The core zone decisive of marine conservation area in Southeast Sulawesi using marxan

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Abstract. The Southeast Sulawesi Marine Conservation Area is one of the marines protected areas, namely Aquatic Tourism Park type, appointed by The Governor's decree of Southeast Sulawesi Number 98 the Year 2016. This area is located in The Konawe Regency, Kendari City and The South Konawe Regency with 21,786.14 ha. This area was still in initiation, so it has not marine spatial planning. This study aims to formulate and determine the core zone. Marxan was used to assign the core zone and solve the marine spatial planning and utilization conflict. Three scenarios were used to analyze the critical habitat of level protection at 30%, 50%, and combinations. These results described that scenario A has 751 ha, scenario B has 1008 ha, and combinations scenario have 1498 ha. The core zone area is under 1 % of the total area conservation. So, all scenarios do not qualify the criteria required by the International Union for Conservation of Nature (IUCN). Besides, all scenarios have qualified the thirty percents of critical habitat protection. Managers and stakeholders could use these findings to decide the core zone, spatial planning, and sustainable developments.

Keywords: core zone area, critical habitat, marine protected area, marine spatial planning, Southeast Sulawesi

1. Introduction
The Ministry of Marine Affairs and Fisheries has set a target for establishing 20 million hectares of Marine Conservation Areas from 2009 to 2020 to protect Indonesia's marine biodiversity from various increasingly intensive threats. Until 2020, as many as 201 conservation areas have been designated or reserved with a total area of 24.11 million hectares [1]. Currently, 16.8 million hectares have been established, and 7.3 million hectares are still in reserve. One of the conservation areas that has been reserved is the marine conservation area regional (KKPD) of Southeast Sulawesi through the Decree of the Governor of Southeast Sulawesi Number 98 of 2016 with the type of area as an Aquatic Tourism Park. The location is located on the coast of Konawe Regency, Kendari City, and South Konawe Regency with 21,786.14 ha Based on the results of the Southeast Sulawesi KKPD Regional Initiation Team, the area has high potential. The average live coral cover, seagrass cover, and mangrove density are in a good category, above 50% [2, 3].

Marine conservation areas have an important role in protecting and enhancing, and restoring fishery stocks—systematic conservation planning aimed at designing conservation areas to achieve conservation targets [4]. Conservation area is defined as a geographical area of space that is clearly defined, allocated, recognized, and effectively managed through regulations to achieve conservation target with its ecosystem-related services and cultural values [5]. The definition is clear that the main objective of a conservation area should be to conserve existing resources and protect biodiversity successfully. Conservation area programs generally involve zoning in spatial planning, focusing on core

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zones [6]. The core zone is one part of the zoning system in conservation areas which is the key to the success of area management.

Problems that are often found in maintaining coastal and marine ecosystems in conservation areas are determining their ecological boundaries and applying them to the design of conservation areas [7]. Marxan (Marine Reserve Design Using Spatial Explicit Anealling) can be used to help resolve spatial allocation conflicts between not take zones and use zones. Communities are generally very difficult to release an area that has the potential to be a conservation area Conformity analysis using marxan to find solutions for efficient core zone areas in the spatial system to protect biodiversity [8]. There are two main types of conflicts that often occur in the use of marine space, according to [9]: First, conflicts between land users (between land users). The second is the conflict between humans as beneficiaries and the marine environment. This conflict can reduce the quality of ecology and ecosystem services affected by the inappropriate allocation of marine space.

The core zone suitability analysis is one of the applications of marine space utilization by allocating part of the area to become a habitat and ecosystem protection area. Area-based management is one of the most effective management strategies for managing resources in a sustainable manner [10]. The determination of conservation areas effectively manages ecosystems and resources, especially when considering their ecological values [11]. Determination of the area followed by integrated zoning-based management needs to be done to reduce high activity in coastal areas [9]. Marine protected areas have proven to be an effective way to achieve conservation goals by restoring marine ecosystems [12]. Choosing the right location can reduce pressure on the ecosystems in the conservation area [13]. Protection conservation areas need to be done to support the life of biota in the area to be able to provide benefits to the surrounding community. One of the suitability analysis tools to determine the core zone is to use Marxan. Marxan is one tool to help identify locations with high conservation value [14]. This research aims to help formulate the core zone to support the management and zoning plan of the Southeast Sulawesi KKPD.

2. Material and methods
The research was conducted in September 2019 – March 2020 in the Southeast Sulawesi Water Conservation Reserve Area. This area is located in three city and district administrations; Kendari City, Konawe Regency, and South Konawe Regency. The potential of this area is relatively abundant because outside the area directly adjacent to the Banda Sea, which is famous for various types of high economic fish such as tuna, skipjack, kite, and mackarel. The Southeast Sulawesi KKPD reserve area has great wealth and biodiversity such as fish resources, coral reefs, mangroves, and seagrass beds. In addition, there are also marine environmental services that can still be developed, such as marine tourism services and marine transportation services. Activities related to the utilization of fishery resources in the KKPD reserve area are quite dense. The surrounding community is very dependent on the fishery resources in it.

Marxan was able to factor in the cost features to protect the biodiversity conservation targets that had been planned [15]. The use of marxan software in determining the selection and non-selection of some spaces from the area as core zone. Marxan with Zones is an analytical tool that considers all the constraining factors in the design of the base reserve to allow the selection of zones [16].

The analytical tool used to assist the design of core zone determination while still considering user is the Marine Reserve Design Using Spatial Explicit Anealling (Marxan). Marxan can be used to help resolve spatial allocation conflicts between the not take zone and the use zone. Marxan was able to find an efficient solution in selecting core zone in the spatial system to achieve the target of protecting biodiversity [8]. Marxan in determining the zoning of conservation areas is in line with the government's target to protect habitat and species ecosystems in coastal and marine areas. So in the design of determining the core zone, we include conservation features and cost features as the basis for the Planning Unit. Conservation planning by establishing an area that considers all available information on the cost feature [17]. Planning allocations and various information related to conservation areas will provide different levels of protection [16].
2.1. Area of interest (AOI)

The Area of Interest (AOI) is the initial stage in the suitability analysis using Marxan. The formation of the AOI was accompanied by the merger of the Planning Unit (pu.shp). The AOI made will contain information on both conservation features and cost features as a reference in designing conservation areas using Marxan. The AOI shape in this study was chosen as a Hexagon shape. The AOI shape in this study was chosen as hexagon shape, because hexagon shape is closest to circle shape and has low edge ratio [18]. One hexagon unit is expected to be able to represent the data information contained in the Planning unit. The research location also forms a conservation boundary with many bends, so it is considered to form an AOI with a hexagon shape (figure 1). Each hexagon contains data containing conservation feature data and cost features obtained based on primary and secondary data.

The conservation area reserve area of 21,786.14 ha is the basis and limit for forming the AOI. In this study, the data in the AOI are all data obtained in the field, which are entered as supporting data in the processing of marxan using the simulated annealing process. Data obtained from FGDs, field surveys, and secondary data are input into PUID. Each Pu Id in this simulation has a size of about 10.37 ha. This limitation of the AOI will focus on being used to analysis the suitability of the core zone, along with all information on conservation features and cost features.

AOI will contain data from each component that has been entered into each unit ID. This data will later assist in determining the selected and non-selected areas as core zones. In this study, 2320 Pu ID were formed, each of which Planing unit ID has the same area.

2.2. Conservation features and cost feature

Conservation features can be defined as elements that researchers want in a particular zone [19]. Conservation features are defined as elements that will be considered in certain spatial areas [19] [17]. In this study, conservation features are used to determine the priority areas desired to be selected core zones. Determination of conservation features in this study is various features that will be protected and their sustainability can be maintained. Target-based planning looks at the past and current potential for setting priorities for conservation targets [16]. Conservation areas and the protection of biodiversity in them that have been targeted must have proper planning and have a clear legal basis—and considered based on the results of previous studies to be included in the conservation features.

Determination of penalties and weighting is chosen based on the ecological vulnerability level in the Southeast Sulawesi KKPD Reserve area. The assessment of the penalty value is also considered from
The gap analysis results to represent what targets are included and are important enough to be protected and what percentage of the protection scenarios are these conservation features. Influential targets are given high scores based on survey and analysis results. The determination of the penalty in the area is given according to the level of importance of protection. In this study, the penalty value on the conservation target that is in the conservation feature is assigned a value of penalty 1.00 (table 1). This value is given with the consideration that all conservation features have the same level of importance to be protected. Ministerial Regulation No. 31 of 2020 concerning the management of conservation areas states that it requires absolute protection of conservation targets.

The cost features for Marxan inputs reflect the socio-political and activity barriers that hindered the selection of core zones. The cost feature is to set aside planning units for conservation actions in social data related to population, patterns of resource use and area utilization. Areas that have special regional characteristics, apart from traditional policy, are very important in determining the zoning of marine conservation areas. Often in determining the area’s zoning, this particular area becomes a core zone where the community becomes unable to take advantage of the coastal area. Considering the cost feature is one form of designing the area with various considerations so that an optimal area appears based on the results of simulated annealing from marxan.

The cost features included in this study are in the form of several spatial use activities that occur in the conservation area (table 2), giving the same penalty value as the conservation feature based on the level of importance of these activities in the conservation area. The higher the penalty value given, the more difficult it is to allocate it as a core zone.

The awarding of the same value is because permanent cost features are scored with a penalty value of 2. *Species Penalty Factor* (SPF) penalties on cost features such as fishing ground and floating net

| No. | Conservation features | Penalty | Information                          |
|-----|-----------------------|---------|--------------------------------------|
| 1   | Coral reefs good condition | 1.00    | average cover > 50%                  |
| 2   | Coral reefs bad condition | 1.00    | average cover < 50%                  |
| 3   | Seagrass good condition  | 1.00    | average cover > 60%                  |
| 4   | Seagrass bad condition  | 1.00    | average cover < 60%                  |
| 5   | Mangrove good condition | 1.00    | density ≥1000 mangrove/ha            |
| 6   | Mangrove bad condition  | 1.00    | density < 1000 mangrove/ha          |
| 7   | Stenella longirostris    | 1.00    | plot in fourth locations             |
| 8   | Cheilinus undulatus      | 1.00    | be discovered in six locations       |
| 9   | Chelonia mydas & Eretmochelys imbricate | 1.00 | be discovered in two locations |
| 10  | Spawning ground Panulirus spp. | 1.00 | around the coast of bororo          |
| 11  | Tridacna sp.            | 1.00    | be discovered in six locations       |
| 12  | Isis sp.                | 1.00    | be discovered in seven locations     |

| No. | The cost features | Penalty (SPF) |
|-----|-------------------|---------------|
| 1   | Floating net cage | 1.00          |
| 2   | Jetty             | 2.00          |
| 3   | Fishing ground    | 1.00          |
| 4   | Coastal settlement| 2.00          |
| 5   | Ship lane traffic | 2.00          |
cage are given the lowest SPF value with a penalty value of 1. They are giving a penalty value (SPF) to provide different interests both in terms of conservation features and cost features, for example, cost features that have high importance in conservation areas [20]. Marxan will consider cost features and assist in achieving pre-determined biodiversity targets [15].

2.3. Scenario
Spatial value weighting in zoning arrangement is an important step in developing Marine Spatial Planning while minimizing management budgets and social conflicts by minimizing overlapping spatial uses [21]. Marxan uses an optimization method known as simulated annealing, which is different from other algorithms, increasing the probability of finding a close to an optimal region [22]. In general, the logarithm in Marxan works in 4 terms as follows:

\[ C = \Sigma \text{Cost} + (\text{BLM} \times \Sigma \text{Boundary Length}) + \Sigma (\text{Species Penalty} \times \text{SPF}) + \text{CTP} \]  \hspace{1cm} (1)

Total cost of the selected core zone with symbol “C”. To find out the total cost, you must know several parts of the algorithm, including: \( \Sigma \text{Cost} \) is Planning unit cost is a value combination from cost social-economic in planning units. \( \Sigma \text{Boundary Length or Total Boundary Length} \), this value is a value set by the user and corresponds to the connectivity level of each planning unit. The higher the BL value, the more compact the solution area. Species Penalty is the penalty value given if the target for biodiversity protection is not fulfilled. While the Species Penalty Factor (SPF) is a user-set value that relates to how important the targeted biodiversity is. The higher the SPF given to a feature, the more Marxan will prioritize the target of the feature. Cost Threshold Penalty (CTP) is a penalty solution that generates costs even though all feature targets are reached.

This study determined the scenarios is divided into three scenarios for protection of important habitats of 30%, 50%, and a combination based on the gap analysis results (table 3). Scenario A with an allocation of 30% important ecosystem protection is because protection can go hand in hand with utilization in conservation areas. Based on the IUCN, at least 30% of the critical habitat is a core zone area. The proportion of habitat protection should cover 20-30% of coral reefs, seagrass, and mangrove habitats [23]. 30% protection is also chosen in this scenario. According to [24], habitat protection is 30% part of efforts to restore fish stocks and populations that have declined and can still provide economic benefits for fishing activities. In a scenario, A for conservation targets with migratory biota

| No. | Conservation features          | Scenario  | Scenario  | Scenario  |
|-----|--------------------------------|-----------|-----------|-----------|
|     |                                | A         | B         | C         |
| 1   | Coral reefs good condition     | 30%       | 50%       | 50%       |
| 2   | Coral reefs bad condition      | 10%       | 20%       | 30%       |
| 3   | Seagrass good condition        | 30%       | 50%       | 50%       |
| 4   | Seagrass bad condition         | 10%       | 20%       | 30%       |
| 5   | Mangrove good condition        | 30%       | 50%       | 50%       |
| 6   | Mangrove bad condition         | 10%       | 20%       | 30%       |
| 7   | *Stenella longirostris*        | 5%        | 10%       | 10%       |
| 8   | *Cheilinus undulatus*          | 30%       | 50%       | 30%       |
| 9   | *Chelonia mydas & Eretmochelys imbricate* | 5% | 10% | 10% |
| 10  | Spawning ground *Panulirus* spp.* | 30% | 50%       | 30%       |
| 11  | *Tridacna sp.*                | 30%       | 50%       | 30%       |
| 12  | *Isis* sp.                    | 30%       | 50%       | 30%       |
types, a conservation target of 5% is given. This is because these biota are found to have immigrated in the KKPD area only in certain months. Biota protected with permanent habitats such as clams, sea bamboo, and napoleon are given the same protection according to their habitat.

Scenario B is a habitat protection goal of 50%. The 50% protection target has stronger ecosystem protection in conservation area planning [25]. This study tries to simulate 50% protection for all ecosystems in good condition in scenario B. The target of migratory or moving species not in one protected place in scenario B tries to protect 10%. This considers the ratio of encounters that are very rare and can only be found in certain months and to prevent changes in the conditions of the migration path. The 0-10% scenario was created to reduce the risk of habitat change [26]. Protection scenarios for other protected species, such as clams, sea bamboo, and napoleon fish following their habitat, believe coral reefs with 50% protection. Scenario B was created to design a core zone with optimal protection for critical habitats.

Scenario C is designed by combining the optimal protection and the results of the gap analysis. Where ecosystems that experience a decline from their previous conditions receive additional protection targets, this is so that the condition of the ecosystem that has been damaged can be protected and can slowly return to its previous condition. The design of the protection target is based on the points of the damaged ecosystem, and the protection target is 30%. Ecosystem targets that are categorized as good can be protected with protection targets following scenario B. This aims to optimize the protection of ecosystems that are still in good condition. Ecosystems with good conditions also indicate a lack of activity in the area so that the protection target can be made optimally at 50%. Protection of migratory species is made similar to scenario C to keep areas frequently traversed for migration unchanged. Based on the Appendix, the target species for protection are set for habitat protection targets ranging from 10-30%. This is seen from the risk of extinction vulnerability of protected species [26].

3. Results and discussion
Marxan analysis scenario A is designed with 30% habitat protection. The BLM value of 1000 in the core zone suitability analysis using Marxan aims to make the planning unit that has been designed in

Figure 2. Core zone distribution based on the Marxan scenario A.
the scenario more concentrated on the results. The simulation using Marxan simulates the conservation features set by entering the value of the proportion of target (Prop) according to the predetermined scenario design. The proportions are based on the total number of defined conservation features in the planning unit [20]. So that in designing the core zone in a conservation area, detailed information is needed to get closer to the needs of the conservation target to be protected into the core zone. The value

Figure 3. Core zone distribution based on the Marxan scenario B.

Figure 4. Core zone distribution based on the Marxan scenario C.
for the 30% percentage target on the simulated prop value will be set to 0.3. The simulation results will determine the core zone according to the prop that has been determined from the conservation features that have undergone the Marxan annealing process. Marxan's results for scenario A obtained 751 ha, which was selected to be the core zone (figure 2). Protection targets based on IUCN are at least 30% of the protected targets.

Scenario B is designed to protect optimal ecological needs by allocating more land to be protected. The protection target of 50% has a stronger basic ecological protection capability [27]. The results obtained are 1008 Ha (figure 3). The division of zoning in conservation areas is an effort to meet the community's needs, with various environmentally friendly activities that can be carried out in addition to the core zone. However, the results in this study did not reach the protection of 20% of the area. The research results of Estradivari et al. [14] and Krueck et al. [23] stated that the ideal area of coastal and marine areas that must be protected is 20-30% of the total coastal and marine area. Thus able to increase fish up to more than 80% Maximum Sustainable Yield (MSY) and export at least 30% of larvae to fishing locations. MPA area larger than 30% is less effective because, in addition to high management costs, fish productivity will decrease due to a lack of fishing locations. This principle was adopted to determine the area of the core zone in the MPA believed to be between 20-30% of the total area MPA.

The third scenario design considers poor ecosystem conditions to get 30% still purp protection and 50% or 0.5 purp ecosystems. The results obtained are 1498 ha, which can be seen in Figure 4. This criterion is included in the IUCN protection, which protects 30% of important habitats in the area. Krueck et al set a minimum diameter of each core zone between 1-10 km². It can protect 20-30% of important fish species at each trophic level and spread 30% of larvae produced by these locations outside the area. The ideal core zone diameter size will generally protect almost all marine biota in the MPA, especially fish with large cruising ranges such as sharks, whales, turtles, and dolphins. This scenario is included in the category because it provides a 30-50% protection scenario design and has a core zone size of 10 km² where the core zone is 1498 ha or around 14 km².

4. Conclusions
The scenario that has been made will be applied using Marxan as a tool for analyzing the suitability of the core zone. The protection of the reserve for the Southeast Sulawesi waters conservation area obtained that scenario A protects 751 ha, or the area is selected as the core zone. Scenario B is selected as the core zone covering an area of 1008 ha. Scenario C obtained an area of 1498 ha. Of the three scenarios, B and C, it is by protecting important habitats by providing habitat protection of 30%. Scenario C can also be categorized as a design to restore a damaged ecosystem that is well damaged while still considering the poor ecosystem into the scenario's design to remain protected and restore the condition of the ecosystem.

The core zone area is under 1% of the total area conservation. So, all scenarios do not fulfill the criteria required by the International Union for Conservation of Nature (IUCN). The core zones must guarantee the protection of 2% of the total marine protection area. Besides, all scenarios have qualified the 30% of critical habitat protection, the target of 30% protection is the recommendation of the IUCN, 2003, and has also been applied in studies [28].

5. References
[1] Kementerian Kelautan dan Perikanan (KKP). Direktorat Jendral Pengelolaan Ruang Laut 2020. Data jumlah dan luasan kawasan konservasi Tahun 2020.
[2] Adnyana P B 2014 Analysis of the potential and condition of the coral reef ecosystem of Menjangan Island for the development of integrated education-based marine ecotourism (translate English). Jurnal Sains dan Teknologi 3 361-377.
[3] Dinas Kelautan dan Perikanan (DKP) Sulawesi Tenggara 2016 Dokumen dokumen inisiatif penambahan area pencadangan
[4] Margules C R and Pressey R L 2000 Systematic conservation planning Nature 405 243-253.
[5] Day J C, Laffoley D, Zischka K, Gilliland P, Gjerde K, Jones P J and Wilhelm A 2019 Gestión de áreas marinas protegidas In Gobernanza y gestión de áreas protegidas. ANU Press: 609-650.

[6] Klein C J, Steinback C, Watts M, Scholz A J and Possingham H P 2010 Spatial marine zoning for fisheries and conservation Frontiers in Ecology and the Environment 8 349-353.

[7] Yulianda F, Fahrudin A, Hutabarat A A, Harteti S, Kusharjani and Kang H S 2010 Pengelolaan Pesisir dan Laut Secara Terpadu (Integrated Coastal and Marine Management). Bogor (ID): IPB Pr.

[8] Meerman J C 2005 Belize Protected Areas Policy and System Plan: RESULT 2: Protected Area System Assessment & Analysis National List of Critical Species. Belize Tropical Forest Studies. 1-8

[9] Ehler, Douvere F 2009 Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides. Paris (FR): UNESCO.

[10] Hind E J, Hiponia M C and Gray T S 2010 From community-based to centralised national management—A wrong turning for the governance of the marine protected area in Apo Island, Philippines? Marine Policy 34 54-62.

[11] Agardy M T 1994 Advances in marine conservation: the role of marine protected areas Trends in ecology & evolution 9 267-270.

[12] Di Franco A, Thiriet P, Di Carlo G, Dimitriadis C, Francour P, Gutiérrez N L, De Grissac A J, Koutsoubas D, Milazzo M and Otero M D M 2016 Five key attributes can increase marine protected areas performance for small-scale fisheries management Scientific reports 6 1-9.

[13] Aulia F, Rusdi M, Deli A, Fuadi A, Irham M and Indra I 2021 The Marxan model for determining no-catch zones based on conservation targets in the north-eastern region of Simeulue District In IOP Conference Series: Earth and Environmental Science 711 1-8.

[14] Estradivari, Handayani C N N, Firmansyah F, Yusuf M and Santiadjji V 2017 Marine Protected Areas: Smart Investments for Protecting Marine Biodiversity and Developing Indonesian Fisheries. Jakarta(ID):WWF

[15] Possingham H, Wilson K, Andelman S A, Vynne C H 2006 Protected areas: goals, limitations, and design Principles of Conservation Biology 3 507-549.

[16] Carwardine J, Klein C J, Wilson K A, Pressey R L and Possingham H P 2009 Hitting the target and missing the point: target-based conservation planning in context Conservation Letters 2 4-11.

[17] Watts M E, Ball I R, Stewart R S, Klein C J, Wilson K, Steinback C and Possingham H P 2009 Marxan with Zones: software for optimal conservation based land-and sea-use zoning Environmental Modelling & Software 24 1513-1521.

[18] Loos S A 2006 Exploration of MARXAN for utility in Marine Protected Area zoning (Doctoral dissertation). Melbourne (AU): University of Victoria

[19] Stewart R R, Ball I R and Possingham H P 2007 The effect of incremental reserve design and changing reservation goals on the long-term efficiency of reserve systems Conservation Biology 21 346–354.

[20] Game E T and Grantham H S 2008 Marxan User Manual: For Marxan version 1.8.10. University of Queensland(AU)

[21] Deas M, Andréfouët S, Léopold M and Guillefaut N 2014 Modulation of habitat-based conservation plans by fishery opportunity costs: a New Caledonia case study using fine-scale catch data PloS One 9 1-13.
[22] Game E T, Watts M E, Wooldridge S and Possingham H P 2008 Planning for persistence in marine reserves: a question of catastrophic importance *Ecological Applications* **18** 670-680.

[23] Krueck N C, Ahmadia G N, Green A, Jones G P, Possingham H P, Riginos C, Treml E A and Mumby P J 2017 Incorporating larval dispersal into MPA design for both conservation and fisheries *Ecological applications* **27** 925-941.

[24] Firmansyah F, Estradivari E, Handayani C, Krueck N, Mustofa A and Daniel D 2018 Integration of Larvae Connectivity Model and Optimum Size of Core Zone in Marine Protected Area Design (translate English) *Majalah Ilmiah Globe (ID)* **20** 107-116.

[25] Delavenne J, Metcalfe K, Smith R J, Vaz S, Martin C S, Dupuis L and Carpentier A 2012 Systematic conservation planning in the eastern English Channel: comparing the Marxan and Zonation decision-support tools *ICES Journal of Marine Science* **69** 75-83.

[26] Tantipisanuh N, Savini T, Cutter P and Gale G A 2016 Biodiversity gap analysis of the protected area system of the Indo-Burma Hotspot and priorities for increasing biodiversity representation *Biological Conservation* **195** 203-213.

[27] Delavenne J, Metcalfe K, Smith R J, Vaz S, Martin C S, Dupuis L and Carpentier A 2012 Systematic conservation planning in the eastern English Channel: comparing the Marxan and Zonation decision-support tools *ICES Journal of Marine Science* **69** 75-83.

[28] Klein C J, Steinback C, Scholz A J and Possingham H P 2008 Effectiveness of marine reserve networks in representing biodiversity and minimizing impact to fishermen: a comparison of two approaches used in California *Conservation letters* **1** 44-51.