lessepsian species of increasing importance in the area such as *Siganus luridus* (Azzurro, 2008).

5. Commercial species and reference points (Fmsy, Bmsy)

The most important commercial species in the area is the deep-sea rose shrimp (*Parapenaeus longirostris*) with 5000-10.000 tons /year. Followed by the giant red shrimp (*Aristomorpha foliacea*), sardine, European hake, anchovy, swordfish (Tab. 6.4).

The assessment of the status of the stocks in the region is carried out both by the working groups of the GFCM and the Scientific, Technical and Economic Committee for Fisheries (STECF) of the EC. GFCM plays a key role in fostering the development of assessment on shared stocks between EU and non-EU countries also in cooperation with the FAO regional project Med-SudMed.

The results of the assessments carried out in the last years pointed out a general condition of overfishing of the main commercial stocks (tab. 6.5). The only stock that resulted as sustainably exploited in 2012 was the Norway lobster. Even though the general trend in the area shows a reduction of the fishing mortality (F), the current F is still generally far from F at MSY (F_{MSY}).

As in the rest of the Mediterranean, stock productivity and fleet profitability are generally impaired by a combination of high fishing mortality and poor selectivity (i.e. high mortality on juveniles) featuring the main fisheries (Colloca et al., 2014).

Table 6.4. Main commercial species of fish and shellfish landed in 2013 in GSA 16.

Species	Annual landing (tons)	%
Deep water rose shrimp	5962.5	30.7
Giand red shrimp	1869.3	9.6
Sardine	1767.0	9.1
European hake	1551.5	8.0
Anchovy	1163.6	6.0
Swordfish	662.3	3.4
Silver scabbard	646.3	3.3
Striped red mullet	522.7	2.7
Red mullet	411.7	2.1
Bogue	328.8	1.7

Table 6.5. Overview of the status of commercial stocks in the N sector of the Strait of Sicily in 2010-2012. Estimates of fishing mortality (F), and proxies for F_{MSY} are also provided. Scores above1 in the F/F_{MSY} ratio indicate unsustainable pressure and are highlighted in red.

Scientific Name	Stock name	F_{MSY} (F_{01})	F_{2010}	F_{2011}	F_{2012}	F/ F_{MSY}
Mullus barbatus	Red mullet	0.45		0.8	1.3	2.9
Mullus surmuletus	Striped red mullet	0.19	1.05	1.2	0.78	4.1
Pagellus erythrinus	Common pandora	0.3		0.6	0.72	2.4
Lophius budegassa	Blackbellied angler fish	0.16			0.3	1.9
Merluccius merluccius	European hake	0.16	0.66			4.1
Aristaeomorpha foliacea	Giant red shrimp	0.3		1.09	1.67	5.6
Nephrops norvegicus	Norway lobster	0.2			0.15	0.8
Aristeus antennatus	Aristeus antennatus	0.26			0.81	3.1
Parapenaeus longirostris	Deep-water rose shrimp	1.22			1.6	1.3

6. Socio-economic indicators (performance)

The Sicilian fisheries follow the path of the general decline seen in the last few years in Italy. The sustained rise in intermediate costs, combined with a fall in production due also to overfishing, eroded added value and profits, further weakening a marginal sector already in recession. Table 6.6 provides an overiview of the economic performance of fishing fleets in South Sicily. The Sicilian trawling fleet, is the largest in Italy, landed 18,570 tonnes in 2011, down 5.6% from 2010. Over 80% of the fleet is concentrated on the southern side of the island. Vessels above 24 meters, based in Mazara del Vallo, have been suffering a deep crisis for years due mostly to fuel costs, but also to difficulties in accessing traditional fishing areas near Maghreb in international waters, like Libya and Tunisia. Over the last few years finding specialised workforce, especially captains, has been particularly hard for several vessels. In this segment alone, 30 vessels are due to terminate activities and others are waiting contributions for permanent withdrawal.

Table 6.6. Economic performance of fishing fleets on the South coasts of Sicily.

	Incomes	Intermediate costs	Added value	Labour costs	Gross profit
Fleet segment			**million euro**		
Bottom trawlers	132,42	81,84	50,57	26,76	23,82
Mid pair trawlers	2,57	1,61	0,96	0,44	0,52
Purse seiners	12,45	4,74	7,71	3,75	3,97
Small scale vessels	20,97	10,29	10,68	5,47	5,21
Polyvalent vessels	4,39	1,61	2,78	1,43	1,34
Longliners	17,68	5,11	12,58	5,67	6,91
Total	190,49	105,21	85,28	43,52	41,76

7. Governance and management rules enforced (fisheries management, mpa, others that can affect fisheries and ecosystem)

Italian national waters extend to the 12 miles limit. Malta established a 25-mile exclusive fishing zone (Territorial Waters and Contiguous Zone Amendment Act of 18 July 1978). Under Legislative Act No. X of 26 July 2005, fishing waters may be designated beyond the limits laid down in the 1978 Act and jurisdiction in these waters may also be extended to artificial islands, marine scientific research and the protection and preservation of the marine environment.

Marine and coastal environment

As regards the protection of the marine environment In the Mediterranean the main treaties are the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona, 1976; amended in 1995), with its seven protocols, and the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (Monaco, 1996; ACCOBAMS).

The Barcelona Convention includes the Specially Protected Area Protocol (SPA Protocol, 1995), which applies to all the marine water, seabed, and terrestrial coastal areas. This protocol provides for the development of SPAs of Mediterranean Importance (SPAMIs) with clear procedures for the listing of these areas. The SPAMI list represents the core of a protected area network for the conservation of Mediterranean heritage (Micheli et al., 2013). The EU regulation 1967/2006 concerning the management of Mediterranean fisheries establish the protection from certain types of fishing of seagrass beds of, in particular, *Posidonia oceanica* or other marine phanerogams, coralligenous habitats and mäerl beds.

The General Fisheries Commission the Mediterranean (GFCM) it is the other international body with the mandate to develop specific binding recommendation related to the conservation and management of marine species and habitats by reducing the impact of fishing:

Among these can be mentioned:

- Recommendation GFCM/35/2011/2 on the exploitation of red coral in the GFCM Competence Area.
- Recommendation GFCM/36/2012/1 on further measures for the exploitation of red coral in the GFCM area
- Recommendation GFCM/36/2012/2 on mitigation of incidental catches of cetaceans in the GFCM area
- Recommendation GFCM/36/2012/3 on fisheries management measures for conservation of sharks and rays in the GFCM area
- Recommendation GFCM/35/2011/3 on reducing incidental by-catch of seabirds in fisheries in the GFCM Competence Area
- Recommendation GFCM/35/2011/4 on the incidental by-catch of sea turtles in fisheries in the GFCM Competence Area
- Recommendation GFCM/35/2011/5 on fisheries measures for the conservation of the Mediterranean monk seal (*Monachus monachus*) in the GFCM Competence Area. The Pan European Ecological Network which includes the European Union Natura 2000 network (EU Directive 92/43/EEC, EU Directive 2009/147/EC) [4] plays a key role at the European level.

Of increasing importance in the next years is the Marine Strategy Framework Directive (MSFD) which requires the European States of the Mediterranean to prepare national strategies to manage their seas to achieve or maintain good environmental status by 2020. Finally the Barcelona Convention is now going to play a relevant role on the application of the so-called "Ecosystem Approach" in the Mediterranean waters, as agreed by the Conference of the Parties in 2008 (Decision IG17/6), being aimed at achieving GES in the Mediterranean Sea by 2020.

Marine Protected Areas (MPAs) and Fisheries Restricted Areas (FRAs)

Fig. 6 shows the spatial managements enforced in the area as well as the area were local management plans are developed. There are two MPAs in south Sicily: Isole Egadi, Isole Pelagie.

Ramsar areas

The are two coastal protected areas under the Ramsar convention:

Biviere di Gela. 256 ha; National Park, Natural Reserve, Wildlife Sanctuary. A coastal, freshwater lagoon at the mouth of the Torta River backed by hills and separated from the sea by a dune system. The area is important as a staging area for numerous species of migratory birds, including important numbers of Phalacrocorax carbo sinensis. The site also supports the highest diversity of nesting waterbirds of any wetland in Sicily.

Vendicari**.** Special Protection Area EC Directive; Regional Natural Reserve. A complex of five brackish lakes subject to marked seasonal variations in extent and salinity. Saline areas support typical salt-resistant vegetation, while freshwater areas give rise to a more varied flora. The site supports up to 20,000 waterbirds during the spring migration period, and is also important for wintering birds. Several notable nesting species as well as large numbers of shorebirds use the area.

[4] EU (1992). Council Directive on the conservation of natural habitats and of wild fauna and flora. European Union, Directive 92/43/EEC. Official Journal of the European Communities L206: 7–50. doi: 10.1017/cbo9780511610851.039
EU (2009) Directive of the European Parliament and the Council on the conservation of wild birds. European Union, Directive 2009/147/EC. Official Journal of the European Communities L20: 7–25

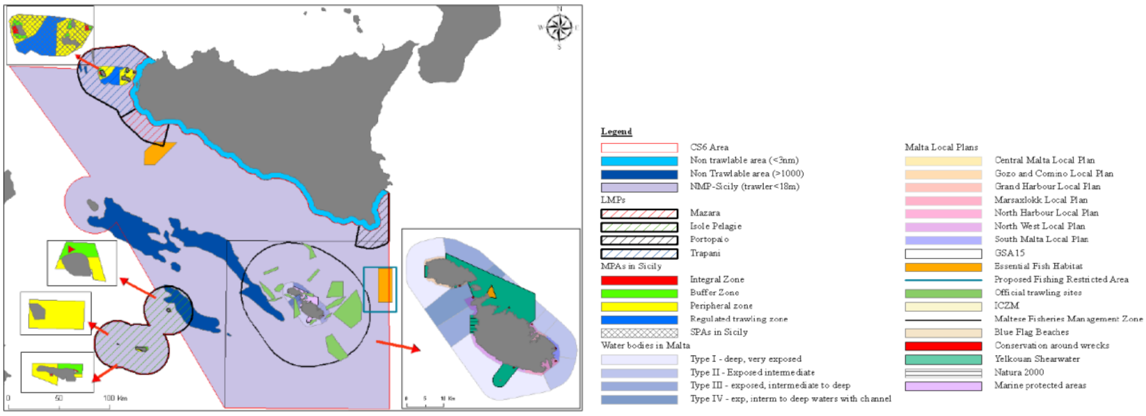

Fig. 6.6. Spatial managements enforced in EU waters of the Strait of Sicily. LMP: local management plans for fisheries. MPA (Marine Protected Areas).

Fisheries governance

The main regulation governing management in the EU waters of the Strait of Sicily is the EU reg. 1967/2006 related to the management of fisheries resources in the Mediterranean Sea and the new Common Fisheries Policy (EU reg. n. 1380/2013). Its aim is to ensure sustainable harvesting through ecosystem management. The establishment of multi-annual management plans both nationally and at the Community level are allowed for. Member States must draw up National Management Plans for the fisheries in their territorial waters.

Specific EU provisions against IUU fishing has been enforced by the Regulation (EC) No.1005/2008 of 29 September 2008, establishing a Community system to prevent, deter and eliminate illegal, unreported and unregulated fishing, and Regulation (EC) No. 1224/2009 of 20 November 2009, establishing a Community control system for ensuring compliance with the rules of the common fisheries policy.

The General Fisheries Commission for the Mediterranean is the Regional Fisheries management Organization that under the auspices of the FAO co-ordinate activities related to fishery management, regulations and research in the Mediterranean and Black Seas and connecting waters. It now has twenty-four members, including one non-regional State (Japan) and the European Union. The area covered by the GFCM Agreement includes both the high seas and marine areas under national sovereignty or jurisdiction. The GFCM has the purpose of promoting the development, conservation, rational management and best utilization of all marine living resources, as well as the sustainable development of aquaculture in the area falling under its competence. Its specific functions and responsibilities include the formulation of binding recommendation of measures for the conservation and management of living marine resources. Several GFCM recommendations regard the development and establishment by parties of the appropriate legal framework defining access to the fisheries resources and fishing grounds, as well as the implementation of management measures and the activities on monitoring, control and surveillance. They relate, *inter alia*, to technical measures in line with those established by EU in an attempt to achieve compliance also in non-EU waters. Particularly notable is the recommendation 2005/1 on the management of certain fisheries exploiting demersal and deepwater species which prohibits the use of towed dredges and trawl nets fisheries at depths beyond 1.000 m.

Finally, the International Commission for the Conservation of Atlantic Tunas (ICCAT) is competent for fisheries of tuna and tuna-like fishes in the Convention Area, which includes the whole of the Atlantic, as well as the Mediterranean as a connected sea. ICCAT has the power to adopt resolutions that are binding on its parties and establish a total allowable catch regime and national quotas for bluefin tuna fisheries in the East Atlantic and Mediterranean waters, within the framework of a multiannual recovery plan.

Managemenent measures enforced

As in other Mediterranean areas, fisheries management in Italy and Malta is based on control of fishing capacity (licenses), fishing effort (fishing activity), technical measures (mesh size and area/season closures).In order to limit the over-capacity of the fishing fleet, no new fishing licenses have been assigned in Italy since 1989 and a progressive reduction of the trawl fleet capacity is currently underway. Maltese fishing capacity licenses had been fixed at a total of 16 trawlers since 2000, but eight new licenses were issued in 2008 and one in 2011, to balance capacity reductions in other segment of the Maltese fishing fleet.

A compulsive fishing ban for 30 days in August-September was recently adopted by Sicilian Government. There is no closed season in place in Malta, but the Maltese Islands are surrounded by a 25 nautical miles fisheries management zone where fishing effort and capacity are being managed by limiting vessel sizes, as well as total vessel engine powers (EC 813/04; EC 1967/06). Trawling is allowed within this designated conservation area, however only by vessels not exceeding an overall length of 24 m and only within designated areas. Vessels fishing in the management zone hold a special fishing permit in accordance with Regulation EC 1627/94. Moreover, the overall capacity of the trawlers allowed to fish in the 25nm zone cannot exceed 4800 kW, and the total fishing effort of all vessels is not allowed to exceed an overall engine power and tonnage of 83 000 kW and 4 035 GT respectively. The fishing capacity of any single vessel with a license to operate at less than 200m depth cannot exceed 185 kW.

In order to protect coastal habitats the use of towed gears is prohibited within 3 nm of the coast or within the 50 m isobath if the latter is reached closer to the coast in both Malta and Italy (Reg. EC 1967/2006; Res. GFCM 36/2012/3).

In terms of technical measures, EC 1967/2006 fixed a minimum mesh size of 40 mm square or at the duly justified request of the ship owner a 50 mm diamond mesh for bottom trawling of EU fishing vessels and establishes the minimum size for the main commercial species. Diamond mesh panels can only be used if it is demonstrated that size selectivity is equivalent or higher than using 40 mm square mesh panels (EC 1343/2011). The same regulation prohibits the use of purse seines within 300 meters of the coast or within the 50 metres isobath where that depth is reached at a shorter distance from the coast. Finally, Reg. EC 1967/2006 establishes the technical measures (e.g. maximum length, minimum mesh size) of fixed gears such as trammel nets, gillnets and longlines.

Since 2011, specific local management plans, based on the concept of co-management, have been adopted in several coastal areas basically to manage artisanal fisheries. The plans, based on the enforcement of property rights, are aimed at increasing the sustainability of coastal fisheries through the adoption of more restrictive measures agreed by at least the 70% of the local fishing enterprises. Specific measures include area/temporal closures, increased minimum mesh sizes and landing sizes, more restrictive gear dimensions.

8. Conservation priorities (protected habitats, species, etc.);

The Strait of Sicily is recognized as a high biodiversity hot spot in the Mediterranean a also associated with complex and diversified benthic biocoenosis (Coll et al., 2010; Garofalo et al., 2007). Coll et al. (2010) found around Sicily the highest richness of marine vertebrate (375 species per 0.1x0.1 degree cell). Recent studies showed a high diversity and biomass of demersal communities over the offshore detritic bottoms of the Adventure bank (Gristina et al., 2006, Garofalo et al., 2007a). Such high diversity is linked to the nature of "crossroad" of the Strait of Sicily for species of distinct tropical origins (Atlantic and Indo-Pacific), expanding their range longitudinally within the Mediterranean (Azzurro, 2008; Lejeusne et al., 2010). The ecotonal nature of the area is well depicted by some examples such as the co-occurrence in the Strait of Sicily of two species of the genus *Charonia*, one of the biggest Mediterranean gastropods, *C. lampas lampas* (L.) typical of the western basin and *C. tritonis variegata* (Lamarck) widespread in the eastern basin (see Bianchi, 2007).

The area has been prioritized for conservation by de Juan et al. (2012) and Oceana (2011) with several sites, such as the Adventure Bank, Malta Bank, Urania Bank, Licosa Bank and Southern Sicilian seamounts identified for their future inclusion in a Mediterranean network of marine protected areas.

9. Management priorities and possible scenarios (input from case study meetings).

A multi-annual management plan for shared fisheries (deep sea rose shrimp and hake) in the Strait of Sicily is under development in the framework of the GFCM and with the support of the MEDSUDMED FAO regional project. The final management outputs of the plan will be incorporated into scenarios to be evaluated using the decision support tool provided by WP6.

A case study meeting was carried in at the IAMC-CNR of Mazara del Vallo on 20 June 2014 to discuss the main issues faced by fisheries in the Strait of Sicily. The meeting was attended by 15 participants, including members of RACMED, Sicily Region, fishermen representatives, ONG (Greenpeace) and fishery scientists. The discussion was focused mostly on trawl fisheries. The main issues identified were related to the loss of productivity of the fishing enterprises due to a series co-occurring factors such as: i) increasing of oil price, ii) poor market condition (e.g. low gross prices of fish products), iii) increased and unregulated access at the fishing grounds of the area in international waters, iv) old age of the trawlers, v) lack of marketing actions to increase the value of the products. There is a general poor understanding of the negative global effect of overfishing on the economic performance of the fisheries.

One of the main challenge of the project is to incorporate good environmental status indicators (GES) of MSFD into models in order to forecast the possible outcome of different management and climatic scenarios. Models will be adapted to include the necessary mathematical processes required to incorporate GES indicators, economic and social indicators (identified in WP6 and WP7) and parameterise models to reproduce the existing time series. This simulated ecosystem will then provide simulated data for the indicators associated with GES, as well as a minimum set of economic and social indicators in support of the EAFM. Some possible scenarios that might be interesting to test for their effect on the trophic web and fisheries socio-economy are the following:

Single species conservation targets.

GES addressed: Descriptor 3 – Criterion 3.1 (i.e fishing mortality below F_{MSY} by 2020). The scenario will be aimed at evaluating the effect on the ecosystem of a reduction of fishing mortality of commercial stocks toward F_{MSY}.

The high biodiversity of Mediterranean fish-shellfish communities is mirrored by the multispecies/multi-gear nature of fisheries in the region. These aspects can be critical for the achievement of GES and should be taken into account for the identification of the appropriate management measures to be enforced. In this regard, Atlantis and Gadget should be explored for their capability to model trade-offs, such as the effect of different single species target on prey-predators interactions. Moreover, there is a growing body of knowledge on the effect of ongoing climate change on productivity of fish stocks in the Mediterranean that would need to be considered in defining management objectives toward GES

Socio-economic vulnerability relating to fisheries and climate driven changes

Indicators: Annual catch, harvest value; fisheries income

The predicted scenarios by which the general circulation MTHC could be strongly weakened during the 21st Century are likely to affect the SST pattern, biogeochemistry, regional climate and dynamics of the ecosystem (e.g. spatial distribution, species-specific habitat suitability and trophic interactions). Several studies have shown the potential of changes in the physical and chemical environment in causing serious mutations in marine and coastal ecosystems (Pörtner and Farrell, 2008; Rosenzweig et al., 2008). Such changes influence directly the eco-physiological response of organisms at different levels of the ecosystem (Pörtner and Peck 2010). In particular, the progressive rise in temperature is thought to be a critical factor responsible for the migration of several fish species towards higher latitudes (Perry et al., 2005). The effects of climate change are more likely to affect coastal species living on the continental shelf of the Mediterranean Sea, as they are not benefiting from the temperature inertia of deep waters.

Under this warming scenario the ecosystem models will be used in the SS to investigate the effect of such environmental changes on particularly sensitive species such as the small pelagic species, which are characterized by a high interannual variability strongly correlated to environmental condition. For example, the anchovy population developed a reproductive strategy that is coupled to the surface circulation of the Atlantic Ionian Stream (AIS). Anchovy spawning is generally confined to shelf edges, where various kinds of enrichment processes may occur, and it relies on the meandering surface current flowing towards the Ionian Sea for the transport of eggs and larvae downstream towards the south-east end, off Cape Passero, where larvae are retained in a frontal structure that originates from the meeting of AIS and Ionian Sea water masses (García Lafuente et al., 2002).

If the AIS path moves further offshore, the northern coasts can show a greater upwelling extension, thereby modifying the temperature regime of the surface waters, cooling them below the optimal temperatures for anchovy spawning, which is 19-23°C and the normal temperature range in anchovy spawning grounds off the west Mediterranean basin during summer, when peak spawning takes place (June to July) (Basilone et al., 2013). This might cause severe consequences, not only on the species recruitment and biomass, but also on the socio-economic compartments, considering that sardine and anchovies jointly represent more than 90% of the commercial small-pelagic-fish landings in Sciacca, the main port for this fishery on the southern coast of Sicily.

Fisheries induced variation in trophic dynamic.

GES addressed: Indirect effects of fishing: trophic structure

Industrial fishing has many effects on marine ecosystems, including reduction of fish abundance and mean body size, decrease in diversity and physical habitat damage. In particular commercial trawling has been proved to alter the size structure of fish communities through size selective mortality. Such fishing-induced changes in the size structure of fish communities may in turn affect the interspecific trophic-depth relationships and, hence, species composition (Colloca et al., 2010; Sinopoli et al., 2012). The effect of commercial trawling in changing the feeding habits (more selective feeding in untrawled areas) and size composition of demersal fish has been reported for a variety of species (Fanelli et al., 2010).

Several authors already stressed that the effect of fishing on the size structure of fish assemblages and communities should be a focal point of future studies aimed to improve the ecosystem approach on fisheries management (Coll et al., 2006; Colloca et al., 2013), especially in the Mediterranean where 85% of the assessed stocks are currently overfished while populations of many commercial species are characterized by truncated size- and age-structures (Colloca et al., 2013). The aim of this scenario is make use of information derived from isotopes studies to reproduce the changes in the trophic links and energy flow through the ecosystem as induced by the effect of fishing size selectivity on the trophodynamic of selected demersal and pelagic species (e.g. adult hake and sardine).

Establishment of MPAs and Protection of recruitment hot spots

GSED addressed: Change in spatial exploitation pattern

Reducing any adverse impact, primarily fishing, on nurseries and other essential fish habitats, which are essential to allow the completion of a full life-cycle of a species (breeding, spawning, settlement, feeding, and growth to maturity), is one of the mandates of an ecosystem approach to fisheries management. The establishment of a trawling exclusion zone in the Gulf of Castellammare a clear recovery of the shelf demersal fish biomass has been recorded (Pipitone et al. 2000) and the effects of protection on the trophodynamics of fish has been investigated (Badalamenti et al. 2008, 2010).

Recently, the socio-economic effect of spatial measures (e.g. nursery closures) has been evaluated in the Strait of Sicily (Russo et al., 2014).

The aim of this scenario will be to investigate the effect on local fisheries and target commercial stocks of the establishment of a single or network of MPAs or closed areas, based on the protection of the persistent and highly productive nurseries of of demersal species identified in the area (see the Essential fish habitats section). VMS data available for the area will allow incorporating the effect of change in spatial distribution of the fleets due to MPAs implementations.

In addition, other spatial conservation scenarios will be discussed and agreed with local stakeholders.

VII. Black Sea Turbot case study

1. Oceanography-water circulation pattern and environmental features

Bottom topography and circulation

The Black Sea is one of the largest almost enclosed seas in the world: its area is about 420 thousands km2, the maximum water depth 2.212 m, the total water volume of about 534,000 km3. The Black Sea is placed in the southeastern part of Europe between 40º 54' 40" and 46º 34' 30" northern latitudes, 27º 27' and 41º 46' 30" eastern longitudes. The sea is roughly oval-shaped (BSC, 2008).

The Black Sea is connected to the Mediterranean Sea to the west and to the Sea of Azov to the north. The connection with the Mediterranean Sea is limited to the Istanbul-Canakkale (Bosporus-Dardanelles) straits. The Istanbul Strait is a rather narrow (0.76 – 3.6 km wide) and shallow strait (presently 32 – 34 m at the sill) restricting the two-way water exchange between the Black and Mediterranean Seas. The other connection, with the Sea of Azov is realized by the Strait of Kerch.

The Black Sea basin can be divided into four physiographic provinces: the shelf representing about 29.9% of the total area of the sea, the basin slope - about 27.3% of the total area, the basin apron, with 30.6%, and the abyssal plain - 12.2%

One of the most prominent physiographic features is the very large shallow (less than 200 m deep) continental shelf within the northwestern Black Sea (about 25 % of the total area of the sea). The Crimean, Caucasian and southern coastal zones are bordered by very narrow shelves and often intersected by submarine canyons (Fig.7.1).

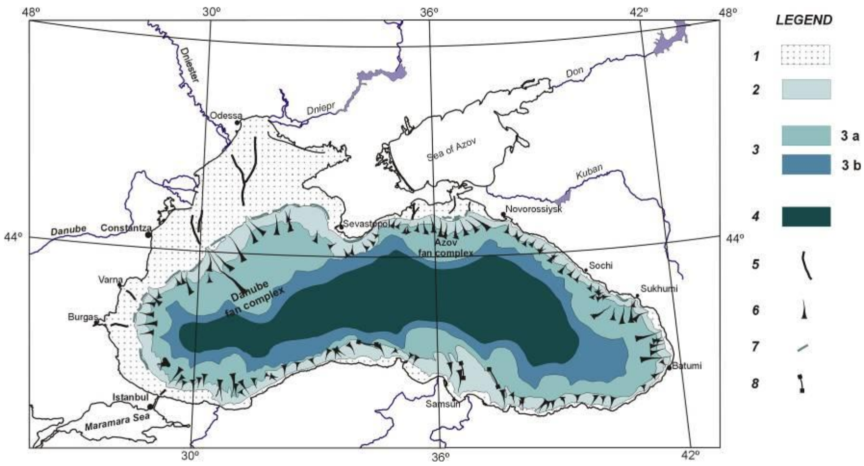

Figure 7.1 Geomorphologic zoning of the Black Sea (after Ross et al.,1974, Panin and Ion, 1997).

Legend; 1, continental shelf; 2, continental slope; 3, basin apron: 3 a - deep sea fan complexes; 3 b - lower apron; 4, deep sea (abyssal) plain; 5, paleo-channels on the continental shelf filled up with Holocene and recent fine grained sediments; 6, main submarine valleys - canyons; 7, paleo-cliffs near the shelf break; 8, fracture zones expressed in the bottom morphology.

Main fishing grounds at the Romanian littoral

The Romanian fishing area is comprised between Sulina and Vama-Veche; coastline and extends for over 240km, which can be divided into two main geographical and geomorphologic sectors (Radu G., 2013):

- 1/ the northern sector (about 158km in length) lies between the secondary delta of the Chilia branch and Constantza, constituted of alluvial sediments;

- 2/ the southern sector (about 85km in length) lies between Constantza and Vama-Veche characterised by promontories with active, high cliffs, separated by large zones with accumulative beaches often protecting littoral lakes.

The distance from the sea shore to the shelf limits (200m depth) varies from 100 to 200km in the northern sector and to 50 km in the southern one. The submarine slope of the shelf is very gentle in the north, while in the southern depth the slope increases very quickly.

Mesoscale variability of the circulation system

A primary feature of the Black Sea circulation system is the highly dynamic structural organization of the interior cyclonic cell and the Rim Current. The latter flows along abruptly varying continental slope and margin topography around the basin, whereas the interior circulation, formed by several sub-basin scale cyclonic gyres and eddies, evolve continuously due to interactions among these eddies and meanders and filaments of the Rim Current (BSC, 2008) (Fig. 7.2). The coastal side of the Rim Current are subject to a series of recurrent anticyclones. The overall basin circulation is primarily driven by the curl of wind stress curl throughout the year and further modulated by seasonal evolution of the surface thermohaline fluxes and mesoscale features arising from the basin's internal dynamics. In addition, fresh water discharge from the Danube and other northwestern rivers contributes to the buoyancy-driven component of the basin-wide circulation system.

Flow structure in the northwestern shelf is driven by spreading of the Danube outflow under temporally varying wind forcing. The Danube plume can spread northward or southward along the coast, or is expanded offshore depending on winds, internal dynamics, and initial vorticity of the plume. Southerly winds cause upwelling along the Romanian – Bulgarian coast bringing nutrient-rich deep sea waters into the surface layer and promote biological production. On the other hand, northerly winds trap the freshwater plume along the coast and the southward thin boundary current is separated from offshore waters by a well-defined front (Fig. 2) which sometime displays unstable features, exhibits meanders, extends across the wide topographic slope zone and spawns filaments (NIMRD, 2013)(Fig.2).

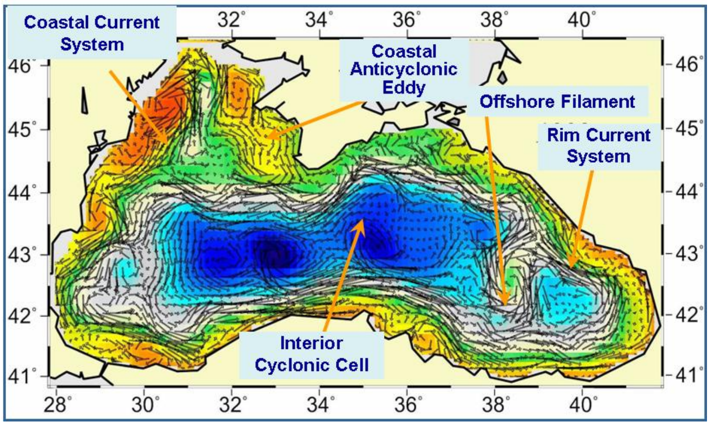

Figure 7.2 A typical structure of the upper layer circulation field deduced from a circulation model using assimilation of altimeter sea level anomaly data. (after Korotaev et al., 2003).

Broad scale climate and oceanographic features and drivers

The Black Sea ecosystem transformations in the 1980-1990s were accompanied with strong decadal scale climatic perturbations. These climatic changes modulated the ecosystem properties concomitantly with the anthropogenic impacts. They were locally even more pronounced. These decadal variations were an order of magnitude greater than the global SST changes of ~0.25^{o}C for 1930-2005. The annual-mean SST variations indicate a succession of decadal-scale cooling-warming cycles on the order of 1.0^{o}C. The period 1937-1957 was characterized by 0.9^{o}C cooling followed by 1.0^{o}C warming during 1957-1978, and subsequently two consecutive cooling and warming cycles of ~1.5^{o}C during 1978-1993 and 1993-2002. The system switched to the cooling cycle during 2002-2005. The switch to the warming phase in the 1990s occurred in the western coast as early as 1988 whereas it was disrupted by the 1997-1998 short-term cooling events. The strong warming trend in 1993-2002 brought the annual-mean sea surface temperature to the level in the mid-1960s (BSC, 2008).

At the Romanian littoral, the evolution of temperature in the active layer is determined by the periodical changes of the thermal balance at the air-water interface, while in deeper layers the vertical distribution is maintained by the geothermal flow (NIMRD, 2013).

Seawater temperature in Constanța, throughout the 12 months of the 2012 period, was 1.57°C higher than the reference period (1959 - 2011).The monthly means varied between -0.9°C, in February (daily minimum -3.0°C on 22 February) and 24.9°C in July (daily maximum 28.6°C on 29 July), predictably given the air temperature evolution.

Nutrients, primary production, eutrophication, hypoxia (anoxia)

River nutrient loads: Following the early 1990s, economical recession in the former eastern block countries indirectly resulted in closure of ecologically ineffective large animal farms (agricultural sources) and of nutrient discharging (e.g. fertilizer) industries. Phosphate content was also reduced in detergents, and nutrient removal from waste water was improved in the countries along the Danube River.

Nutrient concentrations: During the present decade, DIN concentration along the northwestern and northeastern coasts of the NWS as well as along the Romanian shelf experienced locally either a rising trend or maintained its level in the 1980s-1990s (NIMRD, 2013; BSC, 2008).

Chlorophyll concentration: According to the satellite ocean color data (BSC, 2008), annual-mean surface chlorophyll concentration in 1998-2007 possesses three-fold higher values in the northwestern region (~3 mg m^{-3}) with respect to the western interior basin (~1 mg m^{-3}).

Moreover, in-situ summer chlorophyll-a measurements near the Zmeiny Island reveal summer mean surface Chl-a concentration around 1.0-2.0 mg m^{-3} which are at least twice lower than the mean value of 4.5 mg m^{-3} for 1980-1995 (Kovalova et al., 2008), therefore supporting a decrease in primary production during the present decade.

Hypoxia coverage: the Ukrainian sector of northwestern shelf continued to experience successive large scale hypoxia shocks (> 10,000 km^2) once every few years. Although no published data are available after 2001, the hypoxic areas were reported to decrease in the present decade except some short-term events in localized shallow regions upstream and downstream sides of the Danube delta region (e.g. summer 2005) (BSC,2008).

According to recent studies, hypoxia decreased in Romanian coastal waters as compared to the previous decade (NIMRD, 2013).

2. Food- web description, key species, ecological functional groups and fleets

Food-web – general overview, main processes

Phytoplankton

The annual-mean phytoplankton biomass over the Ukrainian, Romanian and Bulgarian shelf waters experienced a decreasing trend from ~10 gm^{-3} during the late 1980s and the early 1990s to less than 4 g m^{-3} during the 2000s. Relatively high values greater than 20 g m^{-3}, however, occasionally measured in hot spot regions along the entire coast (BSC, 2008).

On the other hand, a the two-fold increase in species diversity from roughly 20 to 40, the decreasing phytoplankton/zooplankton biomass ratio together with the diminishing bloom frequency and the tendency of a shift of annual maximum algal development from summer to the classical spring and autumn forms during the present decade all indicate an tendency of algal community reverting towards its normal status. In fact, the shifts in phytoplankton taxonomic composition have become more and more evident since 2000. The blooms of non-traditional species (Dactylosolen fragilissimum, Pseudosolenia calcar-avis, Akashiwo sanguinea, Emiliana huxleyi, microflagellates) are more frequently observed and a high number of new species have successfully adapted to the Black Sea environment, however, some of themse are however potentially toxic (BSC, 2008).

Trends in phytoplankton biomass may not always be a firm indicator for the state of eutrophication due to strong modulation of bloom intensity and species structure by climate-induced changes. Even if the phytoplankton biomass has been improved recently, it does not indicate a stable structure; instead it implies a transitional phase with fragile ecological conditions under relatively high nutrient concentrations (BSC, 2008).

Bacterioplankton

The annual-mean bacterioplankton abundance within the northwestern shelf during 1979-2008 resembles closely the long-term changes in phytoplankton biomass. It reveals an increasing abundance from the average value of 1.2 million cells ml^{-1} during the late 1970s and the early 1980s (the range: 0.3-2.6 million cells ml^{-1}) to 3.3 million cells ml^{-1} (the range 1.0-7.3 million cells ml^{-1}) in 1990-1991. It was followed by an abrupt drop to ~2.5 million cells ml^{-1} in 1993-1994 and a steady decreasing trend to 1.5 million cells ml^{-1} up to 2008. The average bacterioplankton abundance was therefore reduced during 2003-2008 by more than twice with respect to 1990-1992 (BSC, 2008).

The NWS bacterioplankton abundance attains lowest values in winter (January-February) and highest in summer under high organic matter accumulation in water column. During the intense eutrophication phase (1983-1997), abundance greater than 2 million cells ml^{-1} prevailed from March to October with the highest population close to 3 million cells ml^{-1} in August. During 2004-2007, maximum abundance reduced to 1.5 million cells ml^{-1} and summer abundances varied around 1 million cells ml^{-1} from April-to-September (BSC, 2008).

Zooplankton

Edible Zooplankton: The annual-mean edible zooplankton biomass formed by averaging of the Ukrainian, Romanian and Bulgarian data sets exhibited a declining trend from ~300 mg m^{-3} in 1960 to 20 mg m^{-3} in 1990, persisted at this level up to 1995, and then fluctuated interannually within 50-200 mg m^{-3} range during 1996-2004 (Fig. 9). These fluctuations were mostly provided by the intermittent recovery of edible zooplankton (up to ~300 mg m^{-3}) within the Romanian shelf contrary to only a slight improvement (~100 mg m^{-3}) in the Ukrainian NWS and the Bulgarian shelf. According to this amalgamated data, the highest biomass registered within 1996-2004 was almost half of the biomass attained prior to the 1970s (BSC, 2008).

Although fodder zooplankton biomass has not yet increased to a level observed in the 1970s in the NWS and western coastal waters, its community was partially recovered in terms of species diversity. The community structure was re-organized by an increase in abundance and biomass of copepods and cladocerans, such as *A. tonsa, P. mediterranea, C. euxinus* and *A. patersoni* which were almost absent during 1980s-1990s. The extinct species *P. mediterranea*, being an indicator of non-eutrophic waters, has re-appeared since 2000 as a sign of positive ecosystem changes. Similar changes were also noted within the northeastern basin (BSC, 2008).

Gelatinous zooplankton: According to recent observations (1998-2004), *Mnemiopsis* biomass had a decreasing trend following its population control by *Beroe* after 1998. Nonetheless, *M. leidyi* can occasionally be abundant in the northwestern and western coastal waters (Figs. 11), in contrast to deeper part of the western shelf and the northeastern basin where the share of *A.aurita* was increased due to its competitive advantage under low *Mnemiopsis* populations.

As for the long-term variations of phytoplankton, zooplankton biomass and community structure also appear to be strongly regulated by climatic variations. Relatively mild years with warmer winter temperatures favour more efficient Mnemiopsis and edible zooplankton growth, whereas severe years with colder winter temperatures limit edible zooplankton production albeit producing stronger spring phytoplankton blooms and promote more favourable N. scintillans and A. aurita development. The spring temperature conditions are particularly critical for the intensity and species succession of zooplankton production. Mnemiopsis attained higher biomass when August surface temperature was relatively high as in the case of 2000-2001 and 2005 or but lower biomass with as in the case of relatively cold August temperatures seen during 1996-1998 and 2003-2004 (BSC, 2008).

Benthos

Macrophytobenthos: The red algae *Phyllophora* field in the northwestern shelf was known to be one of the most extensive macrophytobenthos habitats in the world. It was not only an important generator of oxygen but also the nucleus of benthic community involving more than 100 species of invertebrates and more than 40 species of fish (BSC, 2008). Following the deterioration of environmental conditions since the early 1970s from a combination of reduced transparency, lifting of mud particles in the water column during bottom trawling and hypoxia, the settlement size and stock of *phyllophora* field reduced from about 9 million tons to 8 thousand tons in 2000.

The dominance of green opportunistic algae was reported in the northern sector of the Romanian coast and the occurrence of the brown alga *Cystoseira barbata* in Mangalia, 2 Mai and Vama Veche, where it is known that marine waters have a better quality (NIMRD, 2013).

Macrozoobenthos: The most notable changes in zoobenthos community of the 1980s and 1990s in response to intensifying eutrophication and sustained organic enrichment of sediments were lower species diversity, reduced abundance and biomass of benthic populations, and thus a more simplified community structure dominated mostly by opportunistic and invasive species with high total abundance but low total biomass, increasing role of hypoxia-tolerant groups (bivalve molluscs), high fluctuations of populations (BSC, 2008).

As these modifications signaledsignalled the beginning of the rehabilitation trend, the general state of this biotic component of the marine ecosystem is still fragile over large areas of the Ukrainian and Romanian shelves and represents clear symptoms of undesirable disturbances, such as patchiness, domination of the zoobenthos system by opportunistic and hypoxia tolerant species as indicators of organic pollution. Shallow, coastal regions remain to be vulnerable to anthropogenic disturbances as compared to offshore areas deeper than 30-50m. The muddy bottom biocoenoses of Modilus phaseolinus at deeper than 50 m has not yet recovered due to the impact of hypoxia, opportunistic species, and degradation of bottom by dredging and trawling. Therefore, there are great deals of uncertainty to claim the a full recovery cannot yet be claimed (BSC, 2008; NIMRD, 2013).

Fishing

Historically, the main factors leading to stock collapses and great losses in fisheries were eutrophication-induced changes in the food web, overfishing and the invasion of the comb-jelly *M. leidyi*. In the recent period 2000-2005, the major threats for the fish resources appears to be illegal fishing and the use of destructive harvest techniques as well as the lack of regional cooperative management of fisheries and eutrophication (BSC, 2008).

Pelagic fishes in general and their small-sized plankton-eating types in particular are the most abundant species in the Black Sea ichthyocenosis. The total catch main target species European anchovy (*Engraulis encrasicolus*) constituted 31-75% of the total Marine Living Resources (MLR) during the last 15 years. European sprat (*Sprattus sprattus*), Mediterranean horse mackerel (*Trachurus mediterraneus*), Atlantic bonito (*Sarda sarda*) and bluefish (*Pomatomus saltatrix*) are the other pelagic fishes in terms of fishing value. The latter three species are large-sized predators which migrate into the Black Sea from the Marmara and Aegean Seas for feeding and spawning in spring and return to their native places for wintering in late autumn. The catch around 350,000 ± 100,000 tons suggest partial recovery of major pelagic species after the fishery collapse at 1991 (BSC, 2008).

From the fisheries perspective, the most important demersal fish species in the Black Sea are whiting (*Merlangius merlangus*), picked dogfish (*Squalus acanthias*), turbot (*Psetta maxima*), striped and red mullets (*Mullus barbatus*, *M. surmuletus*), four species of the family *Mugilidae*, including so-iuy mullet (*Mugil soiuy*). The total catch of these demersal fish species had a tendency towards reduction after 2000. Its present catch size is approximately half of the 1990s (BSC, 2008).

Among the mollusks, the clams (*Chamelea gallina*, *Tapes spp.*), the Mediterranean mussel (*Mytilus galloprovincialis*), and the sea snail (*Rapana venosa*) have the greatest commercial value. The former two species are harvested only by Turkey and the latter species by all countries of the region (BSC, 2008; NIMRD, 2013).

Globally, at the Romanian littoral, the dynamics of catches (Fig.7.3) in recent decades closely mirrors the discrepancy between the size of the fishing effort and the production capacity of the exploited stocks. This disproportion is also found in the Black Sea basin, between the fishing capacity of the six riparian countries (e.g. for the year 1985, of the 2,448 units of 1-24.9 GRT, Turkey held approximately 99% (2,415) (FAO, 1998). Depending on the status of fish populations, the fishing effort applied and the type of fishing gear used, the catches on the Romanian littoral had a variable evolution of the qualitative and quantitative structure (Radu, 20010, IRCM/INCDM 1980-2009).

Turbot, the species considered **by the case study of the Black Sea**, occurs all over the shelf of the Black Sea. It is a large-sized fish with a long life cycle; it reaches a length of 85 cm, a weight of 12 kg and age of more than 17 years old in the Black Sea (Svetovidov, 1964). Turbot fecundity is very high, up to 12.8 million of eggs per year. Larvae and fry in the first two months inhabit in the pelagic zone, feeding on zooplankton. Adults feed on fish mainly, both on demersal (whiting, red mullet and gobies), and with pelagic species (anchovy, sprat, horse mackerel, shad) species. Diet of turbot also includes crustaceans (shrimps, crabs, etc.), mollusks and polychaetes. Like whiting, it does not undertake distant transboundary migrations. Local migrations (spawning, feeding and wintering) have a general direction from the open sea towards the coast or from the coasts towards offshore. It usually matures between the ages of 3 – 5 years in the waters of Bulgaria (Ivanov and Beverton, 1985), at the age of 5 – 6 years in the waters off Ukraine and the Russian Federation (Popova, 1967). It spawns in spring, from the late March until the late-June, at water temperature range 8 – 12ºC. The peak of spawning occurs in May at depths from 20 – 40 to 60 m. After the spawning, turbot moves downwards to the depths 50 – 90 m and maintain a low-activity life with limited feeding until the early autumn. In autumn turbot returns to coastal waters again, where it feeds intensively. For wintering it migrates to the depths from 60 m to 140 m (BSC, 2008).

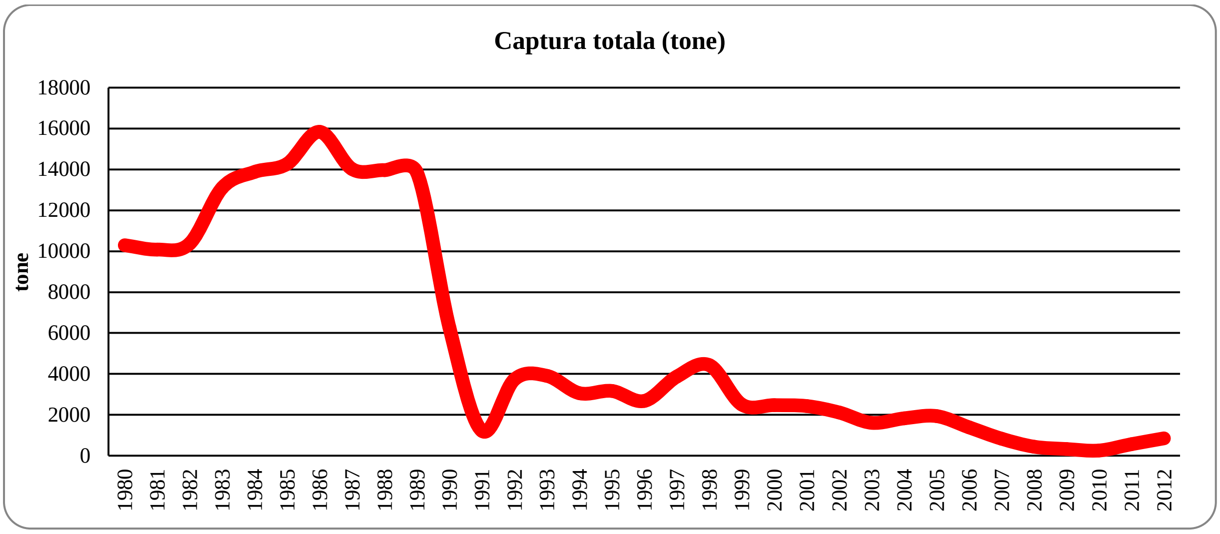

Figure 7.3 Catches dynamics at Romanian littoral in the period 1980-2012.

In all the Black Sea countries, turbot is one of the most valuable fish species. Its target fisheries is conducted with bottom (turbot) gill nets with minimum mesh size 180 mm in the waters of Bulgaria, Georgia, Romania, the Russian Federation and Ukraine (Prodanov *et al.,* 1997) and with minimum mesh size 160 – 200 mm as well as with bottom trawls with minimum mesh 40 mm in the waters of Turkey (Tonay and Öztürk, 2003). Turbot as a by-catch is harvested during target fisheries of other species with trawls, long-lines and purse seines. According to Zengin (2003), 72% of turbot fishing in Turkish waters of the Black Sea has been carried out by bottom gill nets, 26% by trawls and 2% as the by-catch from purse seines (BSC, 2008).

At the Romanian littoral the turbot catches are presented in the Fig. 7.4.

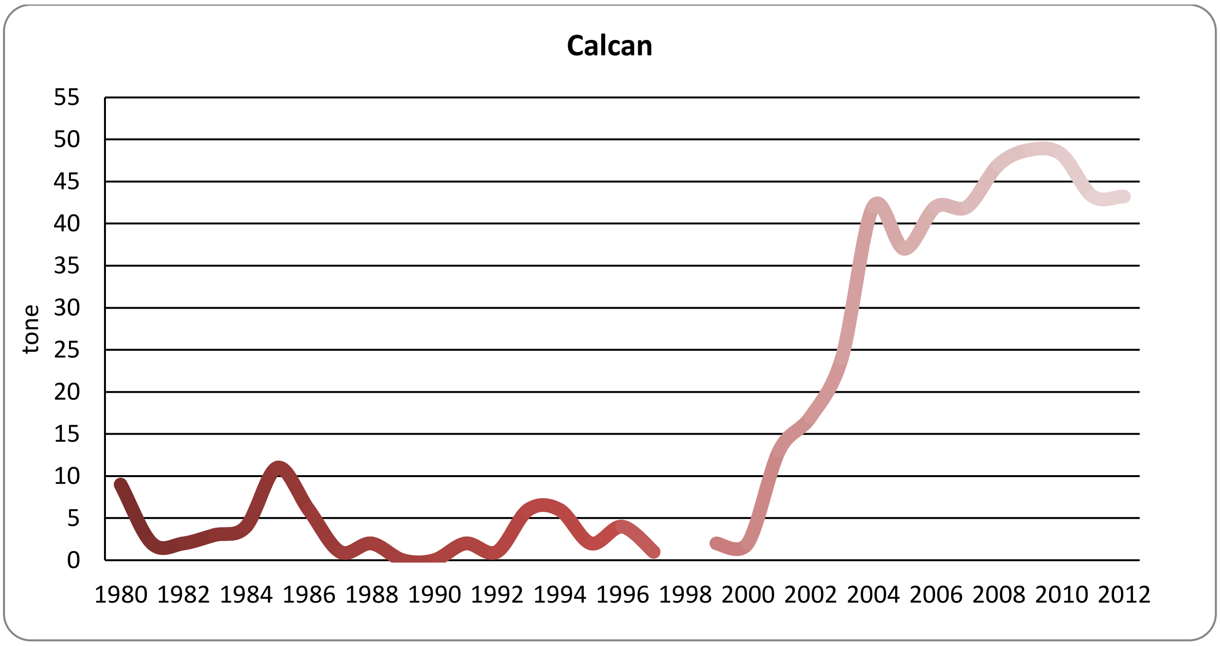

Figure 7.4 Turbot catches in the Romanian marine area in the period 1980-2012.

Turbot is present over the entire shelf, but the concentration of fishing agglomerations decreasing from year to year. The calculated biomass oscillated between 1,712 tons (2008) and 553 tons in 2013.

Birds and mammals

The harbour porpoises (*Phocoena phocoena relicta*), common dolphins (*Delphinus delphis ponticus*) and bottlenose dolphins (*Tursiops truncatus ponticus*) are the top predators without any natural enemies in the Black Sea except humans. Their populations were badly damaged during the last four decades due to anthropogenic-induced habitat degradation, depletion of food resources and commercial and intentional killing until the early 1980s. They are supposedly protected by the international agreements, but in practice their conservation status has not been adequately assured yet (BSC, 2008).

The present state of Black Sea cetacean populations is not quite clear or encouraging in spite of certain research and conservation progress achieved during last decade, since the two essential instruments have been adopted in 1996 – the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS), and the Strategic Action Plan for the Rehabilitation and Protection of the Black Sea (BS SAP). The insufficiency of scientific information includes population abundance, distribution, migrations, critical habitats, anthropogenic and natural threats as well as some basic aspects of life history and pathology (BSC, 2008).

Currently, the most obvious threats affecting Black Sea cetacean populations are accidental mortality in fishing gear; habitat degradation causing the reduction of prey resources; water pollution and epizootics resulting in cetacean mass mortality events. All these factors are directly or indirectly dependent on enhanced (and poorly managed) human activities in the sea and in the entire Black Sea Basin (BSC, 2008).

Food web functional groups included to the model(s)

Ecopath with Ecosim – Black Sea Sea

- Phytoplankton
- Zooplankton
- Jelly-plankton
- Zoobenthos
- pelagic fish (sprat, anchovy, horse mackerel)
- Demersal fish (turbot, whiting, gobies, dogfish)
- Cetaceans

Environment

- Temperature
- Salinity
- O_2
- pH

Biology

- Abundance
- Growth
- Mortality
- Recruitment (sprat)
- Catches

Migration

- Dispersal

Ecology

- Diet
- Habitats
- Interaction terms

ii.GADGET

- catch data;
- length distributions,
- age length keys,
- mean length/ weight at age;
- survey indices by length and age,
- catch CPUE,
- stomach content data,
- data on proportion mature at age/leng

Commercial species and reference points (i.e F_{msy}, B_{msy})

In this material is presented a brief description of the state of the main fish species of commercial interest in the Romanian littoral in the last five years (Radu *et al.*, 2013).

Are presented and analyzed data as well:

- Short biological characterization of the main fish species (sprat, anchovy, horse mackerel, turbot, shark, whiting);

- Distribution and abundance of fishing agglomerations (maps);

- Assessing the biomass of fishing agglomerations;

- Population structure by size classes;

- Growth parameters and mortality rates;

Sprat - *Sprattus sprattus* L.,1758

Marine pelagic species. Forms important agglomerations and performs unregulated migrations between nutrition areas and spawning places determined by temperature conditions. In the spring exists a tendency of movement of the shoals toward coast and northwards and toward offing in the autumn, but are not exist specific migrations of spawning or feeding. The sprat wintering offing at depths of 80-100m; in April - May is nearing of littoral area in exploitable quantities, while in the summer avoids high water temperature performing migrations from coast to offing (Radu *et al.*, 2010).

The sprat (Sprattus sprattus) has lengths comprised among 50 and 130 mm over the whole reference period, the highest frequency pertaining to the individuals of 70-100 mm lengths.

The age corresponding to these lengths was 1 - 3:3+, the ages 1:1+ - 2;2+ having a significant participation. In the period analysed, the age classes 4;4+ years disappeared from the catch of this species, meaning the increase of the pressure through fishing exerted on the populations. While the share of this age decreased, the prevalence 1;1+ ages became increased, reaching to 60%.

During last years, the 2;2+ and 3;3+ ages have been prevailing, meaning that the pressure through fishing on this species decreased in the commercial catches from Romanian littoral (Maximov *et al.*, 2010; Radu *et al.*, 2010; Radu and Nicolaev, 2009-2013; NIMRD 2009-2013).

For sprat, Expert Working Group (EWG 12-16) calculated current F=0.811, that equals an exploitation rate of about E=0.46 (natural mortality M=0.95) and makes the EWG to considers the stock exploited unsustainably table 1) (Daskalov *et al.*, 2009- 2012)

Anchovy- *Engraulis encrasicolus* L., 1758

Marine, pelagic, gregarious, coastal species, forms large schools.

Migrations are unregulated, from open sea to coast and vice versa, function of water temperature and food. In March - April (when water reaches the temperature of 13-14 °C) migrates toward northern part on western and east coast where feeds intensive.

Migration for wintering begins in October and follow the same route.

Larvae and juveniles, mostly are found in the spawning area where also are feeding (Radu *et al.*, 2010).

Engraulis encrasicolus (anchovy) was present in catches with individuals of 45-145 mm length; the dominance was due to the 80-105 mm length-classes, the mean length being 95 mm and the mean, having 0+ - 3:3+ years.

By 2008, the composition on age-class shows the presence of individuals with ages comprised from 0+ to 4;4+ years, the classes 0+ and 3;3+ years prevailing. In this period, from the anchovy's catches the 3;3+ and 4;4+ ages almost disappeared, only 0+, 1;1+ and 2;2+ years remaining, the groups 0+ and 1;1+ prevailing (Fig.32). During this period, the anchovy stock suffered very much due to the over-exploitation (Maximov *et al.*, 2010; Radu and Nicolaev, 2009-2013; NIMRD 2009-2013)

For anchovy, the estimated F(1- 3) = 1.295 exceeds such exploitation rate E≤0.4, which equals Fmsy(1-3) in the range of 0.54 given M 1-3 = 0.81. The stock is overexploited (Daskalov *et al.*, 2009-2012).

Horse mackerel -*Trachurus mediterraneus ponticus* Aleev,1956

Appearance of the horse mackerel at Romanian littoral is closely related to water heating up to 14 °C in the last decade of May. The nearness of the shoals to our littoral is favoured by the salinity of 12-16‰ and southern winds. Horse mackerel remains in front of Romanian littoral till October. In this period, function of environmental variations, horse mackerel shoals perform movements on whole littoral between coast and open sea (Radu *et al.*, 2010).

Trachurus mediterraneus ponticus (horse mackerel) is one of the species whose population has suffered very much during last 20 years. During last years, the analyzed samples contained juveniles but also mature individuals. The length spectrum oscillated from 45 to 175 mm, and the age was mainly 2;2+ years.

By 2008, its catches were composed from age-classes up to 6 years, the ages between 1 and 3 years were prevailed. This shows the high pressure exerted by fishing on the stock (Maximov *et al.*, 2010; Radu and Nicolaev, 2009-2013; NIMRD 2009-2013).

Given the available data for the assessment of horse mackerel in the Black Sea, EWG 12-16 is unable to provide advice for the medium term future. But, taken into account the Romanian data, the stock is overexploited in the wintering area (Daskalov *et al.*, 2009-2012).

Turbot- *Psetta maxima* maeotica *(Pallas, 1814)*

Marine demersal species, specific of the sandy, rocky or mixed bottoms.

In winter, adults are encountered at depths of 70-100m; in spring (March - April) are nearing of shore until 18 - 30m for reproduction. After spawning, adults are spreading and retiring again towards deeper water. Turbot migrations are relative shorts and perpendicular on shore (Radu *et al.*, 2010).

The length spectrum of the turbot individuals ranged between 19-82 cm, dominant being the class of 49-52 cm.

The structure on age of the turbot catches indicates the presence of the individuals of 1-9 years, the catch basis is formed by the individuals of 3 years (24.107%), 4 years (33.929%) and 4 years (26.786%) (Fig.25) (Maximov *et al.*, 2010; Radu *et al.*, 2010; Radu and Nicolaev, 2009-2013; NIMRD 2009-2013).

For turbot, F is at the historical high level around 1.00, almost 6 times Fmax. The EWG classifies the stock of turbot in the Black Sea as being exploited unsustainably. The EWG notes that despite the recently low TACs in the communitarian area (Romania and Bulgaria) the fishing mortality remains at a level with no signal of reduction (Daskalov *et al.*, 2009-2012).

Whiting - *Merlangius merlangus (Linnaeus, 1758)*

Marine benthopelagic species, in cold water, mostly is encountered in coastal waters until 200m depth, on continental shelf from 10 to 130m, on mud and gravel bottoms, but also on sand and rock. In spring and autumn found near shore while in summer when the temperature increases it gives way offing and is nearing of coast only with cold-water streams. Juveniles found closer of shore, from 5m to 30m depth (Radu *et al.*, 2010).

The catches of *Merlangius merlangus euxinus* (whiting) had also the age 5 years in the age-class composition but little by little, the ages spectrum reaching 0+ and maximum 3;3+ years during last years; the 1+ and 2;2+ groups prevailed.

Like for the sprat, the phenomenon means that the pressure through fishing on the species populations increased once with the decrease of importance of anchovy and mackerel. As soon as the stocks of the last two species, especially of anchovy, begun to rehabilitate, the pressure on waiting decreased, leading to a slightly restoration of its stock (Maximov *et al.*, 2010; Radu *et al.*, 2010; Radu and Nicolaev, 2009-2013; NIMRD 2009-2013).

For whiting the estimated F(1-4)= 0.66 exceeds F_{MSY}. The EWG 12-16 classifies the stock of whiting in the Black Sea as being exploited unsustainably (Daskalov *et al.*, 2009-2012).

Spiny dogfish *Squalus acanthias* Linnaeus, 1758

Migratory species lives in cold water. Concerning spatial and temporal distribution at Romanian littoral of this species, researches have demonstrated that dogfish has two seasons to approaching of the shore: first in April - June and second in October - November at a depth ranged between 20-50m. In the winter and spring time, dogfish inhabiting the marine areas with depths over 65m until 120m, while in June - August is encountered at depths until 60m being disperse in water mass.

Structure analysis on length and mass class of the spiny dogfish in period 200-2012, evidenced the presence of the individuals of medium size, the length spectrum ranged between 89-134 cm, dominant being the classes 107-122 cm (Maximov *et al.*, 2010; Radu *et al.*, 2010; Radu and Nicolaev, 2009-2013; NIMRD 2009-2013).

For dogfish, the estimated F = 0.264 being exceeds $F_{0.1}$ classifies the stock of dogfish in the Black Sea as being exploited unsustainably (Daskalov *et al.*, 2009-2012).

3. Main fisheries (fleets/metiers), target species and catch composition, seasonality and main spatial patterns in the fisheries

Number of Vessels

At present, the Black Sea fishing operates a total of 7,064 fishing units (not including Russia and Georgia), of which 75.8% belong to Turkey, 14.3% - Bulgaria, Ukraine - 7.3% and only 2.6% Romania.

In Turkey are registered a number 5,358 vessels, of which: 70.2 % (vessels 6 - 12 m), 13.8% (12 - 18 m), 8.6 % (18 - 24 m), 6.7 % (24 - 40 m) and 0.7 % (> 40 m) and in Bulgaria are recorded a number of 1,009 fishing units, of which: 33.9% boats smaller than 6 m, 8.0 % vessels 6 - 12 m, 5.2%, vessels 12 - 18 m, 1.6 % - vessels 18 -24 m and 1.2 % vessels 24 - 40 m (Maximov *et al.*, 2013).

The core of catches is made up by fish - 99%, and small pelagic fish species (sprat and anchovy) prevail among fish in catch. The prevalent type of fisheries is industrial, which brings 95% of recorded fish products. The portion of artisanal fisheries is quite small - 5%, though its role is important from the point of view of ensuring people employment. It should be noted that actual catches are bigger than those indicated by official statistics because of presence of unrecorded catch (Maximov *et al.*, 2013).

Total catch of the Black Sea

The total catch of the four state (except Russia and Georgia), namely Turkey, Bulgaria, Ukraine and Romania, ranged, in the past three years, between 455,000 tons and 400,000 tons. The total catch recorded a downwards trend, in 2011 being by 7.41% smaller than in 2010, and in 2012 by 4.88% than in 2011 and by 11.93% than in 2010 (Maximov *et al.*, 2013).

Turkey is by far the main fishing country in the Black Sea, reaching a catch exceeding 85% (87.91 - 88.43%) of the total catch, followed at great distance by Ukraine, with almost 10% (9.50 – 9.80 %), Bulgaria with 2% (1.94 - 2.13 %) and under 1% Romania (0.06 - 0.21 %)(Maximov *et al.*, 2013).

Out of the total catch recorded during 2010-2012, the small pelagic species are the background of Black Sea fisheries, with a percentage of 78%, followed at great distance by demersal species 2%, other species 17% and the rapa whelk 3% (Maximov *et al.*, 2013).

Fleets, fishing gears and fishing effort

Sea fishing, conducted along the Romanian coastline, is limited to the marine areas up to 60-70 meter isobaths, as a consequence of the characteristics of the vessels and their limited autonomy.

Romanian fleet operates up to 30–35 marine miles out in the Black Sea.

Trawl fishing has a seasonal pattern linked to the presence of the fish in the areas.

Traditionally, the fishing in the Romanian Black Sea area was carried out in two ways:

- Coastal trawlers, equipped with pelagic trawls and turbot gillnets, activating at depths greater than 20 m. In 2013 beam trawling was initiated, with this fishing gear being equipped boats/vessels over 12 m length. During a fishing season, a vessel may alternate the use of fishing gear such as pelagic trawls, beam trawls or gillnets for turbot (NIMRD, 2009-2013).

- Fishing practiced along of the coastline in about 28 fishing points between Sulina - Vama Veche, in the coastal area with small depth (3,0 – 11,0 m) with fixed gear (pound nets, gillnets, long lines, and beach seine) and up to 40 – 60 m depth, with gillnets and long lines mainly for turbot and dogfish (NIMRD, 2009-2013).

Year after year the activity of active fishing decreased gradually to the point where, in 2010 from 20 vessels with LOA between 24-40 m registered in the last years in the Fishing Fleet Register, only one vessel was active for a very short period of time. In 2011, number of active vessels of 24-40m was 2, one of them being trawler and the other vessel activating as gillnetter. In 2012, also have been two vessels of 24-40 but one of them were inactive.

In 2013, the total number of boats/vessels registered has been 196, in which 112 active vessels and 84 inactive vessels. Only two vessels belonging to the length class of 24-40m (NIMRD, 2009-2013).

Fishing gears used at the Romanian littoral

There are different types of fishing gears for the active and passive fishery practised in the inshore and offshore coastal fishery (NIMRD, 2009-2013).

The passive fishing gears include the equipment for catching in general the fish migrating for spawning and feeding in shallow waters, namely:

- long lines and bottom lines;

- gillnets for turbot, Danube shad, dogfish, gray mullet, gobies and horse mackerel;

- sea pound nets.

Another category of fishing equipment used in the Romanian coastal zone includes the active fishing gear like beach seine, pelagic trawl and since 2013, beam trawl.

Catches and catch composition

In the coastal zone of the Romanian marine sector with small depth, fishing with fixed gear is characterized by the concentration of activity mainly in the first three / four months of the season (April-July), when usually the turbot migrates to the coastal area for reproduction and other species migrate for feeding. In generally, total fishing season being of about eight months. The capture level and the level of fishing productivity differs from one year to another, depending on the fishing effort (number of pound nets, number of turbot nets and effective fishing days), and also depends on the evolution of hydro climatic conditions and at last but not least, the state of fish stocks.

The structure on species of the catches mirrored only partly the composition of Black Sea ichtyofauna from the Romanian sector, because the type of gear conditions the ratio between the different fish species. As a general rule, the pelagic species, small-sized and short life cycle keep continue to be dominant in catches.

During 2000-2013 periods, the level of total catch declining from 2476 tons to 443.9 tons (2008), 330 tons (2009), 258 tons (2010), 568 tons (2011), 835 tons (2012) and 1710 tons (2013). In the last three years total catches increased compared to the previous period due to the rapana catches. The main species in the 2013 catches have been: rapana (1338 tons); anchovy (116 tons); sprat (98 tons); turbot (43 tons); horse mackerel (26 tons), etc.

4. Socio-economic indicators (performance)

At the Romanian littoral, the total number of fisherman in 2011 was 447, in 2012 have been 471. The number of fishermen for vessels with length bigger than 24m decreased from 180-200 to only the crews of two vessel crew (13 persons). Similarly to the situation in the coastal fishing fleet, the stationary fishing at the Romanian littoral has also declined. In 2012 a number of 371 fishermen acted for the small scale fisheries (boats 6-12m), who served several types of gears 74 persons acted for boats smaller than 6 m (Nicolaev and Radu, 2013).

Fishermen Income

In terms of landings composition, in 2011 and Rapa whelk was the most common species landed in terms of volume (0.22 thousand tones), followed by European sprat (0.13 thousand tonnes) and Pontic shad (0.05 thousand tonnes). In 2011 rapa whelk accounted for the highest value of landings (€ 0.89 million) by the national fleet, followed by turbot (€0.21 million) and then Pontic shad (€0.1million). The prices obtained for these key species generally declined between 2008 and 2010. In terms of prices, in 2010 Turbot achieved the highest average price per kilo by the Romanian national fleet (€4.79 per kg), followed by rapa whelk (€2.46 per kg in 2011, in 2012 the price decreasing) and Pontic Shad (€2.19 per kg) (Nicolaev and Radu, 2013).

Governance and management rules enforced (fisheries management, mpa, others that can affect fisheries and ecosystem)

Institutional framework in Romania (Radu and Nicolaev, 2009-2013)

The overall responsibility for fisheries policy in Romania falls under auspices of the National Agency for Fisheries and Aquaculture (NAFA), public institution integrally financed from the state budget subordinated to the Ministry of Agriculture and Rural Development.

This Agency shall draw up the strategy and legal framework for fisheries in Romania, and it shall carry out the implementation of technical measures and the control of regulations in fisheries and aquaculture.

The National Sanitary-Veterinary and Food Safety Authority provides the legal framework and development of the specific regulations for the activities in the veterinary and food safety field. This authority supervises and controls the implementation and observance of the sanitary-veterinary and food safety norms.

Ministry of Environment and Waters Management draws up specific legal acts regarding environment protection, waters management as well as authorization procedures for all activities, including fisheries enterprises.

Management system

- Vessel licensing
- Fishing authorisation
- Fishing Vessel Register
- Quota System

5. Policy Framework

The National Strategic plan for Fishing and Aquaculture in Romania was drafted according to Article 15 of Council Regulation (CE) no. 1198/2006 of July 27, 2006 on the European Fishing Fund (EFF) following a consultation process with the socio-economic stakeholders, national local government authorities, trade unions, NGOs and professional organizations. The National Strategic Plan (NSP) for the period between 2007 and 2013 covers all the aspects of the Common Fisheries Policy (CFP) in Romania. The National Strategic Plan shows the priorities, objectives and public financial resources required for the implementation of the CFP in Romania (Radu and Nicolaev, 2009-2013).

6. Other effects of human use of the ecosystem - drivers

ANTHROPOGENIC PRESSURES

Pressures in the coastal zone (NIMRD, 2013)

The main anthropogenic pressures identified in the Romanian coastal zone result from the pronounced development of various socio-economic activities in the coastal zone natural space: tourism and leisure, buildings/holiday homes in tourist areas, expansion and modernization of existing tourist marinas, harbors and navigation, marine fisheries, agriculture and food industry, petrochemical industry, refineries etc. (NIMRD, 2013).

As a result of these pressures, the Romanian coastline faced significant problems regarding habitat destruction, coastal erosion, water pollution and depletion of natural resources. The rapid population growth in residential areas, in previously tourist areas and the rapid development of the related infrastructure have led to severe degradation and decline in the quality of the Romanian coastal zone, along with the large-scale exploitation of natural resources.

In addition, maritime traffic, including leisure boats traffic, with high incidence in summer, involves multiple pressures on the Black Sea biodiversity, including the discharge of nutrients, production of underwater noise, oil leaks and spread of non-indigenous, exotic organisms (NIMRD, 2013).

Also, the urban sprawl/coverage of beach areas with constructions and extending vertically/raising the old historical buildings/terraces on the beach by running multiple stories above them (Mamaia area), and the uncontrolled development of temporary tourist constructions and tourist, recreation and leisure activities over the carrying capacity of the coastal environment led to the additional pressures exerted by tourism on the environment, in terms of population doubling during the summer season, becoming significant, linked to increasing/doubling the amount of domestic wastewater requiring treatment, increasing/doubling car traffic and recreational boating, with subsequent increases in emissions and noise level (NIMRD, 2013).

Local pressures generating organic substances/pollutants are concentrated in the southern part of the Romanian Black Sea coast, as this area is more developed from the industrial and urban point of view.

7. Conservation priorities (protected habitats, species, etc.)

Management measures (Details) (Radu and Nicolaev, 2009-2013)

Areas and periods of prohibition 2012

Alosa Pontica

- Danube branches from Black Sea and Danube sector up to Cetal Chilia, Mm 43
14April –April, 10 days, prohibited
- Danube river and its branches from Ceatal Chilia up to Vadul Oii, km 238
16 April - 05-May, 20 days, prohibited
- Danube river and its branches from Vadul Oii, km 238 up to Gura Timocului
26 April – 25 May, 30, days, prohibited
For protecting the reproduction or rehabilitation the stocks of these species, the catches, the minimum admissible size, the periods, etc. are regulated.

Squalus acanthias

Black Sea Romanian teritorial waters, from 15-March - 30-April, 47 days, prohibited. Throughout the year, is prohibited retention on board of the pregnant females.

Psetta maxima maeotica

Under EC Regulations. Mesh size of 2a=40cm and minimum admissible total length of 45 cm.

Acipenseridae

Danube river and Black Sea, from Apr-2007 to Apr-2016, 10 years, prohibited. Sturgeon, for reproduction, is fishing in living state in the areas recommended by CITES, for a period of 46 days between 1 March- 15 April

Marine Mammals

Romanian marine waters, whole year, prohibited. It is an obligation as cetacean by-catches to be reported.

The rest of marine fish species are allowed.

Are declared zones with integral protection regime for aquatic marine resources from the Black Sea the following:

a/ Sacalin-Zătoane zone;

b/ Marine Reserve Vama Veche – 2 Mai.

Gears, minimum mesh size and fishing methods

In the economic fishing activity, it is banned to use:

a/ in marine fishing, all kind of trammel nets, sturgeon gill nets, drifted gill nets whose total length is higher than 2.5 m, as well as the turbot gill net manufactured from threads with thickness smaller the 6.350 m/Kg;

b/ the trawl in marine zone under the 20 m depths;

c/ gears type dredge and bottom trawl in the Black Sea;

j/ gill nets for shad, during 1 August -31 December

m/ hooks and lines and little hooks and lines in natural fish basins;

n/ fishing gears monofilament net.

It is banned to utilize the fishing gears with minimum mesh size smaller then:

a/ a = 30 mm, 2a – 60 mm respectively, at the actively fishing gears for Danube shad and mugill;

b/ a = 20 mm, 2a = 40 mm respectively, at gears codend type settled at the dams of littoral lakes;

c/ a = 7 mm, 2a = 14 mm respectively, at the room catching of pound nets in the Black Sea Romanian littoral zone;

d/ a = 180 mm, 2a = 360 mm respectively, beyond the territorial waters, and 200 mm, 2a = 400 mm respectively, in the territorial waters at the turbot gill nets;

e/ a = 7 mm, 2a = 14 mm respectively, at the trawl in the Black Sea;

f/ a = 10 mm, 2a = 20 mm respectively, at codend of beach seines.

g) a = 10 0mm, 2a = 200 mm for dogfish gillnets.

Minimum dimensions of the fish in centimetres and other living aquatic resources able to be fished are regulated by Order no. 342/2008 on minimal size of the aquatic living resources (table 7.1).

Table 7.1 Fish size restriction (minimum admissible length)

Latin name	Common name	Minimum admissible length (cm)
Clupeonella cultriventris	Kilka	7
Engraulis encrasicolus	Anchovy	7
Sprattus sprattus	Sprat	7
Platichthys flessus luscus	European flounder	20
Trachurus mediterraneus ponticus	Horse mackerel	12
Mugilidae	Grey mullets	25
Alosa pontica pontica	Pontic shad	22
Alosa caspia nordmani	Caspian shad	15
Atherina boyeri	Sand smelt	7
Squalus acanthias	Spiny dogfish	120
Psetta maeotica	Turbot	45

8. Management priorities and possible scenarios (input from case study meetings)

For turbot, species in Black Sea Case Study

Spatial restrictions

- Areas restricted to trawling
- Areas restricted to gillnet fisheries
- Areas restricted to other fisheries catching turbot as by-catch
- No-take areas

Temporal restrictions

Close fishery during spawning season. If similar spawning season occur in different areas, a common closed season should be established.

Gear restrictions

Maximum length and height of gillnets

Hanging ratios of gillnets

Minimum mesh size for gillnets

By-catch Reduction Devices for beam trawl and bottom trawl

Maximum monofilament or twine diameter in bottom set gillnets of 0.5 mm (not implemented in Ukraine)

Effort restrictions

Limit the overall capacity of the authorized fleet

Number of days, hours at sea

Others…

Catch restrictions (e.g. TAC or Limit)

By-catch restrictions (e.g. maximum number or weight of turbot allowed to be caught as by-catch)

Restocking

VIII. Chatham Rise case study

1. Oceanography-water circulation pattern and environmental features

Bottom topography and circulation

The Chatham Rise is a broad ridge lying to the east of central New Zealand and extending for c. 1400 km to c. 168° W, east of the Chatham Islands (Figure **8.1**). The case study will focus on the deep water ecosystem dominated by hoki (*Macruronus novaezelandiae*) in the area, from 200 to 800m.

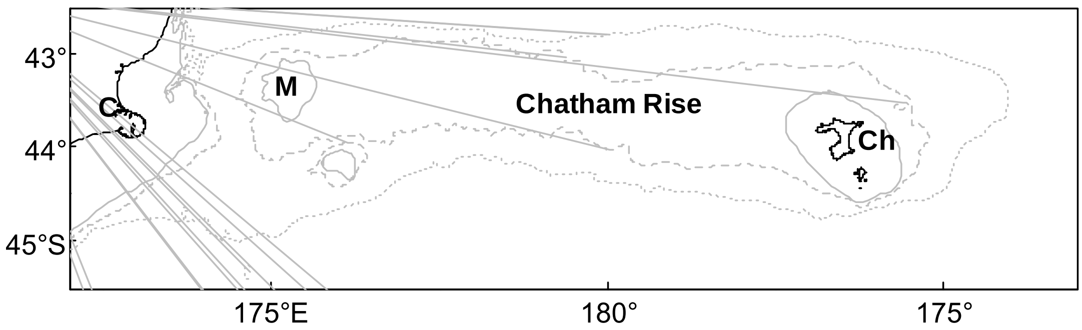

Figure 8.1: Chatham Rise case study area. C – Christchurch, Ch – Chatham Islands, M – Mernoo Bank.

Data is currently being collated to develop the bioregionalisation for the Chatham Rise region. This includes spatial data on catch composition, seabed communities and habitats, and other relevant information on oceanography. Once the bioregionalisation has been completed, the data will be stratified to the appropriate spatial areas for inclusion within the Atlantis model.

The bathymetry of the Chatham Rise is well documented (Figure 8.2). Over the large-scale, the Chatham Rise appears smooth-topped, but at a more detailed level it includes four banks with depths of less than 250 m, and many underwater topographic features in deeper waters. Much of the area is composed of soft sediments, except where old volcanic rocks emerged above the sediment to form rocky banks such as Mernoo and Veryan Bank, and patches of rough ground on the eastern Chatham Rise near the Chatham Islands. A large number of sediment samples are available for the region, from many years of study, but these have not been collated into a comprehensive sediment map of the area. Terrigenous sediments giving way to pelagic sediments at c. 179° E.

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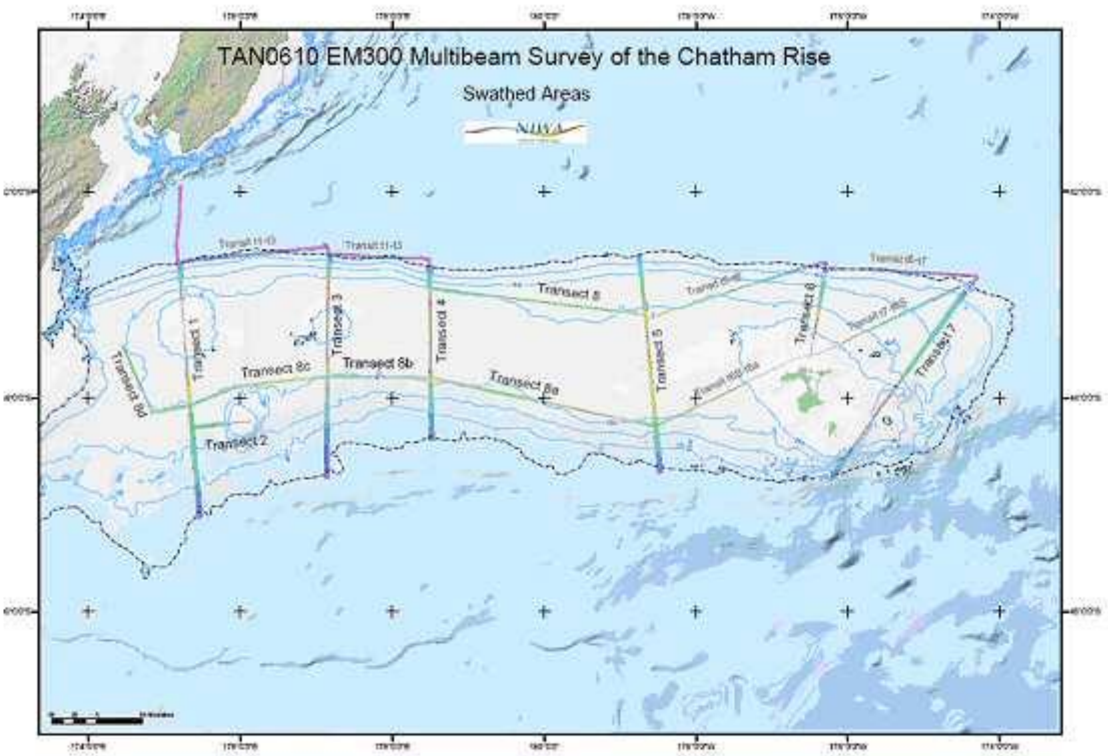


Figure 8.2: Chatham Rise region, showing recent multibeam survey transects

The Chatham Rise case study area also includes a number of seamounts, which are important for biodiversity, and fisheries. The largest group of these are the Graveyard seamounts. The Graveyard seamount complex (Figure 8.3) consists of 28 seamounts on the northern slopes of the Chatham Rise. The largest rises from a depth of 1,100 metres to a peak at 750 metres below the surface.

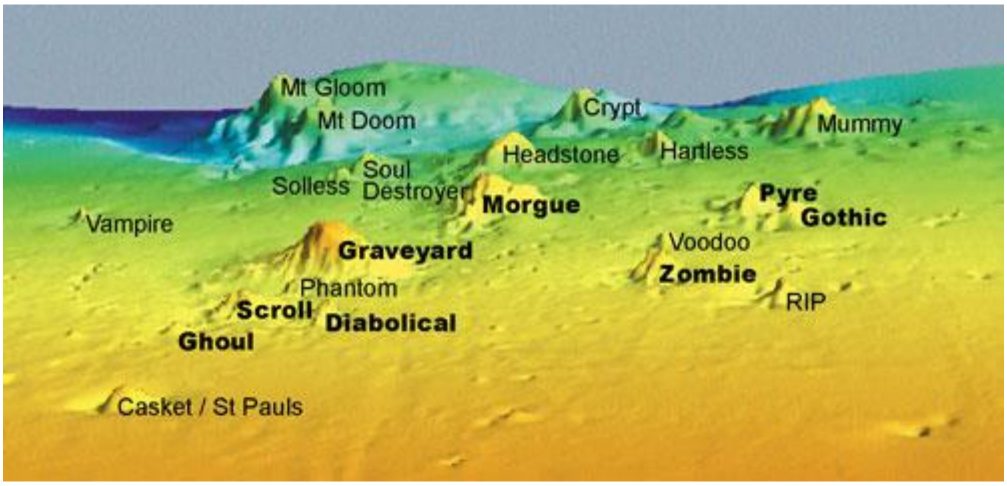


Figure 8.3: Graveyard seamount complex, Chatham Rise.

A wide range of oceanographic data are available for the Chatham Rise region, and once the spatial regions have been defined by the bioregionalisation, a ROMs model will be developed to provide the physical forcing for the Atlantis model. Data include satellite derived SST (Figure 8.4), research vessel CTD and expendable bathythermograph data, modelled seabed temperature (Figure 8.5), general ocean circulation data (Figure 8.6), satellite derived SSH (Figure 8.7), and ocean drifter data (Figure 8.8). Data on ocean acidity are also available (Figure 8.9), and we aim to include investigation of climate change scenarios within our modelling.

Summarizing the oceanography, warm subtropical surface waters from the north and cold subantarctic surface waters from the south meet at the western end of the Chatham Rise and then run eastwards forming the subtropical front as they mix along the crest of the Rise. Bottom temperatures are usually 2–3°C warmer on the northern flank. The nutrient rich waters from the south mix with warm northern waters, and create ideal conditions for primary productivity and the animals that feed on this, making the seas the most productive around New Zealand. The cold-water current and mixing area extends northwards to a variable degree at the western end of the Chatham Rise (to the west of the Mernoo Bank), and this area is of especially high productivity, and is the focus for several commercial fisheries. To the north, east, and south, the Chatham Rise is effectively bounded by areas of deep (>3000 m) and cold (<2°C) water.

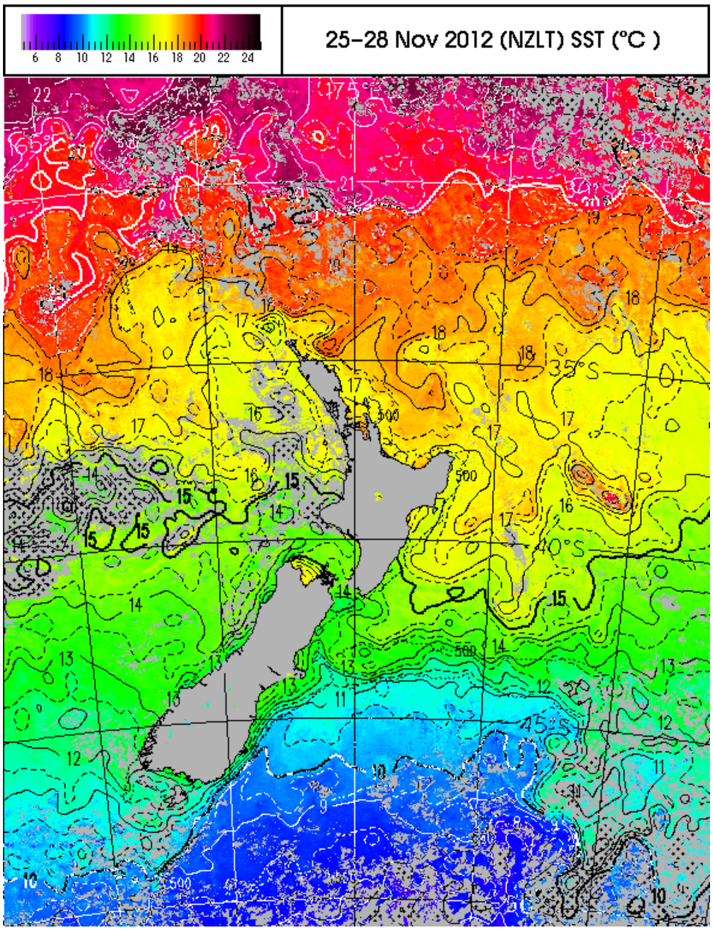


Figure 8.4: Satellite derived sea surface temperature for the New Zealand region for 25–28 Nov 2012.

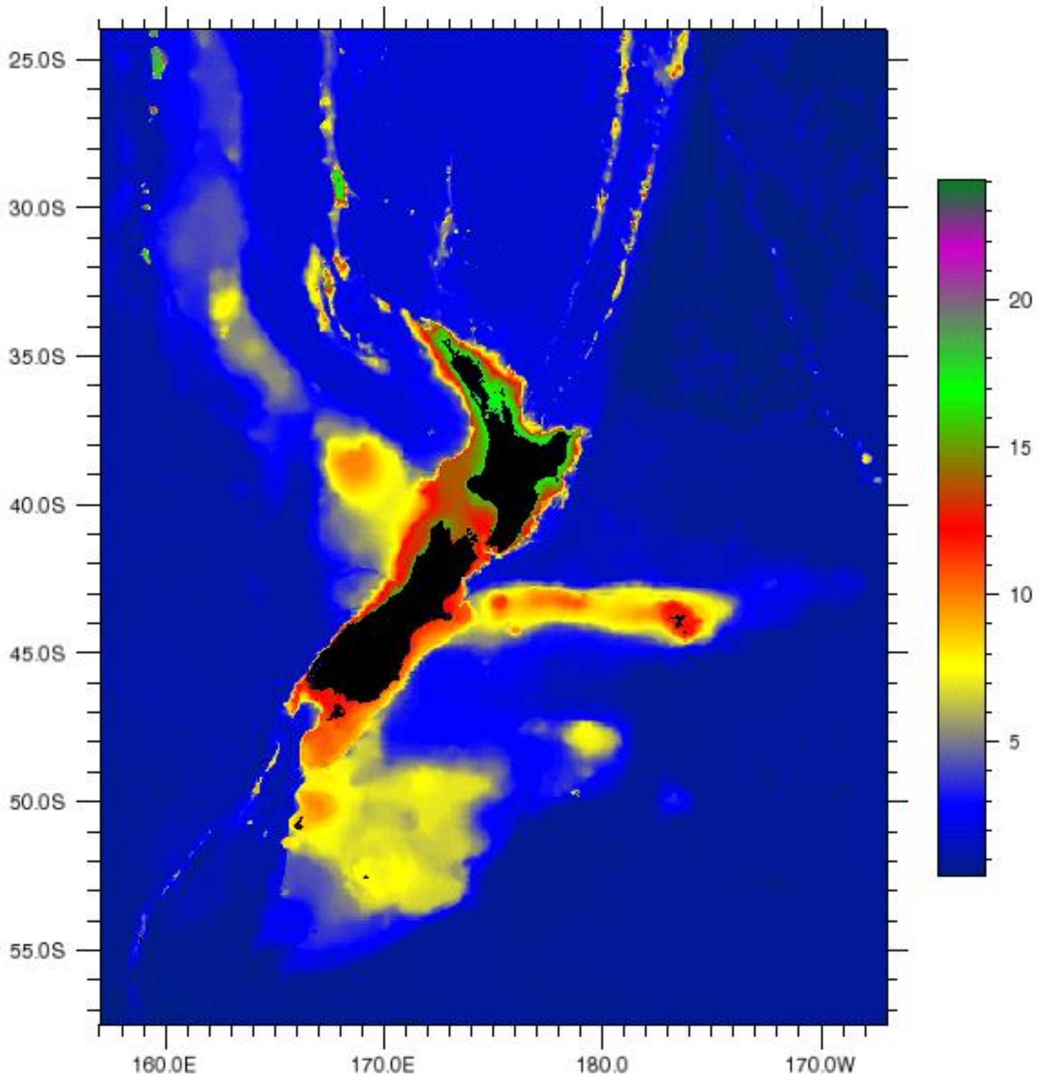


Figure 8.5: Estimated temperature at the sea-bed produced by 3-dimensional interpolation of temperature-depth-location data onto a Mercator projection grid at 1 km resolution (Pinkerton et al. 2005).

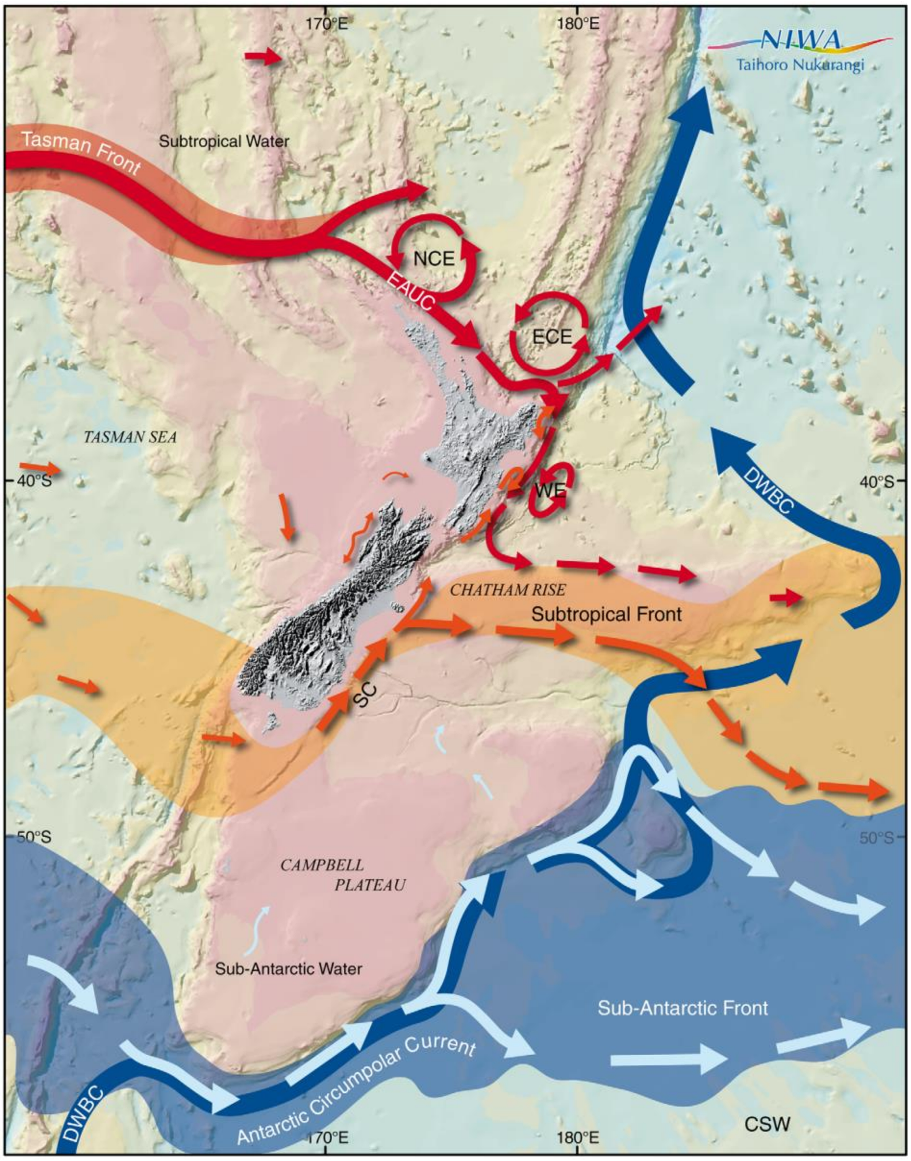


Figure 8.6: Ocean currents and water mass frontal systems in the New Zealand region. The Tasman Front (TF), the Subtropical Front (STF) and the Sub-Antarctic Front (SAF) approach New Zealand from the west. The STF represents the meeting of Subtropical Water (STW) and Sub-Antarctic Water (SAW), while the SAF is formed by the meeting of SAW and Circumpolar Surface Water (CSW). The fronts contain or generate currents and there are several permanent eddies off the eastern North Island (EAUC, East Auckland Current; WAUC, West Auckland Current; ECC, East Cape Current; DC, D'Urville Current; WC, Westland Current; SC, Southland Current; ACC, Antarctic Circumpolar Current; NCE, North Cape Eddy; ECE, East Cape Eddy; WE, Wairarapa Eddy). There are also areas of tidal mixing in Foveaux Strait between Stewart Island and the South Island, in Cook Strait between the North and South islands, and north of Cape Reinga.

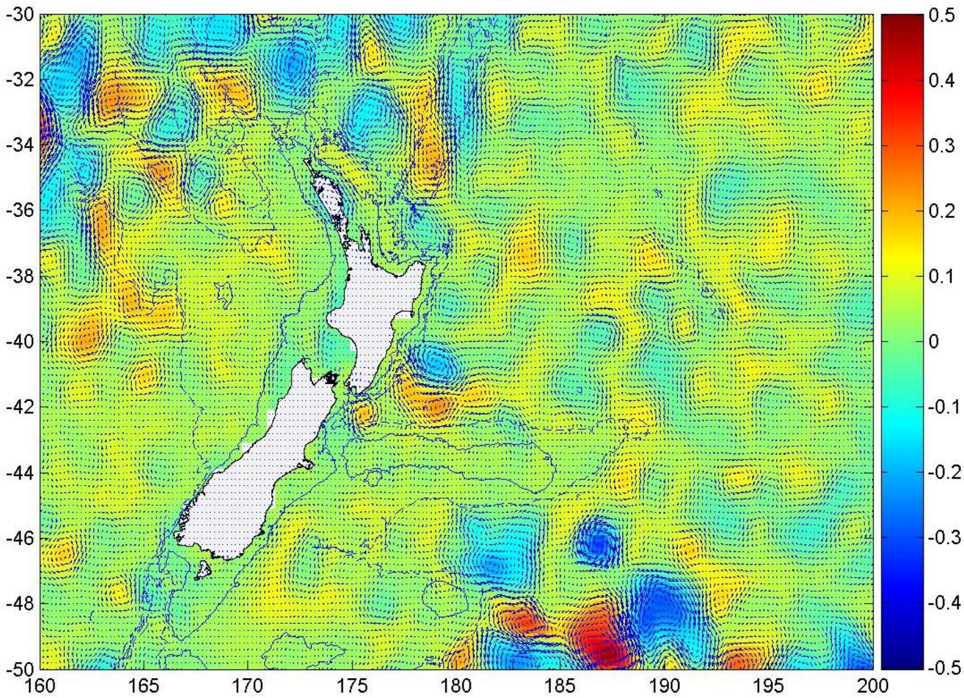


Figure 8.7: Sea surface height anomaly (m) for the New Zealand region from 1 January 2001 from AVISO merged dataset. Vectors show surface current anomalies corresponding to this anomaly.

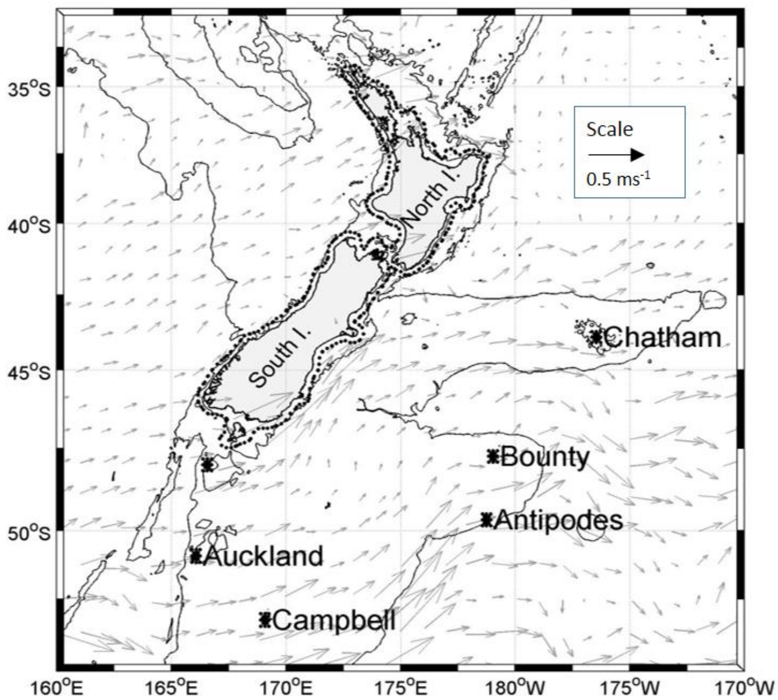
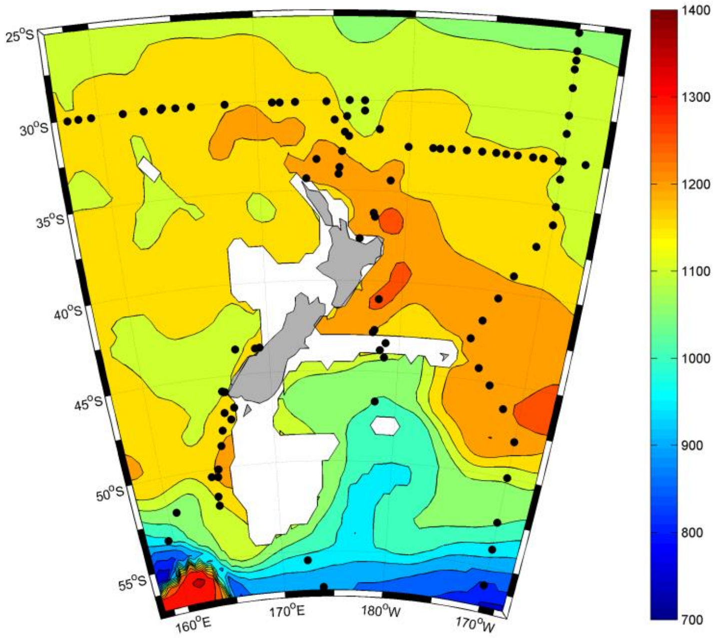


Figure 8.8: Mean surface flow computed from the drifters passing through the New Zealand region.



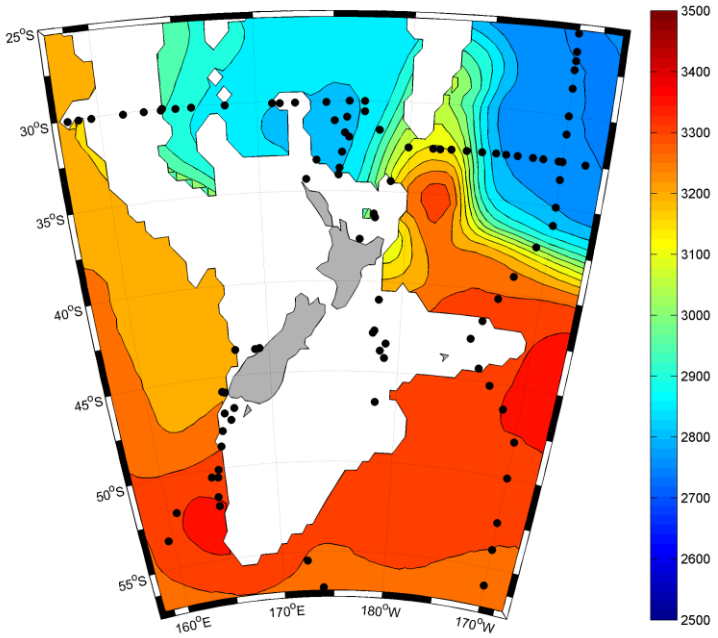


Figure 8.9: Detailed aragonite saturation horizon (ASH, upper plot) and calcite saturation horizon (CSH, lower plot) maps using the algorithms and the CARS climatology for the New Zealand region. Plots show the depth of the respective horizons in metres. The location of the WOCE and NIWA stations where alkalinity and DIC were sampled are shown by black dots. The white regions in each plot represent topography shallower than the ASH and CSH (Tracey et al. 2013).

Broad scale climate and oceanographic features and drivers

Open ocean ecosystems are affected by natural interannual climate variability. This can result in changes in the frequency, magnitude, or timing of water column mixing and stratification, and primary production which may lead to marked changes in the organisation of the whole ecosystem (Fasham et al. 2001). The state of the New Zealand climate has important effects on the regional oceanography and hence marine ecosystems. Pressures relating to climate change have been identified as having a substantial potential effect on New Zealand marine ecosystems (MacDiarmid et al. 2012). Globally, a number of climate and oceanographic indices have been found to be correlated with fish population processes, and have been used to identify evidence of environmental regime shifts. Recently, recognising that climate and regional oceanography may be linked to recruitment strength and, potentially, population biomass in some fish species (Dunn et al. 2009b), several indicators of climate and oceanographic state of the New Zealand EEZ have been brought together to provide background environmental data relevant to fisheries management (Dunn et al. 2009b, Hurst et al. 2012). Broad scale drivers of relevance to the Chatham Rise include the Interdecadal Pacific Oscillation, the Southern Oscillation Index, and the Antarctic Oscillation.

The Interdecadal Pacific Oscillation (IPO, also called the Pacific Decadal Oscillation, PDO) is a 15–30-year cycle that affects parts of the Pacific Basin, causing variability in climate, including sea temperature, and has substantial and long-lasting effects on regional ecosystems. For example, under the IPO variation, community structure in the Gulf of Alaska ecosystem changed dramatically and abruptly after the climate regime shift of 1976/77 from a cold regime to a warm one (Anderson & Piatt 1999). Over a 40-year study period, prey species such as pandalid shrimp (three species) and capelin were the dominant species until 1976; after 1977, recruitment of predatory fish increased and, by the 1980s, these prey species had essentially disappeared. Total biomass in the standardised survey catches increased by over 250% (Kennedy et al. 2002). In a broader survey of the biological effects of the 1970s climate shift, Francis et al. (1998) documented major changes in the large marine ecosystems of the northeast Pacific, including abrupt population increases (and decreases) for zooplankton, fish, birds, and marine mammals. Although the exact mechanism by which these changes occurred is unknown and probably differs between species, the driving force behind these widespread ecosystem modifications was climate variability (Kennedy et al. 2002).

Figure 8.10 shows the variations in the IPO derived from global sea surface temperatures. New Zealand experienced significant climate cooling in 1950 and again in 1977, after which the pattern shifted to a warmer phase. Between 1978 and 1998, El Niño events increased and there has been much debate about whether this was a result of global warming or due to natural variations in the climate over decades (10-year periods) (Mullan et al. 2009).

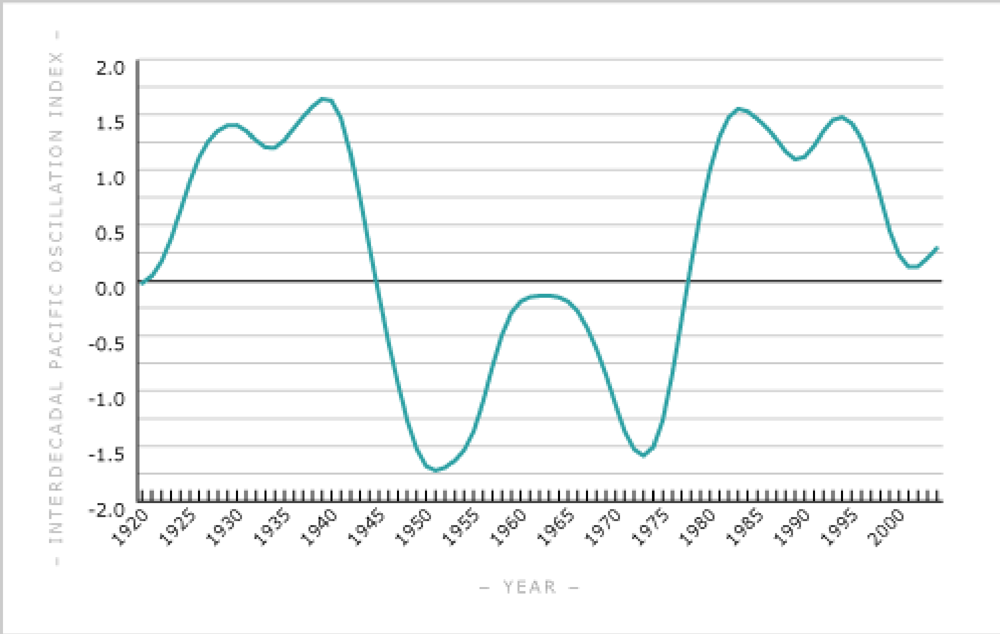


Figure 8.10: Interdecadal Pacific Oscillation index based on Mullan et al. (2009). This index is also called the Pacific Decadal Oscillation (PDO).

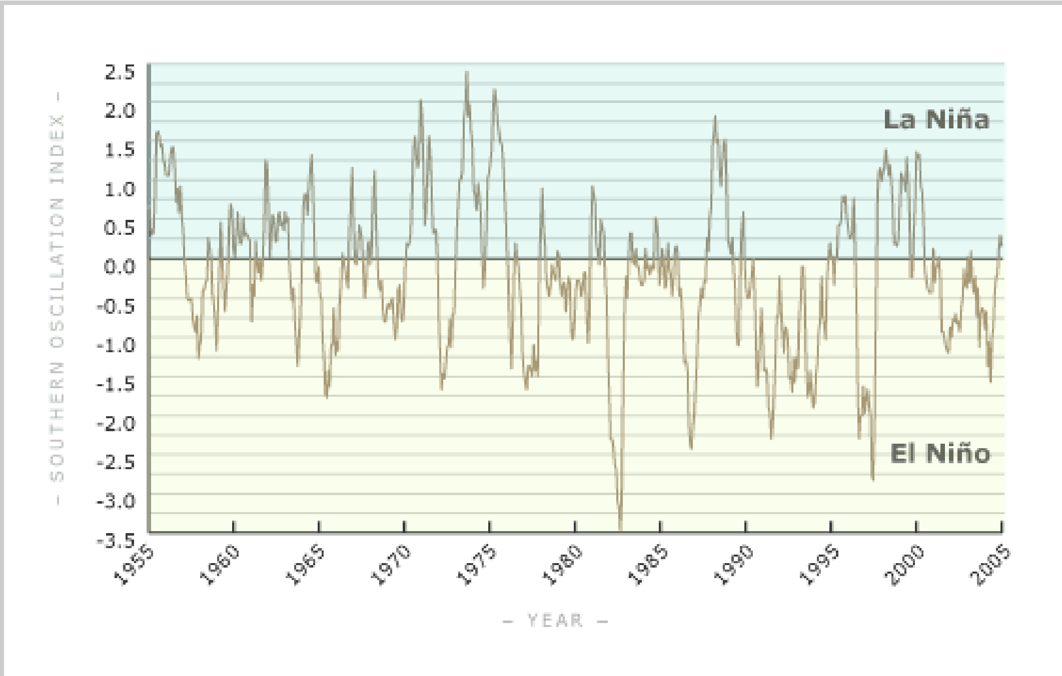


Figure 8.11: Southern Oscillation index based on Mullan et al. (2009).

The Southern Oscillation Index (SOI) is the normalized mean sea surface pressure difference between Tahiti and Darwin (Australia) (after Trenberth 1984). The SOI is related to the strength of the trade winds in the Southern Hemisphere tropical Pacific (Mullan 1995) and SOI values for May-September are often used as an indicator of El Niño-La Niña Southern oscillation (ENSO, Trenberth 1997). There are two phases of ENSO — El Niño (warm ENSO phase) and La Niña (cool ENSO phase). El Niño refers to the appearance of anomalously warm waters extending west of the International Dateline. Off the west coast of South America, this results in the disappearance of cool nutrient-rich upwelled water. La Niña represents the appearance of anomalously cool waters in the same region of the Pacific, with upwelling enhanced. A year is often defined as a La Niña year if at least one SOI value for May-September is equal to 1 or more; if there is at least one SOI value less than or equal to -1, the year can be defined as an El Niño year; in all other cases, the year is considered "Normal" (Figure 8.11). Jiang et al. (2006) found this definition to be consistent with the season-by-season breakdown list of occurrences of ENSO events provided by the USA's National Center for Environmental Prediction (NCEP 1999). In the New Zealand region, the SOI is correlated with rainfall, wind, temperature and oceanography (Figure 8.12) (Basher & Thompson 1996, Salinger & Mullan 1999).

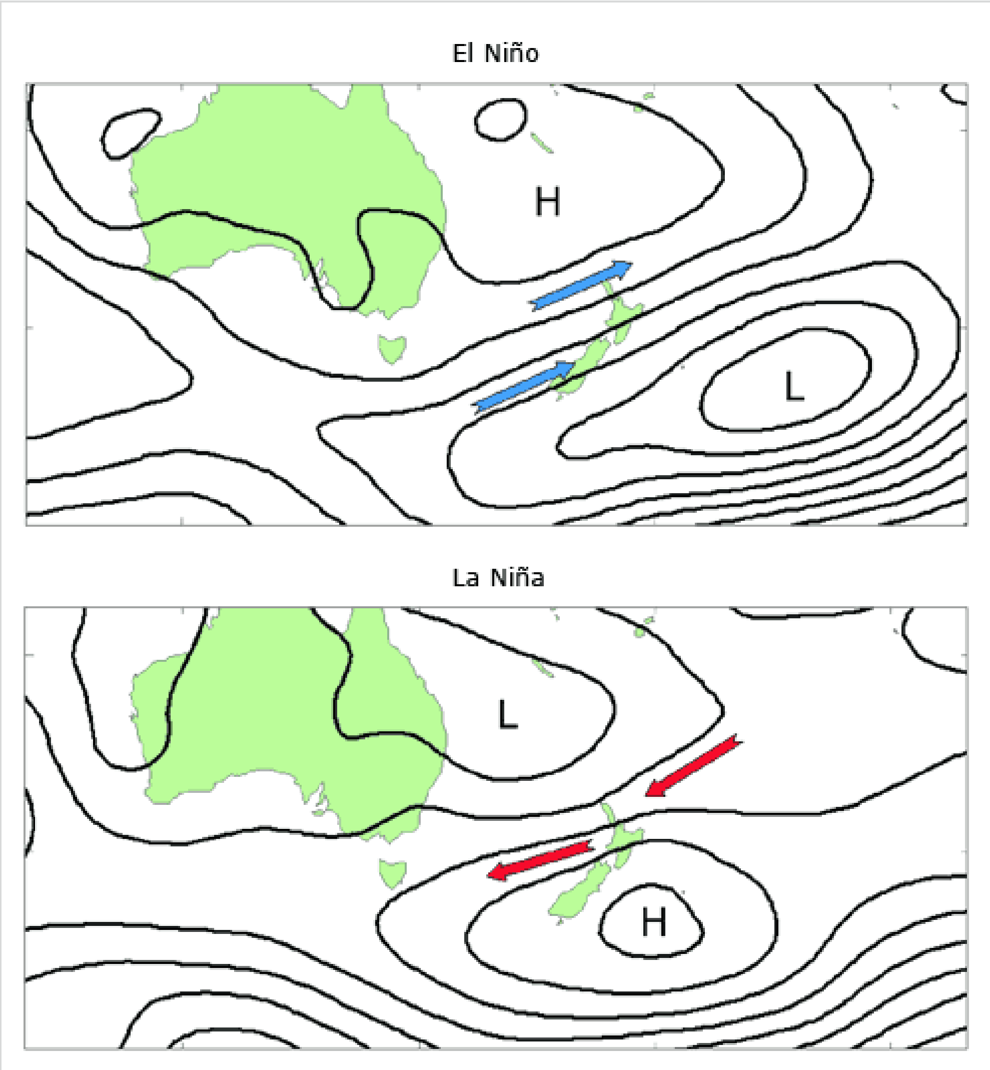


Figure 8.12: Pattern of air pressure and wind direction during El Niño and La Niña phases of the Southern Oscillation. During the El Niño phase, pressures are high (H) to the north. Strong south-westerly winds bring drought to the north-east of the country. When La Niña is operating, there are high pressures over the South Island. These bring north-easterlies and rain to the north and east of the North Island.

The Antarctic Oscillation (AAO, also known as the High Latitude Mode or Southern Annular Mode) is the alternate weakening (negative phase) and strengthening (positive phase) of the westerlies, roughly every month (Figure 8.13). The AAO is the dominant pattern of non-seasonal tropospheric circulation variations south of 20°S (Thompson & Wallace 2000). Over the last 30 years there has been a trend towards a stronger positive phase – stronger westerly winds at latitude 50° south which has been attributed to increased greenhouse gases and ozone depletion in the stratosphere (Mullan et al. 2009).

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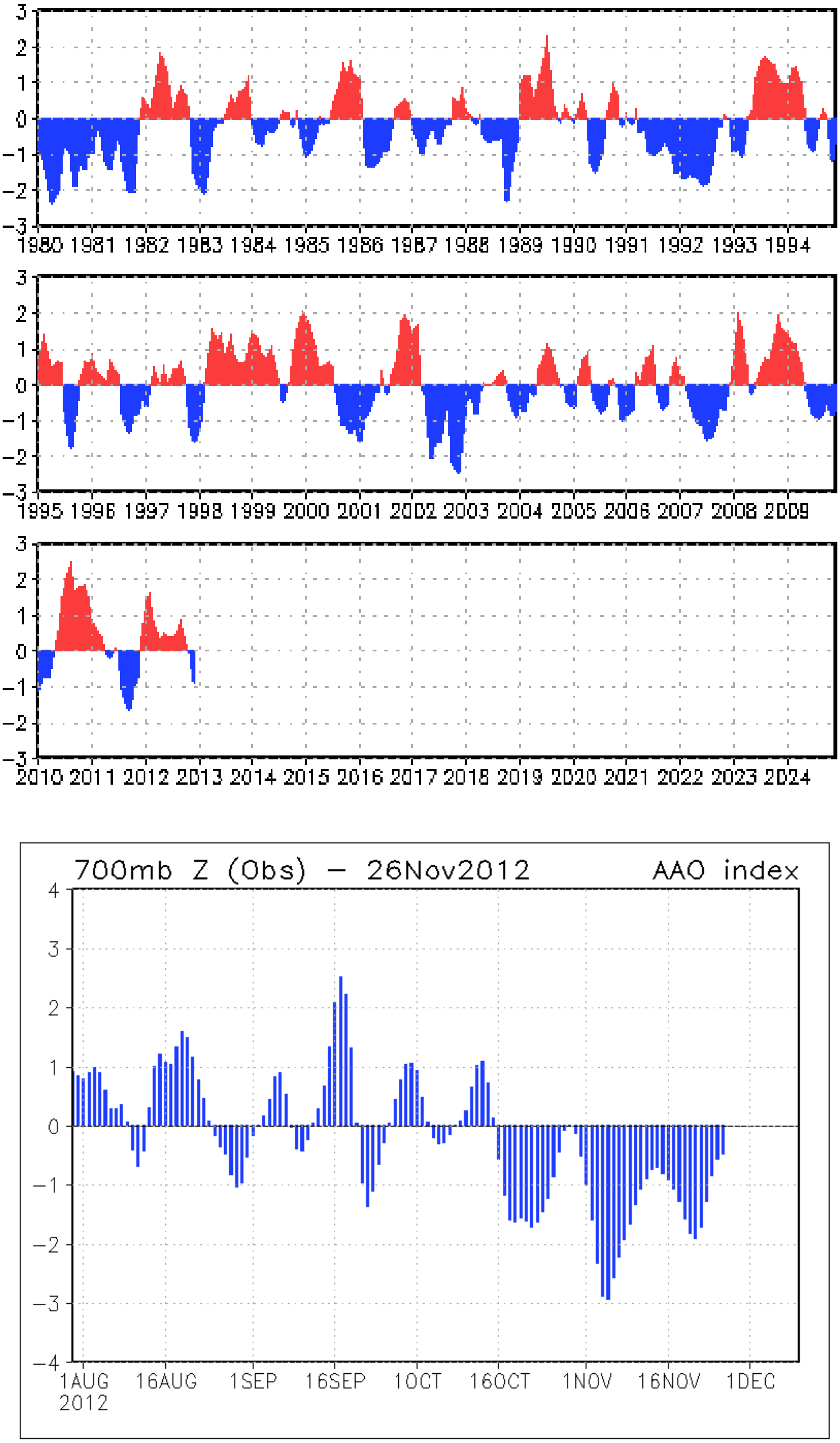

Figure 8.13: Antarctic Oscillation index (AAO). Top three panels: AAO for the period 1980–2012, with 3-month running mean. Bottom panel: Daily AAO for 2012 (Source: www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/aao/aao_index.html).

Primary production and hypoxia (anoxia)

Satelite data are available for primary productivity around New Zealand (Figure 8.14). The satellite-based method of observing, characterising and monitoring phytoplankton biomass has become standard for management and research purposes at moderate to large spatial and temporal scales (tens to thousands of kilometres; weeks to decades). The accuracy of the satellite based method (typically a target accuracy of within 35%) is much less than in situ methods, and periodic research and validation voyages in regions like the New Zealand EEZ are required to ensure that this target accuracy is being achieved and that data are fit for purpose.

A summary of patterns in Chl-*a* from SeaWiFS measurements in the New Zealand EEZ between 1997 and 2000 is given in Murphy et al. (2001), with some subsequent validation (Pinkerton et al. 2005). More recently, Chiswell et al. (2013) examined the 13-year time-series of Chl-*a* derived from SeaWiFS in the New Zealand region. The mean near-surface Chl-*a* is elevated in the Subtropical Front and around the sub-Antarctic islands that have an associated shelf (Figure 8.14). Note that elevated Chl-*a* around the New Zealand coast is probably indicative of suspended sediment as well as potentially elevated phytoplankton biomass in these areas, as explained above. The annual cycle in surface Chl-*a* shows a ubiquitous unimodal summer bloom in sub-Antarctic water; autumn, winter and spring blooms occur variously in Subtropical waters and across the Subtropical Front (Figure 8.15). The autumn and winter blooms progress equator-wards with time and develop in response to deepening of the mixed layer; spring blooms show significant spatial structure and are different from year to year (Chiswell et al. 2013).

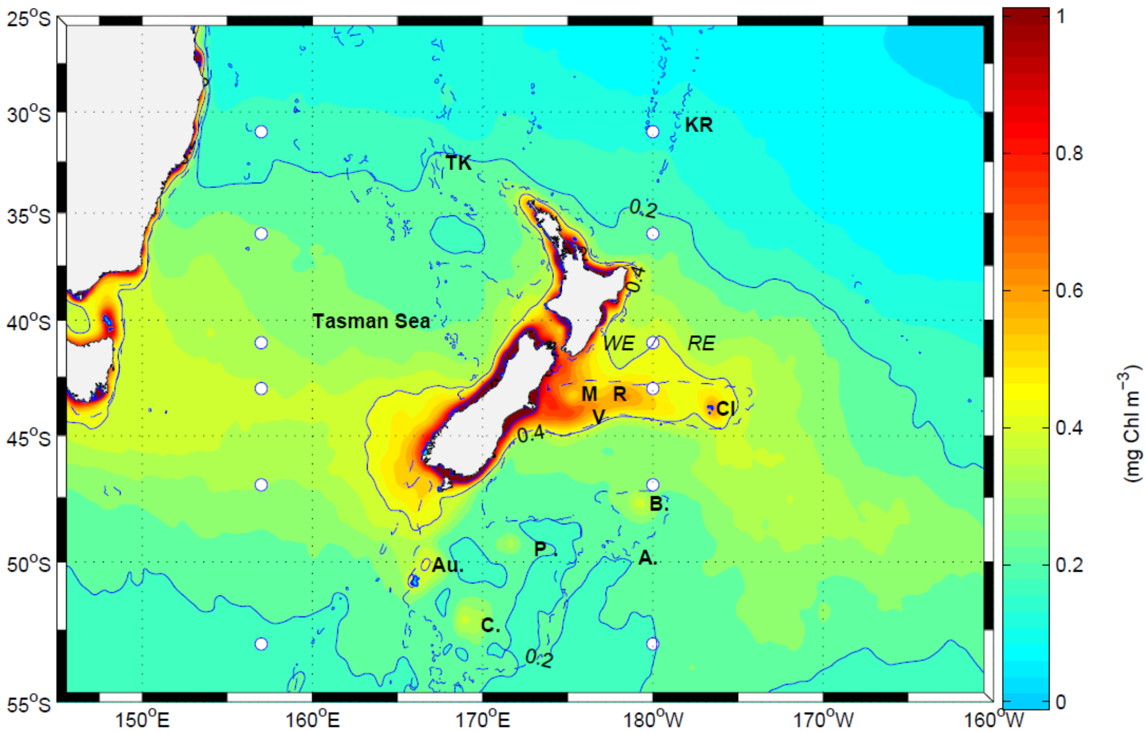

Figure 8.14: Mean surface chlorophyll-a concentration (mg Chl-*a* m^{-3}) computed from 13 years of SeaWiFS data (1997 to 2010). The 0.2 and 0.4 mgChl-*a* m^{-3} contours (solid lines) and 1000 m isobaths (dashed line) are shown. Locations are: Three Kings Island (TK), Mernoo (M), Reserve (R) and Veryan (V) Banks, Auckland Islands (Au), Campbell (C), Chatham Islands (CI), Antipodes (A) and Bounty (B) Islands, Pukaki (P) Rise, Wairarapa (WE) and Rekohu (RE) eddies, and the Kermadec Ridge (KR).

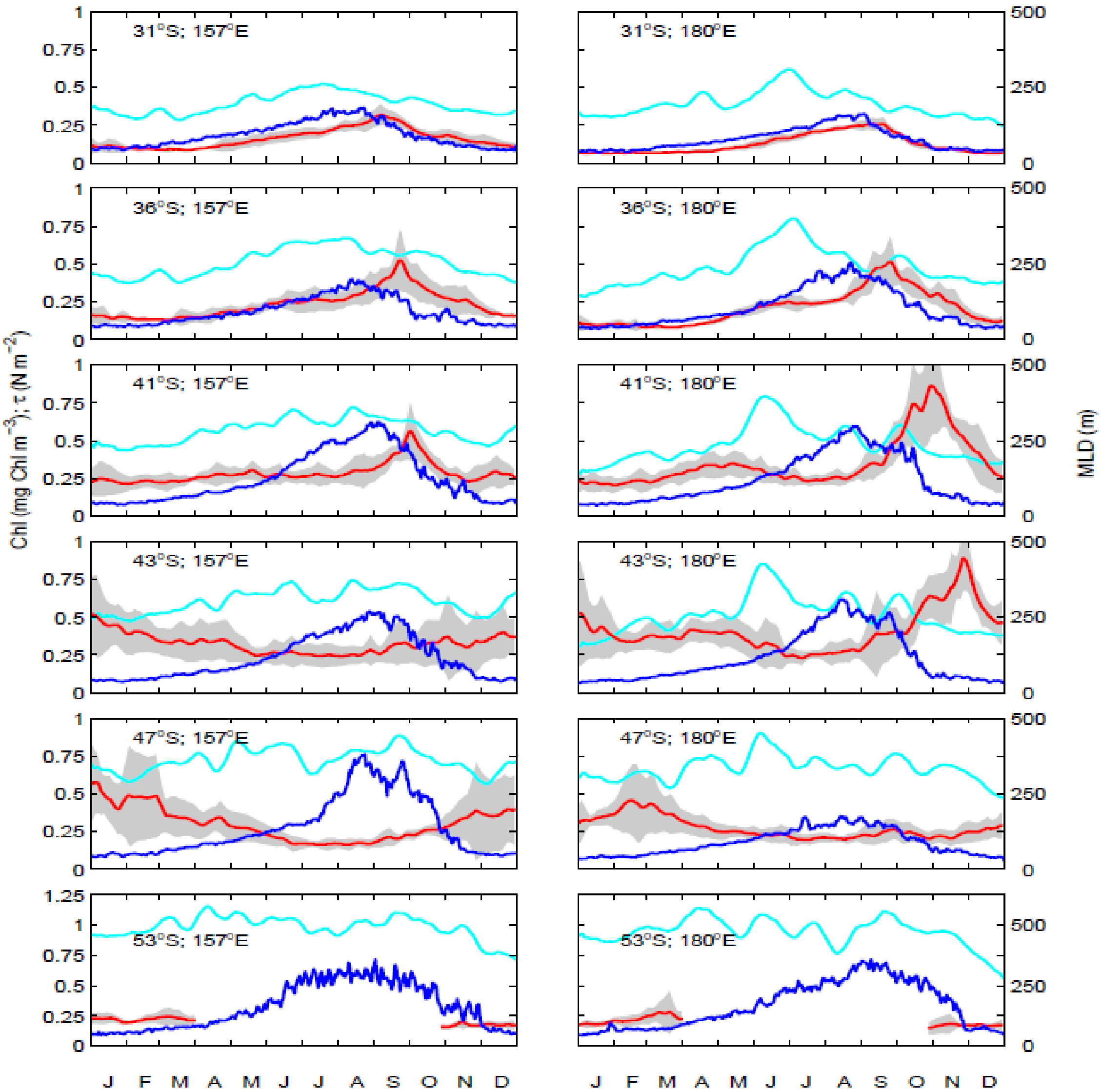

Figure 8.15: Annual cycles in surface chlorophyll (red), mixed-layer depth (blue) and wind stress (cyan) for the 12 sites shown in Figure 8.14. Grey shading indicates one standard deviation in surface chlorophyll annual cycle. Note change in scale for locations at 53°S (Chiswell et al. 2013). Because of low solar elevation and persistent cloud cover, no ocean colour satellite data are available for 53°S April to October.

In the New Zealand region, dead zones have been found in the coastal zone, for example, in the Bay of Plenty following mangrove removal (Morton 2011) but to date no dead zones have been reported offshore.

2. Food- web description, key species, ecological functional groups and fleets

Food-web – general overview, main processes

A balanced trophic model for the Chatham Rise using the Ecopath approach is already available (Pinkerton 2011), and this will be developed further within the Atlantis model.

The subtropical convergence on the Chatham Rise gives the region high biodiversity, and makes it the most productive in New Zealand waters. The ecosystem supports substantial commercial fisheries production, with the main species at depths of 200–800 m being demersal finfish exploited primarily by bottom trawlers. The main commercial species are hoki (*Macruronus novaezelandiae*), hake (*Merluccius australis*), and ling (*Genypterus blacodes*), although trawl surveys regularly catch over 100 finfish species. The convergence is a meeting point of two different ecosystems, and as a result the fish assemblages are different on the north and south flanks of the Rise, although many species range over the entire area. The mesopelagic species assemblage has been found to change from north to south across the area, and recent research has found associated changes in the diet composition of many commercial fish species.

The high productivity of the Chatham Rise supports a high diversity of seabird, cetacean, and large pelagic fish species, many of which are protected under New Zealand law but threatened by human activities. New Zealand has the most diverse seabird community in the world, including many species which feed and reproduce on the Chatham Rise. These include the black-bellied storm petrel (*Fregetta tropica*), Buller's mollymawk (*Diomedea bulleri*), sooty shearwater (*Puffinus griseus*), northern royal albatross (*Diomedea sanfordi*), and the endemic Chatham Islands blue penguin (*Eudyptula minor chathamensis*). Cetaceans include dusky dolphins (*Lagenorhynchus obscurus*), sperm whales (*Physeter catodon*), and Sei whales (*Balaenoptera borealis*). The New Zealand fur seal (*Arctocephalus forsteri*) occurs on the Chatham Rise, and the white shark (*Carcharodon carcharias*) is a regular visitor to the waters around the Chatham Islands.

Annual (middle depths, 200-800m) trawl surveys have been conducted in the region since 1992 (O'Driscoll et al. 2011), and these provide abundance indices and size composition data for all the main species, and also a range of ecosystem indicators (Tuck et al. 2009). Multibeam backscatter data collected during these surveys (in more recent years) also provides an index of mesopelgic biomass, and can be used to derive indices of abundance of mesopelagic fish and krill in these regions. The main fishery species not adequately sampled by the middle depth surveys is the scampi *Metanephrops challengeri*, which has its own targeted trawl and photographic surveys every three years (Tuck et al. 2011).

Data on benthic communities is available from dedicated sampling, and trawl survey bycatch, but is patchy. The photographic surveys for scampi also provide data on epifauna in the regions they are conducted (Tuck & Spong 2013).

Trophic structure is quite well understood, and a number of studies have examined fish diet in the region (Dunn et al. 2009a, Dunn et al. 2009b, Dunn et al. 2010a, Dunn et al. 2010b, Dunn et al. 2010c, Horn & Dunn 2010, Horn et al. 2010, Horn et al. 2011, Stevens & Dunn 2011, Stevens 2012, Dunn et al. 2013, Horn et al. 2013b, Horn et al. 2013c).

Some of the seabirds interacting with Chatham Rise fisheries nest outside the NZ region, but for native species, reasonably regular surveys are conducted (e.g., Baker et al. 2013). Ministry for Primary Indistries (MPI) fisheries observers record all fishery interactions with protected species while on observer trips, and these data are used to estimate annual interactions (Thompson et al. 2012).

Food web functional groups included to the model(s)

The aim of the Chatham Rise case study is to include all the key components. The specific structure will be based on that previously developed within the balanced trophic model using the Ecopath approach (Figure 8.16), which is also being examined within a qualitative modelling framework to investigate the potential for simplification (Figure 8.17)

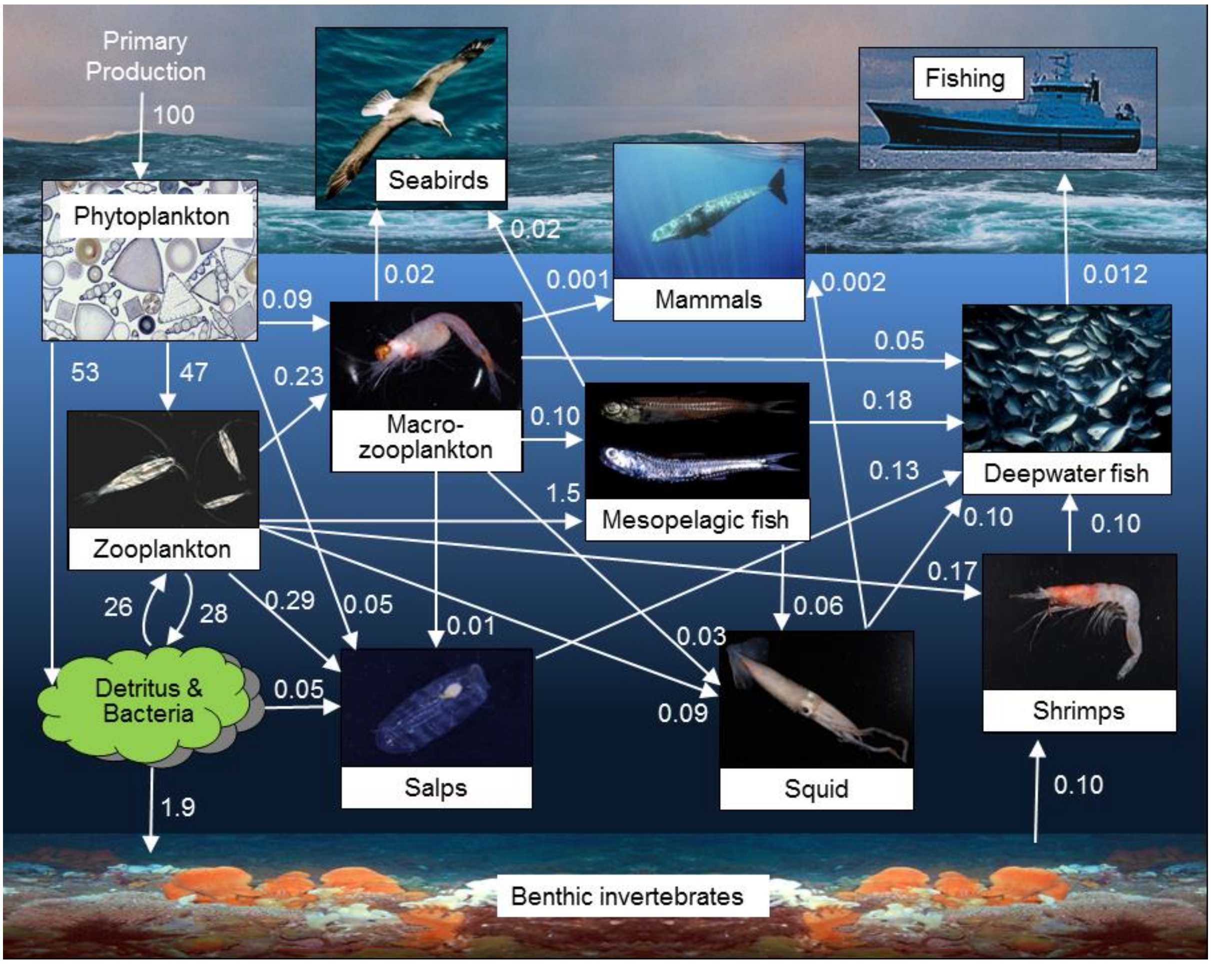

Figure 8.16: Simplified trophic model of the Chatham Rise, New Zealand (based on precursor to Pinkerton 2011). The growth of phytoplankton generates organic matter that is the fuel for the marine ecosystem. Figures show the annual flow of energy through unit area of the food-web normalised to an NPP=100, based on an equilibrium mass-balance model (similar to Ecopath).

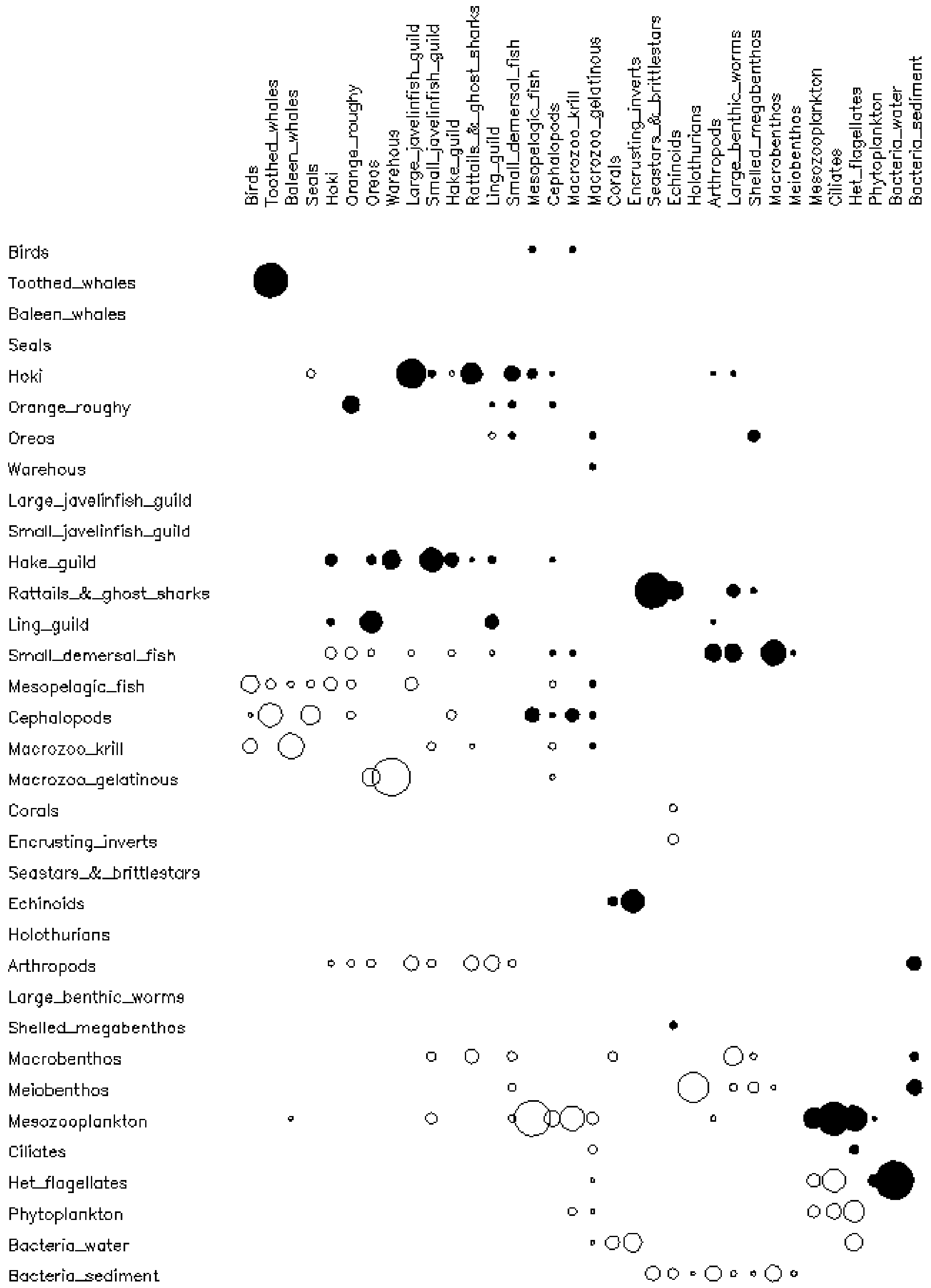

Figure 8.17: Chatham Rise food web Mixed Trophic Index (MTI) matrix.

3. Commercial species and reference points (i.e F_{msy}, B_{msy})

New Zealand fisheries are managed within the Quota Management System (QMS), with MSY reference points defined by the Harvest Strategy Standard (Ministry of Fisheries 2008). Most fisheries have a target biomass of 40% SSB_0.

4. Main fisheries (fleets/metiers), target species and catch composition , seasonality and main spatial patterns in the fisheries

Annual landings data are being collated for the commercial species in the area. Trip by trip landings data are available for all species included withon the Quota Management System (QMS), and MPI observer data will be used to estimate bycatch of non quota species (e.g., Anderson 2012). Fishing effort (and estimated catch for main species) is recorded at the tow by tow level for deepwater fisheries, and fishing effort on the Chatham Rise can therefore be mapped at reasonable accuracy, for estimation of benthic disturbance (Figure 8.18).

Regular age or length based assessments are available for the main commercial species (e.g., Horn et al. 2013a, McKenzie 2013, Tuck 2013)

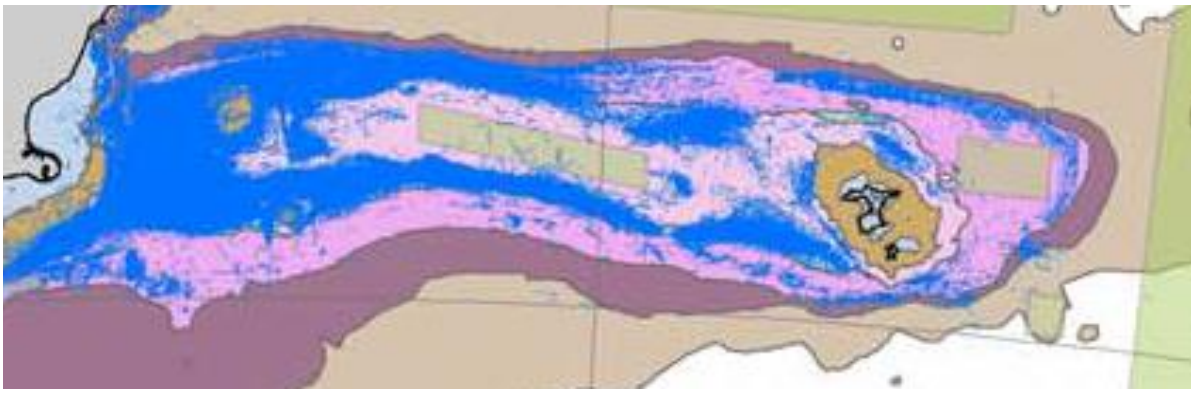

Figure 8.18: Trawl footprint for Chatham Rise region for fishing years 1991/92 – 2005/06.

The main target fisheries on the Chatham Rise are for hoki, hake, ling, orange roughy and scampi, although a preliminary metier analysis of New Zealand's deepwater trawl fisheries identified 13 catch composition groups, 12 of which were reported at least on occasion from the Chatham Rise region (Castle 2013). There is also long line fishing for ling in shallower (300 m) areas of the region. A more detailed analysis of the seasonal and spatial fishery activity will be conducted once the bioregionalisation has been completed, to relate fishery removals to spatial areas within the ecosystem model.

5. Socio-economic indicators (performance)

NA.

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 613571

6. Governance and management rules enforced (fisheries management, MPA, others that can affect fisheries and ecosystem)

In New Zealand, decisions on fisheries Regulations, including TAC setting and allocation, are always made by the Minister for Primary Industries. After setting a TAC, an allocation decision also needs to be made, specifying allowances for the customary (Maori) sector, recreational fishers and other sources of fishing mortality. After these allowances are made, the remaining share is allocated to the commercial fishing sector, and is referred to as the TACC (Total Allowable Commercial Catch).

Since 1986, New Zealand has managed its main fisheries with individual transferrable quotas (ITQs). The evolution of the fisheries science and management systems has recently been described by Mace et al (2014).

A number of top marine predators in New Zealand waters have been classed as threatened (Hitchmough 2002, Miskelly et al. 2008, Baker et al. 2010), and all marine mammals, almost all New Zealand seabirds, and a number of sharks and rays are protected under the Wildlife Act 1953.

In November 2007 17 Benthic Protection Areas (BPAs), with a total area of about 1.2 million km^2, were closed to bottom fishing methods, namely bottom trawling and dredging, in perpetuity [Fisheries (Benthic Protection Areas) Regulations 2007]. One of these areas is on the crest of the Chatham Rise, and two other areas to the north and east cover seamount areas (Figure 8.19).

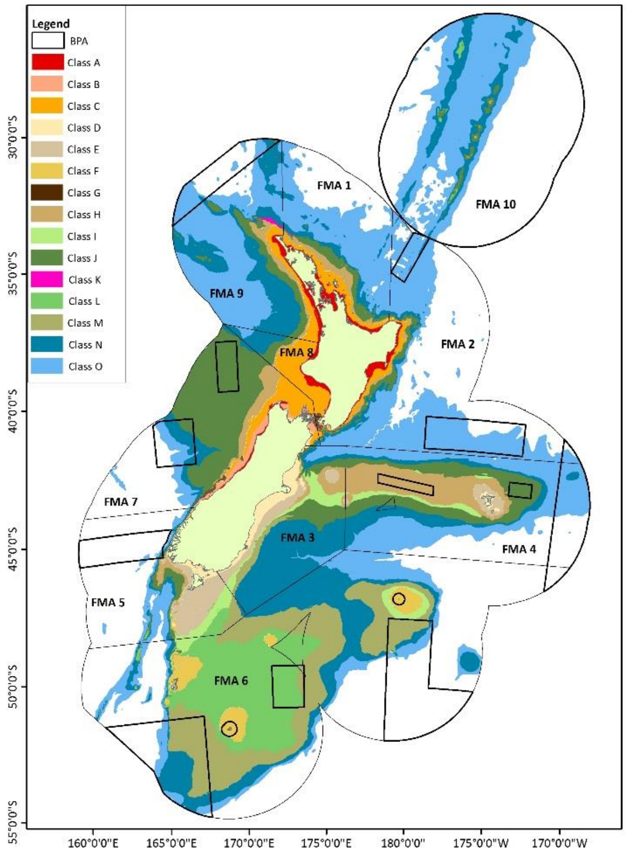

Figure 8.19: New Zealand Benthic Protection Areas (BPAs) overlaid on the 15 level BOMEC (a broad scale habitat classification (Leathwick et al. 2012)).

The Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 providesa legislative framework for the many activities taking place outside of the territorial sea but within New Zealand's EEZ and Continental Shelf.

7. Other effects of human use of the ecosystem

Phosphorite nodule mining

Phosphorite nodules (Figure 8.20) have been found in the vicinity of the BPA area on the crest of the Chatham Rise (Figure 8.190), and a commercial seabed mining company is currently in the process of applying to the New Zealand Environmental Protection Agency, for a license to mine.

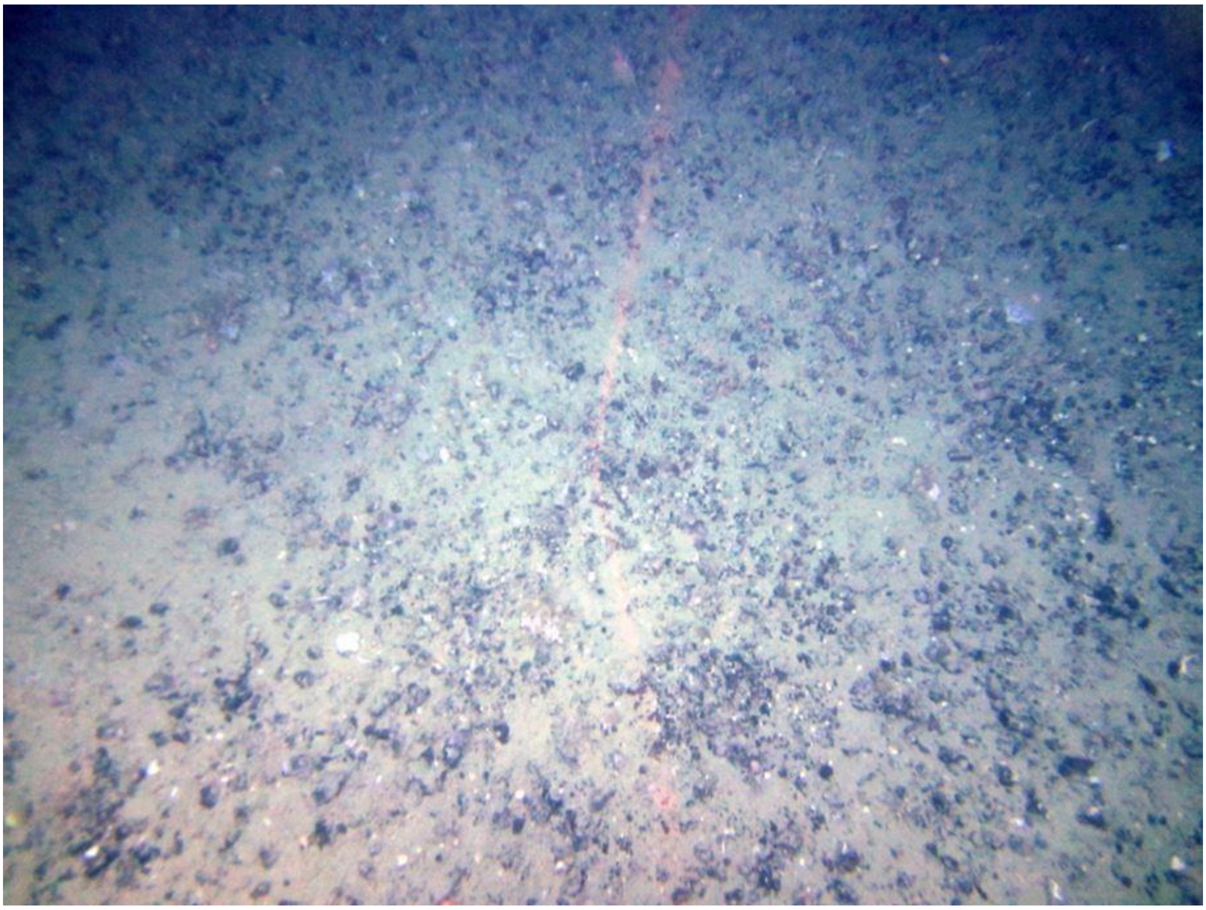

Figure 8.20: Dense concentrations of medium sized phosphorite nodules on the crest of the Chatham Rise. Image shows an area of seabed about 4 m wide.

There are conservation and fishing industry concerns over the potential effects of the seabed mining, and the proposal is currently under consideration by the Environmental Protection Agency.

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8. Conservation priorities (protected habitats, species, etc.)

See 6: Governance

9. Management priorities and possible scenarios (input from case study meetings).

A meeting was held with stakeholders in Wellington in March 2014. The meeting was held with participants from the Ministry of Primary Industries, Ministry for Environment, Department for Conservation, the deepwater fishing industry, the seabed mining industry, and Maori interests. The main ecological considerations raised were

- Sustainable exploitation of target stocks.
- Mammal and seabird bycatch.
- The effects of climate change.
- Impacts of deep sea mining on benthic habitats, and incidental effects on fisheries

The specific stakeholder concerns were

- Difficulties if tradeoffs between fishing/conservation/seabed mining.
- Lack of framework for tradeoffs to be considered.
- Property right issues for fisheries.
- Short term perspective from politicians.

Conclusion

Deliverable 5.1 covers a wide range of ecosystem types, biological complexity (e.g. Baltic/Mediterranean Sea/North Sea), ecological knowledge (e.g. data-poor/data rich areas) and a large array of management practices, issues and priorities. In general the case studies (CS) included in MAREFRAME represent a cross section of the European seas that are characterized by different ecosystem structure and management policies. The marine systems represented CS are:

- Open marine waters (Iceland, Northern waters; Southern Western Waters)
- Continental shelf seas (North Sea)
- Semi-enclosed seas (Baltic Sea, Mediterranean-Strait of Sicily and Black Sea).

These ecosystems clearly differ in the main physical factors and drivers impacting the food-web structure, as well as in the key species and management priorities. In all CS description conceptual models cover all trophic levels, from primary producers up to top predators, but mostly focus on intermediate trophic levels, where target species/functional groups are mainly located. The conceptual food web models encapsulate the prey-predator relationships between the numerous functional groups identified within the ecosystem. The target stocks of the fisheries are well identified in each conceptual food-web model (e.g. gadoids, clupeids) as well as key species/functional groups important for ecosystem functioning, such as zooplankton (*Pseudocalanus sp* for the Baltic Sea, *Calanus finmarhicus* for the North Sea, etc), jellyfish in the Black Sea, marine mammals in the North Atlantic and West of Scotland

Even though case studies represent various types of ecosystems, with specific ecological processes and a differing stochastic interplay of forcing factors, there are processes common to many of the CS to be modelled, namely:

(i) Fleet specific fishing exploitation: The species/groups in the models are subject to various types and levels of fishing mortalities which will impact their overall mortality and abundance.

(ii) Recruitment: The species/groups in the model are impacted by various types of forcing which cause variation in the recruitment to key fish species, which in turn could be a driving force for entire food-web dynamic.

(iii) Prey-predator interactions: This is a key process to be captured in an ecosystem model, albeit difficult to parameterise accurately. A high predators' abundance will negatively impact the abundance of preys while a high abundance of prey species may, depending on the fishing pressure applied on the predator species, positively impact the growth and abundance of predators. This can in turn impact landings and associated profits.

(iv) Density-dependence: For certain species, density –dependence processes can have a large impact on species' abundance.

(v) Marine mammals interactions: The species/groups in the model are subject to mammals predation which, like fishing, will impact the overall mortality.

(vi) Eutrophication and changes in primary production: Changes in the lower trophic level play an important role in shaping energy transfer for exploitable stocks and may led to changes in landings and trade-offs between fisheries and other ecosystem services.

An initial effort to identify the main management issues and priorities was attempted during stakeholders meetings held in each case study area (WP1 – Task 1.5) as input for WP5 and base for development of management scenarios in T5.3. The common picture from all case studies suggests set of parallel management issues and priorities:

- Recovery of commercial stocks;
  Implementation of an ecosystem approach to fisheries management that accounts for species interactions and environmental factors;
- Identification of maximum sustainable/maximum economic yields (MSY/MEY) within a multispecies context;
- Ecosystem implications of landing obligations.
- Multiannual management plans including a way ; of achieving EAFM that worked with the grain of the fisheries and encouraged responsible and law abiding fisheries;
- Effects of climate change (climatic scenarios); A simplified form of the proposed models that stakeholders can use as a tool to explore various management options and see the EAFM consequences of various alternative approaches.

It is however clear that more work is required in each case study to better identify the management scenarios to be tested in WP 5 to assess the effects of different sets of management measures on the different ecosystem components (e.g. trade-offs) and the main fisheries. In this context, one of the main challenges of the project is to incorporate the good environmental status indicators (GES) of the Marine Strategy Framework Directive into models in order to forecast the possible outcome of different management and climatic scenarios. Models will need to be adapted to include the necessary mathematical processes required to incorporate GES indicators and economic and social indicators (identified also in WP6 and WP7). Based on the description of all case study it is clear that more focus has been put on the ecological and fisheries part than on the socio-economic implications. Consequently a further effort is clearly necessary to better identify socio-economic indicators, also in collaboration with WP 6 and WP 7, to be included into modelling. Continued application of the Co-creation approach to refine formulating and implementing the scope of the models will be both helpful and essential to providing a usable product. The co-creation process in the CS also needs to evolve to include the involvement of categories of stakeholders as well as fishermen representatives, to incorporate for example local and regional conservation priorities (i.e using GES indicators) into management scenarios.

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