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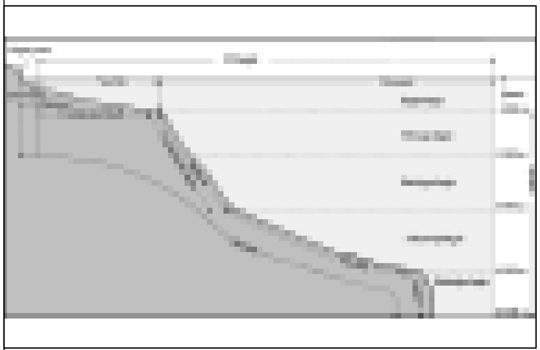
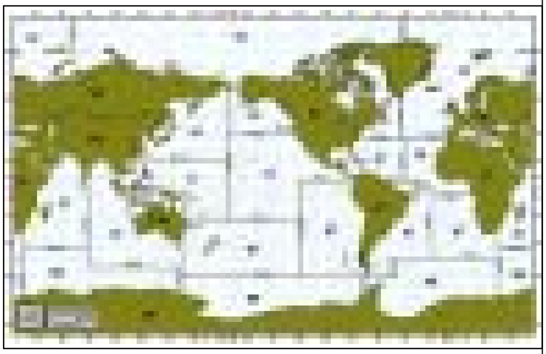
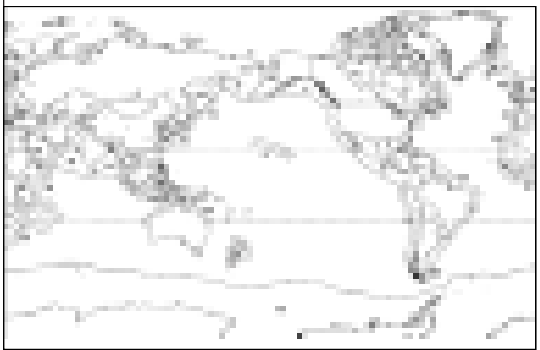
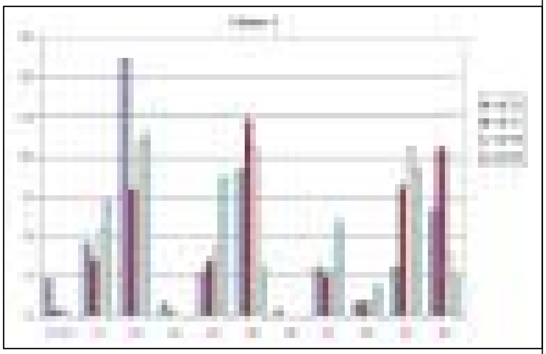
Trends in oceanic captures and clustering of large marine ecosystems

Two studies based on the FAO capture database

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PREPARATION OF THIS DOCUMENT

The two studies that form this document are based on the data held in the FAO capture fisheries production database, for which species items have been classified as oceanic or living on the continental shelves. A preliminary work on the feasibility of the re-arrangement of FAO capture data into Large Marine Ecosystems' borders was prepared in September 1999 with reference to a visit to FAO by Prof. Sherman, one of the leading authors on this subject. However, the work to re-assign the FAO capture statistics organized by 19 marine fishing areas into the 50 LMEs proved to be quite complex and time consuming. Regional sub-sets of the national data reported by some countries had to be retrieved from national publications and web sites, compared with the data already in the FAO database and computerized. Some LMEs had to be excluded from this exercise, as relevant data are not available. For these reasons, the data retrieved cover only a limited period of 10 years (1990-99). Given these limitations, the analysis of the statistics by LME, rather than focusing on changes in the catch trends, has aimed to identify similarities among the LMEs' catch patterns, to provide an insight to the fishery characteristics of the LMEs which have already been extensively studied for their ecological and oceanographic conditions.

While the work on LMEs was in progress, the World Resources Institute (WRI) offered to fund the FAO Fishery Information, Data and Statistics Unit (FIDI) to undertake a study on oceanic fisheries based on the data contained in the FAO fishery statistics databases. Oceanic species in the FAO capture database were identified and subdivided into epipelagic and deep-water species. The complete report, also including analyses of other FIDI statistics on oceanic fishers and fishing vessels, was delivered to WRI in September 2001. As a consequence of the completion of this work, it was decided to revise the species included in the LME project, excluding those categorized as oceanic to obtain two complete separate sets of species items from the FAO capture database. The species included in the LME study are those classified as spending most of their life cycle on the continental shelf whereas the species categorized as oceanic are those living beyond the shelf. The section of the report to WRI on trends of oceanic catches, analysed over a 50-year period (1950-99) and by FAO fishing area, is published here with some modifications thanks to an agreement between FAO and WRI which allows both institutions to disseminate the results of the study separately.

ACKNOWLEDGEMENTS

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Trends in oceanic captures and clustering of Large Marine Ecosystems:
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FAO Fisheries Technical Paper. No. 435. Rome, FAO. 2002. 71p.

ABSTRACT

Species items reported in the FAO capture fisheries production database have been classified as oceanic or living on the continental shelf. Catch trends of oceanic species, further subdivided into epipelagic and deep-water species, have been analysed over a 50-year period (1950-99) while statistics for shelf species have been re-assigned to Large Marine Ecosystems (LMEs) for a shorter period (1990-99) and used to investigate catch patterns among the various LMEs.

Oceanic fisheries constitute, both in terms of number of species items and in quantities of recent catches, about 10% of global marine catches. Catches of epipelagic species (mostly tunas) and of deep-water species (mostly Gadiformes) have been continuously increasing and reached 8.6 million tons in 1999. Oceanic catches by Distant Water Fleets (DWFs), mostly targeting tunas, have been decreasing in recent years although their share of total DWF catches has increased due to the concurrent drop of non-oceanic DWF catches. Trends of oceanic catches and the contribution of DWFs are examined for all FAO marine fishing areas which show different patterns, mainly depending upon whether they are temperate or tropical areas.

Eleven clusters of LMEs have been identified on the basis of similarities in their catch composition classified into eleven species groupings. For each cluster, the distinguishing catch pattern and recent trends by species groupings in each LME are discussed, and considered in relation to information on primary productivity and the abiotic characteristics of the LME.

Distribution:

Marine Fisheries list
Fisheries Statistics list
Directors of Fisheries list
FAO Fisheries Department
FAO Regional and Subregional offices

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Trends in oceanic captures: an analysis of 50 years' data by FAO fishing areas

1. THE OCEANIC REGION

1.1 Physical environment

The oceans cover 71% of the Earth's surface and have an average depth of 3,800 m (Angel, 1993). The oceanic environment is defined as the marine water portion that extends over the continental slope and the abyssal plain. The portion of waters over the shelf, which conventionally extends out to a depth of 200 meters, is usually referred to as the neritic environment (see Figure 1).

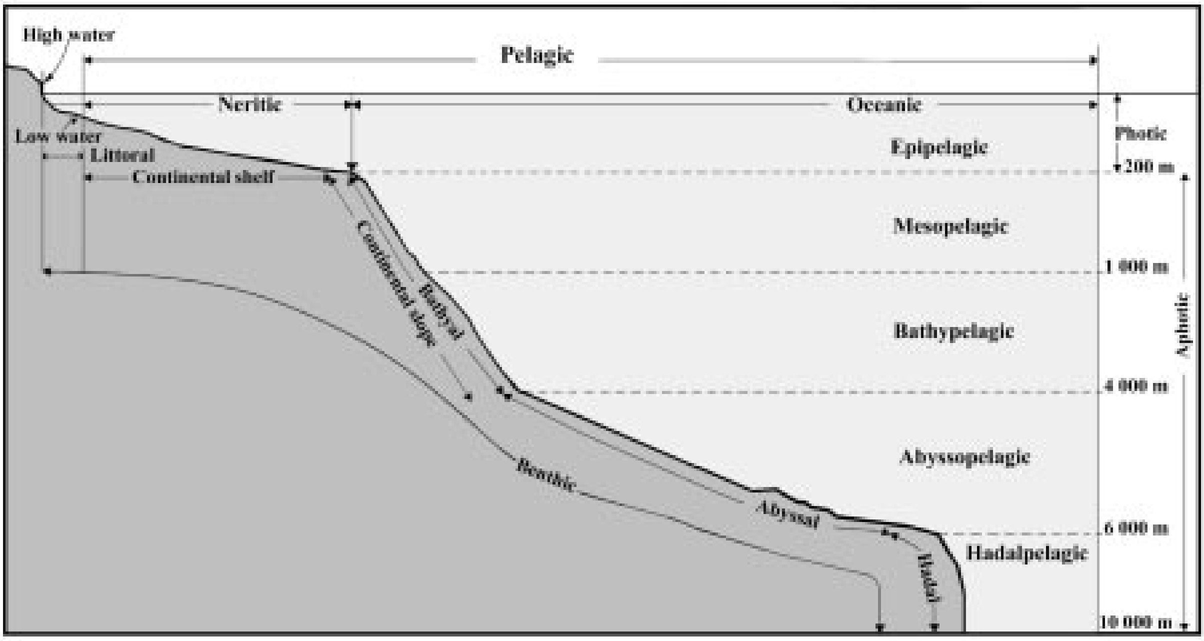


Figure 1. Marine zones
(from Carpenter and Niem, 1999)

Out of a total ocean surface of about 360 million km^2, the neritic environment over the continental shelves covers almost 32 million km^2 and hence the oceanic region accounts for over 91% of the world oceans. Table 1 (modified from Caddy *et al.*, 1998) shows the surfaces and percentages of the oceanic portions of each FAO major fishing area defined for statistical purposes (Figure 2). The figures provided are prior to the 2001 modification (implemented in the map below) of the border between areas 51 and 57 (previously Sri Lanka was included in area 51, now it is in area 57).

Although mean productivity per unit area is much lower in the oceans than on land, their very large surface means that the oceans still account for at least a third of the annual global fixation of carbon. For this reason, oceanic communities contribute significantly to global processes (Angel, 1993).

Table 1. Continental shelf and oceanic portions of the FAO fishing areas
(after Caddy *et al*., 1998)

FAO fishing area	Continental shelf area (km^2)	Oceanic area (km^2)	Total surface fishing area (km^2)	Oceanic area on total surface %
18	4,482,818	4,738,373	9,221,191	51.4
21	1,294,988	4,969,856	6,264,844	79.3
27	2,745,303	11,594,192	14,339,495	80.9
31	1,533,538	13,111,016	14,644,554	89.5
34	654,364	13,463,294	14,117,658	95.4
37	683,540	2,304,357	2,987,897	77.1
41	1,961,493	15,582,750	17,544,243	88.8
47	422,667	17,939,641	18,362,308	97.7
48	207,613	11,609,290	11,816,903	98.2
51	1,896,583	28,285,447	30,182,030	93.7
57	2,374,430	27,506,544	29,880,974	92.1
58	175,311	12,446,060	12,621,371	98.6
61	3,632,571	15,099,749	18,732,320	80.6
67	1,336,799	6,257,136	7,593,935	82.4
71	6,611,254	27,284,538	33,895,792	80.5
77	806,464	47,439,912	48,246,376	98.3
81	409,520	27,248,565	27,658,085	98.5
87	569,318	30,228,835	30,798,153	98.2
88	137,308	9,390,124	9,527,432	98.6
TOTAL	**31,935,882**	**326,499,679**	**358,435,561**	**91.1**

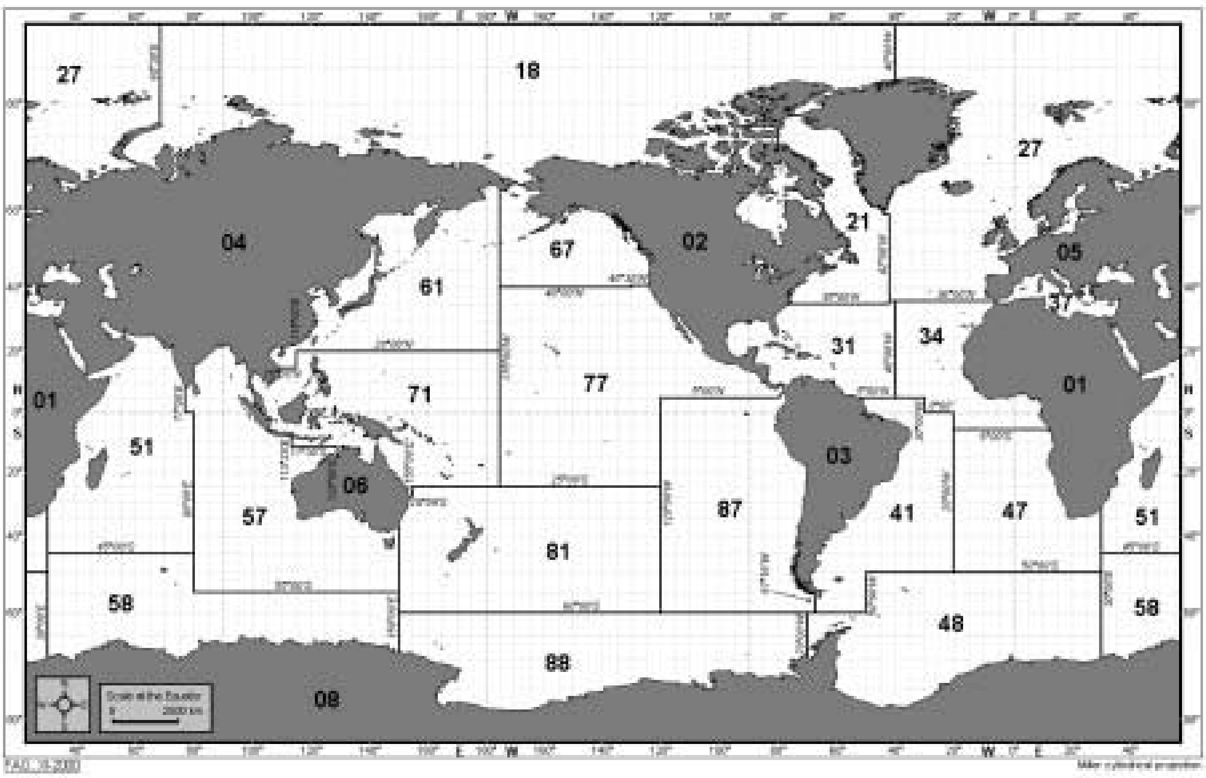


Figure 2. FAO major fishing areas for statistical purposes

Oceanic phytoplankton is responsible for the primary production of the oceans and constitutes the basis of the food chain in the high seas. Primary production is restricted to the so-called euphotic layer, or upper part of the photic zone, where sufficient sunlight penetrates to allow photosynthesis. The depth of the euphotic zone depends on the amount of suspension and detritus present in the water and can vary from 40-50 m in turbid waters to over 100 m where the waters are particularly clear. Production is also limited by the availability of inorganic nutrients.

Below the photic layer there is the aphotic zone, where no light arrives and primary production is absent. Organisms living in this zone which are not performing vertical migration to upper waters are exclusively carnivores, suspension or detritus feeders.

Great quantities of nutrients are continually lost to the aphotic zone and are not available for photosynthesis, however large-scale ocean circulation linked to Earth’s rotation, climatic cycles (seasons) and topography of the ocean basins allow periodical or semi-permanent (in some areas) mixing of superficial and nutrient rich deep waters. This phenomenon called upwelling is the cause of extremely high productivity of some fishing areas.

1.2 Biological resources and their exploitation

Oceanic resources include species that are distributed beyond the continental shelf, although they may spend part of their life cycles in the coastal areas. According to the terminology adopted in this report, oceanic resources are marine animals living in the epipelagic, mesopelagic and bathypelagic zones in the oceanic region (Figure 1). Exploitable species living in these zones are fishes, crustaceans, cephalopods and marine mammals. Fishes have the greatest importance, both in number of species and in terms of fishery revenues. According to Helfman *et al*. (1997), out of approximately 25,000 species of fishes about 325 are epipelagic, representing 1.3% of the total. Mesopelagic and bathypelagic fishes comprise about 1,250 species, corresponding to 5% of the total.

For the purpose of this study, species living in the oceanic region have been classified as either epipelagic or deep-water species (inhabiting the meso- and bathypelagic zones). This classification is somewhat artificial and in several cases it has been difficult to assign species to one of the two categories since several species effect vertical migrations in relation to feeding, reproductive season and circadian rhythms. In such cases, species have been classified on the basis of the zone in which they are usually caught by commercial fisheries.

The reason for categorizing epipelagic and deep-water species among the oceanic resources is that the fisheries targeting the two groups of species are often different in terms of importance, technology, history and value. The valuable and still developing fisheries for tuna and tuna-like species constitute the bulk of the fisheries targeting epipelagic species, although other epipelagic resources such as cephalopods (short-lived and with a rapid turn-over; Caddy and Rodhouse, 1998) might sustain expanding oceanic fisheries, being able to respond promptly to favourable environmental changes (Gonzales *et al*., 1997).

On the other hand, most oceanic deep-water resources are very dispersed and difficult to harvest and several fisheries on these resources have been discontinued because they were not economically viable. Catches of some deep-water species (in particular blue whiting, *Micromesistius poutassou*, which constitutes almost half of the deep-water catches in the last twenty years) are mostly destined for reduction into fishmeal because of the rapid deterioration of their flesh, the presence of parasites, and the low market value for the fresh or processed product (Torry Research Station, 1980). In addition, the lack of sound biological information is often a major source of uncertainty on the long-term sustainability of such fisheries (Clark, 1998). Deep-water species are in general characterized by slow growth rates and late age at first maturity (e.g. 25 years for orange roughy, *Hoplostethus atlanticus*; Smith *et al*., 1995), which led to weak biological compensation of fishing mortality (Clark, 1998).

Oceanic resources are usually exploited by long-range fleets operating in areas where target species concentrate for feeding or reproduction. The more rapid increase of world fishery fleet sizes as compared to catches and the contemporaneous depletions of some coastal resources have contributed to the increase of fishing effort in oceanic areas (FAO, 1994).

Given the complex interrelations between economic and political factors and the scarce knowledge of oceanic stocks, the issue of oceanic resources management is increasingly coming to international attention in the light of a growing world human population and limited food fish supplies. Furthermore, considering that oceanic species live in a virtually boundless environment and exhibit extensive migratory behaviour amongst high seas and national jurisdictions, their management has necessitates international cooperation. For these reasons, issues concerning highly valuable oceanic stocks such as tuna species are of paramount importance and complexity (FAO, 1994).

2. CAPTURE TRENDS OF OCEANIC SPECIES

2.1 Species selected from the FAO capture database

The FAO database for capture fishery statistics released in 2001 (FAO, 2001a) covers a period of 50 years, from 1950 to 1999. For the 1950-1969 period, aquaculture production has not yet been separated from capture fisheries production. However, this does not affect oceanic species, since data for the only two oceanic species that have aquaculture production (i.e. northern and southern bluefin tunas) start later in the time series.

The 2001 release of the FAO database included capture statistics for 1,205 species items. “Species items” is the term used to identify the statistical taxonomic unit, which can correspond to species, genus, family or to higher taxonomic levels.

The first step to identify oceanic species among those included in the FAO database consisted in the consultation of two lists already existing: Annex 1 of the 1982 Convention on the Law of the Sea which lists highly migratory species (FAO, 1994) and the oceanic and deep-water resources listed in Table 3 of Caddy *et al.* (1998). These two lists have been expanded by the addition of other species items recently included in the FAO database and, after the consultation of current literature, amended in a few cases.

Out of 1,205 species items, 120 have been recognized as oceanic because they spend most of their adult life or are caught in the epipelagic, mesopelagic or bathypelagic zones (Figure 1). These species items were further divided into epipelagic (58 species items) and deep-water species (62 items). See Table 2 for the full list of the oceanic species items selected.

The epipelagic group consists of 49 fish, 2 crustacean (krill) and 7 cephalopod (family Ommastrephidae) species items. The two main groups of epipelagic fishes are tuna and tuna-like species (24 species items), which belong to group 36 (Tunas, bonitos, billfishes) of the ‘International Standard Statistical Classification for Aquatic Animals and Plants’ (ISSCAAP) classification used in compiling the FAO fishery statistics, and oceanic sharks (17 species items). The deep-water group consists of 55 fish and 7 crustacean (shrimps and crabs) species items. Several families and orders are represented among the fish species but the most significant group, both in terms of number (15 species items) and economic importance, is that of the Gadiformes.

Marine mammals have not been considered in this study because fishery statistics for blue-, fin-, sperm- and pilot-whales included in the FAO database are given in number of specimens and this does not allow for aggregations with the other data which are all expressed in metric tonnes.

A data sub-set containing capture statistics of the selected oceanic species has been created from the FAO database. Catches reported by flag States for vessels fishing in areas other than those adjacent to the flag State have been classified as Distant Water Fleet (DWF) catches. Vessels fishing in the same FAO fishing area in which their flag State has access to the sea are instead referred to as “bordering countries” throughout the document.

Table 2. List of species items selected as oceanic (epipelagic or deep water)

Epipelagic			
Scientific name	**FAO English name**	**Family**	**ISSCAAP group**
Auxis rochei	Bullet tuna	Scombridae	Tunas, bonitos, billfishes
Auxis thazard	Frigate tuna	Scombridae	Tunas, bonitos, billfishes
Auxis thazard, A.rochei	Frigate and bullet tunas	Scombridae	Tunas, bonitos, billfishes
Euthynnus affinis	Kawakawa	Scombridae	Tunas, bonitos, billfishes
Euthynnus alletteratus	Little tunny(=Atl.black skipj)	Scombridae	Tunas, bonitos, billfishes
Istiophoridae	Marlins,sailfishes,etc. nei	Istiophoridae	Tunas, bonitos, billfishes
Istiophorus albicans	Atlantic sailfish	Istiophoridae	Tunas, bonitos, billfishes
Istiophorus platypterus	Indo-Pacific sailfish	Istiophoridae	Tunas, bonitos, billfishes
Katsuwonus pelamis	Skipjack tuna	Scombridae	Tunas, bonitos, billfishes
Makaira indica	Black marlin	Istiophoridae	Tunas, bonitos, billfishes
Makaira mazara	Indo-Pacific blue marlin	Istiophoridae	Tunas, bonitos, billfishes
Makaira nigricans	Atlantic blue marlin	Istiophoridae	Tunas, bonitos, billfishes
Tetrapturus albidus	Atlantic white marlin	Istiophoridae	Tunas, bonitos, billfishes
Tetrapturus angustirostris	Shortbill spearfish	Istiophoridae	Tunas, bonitos, billfishes
Tetrapturus audax	Striped marlin	Istiophoridae	Tunas, bonitos, billfishes
Tetrapturus pfluegeri	Longbill spearfish	Istiophoridae	Tunas, bonitos, billfishes
Thunnini	Tunas nei	Scombridae	Tunas, bonitos, billfishes
Thunnus alalunga	Albacore	Scombridae	Tunas, bonitos, billfishes
Thunnus albacares	Yellowfin tuna	Scombridae	Tunas, bonitos, billfishes
Thunnus atlanticus	Blackfin tuna	Scombridae	Tunas, bonitos, billfishes
Thunnus maccoyii	Southern bluefin tuna	Scombridae	Tunas, bonitos, billfishes
Thunnus obesus	Bigeye tuna	Scombridae	Tunas, bonitos, billfishes
Thunnus thynnus	Atlantic bluefin tuna	Scombridae	Tunas, bonitos, billfishes
Xiphias gladius	Swordfish	Xiphiidae	Tunas, bonitos, billfishes
Brama brama	Atlantic pomfret	Bramidae	Miscellaneous pelagic fishes
Cololabis saira	Pacific saury	Scomberesocidae	Miscellaneous pelagic fishes
Coryphaena hippurus	Common dolphinfish	Coryphaenidae	Miscellaneous pelagic fishes
Cypselurus agoo	Japanese flyingfish	Exocoetidae	Miscellaneous pelagic fishes
Lampris guttatus	Opah	Lampridae	Miscellaneous pelagic fishes
Regalecus glesne	King of herrings	Regalecidae	Miscellaneous pelagic fishes
Scomberesox saurus	Atlantic saury	Scomberesocidae	Miscellaneous pelagic fishes
Trachipterus spp	Dealfishes	Trachipteridae	Miscellaneous pelagic fishes
Alopias superciliosus	Bigeye thresher	Alopiidae	Sharks, rays, chimaeras
Alopias vulpinus	Thresher	Alopiidae	Sharks, rays, chimaeras
Carcharhinidae	Requiem sharks nei	Carcharhinidae	Sharks, rays, chimaeras
Carcharhinus brachyurus	Copper shark	Carcharhinidae	Sharks, rays, chimaeras
Carcharhinus falciformis	Silky shark	Carcharhinidae	Sharks, rays, chimaeras
Carcharhinus limbatus	Blacktip shark	Carcharhinidae	Sharks, rays, chimaeras
Carcharhinus obscurus	Dusky shark	Carcharhinidae	Sharks, rays, chimaeras
Carcharhinus plumbeus	Sandbar shark	Carcharhinidae	Sharks, rays, chimaeras
Cetorhinus maximus	Basking shark	Cetorhinidae	Sharks, rays, chimaeras
Isurus oxyrinchus	Shortfin mako	Lamnidae	Sharks, rays, chimaeras
Isurus paucus	Longfin mako	Lamnidae	Sharks, rays, chimaeras
Isurus spp	Mako sharks	Lamnidae	Sharks, rays, chimaeras
Lamna nasus	Porbeagle	Lamnidae	Sharks, rays, chimaeras
Prionace glauca	Blue shark	Carcharhinidae	Sharks, rays, chimaeras
Sphyrna lewini	Scalloped hammerhead	Sphyrnidae	Sharks, rays, chimaeras
Sphyrna zygaena	Smooth hammerhead	Sphyrnidae	Sharks, rays, chimaeras
Sphyrnidae	Hammerhead sharks, etc. nei	Sphyrnidae	Sharks, rays, chimaeras
Euphausia superba	Antarctic krill	Euphausiidae	Krill, planktonic crustaceans
Meganyctiphanes norvegica	Norwegian krill	Euphausiidae	Krill, planktonic crustaceans
Dosidicus gigas	Jumbo flying squid	Ommastrephidae	Squids, cuttlefishes, octopuses
Illex illecebrosus	Northern shortfin squid	Ommastrephidae	Squids, cuttlefishes, octopuses
Martialia hyadesi	Sevenstar flying squid	Ommastrephidae	Squids, cuttlefishes, octopuses
Nototodarus sloani	Wellington flying squid	Ommastrephidae	Squids, cuttlefishes, octopuses
Ommastrephes bartrami	Neon flying squid	Ommastrephidae	Squids, cuttlefishes, octopuses
Todarodes pacificus	Japanese flying squid	Ommastrephidae	Squids, cuttlefishes, octopuses
Todarodes sagittatus	European flying squid	Ommastrephidae	Squids, cuttlefishes, octopuses

Table 2 (continued).

Deep water			
Scientific name	**FAO English name**	**Family**	**ISSCAAP group**
Antimora rostrata	Blue antimora	Moridae	Cods, hakes, haddocks
Brosme brosme	Tusk(=Cusk)	Gadidae	Cods, hakes, haddocks
Coryphaenoides rupestris	Roundnose grenadier	Macrouridae	Cods, hakes, haddocks
Lepidorhynchus denticulatus	Thorntooth grenadier	Macrouridae	Cods, hakes, haddocks
Macrouridae	Grenadiers, rattails nei	Macrouridae	Cods, hakes, haddocks
Macrourus berglax	Roughhead grenadier	Macrouridae	Cods, hakes, haddocks
Macrourus spp	Grenadiers nei	Macrouridae	Cods, hakes, haddocks
Macruronus magellanicus	Patagonian grenadier	Merlucciidae	Cods, hakes, haddocks
Macruronus novaezelandiae	Blue grenadier	Merlucciidae	Cods, hakes, haddocks
Macruronus spp	Blue grenadiers nei	Merlucciidae	Cods, hakes, haddocks
Micromesistius australis	Southern blue whiting	Gadidae	Cods, hakes, haddocks
Micromesistius poutassou	Blue whiting(=Poutassou)	Gadidae	Cods, hakes, haddocks
Molva dypterygia	Blue ling	Gadidae	Cods, hakes, haddocks
Molva molva	Ling	Gadidae	Cods, hakes, haddocks
Mora moro	Common mora	Moridae	Cods, hakes, haddocks
Alepocephalus bairdii	Baird's slickhead	Alepocephalidae	Miscellaneous demersal fishes
Anoplopoma fimbria	Sablefish	Anoplopomatidae	Miscellaneous demersal fishes
Aphanopus carbo	Black scabbardfish	Trichiuridae	Miscellaneous demersal fishes
Argentina spp	Argentines	Argentinidae	Miscellaneous demersal fishes
Beryx spp	Alfonsinos nei	Berycidae	Miscellaneous demersal fishes
Centroberyx affinis	Redfish	Berycidae	Miscellaneous demersal fishes
Chlorophthalmidae	Greeneyes	Chlorophthalmidae	Miscellaneous demersal fishes
Dissostichus eleginoides	Patagonian toothfish	Nototheniidae	Miscellaneous demersal fishes
Dissostichus mawsoni	Antarctic toothfish	Nototheniidae	Miscellaneous demersal fishes
Emmelichthyidae	Bonnetmouths, rubyfishes nei	Emmelichthyidae	Miscellaneous demersal fishes
Emmelichthys nitidus	Cape bonnetmouth	Emmelichthyidae	Miscellaneous demersal fishes
Glossanodon semifasciatus	Deepsea smelt	Argentinidae	Miscellaneous demersal fishes
Hoplostethus atlanticus	Orange roughy	Trachichthyidae	Miscellaneous demersal fishes
Hyperoglyphe antarctica	Bluenose warehou	Centrolophidae	Miscellaneous demersal fishes
Lampanyctodes hectoris	Hector's lanternfish	Myctophidae	Miscellaneous demersal fishes
Lepidocybium flavobrunneum	Escolar	Gempylidae	Miscellaneous demersal fishes
Lepidopus caudatus	Silver scabbardfish	Trichiuridae	Miscellaneous demersal fishes
Macroramphosus scolopax	Longspine snipefish	Macroramphosidae	Miscellaneous demersal fishes
Maurolicus muelleri	Silvery lightfish	Sternoptychidae	Miscellaneous demersal fishes
Myctophidae	Lanternfishes nei	Myctophidae	Miscellaneous demersal fishes
Oreosomatidae	Oreo dories nei	Oreosomatidae	Miscellaneous demersal fishes
Pterygotrigla picta	Spotted gurnard	Triglidae	Miscellaneous demersal fishes
Rexea solandri	Silver gemfish	Gempylidae	Miscellaneous demersal fishes
Ruvettus pretiosus	Oilfish	Gempylidae	Miscellaneous demersal fishes
Seriolella caerulea	White warehou	Centrolophidae	Miscellaneous demersal fishes
Seriolella punctata	Silver warehou	Centrolophidae	Miscellaneous demersal fishes
Thyrsitops lepidopoides	White snake mackerel	Gempylidae	Miscellaneous demersal fishes
Trachichthyidae	Slimeheads nei	Trachichthyidae	Miscellaneous demersal fishes
Trichiuridae	Hairtails, scabbardfishes nei	Trichiuridae	Miscellaneous demersal fishes
Callorhinchus capensis	Cape elephantfish	Callorhinchidae	Sharks, rays, chimaeras
Callorhinchus milii	Ghost shark	Callorhinchidae	Sharks, rays, chimaeras
Callorhinchus spp	Elephantfishes nei	Callorhinchidae	Sharks, rays, chimaeras
Centrophorus squamosus	Leafscale gulper shark	Squalidae	Sharks, rays, chimaeras
Centroscymnus crepidater	Longnose velvet dogfish	Squalidae	Sharks, rays, chimaeras
Chimaera monstrosa	Rabbit fish	Chimaeridae	Sharks, rays, chimaeras
Chimaeriformes	Chimaeras, etc. nei		Sharks, rays, chimaeras
Hydrolagus novaezealandiae	Dark ghost shark	Chimaeridae	Sharks, rays, chimaeras
Hydrolagus spp	Ratfishes nei	Chimaeridae	Sharks, rays, chimaeras
Somniosus microcephalus	Greenland shark	Squalidae	Sharks, rays, chimaeras
Somniosus pacificus	Pacific sleeper shark	Squalidae	Sharks, rays, chimaeras
Chionoecetes opilio	Queen crab	Majidae	Crabs, sea-spiders
Geryon quinquedens	Red crab	Geryonidae	Crabs, sea-spiders
Geryon spp	Geryons nei	Geryonidae	Crabs, sea-spiders
Lithodes aequispina	Golden king crab	Lithodidae	King crabs, squat-lobsters
Paralomis spinosissima	Antarctic stone crab	Lithodidae	King crabs, squat-lobsters
Pleoticus robustus	Royal red shrimp	Solenoceridae	Shrimps, prawns
Plesiopenaeus edwardsianus	Scarlet shrimp	Aristaeidae	Shrimps, prawns

2.2 Global trend

Global catches of oceanic species have been steadily increasing (except for a small decrease in the early 1980s) during the 50 years (1950-1999) for which data are available in the FAO database and reached about 8.6 million metric tonnes in 1999 (Figure 3). The share of oceanic catches in global marine catches ranged between 4 and 8 percent from 1950 to 1989. In recent years, the contribution of oceanic catches to total catches increased and exceeded 10% in 1998 and 1999 (Figure 4).

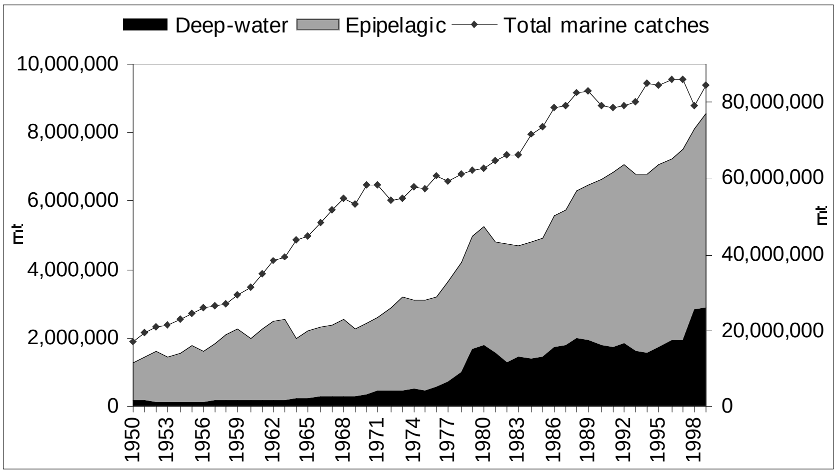


Figure 3. Global catch trend of oceanic species

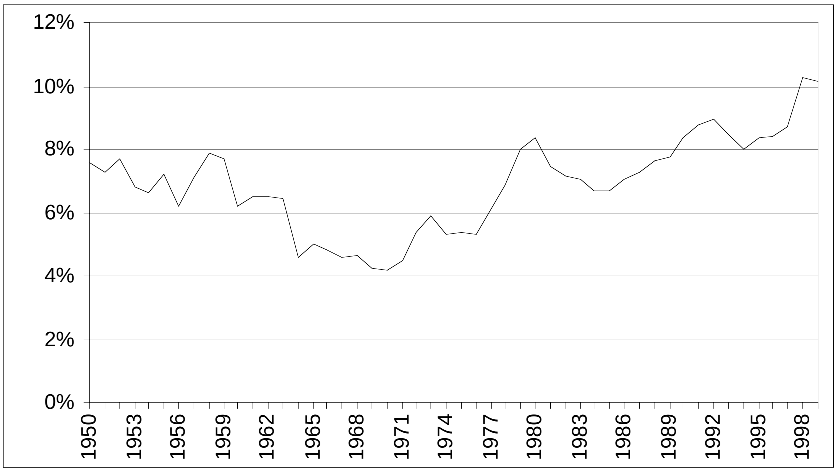


Figure 4. Oceanic species share in total marine catches

Until 1975, catches of deep-water species were relatively small, ranging between 2 and 10% of the total oceanic catches, but since the late 1970s their contribution has consistently been greater than 20%, reaching 33% of the total oceanic catches in the last two years for which catch statistics were available (Figure 3).

Among the epipelagic species, catches of tuna and tuna-like species have been increasing dramatically throughout the years. Since the mid-1960s, the rate of increase of tuna and tuna-like catches has been much higher in comparison to other epipelagic species and tuna catches are still growing at a rapid pace while those of the other species have decreased in recent years (Figure 5). Similarly, the deep-water group is dominated by Gadiformes species (ISSCAAP group 32) but some differences can be noted: over half of the catches of the deep-water Gadiformes in the 1975-99 period was constituted by a single species (i.e. *Micromesistius poutassou*, blue whiting), and the increasing trend of Gadiformes species was not as steady as that of tuna species and it experienced some drops (early and late 1980s, see Figure 6). There is also a big difference in market value between tunas, which are amongst the most valued fishery resources, and deep-water species which, as in the case of blue whiting, are mostly processed into fishmeal.

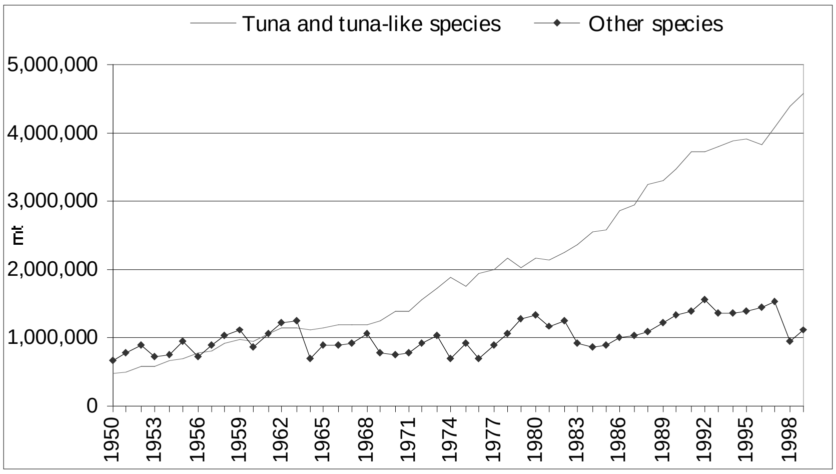


Figure 5. Captures of oceanic epipelagic species

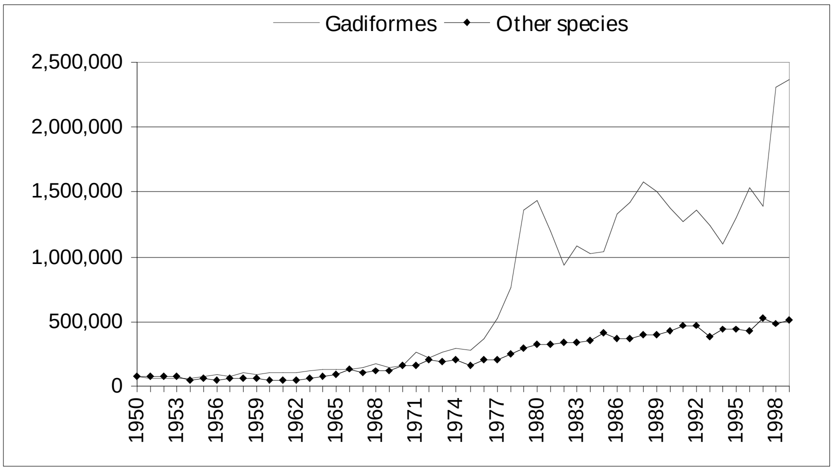


Figure 6. Captures of deep-water species

2.2.1 Oceanic catches of Distant Water Fleets (DWFs)

Total marine catches from distant water fisheries reported by DWFs increased from less than one million tonnes in the early 1950s to about 8 million tonnes in 1972, fluctuated around this value until 1991 and then declined rapidly to about 4.5 million tonnes, remaining stable in the most recent years. As a proportion of total marine captures, those reported by DWFs reached a maximum of 15.5% in 1972 and then declined to about 5%, a level at which they have stabilised since 1993 (Figure 7). The starting points of the two marked decreasing trends of DWF catches coincided with two historical events: the oil price hike (1973) and the dissolution of the Former USSR (1991) whose fleets where actively fishing in all oceans (for a more detailed analysis on global catches from DWFs, see Grainger and Garcia, 1996; for selected case studies on DWFs, see Bonfil *et al*., 1998).

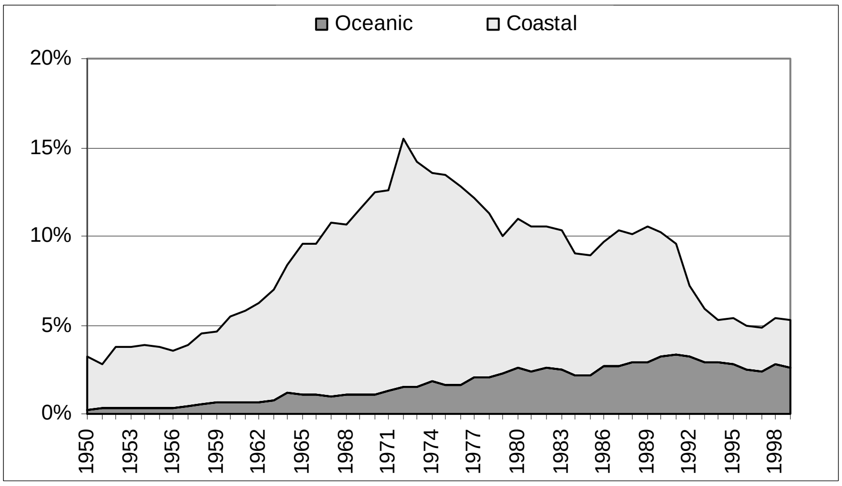


Figure 7. Percentage of DWF catches in total catches broken down as oceanic and coastal species

As can be seen in Figures 7 and 8, until the 1970s catches of oceanic species were a minor portion of the total DWF catches but since 1993 oceanic catches of DWFs account for half or more of the total DWF catches. This remarkable change in the two fractions is due to the contemporaneous decrease of coastal species catches and increase of oceanic catches by DWFs. Following the declarations by an increasing number of countries of the Exclusive Economic Zones (EEZs), after the United Nations Convention on the Law of the Sea (UNCLOS) of 1982, distant water fishing nations had to negotiate access to the marine resources living within the 200 miles limit. This new situation, together with the increasing price of fuel oil, led to an overall increase of costs for DWFs that progressively shifted to oceanic species which are both highly valuable (e.g. tunas) and can be often caught in the high seas, outside areas of national jurisdictions.

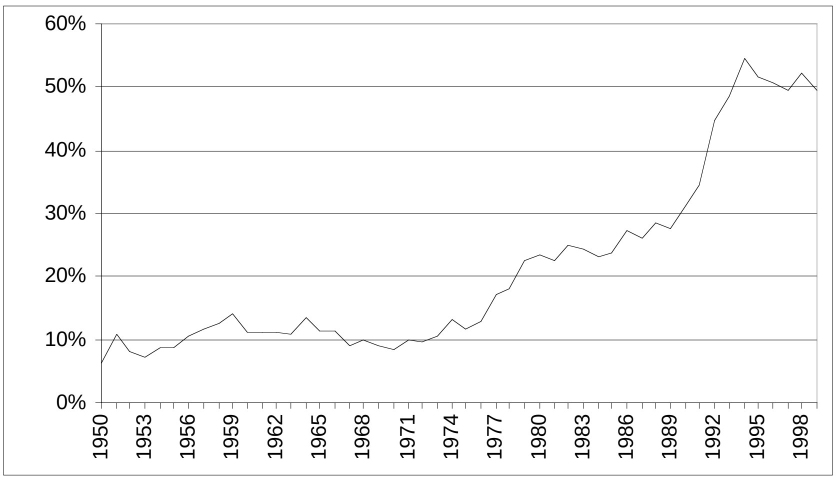


Figure 8. Oceanic share in DWF total catches

However, in terms of quantities, the increase of oceanic catches in recent years is entirely due to the contribution of bordering countries whose catches of oceanic species have been steadily increasing since the early 1980s (Figure 9).

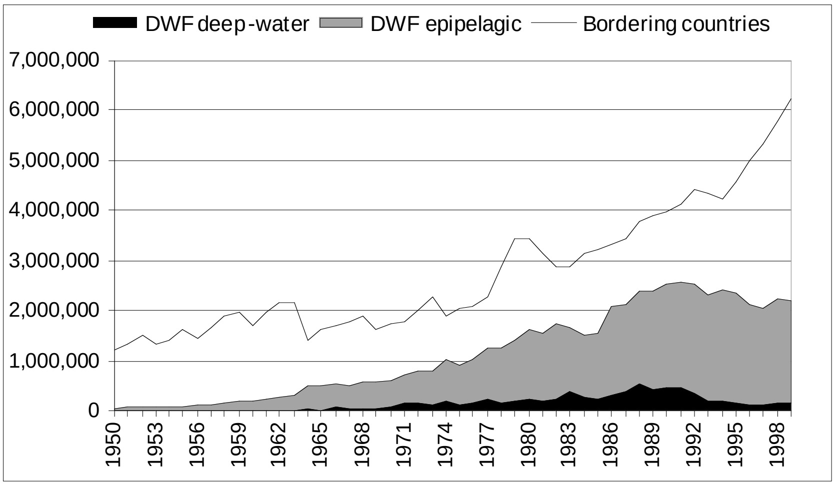


Figure 9. Oceanic catches by DWFs and bordering countries

Figure 9 also shows that the majority (always over 75%) of oceanic catches by vessels of DWFs are of epipelagic species and that deep-water catches exceeded 200,000 tonnes only during the 1982-92 period.

2.3 Capture trends by FAO fishing area

2.3.1 Northwest Atlantic (FAO Area 21)

As a proportion of total marine catches in this area, oceanic catches have a limited importance although there has been an increase in recent years (over 5% since 1994; Figure 10). Another peak of oceanic catches was reached in the late 1970s (a maximum of 8.5% on total catches in 1979) due to high catches (up to 90,000 tonnes) of Northern short-fin squid (*Illex illecebrosus*) reported by Canada. The Northern short-fin squid peak is paralleled by an increase in the same years of molluscan catches in general (Shotton, 1997a). After this peak, catches of deep-water species have always been greater than epipelagic catches reaching 85% of total oceanic catches in 1999. Most of the catches classified as deep-water in Northwest Atlantic are Canadian landings of queen crab (*Chionoecetes opilio*), which have been progressively increasing in the 1990s and reached more than 95,000 tonnes in 1999.

The percentage of oceanic catches taken by DWFs after the 1970s is very low but previously it reached two noticeable peaks in 1966 and the 1971-75 period. Major fishing nations targeting oceanic species in those years were Former USSR, Japan, Spain and Poland.

Catches of tuna and tuna-like species are not very high in this cold-water area and reached two peaks in the mid-1960s and early 1980s of approximately 17,000 tonnes. Since 1993, total catches of tunas have never exceeded 10,000 tonnes.

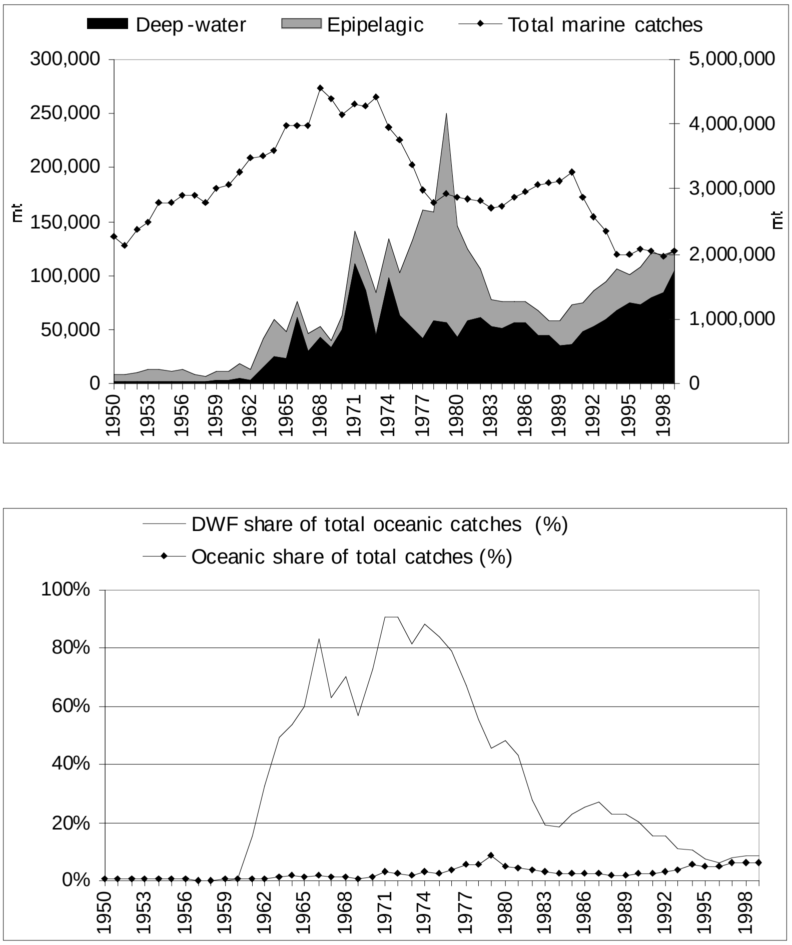


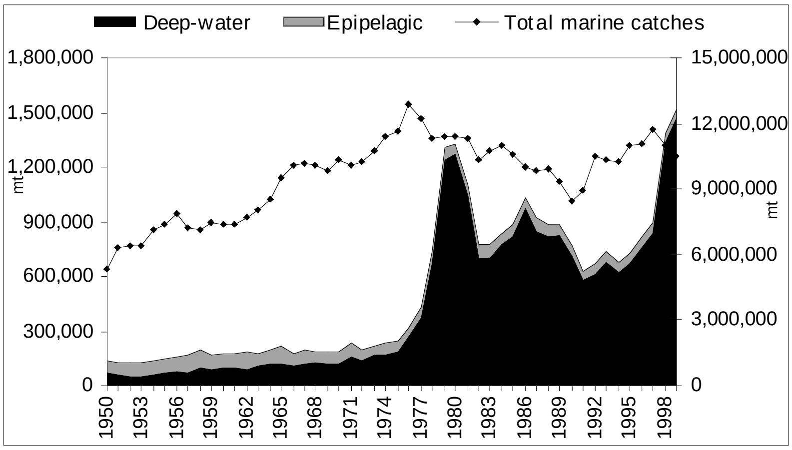
Figure 10. Northwest Atlantic (FAO Area 21)

2.3.2 Northeast Atlantic (FAO Area 27)

In the Northeast Atlantic area, the peak of marine catches was reached in 1976 (Figure 11). In the same year, catches of oceanic species started to increase considerably, mostly due to catches of blue whiting (*Micromesistius poutassou*) reported by the Former USSR. This confirms what has been suggested by Cannon (1997), that when catches of historically valuable or traditional species such as cod, haddock and herring began to decline, they were progressively replaced by oceanic deep-water species, formerly not economically viable to exploit.

Since 1978, catches of blue whiting have contributed over three quarters of the deep-water catches in the area. Besides the Former USSR/Russian Federation, major countries fishing deep-water species in the Northeast Atlantic are Norway, Denmark, and Iceland. However, the marked decrease in recent years of the catch-per-unit-effort (CPUE) for some deep-water species (e.g. blue ling, *Molva dypterygia*, and roundnose grenadier, *Coryphaenoides rupestris*) in this area (Bergstad, *et al*., 2001) has prompted the Advisory Committee on Fishery Management (ACFM) of the International Council for the Exploration of the Sea (ICES) to recommend immediate reduction in deep-water fisheries unless they can be shown to be sustainable (ICES, 2002) and led the European Commission to propose extra measures to protect vulnerable deep-water species (Anonymous, 2002).

Catches of epipelagic species are not negligible in this area, but appear very low when compared to total marine catches. This is because the Northeast Atlantic has always been one of the most productive fishing areas in the world, together with the Northwest Pacific and the Southeast Pacific, due to the high productivity of its continental shelf. Catches of the two most important species, albacore and northern bluefin tuna, peaked in the early 1960s at around 65,000 tonnes and since 1968 have ranged between 27,000 and 42,000 tonnes. DWF catches in this area are very low, usually lower than 2% of the total oceanic catches.



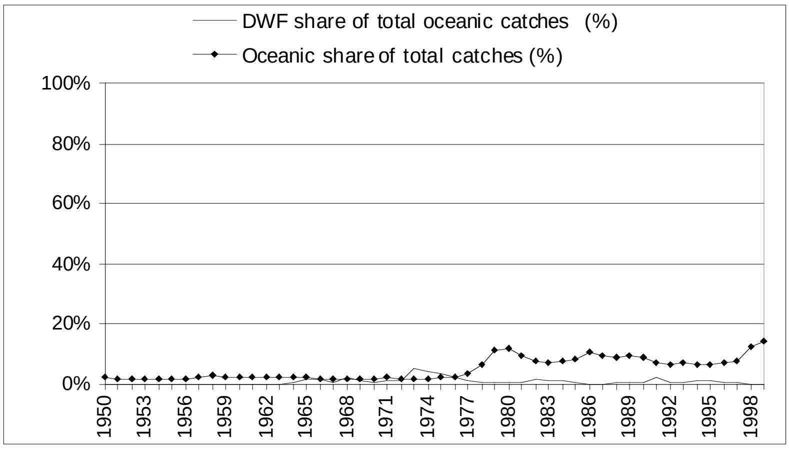


Figure 11. Northeast Atlantic (FAO Area 27)

2.3.4 Eastern Central Atlantic (FAO Area 34)

This area, which extends along the west coast of Africa from Morocco southwards to the Democratic Republic of Congo, is characterized by a share of oceanic catches above the global average and by an historical presence of DWFs. Oceanic catches reached their peak in 1991 (402,000 tonnes) and, since then, they have ranged between 320,000 and 380,000 tonnes (Figure 13). About 95% of these quantities are composed of tuna and tuna-like species, the deep-water portion of oceanic catches always being rather small with a peak value of 43,000 tonnes in 1980 (approximately 28,000 tonnes of which constituted catches of snipefish, *Macroramphosus scolopax*, reported by the Former USSR).

The bulk of oceanic catches in this area is constituted by three species: skipjack, yellowfin and bigeye tunas. The main countries fishing tunas in recent years are Spain, France, Ghana and Japan. As for the Western Central Atlantic, a great and increasing quantity of tuna catches are included in the databases of international organizations (i.e. ICCAT and FAO) as taken by vessels of unknown nationality (“Other nei”). In 1990, the “Other nei” tuna catches were one quarter (36,000 tonnes) of the total tuna catches caught by DWFs, but in 1999 they reached the 40%.

The share of DWFs in oceanic catches has always been very significant in this area (Garibaldi and Grainger, 2002). Note that Spain and Portugal are classified as bordering countries because part of their territories (i.e. Canary and Madeira Islands) lies in this area. Absent until 1954, oceanic catches by DWFs reached almost 88% of total oceanic catches in 1961 and remained at around 80% for the whole of the 1960s. From the early 1970s until 1987 they slowly declined to 33%, but in the 1990s the DWFs share of oceanic catches increased again to about 55%.

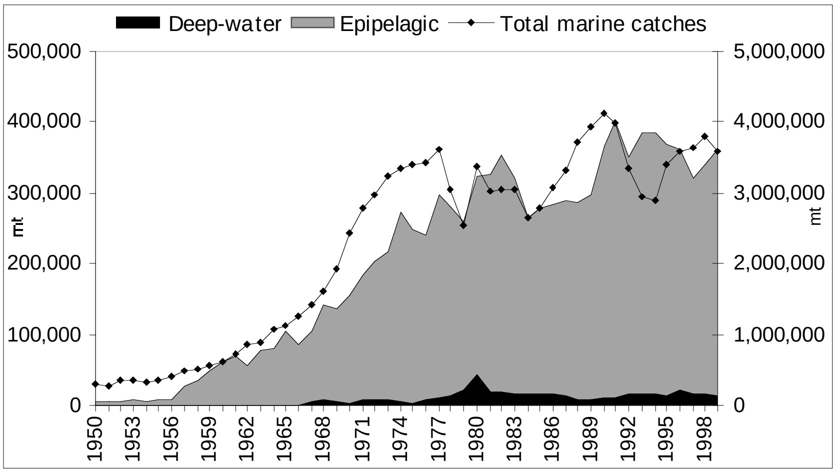


Figure 13. Eastern Central Atlantic (FAO Area 34)

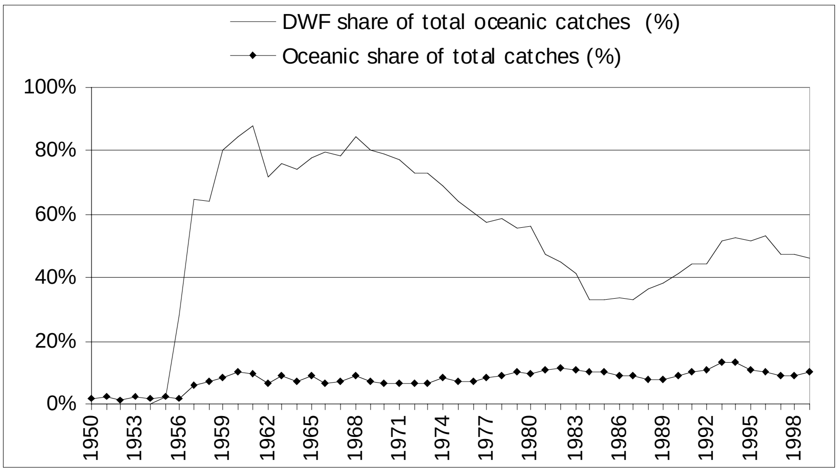


Figure 13 (continued). Eastern Central Atlantic (FAO Area 34)

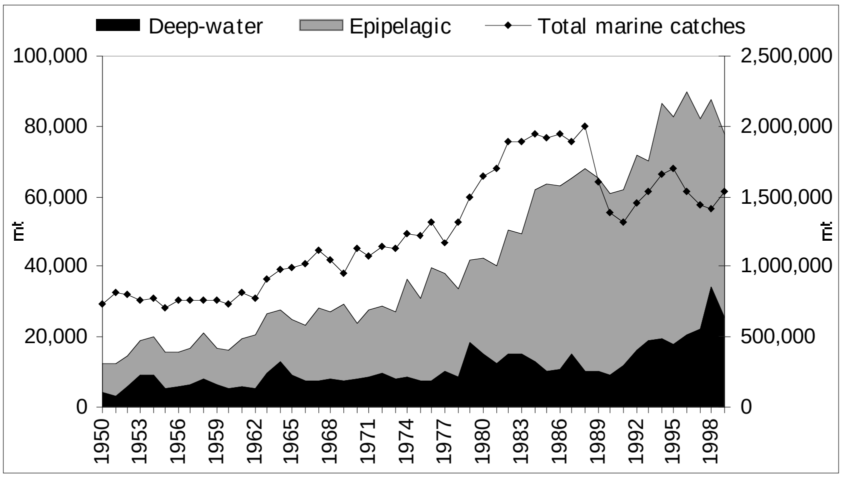
2.3.5 Mediterranean and Black Sea (FAO Area 37)

In FAO Area 37, oceanic catches represent a small portion of total marine catches but they nevertheless have considerable importance due to the high commercial value of some tuna and tuna-like species. Catches of all epipelagic species together have stabilized around 50,000 tonnes since 1984 and, after the highest ever peak of 69,000 tonnes in 1996, they decreased to 52,500 tonnes in 1999 (Figure 14). Bluefin tuna and swordfish are the main target of tuna fisheries, mostly conducted by bordering countries, while Asian countries are catching only a small portion of these very valuable species. Apart from tunas, other epipelagic species of some importance are dolphinfish (*Coryphaena hippurus*) and the European flying squid (*Todarodes sagittatus*).

The practice of fattening wild-caught bluefin tuna in captivity is booming in the area and from 1996 to 2001 there was at least a 20-fold increase in the number of cages in the Mediterranean (Miyake, *et al*., 2002). This practice aims mainly at increasing the fat content of the flesh, which strongly influences the price of the tuna meat in the Japanese *sashimi* market. The development of bluefin tuna farming has statistical, biological, management, environmental and socio-economic effects (GFCM-ICCAT, 2002) that need to be addressed urgently by international and national institutions.

As for the Northeast Atlantic area, the bulk of catches in deep waters are constituted by a single species, the blue whiting (*Micromesistius poutassou).* Landings of this species increased by about 50% in the 1990s in comparison to the previous decade, mainly due to catches reported by Turkey.

The Mediterranean and the Black Sea are semi-enclosed seas and environmental threats such as increasing coastal population, heavy shipping traffic and introduction of alien species are more serious than in open ocean areas. In this area, extended (up to 200 mile) EEZs have not be implemented because of geographical (i.e. complex coastal configurations and the presence of islands) and political circumstances (i.e. longstanding maritime and territorial disputes are historically present and the whole sea would be subject to the jurisdiction of coastal States; for a thorough analysis see: Kliot, 1987). Since national jurisdictions extend much less far than in other areas and the regional fishery management organization is still developing its management role, oceanic resources tend not to be managed and protected effectively.



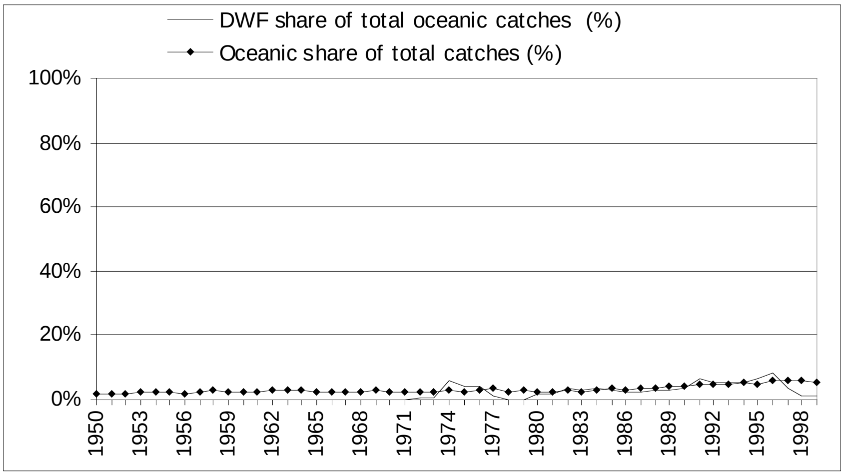
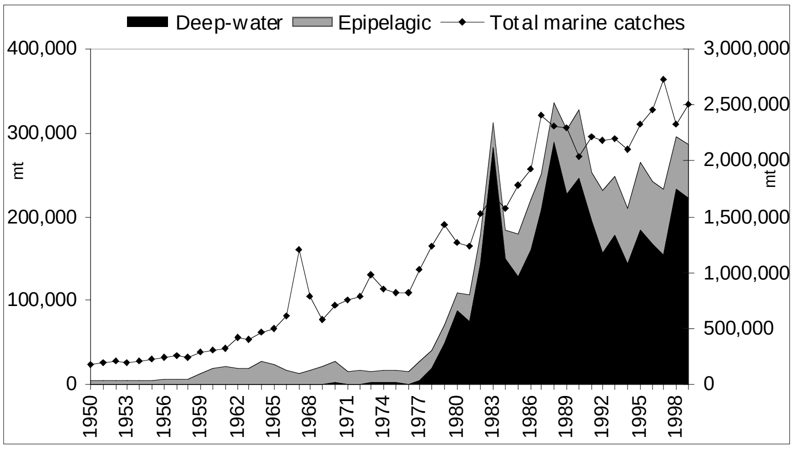


Figure 14. Mediterranean and Black Sea (FAO Area 37)

2.3.6 Southwest Atlantic (FAO Area 41)

The share of oceanic catches in total catches in this area is greater than the global average, exceeding 10% since 1982. Oceanic catches started increasing during the late 1970s (Figure 15); they showed a maximum in 1983 as percentage of total catches (18.5%) and in 1988 as absolute quantity (336,000 tonnes). In the last five years, total oceanic catches fluctuated around 250,000 tonnes. Since the early 1980s, most of the oceanic catches have been composed of deep-water species such as the southern blue whiting (*Micromesistius australis*), grenadiers (*Macruronus magellanicus* and *Macrourus* spp.), and recently by Patagonian toothfish (*Dissostichus eleginoides*). Catch peaks of southern blue whiting and grenadiers show an asynchronous pattern: the former had peak years in 1983 and 1990, the latter in 1988 and 1999. Until 1990, these species were caught mostly by DWFs (i.e. those of the Former USSR and other Eastern Europe countries), but immediately after these countries drastically reduced the activities of their DWFs, Argentina took over as the most important country fishing deep-water resources in the area.

Catches of epipelagic species are mainly composed of tuna and tuna-like species and the fleets accounting for the main catches are from Brazil, Taiwan Province of China, Spain and Japan. In the Southwest Atlantic, there are very important fisheries for cephalopods operated mainly by Argentina and Asian countries, but these catches were not included in the oceanic dataset object of this study, as only one cephalopod species distributed in this area (*Martialia hyadesi*) has been classified as fully oceanic. Significant catches (23,464 tonnes) for this species have been reported only in 1995 by Taiwan Province of China.



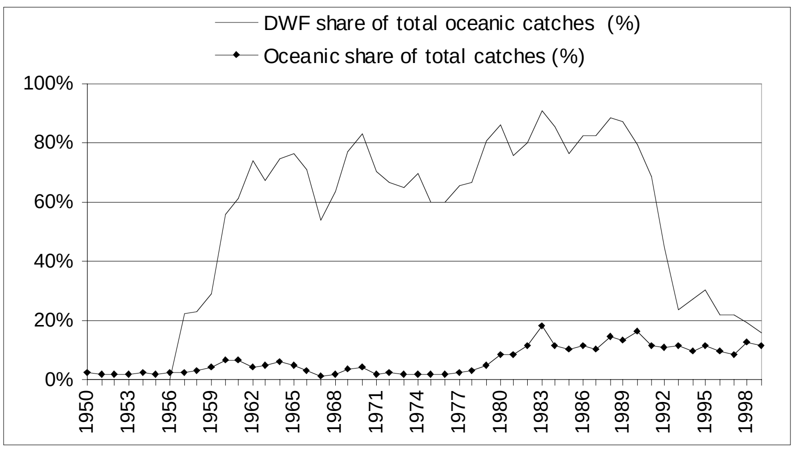
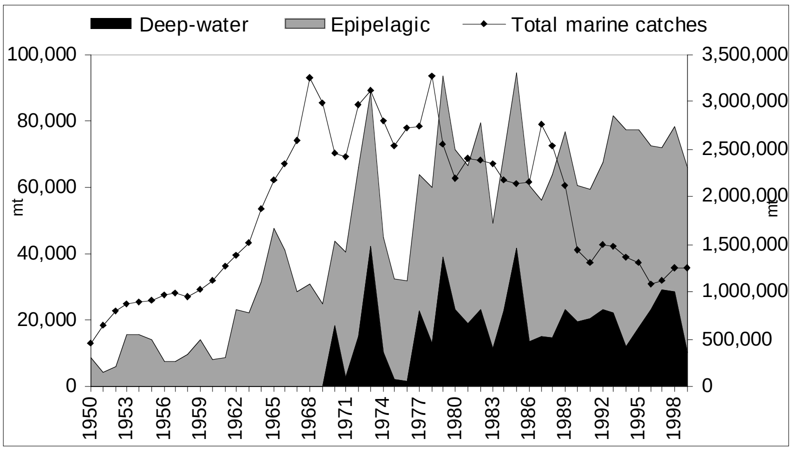


Figure 15. Southwest Atlantic (FAO Area 41)

2.3.7 Southeast Atlantic (FAO Area 47)

This area is characterized by intermittent upwelling regimes that affect quantitative fisheries such as those for small pelagics and this is reflected in the total marine captures, which had periodic peaks (1968, 1973, 1978 and 1987) along the time series (Figure 16). After the 1987 peak (2,750,000 tonnes), total catches have constantly declined and in 1999 they were reduced to less than half (1,250,000 tonnes) of the latest peak. The general decline of marine catches has been associated to environmental changes (low oxygen levels in coastal waters) that led to the marked decrease of sardine stocks in the 1990s (Cochrane, 1997). Apparently, oceanic stocks were not affected by those environmental changes and their fisheries did not undergo any decline.

Share of oceanic catches was below 5% up to 1993, a value around which it has stabilized in recent years. It should be noted, that in this area there are only three coastal countries and that most of the oceanic catches are due to DWFs (Japan, Taiwan Province of China and, before 1980, the Former USSR). The DWFs portion of oceanic catches reached 93% in 1975 and remained high (between 50% and 80%) for the rest of the time series. The DWFs harvested mainly tuna species (bigeye and southern bluefin) and *Geryon* crabs (caught mainly by Japan) among the deep-water resources.



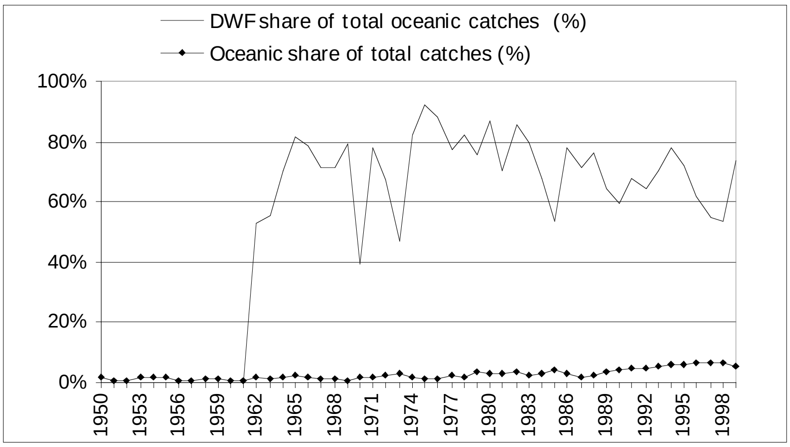
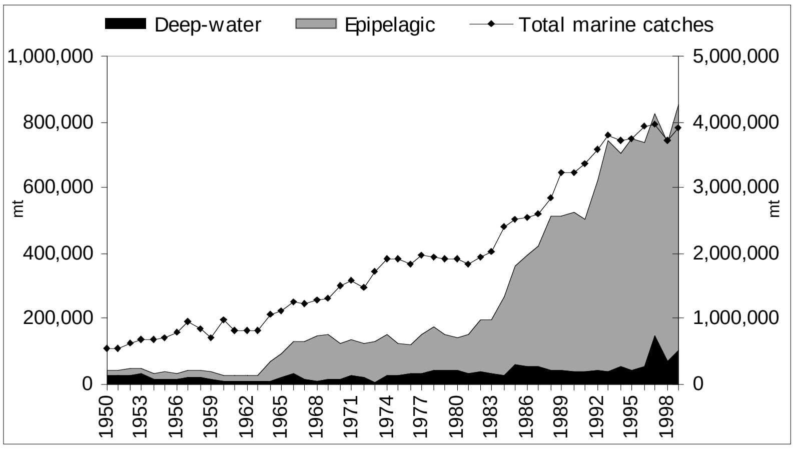


Figure 16. Southeast Atlantic (FAO Area 47)

2.3.8 Western Indian Ocean (FAO Area 51)

Total marine captures in this area increased continuously from 1950 onwards and have stabilized around 3.9 million tonnes since 1997 (Figure 17). For the whole time series, the oceanic share has always been significant, reaching 20% for the first time in 1995 and a maximum of 22% in 1999. Since 1983, more than 75% of the oceanic catches have been from tuna species, while deep-water catches have increased only in the latest years as compared to the quantities reported in the earliest years of the time series. The majority of the deep-water catches are Indian catches of hairtails (family Trichiuridae), a group of fishes which could also be considered as epipelagic because it shows vertical feeding migration (Nakamura and Parin, 1993). A deep-water fishery that could possibly develop in future years is that for lanternfishes (family Myctophidae) in the Arabian Sea (Shotton, 1997b).

Since 1984, catches of oceanic tuna in this area have been increasing steeply and they exceeded 700,000 tonnes in 1999. About two thirds of these catches are harvested by European (e.g. Spain and France) and East Asian (Japan and Taiwan Province of China) fleets. In this area, as for the two tropical areas of the Atlantic Ocean, a great quantity of tuna catches (about 100,000 tonnes in 1999) are attributed to "Other nei" (not identified country) in the Indian Ocean Tuna Commission (IOTC) and FAO databases. Main tuna species caught are skipjack, yellowfin and bigeye tunas. Epipelagic species other than tuna represented in the fishery statistics are dolphinfish and sharks of the family Carcharhinidae.



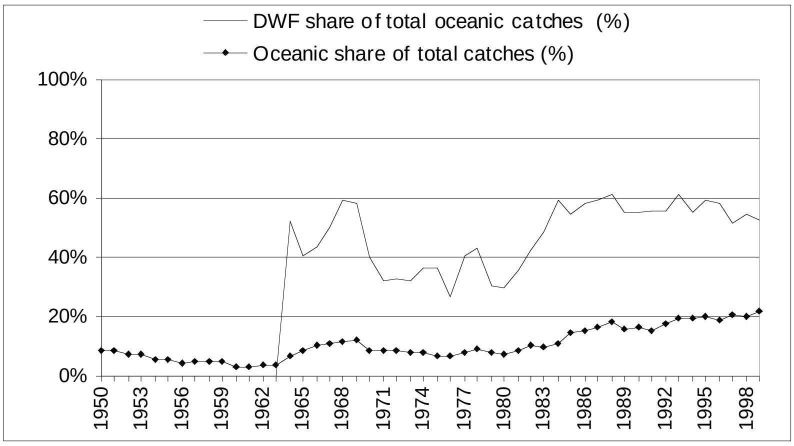


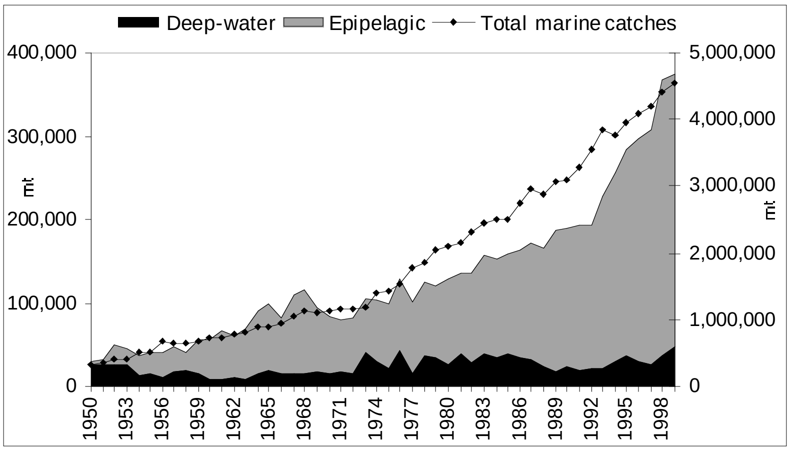
Figure 17. Western Indian Ocean (FAO Area 51)

2.3.9 Eastern Indian Ocean (FAO Area 57)

Trends in both total marine and oceanic captures in the Eastern Indian Ocean are very similar to those in the Western Indian Ocean. In both areas, total catches have been progressively increasing along the entire time series and tuna catches constitute the bulk of oceanic catches. The major differences are that the steep increase of tuna catches in the Eastern Indian Ocean took place about ten years later than in the Western Indian Ocean (in 1993 instead than 1984) and that DWFs have a more limited role in the Eastern area (Figure 18).

Main tuna target species are the same as in the Western Indian Ocean (i.e. skipjack, yellowfin and bigeye tunas). Bordering nations with important tuna fisheries are Sri Lanka and Indonesia, while Japan and Taiwan Province of China are the main distant water fishing fleets. From 1960 onwards, Sri Lanka has been reporting considerable catches of silky shark (*Carcharhinus falciformis*). Since 1980, catches of this species have ranged between 10,000 and 25,000 tonnes.

The share of deep-water catches is slightly higher (on average 18% of the oceanic catches) in comparison to the Western Indian Ocean, with the highest quantities (mostly hairtails catches by India and Indonesia) recorded in 1976 and in 1999. Significant catches of orange roughy in the Eastern area were reported for 1998 and 1999 (4,857 and 7,553 tonnes respectively) by Australia, while in previous years catches of this species were mostly concentrated in area 81 (Southwest Pacific).



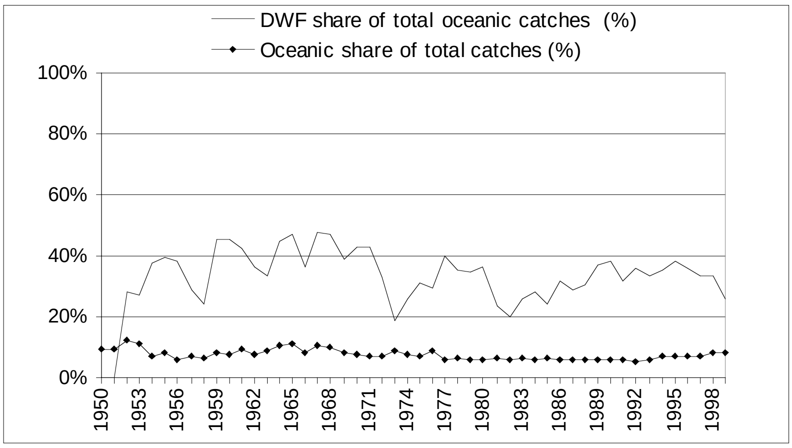


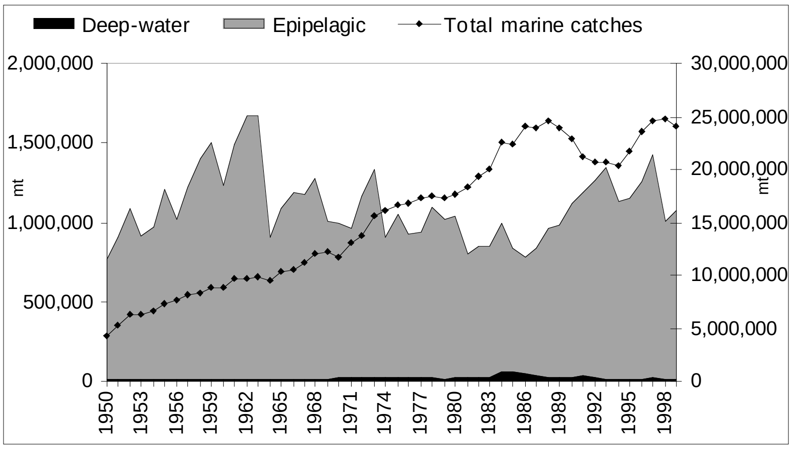
Figure 18. Eastern Indian Ocean (FAO Area 57)

2.3.10 Northwest Pacific (FAO Area 61)

Total catches in this area are strongly influenced by the trend of marine captures reported by China, which imply an average rate of 10% increase per year in the 1984-99 period. If China is excluded, the sum of total catches of other countries has almost halved in the last ten years.

In contrast to other areas, oceanic catches in the Northwest Pacific have had a major importance, both in terms of quantities and of share, in the first half of the time series (1950-74) than in the second one (1975-99)(Figure 19). As for other temperate areas (e.g. Northwest Atlantic), the majority of the catches of epipelagic species are not accounted for by tuna and tuna-like species. The main epipelagic species caught throughout the years, mostly by Japan and secondarily by the Republic of Korea, are the Pacific saury (*Cololabis saira*) and the Japanese flying squid (*Todarodes pacificus*). Variations in the abundance of the latter strongly influence the general trend of oceanic catches in this area. Annual catches of Japanese flying squid depend largely on general environmental and ecological changes (Ogawa and Sasaki, 1991), such as water temperatures and abundance of predators and/or prey, and have shown recovering and increasing trends in the absence of management regulations (Sakurai *et al*., 1998).

Deep-water species represent only a small proportion of oceanic catches, with a single peak in the 1984-86 period due to catches reported by the Former USSR (silvery lightfish and grenadiers). There are no oceanic species catches reported for DWFs in this area.



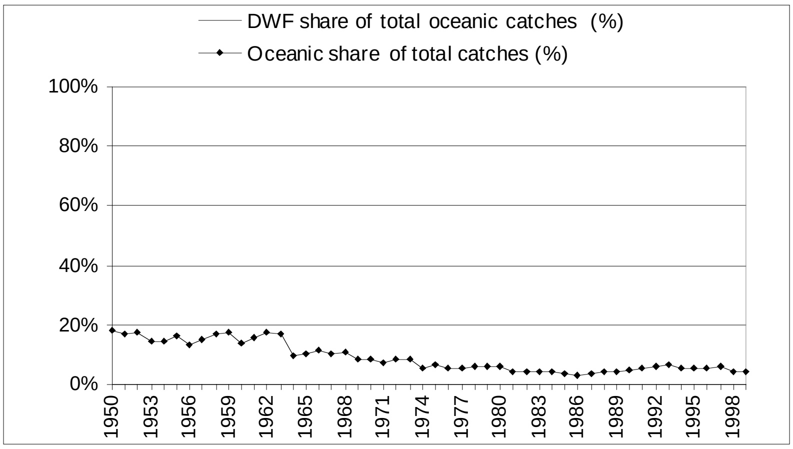
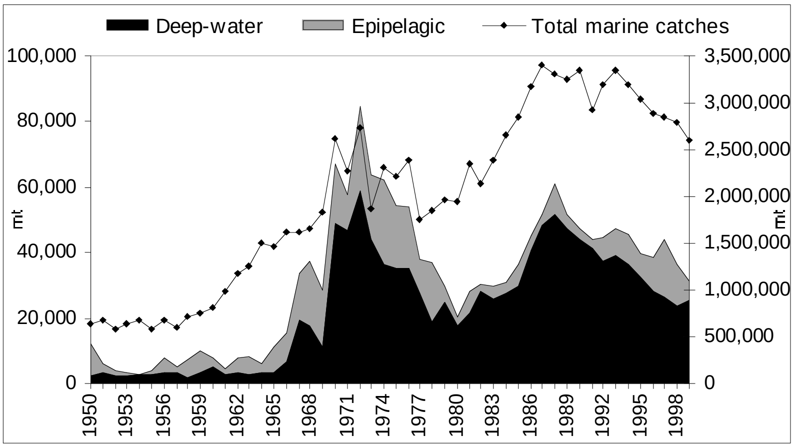


Figure 19. Northwest Pacific (FAO Area 61)

2.3.11 Northeast Pacific (FAO Area 67)

As a proportion of total marine catches, oceanic catches in this area are negligible along the whole time series (percentages never exceed 3.5%; Figure 20). Oceanic catches had two peaks, the first and more significant one in the early 1970s and the second during the 1986-94 period. In both cases the bulk of the catches was represented by the deep-water sablefish, *Anoplopoma fimbria*. However, while the first peak was due to catches reported by DWFs (mostly Japan), the second was attributable to bordering countries (USA and Canada).

Waters of area 67, which extend southwards as far as Cape Mendocino in northern California, should be expected too cold for tuna species but for an eleven year period (1968-78) and in a recent year (1997) catches of tuna and tuna like species have exceeded 15,000 tonnes. Most of these quantities are albacore catches reported by USA. In the latest years, Japan reported about 1,000-2000 tonnes of catches of the neon flying squid (*Ommastrephes bartrami)* in this area.



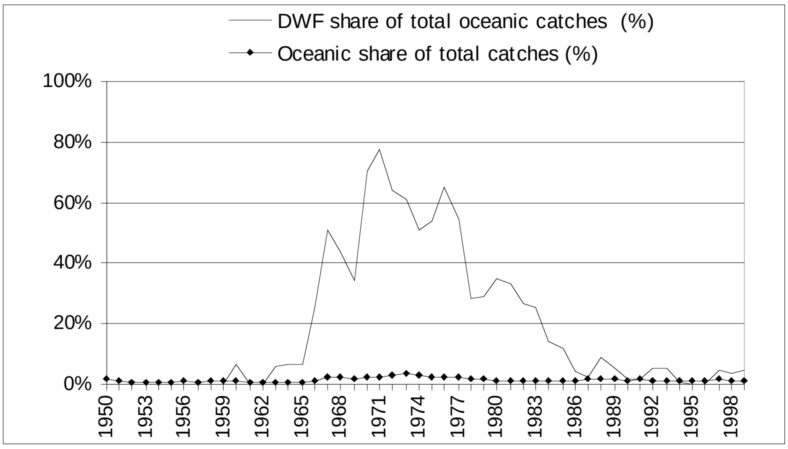


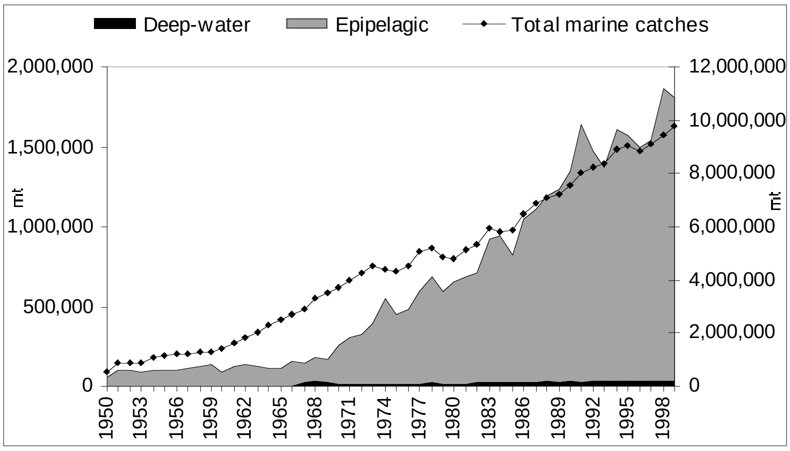
Figure 20. Northeast Pacific (FAO Area 67)

2.3.12 Western Central Pacific (FAO Area 71)

As for the two Indian Ocean areas, total catches in this tropical area have been progressively increasing throughout the years, with oceanic catches accounting for a significant percentage (10-20%) of total catches in terms of quantity and much more in terms of value, and with DWFs always playing an important role (Figure 21). This is by far the most important FAO fishing area for catches of those tuna and tuna-like species classified as epipelagic (about 1.8 million tonnes in 1999; the second area in ranking, the Western Indian Ocean, totalled less than half of this).

The most important oceanic species caught in the area are skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*). Since 1970, catches of these two species have represented, without much oscillation, respectively 40-62% and 18-28% of the total catches of oceanic tunas. Distant water fleets took about half of these tuna catches throughout the whole time series. The main DWFs are from neighbouring Asian countries (i.e. Japan, Korea Rep., and Taiwan Province of China) and the USA. Among the bordering countries, Indonesia, the Philippines and the Solomon Islands are the countries reporting higher quantities of tuna catches in recent years.

Deep-water species have a very limited importance in comparison to the epipelagic species. Only for hairtails (family Trichiuridae) have there been significant catches, and these have been continuously increasing since 1975, reaching about 34,000 tonnes in 1999.



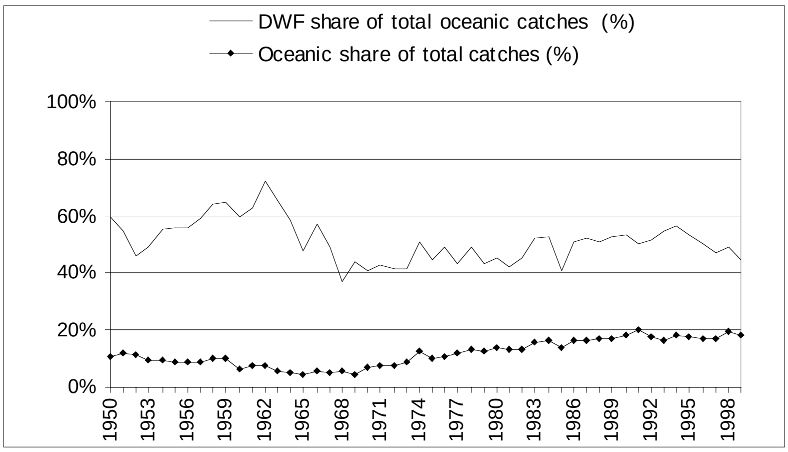


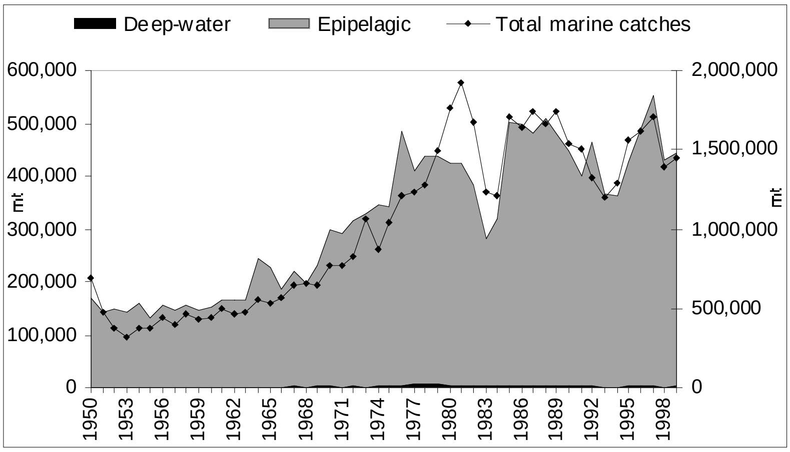
Figure 21. Western Central Pacific (FAO Area 71)

2.3.13 Eastern Central Pacific (FAO Area 77)

Oceanic catches represent a stable percentage (33% on average) of the total marine catches and showed a remarkable increase in the 1963-1985 period (up to 500,000 tonnes in 1985), which subsequently stabilized or slightly decreased (444,000 tonnes in 1999; Figure 22).

In the Eastern Central Pacific, as for the other tropical fishing areas, oceanic catches include mostly tuna and tuna-like species. Yellowfin, skipjack and bigeye are the most frequently caught species. Catches by DWFs have exceeded those by bordering countries in the 1985 and, since then, their share has been oscillating around 50% with a decrease in recent years. Main DWFs are from Japan (which has considerably reduced its portion of tuna catches in the latest years), Republic of Korea and Venezuela. Tuna catches by bordering countries are mostly for Mexico and the USA, with a remarkable change in their shares: in 1970, Mexico was catching 5.4% of the oceanic tunas by bordering countries and the USA 93.5% while in 1999 the Mexican share rose to 74.8% and that by of USA decreased to 14.9%.

In recent years, significant catches have been reported for the jumbo flying squid (*Dosidicus gigas*) and also a good portion of what was reported in previous years as “squids not elsewhere identified” were probably catches of jumbo flying squid (Csirke, 1997). Catches of the family Carcharhinidae and of other oceanic sharks are also represented in the FAO database for this area. Deep-water catches are almost absent in this area except for some thousand tonnes of the deep-water sablefish, *Anoplopoma fimbria*, reported by the USA.



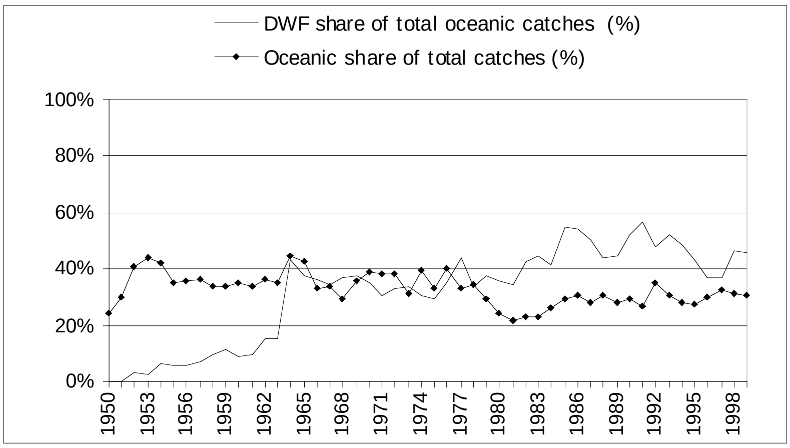


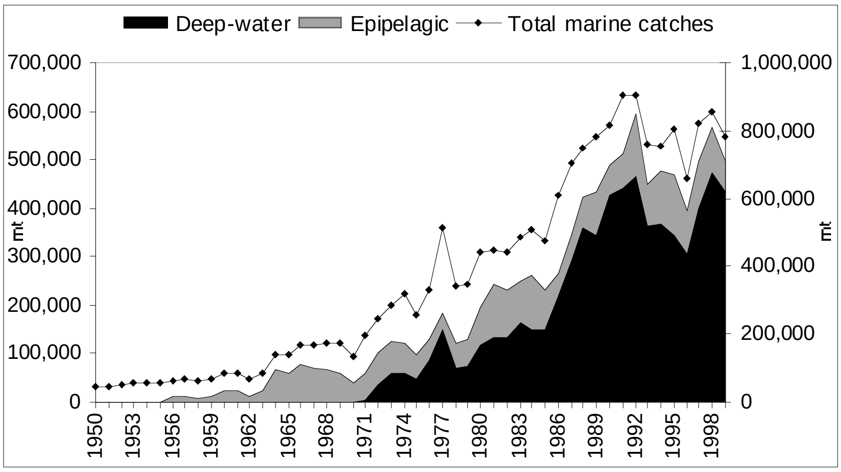
Figure 22. Eastern Central Pacific (FAO Area 77)

2.3.14 Southwest Pacific (FAO Area 81)

This area has been characterized by increasing captures up to 1992 (when total marine catches reached over 900,000 tonnes) and by a slight decrease in the latest years (780,000 tonnes in 1999; Figure 23). This trend is closely matched by that of oceanic catches, mainly represented by deep-water species, which increased from 1,600 tonnes in 1950 to 498,000 tonnes in 1999 after a peak of almost 600,000 tonnes in 1992. The share of oceanic catches in total catches has been constantly increasing since the 1950s and in 1981 it exceeded that of coastal catches; in recent years it has stabilized at around 60%.

The great importance of oceanic catches is due to deep-water fisheries mainly targeting three species: the Gadiformes species blue grenadier (*Macruronus novaezelandiae*) and southern blue whiting (*Micromesistius australis*), and the orange roughy (*Hoplostethus atlanticus*). Up to the beginning of the 1980s, deep-water species were mostly caught by the Former USSR, while since mid-1980s Japan has been the main distant water fishing nation. New Zealand fisheries for deep-water species started to catch significant quantities in 1979 and from 1992 they have exceeded the total catches of all DWFs which have been declining. Australia, the only other bordering country, has caught considerable quantities of deep-water species only for a few years at the beginning of 1990s.

To better describe their trend, catches of epipelagic species can be divided into two time periods, before and after 1980-81. The first period was dominated by tuna catches, in particular those of southern bluefin tuna (*Thunnus maccoyii*). This species was so heavily fished in the 1960s that since mid-1980s the main fishing nations had to apply strict quotas to allow the stock to rebuild after a serious decline (CCSBT, 1997). In the second period, from 1981 onwards, fisheries for the Wellington flying squid (*Nototodarus sloani*) started developing. This species was targeted mostly by Japanese DWF vessels up to 1990, since when catches by New Zealand have progressively replaced those by DWFs.



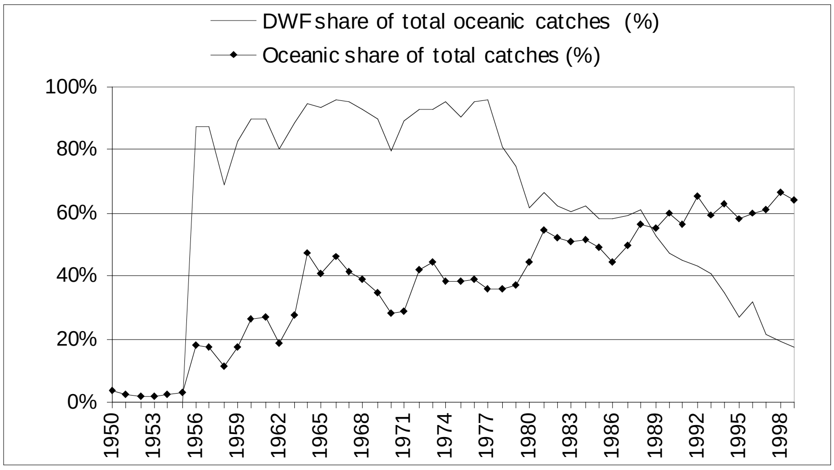


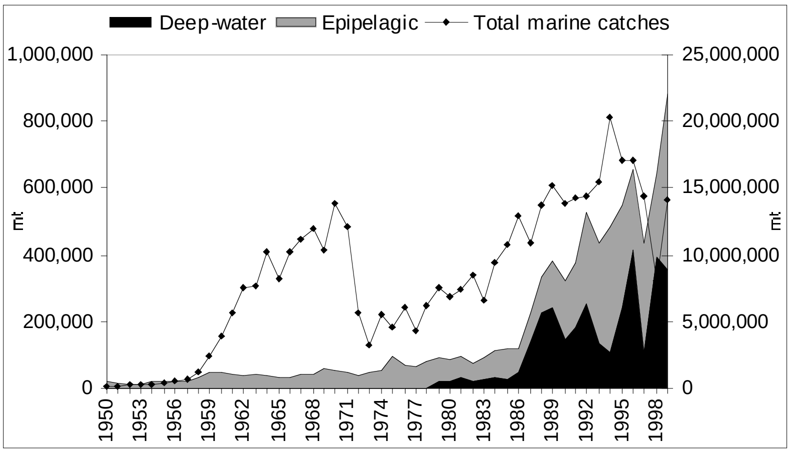
Figure 23. Southwest Pacific (FAO Area 81)

2.3.15 Southeast Pacific (FAO Area 87)

Trend of total catches in the Southeast Pacific is strongly influenced by the oscillations of the anchoveta (*Engraulis ringens*) and of other small pelagic species. Biomass of these species fluctuates in relation to the availability of upwelling nutrients, which is driven by the El Niño phenomenon. Total catches being extremely high in this area (the 1994 peak was over 20 million tonnes), the share of oceanic catches has been always quite low not exceeding 4% up to 1997 (Figure 24). In 1998, total catches were lower due to El Niño, while oceanic catches increased and their share peaked at 8.1%. In 1999, oceanic catches reached their maximum at almost 900,000 tonnes but, with the total catches recovering, their share decreased to 6.2%.

A significant increase of oceanic catches started in 1987. Since then, total catches of epipelagic and deep-water species grouped separately showed a series of asynchronous peaks, although the total catches of each group in the whole 1987-99 period have been very similar. Main species among the epipelagics are skipjack and yellowfin tunas, which are increasingly caught by fleets of bordering countries (e.g. Ecuador and Colombia), while in the past DWFs played a major role. Catches of the jumbo flying squid by Japan, Republic of Korea and Peru had an extended peak in the 1991-97 period, collapsed almost to no catches in 1998 during El Niño, and recovered to a significant level (76,000 tonnes) when El Niño was over in 1999.

Deep-water catches have been mostly composed of Patagonian grenadier (*Macruronus magellanicus*) and secondarily by southern blue whiting (*Micromesistius australis*) and Patagonian toothfish (*Dissostichus eleginoides*). Almost all these catches were reported by Chile, and only very small quantities by DWFs.



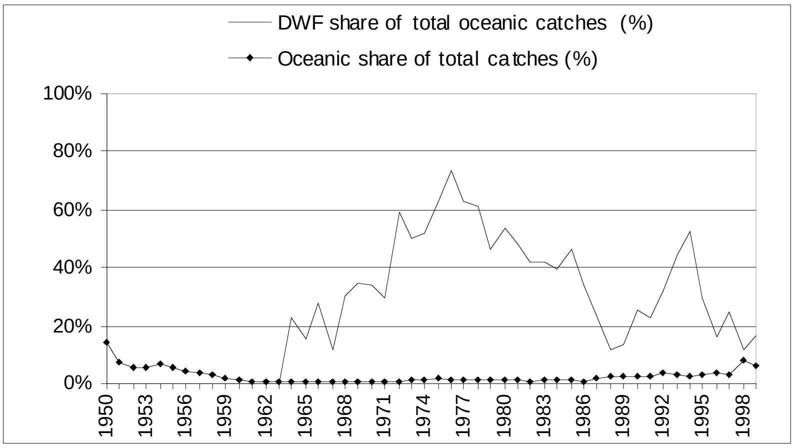


Figure 24. Southeast Pacific (FAO Area 87)

2.3.16 Arctic (FAO Area 18) and Antarctic areas (FAO Areas 48, 58, 88)

For the Arctic area, the Former USSR reported catches to FAO only for the 1967-70 period. For this reason, the Arctic area has not been considered in this analysis.

Reporting of data for the three Antarctic areas started in 1966, but up to 1973 no oceanic species were caught (Figure 25). Since 1979, the krill *Euphausia superba*, an epipelagic species, has accounted for more than 70% of the total catches in the Antarctic areas, with the only exception of 1983-84 when catches dropped. Great quantities of krill have been taken by the Former USSR (with a peak of almost 500,000 tonnes in 1982) up to 1991-92 when, after the dissolution of the USSR, the new Republics drastically reduced their Antarctic fishing activities. In contrast, Japan has steadily caught krill since the 1980s ranging between 40,000 and 80,000 tonnes yearly.

Deep-water species are limited to an extended peak of Myctophidae (lanternfishes) caught during the 1988-92 period by Former USSR countries, and to catches of Patagonian toothfish (*Dissostichus eleginoides*), mainly in area 58 (Antarctic Indian Ocean).

Decreasing total catches in recent years are due to specific causes, such as the distance from other major fishing grounds and the lack of demand for some Antarctic species (Shotton, 1997c; Nicol and Endo, 1999), rather than to a depletion of the living resources, which are carefully managed by the Commission for the Conservation of Antarctic Living Resources (CCAMLR), although concern is rising for IUU catches of Patagonian toothfish (Lack and Sant, 2001).

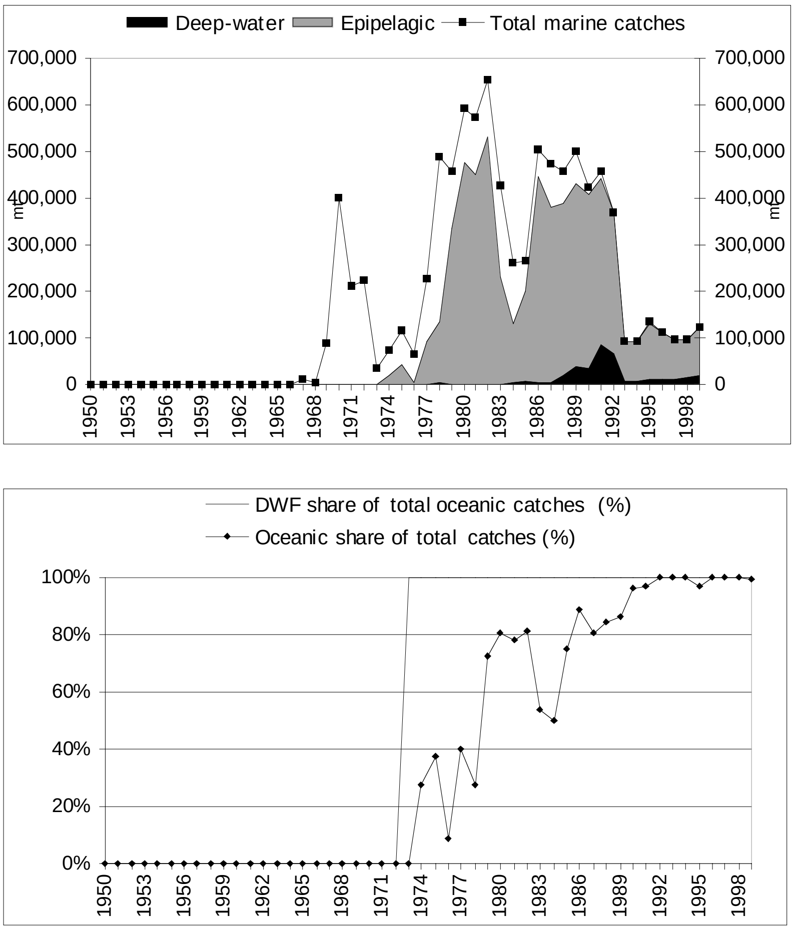


Figure 25. Antarctic areas (FAO Areas 48, 58, 88) all together

3. CONCLUSION

The classification of the oceanic species items (either epipelagic or deep water) included in the FAO capture fisheries database has allowed a description of the increasing share of oceanic catches in total global marine catches. In the 1990s, concurrent with a slightly declining trend in total coastal species catches (excluding Peruvian anchoveta), both groups of oceanic species have increased their catches by 1 million tonnes, epipelagics from 4.8 to 5.7 million tonnes and deep-water species from 1.8 to 2.9 million tonnes.

The majority of oceanic epipelagic catches (mainly tuna and tuna-like species) is from tropical areas whereas deep-water species are mostly caught in temperate regions. In the last decade, a continuous increase of epipelagic catches has occurred in the tropical areas of the Indian and Pacific Oceans whereas in the two tropical Atlantic areas they have been oscillating and in 1999 totalled catches similar to those of 1990. Deep-water catches have recently increased remarkably in the North Atlantic, probably due to a shift of fishing effort to new target species after the decline of other marine resources in the area, although there have been signs of declining catches in other areas (e.g. Southwest Atlantic, Northeast Pacific and Southwest Pacific) where deep-water species have been caught in significant quantities during the 1980s and in the early 1990s.

However, due to the peculiar biological characteristics of deep-water species, concern is rising on the sustainability of deep-water fisheries and, in particular in the Northeast Atlantic, regional fishery commissions and related institutions are proposing action to protect the deep-water stocks (Anonymous, 2002; ICES, 2002). With regard to oceanic tunas and tuna-like species, differences in life history traits between tropical tunas and temperate tunas may result in different responses to fishing pressure (Fromentin and Fonteneau, 2001) and partially explain why catches of tropical species are still growing whereas stocks of temperate bluefin tuna species have shown serious declines in biomass and catches.

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Clustering Large Marine Ecosystems by capture data

1. INTRODUCTION

The Johannesburg Plan of Implementation of the World Summit on Sustainable Development (Anonymous, 2002a), noting the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem (Anonymous, 2001), set the goal of encouraging the application by 2010 of the ecosystem approach to responsible fisheries (paragraph 29(d) of the Plan). This is an internationally agreed starting point for a new approach to fisheries management and fishery related studies utilizing a multinational, interdisciplinary approach, which integrates information concerning productivity, ecology, fisheries, socio-economic aspects and governance. Since mid-1980s, it has been developed the definition of Large Marine Ecosystems (LMEs) that represented a proposal to give an ecology-based partition of global oceans. The LMEs project called for a more ecologically sensible monitoring of fishery resources, to go beyond the purely biological and socio-economic view of marine resources and improve the awareness of shared resources among countries (Sherman and Alexander, 1986, 1989; Sherman *et al.*, 1990, 1991, 1993).

Initially, 49 LMEs were identified (Sherman and Alexander, 1986) and then an additional 50th was proposed (Bakun *et al*., 1999). LMEs were defined on the basis of "*…consideration of distinct bathymetry, hydrography, productivity, and trophically dependent populations…*" (Sherman *et al.*, 1993). This definition is rather broad. For some of the 50 LMEs, not only the ecological aspects but also geopolitical aspects have been considered. In others LMEs, distinct habitats and ecosystems have been put together. For these reasons, and following the publication of numerous papers, books and research results, the list has been expanded and some LMEs subdivided in order to increase their ecological significance, and to expand the coverage of all main shelf areas. The latest list, available at the LME web site managed by NOAA (2002), includes 64 LMEs. However, as the background work for this study initiated in 1999, the paper is based on the 50 LMEs described at that time (see list in Table 1 and map in Appendix 3).

1.1 Overview and scope of the work

The initial purpose of the present work was mainly to made available capture fishery production statistics by LME to scientists carrying out studies on individual LMEs. This encompassed the re-arrangement of the statistics included in the FAO capture database, which are organized into 19 marine fishing areas, and the research of data at the sub-national level needed to disaggregate the national data reported to FAO into defined regions which belong to different LMEs. Preliminary work on the feasibility of re-arranging the FAO capture statistics into the LMEs' borders was carried out and the congruences and incongruences between the two partitions identified. However, in the course of the work, several difficulties have been encountered both in re-assigning the FAO statistics to LMEs and in the availability of additional data from national sources.

Due to data limitations, it has been possible to assemble data series only for a limited number of years (1990-99) and for a majority but not for all LMEs (43 out of 50; see Table 1) as for seven of them sub-national data were not available to FAO. The data compiled can be requested to the FAO Fishery Information, Data and Statistics Unit (FIDI) by scientists interested in LMEs' studies but there is no plan to update the catch series by LME.

Table 1. List of the 50 Large Marine Ecosystems
(as from Sherman and Duda, 1999)

LME no.	LME name	LME no.	LME name
LME 1	Eastern Bering Sea	LME 26	Black Sea
LME 2	Gulf of Alaska	LME 27	Canary Current
LME 3	California Current	LME 28	Guinea Current
LME 4	Gulf of California	LME 29	Benguela Current
LME 5	Gulf of Mexico	LME 30	Agulhas Current
LME 6	Southeast U.S. Continental Shelf	LME 31	Somali Coastal Current
LME 7	Northeast U.S. Continental Shelf	LME 32	Arabian Sea
LME 8	Scotian Shelf	LME 33	Red Sea
LME 9	Newfoundland Shelf	LME 34	Bay of Bengal
LME 10	West Greenland Shelf	LME 35	South China Sea
LME 11	Insular Pacific-Hawaiian	LME 36	Sulu-Celebes Sea
LME 12	Caribbean Sea	LME 37	Indonesian Seas
LME 13	Humboldt Current	LME 38	Northern Australian Shelf
LME 14	Patagonian Shelf	LME 39	Great Barrier Reef
LME 15	Brazil Current	LME 40	New Zealand Shelf
LME 16	Northeast Brazil Shelf	LME 41*	East China Sea
LME 17	East Greenland Shelf	LME 42*	Yellow Sea
LME 18	Iceland Shelf	LME 43*	Kuroshio Current
LME 19	Barents Sea	LME 44*	Sea of Japan
LME 20	Norwegian Shelf	LME 45*	Oyashio Current
LME 21	North Sea	LME 46*	Sea of Okhotsk
LME 22	Baltic Sea	LME 47*	West Bering Sea
LME 23	Celtic-Biscay Shelf	LME 48	Faroe Plateau
LME 24	Iberian Coastal	LME 49	Antartic
LME 25	Mediterranean Sea	LME 50	Pacific Central American Coastal

*LMEs for which, given the unavailability of sub-national capture statistics, data were not compiled.

Although in one of the LME definitions (Sherman *et al.*, 1993) it is mentioned that "*…the seaward limit of the LMEs extends beyond the physical outer limit of the shelves to include all or a portion of the continental slopes as well…*" the principal characteristics described in studies on single LMEs (e.g. Sherman and Alexander, 1986, 1989; Sherman *et al.*, 1990, 1991, 1993, 1996, 1998; Sherman and Tang, 1999; Kumpf *et al.*, 1999) refer mostly to the marine areas over the continental shelves. Furthermore, it seems that recently this definition has been refined as "*Large Marine Ecosystems are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of the major current systems*" (Anonymous, 2002b). For these reasons, only capture statistics of species spending most of their life cycles in the shelf areas have been considered in this analysis, thus excluding all species items classified as oceanic for the other study contained in this volume.

As the short period of data availability did not allow a thorough analysis of trends by LMEs, this study manly focuses on the fishery characteristics of LMEs with reference to the major species groups caught in each LME and tries to identify similar patterns among the various LMEs. The ten years series of capture data available for each LME have been grouped on the basis of the ‘International Standard Statistical Classification for Aquatic Animals and Plants’ (ISSCAAP) which has been recently revised (FAO, 2001a,b) and a LME cluster analysis of the similarity of the average total catches of each group for the studied period. This has produced 11 clusters of LMEs which have similar characteristics in their capture profiles.

For each LME, stacked area charts of species groupings’ catches have been also prepared to show the variations along the 10-year period (see charts in Appendix 2) and the differences in trends between the various LMEs belonging to the same cluster have been discussed when appropriate.

2. METHODS

2.1 Re-arrangement of FAO capture statistics by LME and grouping of species items

A data sub-set from the FAO capture database (FAO, 2001c) was created including the 1990-99 catches for all non-oceanic species items. Only capture production of fishes, crustaceans and molluscs were considered, excluding catches of marine mammals, miscellaneous aquatic animals and products, and aquatic plants. Catches of freshwater and diadromous fishes reported as caught in marine waters (e.g. in the Baltic Sea) have also been included. A dataset comprising 867 species items was obtained. The total catches of these species items represent about 90% of the global marine catches as the oceanic species constitute the remaining 10% (see the “Oceanic” study in this volume). This figure is close to a previous estimate of LMEs producing approximately 95% of the world total marine capture production (Sherman, 1994).

In order to re-arrange FAO catch statistics data by LMEs, the following criteria were followed:

- catch data by country/FAO fishing area, including data for Distant Water Fleets (DWFs) when available, were extracted from the dataset and directly re-assigned to the corresponding LME whenever congruent;
- additional data for those LMEs whose boundaries are not coincident with those of the FAO fishing areas have been extracted from regional databases managed by FAO (e.g. GFCM for the Mediterranean and the Black Sea, CECAF for the Eastern Central Atlantic area and ex-ICSEAF for the Southeast Atlantic) and by regional bodies (e.g. NAFO for the Northwest Atlantic and ICES for the Northeast Atlantic) while additional data at the sub-national level had to be retrieved from national yearbooks of fishery statistics and national databases (see Appendix 1 for a complete list of additional sources consulted);
- catches by species have been assigned to LMEs also on the basis of their ranges;
- in the cases in which the total catches from an additional and more detailed national source differed from the total catches previously submitted by the country’s FAO national correspondent, the proportions by species and by sub-national area for each year as reported in the additional source data were applied to the figures included in the FAO database. In this way, the statistics by species items included in the FAO database could have been redistributed on a sub-national level basis and used for building the LME data sets.

The data obtained from different sources and harmonized to the FAO data were used to build 1990-1999 time series for 43 Large Marine Ecosystems. As stated above, for seven LMEs (i.e. 41, 42, 43, 44, 45, 46, and 47) of the Northwest Pacific area, this was not possible either by using the data from the FAO database or by obtaining additional detailed data either at the regional or national level, and therefore they have not been considered in the analysis.

Data by species items were subsequently aggregated into 12 groupings based on the ISSCAAP divisions and groups, as shown in Table 2.

Table 2. Groupings of species considered in the cluster analysis

ISSCAAP divisions	ISSCAAP groups	ISSCAAP Names
1 – 2		Freshwater and diadromous fishes
	31	Flounders, halibuts, soles
	32	Cods, hakes, haddocks
	33	Miscellaneous coastal fishes
	34	Miscellaneous demersal fishes
	35	Herrings, sardines, anchovies
	36	Tunas, bonitos, billfishes
	37	Miscellaneous pelagic fishes
	38	Sharks, rays, chimaeras
	39	Marine fishes not identified*
4		Crustaceans (excluding freshwater)
5		Molluscs (excluding freshwater)

*Not included in calculations for the cluster analysis

2.2 Cluster analysis

Catches by species groupings were summed up along the ten years period and their percentages in each LME calculated. A cluster analysis, aiming at identifying clusters of LMEs that present similarities in terms of catch composition by species groupings, was performed using the analytical method "partitioning around medoids" or *pam*, as in the statistical software S-Plus, 2000. The cluster analysis was based on eleven of the groups shown in Table 2 as the ISSCAAP group 39 ('Marine fishes not identified') was excluded from the calculations of the percentages used in the cluster analysis. Catches reported in this group may indeed include very different species in different LMEs. However, as the percentage of catches reported as 'Marine fishes not identified' is a good inverse indicator of the degree of breakdown by species in which catch statistics are reported from different countries/areas, the percentage of 'Marine fishes not identified' on total shelf catches for each LME is shown in each trend charts of Appendix 2.

The *pam* technique consists of several steps performed by the software, which accepts a matrix of data in which rows (n) are objects (individual LMEs) and columns (p) are variables (ISSCAAP based groupings of species). The algorithm *pam* computes k representative objects, called medoids, which together determine a clustering. Each object is then assigned to the cluster corresponding to the nearest medoid or, in other words, the function minimizes the sum of the dissimilarities of all objects to their nearest medoid. On the basis of these calculations, a silhouette value $s(i)$ is calculated for each object (LME) as an indication of how well that object has been assigned to a cluster. The value $s(i)$ lies between –1 and +1; objects with a silhouette value close to +1 are well classified, for values around 0 an object lies between two clusters, for values close to –1 objects are not well classified (S-Plus, 2000; for further information on the *pam* method, see Kaufman and Rousseeuw, 1990).

The outputs of this analysis are a cluster membership list of the LMEs and two types of graphs: a clusplot (Pison *et al*., 1999) and a silhouette plot (Rousseeuw, 1987). The clusplot is based on the reduction of the multivariate dimensions of the data by principal component analysis (PCA), which yields a first component which accounts for maximal variance, then a second component with maximal variance among all components perpendicular to the first and so on. The clusplot displays objects relative to the first and second principal components and all observations are represented by points in a plot in which the component 1 is plotted on the horizontal axis and component 2 on the vertical one. Around each cluster an ellipse is drawn. The distance between two clusters can be represented as a line connecting the cluster centers (Pison *et al*., 1999). The silhouette plot consists of a bar graph, in which each object is represented by a bar of length *s(i)*, ranked in decreasing order and showing the objects as visually grouped in clusters. The average silhouette width of the plot (average of the *s(i)* over all objects in the data set) gives an indication of how well objects have been classified for that given number of clusters. As a rule of thumb, the average silhouette width should be around or higher than 0.25 in order to be able to affirm that a structure in the data has been found.

3. CLUSTERS OF LARGE MARINE ECOSYSTEMS

The clustering procedure was run for different numbers of clusters (from 9 to 13) to identify the number of clusters for which the highest average silhouette would be obtained. For 11 clusters, an average silhouette width of 0.23 was reached, slightly below the 0.25 reference value. For 12 and 13 clusters, the same average silhouette width was obtained, but with increasing number of clusters including single LMEs. Therefore, in the clustering by 12 and 13 groups almost half of the clusters would have been constituted by a single LME. Hence, the *pam* analysis grouping the 43 LMEs into 11 clusters was considered as the most statistically and ecologically relevant. Memberships of each cluster are listed in Table 3. The clusplot (Figure 1), as generated by the software, represents the LMEs as points included in an ellipse as an indication of cluster membership. The connecting lines representing the distance between clusters have been removed as the clusplot would have been illegible and because the distance between clusters is not relevant for this study.

Table 3. LMEs' cluster membership as results of the *pam* analysis for 11 clusters

Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**	**Cluster 7**	**Cluster 8**	**Cluster 9**	**Cluster 10**	**Cluster 11**
01	02	03	04	06	11	12	14	17	20	49
		07	05	10	16	15		18	24	
		08	13	30	21	25		19	29	
		09	22	38	31	37		23		
			26	39	32			40		
			27		33			48		
			28		34					
			50		35					
					36					

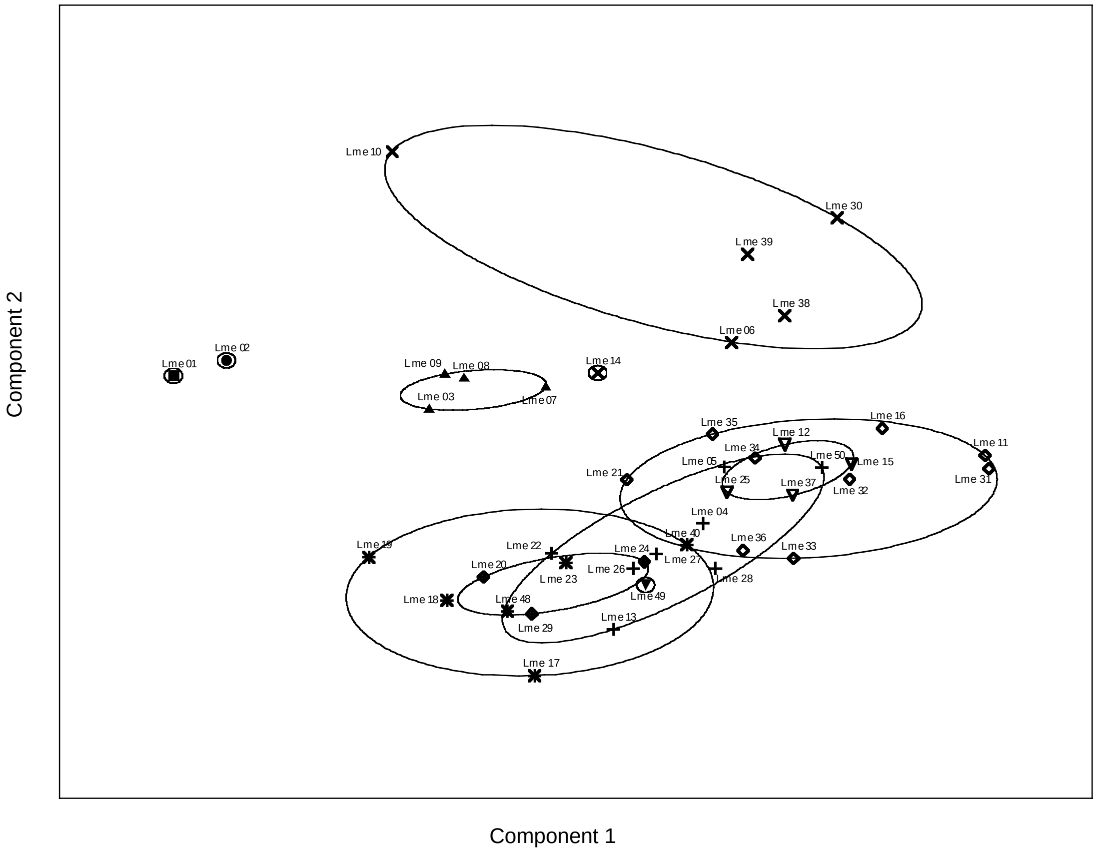

Figure 1. Clusplot for the 11 clusters with individual LMEs identified

Figure 2 shows the silhouette plot of each LME within its cluster. As said above, the silhouette width value is an indicator of how well that object has been assigned to that cluster.

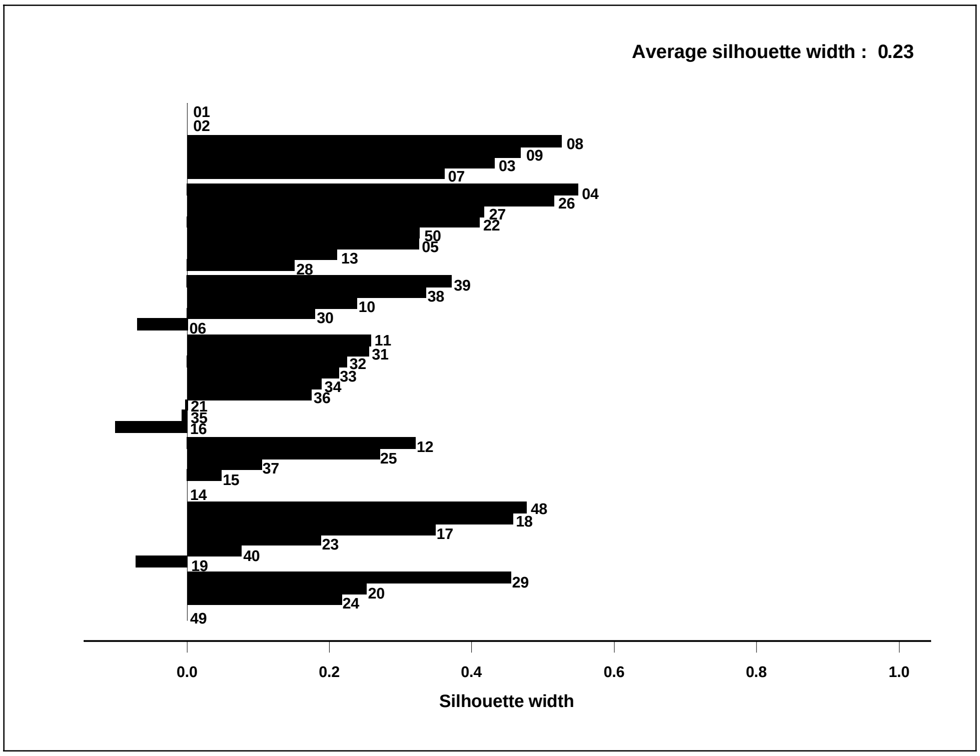

Figure 2. Silhouette plot by LME for 11 clusters

3.1 Discussion by cluster

In this section, each cluster is briefly described evidencing the common characteristics among the LMEs that have led to their classification into the same cluster. Large Marine Ecosystems assigned to the cluster are listed together with the relevant ocean, hemisphere and a general categorization of the climate. A bar chart for each cluster shows the catch percentages of species grouping of LMEs belonging to the same cluster. Charts representing the 1990-99 catch trends by species groupings of each LME are shown in Appendix 2. Information on primary productivity is derived from that produced by the SeaWiFS project (2002), on a model developed by Behrenfeld and Falkowski (1997), as it is presented in the Large Marine Ecosystems web site (NOAA, 2002).

3.1.1 Cluster 1

LME no.	LME name	Ocean	Hemisphere	Climate
LME 1	Eastern Bering Sea	Pacific	Northern	Subarctic

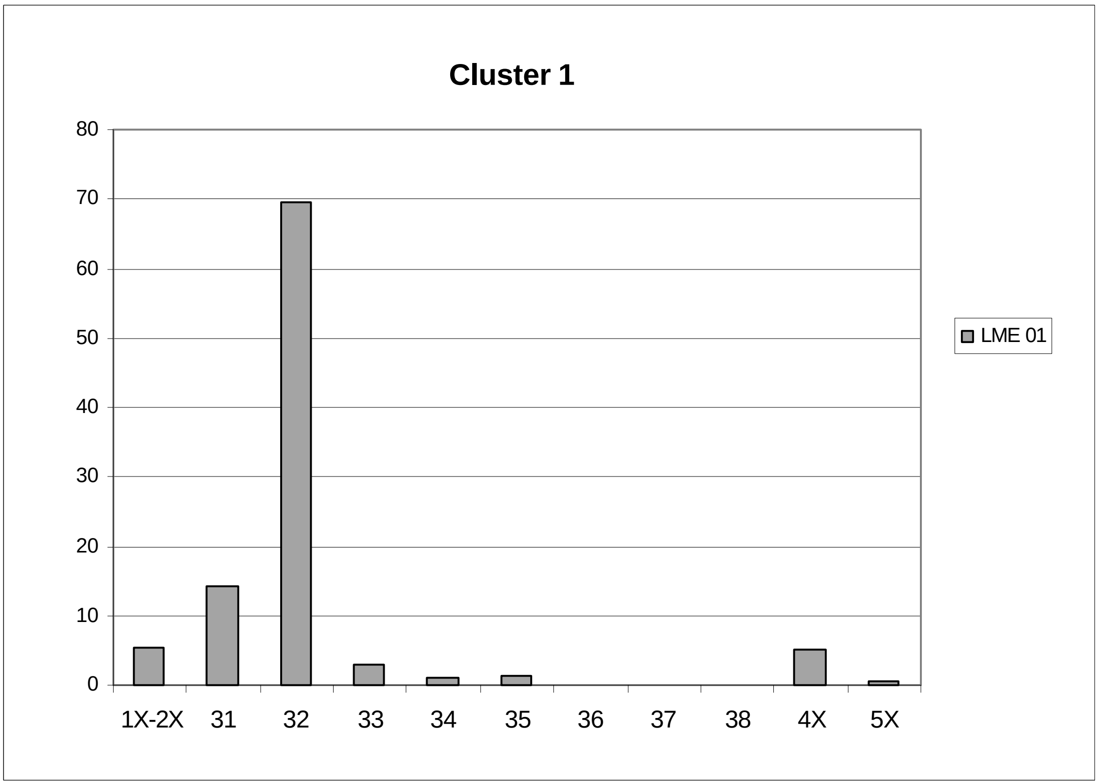

Figure 3. Cluster 1: catch percentages of species groupings

The first cluster comprised only one LME (Eastern Bering Sea). In Figure 3 is shown the catch percentage of each species grouping (listed in Table 2) for the 1990-99 period. Catches of Gadiformes (ISSCAAP group 32) are predominant in this LME; other groups of some importance are flatfishes, salmons (in group 1X-2X) and crustaceans.

This is an LME characterized by an extreme environment at high latitude, in which temperature, currents and seasonal oscillations influence the productivity. According to

SeaWiFS global primary productivity estimates, this LME has been classified as a moderately high productivity ecosystem.

The ten year trend (see Figure 14 in Appendix 2) shows decreasing catches of all major species groups in recent years with the only exceptions being diadromous fishes and crustaceans.

3.1.2 Cluster 2

LME no.	LME name	Ocean	Hemisphere	Climate
LME 2	Gulf of Alaska	Pacific	Northern	Subarctic

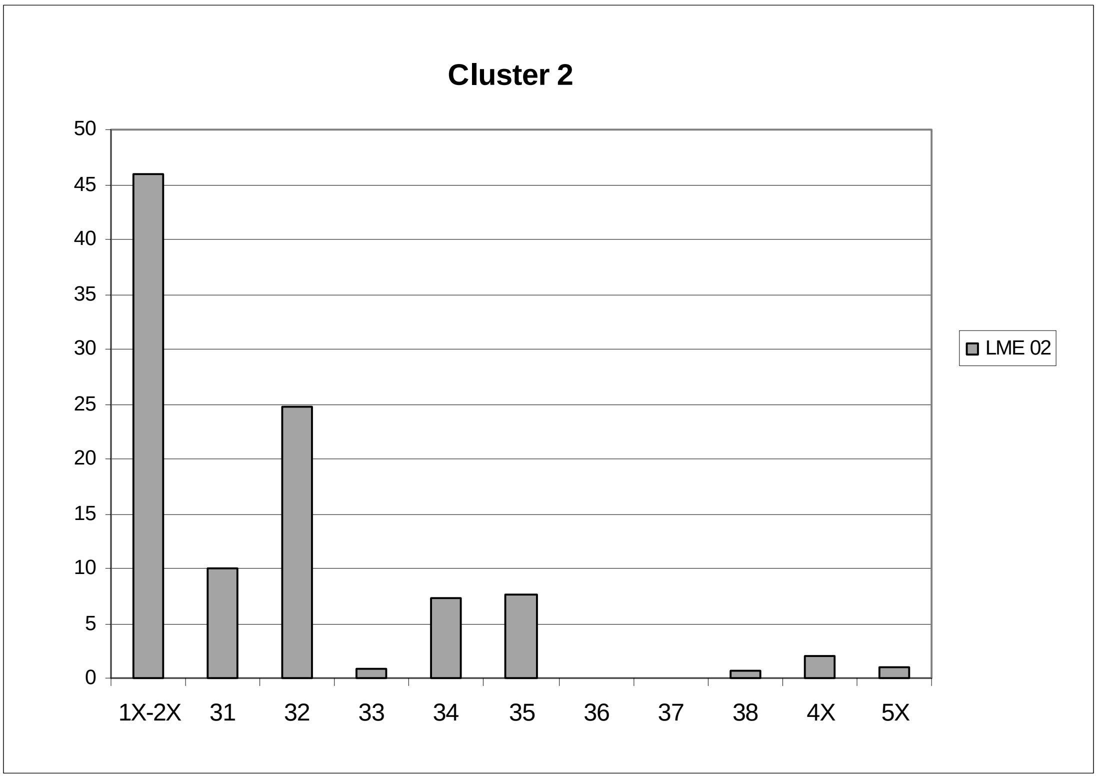

Figure 4. Cluster 2: catch percentages of species groupings

The second cluster, adjacent to the LME in cluster 1, is also 'monotypic'. The Gulf of Alaska is a highly productive ecosystem (SeaWiFS data). It also presents a significant upwelling phenomenon linked to the presence of the counterclockwise gyre of the Alaska Current (NOAA, 2002).

The catch composition of this LME differs from all other LMEs in being characterized by a strong prevalence of the freshwater and diadromous group (Figure 4), this linked to the rich salmon fisheries. Recent researches (Brodeur *et al.*, 1999) have hypothesized changes in the future production of salmons as a consequence of long term shifts in the plankton biomass in the last decades. However, recent catch trends are rather stable (see Figure 15).

3.1.3 Cluster 3

LME no.	LME name	Ocean	Hemisphere	Climate
LME 3	California Current	Pacific	Northern	Temperate
LME 7	Northeast U.S. Continental Shelf	Atlantic	Northern	Temperate
LME 8	Scotian Shelf	Atlantic	Northern	Temperate
LME 9	Newfoundland Shelf	Atlantic	Northern	Subarctic

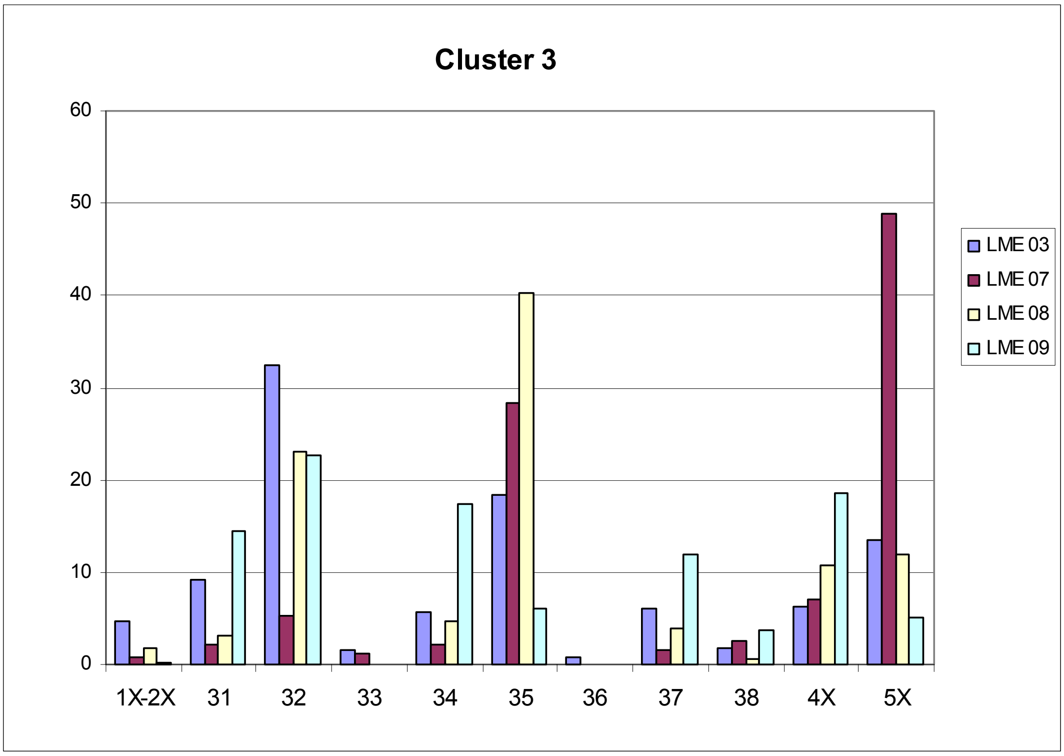

Figure 5. Cluster 3: catch percentages of species groupings

This cluster groups four of the historically most productive LMEs of the northern hemisphere, three in the Northwest Atlantic and one in the Northeast Pacific. They are all classified as moderately high productivity ecosystems, with the exception of the Northeast U.S. Continental Shelf, which is considered as highly productive and is structurally more complex than the other three, with marked temperature and climate changes, river runoff, estuarine exchanges, tides and complex circulation regimes. For what concerns the California Current ecosystem, this is a transition ecosystem between subtropical and subarctic water masses with an upwelling coastal phenomenon (Bakun, 1993) that determines strong interannual oscillations of the productivity of the ecosystem and, consequently, of the catch levels of different species groups.

The catch composition of this cluster is quite diverse as four species groupings contribute, on average among the four LMEs, at least 10% of the total shelf catches (Figure 5). These groups are: clupeoids (35), Gadiformes (group 32), molluscs (5X) and crustaceans (4X). The trend charts (Figure 16) show the marked decreases of Gadiformes catches in the Atlantic LMEs in the early 1990s up to the cod collapse in 1993-94, while in the same years the Gadiformes catches (mainly of *Merluccius products*) in the California Current increased and have remained high since then. The LME 7 is characterized by molluscs' catches (almost 50% of the total) while an increase of crustacean catches in the LMEs 8 and 9 can be noted in recent years although it is not clear if this is due to ecological or to economical reasons (Caddy and Garibaldi, 2000).

3.1.4 Cluster 4

LME no.	LME name	Ocean	Hemisphere	Climate
LME 4	Gulf of California	Pacific	Northern	Temperate
LME 5	Gulf of Mexico	Atlantic	Northern	Tropical
LME 13	Humboldt Current	Pacific	Southern	Mixed
LME 22	Baltic Sea	Atlantic	Northern	Temperate
LME 26	Black Sea	-	Northern	Temperate
LME 27	Canary Current	Atlantic	Northern	Temperate
LME 28	Guinea Current	Atlantic	-	Tropical
LME 50	Pacific Central American Coastal	Pacific	Northern	Tropical

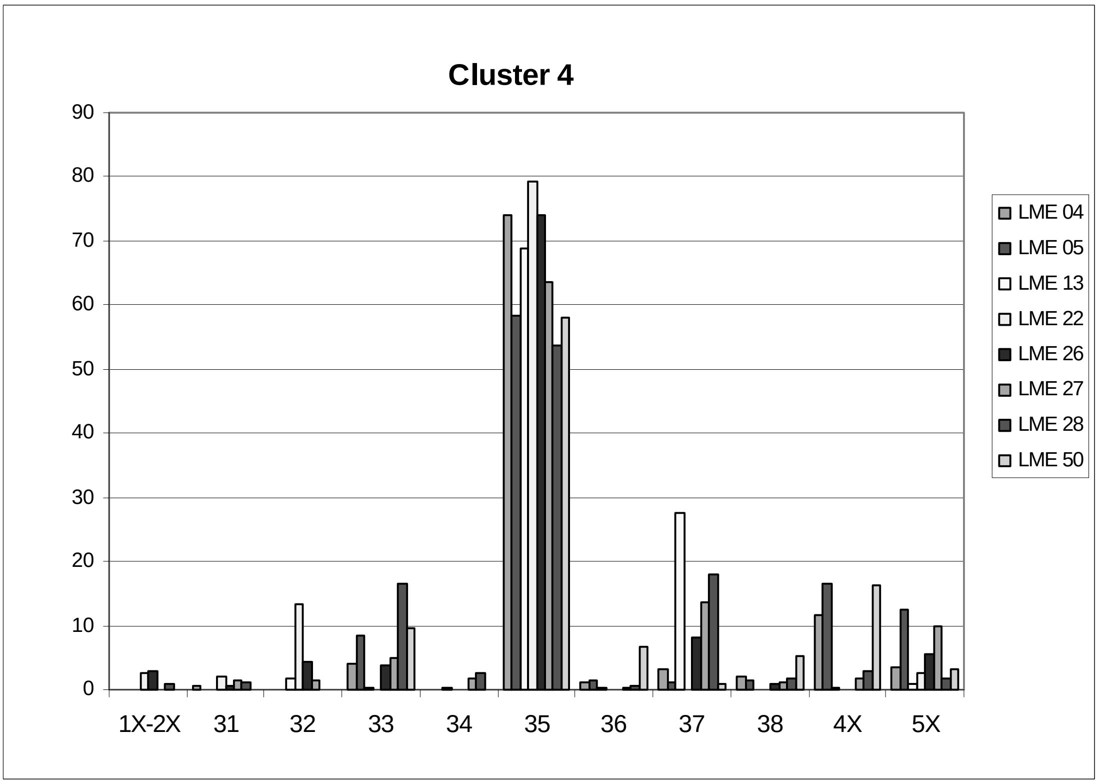

Figure 6. Cluster 4: catch percentages of species groupings

After cluster 6, this is the second cluster for number of LMEs in the present analysis. It is composed by eight LMEs, which, although in different manners, are all enriched by high level of nutrients. This cluster can be subdivided into two main sub-groups: enclosed and semi-enclosed seas (Gulf of California, Baltic Sea and Black Sea), which are strongly influenced by human induced eutrophication, river runoff and/or by a lack of rapid exchange with the adjacent oceans (NOAA, 2002; Kullenberg, 1986; Caddy, 1993) and upwelling ecosystems (two in the Pacific ocean: Humboldt Current and Pacific Central American Coastal, and two in the Atlantic ocean: Canary Current and Guinea Current) that show important upwelling and other seasonal nutrient enrichments (Bernal *et al*., 1983; Bakun *et al*., 1999; Bas, 1993; Binet, 1983). The Gulf of Mexico, although it is partially isolated from the Atlantic Ocean and water enters into it from the Yucatan Channel and exits from the Straits of Florida creating the Loop Current which is associated to nutrients flow and upwelling phenomena (Lohrenz *et al*., 1999), can not be considered as a semi-enclosed sea. Furthermore, this large scale and complex LME is affected by such levels of enriching river runoff (especially from the Mississippi) that large hypoxic areas have been detected in the Gulf in recent years (see Rabalais *et al.*, 1996).

All of these ecosystems are characterized by predominant catches of small-pelagic clupeoids (group 35) that represent over half of the total identified shelf catches in all LMEs (Figure 6). Catch trends (Figure 17), although referring to a limited number of years, show that ups and downs do not occur only in LMEs driven by upwelling regimes but that also enclosed and semi-enclosed LMEs have a high variability in catches.

3.1.5 Cluster 5

LME no.	LME name	Ocean	Hemisphere	Climate
LME 6	Southeast U.S. Continental Shelf	Atlantic	Northern	Temperate
LME 10	West Greenland Shelf	Atlantic	Northern	Subarctic
LME 30	Agulhas Current	Indian	Southern	Mixed
LME 38	Northern Australian Shelf	Pacific	Southern	Tropical
LME 39	Great Barrier Reef	Pacific	Southern	Tropical

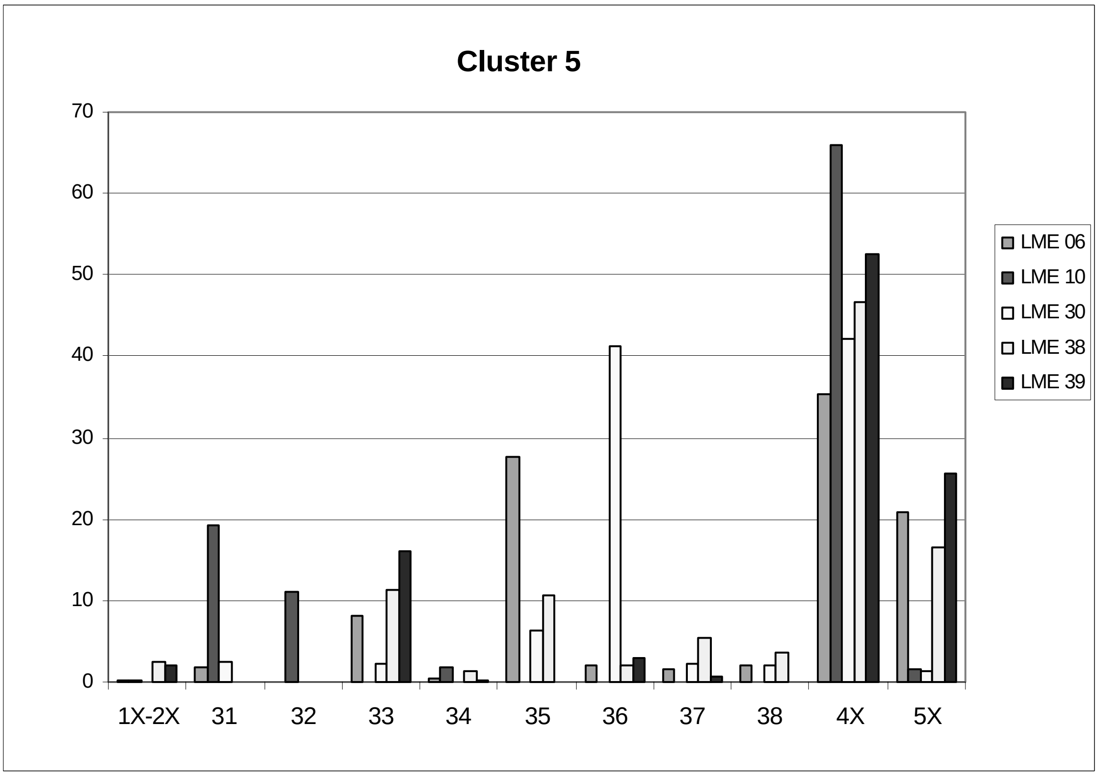

Figure 7. Cluster 5: catch percentages of species groupings

The ecosystems in this cluster are distinguished by a very high percentage of crustacean catches (grouping 4x; Figure 7). The second species group in terms of catches is clupeoids in the Southeast U.S. Continental Shelf, flatfishes in the West Greenland Shelf, non-oceanic tunas in the Agulhas Current, and molluscs in the Northern Australian Shelf and Great Barrier Reef. Catch trends in recent years are very diverse and it is difficult to find common elements (see Figure 18).

These ecosystems are characterized by a rather wide range of productivity levels, from low (West Greenland Shelf) and moderate (Southeast U.S. Continental Shelf and Agulhas Current) to moderately-high and high productivity (Great Barrier Reef and Northern Australian Shelf respectively) according to the SeaWiFS estimates. Geographically, with the exception of the West Greenland Shelf and, partially, of the Northern Australian Shelf, these LMEs all lay along the eastern margins of the continents. Nutrient enrichment and mixing are due to different factors: offshore upwelling regime, although not as intense as in the higher latitude regions, in the Southeast U.S. Continental Shelf (Yoder, 1991; NOAA, 2002); tidal effects in the Great Barrier Reef (Brodie, 1999; NOAA, 2002); changes in sea and air temperature in the West Greenland Shelf (Hovgard and Buch, 1990); current-associated in the Agulhas Current (Beckley, 1998); and tidal mixing, monsoons and tropical cyclones in the Northern Australian Shelf (Furnas, 2002).

3.1.6 Cluster 6

LME no.	LME name	Ocean	Hemisphere	Climate
LME 11	Insular Pacific-Hawaiian	Pacific	Northern	Tropical
LME 16	Northeast Brazil Shelf	Atlantic	-	Tropical
LME 21	North Sea	Atlantic	Northern	Temperate
LME 31	Somali Coastal Current	Indian	-	Tropical
LME 32	Arabian Sea	Indian	Northern	Tropical
LME 33	Red Sea	Indian	Northern	Tropical
LME 34	Bay of Bengal	Indian	Northern	Tropical
LME 35	South China Sea	Pacific	Northern -	Tropical
LME 36	Sulu-Celebes Sea	Pacific	Northern -	Tropical

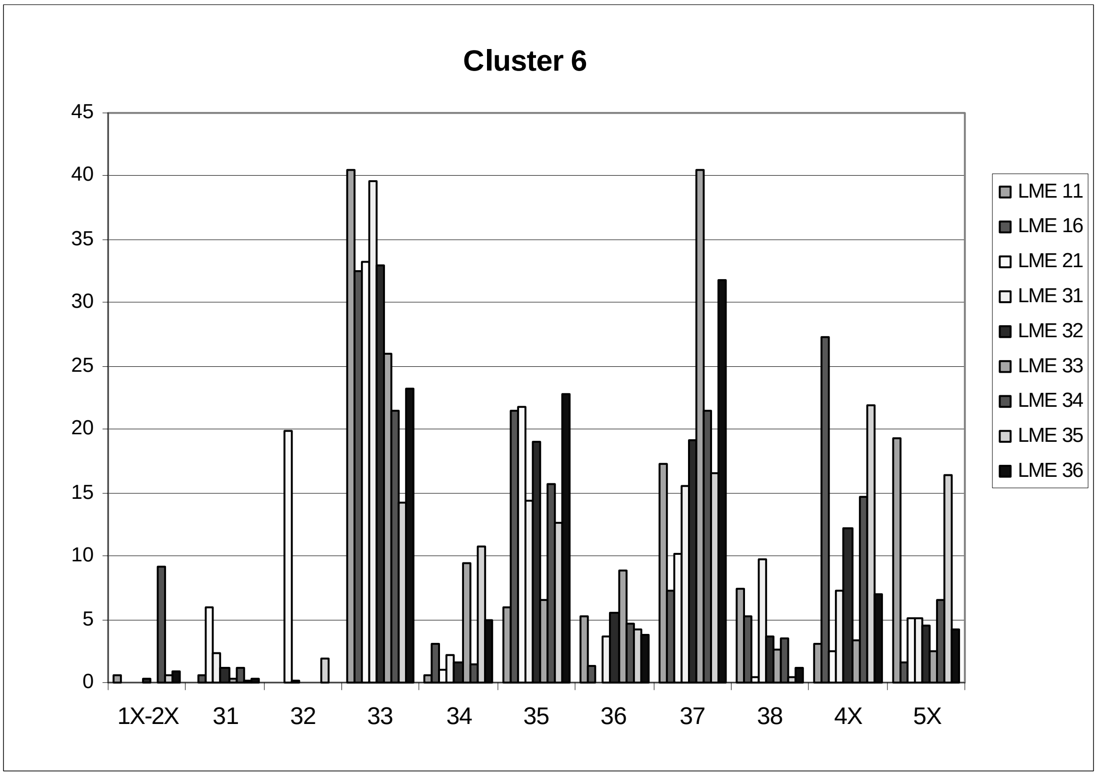

Figure 8. Cluster 6: catch percentages of species groupings

This is the cluster with the highest number of LMEs. These nine ecosystems are probably less characterized than others and for this reason they have been grouped together by the clustering routine. Geographically, this cluster groups all tropical ecosystems, with the sole exception of the North Sea, and it includes four out five of the Indian Ocean LMEs. The general greater marine biodiversity of tropical regions is so reflected in catch composition. The main distinguish feature is the high catch percentages for miscellaneous coastal fishes (group 33) and miscellaneous pelagic fishes (group 37). Secondly, catches of herrings, sardines and anchovies (group 35) and of crustaceans (4x) in the nine ecosystems exceed 10% on average. (Figure 8). Most of these ecosystems are characterized by fishing activities mainly concentrated, for different reasons, on the coastal areas and this explain the high percentages of miscellaneous coastal fish catches. Catch trends in the 1990-99 period (Figure 19) are quite diverse and it is difficult to identify a common pattern. However, for most of these ecosystems, with the only exception of the North Sea and the Sulu-Celebes Sea, statistics are reported with a poor species breakdown, as can be deducted by the high percentages of catches included in the "Marine fishes not identified" category (see texts in charts of Figure 19).

Primary production ranges from low (Insular Pacific-Hawaiian and Sulu-Celebes Sea) to high (North Sea, Northeast Brazilian Shelf and Arabian Sea) with the remaining LMEs classified as moderately or moderately-high (South China Sea) productive.

It should be noted that, according to the LMEs web site (NOAA, 2002), the Insular Pacific-Hawaiian LME does not include only the Hawaii, as usually shown in the maps representing the LMEs (e.g. map in Appendix 3), but it extends also to shelf areas of several other Pacific islands. Catch statistics have been considered accordingly. This region is dominated by the equatorial currents system (NOAA, 2002). Fishery production in the Insular Pacific-Hawaiian and Sulu-Celebes Sea LMEs is mostly concentrated in the coastal waters as the islands are usually surrounded by very narrow shelf areas.

The Northeast Brazil Shelf is characterized by high levels of nutrients in the inner part of the shelf (Medeiros *et al.*, 1999). The North Sea includes one of the most diverse coastal regions of the world, with a great variety of habitats (NOAA, 2002). Three of the Indian Ocean ecosystems (Somali Coastal Current, Arabian Sea and Bay of Bengal) are influenced by monsoons. In the Somali Coastal Current and in the Arabian Sea, the Southwest Monsoon from May to October cause seasonal upwelling phenomena that are on the other hand lacking in the Bay of Bengal (information derived, respectively, from Bakun *et al*., 1998; NOAA, 2002; Dwivedi, 1993). In the Arabian Sea, about 65% of fish landings derive from artisanal fisheries and this would explain the prevalence of coastal species catches but it may also be influenced by the presence of low-oxygen water, which restricts productivity at depths of 200 m and more (Dwivedi and Choubey, 1998; NOAA, 2002). The elongated and narrow shape, semi-enclosed character and circulation patterns of the Red Sea protect the coast from storms and provide habitats for a large number of marine coastal species (Baars, *et al*., 1998). Different sub-systems within the ecosystem have been identified in the South China Sea (Pauly and Christensen, 1993).

3.1.7 Cluster 7

LME no.	LME name	Ocean	Hemisphere	Climate
LME 12	Caribbean Sea	Atlantic	Northern	Tropical
LME 15	Brazil Current	Atlantic	Southern	Mixed
LME 25	Mediterranean Sea	-	Northern	Temperate
LME 37	Indonesian Seas	Pacific	-	Tropical

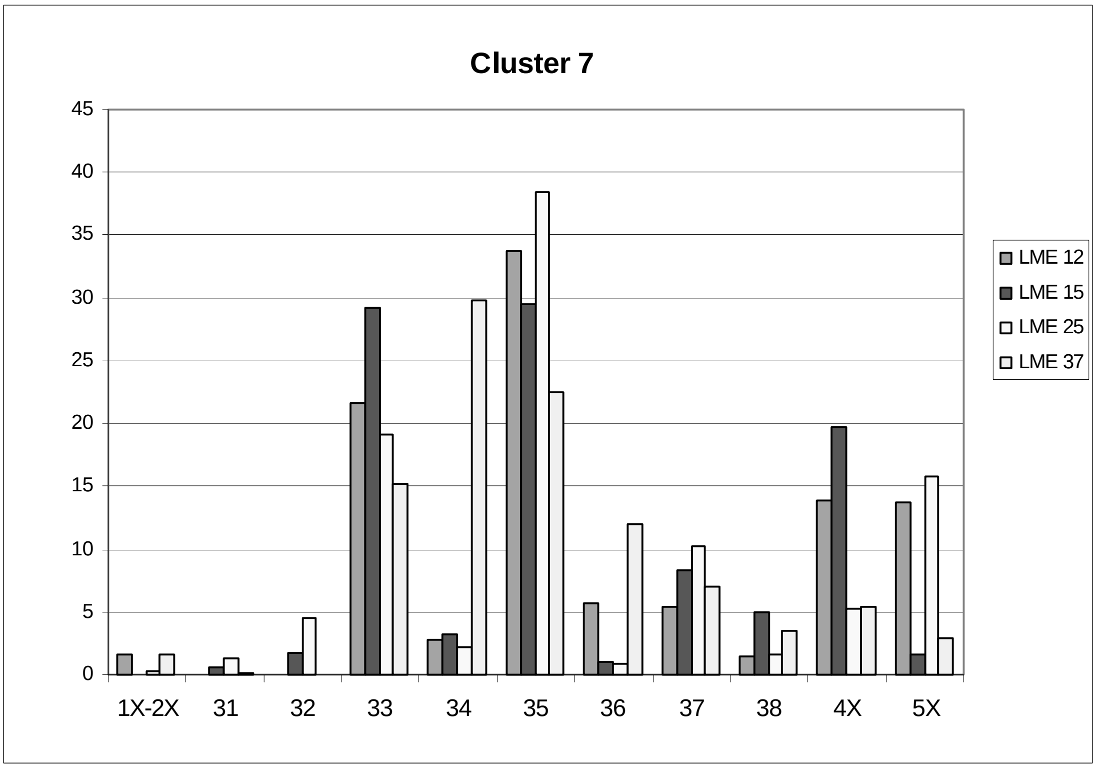

Figure 9. Cluster 7: catch percentages of species groupings

Also in this cluster, group 35 (clupeoids: herrings, sardines and anchovies) is the most important species group in shelf catches but, unlike for cluster 4, other groups (i.e. mostly coastal fishes but also crustaceans, molluscs and miscellaneous demersal fishes for the Indonesian Seas) also contribute significant capture production (Figure 9). Catch trends have been rather stable in recent years (Figure 20) with moderate increases in total shelf catches if comparing the last year (1999) respect to the first year (1990) of the considered period, with the exception of the Indonesian Seas where catches have been quite steadily increasing.

As for its catch composition, the Mediterranean Sea seems one of the most diverse and stable LME in terms of species groupings, their shares in total catches and trends. Its unusual biodiversity for a temperate sea is confirmed by the fact that the Mediterranean and Black Sea together cover only the 0.8% of the total surface of the oceans but represent about 5.5% of the total world marine fauna (Fredj *et al*., 1992).

According to the productivity classification by SeaWiFS, the four LMEs in this cluster are moderately-high (Indonesian Seas), moderately (Brazil Current) or low naturally productive ecosystems (Caribbean Sea and Mediterranean Sea) but the productivity of the last two LMEs is increased by nutrient input from rivers, estuaries and human induced activities. These LMEs have in common a composite structure of environmental conditions, with local areas of upwelling, wind-driven currents, high water temperatures at least in some periods of the year, nutrient inputs from rivers or human activities (see studies on the single LMEs: Richards and Bohnsack, 1990, for the Caribbean Sea; Bakun, 1993, for the Brazilian Current; Caddy, 1993, for the Mediterranean Sea; Zijlstra and Baars, 1990, for the Indonesia Seas).

3.1.8 Cluster 8

LME no.	LME name	Ocean	Hemisphere	Climate
LME 14	Patagonian Shelf	Atlantic	Southern	Mixed

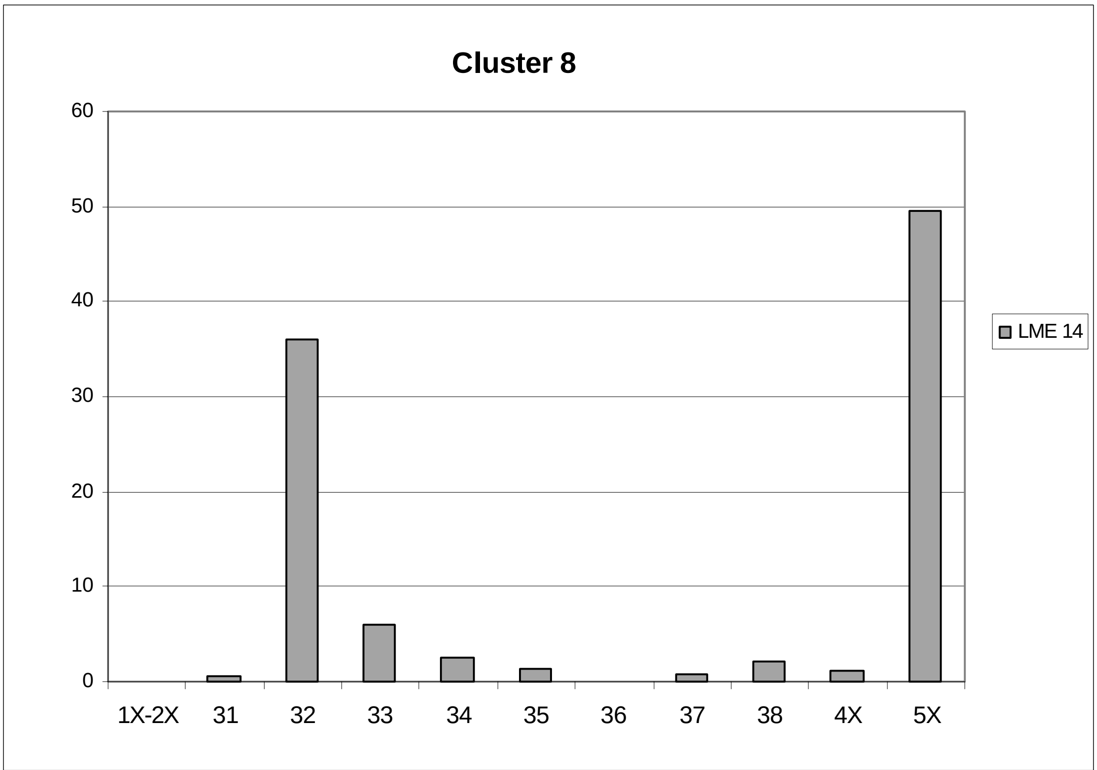

Figure 10. Cluster 8: catch percentages of species groupings

This single LME cluster includes the Patagonian Shelf, which is characterized by high catches of molluscs, mostly cephalopods, and Gadiformes (Figure 10). Cephalopod fisheries developed in the early 1980s by Distant Water Fleets but, since the early 1990s, also local fleets (i.e. Argentina and Uruguay) are actively targeting these species. Following a drop in 1998, cephalopod catches in this area are still increasing (Figure 21). Instead, catches of Gadiformes, mostly by local fleets, increased continuously since the 1970s but from mid-1990s are declining.

These fisheries take place in one of the most extensive continental shelf of the world. According to the SeaWiFS estimates of global primary productivity, the Patagonian shelf is an area of high productivity and it is influenced by intense western boundary currents and wind- and tide-driven upwelling (Bakun, 1993; NOAA, 2002).

3.1.9 Cluster 9

LME no.	LME name	Ocean	Hemisphere	Climate
LME 17	East Greenland Shelf	Atlantic	Northern	Subarctic
LME 18	Iceland Shelf	Atlantic	Northern	Subarctic
LME 19	Barents Sea	Atlantic	Northern	Subarctic
LME 23	Celtic-Biscay Shelf	Atlantic	Northern	Temperate
LME 40	New Zealand Shelf	Pacific	Southern	Temperate
LME 48	Faroe Plateau	Atlantic	Northern	Subarctic

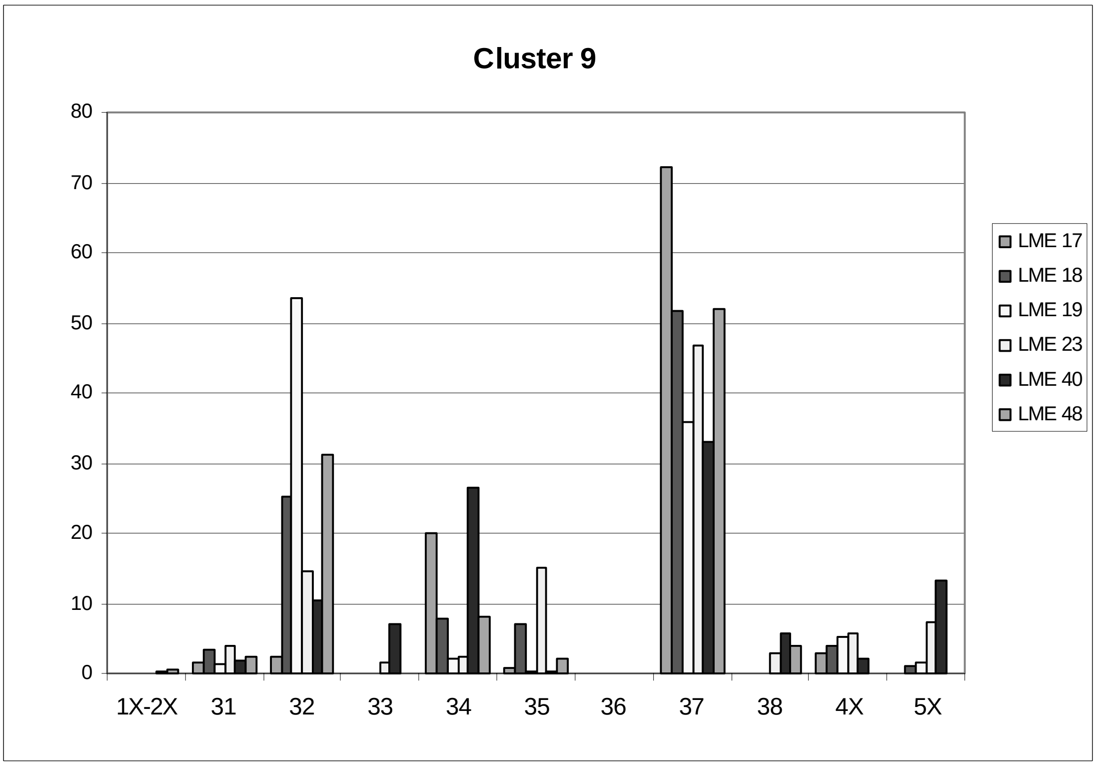

Figure 11. Cluster 9: catch percentages of species groupings

In this cluster, the six ecosystems have a temperate or subarctic climate and five of them belong to the same oceanic region, the Northeast Atlantic. With the exclusion of the New Zealand Shelf and the Celtic-Biscay Shelf, which are influenced also by warm currents, respectively the South Equatorial and the Gulf Currents, the other ecosystems are categorized as high latitude and extreme environments, in which temperature, currents, tides and seasonal oscillations affect productivity. The same division in two sub-groups applies also to data on primary productivity (SeaWiFS, (2002): the New Zealand Shelf and the Celtic-Biscay Shelf are considered highly productive ecosystems, the Iceland Shelf, the Barents Sea and the Faroe Plateau are moderately highly productive ecosystems, and the East Greenland Shelf is a low productivity ecosystem.

The marine environment of the New Zealand Shelf is very diverse and includes estuaries, mudflats, mangroves, seagrass and kelp beds, reefs, seamount communities and deep-sea trenches (NOAA, 2002). The Celtic-Biscay Shelf is characterized by strong interdependence of human impact and biological and climate cycles (Koutsikopoulos and Le Cann, 1996). The East Greenland and Iceland LMEs are both characterized by a seasonal ice cover and by marked fluctuations in salinity, temperature and phytoplankton, factors that can contribute to variations of annual catches of cod and small pelagics (Skjoldal *et al.*, 1993). In the Barents Sea, the ice-coverage extends over one third to two thirds of the LME and it varies considerably during the year and inter-annually (NOAA, 2002). The shallow parts of the shelf in the Faroe Plateau are well mixed by extreme tidal currents and no stratification occurs during the summer (NOAA, 2002).

With regard to catch composition, these ecosystems have in common high percentages of miscellaneous pelagic fishes (group 37; Figure 11) which, for the North-East Atlantic areas, are mostly due to peak catches of capelin in 1992-93. In the LMEs 17, 19 and 48 these peaks have a 'boom and bust' profile and, in the latest years of the observed period, catches of capelin are markedly decreased (Figure 22). Another fish group that shows relevant catches in all ecosystems of this cluster is group 32 (cods, hakes, haddocks), with the sole exception of the East Greenland LME that has been affected by the cod collapse of the early 1990s. In the other three northernmost Atlantic LMEs, total catches of the whole gadiform group have been rather stable during the 10 years examined (see also, Jakupsstovu and Reinert, 1994; Jacobsen, 1997; Nakken, 1998). In the two temperate ecosystems (i.e. New Zealand and the Celtic-Biscay shelves), the second species group in terms of catches is, respectively, miscellaneous demersal fishes (group 34) and clupeoids (group 35).

3.1.10 Cluster 10

LME no.	LME name	Ocean	Hemisphere	Climate
LME 20	Norwegian Shelf	Atlantic	Northern	Subarctic
LME 24	Iberian Coastal	Atlantic	Northern	Temperate
LME 29	Benguela Current	Atlantic	Southern	Temperate

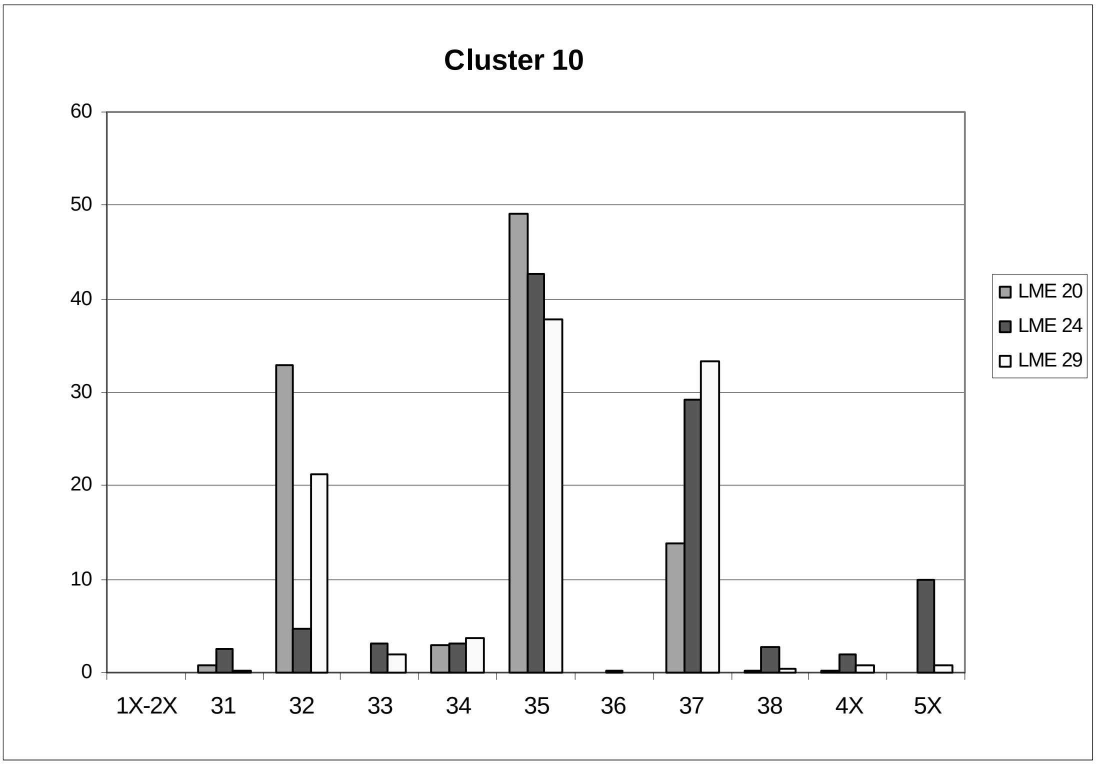

Figure 12. Cluster 10: catch percentages of species groupings

The three ecosystems in this cluster are all western boundary ecosystems. The Norwegian Shelf and the Benguela Current are characterized by a high productivity according to the SeaWiFS classification, whereas the Iberian Coastal LME is considered as moderately productive. The catch composition pattern is dominated by three groups: herrings, sardines and anchovies (group 35), miscellaneous pelagic fishes (group 37) and cods, hakes and haddocks (group 32; Figure 12). Catches of Gadiformes are however very significant, and important for their value, only in the Norwegian Shelf and Benguela Current areas.

The Norwegian Shelf LME has a complex fishery history with concomitant influences of ecological anomalies, high fishery mortality and early implementation of management measures (Blindheim and Skjoldal, 1993; NOAA, 2002). Its high productivity is probably to be linked to the nutrient rich, cold arctic waters that characterize this LME (Furnes and Sundby, 1980). Since the early 1990s there has been a significant increase in *Clupea harengus* catches (Figure 23) which stock recovered after two decades of very low abundance.

The Iberian Coastal LME's productivity is climate and upwelling driven. It is characterized by favorable factors for the production of clupeoids and other small pelagic fishes (Wyatt and Perez-Gandaras, 1989). Trends in catches by species groupings have been quite steady in recent years (Figure 23).

In the Benguela Current LME is one of the most strongly wind-driven coastal upwelling systems known and it presents favorable conditions for a rich production of small pelagics of groups 35 and 37 (Bakun, 1993). Harvests are characterized by stock fluctuations according to the variations in the primary and secondary level productivity.

3.1.11 Cluster 11

LME no.	LME name	Ocean	Hemisphere	Climate
LME 49	Antarctic	Antarctic	Southern	Antarctic

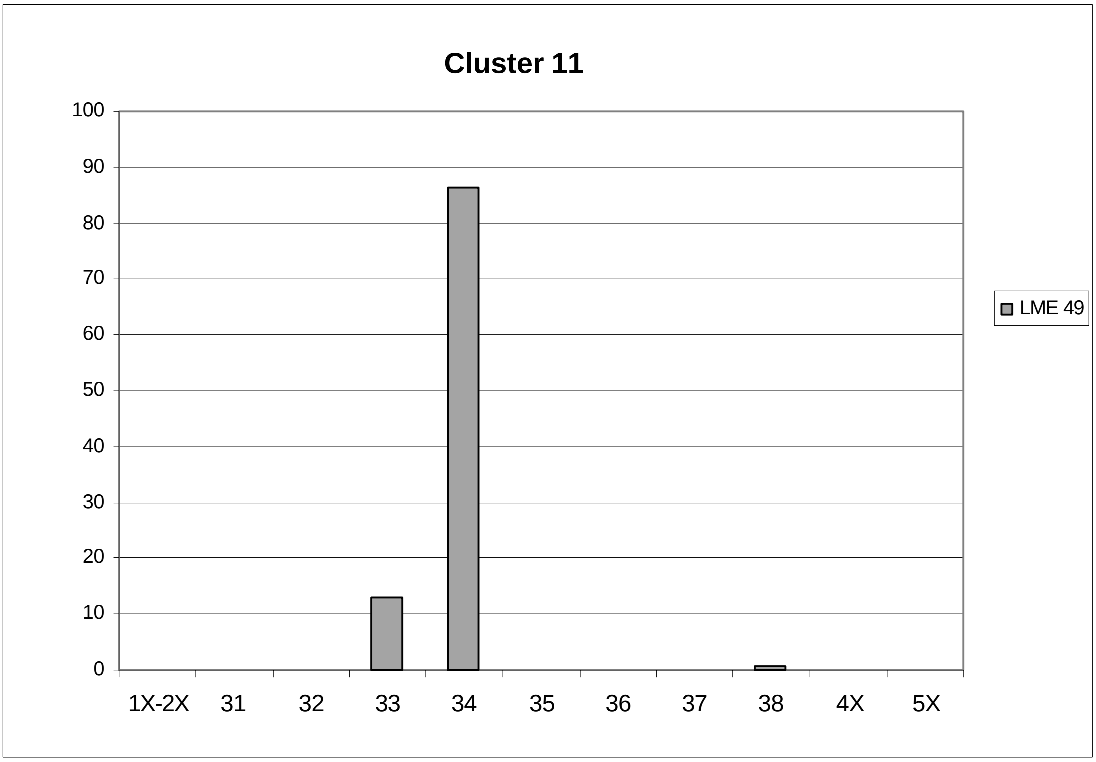

Figure 13. Cluster 11: catch percentages of species groupings

This single ecosystem cluster includes the Antarctic LME, which is unique both for its geographic and climatic characteristics. It is classified as a low productivity ecosystem, according to the SeaWiFS data, a consequence of the extensive seasonal ice cover and extreme weather conditions. The ecological and biological characteristics of Antarctic marine species are also unique from a food-chain point of view in that it is peculiarly short and based almost entirely on krill, a key species crucial to the sustainability and production of all other fisheries (Chopra and Hansen, 1997).

The Antarctic species most significant for fisheries have been considered as oceanic, either epipelagic or deep-water, and their catch trends are discussed in the "Oceanic" study of this volume. As for catches of shelf species, this LME exhibits a prevalence of miscellaneous demersal catches (group 34) and a much smaller percentage of coastal fishes (group 33; Figure 13), although fitting the Antarctic fishes into the categories of the three miscellaneous groups (i.e. coastal, demersal and pelagic) proved to be rather difficult (FAO, 2001b). Catches of shelf species have been remarkably reduced in the early 1990s (Figure 24).

4. CONCLUSION

The general analysis of cluster composition, common characteristics and catch trends (see Appendix 2) of LMEs in the same cluster presented some unexpected analogies between ecosystems of different marine regions and confirmed similarities between areas in which well known ecological phenomena take place (e.g. upwelling regimes).

As expected, ecosystems with extreme characteristics (i.e. northernmost Pacific and Antarctic LMEs) have peculiar catch patterns and, not presenting similarities with other LMEs, have been included in single clusters. Another cluster that includes only a single LME (Patagonian Shelf), is characterized by predominant catches of cephalopods and Gadiformes.

Three clusters (i.e. 4, 7 and 10) are dominated by catches of clupeoids, but some differences between the three groups of LMEs can be noted. The large marine ecosystems in cluster 4 are highly productive, enriched by nutrients as they are either semi-enclosed seas or have upwelling regimes, with clupeoids representing about 50-70% of the catches in their shelf areas (excluding catches reported as “Marine fishes not identified”). Also LMEs in cluster 10 are highly productive and, in addition to clupeoids, they are characterized by catches of Gadiformes and non-clupeoid small pelagics. In contrast, LMEs in cluster 7 have moderate or low productivity and theirs catch composition is more diverse with several other groups (i.e. coastal fishes, crustaceans, molluscs and miscellaneous demersal fishes) represented by significant catches.

An unexpected finding was a cluster of five ecosystems where the majority (between 30 and 65%) of identified catches on the continental shelf are made of crustacean species. This seems to be the only common feature amongst the LMEs of cluster 5, which are quite diverse in their productivity, climate, and second ranking species group in terms of catches. The remaining clusters are characterized by catches distributed quite evenly amongst the major groups of species (i.e. clusters 3 and 6) or with a slight predominance of miscellaneous pelagic fishes (cluster 9).

However, given the global coverage and the limitations in data availability, this study only aimed at providing basic information on catch composition by LME for future studies on single LMEs and some possible starting points for more in-depth ecologically oriented researches on fishery trends.

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APPENDIX 1. – Additional sources

Table 4 lists the sources from which additional capture statistics have been extracted to complement the FAO capture database in building on the LME data series. The seven LMEs (41 to 47) for which, given the unavailability of sub-national data, it was not possible to prepare data series by LME are excluded. The LMEs without any additional sources are those congruent with the FAO fishing areas and to which FAO statistics were assigned directly.

Table 4. Additional data sources used to complement the FAO database

LME no	LME name	Additional data sources
1	Eastern Bering Sea	www.st.nmfs.gov/st1/commercial/landings/annual_landings.html www.cf.adfg.state.ak.us/geninfo/finfish/herring/herrhome.htm www.cf.adfg.state.ak.us/geninfo/shellfsh/shelhome.htm www.cf.adfg.state.ak.us/geninfo/finfish/salmon/salmhome.htm www.fakr.noaa.gov/sustainablefisheries/catchstats.htm www.iphc.washington.edu/halcom/commerc/catchbyreg.htm
2	Gulf of Alaska	www.st.nmfs.gov/st1/commercial/landings/annual_landings.html www.cf.adfg.state.ak.us/geninfo/finfish/herring/herrhome.htm www.cf.adfg.state.ak.us/geninfo/shellfsh/shelhome.htm www.cf.adfg.state.ak.us/geninfo/finfish/salmon/salmhome.htm www.fakr.noaa.gov/sustainablefisheries/catchstats.htm www.iphc.washington.edu/halcom/commerc/catchbyreg.htm
3	California Current	*Anuario Estadístico de Pesca*. SEMARNAP, Tlalpan, México (various years). www.st.nmfs.gov/st1/commercial/landings/annual_landings.html
4	Gulf of California	*Anuario Estadístico de Pesca*. SEMARNAP, Tlalpan, México (various years).
5	Gulf of Mexico	*Anuario Estadístico de Pesca*. SEMARNAP, Tlalpan, México (various years). www.st.nmfs.gov/st1/commercial/landings/annual_landings.html
6	Southeast U.S. Continental Shelf	www.st.nmfs.gov/st1/commercial/landings/annual_landings.html
7	Northeast U.S. Continental Shelf	NAFO capture database
8	Scotian Shelf	NAFO capture database
9	Newfoundland Shelf	NAFO capture database
10	West Greenland Shelf	NAFO capture database
11	Insular Pacific-Hawaiian	www.st.nmfs.gov/st1/commercial/landings/annual_landings.html
12	Caribbean Sea	*Anuario Estadístico de Pesca*. SEMARNAP, Tlalpan, México (various years).
13	Humboldt Current	
14	Patagonia Shelf	
15	Brazil Current	*Estatística da Pesca – Brasil*. IBAMA, Tamandaré, Brasil (complete data available only since 1995).
16	Northeast Brazil Shelf	*Estatística da Pesca – Brasil*. IBAMA, Tamandaré, Brasil (complete data available only since 1995).
17	East Greenland Shelf	ICES catch database
18	Iceland Shelf	ICES catch database
19	Barents Sea	ICES catch database
20	Norwegian Shelf	ICES catch database
21	North Sea	ICES catch database
22	Baltic Sea	ICES catch database
23	Celtic-Biscay Shelf	ICES catch database
24	Iberian Coastal	ICES catch database

25	Mediterranean Sea	GFCM capture production database (managed by FAO-FIDI)
26	Black Sea	GFCM capture production database (managed by FAO-FIDI)
27	Canary Current	CECAF capture production database (managed by FAO-FIDI)
28	Guinea Current	CECAF capture production database (managed by FAO-FIDI)
29	Benguela Current	CECAF capture production database (managed by FAO-FIDI) Southeast Atlantic capture production database (managed by FAO-FIDI)
30	Agulhas Current	
31	Somali Coastal Current	
32	Arabian Sea	Data obtained from the FISHSTAT 51 A questionnaires (managed by FAO-FIDI)
33	Red Sea	Data obtained from the FISHSTAT 51 A questionnaires (managed by FAO-FIDI)
34	Bay of Bengal	*Buku Tahunan Statistik Perikanan* (Fishery Yearbook). DINAS PERIKANAN. Denpasar, Indonesia (various years).
35	South China Sea	*Annual Fishery Statistics*. Dept. of Fisheries Malaysia. Kuala Lumpur, Malaysia (various years). *Buku Tahunan Statistik Perikanan* (Fishery Yearbook). DINAS PERIKANAN. Denpasar, Indonesia (various years). *Fisheries Statistical Yearbook Taiwan Area*. Fisheries Admin. Council of Agriculture. Taiwan. (various years).
36	Sulu-Celebes Seas	*Annual Fishery Statistics*. Dept. of Fisheries Malaysia. Kuala Lumpur, Malaysia (various years). *Buku Tahunan Statistik Perikanan* (Fishery Yearbook). DINAS PERIKANAN. Denpasar, Indonesia (various years).
37	Indonesian Seas	*Buku Tahunan Statistik Perikanan* (Fishery Yearbook). DINAS PERIKANAN. Denpasar, Indonesia (various years).
38	Northern Australian Shelf	*Australian Fisheries Statistics*. ABARE. Canberra, Australia (various years). *Buku Tahunan Statistik Perikanan* (Fishery Yearbook). DINAS PERIKANAN. Denpasar, Indonesia (various years).
39	Great Barrier Reef	*Australian Fisheries Statistics*. ABARE. Canberra, Australia (various years).
40	New Zealand Shelf	
48	Faroe Plateau	ICES catch database
49	Antarctic	
50	Pacific Central American Coastal	*Anuario Estadístico de Pesca*. SEMARNAP, Tlalpan, México (various years).

APPENDIX 2. – Capture trends (1990-1999) of each LME by cluster

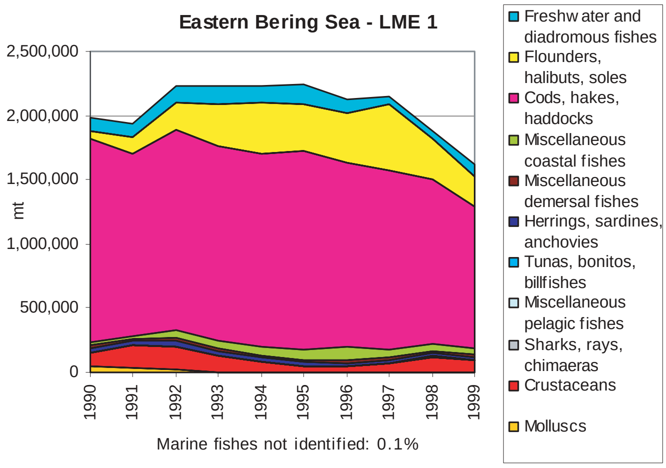


Figure 14. Cluster 1: capture trends of LME 1

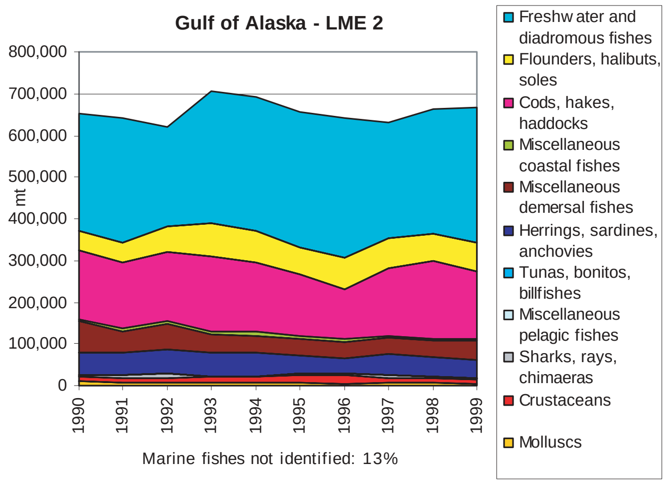


Figure 15. Cluster 2: capture trends of LME 2

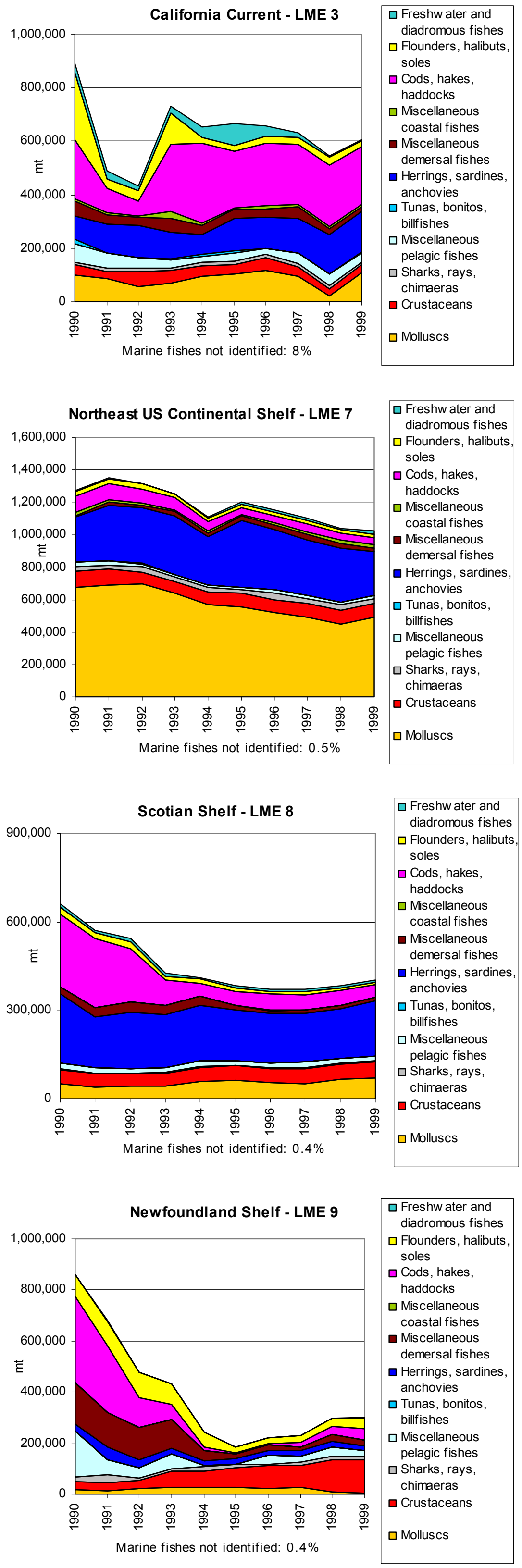


Figure 16. Cluster 3: capture trends of LMEs 3-7-8-9

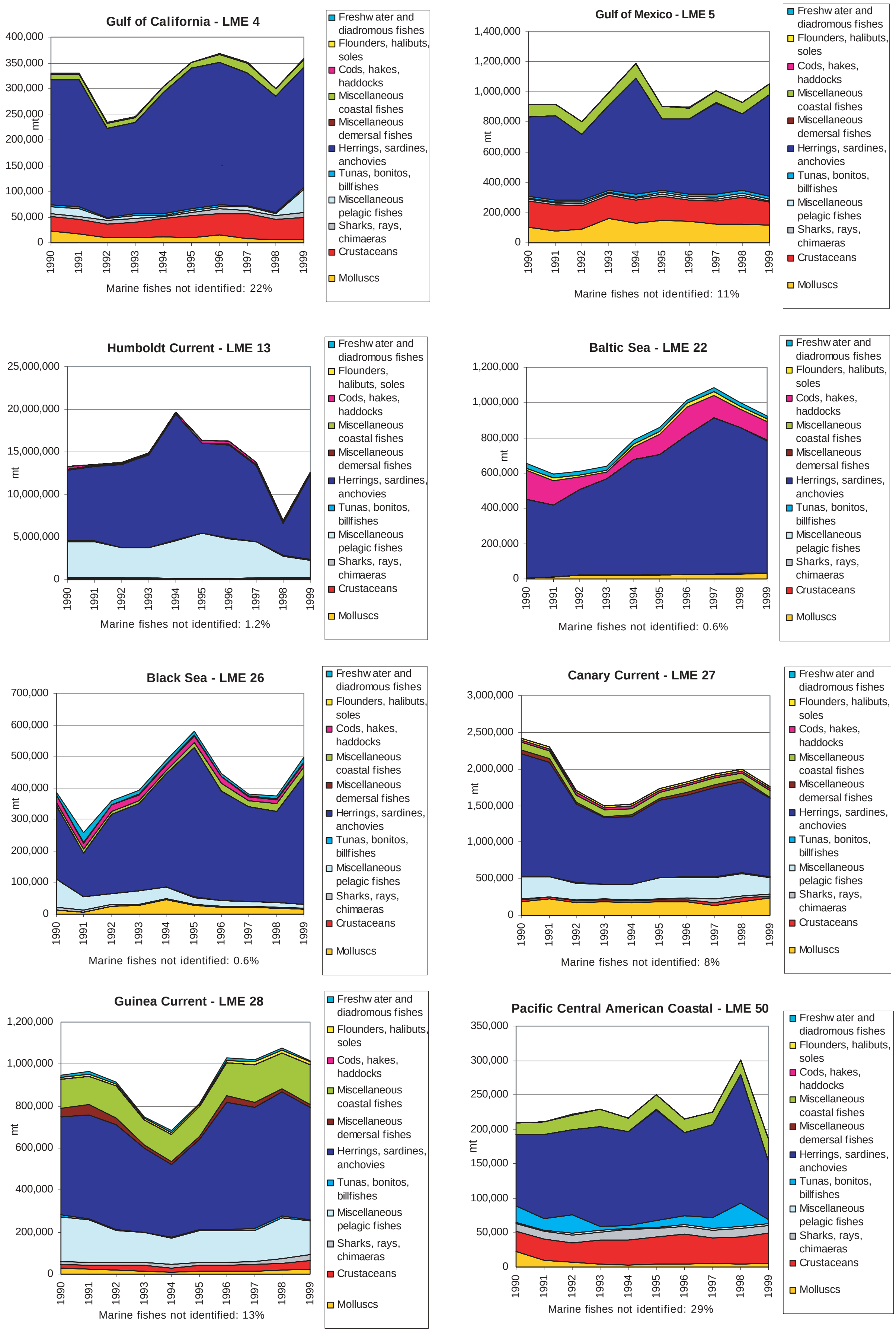


Figure 17. Cluster 4: capture trends of LMEs 4-5-13-22-26-27-28-50

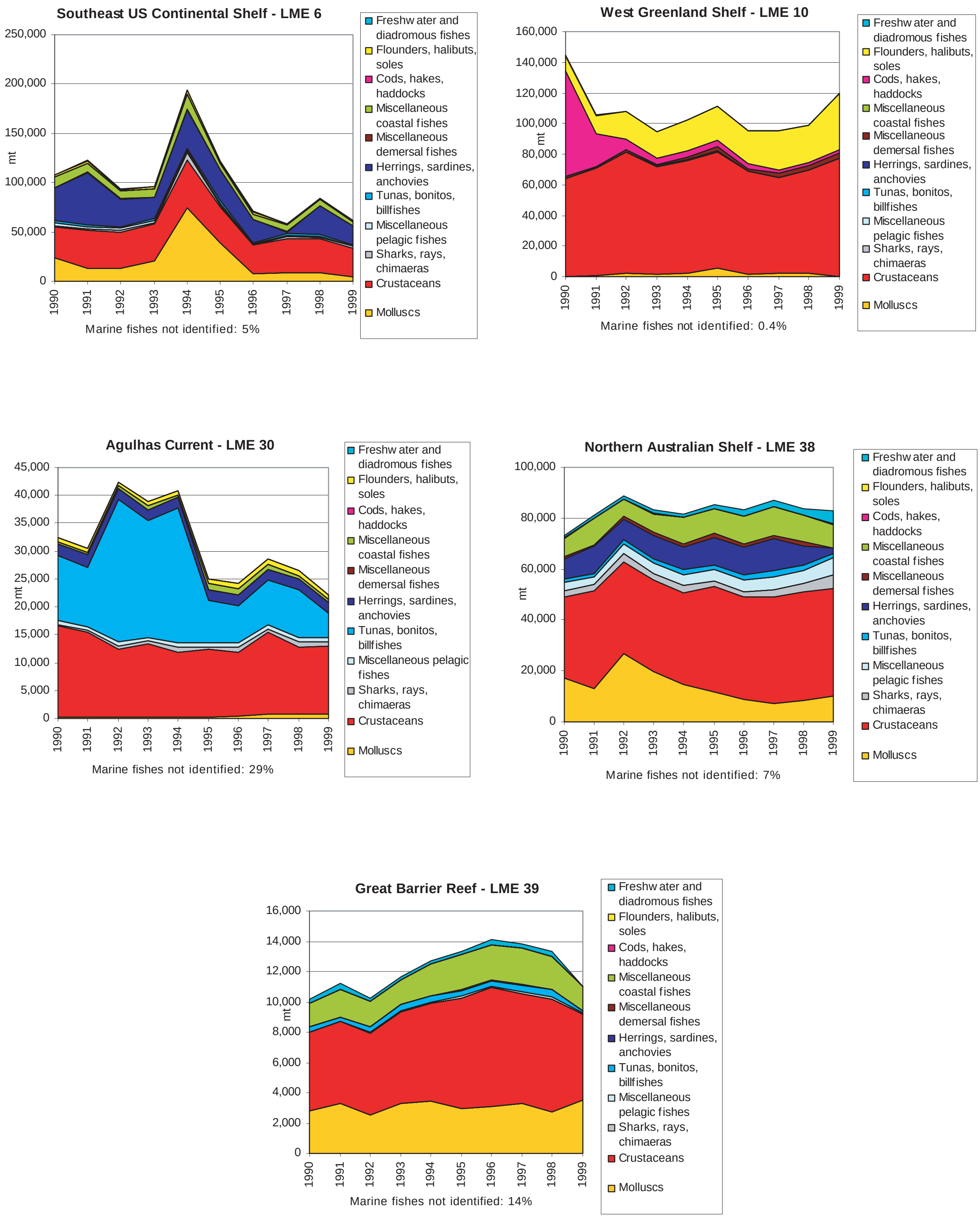


Figure 18. Cluster 5: capture trends of LMEs 6-10-30-38-39

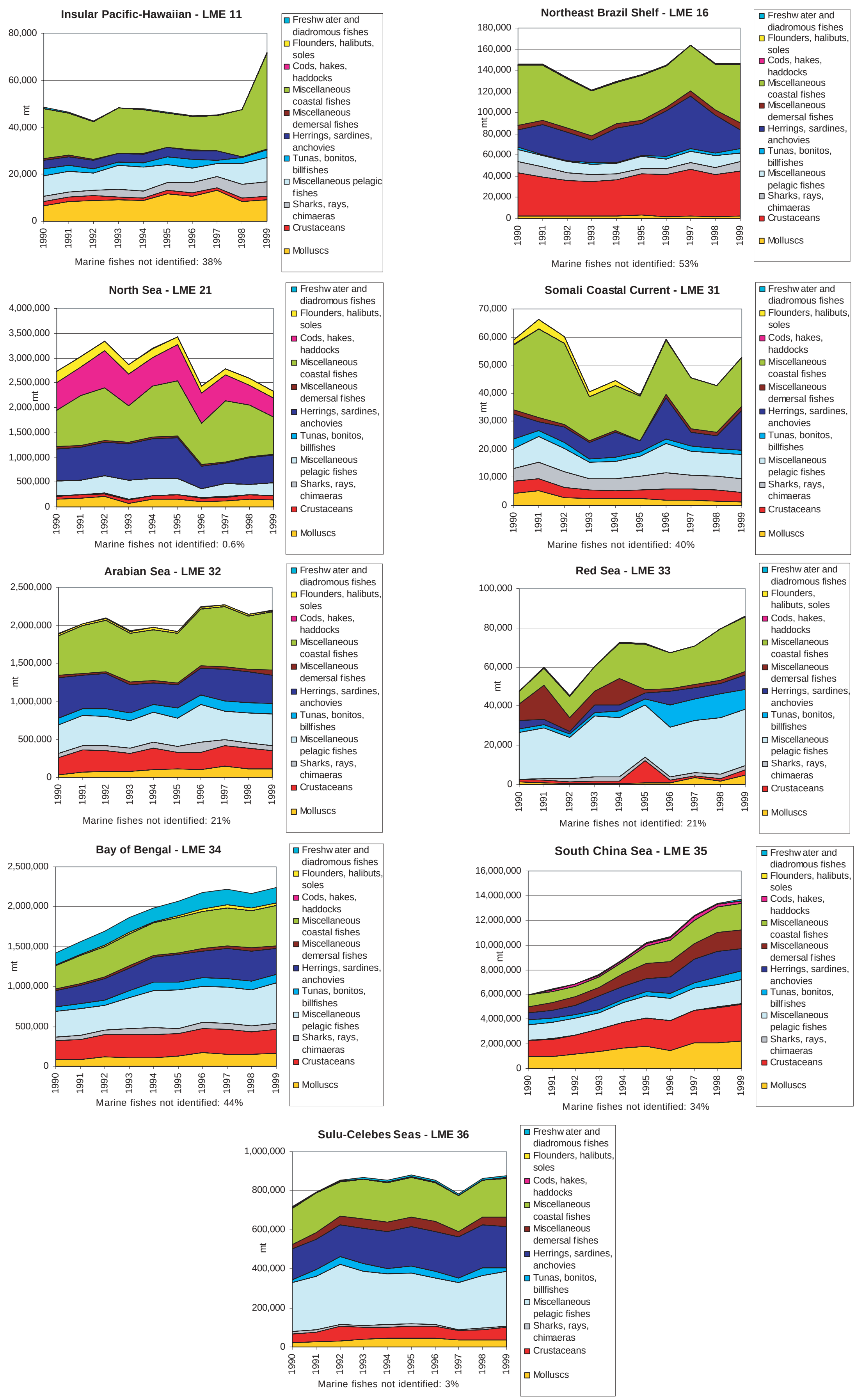


Figure 19. Cluster 6: capture trends of LMEs 11-16-21-31-32-33-34-35-36

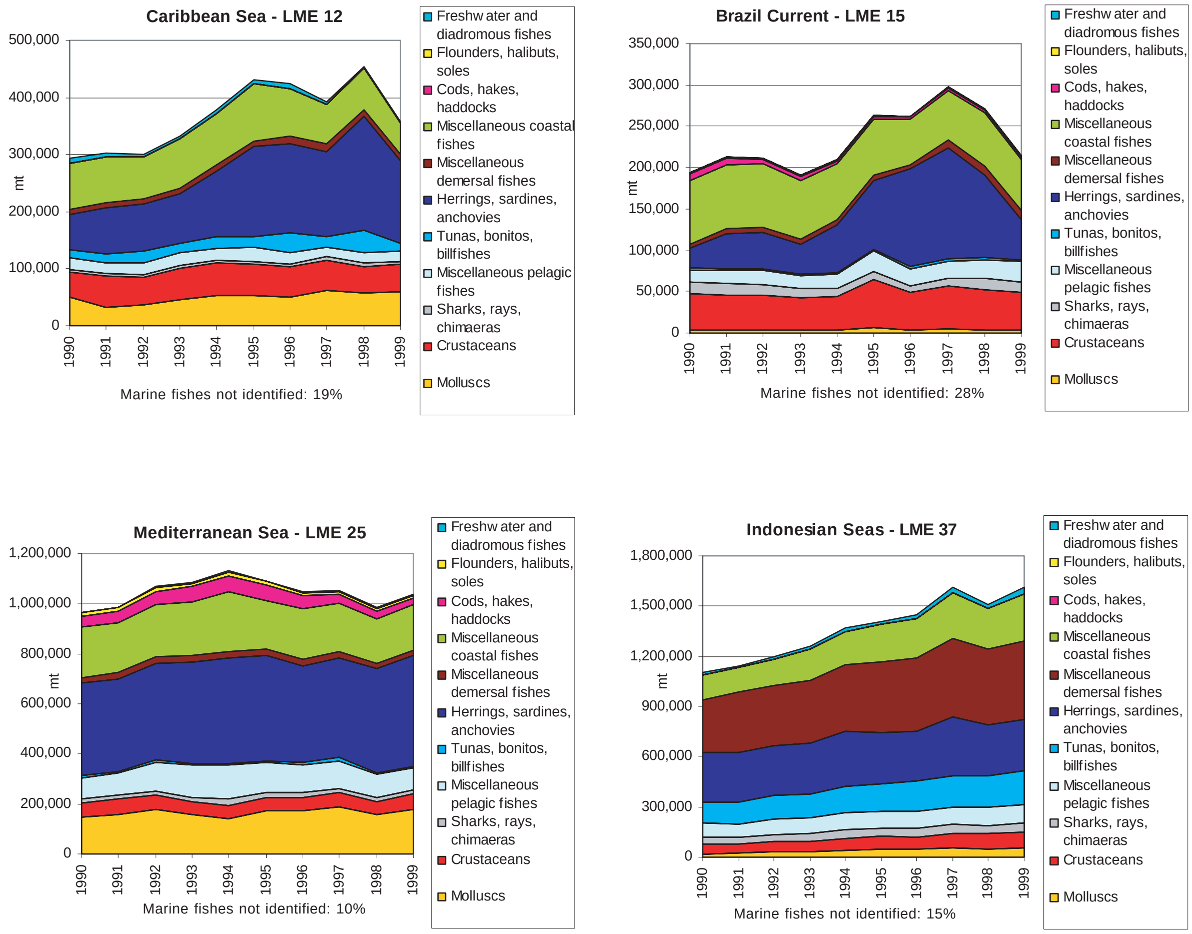


Figure 20. Cluster 7: capture trends of LMEs 12-15-25-37

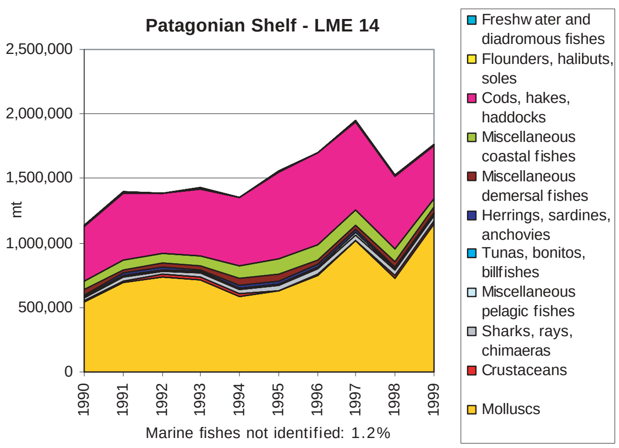


Figure 21. Cluster 8: capture trends of LME 14

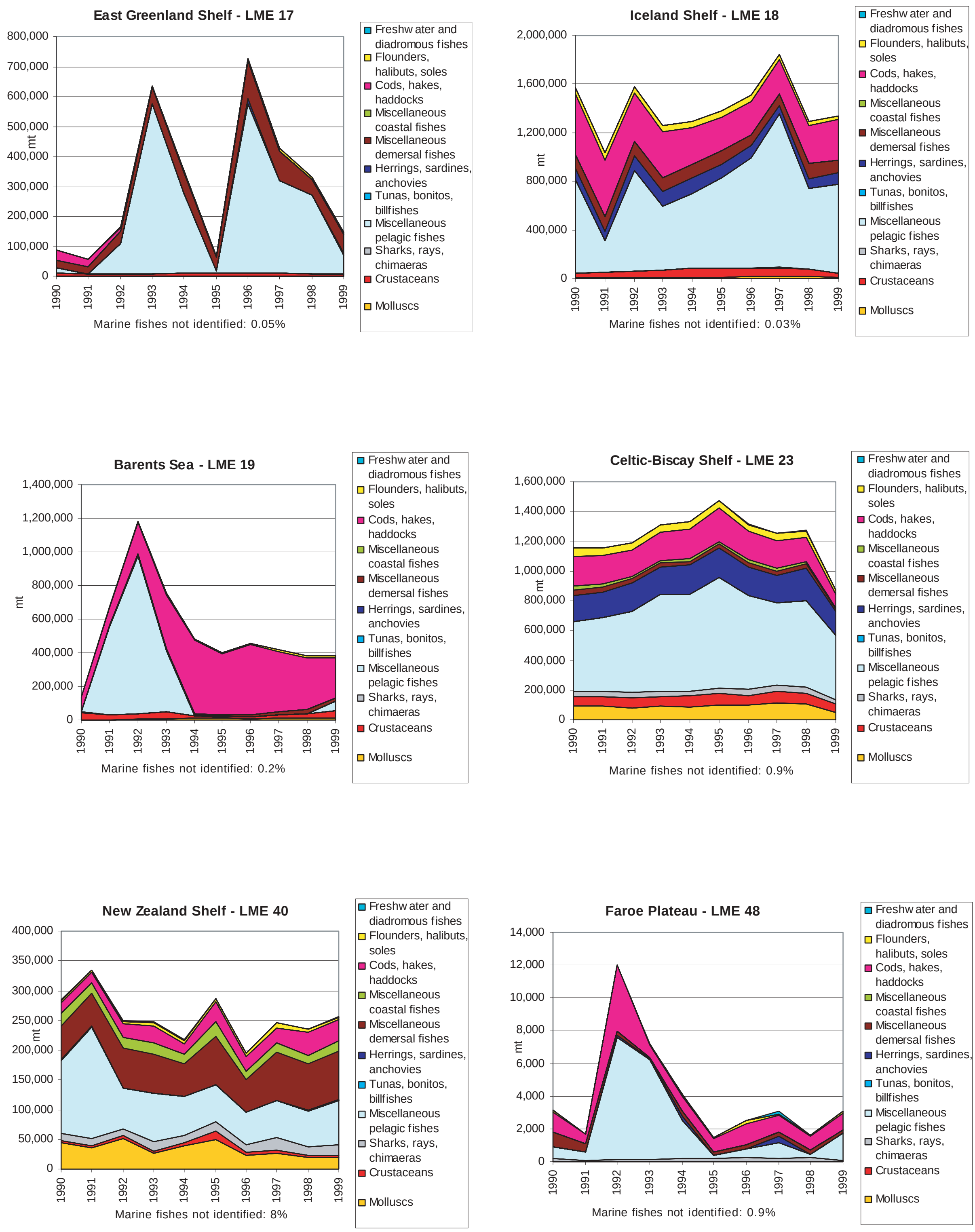


Figure 22. Cluster 9: capture trends of LMEs 17-18-19-23-40-48

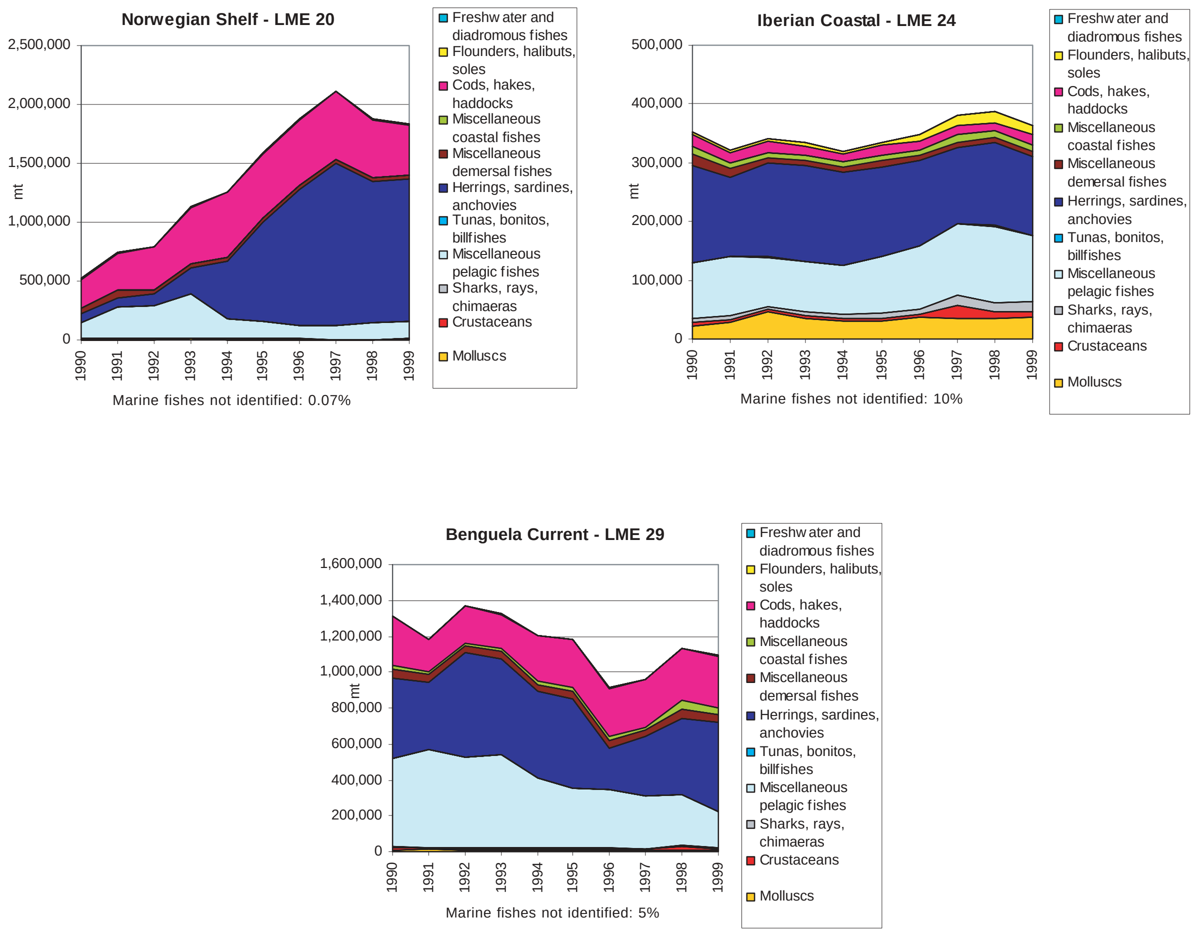


Figure 23. Cluster 10: capture trends of LMEs 20-24-29

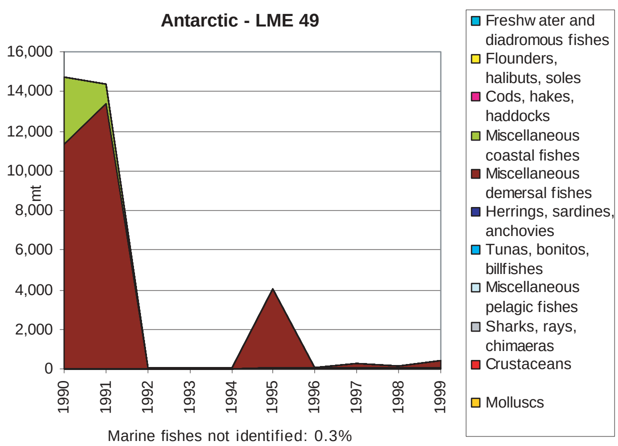
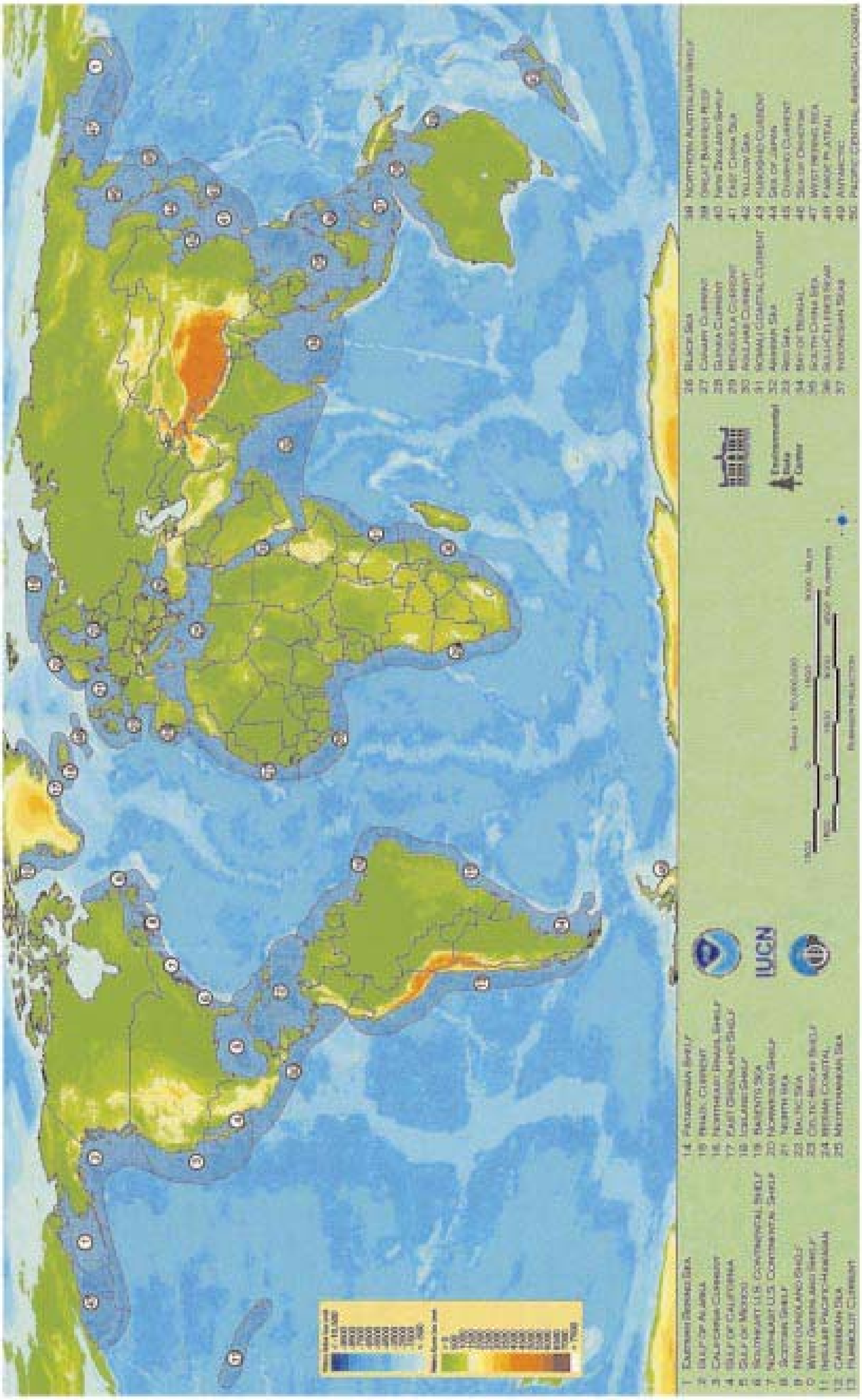


Figure 24. Cluster 11: capture trends of LME 49

APPENDIX 3. – Map of the 50 LMEs (modified from Anonymous, 1998).



Species items reported in the FAO capture fisheries production database have been classified as oceanic or living on the continental shelf. Catch trends of oceanic species, further subdivided into epipelagic and deep-water species, have been analysed over a 50-year period (1950–99), while statistics for shelf species have been re-assigned to large marine ecosystems (LMEs) for a shorter period (1990–99) and used to investigate catch patterns among the various LMEs. Oceanic fisheries constitute, both in terms of number of species items and in quantities of recent catches, about 10 percent of global marine catches. Catches of epipelagic species (mostly tunas) and of deep-water species (mostly Gadiformes) have been continuously increasing and reached 8.6 million tonnes in 1999. Oceanic catches by distant water fleets (DWFs), mostly targeting tunas, have been decreasing in recent years although their share of total DWF catches has increased due to the concurrent drop of non-oceanic DWF catches. Trends of oceanic catches and the contribution of DWFs are examined for all FAO marine fishing areas that show different patterns, mainly depending upon whether they are temperate or tropical areas. Eleven clusters of LMEs have been identified on the basis of similarities in their catch composition classified into eleven species groupings. For each cluster, the distinguishing catch pattern and recent trends by species groupings in each LME are discussed, and considered in relation to information on primary productivity and the abiotic characteristics of the LME.

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