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Assessing worth of marine protected areas for the protection of threatened biodiversity using IUCN Red List and Red List Index. A pilot study in six mediterranean areas

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ABSTRACT

The Mediterranean marine region is considered one of the world's biodiversity hotspots for conservation priorities due the high occurrence of rare and threatened species, endemism and high species richness. However, several pressure such as losses and alterations of habitats are ongoing and in order to increase conservation in this sea region, many marine protected areas were established, including Natura 2000 sites. The latter are areas designated under the Habitat and Bird Directives for the conservation of species in need of strict protection, so that they can reach a favourable conservation status. Species conservation status is also assessed through the IUCN (International Union for Conservation of Nature) Red List of Threatened Species. The aim of our study was to test whether IUCN Red List and the related Red List Index RLI (which aggregates in a single value all the information on conservation status of a particular set of species) can be used as a metrics to characterize MPAs, and orienting, consequently, local marine conservation policies. A pilot study was undertaken in the six Sicilian MPAs (Marine Protected Areas) and results highlighted that Egadi Island has a low RLI value (meaning that the MPA hosts many species with a threatened status) while the Capo Gallo MPA, at the opposite, as an high RLI value (*i.e.*less threatened species); the other four MPAs. Egadi, Pelagie, and Ustica showed similar distribution frequencies of Red List categories having similar RLI values. Biological resource use, natural system modifications, invasive species, and pollution all account for 90% of assessed threats. Outcomes of our study showed that IUCN indicators should be considered as a tool to: assess the conservation status of set of species in protected areas; drive prioritization in the decision process in order to support an effective management conservation plan; designate new MPAs.

1. Introduction

Protected areas, worldwide, are designated for different reasons: from areas of the world with the least amount of human influence to places with Outstanding Universal Value for cultural and historical reasons, such as old towns and villas (UNESCO, 2013). The UNEP-WCMC and IUCN (2016), Biodiversity A-Z website, for example, quotes more than 60 different categories of protected areas, and the IUCN's World Commission on Protected Areas (International Union for Conservation of Nature – WCPA) defined seven categories of Protected Areas management: from Strict Nature Reserves to Protected areas with sustainable use of natural resources (Dudley, 2008).

Protected areas constitute major tools for nature conservation; in the European Union (EU), the Habitats and Birds Directives are the most important policies for driving conservation strategies and legally preserve Europe's characteristic biota (Hoffmann et al., 2018). Conservation is achieved particularly through the establishment of Natura 2000 protected sites designated to protect core areas for habitats and species 'listed' as in need of protection in the above mentioned Directives. Natura 2000 sites are sites with an extraordinary concentration of biodiversity defined by one or more metrics, including the occurrence of rare, endangered, vulnerable, and endemic species (Reid, 1998; Possingham and Wilson, 2005; Harris et al., 2005).

In addition, within the Convention on Biological Diversity (CBD), the Aichi target n. 11, aiming at improving the status of biodiversity, requires the establishment of areas of particular importance for

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biodiversity and ecosystem services, through an effectively and equitably managed, ecologically representative, and well connected systems of protected areas.

Protected Areas also include marine areas, the boundaries of which include marine water; in Italy, Marine Protected Areas (MPAs) are designated following national law n. 394 of 1991 ("Framework act on protected areas") and are areas consisting of marine environments, including sea waters, seabed, and the surrounding coastline.

The designation decrees of MPAs individuates the actions to be pursued by the management and include, among the others: protection of biodiversity and threatened species, improvement of biological resources (i.e. fishery), enhancement of geomorphologic and/or archaeological places, promotion of knowledge on marine and coastal sites, sustainable development, promotion of environmental education programs, research and monitoring activities, economic growth (source Minambiente-Italian Environment Ministry, 2019). Consequently, management, resource allocation, and regulations of MPAs, have to take into consideration several actions, among which the conservation of rare and endangered species is just one of the several priorities.

Indeed, protected marine areas have been set up to protect vulnerable species and ecosystems, to conserve biodiversity, and minimize extinction risk (Hoyt, 2018). Protection of vulnerable specie is particularly important in areas where the marine wildlife and biodiversity are under threat by different pressures, such as fishery overexploitation, pollution, degradation and loss of habitat, invasive species, which can put wildlife at risk and can result in species local extinction (Agardy, 2000; Coll et al., 2012; Airoldi et al., 2008).

The Mediterranean marine region is considered a world hotspot of biodiversity for species richness, endemism and high occurrences of rare and threatened species but is also under severe anthropogenic pressures (Zenetos et al., 2005; Cuttelod et al., 2008; Campana et al., 2018; Crosti et al., 2018).

In Sicily (southern Mediterranean Sea), six MPAs have been established and within, and/or just off, their designated boundaries there are Natura 2000 sites. Conservation objectives of Natura 2000 sites are site-specific and are based on the knowledge of the protected species/habitats present, their ecological requirements, as well as their threats and pressures (European Commission, 2007). It is important, consequently, to ensure that sites are managed in a way to protect listed species and to ensure their Favourable Conservation Status taking into consideration that conservation priorities, established at the local level, are a determination of the most important actions to be taken for the preservation of species/habitats (Giakoumi et al., 2012).

On a global scale, the IUCN Red List of Threatened Species™ (IUCN, 2018) assesses the conservation status of species/taxa, based on population, range, ecology and threatening processes, to promote their conservation on species that have been evaluated using the IUCN Red List Categories and Criteria (IUCN, 2018). This system is designed to determine the relative risk of extinction, and species are classified in the following categories: Extinct or Extinct in the Wild-EX, Critically Endangered-CR, Endangered-EN, Vulnerable-VU (threatened and facing a high risk of extinction), Near Threatened-NT (close to meeting the threatened thresholds), Least Concern-LC (with low risk of extinction), and Data Deficient-DD (with insufficient information to evaluate the conservation status). In Europe, species are not assessed generally when they do not face any particular known threats or are so frequent that they do not face any risk; in this case, species are defined as Not Assessed-NA.

The IUCN Red List Index –RLI-, is an index, based on the IUCN Red List of Threatened Species, that aggregates in a single value all the information on conservation status of a particular set of species and is usually used to measure trends in extinction risk over time (Butchart et al., 2004, 2007; Rondinini et al., 2014). Extinction risk, in fact, is a key measure of potential biodiversity loss that has resonance with the public and decision makers, and that has clear relevance to ecological processes and ecosystem functions (Bubb et al., 2009).

Aim of this study was a preliminary investigation on using indicators such as the IUCN Red List and the Red List Index to assess current capacity of hosting threatened species of Protected Areas in order to:

I. incorporate this information in the protected area management plan which represents the framework for the strategies of conservation actions and measures;
II. consider also information on conservation status (Red List categories) when planning a connected systems of protected areas;
III. take into consideration these metrics prior to designation of a new protected area.

Starting from a dataset of "protected" species of six MPAs, for each species we acquired information on conservation status and threats from the Red List and calculated the RLI. Successively we made comparison among MPAs aiming to feature a metric to worth the credit of the areas in the protection of threatened biodiversity. The pilot investigation was undertaken in the Sicilian MPAs where marine species biodiversity and strong anthropogenic pressure coexist.

2. Materials and methods

2.1. Sites and protected species

The six Sicilian MPAs investigated were: Capo Gallo – Isola delle Femmine (hereafter indicated as Capo Gallo), Isole Ciclopi (Ciclopi), Isole Egadi (Egadi), Isole Pelagie (Pelagie), Plemmirio, Isola di Ustica (Ustica), Fig. 1.

For the aim of this study, similarly to Hoffmann et al. (2018) and Díaz et al. (2020), we considered only species reported as "protected", under the legislative framework of Council Directives 92/43/EEC "Habitat" (as in the Natura 2000 Standard Data Form). All data on species records were output from the webgis of the Osservatorio sulla Biodiversità della Regione Sicilia (ORBS, 2011), the Sicily Region focal point (Biodiversity observatory) of the Italian National Network for Biodiversity, which incorporates historical georeferenced information acquired from published literature or online databases. Only records of marine species at the time -t-, from 1995 to 2014, were used in this study.

"Protected species" falling within the borders (or nearby areas) of the six Sicilian MPAs were used as a dataset (Fig. 1; Table 1); additionally, the number of protected species for each MPA was calculated, and density values were obtained based on both surface (km^2) and coastline (km).

2.2. The IUCN Red List and the Red List Index

The status of extinction risk for each MPA (or better the conservation degree, meaning the conservation status assessment at a local scale, Tsiripidis et al., 2018) was based on the most recent Red List of Threatened Species (IUCN, 2018). We used the Mediterranean scope assessment for high dispersal capacity species, such as marine mammals and turtles and the Italian National Red List Index (Rondinini et al., 2014; http://www.iucn.it/liste-rosse-italiane.php) for the other species. In the absence of such assessments, we used the European or the Global scope.

The IUCN Red List Index was used to assess, at date, the current capacity of MPAs to protect threatened species based on the set of protected species assessed with the Red List of Threatened Species (IUCN, 2018).

Usually the IUCN Red List Index is used to measure the overall extinction risk of sets of species and, if computed at least in two different time periods, can be used to measure trends (Bubb et al., 2009). However, in our investigation, RLI was not used to measure trends overtime in extinction risk (change in the status of the species/taxon

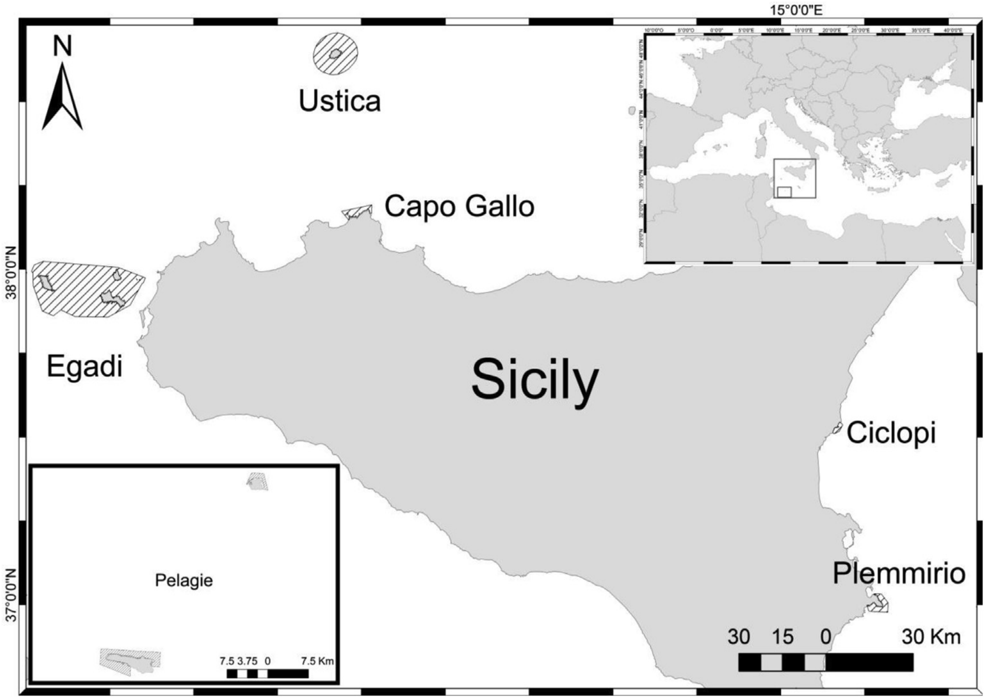

Fig. 1. The study area, the Sicily region, and names, location and boundaries of the six MPAs, including the remote area of the Pelagie (different scales).

Table 1
Surface area, length of coastline, number of protected species, and relative densities.

MPA	Surface in km^2	Km of coastline	N. of protected species	Protected Species/km^2	Protected Species/km coastline
Capo Gallo	21,73	16,02	44	2,0	2,7
Ciclopi	6,23	6,24	60	9,6	9,6
Egadi	539,92	73,99	78	0,14	1,1
Pelagie	41,36	46,28	86	2,1	1,9
Plemmirio	24,29	14,35	78	3,2	5,4
Ustica	159,51	14,45	67	0.,4	4,6

over a period of time within a taxonomical class or biome), but was intended to aggregate in a single value all the information on conservation status of protected species within each MPA. Following Butchart et al. (2007) the RLI was calculated as: $RLI_t = 1 - \frac{\sum_s W_{c(t,s)}}{W_{EX} \cdot N}$; the weight assigned to each IUCN category (excluding DD and NA) ranges from 0 for Least Concern to 5 for Extinct in the wild following an "equal steps weight of 1 for each category". The sum of the product of the number of species for the proper categories divided by the possible maximum product (the number of all the species multiplied by the maximum weight which is Extinct) and subtracted from one, produces an index that ranges from 0 to 1 (Bubb et al., 2009); Wc(t,s) is the weight of category c for species s at time t, (W_{EX}) is the weight for Extinct, and N is the number of assessed species excluding those considered DD. Consequently, an RLI aggregated value of 1 equates to all species being categorized as LC while a value towards 0 indicates that most of the species present are severely threatened.

Relationships among MPAs were assessed through RLI value; the relative abundance (%) of Red List categories (including DD, but without the NA species) was conveyed with pie charts.

Similarly, the frequency distribution of Red List categories for each MPA was also compared between the MPAs using the two sample Kolmogorov-Smirnov (KS) test (with D being the categorical outcome of the test and P the probability of the two frequencies being the same).

Based on the matrix species/Red List category, NMDS and Cluster Analyses (both with Bray-Curtis similarity measure) were used to assess and visualize similarities based on the conservation status category of the sets of species of the six different MPAs.

2.3. The threats

In order to have a feedback on threats for the conservation of the species in the MPAs, the main category of threatening processes, assessed in the Red List of Threatened Species factsheet, at the higher hierarchical level, was associated with the species following the IUCN Threats Classification Scheme – Version 3.2 (IUCN, 2012).

3. Results

3.1. The protected species

Mean number of "protected" species for MPA was 68 (rounded to the nearest unit), with a mean of nearly 60% of the species with a Red List assessment. Pelagie, Egadi, and Plemmirio had greater numbers of "protected" species (N ≥ 78), while Capo Gallo had the minimum with 44 species. Ciclopi, which is the smallest MPA, had higher density values for protected species per surface and coastline (Tables 1 and 2). Overall the species showed a wide taxonomic and structural diversity.

Table 2
Number of protected species, species assessed in the IUCN Red List of threatened species, species used for the Red List Index (i.e. Data Deficient and Not Assessed).

MPA	N. of protected species	N. of species assessed IUCN Red List	N. species used for RLI	% of assessed species	% species used for RLI
Capo Gallo	44	22	21	50,0	47,7
Ciclopi	60	30	28	50,0	46,7
Egadi	78	53	49	67,9	62,8
Pelagie	86	59	54	68,6	62,8
Plemmirio	78	43	41	55,1	52,6
Ustica	67	38	37	56,7	55,2

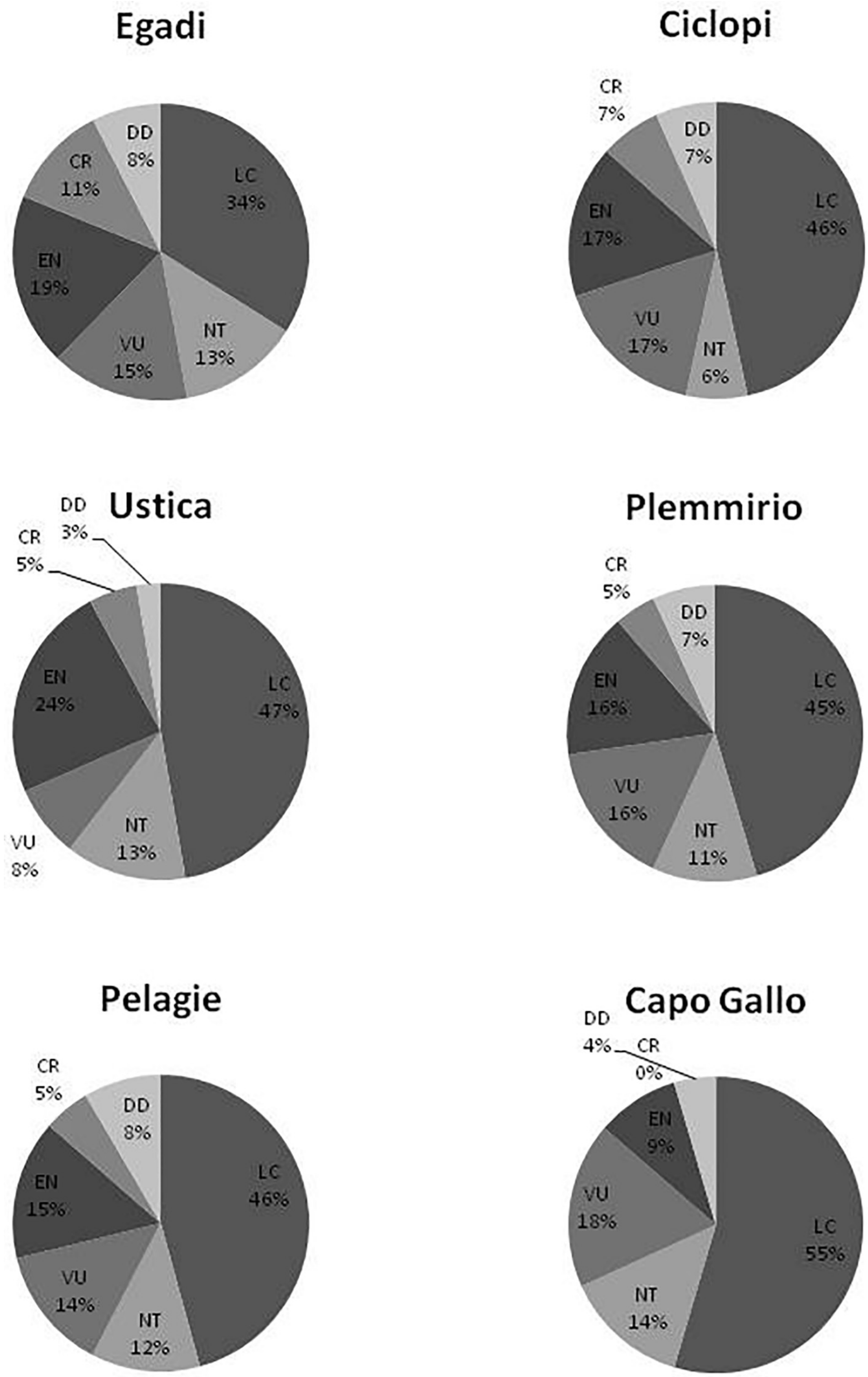

Fig. 2. Pie chart of the six Sicilian MPAs with the relative abundance (in %) of the Red List categories. Critically Endangered-CR, Endangered-EN, Vulnerable-VU, Near Threatened-NT, Least Concern-LC and Data Deficient-DD.

3.2. The IUCN Red List and the Red List Index

Synoptic displaying of the relative abundance (in %) of the IUCN status (pie charts in Fig. 2) showed that LC accounted for the highest values in all the MPAs, ranging from 34% in Egadi, to 55% in Capo Gallo. Ustica had the highest values of Endangered and Capo Gallo the highest values of Vulnerable but no Critically Endangered species. Considering threatened species all together (Critically endangered-CR, Endangered-EN, Vulnerable-V), Egadi and Ciclopi showed the highest values (45% and 41% respectively).

As shown in Fig. 3, the MPA Isole Egadi had a lower RLI value, meaning that the area hosts, compared to the other MPAs, more threatened species; Capo Gallo on the other hand had the highest RLI value, meaning that the area hosts less threatened species. The other four MPAs had similar RLI values.

The KS test (Table 3) showed no statistical differences in the frequency distribution of Red Lists categories among MPAs except for Capo Gallo with Pelagie and Egadi; in general, however, Capo Gallo showed higher differences with all the other MPAs. The biggest similarity was detected between Ustica and Egadi/Pelagie, and low similarity was detected between Pelagie and Ciclopi.

Outcomes of both classification (cluster analysis) and ordination

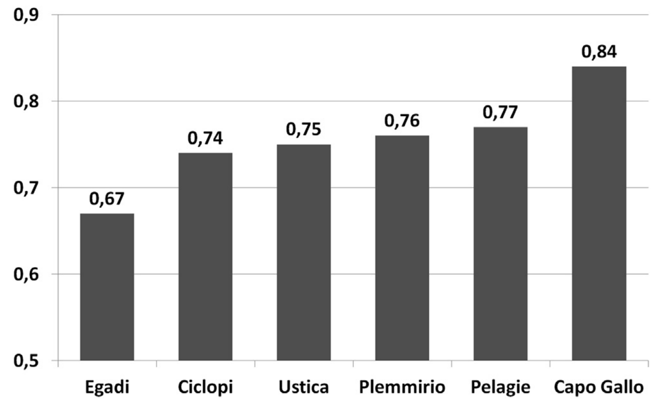

Fig. 3. RLI value of the six MPAs. A lower score means a higher number of threatened species.

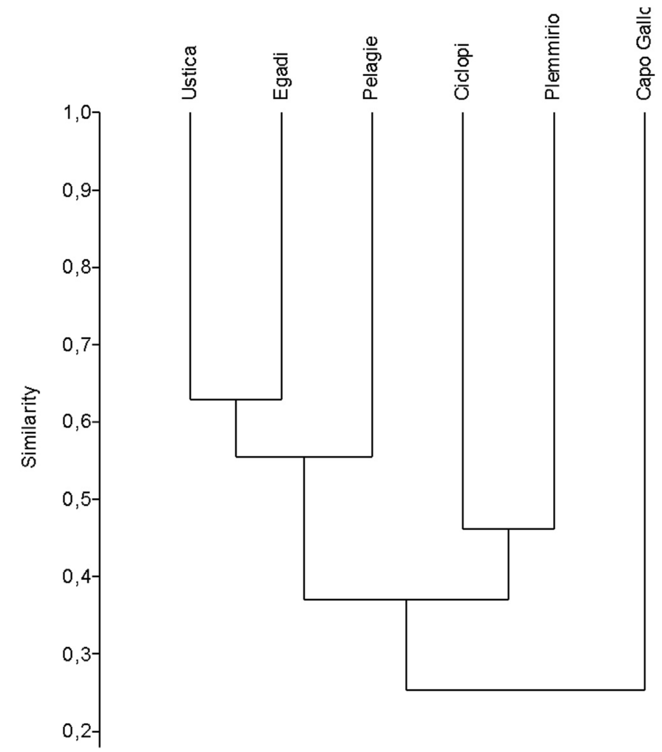

Fig. 4. Cluster analysis of the presence of species in the six MPAs weighted on IUCN Status classes, Bray-Curtis similitarity measure.

(NMDS) largely agree (Figs. 4 and 5): MPAs that were clustered together were also ordinate close to each other, particularly the MPAs Pelagie, Ustica, and Egadi. Capo Gallo seems separated both in classification (the “branch” in the cluster analysis stands on its own) and in ordination (in space, Capo Gallo is located all on one side with higher distance from Egadi along axis 1).

3.3. The threats

Overall the main related category of threats associated to species were, in order: Biological resource use, Natural system modifications, Invasive & other problematic species, genes & diseases, and Pollution. All together these accounted for approximately 90% of associated threat categories (values were similar among the MPAs).

Table 3
Kolmogorov Smirnov test applied on frequency data; being D (top right) the categorical outcome of the test and P (bottom left) the probability of the two frequencies being the same.

	Ustica	Pelagie	Ciclopi	Plemmirio	Egadi	Capo Gallo
Ustica		0,12	0,164	0,09	0,132	0,36
Pelagie	0,945		0,25	0,11	0,15	0,436
Ciclopi	0,773	0,19		0,18	0,22	0,34
Plemmirio	0,896	0,898	0,656		0,149	0,375
Egadi	0,921	0,792	0,339	0,684		0,41
Capo Gallo	0,07	0,0123	0,065	0,0597	0,024	

D

P

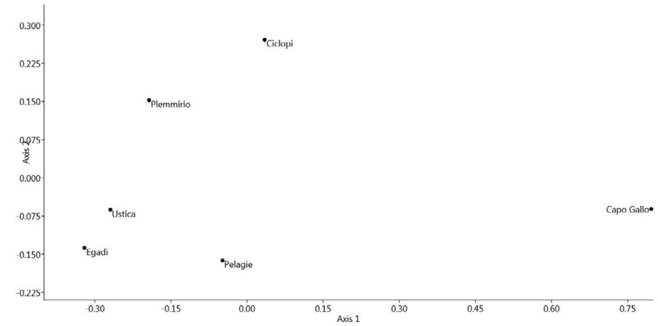

Fig. 5. NMDS of the presence of species in the six MPAs weighted on IUCN Status classes, Bray-Curtis similitarity measure.

4. Discussion

Biodiversity indexes are helpful tools to characterize and categorize the ecological status of the environment, since they help monitor species diversity or other aspects of biodiversity even in complex systems especially if measured with a set of species with a wide phylogenetic and structure in a given geographical region (Lyashevska and Farnsworth, 2012); they are also extremely useful in evaluating the effectiveness of biodiversity policies and management programs. For protected areas, considering their importance for biodiversity protection and conservation, it is important to evaluate indexes ability to prevent declines and guide conservation policies where threatened species are more concentrated. In these terms indexes such as the IUCN Red List of Threatened Species and the Red List Index are a useful approach for examining trends in the extinction risk of species, since they can synthesizes information on species' population, range, ecology, threatening processes, and can contribute valuable information to measure vulnerability which is the likelihood that biodiversity in a site could be lost (Rodrigues et al., 2006; Margules and Pressey, 2000; Butchart et al., 2012). In our study, we provided evidence that such indexes can be appropriate for comparing biodiversity at risk among protected areas in order to identify threatened species hotspots (intended as areas with a high number of threatened species). In particular, the six Sicilian Marine Protected Areas considered in this study have a slight difference in presence of threatened biodiversity, with the highest RLI distance recorded between Egadi (which showed the lowest RLI value) and Capo Gallo (which recorded the highest RLI value). Such a difference is likely to be imputed not only to the difference in the number of protected species considered for RLI computation but also to the different IUCN conservation status of the species and to the extent of the area and the different marine habitats present. In fact, Capo Gallo MPA showed the highest relative percentage of Least Concern species, indicating a minor presence of threatened species compared to the other MPAs, in particular compared to Egadi and Pelagie. While Pelagie MPA, which including the nearby areas has a large extension, has the highest number of protected species, it has an intermediate RLI score, because the number of threatened species (which weigh more in the index) are relatively lower compared to the other sites. On the other hand in the Egadi MPA, according to the published literature and online marine species database, there are records of several species (11%) with a Critically Endangered status, such as *Squatina squatina* and *Monachus monachus*; it has to be noted however, that these records are likely to be attributable to just single vagrant individuals and not a stable population: both species, in fact, occur in the Aegean and Levantine sea and have only sporadic records in the investigated areas (Ferretti et al., 2016; Aguilar and Lowry, 2010). On the other hand, rare vagrant cetacean species, such as *Grampus griseus*, in the Mediterranean are assessed as Data Deficent (Gaspari and Natoli, 2012), and the recorded presence within the MPA (i.e. Egadi) could not be used in the RLI assessment.

From a management point of view, this result suggests a need for focusing conservation actions on threatened species as a priority in Egadi MPA, while instead a priority in Capo Gallo MPA could be to enhance knowledge on species for example by improving research and monitoring actions. In the Egadi MPA, thus the management plan strongly needs to focus, among the actions to be pursued, on threatened species protection and conservation as a priority over other actions. Presence of threatened species in fact, entails a higher conservation effort for the hosting MPA (Karr, 1991; Caro, 2010).

Our results also stresses the need to identify anthropogenic pressures considering the fact that species conservation differ in sensitivity to different main threats (Siddig et al., 2016). Many of the identified threats, in fact, are of anthropogenic origin which include Biological resource use, Natural system modifications, Invasive & other problematic species and Pollution. In particular, while global changes (such as climatic change) are modifying, among others, the modality of alien species migration (one of the main threats of the occurring protected species), restoring native habitat functionality is a task that MPA management should strongly take into consideration to increase the resilience of native threatened species (as well as putting in action adaptation against marine alien species). Indeed, the RLI can be used also to measure the impact of alien species when (as in Butchart, 2008) measuring trends over time of genuine conservation local status changes for species of which the main category of threats is "Invasive & other problematic species". Other threats, however, such as local pollution (sewage, run off, marine litter) and the use of biological resources (overfishing; Illegal Unreported, and Unregulated Fishing) can be handled within the MPAs management conservation plan. Scarcity of information on presence, extent, and magnitude of threats on biodiversity may lead, in fact, to ineffective management decisions (Coll et al., 2012; Mazaris et al., 2019), particularly in MPAs where the origin of threat could originate outside of the area. Compared to Mazaris et al. (2019) which used the Natura 2000 Data Forms to acquire data of threats in MPA at a site level instead of the IUCN Red List at species level, in our investigated MPAs "Human intrusion and disturbances" (i.e. outdoor sports and recreational activities) was not considered a threat.

Our work also highlighted the possibility of taking into consideration when planning a connected systems of protected areas, not only species but also the species conservation status (Red List categories), in our case Pelagie, Ustica and Egadi have similar conservation status as showed by the investigation based on the matrix species/Red List category.

5. Conclusions

Different initiatives stressed the importance for prioritizing the management actions in MPAs, supporting managers and decision-makers in assessing the effectiveness of the MPA use (e.g. Pomeroy et al., 2005). This present paper investigated the value of MPAs for the protection of threatened species also at the regional level so to guide conservation policies, indicating where threatened marine species are more concentrated. The assessment was undertaken on the "protected species" in the six Marine Protected Areas in Sicily in the middle of Mediterranean Sea and was based on the IUCN Red List of Threatened Species, which is one of the most effective services of information for conservation planners both at large or local scales (Lamoreux et al., 2003; Rodrigues et al., 2006), and on the related Red List Index in order to identify local biodiversity hotspots. Outcomes of this study highlighted the current conservation status of sets of protected species in the investigated MPAs, showing differences in the occurrence of threatened species aspiring, consequently, to different priority needs for conservation and management of MPA; in the future outcomes, with changes over time, could be used also as a baseline to evaluate effectiveness of policy management programs but at basin scale (e.g. Western Mediterranean) in reducing pressures and threats. Identification of the main related category of threatening processes associated to the threatened species, would direct inform managers on the priority mitigation actions to be undertaken. This should also include the pelagic domain of the high sea (McCook et al., 2010; Agardy et al., 2011) where most of the high dispersal marine vertebrate species listed in the Habitats Directive occurs. Establishment of new MPAs should focus, as well, in taking into consideration areas where conservation status of protected species is not favourable, and the investigated indexes provide useful data to prioritize marine areas with a pertinent metric to assess biodiversity at risk sustaining the effective improvement of the biodiversity status (as from Aichi n.11). The use of RLI should be integrated in the management of all the protected area or Natura 2000 sites using the EU list of protected species; main threats to the protected species should be mentioned in the designation decree in order to favour future mitigation actions.

CRediT authorship contribution statement

Roberto Crosti: Conceptualization, Methodology, Data curation, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Antonella Arcangeli:** Conceptualization, Writing - original draft, Writing - review & editing. **Silvana Campagnuolo:** Data curation, Formal analysis. **Luca Castriota:** Writing - original draft. **Manuela Falautano:** Data curation, Project administration. **Teresa Maggio:** Data curation. **Franco Andaloro:** Writing - original draft, Project administration, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Agardy, T., 2000. Effects of fisheries on marine ecosystems: a conservationist's perspective. ICES J. Mar. Sci. 57 (3), 761–765.
Agardy, T., Di Sciara, G.N., Christie, P., 2011. Mind the gap: addressing the shortcomings of marine protected areas through large scale marine spatial planning. Mar. Policy 35 (2), 226–232.
Aguilar, A., Lowry, L. 2010. Monachus monachus. The IUCN Red List of Threatened Species 2010: e.T13653A4305567.
Airoldi, L., Balata, D., Beck, M.W., 2008. The gray zone: relationships between habitat loss and marine diversity and their applications in conservation. J. Exp. Mar. Biol. Ecol. 366 (1–2), 8–15.
Bubb, P., Butchart, S.H.M., Collen, B., Dublin, H., Kapos, V., Pollock, C., et al., 2009. IUCN Red List Index: Guidance for national and regional use.
Butchart, S.H.M., 2008. Red List Indices to measure the sustainability of species use and impacts of invasive alien species. Bird Conserv. Int. 18 (S1), S245–S262.
Butchart, S.H.M., Stattersfield, A.J., Bennun, L.A., Shutes, S.M., Akçakaya, H.R., Baillie, J.E., Mace, G.M., 2004. Measuring global trends in the status of biodiversity: Red List Indices for birds. PLoS Biol. 2 (12), e383.
Butchart, S.H.M., Akçakaya, H.R., Chanson, J., Baillie, J.E.M., Collen, B., Quader, S., Turner, W.R., Amin, R., Stuart, S.N., Hilton-Taylor, C., 2007. Improvements to the Red List Index. PLoS One 2 (1). https://doi.org/10.1371/journal.pone.0000140.
Butchart, S.H.M., Scharlemann, J.P.W., Evans, M.I., Quader, S., Arico'S, et al., 2012. Protecting important sites for biodiversity contributes to meeting global conservation targets. PLoS ONE 7 (3). https://doi.org/10.1371/journal.pone.0032529.
Campana, I., Angeletti, D., Crosti, R., Di Miccoli, V., Arcangeli, A., 2018. Seasonal patterns of floating macro-litter across the Western Mediterranean Sea: a potential threat for cetacean species Rendiconti Lincei. Sci. Fis. Natl. 1–15.
Caro, T., 2010. Conservation by proxy: indicator, umbrella, keystone, flagship, and other surrogate species. Chapter 3 Species Indicators of Biodiversity in Reserve. Island Press, Washington.
Coll, M., Piroddi, C., Albouy, C., Ben Rais Lasram, F., Cheung, W.W., Christensen, V., et al., 2012. The Mediterranean Sea under siege: spatial overlap between marine biodiversity, cumulative threats and marine reserves. Global Ecol. Biogeogr. 21 (4), 465–480.
Crosti, R., Arcangeli, A., Romeo, T., Andaloro, F., 2018. Assessing the relationship between cetacean strandings (Tursiops truncatus and Stenella coeruleoalba) and fishery pressure indicators in Sicily (Mediterranean Sea) within the framework of the EU Habitats Directive. Eur. J. Wildl. Res. 63 (3), 55.
Cuttelod, A., García, N., Abdul, Malak D., Temple, H., Katariya, V., 2008. The Mediterranean: a biodiversity hotspot under threat. In: Vié, J.-.C., Hilton-Taylor, C., Stuart, S.N. (Eds.), The 2008 Review of The IUCN Red List of Threatened Species. IUCN Gland, Switzerland, pp. 13.
Díaz, M., Concepción, E.D., Oviedo, J.L., Caparrós, A., Farizo, B.Á., Campos, P., 2020. A comprehensive index for threatened biodiversity valuation. Ecol. Ind. 108, 10569.
Dudley, N. (Ed.), 2008. Guidelines for Applying Protected Area Management Categories. IUCN.
European Commission, 2007. Guidelines for the establishment of the Natura 2000 network in the marine environment. Application of the Habitats and Birds Directives. http://ec.europa.eu/environment/nature/natura2000/marine/docs/marine_guidelines.pdf.
Ferretti, F., Morey, G, Serena, F., Mancusi, C., Fowler, S.L., Dipper, F. Ellis, J.R., 2016. Squatina squatina. The IUCN Red List of Threatened Species 2016: e. T39332A101695971.
Gaspari, S., Natoli, A. 2012. Grampus griseus (Mediterranean subpopulation). The IUCN Red List of Threatened Species 2012: e.T16378423A16378453.
Giakoumi, S., Katsanevakis, S., Vassilopoulou, V., Panayotidis, P., Kavadas, S., Issaris, Y., Kokkali, A., Frantzis, A., Mavrommati, G., 2012. Could European marine conservation policy benefit from systematic conservation planning? Aquat. Conserv. Mar. Freshwater Ecosyst. 22 (6), 762–775.
Harris, G.M., Jenkins, C.N., Pimm, S.L., 2005. Redefining biodiversity conservation priorities. Conserv. Biol. 19, 1957–1967.
Hoffmann, S., Beierkuhnlein, C., Field, R., Provenzale, A., & Chiarucci, A. (2018). Uniqueness of Protected Areas for Conservation Strategies in the European Union. Scientific reports, 8.
Hoyt, E., 2018. Marine protected areas. In: Encyclopedia of Marine Mammals. Academic Press, pp. 569–580.
IUCN, 2012. IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp.
IUCN, 2018. The IUCN Red List of Threatened Species. Version 2018-2. http://www.iucnredlist.org.
Karr, J.R., 1991. Biological integrity: a long-neglected aspect of water resource management. Ecol. Appl. 1, 66–84.
Lamoreux, J., Akçakaya, H.R., Bennun, L., Collar, N.J., Boitani, L., Brackett, D., Rylands, A.B., 2003. Value of the IUCN red list. Trends Ecol. Evol. 18 (5), 214–215.
Lyashevska, O., Farnsworth, K.D., 2012. How many dimensions of biodiversity do we need? Ecol. Ind. 18, 485–492.
Margules, C.R., Pressey, R.L., 2000. Systematic conservation planning. Nature 405 (6783), 243.
Mazaris, A.D., Kallimanis, A., Gissi, E., Pipitone, C., Danovaro, R., Claudet, J., et al., 2019. Threats to marine biodiversity in European protected areas. Sci. Total Environ. 677, 418–426.
McCook, L.J., Ayling, T., Cappo, M., Choat, J.H., Evans, R.D., De Freitas, D.M., Marsh, H., 2010. Adaptive management of the Great Barrier Reef: a globally significant demonstration of the benefits of networks of marine reserves. Proc. Natl. Acad. Sci. 107 (43), 18278–18285.
Minambiente: https://www.minambiente.it/pagina/aree-marine-istituite. Downloaded 08/10/2019.
ORBS, 2011. Progetto Osservatorio Regionale della Biodiversità Siciliana, Regione Siciliana – SITR", D.D.G. del Dipartimento Ambiente della Regione Siciliana n. 342 < http://www.sitr.regione.sicilia.it/geoportalen/orbs/ > .
Pomeroy, R.S., Watson, L.M., Parks, J.E., Cid, G.A., 2005. How is your MPA doing? A methodology for evaluating the management effectiveness of marine protected areas. Ocean Coast. Manage. 48 (7–8), 485–502.
Possingham, H.P., Wilson, K.A., 2005. Biodiversity: turning up the heat on hotspots. Nature 436 (7053), 919.
Reid, W.V., 1998. Biodiversity hotspots. Trends Ecol. Evol. 13 (7), 275–280.
Rodrigues, A.S., Pilgrim, J.D., Lamoreux, J.F., Hoffmann, M., Brooks, T.M., 2006. The value of the IUCN Red List for conservation. Trends Ecol. Evol. 21 (2), 71–76.
Rondinini, C., Battistoni, A., Teofili, C., 2014. Lo stato della Biodiversità in Italia: l'applicazione dell'approccio Sampled Red List e Red List Index. IUCN-Italia 34.
Siddig, A.A., Ellison, A.M., Ochs, A., Villar-Leeman, C., Lau, M.K., 2016. How do ecologists select and use indicator species to monitor ecological change? Insights from 14 years of publication in Ecological Indicators. Ecol. Ind. 60, 223–230.
Tsiripidis, I., Xystrakis, F., Kallimanis, A., Panitsa, M., Dimopoulos, P., 2018. A bottom–up approach for the conservation status assessment of structure and functions of habitat types, Rendiconti Lincei. Sci. Fis. Natl. 29 (2), 267–282.
UNEP-WCMC and IUCN, 2016. Protected Planet Report 2016. UNEP-WCMC and IUCN, Cambridge UKand Gland, Switzerland.
UNESCO World Heritage Committee, 2013. Operational Guidelines for the Implementation of the World Heritage Convention WHC. 13/01 July 2013.
Zenetos, A., Çinar, M.E., Pancucci-Papadopoulou, M.A., Harmelin, J.G., Furnari, G., Andaloro, F., Zibrowius, H., 2005. Annotated list of marine alien species in the Mediterranean with records of the worst invasive species. Mediterr. Mar. Sci. 6 (2), 63–111.