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Marxan as a Tool for Systematic Conservation Planning in Seascape — A Chronological Review

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ABSTRACT

This paper reviews the major contributions to the systematic conservation planning in seascape with Marxan software throughout a 12-year period from 2004 up to 2015. After surveying many papers in this field, the volume of the existing works is identified and classified. The paper summarizes all of the reviewed papers in two tables. These tables determine the region of study, year of study, selected information for planning, and main contributions in papers. The socio-economic information along with the biophysical information is considered in the majority of papers for planning, which shows the vital function of this information for decision. It is also demonstrated that more attention is paid to systematic conversation planning using toolboxes based on optimization algorithm such as Marxan in recent years. It concludes with comparative graph demonstrating the frequency of applying Marxan software in systematic conservation planning in seascape. So, it can be used as a guideline for researchers in this field.

INTRODUCTION

Preserving wildlife habitats and populations is performed by the protection of representative natural areas. It is impractical to expect protection for all places to conserve biodiversity, because it would essentially need the protection of the entire planet. The prioritization of sites and then selection of the most representative areas for protection are the suitable alternative to solving this problem [1]. The determined areas should meet the overall goals of systematic conservation planning such as representativeness and persistence. Currently, most of the protected areas have been chosen by a non-systematic approach. The selection of such areas is powered by economic and political considerations which are not totally based on their ecological value. The economic value of many of these areas is relatively low. The goals and criteria for protection usually differ from the goals of the residents of candidate sites or their periphery for protection [2]. Considering all the criteria and goals as well as selecting the largest, most complete, and most integrated areas for protection are the best approach [3].

Several systematic approaches are introduced to aid the selection of a network of biologically diverse protected areas [4]. Using artificial intelligence is one of these approaches. Computer algorithms are employed by this approach to calculate objective functions and find the best network of areas to be protected and these areas have a high conservation value[2]. The optimal and heuristic algorithms are main types of site selection algorithm. The complex mathematical processes (linear programming) which are used by optimal algorithms against heuristic algorithms use a simple procedure to obtain optimal solutions [5]. The selection of the protected area is performed by several heuristic algorithms. One of the most common heuristic algorithms for optimization and spatial arrangement of suitable sites is simulated annealing (SA) [6]; this algorithm has a multi-dimensional space which is described in terms of objectives and different options are generated that accommodate multi-dimensional goals. At last, areas that meet the objectives are chosen [3]. This algorithm is used in scientific software named Marxan [7] for determining the priority of protected areas and spatial management of sites. Marxan is the most widely used conservation planning software in the world and is provided for solving complex conservation planning problems in landscapes and seascapes. Marxan provides a flexible approach capable of incorporating large amounts of data and using categories. It is computationally efficient and lends itself well to enabling stakeholder involvement in the site selection process [7].

This paper reviews the works in which Marxan software is used as a tool for systematic conservation planning in seascape.

APPLICATION OF MARXAN FOR SYSTEMATIC CONSERVATION PLANNING IN SEASCAPE

Marine protected areas (MPAs) aim to manageand protect marine environments. However, their design often disregards both the thorough knowledge of the distribution of habitats and assemblage and the use of proper experimental evaluations of the efficacy of MPAs by comparing protected versus unprotected zones [8].

In Tognelli [9], complementarily analyses were performed to identify priority areas for the conservation of all coastal marine vertebrate species in Chile (265 species) and congruence was evaluated among the different target groups. Also, near-minimum area sets were calculated for all vertebrate species, for endemic species, for threatened species, and for each taxonomic group independently (mammals, birds, reptiles, and fish). Complementarily analyses were performed using Marxan software.

Using information on the spatial distribution and intensity of commercial rock lobster catch in South Australia, in Stewart [10], the capacity of mathematical reserve selection procedures to integrate socio-economic and biophysical information for marine reserve system design was demonstrated. Analyses of trade-offs highlighted the opportunities to design representative, efficient, and practical marine reserve systems that could minimize potential loss to commercial users.

In Loos [11], the UK's Joint Nature Conservancy Council's(JNCC) Marxan analysis of 19 environmental, biological, and anthropogenic datasets resulted in a map of the minimum protected area which was recommended to meet conservation targets for nationally important marine wildlife.

Alpine and Hobday [12] described the use of the conservation planning software Marxan to assist in developing a pelagic MPA network along Australia's east coast. The primary goal of the MPA network was to protect five pelagic species targeted by the eastern Australian tuna and billfish long line fishery as well as providing ecosystem-wide protection from negative fishery impacts.

In Banks [13], "shoreline types", derived using physical properties of the shoreline, were used as a surrogate for intertidal biodiversity to assist the identification of sites to be included in a representative system of marine reserves. The use of local-scale shoreline types increased the likelihood by which the sites identified for conservation achieved representation goals for the mosaic of habitats and microhabitats and, therefore, the associated biodiversity present on rocky shores, compared with the one provided by the existing marine reserve protection. Marxan was used to identify potential combinations of shoreline types that should be included in a representative system of marine reserves.

In Ban NC [14], the decision support tool Marxan was applied to a reef system in the central Philippines where 30 MPAs were established in communities without much use of biophysical data. The intent was to explore how Marxan might assist the legally required expansion to protect 15% of marine waters and how the existing MPAs might affect that process.

In Christensen [15], two approaches were described for the spatial optimization of protected area placement, both of which were based on maximizing an objective function that incorporated ecological, social, and economical criteria. Of these, a seed cell selection and the other was a Monte Carlo approach. The results were compared with Marxan, a priority-selection decision-support tool based on optimization algorithms using geographic information system data.

In Tognelli [16], the most comprehensive information currently available on the distribution of 2513 marine species in Chile by Marxan was used to assess the efficiency of the existing system of MPA and the conservation priority sites identified by the government. Additionally, the vulnerability of the reserve network selected with respect to threatening human activities was evaluated. The results showed that both the existing protected areas and the proposed priority sites were relatively effective for protecting Chilean marine biodiversity. Marine protected area (MPA) networks designed without the consideration of the interests of local communities were likely to fail.

In Loos [17], the experimentation with various Marxan settings using the Southern Strait of Georgia, British Columbia, Canada, was reported as a study area and interviews were conducted with zoning practitioners, in the context of developing Marxan as a decision support tool for MPA zoning.

In Smith [18], a decision support tool (Marxan) was applied for marine protected area design in two regions of British Columbia, Canada, and sequentially the datasets with the most limited geographic distribution was excluded. It was found that the reserve selection method was robust to some missing datasets. The removal of up to 15 of the most geographically limited datasets did not significantly change the geographic patterns of the importance of areas for conservation.

The Marxan tool has been used for the design of multiple-use marine parks in Europe [19], North America [20], Western Australia [21] Africa [22], and Indonesia [23].

In Weeks [24], the effects of including different surrogates for small-scale fishing effort in the systematic design of an MPA network for Siquijor Province in the Philippines were investigated. The paper compared a reserve selection scenario in which socioeconomic data were not considered with four different surrogates for fishing effort and with empirical data on the spatial distribution of fishing effort collected through interviews. The paper used the conservation planning software Marxan to identify MPA networks that fulfilled a conservation objective while minimizing foregone opportunity costs to small-scale fishers.

In Osmond [25], three processes to establish MPAs within the United States and Australia by Marxan software were compared and reviewed. These two countries share many similarities in their cultures, but their approaches to managing marine resources differ considerably. Systematic approaches to site selection for marine protected areas (MPAs) are often favored over opportunistic approaches as a means to efficiently meet conservation objectives.

In Loos [26], Marxan was explored as a decision support tool for MPA zoning. It aims to answer two questions: Can the use of Marxan be streamlined and thereby remove some of the guesswork associated with its use? And how can zone configurations be developed to incorporate large amounts of data and stakeholder opinions while being transparent, repeatable, and scientific? Also, the experimentation with various Marxan settings using the Southern Strait of Georgia, British Columbia, Canada, was reported as a study area and interviews were conducted with zoning practitioners, in the context of developing Marxan as a decision support tool for MPA zoning.

In Lotter [27], Good Practices Handbook was introduced.

In Hansen [28], the authors analytically compared the conservation value of systematic and opportunistic approaches for site selection. They located this study in Danajon Bank, central Philippines, where many MPAs were established opportunistically based on community preference, with few if any contributions from biophysical data. In this paper, Marxan was the tool for systematic analysis.

The authors in Adams [29] presented a novel method for calculating the opportunity costs to fishers from their displacement by establishing marine protected areas (MPAs). They used a fishing community in Kubulau District, Fiji, to demonstrate this method. They modeled opportunity costs as a function of food fish abundance and probability of catch based on gear type and market value of species. They included our opportunity cost model in Marxan, a decision support tool used for MPA design, to examine the potential MPA configurations.

In Rosendo [30], an important research initiative aimed to improve marine conservation planning in East Africa with a focus on border regions between Tanzania, Mozambique, and South Africa. This paper mapped marine habitats on the borders of these countries using Landsat 5TM satellite imagery and sought to assess the biodiversity in key habitats, identify biodiversity hotspots and critical habitats, including nursery grounds and spawning aggregations, and assess the relative contribution of each habitat to ecological functioning at the regional scale. Considering socio-economic factors, the data were analyzed in Marxan software.

In Giakoumi [31], priorities for the location of marine reserves were determined using spatial prioritization by Marxan software in the eastern Mediterranean Sea. Also, biophysical data from visual census surveys on fish species abundance, presence of various habitat types, and percent coverage of sea grasses and canopy algae, were used. Efficient conservation planning requires spatially explicit information on how proposed management will affect stakeholders, which in this region was very limited. It created novel socio-economic cost indices to account for fisheries and tourists.

In Delavenne [32], an investigation was conducted on whether the choice of software could influence the location of priority areas by comparing outputs from Marxan and Zonation, two widely used conservation-planning, decision-support tools. Using biological and socio-economic data from the eastern English Channel, the outputs were compared and it was shown that the two software packages identified similar sets of priority areas although the relatively wide distribution of considered habitat types and species offered much flexibility.

Systematic planning, using algorithm tools, can improve biodiversity representation in "no-take"zones in a marine park while reducing costs of meeting conservation targets. In Malcolm HA [33], the current zoning plan for the Solitary Islands Marine Park, designed without algorithm tools, provided an example to compare the efficiency of zoning scenarios that included or ignored the existing zoning scheme and to assess the utility of habitat and/or biotic data for planning. Marxan was used to compare the representation of habitat categories and a selection of fish species using 3 scenarios.

In Juliette Delavenne [34], the systematic conservation planning was performed in the eastern English Channel. In this reference, the Marxan tool was compared with Zonation decision-support tool.

The boundaries of 19 Marine Protected Areas were designated by the Government in South Australia. These boundaries were decided on by a lengthy and detailed procedure of scientific and government discussion and public participation. In Kirkman

[35], 14 design principles used to make decisions on these boundaries were defined. The Delphic approach was the main method used, but the computer modeling program Marxan added some insights to MPA boundaries.

Seagrass beds are of exceptional economic, ecological, and social value in the Coral Triangle. The large number of people who live close to the coast and rely directly on marine resources for food and income paradoxically increases the value of, but also the threats to, these ecosystems. A key strategy of the Coral Triangle Initiative is to protect shallow coastal ecosystems through the design and implementation of resilient networks of marine protected areas (MPAs). In Torres-Pulliza [36], eco-regional scale sea grass mapping was confirmed as a tool to support resilient MPA network design by Marxan software in the Coral Triangle.

Coral reefs are threatened by human activities both on the land and in the sea. However, standard approaches for prioritizing locations for marine and terrestrial reserves neglect to consider connections between ecosystems. In Makino [37], an integrated approach was demonstrated for coral reef conservation with the objective of prioritizing marine reserves close to catchments with high forest cover in order to facilitate ecological processes that rely upon intact land–sea protected area connections and minimize negative impact of land-based runoff on coral reefs. In this reference, Marxan software was the tool for MPA network design.

The aim of reference Grantham [38] was to identify different zoning configurations for the Raja Ampat MPA network in Eastern Indonesia that addressed biodiversity, sustainable fisheries, and community resource access objectives. Identifying zoning configurations is particularly difficult here given the importance of protecting high biodiversity reefs and other conservation values, and the high reliance of local communities on their marine resources. MPA network was designed by Marxan software.

Marine protected areas (MPA) are rapidly being established to minimize the impact of anthropogenic disturbances; yet, while climate change is acknowledged as a growing threat, very limited research exists about how to directly incorporate climate-related disturbances into MPA design. In Levy JS [39], using the conservation planning software Marxan and the Indo-west Pacific as a study region, an illustrative approach was developed that incorporated climate change projections into the process of identifying priority areas for marine conservation.

Reference Peckett [40] aimed to evaluate the effectiveness of currently available substrate data to designate marine reserves in order to meet conservation objectives. The case study site was Lyme Bay in the western English Channel and the aim was to protect reefs which were an important habitat for pink sea fan. The effects of using different substrate data resolution on the selection of sites to protect a range of biotopes using the Marxan package were determined. The effect of including a closed area on the efficiency of a marine reserve network was also investigated.

In Ban [41], the meta-analysis of ecological effectiveness of IUCN Categories I–II (no-take), IV, and VI (MPAs) compared with the unprotected areas was carried out. Then, its ecological effectiveness estimates – the added benefit of marine protection over and above the conventional fisheries management – was applied to the gap analysis of the existing MPAs and the MPAs proposed by four indigenous groups on the Central Coast of British Columbia, Canada. A decision support tool, Marxan, was also used to identify conservation priorities that could fill any gaps in the current and proposed MPA representation.

In Mills [42], three potential contributions of social network analysis were discussed for systematic conservation planning: identifying stakeholders and their roles in social networks and characterizing relationships between them; designing and facilitating strategic networking to strong then linkages between local and regional conservation initiatives; and prioritizing conservation actions using measures of social connectivity alongside ecological data by Marxan tool.

In Gonzalez-Mirelis [43], vessel monitoring system (VMS) data were used to map the distribution of prawn trawling and calculate fishing intensity for 1-ha grid cells in the Kosterhavet National Park (Sweden). Then, the software Marxan was used to generate cost-efficient reserve networks that represented every biotope in the Park. It asked what the potential gains and losses in terms of fishing effort and species conservation of different planning scenarios were.

In Ruiz-Frau [44] the focuses was on Wales (UK) and the systematic conservation software Marxan with Zones was used to quantify the benefits of integrating extractive and non-extractive interests in the planning process of MPAs and assess whether the impacts on affected users differed between MPAs of single versus multiple zones.

Reference Ruiz-Frau [45] was aimed to assess, compare, and integrate two different approaches to the planning process of MPAs in Wales (UK). A stakeholder-based approach and a science-based systematic approach were compared. Stakeholder priorities for the establishment of MPAs were identified during individual interviews with relevant stakeholders' representatives. Science-based solutions were developed using biological and socioeconomic spatial data in the decision support tool Marxan.

Complementation analysis in Yamakita [46] by Marxan was originally used to prioritize the protected area by maximizing the number of species to be conserved while minimizing the number of sites. Because Marxan solves the proximity of the combinational optimization problem, it can be also used to evaluate suitable locations to maximize the total points of the 7 different criteria within a limited number of selected sites. Regarding methods for the quantitative evaluation of each criterion and their integration, application of these methods to keep forest ecosystems in Hokkaido, Northern Japan, is presented as a case study.

In Yates [47], empirical data and Marxan planning software were used to identify priority areas for multiple ocean zones, which incorporated goals for biodiversity conservation, two types of renewable energy, and three types of fishing. This paper developed an approach to evaluate trade-offs between industries and investigated the impacts of co-locating some fishing activities within renewable energy sites.

The U.S. is adopting a Marine Spatial Planning (MSP) approach to address conflicting objectives of conservation and resource development and usage in marine spaces. At this time, MSP remains primarily as a concept rather than a well-defined framework; however, expanding anthropogenic impacts on coastal and marine areas reinforces the need to adopt an MSP approach to manage societal demands while preserving the marine environment. In Stamoulis [48], a review of the current literature revealed the available technological and methodological tools such as Marxan that were best suited for marine spatial planning and areas were suggested for further research in order to better inform this process in the U.S.

Marine spatial planning and marine zoning hold great promises for addressing and balancing a number of marine management objectives in St. Kitts and Nevis under a common framework. In Agostini [49], the key activities leading to the development of a draft marine zoning design for St. Kitts and Nevis by Marxan tool were outlined and outcomes of the planning process and possible next steps towards the implementation of a marine zoning plan were discussed.

In Lopez [50], Marxan tool for identifying key areas for sea turtle nesting along the coast northern coast of Bahia in Brazil was presented. A Sensitivity Map was created using a detailed GIS map graded by colors representing relevance levels of the coast for sea turtle nesting. From this map, recommendations of management practices corresponding to each sensitivity category could be made.

In Metcalfe [51], an approach to addressing many issues by identifying a series of MPA networks was explored using the Marxan and Marxan with Zones conservation planning software and linking them with a spatially explicit ecosystem model developed in Ecopath with Ecosim. Then, they were used to investigate the potential trade-offs associated with adopting different MPA management strategies.

There is already a database full of geo-referenced information about marine habitat distribution, communities, endangered species, and human activities around La Palma (Canary Islands, Spain). In Martín-García [52], this information was analyzed using GIS tools and the algorithm Marxan and then seven alternative MPA zones were presented in the sublittoral environments around La Palma. It was the first time that an objective and systematic process, combining knowledge about human activities as well as conservation status, was used to establish the suitable placement of MPAs in the Canary Islands.

Tables 1 and 2 show the summery of the reviewed papers. **Table 1** describes case study region and type of information for systematic conservation planning and **Table 2** illustrates the main contribution in these papers.

Table 1. Case study region and type of information for systematic conservation planning in reviewed.

Authors	Year	region	Selected Information for Planning
F. Marcelo etal.	2005	Chile	biophysical
R. Romola etal.	2005	South Australia	socio-economic and biophysical
S. A. Loos	2006	England	biological, and anthropogenic
J.E. Alpine etal.	2007	Australia’s east coast	socio-economic and biophysical
A. Banks etal.	2007	-	biophysical
N. C. Ban etal.	2009	Central Philippines	biophysical
V. Christensen etal.	2009	-	socio-economic and biophysical
M. F. Tognelli etal.	2009	Chile	biophysical
S. A. Loos etal.	2009	Georgia, British Columbia, Canada	biophysical
N. C. Ban etal.	2009	British Columbia, Canada	biophysical
R.J Smith etal.	2009	Europe	--
N. C. Ban	2009	North America	-
C.J Klein etal.	2009	North America	-
M.E. Watts etal.	2009	Western Australia	-
T. N. C. Global Marine Team	2009	Indonesia	-
R. Weeks etal.	2010	Siquijor Province, Philippines	socio-economic and biophysical
M. Osmond etal.	2010	United States and Australia	socio-economic and biophysical
S. A. Loos etal.	2010	Georgia, British Columbia, Canada	socio-economic and biophysical
G. J. A. Hansen etal.	2011	Danajon Bank, central Philippines	socio-economic and biophysical

V. M. Adams etal.	2011	Kubulau District, Fiji	socio-economic and biophysical
S. Rosendo etal.	2011	border regions between Tanzania, Mozambique and South Africa	socio-economic and biophysical
S. Giakoumi etal.	2011	eastern Mediterranean Sea	socio-economic and biophysical
J. Delavenne etal.	2011	eastern English Channel	socio-economic and biophysical
H.A. Malcolm etal.	2012	Solitary Islands Marine Park	biophysical
T.F. Allnutt etal.	2012	Africa	--
T.F. Allnutt etal.	2012	Indonesia	-
J Delavenne etal.	2012	eastern English Channel	socio-economic and biophysical
H. Kirkman	2013	South Australia	socio-economic and biophysical
D. Torres-Pulliza etal.	2013	-	socio-economic and biophysical
A. Makino etal.	2013	-	biophysical
H. S. Grantham etal.	2013	Raja Ampat, Eastern Indonesia	socio-economic and biophysical
J. S. Levy etal.	2013	Indo-west Pacific	biophysical
F. J. Peckett etal.	2014	Lyme Bay, western English Channel	biophysical
N. C. Ban etal.	2014	Central Coast of British Columbia, Canada	socio-economic and biophysical
M. Mills etal.	2014	-	socio-economic and biophysical
G. Gonzalez-Mirelis etal.	2014	Kosterhavet National Park, Sweden	socio-economic and biophysical
A. Ruiz-Frau etal.	2015	Wales, UK	socio-economic and biophysical
T. Yamakita etal.	2015	Hokkaido, Northern Japan	biophysical
K. L. Yates etal.	2015	-	socio-economic and biophysical
K. A. Stamoulis etal.	2015	-	-
V. N. Agostini etal.	2015	St. Kitts and Nevis	socio-economic and biophysical
G. G. Lopez etal.	2015	coast northern coast of Bahia in Brazil	biophysical
K. Metcalfe etal.	2015	-	biophysical
L. Martín-García etal.	2015	La Palma,Canary Islands, Spain	socio-economic and biophysical

Table 2. The main contribution for systematic conservation planning in reviewed papers.

Authors	Main contribution
F. Marcelo etal.	Finding near-minimum area sets for all vertebrate species
R. Romola etal.	Creating opportunities to design representative, efficient and practical marine reserve systems
S. A. Loos	resulted in a map of the minimum protected area
J.E. Alpine etal.	protecting five pelagic species targeted by the eastern Australian tuna and billfish long line fishery
A. Simon etal.	identifying potential combinations of shoreline types that should be included in a representative system of marine reserves
N. C. Ban etal.	Exploring how Marxan might assist with the legally required expansion to protect 15% of marine waters
V. Christensen etal.	Comparing a seed cell selection and Monte Carlo approach for spatial optimization of protected area placement
M. F. Tognelli etal.	evaluating the vulnerability of the reserve network selected with respect to threatening human activities
S. A. Loos etal.	reports on experimentation with various Marxan settings
N. C. Ban etal.	Founding that the reserve selection method was robust to some missing datasets.
R.J Smith etal.	the design of multiple-use marine parks
N. C. Ban	the design of multiple-use marine parks
C.J Klein etal.	the design of multiple-use marine parks
M.E. Watts etal.	the design of multiple-use marine parks
T. N. C. Global Marine Team	the design of multiple-use marine parks
R. Weeks etal.	investigating the effects of including different surrogates for small-scale fishing effort in the systematic design of an MPA network
M. Osmond etal.	comparing and reviews three processes to establish MPAs within the United States and Australia
S. A. Loos etal.	reports on experimentation with various Marxan settings
G. J. A. Hansen etal.	establishing MPA based on community preference, with contributions from biophysical data
V. M. Adams etal.	Presenting a novel method for calculating the opportunity costs to fishers from their displacement by the establishment of marine protected areas

S. Rosendo etal.	Mapping marine habitats regarding to assess the biodiversity in key habitats; identify biodiversity hotspots and critical habitats, and assess the relative contribution of each habitat to ecological functioning at the regional scale.
S. Giakoumi etal.	determining priorities for the location of marine reserves using spatial prioritization
J. Delavenne etal.	investigating into whether the choice of software influences the location of priority areas by comparing outputs from Marxan and Zonation
H.A. Malcolm etal.	comparing the efficiency of zoning scenarios that include or ignore the existing zoning scheme
T.F. Allnutt etal.	the design of multiple-use marine parks
T.F. Allnutt etal.	the design of multiple-use marine parks
J Delavenne etal.	investigating into whether the choice of software influences the location of priority areas by comparing outputs from Marxan and Zonation
H. Kirkman	Defining 14 Design Principles used to make decisions on boundaries of MPA.
D. Torres-Pulliza etal.	Confirming that eco regional scale sea grass mapping can be as a tool to support resilient MPA network design in the Coral Triangle.
A. Makino etal.	demonstrating an integrated approach for coral reef conservation with the objective of prioritizing marine reserves close to catchments with high forest cover
H. S. Grantham etal.	Identifying zoning configurations with considering the importance of protecting high biodiversity reefs and other conservation values, and the high reliance of local communities on their marine resources
J. S. Levy etal.	incorporating climate change into the process of identifying priority areas
F. J. Peckett etal.	Determining the effects of using different substrate data resolution on the selection of sites to protect a range of biotopes
N. C. Ban etal.	Carrying out a meta-analysis of ecological effectiveness of IUCN Categories I–II (no-take), IV and VI (MPAs) compared to unprotected areas.
M. Mills etal.	discussing potential contributions of social network analysis to systematic conservation planning
G. Gonzalez-Mirelis etal.	Calculating the potential gains and losses in terms of fishing effort and species conservation of different planning scenarios.
A. Ruiz-Frau etal.	quantifying the benefits of integrating extractive and non-extractive interests in the planning process of MPAs
A. Ruiz-Frau etal.	integrating stakeholder-based approach and a science-based systematic approach to the planning process
T. Yamakita etal.	prioritizing the protected area by maximizing the number of species to be conserved while minimizing the number of sites
K. L. Yates etal.	developing an approached to evaluate trade-offs between industries and investigating the impacts of co-locating some fishing activities within renewable energy sites
K. A. Stamoulis etal.	reviewing of the current literature reveals the available technological and methodological tools such as Marxan that are best suited for marine spatial planning
V. N. Agostini etal.	outlining the key activities that led to the development of a draft marine zoning design
G. G. Lopez etal.	A Sensitivity Map was created, using a detailed GIS map graded by colors representing relevance levels of the coast for sea turtle nesting.
K. Metcalfe etal.	identifying a series of MPA networks using conservation planning software and linking them with a spatially explicit ecosystem model
L. Martín-García *etal*.	analyzing socio-economic and biophysical information, using GIS tools and the algorithm Marxan, and presented seven alternative MPA zones in the sublittoral environment

CHRONOLOGICAL ANALYSIS

Totally, 56 papers were surveyed in this paper, covering the sufficient depth of works in the systematic conservation planning with Marxan in the seascape field for the time span of 2004 to 2015. **Figure 1** shows the percentage of the published papers about systematic conservation planning in seascape versus a one-year period from 2004 up to 2015. It can be surveyed that, in 2009 and 2015, the maximum number of papers was published about this field (20% in each year) and, afterwards, 2011was ranked second with 10%. It can be noted that the majority of papers considered the socio-economic information along with the biophysical information for planning, demonstrating the important role of this information for decision-making.

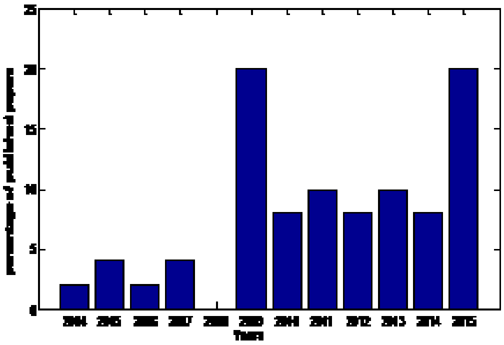

Figure 1. Percentage of published papers about systematic conservation planning in seascape.

CONCLUSIONS

In this paper, almost 56 papers were surveyed about systematic conservation planning in seascape. Among these papers, 20 considered socio-economic information for planning and showed the importance of the information.

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