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Mediterranean Countries' Potential Vulnerability to Ocean Acidification

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Ocean acidification (OA) refers to changes in ocean chemistry brought about by increase in atmospheric CO_2 from combustion of fossil fuels, deforestation and cement production. The ocean is particularly sensitive to these emissions because it currently absorbs about one-fourth of the anthropogenic CO_2 that is emitted to the atmosphere. As anthropogenic CO_2 is absorbed by the ocean, it produces carbonic acid that reduces the levels of carbonate ion, which is used by many marine organisms to construct shell and skeletal material. These changes in ocean chemistry are expected to adversely affect many marine organisms, including some commercially important species. Scientific research on OA is still in its infancy but most studies show decreasing production of shell and skeletal formation (calcification) with increasing acidification. Acidification-induced alterations in plankton communities may cause disturbances to marine food webs that will affect fisheries (Hilmi&Al, 2009).

Such projections are of particular economic importance, because the aquaculture industry is positioning itself for a 'blue revolution', i.e., the aquatic analogue of the agricultural 'green revolution' that began in the 1960's, to fill much of the projected shortfall in food production from conventional agriculture as needed to feed the increasing world population during subsequent decades (Sachs 2007).

Following the lead of the Stern Review (Stern 2006) in regards to global climate change, we take a macroeconomic approach to begin to assess the economic impacts of Mediterranean Sea acidification. Cooley and Doney (2009) made an economic assessment of ocean acidification on US coastal waters, taking a precautionary approach to management, i.e., offering advice for political actions "before ocean acidification's effects on marine resources become obvious and perhaps irreversible"; we adopt a similar rationale and strategy here. Costanza *et al.* (1997), highlight that such an approach may reduce fishery revenue in the short term, but that in the long term, a conservation strategy will be sustainable. Charles (2007) and Lenton *et al.* (2008) also emphasize an interdisciplinary approach focused on monitoring, as we do here. This study confirms the necessary link between natural economic sciences that is needed to evaluate the effects of ocean acidification not only on the environment but also on the economy. Our approach is global and international, but it must focus geographically, to properly assess the specificities of the Mediterranean Sea. For a consistent analysis across countries, we rely on the homogenised data from the FAO Fishstat database and the International Labor Organisation, and provide only some summary conclusions here that will elaborated upon in a subsequent publication.

Importance of fisheries activities at the global level

On the following table, we notice that the world production of fisheries tend to decrease in the developed countries and to increase in the developing countries.

Table 1 : Total Fisheries Production (metric tonnes)

	1990	1995	2000	2006	2007	2008
Developed countries	42369456	34876128,9	33112099,4	29672029	29660156,3	28504626,6
Least Developed Countries	4093394,6	4655552,4	6195198,3	9100049,5	9676705,7	10012274,5
Other developing countries	56271076,8	85018477	96858091,6	113279709	116416740	120572794
Other	88855	312449	240124	74700	63346	59408
TOTAL	102822782	124862607	136405513	152126488	155816948	159149103

In fact, the capture activities decresease in the advanced economies and increase in the developing countries.

Table 2 : Capture Fish production (Quantity, metric tonnes)

	1985	1990	1995	2000	2006	2007	2008
Developed countries	41070392	38926655	31286269	29032361	25381484	25145576	24128680
Least Developed Countries	3229457	3858164,6	4213444,4	5333656,3	7402559,5	7881815,7	8077904,5
Other developing countries	35043026	43123151	57854194	60126843	57878522	57898172	58534168
Other	24588	88855	312449	240124	74700	63346	59408
TOTAL	**79367463**	**85996825**	**93666357**	**94732985**	**90737265**	**90988910**	**90800160**

But aquaculture increases in all the areas of the world represented on the table below, and moreover in developing countries.

Table 3 : Aquaculture Fish production (Quantity, metric tonnes)

	1985	1990	1995	2000	2006	2007	2008
Developed countries	2863231	3442801	3589860	4079738	4290545	4514580	4375947
Least Developed Countries	140731	235230	442108	861542	1697490	1794890	1934370
Other developing countries	8349379	13147926	27164283	36731249	55401188	58518569	62038626
TOTAL	**11353341**	**16825957**	**31196251**	**41672529**	**61389223**	**64828039**	**68348943**

If the developed countries fish less, their needs in seafood have not diminished. We consider the commercial aspect now to see if their imports compensate the decrease of their production.

Indeed, the table below shows a significant rise of seafood imports and exports in advanced economies. Imports are far more important than exports, contributing to their international trade deficit.

Table 4 : TRADE Quantity (metric tonnes) and Value (thousands of dollar)
Developed countries or areas

	1985	1990	1995	2000	2005	2006	2007
Export Quantity	8531175	9865868	11518376	13156786	14918124	14710903	14870371
Export Value	9747245	20323353	25789479	27528355	40550453	43814801	48619456
Import Quantity	10205141	12694640	15546247	17666415	19581915	19630365	19974834
Import Value	16277402	34675470	48193602	50602212	66165247	72655621	78244752
Production Quantity	22474709	22364498	19148243	19413188	18933860	18818870	18906472
Reexport Quantity	4036	6435	154	344	2737	4452	3510
Reexport Value	15756	29680	520	958	18013	23851	30194

Concerning the developing countries, the trade of seafood is also increasing. But in those countries imports are superior to exports and rexports increase too because, thanks to a cheaper labor cost, they treat the marine products and sell them abroad. So the fisheries sector not only covers their consumption needs, but also balances their commercial deficits.

Table 5 : TRADE Quantity (metric tonnes) and Value (thousands of dollar)
Other developing countries or areas

	1985	1990	1995	2000	2005	2006	2007
Export Quantity	5094878	6906306	10575840	12723185	15204209	15779508	15786119
Export Value	6911830	14737838	25133990	26922745	36105641	40585324	42947764
Import Quantity	2676249	4421798	6530883	8624661	11781126	11880065	12369289
Import Value	3008725	5034469	8716390	10279232	16237950	17960678	20309119
Production Quantity	10109625	13739063	19021157	20645268	25685423	26224363	27170201
Reexport Quantity	54501	53160	145748	167537	168145	166422	203232
Reexport Value	228043	46674	487590	673778	468951	439950	543661

For the least developed countries, the global trend shows an increase of the seafood trade, but the figures are very weak compared to international data.

Table 6 : TRADE Quantity (metric tonnes) and Value (thousands of dollar)
Least developed countries or areas

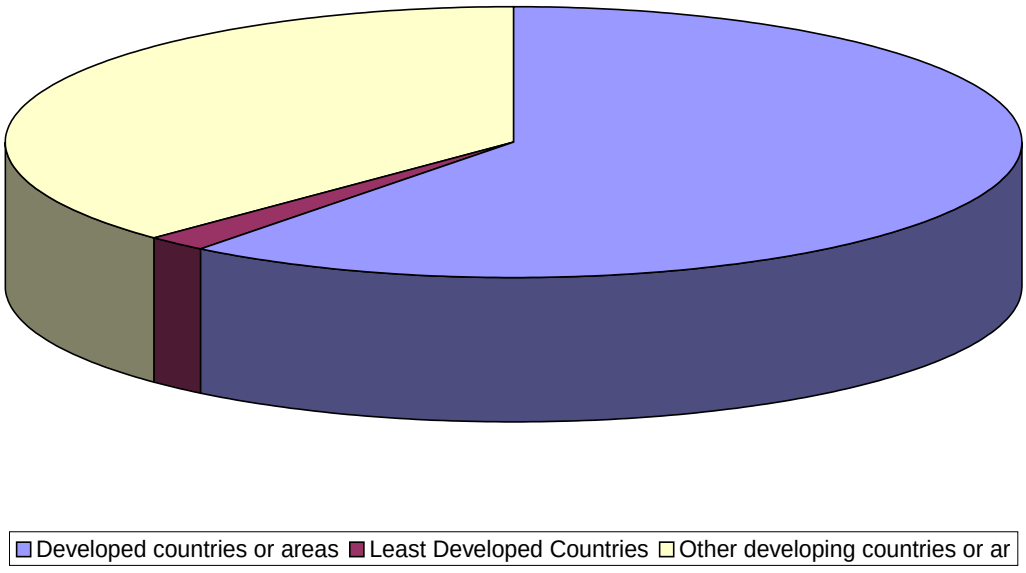
	1985	1990	1995	2000	2005	2006	2007
Export Quantity	252502	326299	534199	629652	1030256	998709	1062422
Export Value	473227	796505	1330163	1365563	2415603	2173245	2496543
Import Quantity	368219	284175	237663	336070	531197	561414	674432
Import Value	204563	220581	173084	322662	455657	614506	868824
Production Quantity	578525	671699	770103	975605	1316666	1307585	1511049
Reexport Quantity	4091	1	36	20	832	49736	884
Reexport Value	7418	5	12	87	6052	84275	2652

The graphs below confirm that exports are mainly realized by developing countries and that most of imports are realized by developed countries. So, advanced economies consume more seafood products than they produce. That is why they import them. The developing

countries are very dependant from their fisheries, for their consumption, but also for their trade.

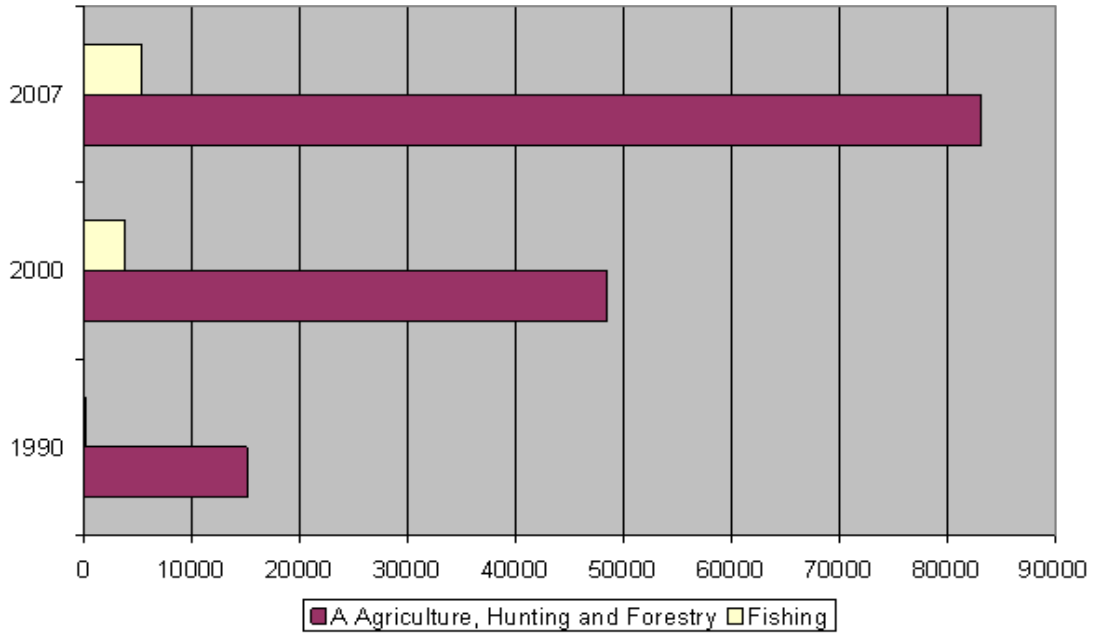
Fig. 1 : Fisheries exports quantities in 2007

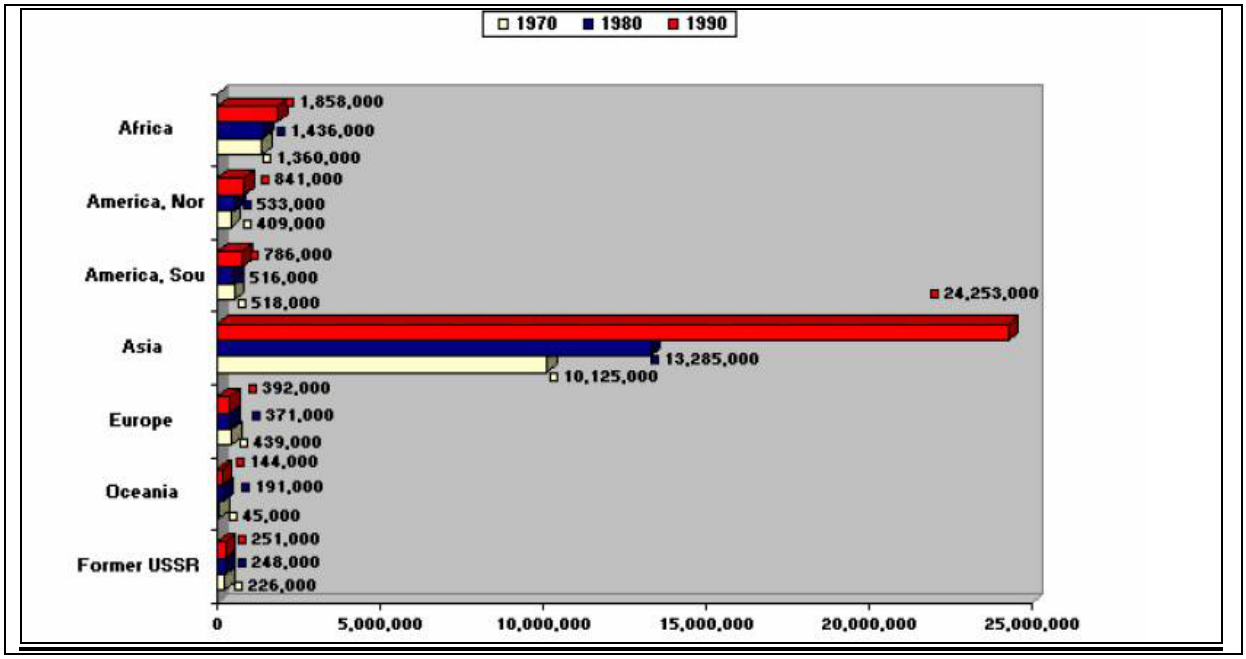
Fig. 2 : Fisheries imports and imports quantities in 2007



This vulnerability of developing countries is confirmed when we consider their active population working in the fishery sector. The graph below compares the population working in the fisheries and the population working in the primary sector. Even if the part of population working for fisheries seems small, it is very important in the regions as Asia and Africa, which are very dependant on the fisheries activities.

Fig. 3 : Evolution of the active population of fishermen at global and continental (Thousands of persons)





About the risks of ocean acidification in the different areas of the world, we can conclude that:

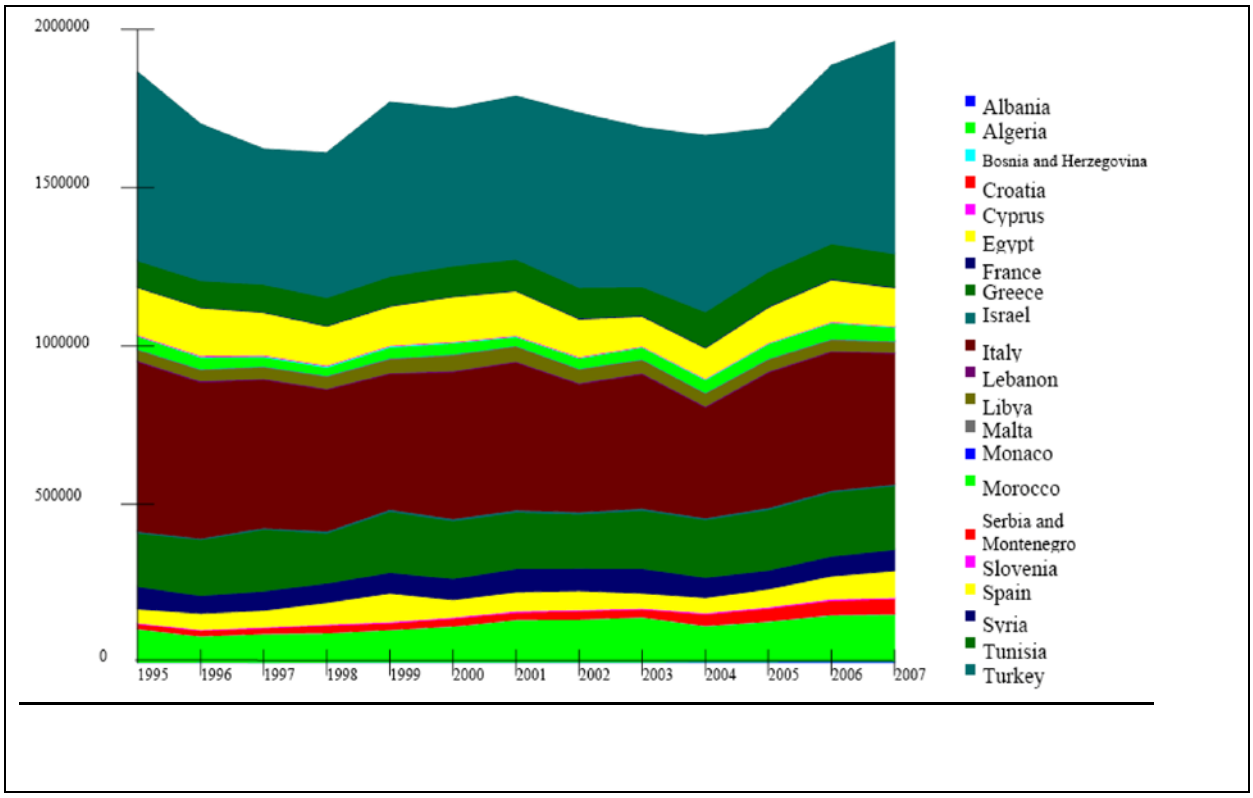
- The developing countries have an important place in the world activities of fisheries, capture and aquaculture.
- Aquaculture is developing and the number of cultivated species is increasing.
- The trade of seafood is growing too, especially in developing countries.
- The population working for the fishery sector is increasing and the developing countries are dependant from fisheries for their subsistance and for their trade.

Finally, the developing might be highly impacted by ocean acidification, particularly in Asia and Africa.

Economic importance of fisheries for the Mediterranean countries

Although the economic importance of commercial fisheries is generally low for most Mediterranean countries relative to their Gross National Products, coastal activities can be quite large in some countries. A fishery can be a recreative value, and thus linked to tourism which can be an important economic sector in some countries such as Egypt and Croatia. Moreover, seafoods are essential to subsistence of the coastal population particularly in the less developed countries and also marine-related industries create jobs and distribute revenues. Fig. 2 gives an overview of the importance of fishery production for each of the 22 countries having a coastline on the Mediterranean Sea.

Fig. 4 : Total Fishery Production in Mediterranean Countries (metric tonnes)



The evolution of the total fishery production in the different Mediterranean countries indicates that curves generally follow a country's major economical and political events, that

countries typically exploit one or two main species, and that the contribution of each species relative the total production is quite stable over time. However, there are wide differences between countries in terms of the species farmed and the trends in production. This monoculture or restricted number of fished species in each country is important if we want to put in evidence the impact of ocean acidification on the different species because some countries may be economically affected more quickly and deeper than other ones. This total fishery production can be split into capture and aquaculture (Fig. 3).

Capture is more important than aquaculture (in metric tonnes) and there has been a modest substantial increase in aquaculture over the 12-year record. If we break down these total fisheries data by species, separating capture and aquaculture, we can measure the values of the ocean acidification's possible economic impact.

We can see on the Table 1 that in most European countries, aquaculture represents important values. This is certainly due to European Union's incentives to develop this activity. The Mediterranean aquaculture industry uses some species that were directly used for human consumption (e.g. Sardines and anchovies) to feed animals. The socioeconomic impact is important because large amounts of fishes that were suitable for human consumption are turned into animal feed for fishes eaten by wealthy people (Naylor *et al.*, 2000).

Fig. 5 : Aquaculture and capture fishery production in Mediterranean area (metric tonnes)

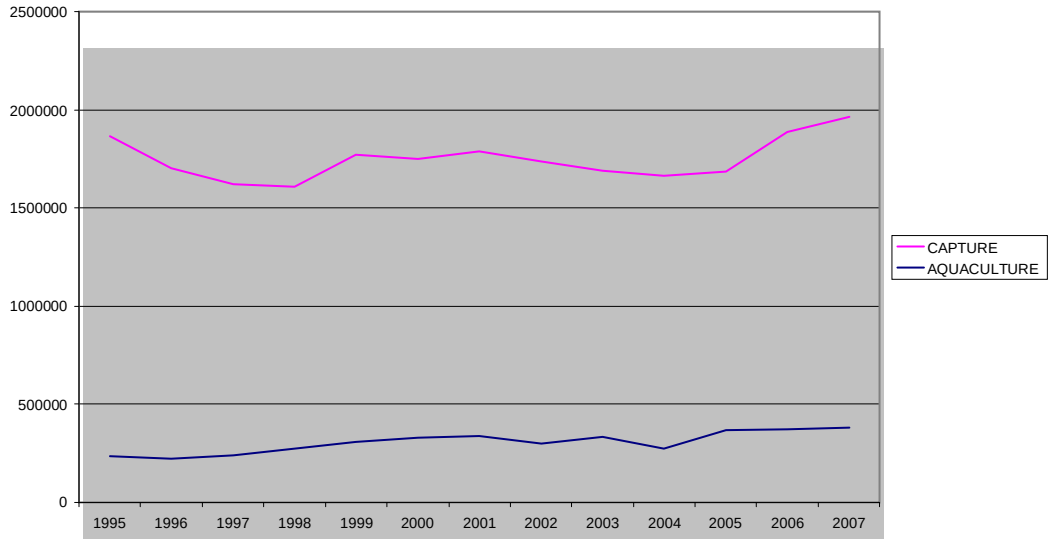
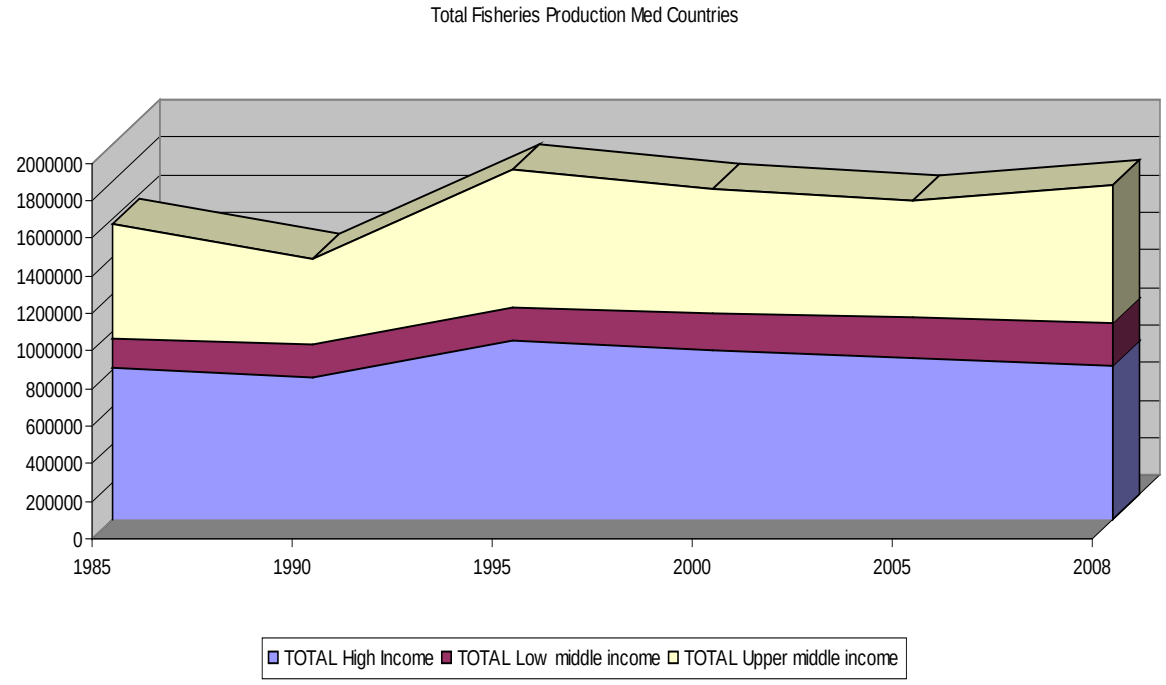


Table 7: Evolution of aquaculture in the Mediterranean countries in terms of monetary value (thousands of US dollar)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Albania	152	204	156	469	721	1531	2102	1862	2481	3556
Algeria	135	121	175	242	243	69	36	36	32	93
Bosnia &Her.	.	.	.	.	1238	1323	614	1706	1816	1771
Croatia	15021	15519	19250	22963	24958	22060	27740	27076	32152	35012
Cyprus	8282	9106	9814	8985	10052	11047	14273	17931	17973	20203
France	72500	67926	49444	59612	61623	76028	94335	99965	109105	109134
Greece	262064	316513	281542	292822	233244	336310	356166	414056	448160	514094
Israel	21693	28049	21619	20277	16461	16318	18353	17828	24680	24887
Italy	289526	252740	332406	279844	255380	365849	266362	487398	486802	615157
Libya	-	-	-	-	-	-	1376	1976	1978	1090
Malta	10560	8509	5011	3080	3747	4541	6328	5366	7935	23980
Morocco	4996	4856	3750	2271	3082	3895	3703	5597	248	528
Serbia & Mont.	34	77	55	72	42	50	74	74	-	-
Slovenia	967	549	565	581	298	602	1153	403	522	422
Spain	3406	6938	8692	11852	12841	10955	17306	13620	13442	8384
Tunisia	7374	2654	5311	7351	7228	8170	10053	11188	12128	16382
Turkey	172218	176733	135565	87193	79331	180501	249960	352214	355588	400744

The fisheries production in the Med Sea represents about 1% of the world total fisheries, while the Med Sea corresponds to only 0,8% of the seas and oceans surface. The part of the developing countries' production is large compared to the advanced economies'.

Fig. 6 : Total fisheries production in Mediterranean area (metric tonnes)



About commercial aspects, the international trade has increased in the Mediterranean countries.

Table 8 : Trade of fisheries commodities in the Med countries
Quantity (metric tonnes) and values (thousands of dollars)

Med countries	1985	1990	1995	2000	2005	2007
Export Quantity	792 652	1 038 765	1 320 443	1 923 565	2 064 428	2 214 436
Export Value	1 208 489	2 757 364	3 782 347	4 590 985	6 983 438	8 768 558
Import Quantity	1 782 014	2 803 713	3 144 818	3 975 291	4 613 566	4 826 205
Import Value	2 710 326	8 089 477	9 396 003	9 879 340	16 025 700	19 625 760
Reexport Quantity	-	763	-	93	2 338	2 759
Reexport Value	4	2 427	-	254	16 516	23 206

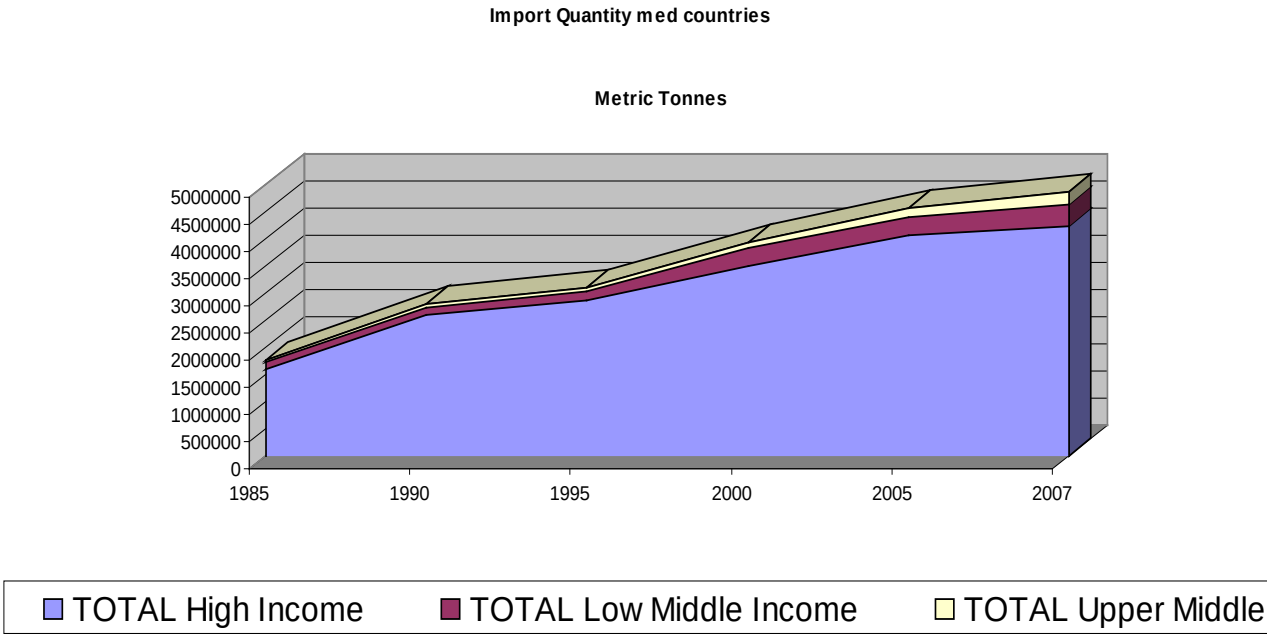
If we compare the seafood figures in Med countries to the ones in the world, we notice that imports are more important than exports.

Table 9 : Ratios Mediterranean countries / world
Quantity (metric tonnes) and values (thousands of dollars)

Med/world	**1985**	**1990**	**1995**	**2000**	**2005**	**2007**
Export Quantity	**5,71%**	**6,08%**	**5,84%**	**7,26%**	**6,63%**	**6,98%**
Export Value	**7,05%**	**7,69%**	**7,24%**	**8,23%**	**8,83%**	**9,32%**
Import Quantity	**13,45%**	**16,11%**	**14,09%**	**14,93%**	**14,47%**	**14,62%**
Import Value	**13,91%**	**20,26%**	**16,46%**	**16,14%**	**19,34%**	**19,74%**
Reexport Quantity		**1,28%**		**0,06%**	**1,36%**	**1,33%**
Reexport Value	**0,00%**	**3,18%**		**0,04%**	**3,35%**	**4,03%**

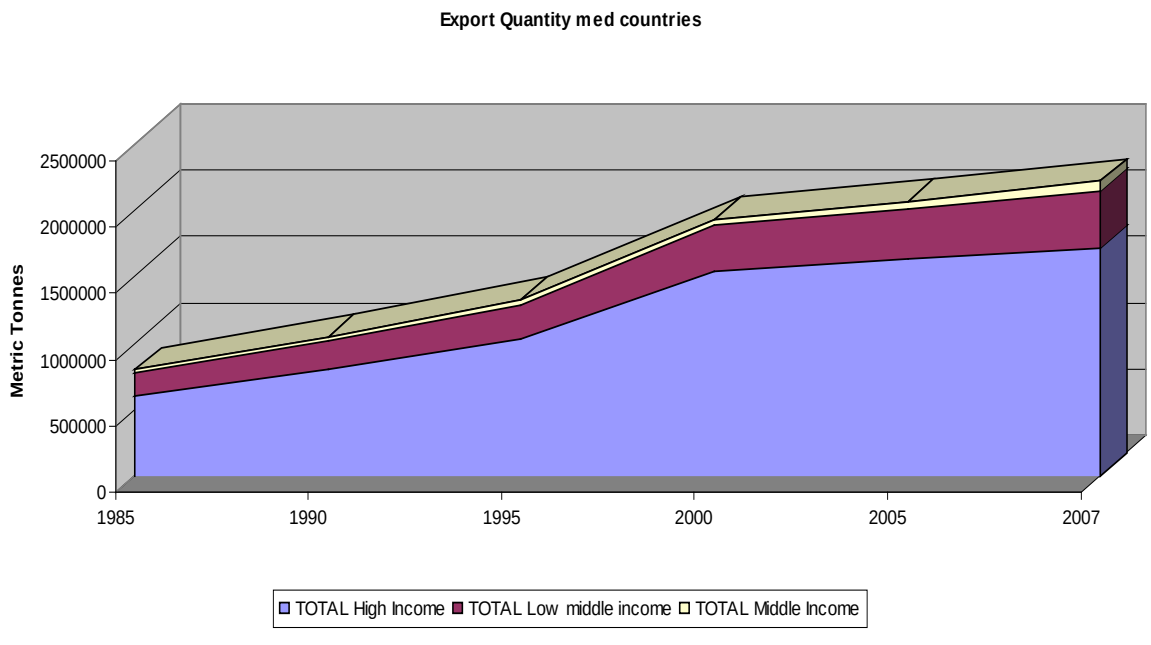
When we separate the Mediterranean imports according to their development levels, we notice that high income countries (France, Italy, Spain, Greece) import more than lower income countries.

Fig. 7 : Change in imports of fishery (metric tons) in the Mediterranean countries based on their level of income



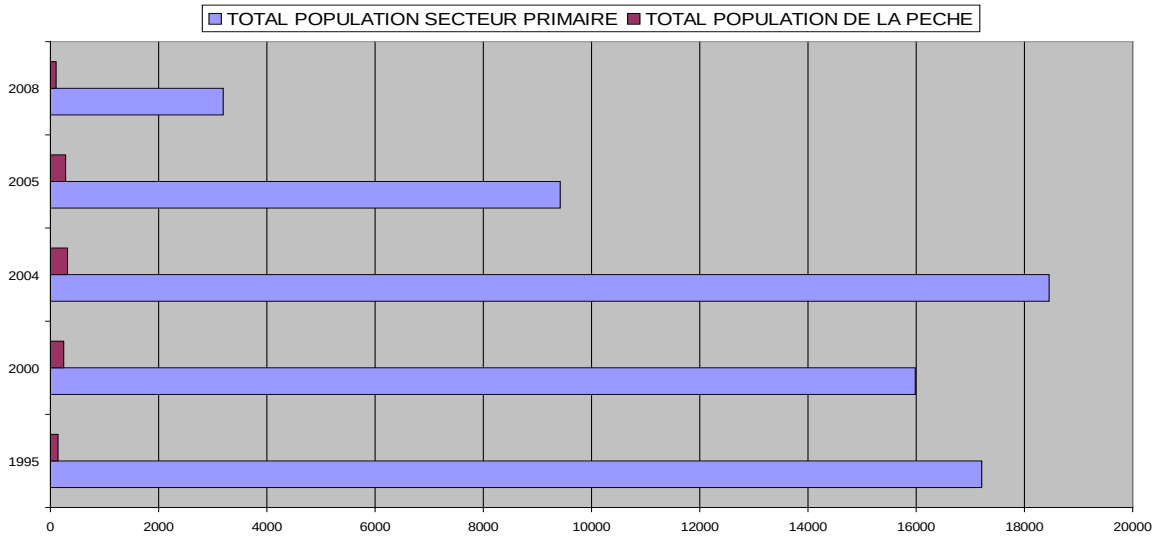
Exports are realized by those high income countries too. So we can conclude that Med developing countries tend to consume their own fishes. Their subsistence is more dependant from seafood.

Fig. 8 : Change in exports of fishery (metric tons) in the Mediterranean countries based on their level of income



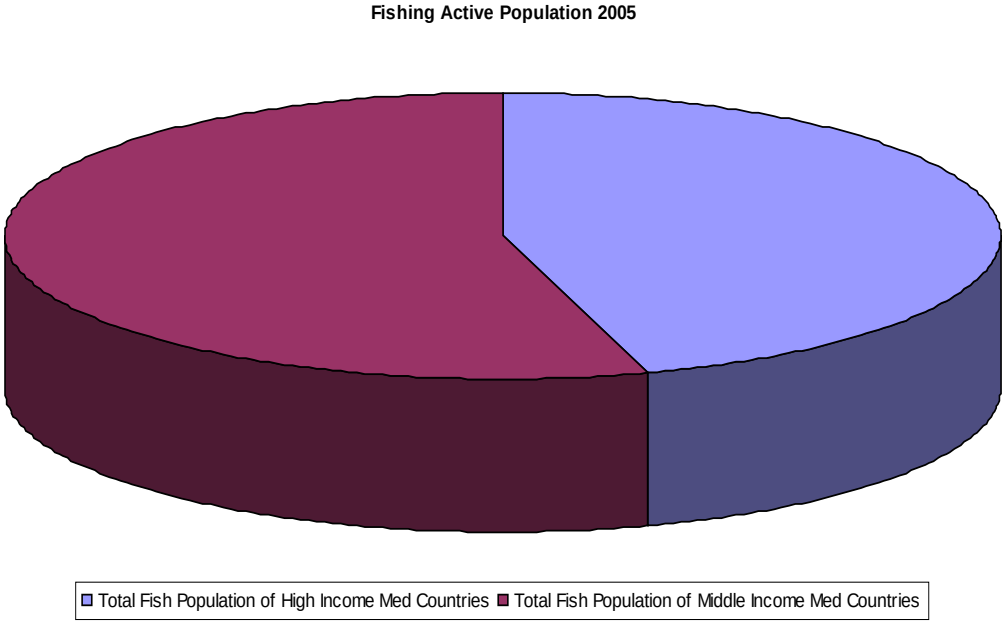
The part of the population living on fisheries activities is weak if compared to the primary sector.

Fig. 9 : Evolution of the active population in the primary sector and the fishery sector in the Mediterranean countries.



In the Mediterranean developing countries, the population living on fisheries is more numerous than in high income Med countries. So, those countries are supposed to be more vulnerable in case of ocean acidification.

Fig. 10 : Fishing active population in the Mediterranean countries based on their level of income in 2005.



In conclusion, while separating the Med countries according to their development level, this analysis put in evidence that lower income countries are more sensible to the risks of ocean acidification.
The Med Sea is an interesting field of study because several levels of development are represented.

Conclusion: Assessment of the potential scale of socio-economic impacts of OA and the equity of their distributions among the Mediterranean countries, that represent a very broad range in their states of economic development.

The Mediterranean Sea may be highly impacted by ocean acidification because its large number of calcifying organisms already suffers from synergistic impacts of other anthropogenic pressures along its heavily populated coastlines. To limit risks, both regional and global efforts are needed. Associated research must be interdisciplinary to propose solutions that will mitigate risks and to develop adaptation strategies. The marine resources will be certainly impacted.

Marine scientists and fisheries economists must try to determine the levels of the implication and forecast environmental and economic consequences. The problem is that, for the moment, scientists can not give conclusive predictions about the effects of ocean acidification, neither on species, nor in term of pH. Because of those uncertainties, economists can not evaluate properly the losses generated by ocean acidification. Working on different scenarios would be one possibility for the next steps of our research.

Even if the modification of the pH level is the same for the Mediterranean coasts, the socio-economic impact will be different in developed and developing countries because of, on one hand, the different weight of fisheries activities in the national GDPs and on the other hand, the equity of distribution of benefits /losses due to the fisheries activities. This approach could be interesting to develop in a further research.

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