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Marine research in the Iberian Peninsula: A pledge for better times after an economic crisis☆

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ABSTRACT

The “17th Iberian Symposium of Marine Biology Studies” took place in San Sebastian (Spain), in September 2012. This contribution is an introduction to a special issue collating the most challenging papers submitted by Portuguese and Spanish scientists to the symposium. The text was structured as a novel, with the three main parts of a novel: (i) Setup: a historical context, from old times to the 1970's. This part presents the main Iberian scientific contribution to marine science, since the 15th Century, as a precedent to modern scientific research; (ii) Conflict: from the 1970's to the economic crisis. This part presents the evolution of Iberian research production, based upon a bibliometric study, from 1974 to 2012; and (iii) Resolution: what for the future?, which shows the main challenges, proposed by the authors, to the European research initiative ‘Horizon 2020’, including aspects such as the need of knowledge-base for marine management, the marine research as a potential source of jobs, the ecosystem-based approach, human activities and Marine Spatial Planning, moving from fisheries to aquaculture, or global change issues, among others.

1. Introduction

In 1979 the first ‘Iberian Symposium of Marine Biology Studies’ took place in San Sebastián (northern Spain) (Niell and Ros, 1982). After 17 editions, in 2012, this symposium returned to the same place, and this Special Issue includes 23 out of the 250 contributions presented there, by Portuguese and Spanish scientists. We have structured this introductory paper as a novel, with the three main parts of a novel: (i) Setup: a historical context, from old times to the 1970's. This part presents the main Iberian scientific contribution to marine science, since the 15th Century, as a precedent to modern scientific research; (ii) Conflict: from the 1970's to the economic crisis. This part presents the evolution of Iberian research production, based upon a bibliometric study, from 1974 to 2012; and (iii) Resolution: what for the future?, which shows the main challenges, that we propose, to the European research initiative ‘Horizon 2020’.

2. Setup: a historical context, from old times to the 1970's

The long and rich history of the Iberian Peninsula (i.e. Portugal and Spain) has reflected also in the early descriptions of marine life, by the historian Pliny the Elder (Gaius Plinius Secundus, Naturalis Historiae, Liber Quartus, 1st Century AC). In the middle age, the Ripoll's Bible (in Catalonia), a valuable manuscript codex dated between 1015 and 1020, includes a map of Roman Hispania showing images of marine fish.

However, it was after the 15th Century, when Spanish and Portuguese navigators sailed to discover new lands (e.g. Bartolomeu Dias turning the Cape of Good Hope, in 1488; Cristóbal Colón, discovering America's continent, in 1492; Vasco da Gama navigating around Africa to India, from 1497 to 1499; Fernão de Magalhães and Juan Sebastián Elcano, in the first expedition circumnavigating the Earth, in 1519–1522; Andrés de Urdaneta, who discovered the fastest navigation route between Asia and America, in 1565; etc.), that these pioneers prepared the way to the future scientific expeditions in the Atlantic and Pacific Oceans, in the 18th and 19th Centuries.

In the 18th Century, the Spanish King Carlos III founded the Royal Cabinet of Natural History, which was the origin of the present Natural History Museum of Madrid, and undertook the first scientific works on marine fauna and flora. In these and immediately following times, ichthyology, oceanography and fisheries were usually studied together (Rallo and Borja, 2004). Hence, one of the most important works undertaken in the Atlantic coast of the Peninsula was the “Essay of a history of fishes and other marine productions of the coast of Galicia, arranged according to the system of Knight Linnaeus”, written by José Cornide de Saavedra, and published in Madrid, in 1788. Between 1789 and 1794 the ‘Malaspina expedition’, commanded by Alejandro Malaspina and including many hydrographers and naturalists, circumnavigated

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the Earth, aiming to increase the scientific knowledge of botany, zoology, geology and hydrography in remote regions of America and the Pacific. These studies, together with others referring to other coasts of the Peninsula, could be considered as the start of a systematic Iberian marine scientific research. In fact, a new 'Malaspina expedition' was organized between 2010 and 2011, in a journey of 42,000 nautical miles around the world, dealing with new issues, such as biodiversity in deep waters, climate change or use of new genomic approaches in studying marine waters (Rebok, 2012).

In the 19th Century, the ultramarine 'Scientific Commission of the Pacific', an expedition to the South America Pacific coasts and on the downstream part of the Amazon River, was of particular interest; this departed in 1862, returning in 1866 with extensive observations and collected material. This expedition provided a renaissance of marine research in the last three decades of the 19th Century. Hence, in 1871, the Spanish Society of Natural History was founded, in Madrid. One of the earliest activities of the Society was to promote and to request the creation of Marine Laboratories along the Spanish coast. The plan included several visits to other European centres working in marine biology and oceanography (in particular the 'Stazione Zoologica de Napoli', in Italy). The first Marine Laboratory was created in Santander, in northern Spain, in 1886, which was integrated into the Spanish Institute of Oceanography, created in 1914 to join and coordinate the research in all the institutional marine laboratories in Spain. At the end of the 19th Century, Adolfo Navarrete y de Alcázar published the first modern Spanish texts on Oceanography (1896) and Marine Biology (1898) (Duarte et al., 2006).

As early as 1908, the Oceanographic Society of Gipuzkoa (Basque Country, northern Spain) was founded (the second oldest in the world, after that of Monaco), having in mind the development of practical and applied knowledge of the sea. In 1913, there were several considerations published by this Society, which can be accepted as valid today: "Many people believe that the sea is an endless source of marine products, and that however much that men take from it, using any kind of catchment procedures, sea richness does not become diminished and will remain forever. It is necessary to say and repeat that fish, as all the products of nature, have the risk to be exhausted" (see Rallo and Borja, 2004).

The scientific activities of these societies included oceanographic research cruises undertaken along the Spanish coasts. In parallel, in Portugal, from 1896 to 1907, the King D. Carlos I promoted and participated as naturalist in several oceanographic cruises, along the Portuguese coast. As a whole, these expeditions generated an important practical and theoretical knowledge of the marine systems, namely regarding commercial fisheries.

A number of Iberian faunistic and floristic monographs were published from mid-19th Century to mid-20th Century; e.g. crustacea (de Buen, 1886); cryptogams (Colmeiro, 1889; Lázaro-Ibiza, 1889, 1893); porifera (Ferrer-Hernández, 1914a, 1914b); molluscs (Hidalgo, 1917; Nobre, 1936); fishes (de Buen, 1942; Lozano Rey, 1928); polychaetes (Rioja, 1931); etc.

By this time, habitat conditions and other ecological aspects were included as being characteristic of the species. Nevertheless, although there are some early studies concerned with oceanography, bionomics and ecology, these disciplines acquired its present significance with Ramón Margalef (1919–2004), considered one of the fathers of modern ecology. His book 'Ecology' (Margalef, 1977) represents the hinge between the 'old Iberian marine science' and the 'new one'. Around that time (in 1979), some of Margalef's students, started to organize scientific meetings that are at the genesis of today's 'Iberian Symposium of Marine Biology Studies', the first of which took place in San Sebastián (northern Spain) (Niell and Ros, 1982). Hence, this overview introduction wants to be a tribute to all marine naturalists and scientists, who have contributed to expand the marine knowledge in the Iberian Peninsula in the past 300 years, presenting also the current research topics and future challenges.

3. Conflict: from the 1970's to the economic crisis

After the reinstitution of democracy in Portugal and Spain (in 1970's), science in general and marine science in particular, experienced a rapid growth, with the creation of five faculties of marine science and several research institutes in Spain (Delgado et al., 1999). In Portugal, a research funding scheme was then initiated and evolved from calls sponsoring persons and research projects only, to its current status, where PhD programs, multi-institutional research centres and associate laboratories dedicated to Marine Science are all part of the state funding system, under international assessment. Iberian marine research benefited from Portuguese and Spanish adhesion to the European Community, in 1986, and the accession to European research funds, such as the thematic programme MAST (Marine Science and Technology), and the successive research Framework Programmes. In addition, national governments invested also in training, research infrastructures and oceanographic vessels (Delgado et al., 1999; Duarte et al., 2006).

This resulted in an increasing presence of Iberian marine research in international scientific journals (Duarte et al., 2006). In order to get an objective view of the current scientific production in the Iberian Peninsula, the Elsevier's search tool 'SCOPUS' was consulted on 3rd February 2013. As this special issue deals with the 'Iberian Symposium on Marine Biology Studies', the terms "marine biology", or "marin*", or "coast*", or "estuar*", appearing in the abstract, title or keywords within articles or reviews, were searched together with the affiliation of the authors in Portugal or Spain. The search was only in the Science Citation Index (SCI) journals. This selection can show differences with previous bibliometric studies in the area (e.g. Duarte et al., 2006), in which terms such as 'oceanography', 'engineering' and others were used also.

Hence, over a total of 516,114 papers published in the world under the topics selected, 21,565 papers were published in Iberia (4.2%), for the period 1974–2012. Spain is in the 9th position and Portugal in 21st position of the countries publishing in marine biology (Fig. 1), which is much higher than the corresponding position in population (27th and 81st, respectively). In fact, the progress was very important, since they occupied the positions 27th and 72nd, in 1980; 23rd and 70th, in 1985; 15th and 43rd, in 1990; 12th and 34th, in 1995 and 9th and 26th, in 2000, respectively.

The number of SCI manuscripts per year was very small (<10) in the 1970's, increasing from 18, in 1980, to 251, in 1995 (Fig. 2). In 1996 a sudden increase occurred (to 469 manuscripts) and then an exponential increase can be observed until >2000 manuscripts per year, after 2010 (Fig. 2).

The authors who have published more than 70 papers each during that period of time are listed in Table 1. From 21 authors, 8 are Portuguese and 13 Spanish. The first most productive author is the Spanish scientist C.M. Duarte, and the next 5 most productive authors are Portuguese. The authors work mainly in universities (12, including 6 Portuguese and 6 Spanish), followed by the Spanish CSIC ('Consejo Superior de Investigaciones Científicas', with 6 centres), 2 Portuguese institutes, and 1 Spanish private research foundation (AZTI-Tecnalia) (Table 1). The increase in papers after 2004 could be attributed, among other factors, to two main issues: (i) the investment of research after the 'Prestige' oil spill, in 2002 in northern Spain, which, after an initial lack of research coordination (Freire et al., 2006), supposed an international cooperation in the investigation of the effects; and (ii) the relevant role of Portuguese and Spanish scientists in the implementation of the Water Framework Directive (WFD, 2000/60/EC), and the subsequent development of different ecological assessment methods (Birk et al., 2012).

The most cited authors ($>10{,}000$ citations each) are 3 Spanish scientists: D. Barceló, C.M. Duarte and J.O. Grimalt, all of them working at the CSIC (Table 1). The highest H_{index} values (>30) are shown by Spanish scientists, all of them working at the CSIC (the abovementioned authors and J.M. Gasol, J.M. Bayona and J. Albaigès), excepting A. Borja,

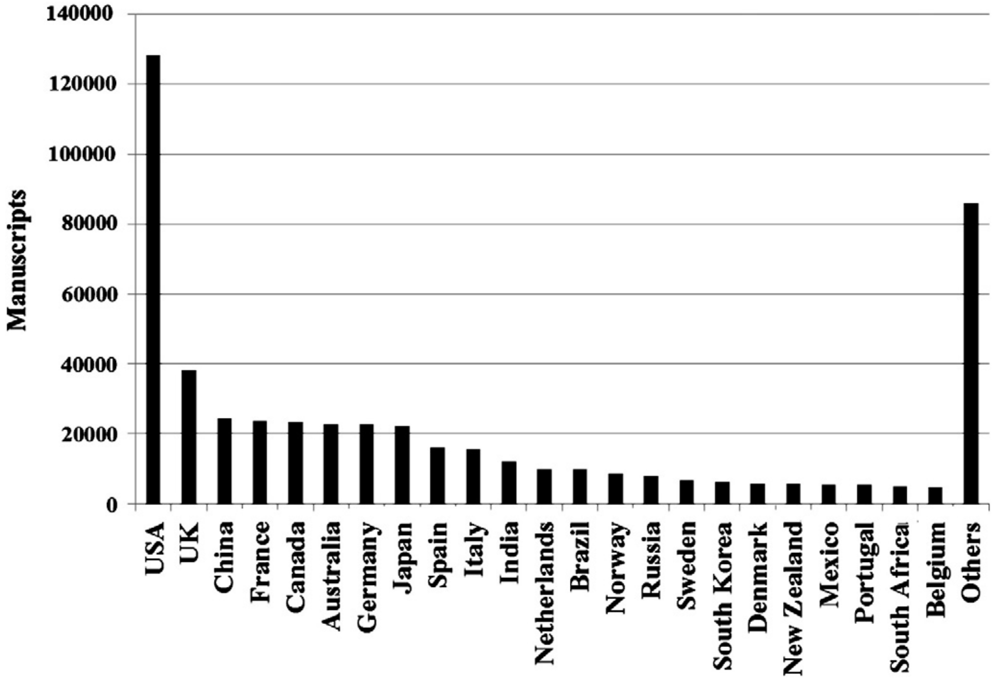

Fig. 1. Countries publishing more than 4000 manuscripts, under the terms: "marine biology", or "marine", or "coast", or "estuary", appearing in the abstract, title or keywords, since 1974 (consulted in SCOPUS, on 3rd February 2013).

who works at AZTI-Tecnalia, and by a Portuguese, J.C. Marques, working at IMAR — Institute of Marine Research, University of Coimbra (Table 1).

From the total of papers published in the period 1974–2012, Iberian authors have published at least 25 papers in 160 different SCI journals, representing 45% of the total papers (Table 2). The most selected journal was 'Estuarine, Coastal and Shelf Science', with 506 papers; then, 'Marine Ecology Progress Series', with 435; and 'Marine Pollution Bulletin', with 372 (Table 2). A Spanish journal, 'Scientia Marina', published by the CSIC, occupies the 5th place, with 310 papers (Table 2). It is of note that highly ranked SCI journals, such as 'Nature' and 'Science', have only 38 and 32 papers, respectively, from Iberian authors in the selected topics (Table 2).

From the keywords used by Spanish and Portuguese scientists, it can be seen (Table 3) that the most frequent topics, both in the Atlantic Ocean and the Mediterranean Sea, are: (i) biodiversity, taxonomy and community structure (different taxonomic groups studied, etc.), which appear in 20.8% of the papers; (ii) environmental research (water pollution, environmental monitoring, etc.), in 18.3%; (iii) estuarine and coastal environments, in 11%; (iv) oceanography (seawater, salinity, upwelling, modelling, etc.), in 9.41%; (v) effects of pollution (bioaccumulation,

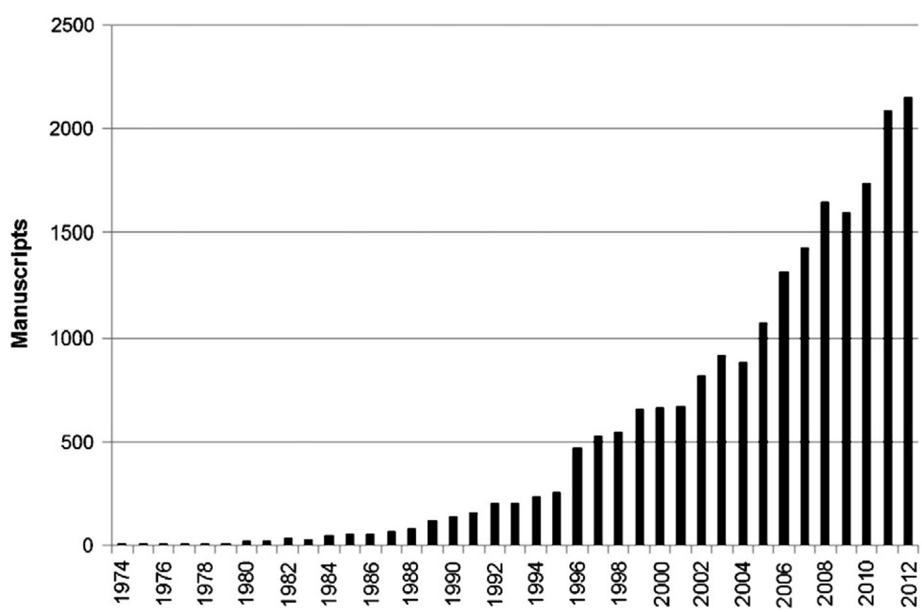

Fig. 2. Number of manuscripts, published by Portuguese and Spanish authors under the terms: "marine biology", or "marine", or "coast", or "estuary", appearing in the abstract, title or keywords, since 1974 (consulted in SCOPUS, on 3rd February 2013).

Table 1
Portuguese and Spanish authors who have published more than 70 papers, within the period 1974–2012, under the terms: "marine biology", or "marine", or "coast", or "estuary", appearing in the abstract, title or keywords, together with the affiliation. Papers: number of papers published on those terms; Total: total number of papers published; Citations: total citations received by the authors; H_{index} of the authors (consulted in SCOPUS, on 3rd February 2013). Key: TM: too many to be consulted.

Authors	Institution	Country	Papers	Total	Citations	H_{index}
Duarte, CM	CSIC-IMEDEA	Spain	196	422	14230	53
Vale, C	Portuguese Institute of Sea and Atmosphere	Portugal	149	178	2686	25
Pardal, MA	U. Coimbra	Portugal	141	178	2752	29
Marques, JC	U. Coimbra-IMAR	Portugal	138	185	3268	31
Cabral, HN	U. Lisbon	Portugal	137	204	2144	25
Costa, MJ	U. Lisbon	Portugal	110	145	1744	23
Albaiges, J	CSIC	Spain	109	197	5335	30
Prego, R	CSIC-IIM	Spain	103	138	1959	24
Botana, LM	U. Santiago de Compostela	Spain	97	231	2876	26
Guedes-Soares, C	Instituto Superior Tecnico	Portugal	96	435	3709	27
Sánchez-Arcilla, A	U. Politécnica de Cataluña	Spain	95	129	727	13
Borja, A	AZTI-Tecnalia	Spain	90	133	3390	31
Medina, R	U. Cantabria	Spain	87	122	684	14
Bayona, JM	CSIC	Spain	85	255	5957	36
Gasol, JM	CSIC-ICM	Spain	84	158	5072	38
Grimalt, JO	CSIC-IDAEA	Spain	84	397	10342	49
Barceló, D	U. Girona	Spain	80	776	TM	70
Gómez Parra, A	U. Cádiz	Spain	78	102	1632	24
Duarte, AC	U. Aveiro	Portugal	77	316	2921	26
Bebianno, MJ	U. Algarve	Portugal	73	126	2693	24
DelValls, TA	U. Cádiz	Spain	72	121	1735	25

eutrophication, etc.), in 3.81%; (vi) fisheries and aquaculture, in 3.29%; (vii) genetics and genomics (molecular and nucleotide sequence, etc.), in 3.27%; and (viii) climate change, in 1.07%.

Despite of the number of published papers in recent years, since 2009 the Iberian countries have experienced an important economic crisis, leading to cut the operational budgets of statutory bodies and universities (in some cases more than 50%). This has resulted in a reduction of monitoring networks, environmental protection and nature conservation (Borja and Elliott, 2013), a reduction of projects funding, PhD students and personnel in universities and research centres and, probably in the near future, will lead to a reduction of the scientific production and publications.

4. Resolution: what for the future?

In this panorama of economic crisis, the European programme 'Horizon 2020' (European Commission, 2012), together with some national initiatives, will be the main instrument for Iberian countries to maintain scientific excellence in the period 2014–2020. This research will be rooted in that which is being done by the authors leading the list in the previous section, including ecotoxicology issues (biological responses to pollutants; adaptability of organisms; etc.), analytic organic chemistry (including pharmaceuticals, new analytical methodologies, etc.), reconstruction of past climate and ecology, molecular analysis of marine microbial food-webs, seagrass and other coastal vegetation, carbon dynamics in land–ocean exchange, functioning of coastal food-webs in relation to hydrography and small-scale physical processes, etc. This research will provide continuation in excellence. But, in addition to those, which could be the main challenges for Iberian marine research in this period? We think that, at some extent, they can be similar to the marine research questions prioritized in several surveys to scientists made recently by Rudd and Lawton (2013), at global scale; Rees et al. (2013), in the United Kingdom; Fissel et al. (2012), in Canada; or the International Council for the Exploration of the Sea (ICES) Draft Science Plan (2014–2018), which we have compared with the Iberian marine research that we propose in the bullets below (Table 4). All of them focus on main challenges regarding global change, biodiversity, management, integrative assessment, conservation or understanding of human impacts on marine ecosystems, among others. Hence, we think that the main challenges for Iberian research are related to those global issues identified everywhere.

4.1. Marine management: a knowledge-based issue

It is well known that research is needed to inform, provide support for and implement existing and future European policies, which must, in any case, encompass different perspectives and apprehensions and account for: (i) the search for human well-being and the maintenance of human health and safety; (ii) the attempt of using marine ecosystem in an ecologically sustainable way; and (iii) the tolerance of these ecosystems to increasing human population pressures and demand for wealth creation (for instance to access sea bottom resources after the United Nations completion of countries continental shelf extension process) (Marques et al., 2009). Hence, knowledge should be transferred towards development of evidence-based policy regulation and management (Minster and Connolly, 2006). Adoption of a knowledge-based approach is required in the elaboration of a range of European maritime policies, whether sectoral (research, energy, fisheries, transport, security) or general (European Maritime Policy). A knowledge-based approach is also required for the implementation of the different Environmental Action Plans and associated thematic strategies, research framework programmes and directives (e.g. Marine Strategy Framework Directive (MSFD, 2008/56/EC), WFD, Common Fisheries Policy, Integrated Coastal Zone Management (ICZM), Marine Spatial Planning and Coastal Management Directive, Natura 2000, etc.). Strengthening the science-base of these and related policies should be an inherent requirement in their implementation (Minster and Connolly, 2006).

4.2. Marine research: a source of jobs?

The European Maritime Policy recognises that the maritime industries and services encompass a wide range of sectoral economic activities, from shipbuilding to shipping and ports, to fisheries and aquaculture, to recreational activities and tourism, to offshore energy exploration and extraction, and to a large number of related technical and economic services. Now, with the world economy facing a deep crisis, perhaps this marine environmental legislation can be a source of technological development and job opportunity in a range of marine sectors. At present, marine economic activities in Iberian mainly focus on tourism and fisheries/aquaculture. We need more technological development (research, scientific-technical, oceanography, exploitation of new energy sources, etc). Hence, as stated by Borja (2011), marine researchers must provide information to these sectors on which different issues

Table 2
Science Citation Index journals in which Iberian authors have published at least 25 manuscripts, within the period 1974–2012 (consulted in SCOPUS, on 3rd February 2013).

Journal	Papers	(%)	Journal	Papers	(%)	Journal	Papers	(%)
Estuarine Coastal and Shelf Science	506	2.35	Journal of Applied Ichthyology	62	0.29	Harmful Algae	38	0.18
Marine Ecology Progress Series	435	2.02	Environmental Microbiology	60	0.28	Journal of Applied Phycology	38	0.18
Marine Pollution Bulletin	372	1.73	Marine Policy	59	0.27	Polar Biology	38	0.18
Hydrobiologia	317	1.47	Water Science and Technology	58	0.27	Revista de Obras Públicas	38	0.18
Scientia Marina	310	1.44	IFAC Proceedings Volumes IFAC P	57	0.26	Bulletin of Marine Science	38	0.18
Journal of Coastal Research	257	1.19	Marine Chemistry	57	0.26	Geologica Acta	37	0.17
J. Marine Biological Association UK	254	1.18	Botanica Marina	56	0.26	Ecotoxicology	36	0.17
Marine Biology	210	0.97	Journal of Environmental Radioactivity	56	0.26	Marine Micropaleontology	36	0.17
Aquaculture	200	0.93	Aquatic Toxicology	56	0.26	Aquatic Conserv. Mar. & Fresh. Ecosystems	36	0.17
Science of the Total Environment	197	0.91	Ecological Modelling	56	0.26	Geological Society Special Publication	36	0.17
Journal of Marine Systems	171	0.79	Water Research	56	0.26	Environmental Geology	36	0.17
J. Exp. Marine Biology and Ecology	169	0.78	Diseases of Aquatic Organisms	55	0.26	Oceanologica Acta	36	0.17
Chemosphere	163	0.76	Environment International	54	0.25	Fresenius Environmental Bulletin	36	0.17
Fisheries Research	161	0.75	Journal of Coastal Conservation	53	0.25	J. Radioanalytical and Nuclear Chemistry	35	0.16
Palaeogeography Palaeoclimatology	157	0.73	Tetrahedron	53	0.25	Crustaceana	35	0.16
Plos One	154	0.71	Earth and Planetary Science Letters	53	0.25	Journal of Molluscan Studies	34	0.16
Continental Shelf Research	144	0.67	Geophysical Research Letters	52	0.24	Journal of Archaeological Science	34	0.16
Boletín Instituto Español Oceanografía	141	0.65	Journal of Natural Products	52	0.24	Atmospheric Research	34	0.16
Proc. Coastal Engineering Conference	139	0.64	Quaternary International	52	0.24	Molecular Phylogenetics and Evolution	33	0.15
Journal of Plankton Research	134	0.62	FEMS Microbiology Ecology	52	0.24	Acta Geologica Hispanica	33	0.15
Marine Environmental Research	131	0.61	Journal of Environmental Monitoring	51	0.24	Journal of Iberian Geology	33	0.15
Marine Geology	125	0.58	Tetrahedron Letters	51	0.24	International Journal of Climatology	33	0.15
Coastal Engineering	121	0.56	Geobios	51	0.24	Biological Conservation	33	0.15
Ciencias Marinas	119	0.55	Bull. of Env. Contamination and Toxicol.	51	0.24	International Journal of Remote Sensing	33	0.15
ICES Journal of Marine Science	115	0.53	Talanta	51	0.24	Journal of Parasitology	33	0.15
Environmental Pollution	110	0.51	Analytical and Bioanalytical Chemistry	51	0.24	Cretaceous Research	33	0.15
Sedimentary Geology	108	0.50	Oceans 2011 I.E. Spain	49	0.23	Proc. Int. Off. & Polar Engineering Conf.	32	0.15
Appl. & Environmental Microbiology	103	0.48	Acta Horticulturae	49	0.23	Science	32	0.15
Environmental Science & Technology	99	0.46	Cahiers De Biologie Marine	49	0.23	Ocean Engineering	31	0.14
Journal of Chromatography A	96	0.45	Journal of Biogeography	48	0.22	Marine Technology and Engineering	31	0.14
Atmospheric Environment	93	0.43	Journal of Phycology	47	0.22	Microbial Ecology	31	0.14
Deep Sea Research Part II	88	0.41	Aquatic Botany	47	0.22	Analytical Chemistry	31	0.14
Ecological Indicators	86	0.40	Tectonophysics	46	0.21	Int. J. Environmental Analytical Chemistry	30	0.14
Aquatic Microbial Ecology	85	0.39	Proc. Int. Society for Optical Engineering	46	0.21	Journal of Hydrology	30	0.14
Ocean and Coastal Management	85	0.39	Marine Drugs	46	0.21	Environmental Science and Pollution Res.	30	0.14
Toxicon	84	0.39	Helgoland Marine Research	45	0.21	Paleoceanography	30	0.14
Analytica Chimica Acta	80	0.37	J. of Geophysical Research Atmospheres	45	0.21	Journal of Shellfish Research	30	0.14
Progress in Oceanography	79	0.37	Europ. Space Agency Sp. Publ. ESA	45	0.21	Journal of Bacteriology	29	0.13
Journal of Sea Research	79	0.37	Int. Geoscience & Remote Sensing Symp.	45	0.21	Desalination	29	0.13
Limnology and Oceanography	79	0.37	Organic Geochemistry	45	0.21	Cybium	29	0.13
J. Geophysical Research C Oceans	77	0.36	Environmental Toxicology and Chemistry	45	0.21	Ardeola	28	0.13
Geomorphology	74	0.34	Estuaries and Coasts	42	0.19	Facies	28	0.13
Journal of Fish Biology	72	0.33	Proc. Int. Conf. Off. Mechanics & Arctic Engin.	42	0.19	Lecture Notes in Computer Science	28	0.13
Ecotoxicology and Environmental Safety	71	0.33	Wit Transactions on Ecol. & Environment	41	0.19	European Journal of Phycology	28	0.13
Env. Monitoring and Assessment	70	0.32	Zootaxa	40	0.19	BMC Evolutionary Biology	28	0.13
Molecular Ecology	68	0.32	Geo Marine Letters	40	0.19	Aquatic Living Resources	28	0.13
Boletín Geológico y Minero	66	0.31	Bolleti Societat Historia Natural Balears	40	0.19	Journal of Agricultural and Food Chemistry	27	0.13
Arch. Env. Contamination and Toxicol.	65	0.30	Proc. National Academy of Sciences USA	40	0.19	Holocene	27	0.13
Quaternary Science Reviews	65	0.30	Systematic and Applied Microbiology	40	0.19	Parasitology Research	27	0.13
Marine Ecology	63	0.29	Aquaculture Research	39	0.18	Biological Journal of the Linnean Society	27	0.13
Deep Sea Research Part I	63	0.29	Sedimentology	39	0.18	Bioresource Technology	26	0.12
Acta Oecologica	62	0.29	Natural Hazards and Earth System Science	39	0.18	Others	11769	54.57
Int. J. of Systematic and Evolutionary Microbiology	62	0.29	Biological Invasions	39	0.18	Total	21565	100.00
Water Air and Soil Pollution	62	0.29	Nature	38	0.18			

within this legislation worldwide need technological development supported with job opportunities. This author proposes a series of thematic areas to which marine research can play an active role in developing new products.

4.3. The ecosystem-based approach: a challenge for integration

As commented above, Portuguese and Spanish scientists have played an important role in implementing the WFD (an example can be seen in the number of assessment methods developed in these countries: Birk et al. (2012)). Now, they are also participating in implementing the MSFD, in which the main objective is to maintain a good environmental status for marine waters, habitats and resources, delivering an integrated ecosystem-based approach. The need of studying multiple components of the ecosystem, together with the integration of the information, makes the MSFD as an important area of research (Borja et al., 2011). In this particular case, while we have a good knowledge of the structural aspects of marine systems and associated study methods (see Birk et al., 2012), our knowledge of the ecosystem functioning, resilience and threshold effects is scarce and the methods and indices for their study are more uncertain and require to be investigated (Borja et al., 2010a; Folke et al., 2002). In addition, the use of models (e.g. hydrodynamic, habitat suitability models, ecosystem models, etc.) will be of importance for an adequate management of marine waters.

4.4. Human activities and impacts to the ecosystem: need of a Marine Spatial Planning

Human activities are producing increasing impacts in marine ecosystems (Halpern et al., 2008), which usually are cumulative and need

Table 3
Most frequent keywords used by Portuguese and Spanish scientists, between 1974 and 2012 (consulted in SCOPUS, on 3rd February 2013).

Keywords	Papers	(%)	Keywords	Papers	(%)	Keywords	Papers	(%)
Animal(s)	3446	6.80	Seasonal variation	578	1.14	Heavy metals	402	0.79
Water pollutants(tion)	2501	4.93	Oceanography	571	1.13	Species diversity	396	0.78
Coastal zone(s)/waters	2154	4.25	Taxonomy	559	1.10	Chemistry	394	0.78
Mediterranean Sea	1933	3.81	Bioaccumulation	550	1.08	Community structure	391	0.77
Estuary(es)-environment	1903	3.75	Climate change	542	1.07	Sampling	373	0.74
Sediment(s)	1882	3.71	Metabolism	536	1.06	Upwelling	369	0.73
Atlantic Ocean	1785	3.52	Copper	517	1.02	Temperature	367	0.72
Seawater	1681	3.32	Salinity	503	0.99	Diet	362	0.71
Environmental monitoring	1408	2.78	Nucleotide sequence	499	0.98	Coastal lagoon	355	0.70
Fish-Pisces	1370	2.70	Lead	464	0.92	Physiology	339	0.67
Algae	1228	2.42	Numerical model	452	0.89	Computer simulation	336	0.66
Marine environment	1168	2.30	Morphology	450	0.89	Eutrophication	335	0.66
Bacteria	1102	2.17	Seashore	449	0.89	Sedimentation	325	0.64
Ecosystem(s)	901	1.78	Environmental impact	446	0.88	Anthropogenic effect	319	0.63
Concentration	874	1.72	Ecology	444	0.88	Chlorophyll	314	0.62
Mollusca	864	1.70	Zinc	441	0.87	Organic matter	312	0.62
Crustacea(n)	816	1.61	Genetics	438	0.86	Primary production	300	0.59
Molecular sequence	724	1.43	Water quality	436	0.86	Aquaculture	297	0.59
Biomass	701	1.38	Spatial distribution	431	0.85	Seagrass	296	0.58
Biodiversity	686	1.35	Mathematical model	421	0.83	Remote sensing	291	0.57
Growth (rate)	654	1.29	Benthos	407	0.80	Nitrogen	288	0.57
Abundance	645	1.27	Hydrodynamics	407	0.80	Risk assessment	286	0.56
Phytoplankton	602	1.19	Cadmium	406	0.80	Carbon	280	0.55
Phylogeny	592	1.17	Coastal engineering	402	0.79			

research to conserve and manage the oceans (Ban et al., 2010). In addition, the increasing human uses of marine waters (e.g. fisheries, aquaculture, shipping, renewable energies, recreation, mining, etc.) has promoted the discussion about how to appropriately manage the simultaneous need to conserve marine resources and keep our current essential uses (Collie et al., 2013). The approach to find a balance of these two aims is the Marine Spatial Planning (Ehler and Douvere, 2009). With the adoption of the new European Marine Spatial Planning and Coastal Management Directive (now in draft), this will be a field of research which is increasing very fast (Qiu and Jones, 2013; Stelzenmüller et al., 2013; Suárez de Vivero and Rodríguez Mateos, 2012).

4.5. Ecosystem services: is there a price for using marine resources?

It is well known that marine ecosystems provide numerous goods and services (Barbier et al., 2012), such as biogeochemical services (e.g. carbon sequestration), nutrient cycling, coastal protection (e.g. provided by coral reefs), food provision, etc. (Costanza et al., 1997). Despite the important role of such goods and services, their study and their associated monetary value is still limited and, although some studies have been undertaken in Iberian seas (e.g. Murillas-Maza et al., 2011; Pinto et al., 2013a, 2013b) much more research is needed for a better management of the oceans.

4.6. From fisheries to aquaculture

Spain and Portugal have good research records in fisheries. Since the 1980's both countries, and especially Spain, are leading some aquaculture production, in shellfish and fishes. In this way, Iberian scientists have been involved in different topics of aquaculture research, from new species, new products, better production practices, to environmental impacts. Now, there is also place to investigate the reduction of impacts and implement new sustainable aquaculture methods, including multitrophic approaches (Aguado-Giménez et al., 2012; Quintino et al., 2012; Ruiz et al., 2010; Sanz-Lázaro and Marín, 2006), and the adaptation both of fisheries and aquaculture to climate change (Merino et al., 2012).

4.7. Global change: from studying impacts to adaptation and mitigation

The oceans are changing rapidly due to human actions (Halpern et al., 2008). Surface waters are warming, sea-level rise is accelerating

Table 4
Some key research topics identified in recent times at different scales. ICES: International Council for the Exploration of the Sea (ICES).

Research topics	European Commission (2012)	ICES (2013)	Rees et al. (2013)	Fissel et al. (2012)	Rudd and Lawton (2013)	This paper
	Europe	Europe	United Kingdom	Canada	Global topics	Iberian
Marine observation, data collection, monitoring	X	X	X	X	X	X
Climate change adaptation	X			X		X
Informing management and governance	X		X	X	X	X
Ecosystem processes and dynamics		X		X	X	
Ecosystem pressures and impacts		X		X		
Integrated ecosystem-based assessment		X				X
Ecosystem services			X			X
Marine Spatial Planning			X		X	X
Maritime policy and citizenship			X		X	X
Marine conservation			X			X
Contaminants					X	
Mineral resource extraction					X	
Fisheries and aquaculture						X
Restoration						X

and the oceans are becoming increasingly acidic. These 'new' anthropogenic factors are affecting marine ecosystems in the Iberian Peninsula (Chust et al., 2011; Gómez-Gesteira et al., 2011; Vargas Yáñez et al., 2008) which, in many areas, have already been significantly weakened by overfishing, contamination, invasive species and other human-induced influences. Such factors will introduce changes in communities' composition and probably in food webs and ecosystems stability, resilience, and functioning. However, our understanding of the linkages between anthropogenic disturbances, biological diversity, ecosystem services, functionality, and the resilience of marine ecosystems needs to be improved (Narayanaswamy et al., 2013; Pinto et al., 2013b). In fact, for some ecosystem components such as macroalgae, investigating the combined effects of human pressures (e.g., exploitation and wastewater discharges) and environmental variables (e.g., light, waves, temperature), over long-term series, Borja et al. (2013) demonstrated that, in impacted areas macroalgae are more vulnerable to environmental changes and its resilience is more reduced. Currently, there is an insufficient policy, inadequate research and management funding, and gaps in scientific knowledge. For example, it will be necessary for future marine research to increase knowledge on the combined effects of concurrent climate and non-climate stressors and their effects on species interactions and responses at assemblage and ecosystem levels (Olabarria et al., 2012; Wernberg et al., 2012). Intensive monitoring is also a precondition for the further development of coupled ecosystem-global change models, as demonstrated by the above example of macroalgae in Spain. In addition, development of models, scenarios and adaptation measures to global changes are also needed (Ciscar et al., 2011; Nicholls et al., 2012; Tobey et al., 2010).

4.8. Restoration: recovering structure and functioning

Iberian coasts and estuaries have experienced important degradation throughout the 20th Century (Marcos et al., 2009). Hence, ecological restoration is becoming an increasingly important tool to manage, conserve, and repair damaged ecosystems, with significant advances in the past few decades (Hobbs, 2007). Therefore, measuring restoration at community level is neither fast nor easy, and requires a focus on restoration of community function, e.g., habitat reconstruction, species interactions, trophic structure, rather than a focus on the restoration of particular species (Borja et al., 2010b; Verdonschot et al., 2013). Thus, restoration efforts should rely on what is known from theoretical and empirical research on how communities develop and are structured through time. Some areas of community theory (e.g. dispersal/colonisation dynamics, patch dynamics, metapopulations theory) and recovery processes are poorly understood and thus research in these areas will benefit both basic ecology and restoration practices, providing evidence of how this ecological knowledge might enhance restoration success (Verdonschot et al., 2013). Further research is also needed to identify restoration thresholds and develop corrective methodologies to overcome such thresholds.

4.9. Conservation: Marine Protected Areas as important management tools

Marine Protected Areas (MPAs) are an important tool for enhancing the resilience and adaptive capacity of ecosystems (García-Charton et al., 2008). They are also important because they allow mitigation of anthropogenic factors, such as overfishing or habitat destruction within their boundaries, by means of management or prohibition (Mumby et al., 2006). Not only MPAs, but also protection of near-natural ecosystems is a very good strategy for managing climate change-related stressors and biodiversity (Heller and Zavaleta, 2009).

Probably, in addition to the abovementioned research priorities, other research needs could be raised in coming years by the Iberian scientific community. In this Special Issue there are some examples of such new topics, which show the evolution and quality of Iberian investigation in recent years. However, as Bernard de Chartres (13th Century) said, we build science over the shoulder of giants, represented by those individuals who, after the 15th Century sailed the world seas, looking for new opportunities. We are convinced that this is now the opportunity for the Iberian research: make it every day more international and more excellent.

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