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SELECTION OF TARGET SPECIES FOR MARINE PROTECTED AREAS: A MULTI CRITERIA APPROACH USING BENTHIC ORGANISMS

Seleção de espécies-alvo para áreas marinhas protegidas: uma abordagem multicritério usando organismos bentônicos

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ABSTRACT

The selection of optimal target species to define and manage protected marine areas (MPAs) has generated a great scientific discussion during the past decades. Benthic invertebrates are commonly less considered as important target species, despite their pivotal role in marine ecosystems. To address this issue, we determined target species among benthic marine organisms using a multi-criteria approach. For this purpose, we used a data base from the *Katalalixar National Reserve* (RNK) in central Patagonia, Chile. The data were obtained through underwater photography and quantitative sampling by means of scuba diving during three expeditions between 2017 and 2019. Based on the total taxonomical inventory from both methods, a SIMPER analysis was used to determine 10 candidate species, and the Landscape Selection Species program was used for the selection of target species. Finally, eight target species were selected. The black snail *Tegula atra*, the hermit crab *Pagurus comptus*, the gastropod *Crepipatella dilatata*, and the polychaete *Platynereis australis* were selected among errant species. Among sessile species, the encrusting coralline algae *Lithothamnium* sp., the sea anemone *Actinostola chilensis*, the parchment worm *Chaetopterus variopedatus,* and the encrusting ascidia *Didemnum* sp. were the selected species. Based on our results we expect that these species will be included as target species in future management plans to improve protection of the marine environment of the Katalalixar National Reserve, one of the most pristine areas of the Chilean fjord region.

Keywords: macroinvertebrates, macroalgae, biodiversity, Patagonia.

RESUMO

A seleção de espécies-alvo ideais para definir e gerenciar áreas marinhas protegidas (AMPs) gerou uma grande discussão científica nas últimas décadas. Os invertebrados bentônicos são comumente pouco considerados como espécies-alvo importantes, apesar de seu papel central nos ecossistemas marinhos. Para resolver esse problema, determinamos as espécies-alvo entre os organismos marinhos bentônicos usando uma abordagem multicritério. Para tanto, utilizamos um banco de dados da Reserva Nacional Katalalixar (RNK), no centro da Patagônia, Chile. Os dados foram obtidos por meio de fotografia subaquática e amostragem quantitativa por meio de mergulho autônomo durante três expedições entre 2017 e 2019. Com base no inventário taxonômico total de ambos os métodos, uma análise SIMPER foi usada para determinar 10 espécies candidatas, e o programa Landscape Selection Species foi usado para a seleção das espécies-alvo. Finalmente, oito espécies-alvo foram selecionadas. O caracol preto Tegula atra, o caranguejo eremita Pagurus comptus, o gastrópode Crepipatella dilatata e o poliqueta Platynereis australis foram selecionados entre as espécies errantes. Entre as espécies sésseis, as algas coralinas incrustantes Lithothamnium sp., a anêmona marinha Actinostola chilensis, o verme-pergaminho Chaetopterus variopedatus e a ascídia incrustante Didemnum sp. foram as espécies selecionadas. Com base em nossos resultados, esperamos que essas espécies sejam incluídas como espécies-alvo em planos de manejo futuros para melhorar a proteção do ambiente marinho da Reserva Nacional de Katalalixar, uma das áreas mais primitivas da região dos fiordes chilenos.

Palavras-chave: *macroinvertebrados, macroalgas, biodiversidade, Patagônia.*

INTRODUCTION

Worldwide, the selection of targets species is a topic that sparks great scientific discussions and requires a great amount of information regarding the geographical area, as well as the wildlife inhabiting a protected area. The composition and presence of species allow the evaluation of an area, considering characteristics such as biodiversity, ecosystems, assets, environmental services, or cultural and historic attributes (Stringberg, 2007; Roncancio-Duque & Venegas, 2019). Commonly, species that present an endemic and/or infrequent distribution are preferred as targets species (Roncancio-Duque & Venegas, 2019; Vila *et al*., 2010). Five criteria have been picked out in order to select the values for target species: area, heterogeneity, vulnerability, ecological functioning, and socioeconomic importance (Stringberg, 2007). During the past decades, special software has been developed in order to support the selection of target species (Ball; Possingham & Watts, 2009; Strindberg *et al*., 2007). One of these programs is the Landscape Selection Species (LSS), a software providing configurations and tools that facilitate to choose so called landscape species (= targets species) for protected areas.

Benthic marine organisms (BMO) (macroinvertebrates and macroalgae) play essential roles on the ecosystems' functioning (Gérino *et al*., 2003, McLeod *et al*., 2009; Boulton *et al*., 2008). Benthic invertebrates represent 92% of global marine wildlife, and it is estimated that its biodiversity is compound by roughly 163000 species (Mora *et al*., 2011), while benthic macroalgae are represented by approximately 72 500 species (Guiry, 2012).

On the one hand, macroinvertebrates such as crustaceans and shellfish offer numerous provisioning ecosystem services, being also natural sources of great economic importance, (FAO, 2018). Also, they offer ecosystem services of the cultural and regulatory type, for example corals through their beauty promoting tourism and its usefulness as habitat for other marine species (Rossi *et al*., 2017). On the other hand, macroalgae also offer supply ecosystem services through commercial harvesting, which has achieved a global yearly production of 31.2 million tons, representing a market worth USD 11 700 M (FAO, 2012; Chopin & Tacon, 2021). In addition, macroalgae also provide ecosystem services of the supportive and regulatory type, as these organisms are responsible for CO_2 to O_2 exchange and photosynthetic processes (Gómez, 2001). By growing as underwater forests, they also provide other species with substrate (Ríos *et al*., 2007; Soto-Mora *et al*., 2021).

Despite the pivotal role that MBO play on marine ecosystems due to their ecosystem services (Peterson *et al*., 2010; Nahuelhual *et al*., 2017; Brain *et al*., 2020), except for reef forming corals, commonly MBO are not considered as targets species for conservation purposes in marine protected areas. Traditionally, the chosen targets species are seabirds or charismatic species of migratory nature, such as big sea mammals. Seasonally occupied reproductive areas and/or feeding sites used by marine vertebrates are also included as important conservation objects. Paradoxically, native and/or endemic MBO that permanently inhabit conservation areas are rarely considered among targets species (Montiel & Jara, 2019).

In this context, we determined targets species based exclusively on benthic marine organisms using a multicriteria approach, which included both, ecological and socio-economical criteria.

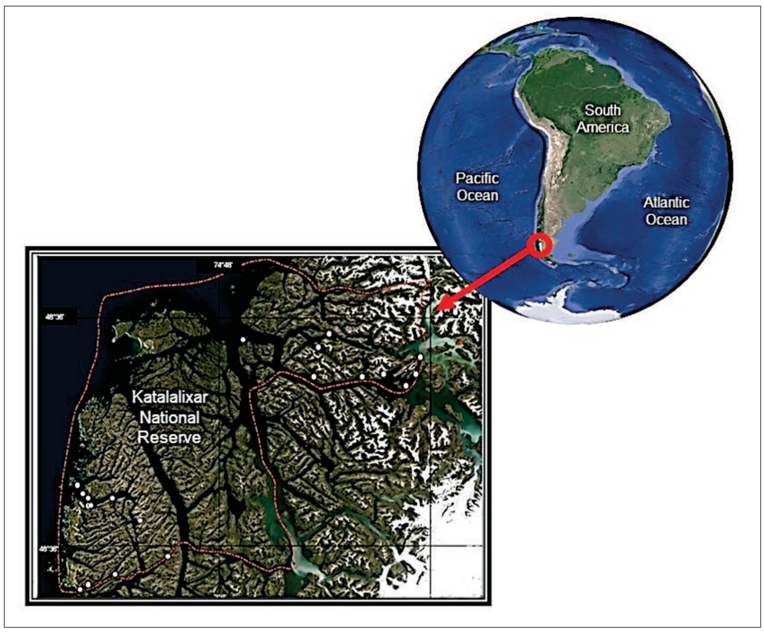
MATERIAL AND METHODS

1 Study area

For the purposes of this study, data from the Katalalixar National Reserve (KNR) were selected since actually no specific marine targets species are defined for any future conservation managing plan. According to the Chilean administration and environmental laws, national reserves represent only a low level of protection and the KNR was created to protect the terrestrial area only. However, the reserve formed by innumerable islands includes all surrounding waters until 80 m of distance from the high tide lines of the coasts (Zorondo-Rodríguez *et al*., 2019).

The KNR is located in the central part of the fjord and channel ecosystems of Chilean Patagonia, between 47.5 °S and 48.5 °S, bordering with the Gulf of Penas in the north, and the Castillo Channel in the south. Longitudinal, the KNR extends from the coastal line of the islands fronting the Pacific Ocean in the west to the Troya Channel in the east, occupying a total surface of 674,500 hectares (Gorny *et al.,* 2020a) (Figure 1). As in the entire region of fjords and channels, most part of the coastal borders are formed mainly by rocky reefs through the first 40 meters of depth (Soto, 2009). Regarding the oceanographic characteristics, the sea's superficial temperature fluctuates between 6.9 and 10.1 °C and salinity of inner waters near effluents of rivers is 10 psu on average in the first meters of depth. In the areas further away from these bodies of freshwater, the salinity increases, reaching 32 psu towards the open ocean (Silva & Calvete, 2002). The waters around the inner islands are highly influenced by the Baker River, which provides organic matter, detritus, and nutrients derived from glaciers, influencing the composition of the macrobenthic communities of the coastal zones (Quiroga *et al.,* 2016). Recently, the marine flora and fauna of the KNR had been described systematically. Gorny *et al*. (2020a) reported a total of 76 invertebrate species on the upper sublittoral, between 5 and 24 m of depth, and 170 species for the deeper sublittoral between 20 and 220 m of depth. In contrast, the phycological inventory of the same area revealed the presence of 99 species of macroalgae (Rosenfeld *et al*., 2019). Species such as penguins, cormorants, and sea mammals like dolphins and sea lions can be found among the marine vertebrate fauna of the reserve (Gorny *et al*., 2020b).

Figure 1 – Katalalixar Nacional Reserve (KNR). The boundaries of the reserve are shown by the red dashed lines



2 Data base

2.1 Data source

Underwater photography (**UP**) was used with the purpose to determine the species inventory on the shallow sublittoral area. The images were obtained by means of scuba diving during the expeditions *Katalalixar I* (2017) on board of the *L/M Mari Paz II* and the expedition *Katalalixar II* (2018) on board of the *N/M Patagonia Explorer* (Gorny *et al.,* 2020b). The UP were taken from the surface to 20 m depth. Thirty-eight high-definition pictures were selected from the total of the photographic material. Additionally, the information from 15 quantitative samples of biological material (**BM**) was used; these samples were collected by scuba diving during the 2019 expedition (further details see in Gorny *et al.*, 2020a).

2.2 Processing of the underwater images

In order to determine the taxonomic composition, every **UP** was treated with the Coral Point software (Kohler & Gill, 2006). A grid formed by hundred points was overlaid on each photograph to systematise the identification of the species. Due to the different surfaces covered by the underwater pictures, only the presence of species per UP were calculated. The guide of the Marine benthic fauna of Chilean Patagonia (Häussermann & Forsterra, 2009) was used in order to identify the invertebrates, and the atlas *Algas Marinas de la Patagonia* (Boraso *et al*., 2004) was used for the determination of macroalgae.

The data from **UP** and the **BM** samples were grouped as a **unique matrix** of binary data (presence/absence), resulting as a unified matrix of both sampling methods, comprising 53 samples each method. The final MBO inventory obtained from the visual documentation and samples was 129 taxa, 125 macroinvertebrates taxa, and 4 macroalgae taxa (Figure 2, step1).

2.3 Selection of candidates for target species

Based on the unified matrix, each species was categorized as errant or sessile, resulting on the creation of two sub-matrixes constituted by 65 errant species and 64 sessile species (Figure 2, step 2). Species qualifying as candidates for target species of each sub-matrix were selected using the Similarity Percentages analysis (SEMPER) (Clarke, 1993). In order to execute this routine, species of the BM group and of the UP groups of each sub-matrix were compared. Based on these results, the 10 species (or genus level) that showed the higher similarity percentages in each group were selected as candidates for target species (Figure 2, step 3).

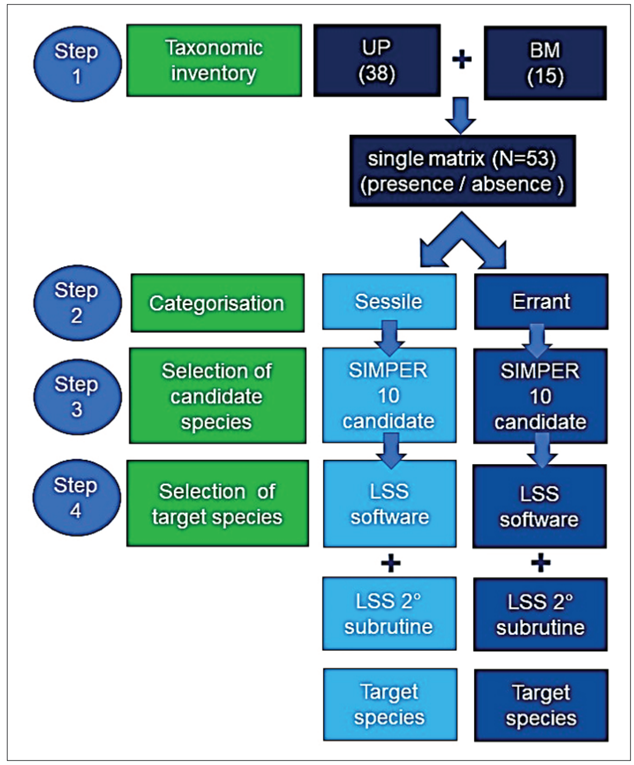
2.4 Selection of target species

The Landscape Selection Species software version 2.1 (LSS) proposed by the Living Landscapes Program from Wildlife Conservation Society (Strindberg, 2007) was used to select the target species (Figure 2, step 4). For the purposes of this study, the selection of landscape species was used as a synonym for conservation objects or target species. The LSS program chooses conservation objects in accordance to: area requirements, heterogeneity, vulnerability, ecological functionalities, and socioeconomic importance. A sub-routine for species selection was used that calculates at which degree a species occupies habitats, management areas, and is impacted by threats. The iterative routine selects targets species using the following steps:

I. The accumulated score of each qualifiable species is calculated (10 species for each group in the case of this study), then, a descending species ranking is constructed. The first-ranking species is selected as a conservation object.
II. The species selected as a conservation object is singled out, to recalculate the group's heterogeneity and vulnerability values, considering only the remaining qualifiable species (9 species in the case of this study).
III. The accumulated score of each remaining qualifiable species is recalculated and a new ranking is developed based on the newer scores. The first- ranking species after the recalculation is selected as the second conservation object.
IV. Steps two and three are repeated until all the criteria are represented by the ensemble of species selected as conservation objects (Further detail see Stringberg, 2007) (Figure 2).

The criteria applied to the habitat selection were eurybathic, stenobathic, hard substrate, soft substrate, epilithics, epibionts, channel, fjord, and coast; all of them were described by Häussermann and Försterra (2009). In relation to the human activities and threats, the following seven criteria were identified: fishing activities, salmon farming, tourism, sea contamination, inshore construction, research activities, and bycatch. Finally, as identified ecological functions, the following were applied: seascape species, zoo-forests, habitat-forming species, bio-indicators of pollutants, apex predators, medium predators, primary producers, carbon immobilisers, bio-toxins accumulators, herbivores, filter feeders, carnivores, omnivores, decomposers, native species, and exotic species. After the corresponding values were assigned to each species, then routines were carried out separately on both errant and sessile groups.

Figure 2 – Scheme of statistical methods used to determine the target species



RESULTS

1 Selection of the candidate for species target

From the sub-matrix constituted by only errant taxa, the chosen candidate species from the group of biological samples were: *Crepipatella dilatata* (Lamarck, 1822) (5.91% of similarity), *Platynereis australis* (Schmarda, 1861) (5.348%), *Cosmasterias lurida* (Phillippi, 1858) (5.227%), *Harmothoe ernesti* (Augener, 1931) (2.514%) and *Odontaster penicillatus* (Phillippi, 1870) (4.402%). As eligible species from the group of photographic samples the following species were selected: *Arbacia dufresnii* (Blainville, 1825) (4.849%), *Pagurus comptus* (White, 1847) (2.381%), *Calliostoma consimile* (Smith, 1881) (2.69%), *Campylonotus vagans* (Bate, 1888) (1.602%), and *Tegula atra* (Lesson, 1831) (2.606%).

From the sub-matrix constituted by sessile taxa, the chosen candidate species from the group of biological samples were: *Chaetopterus variopedatus* (Renier, 1804) (3.129% of similarity), *Notaulax phaeotaenia* (Schmarda, 1861) (2.437%), *Apomatus* sp. (Philippi, 1844) (2.328%), *Perkinsiana magalhaensis* (Kinberg, 1867) (1.996%), and *Ampharete kerguelensis* (McIntosh, 1885) (1.959%). The chosen species from the group of photographic samples were *Lithothamnium* sp. (Heydrich, 1897) (8.567%), *Primonoella* sp. (Grey, 1858) (2.998%), *Metridium* sp. (Braunville, 1824) (2.793%), *Didemnum* sp. (Savigny, 1816) (2.091%), and *Actinostola chilensis* (McMurrich, 1904) (1.751%).

2 Selected target species

Based on the first routine of the LSS, calculating the score of five criteria, the group of errantia species obtained a higher average accumulated score than the group of sessile species (Figure 3). The errantia species showed a higher accumulated score in four of the five categories: habitat, vulnerability, ecological functionality, and socioeconomic value. Only in the category of area requirements both groups achieved the same score (Figure 3). Based on the LLS program sub-routine, the following selection of targets species was made from each group of candidate species.

2.1 Errantia target species

Among the errantia, four species were selected as conservation objects from the 10 total qualifiable species. The black snail *T atra* accumulated the highest score (4.6), followed by the hermit crab *P. comptus*, that accumulated a score of 4.0. The other two species, the gastropod *C. dilatata* and the polychaete *P. australis*, obtained an accumulated score of 3.1 and 2.4 respectively (Figure 3). In relation to the degrees of habitat occupation, the management areas, and the threats, *T.atra* presented values of 7.0, 1.0 and 5.0 respectively, whereas the remaining species showed lower values (Figure 4).

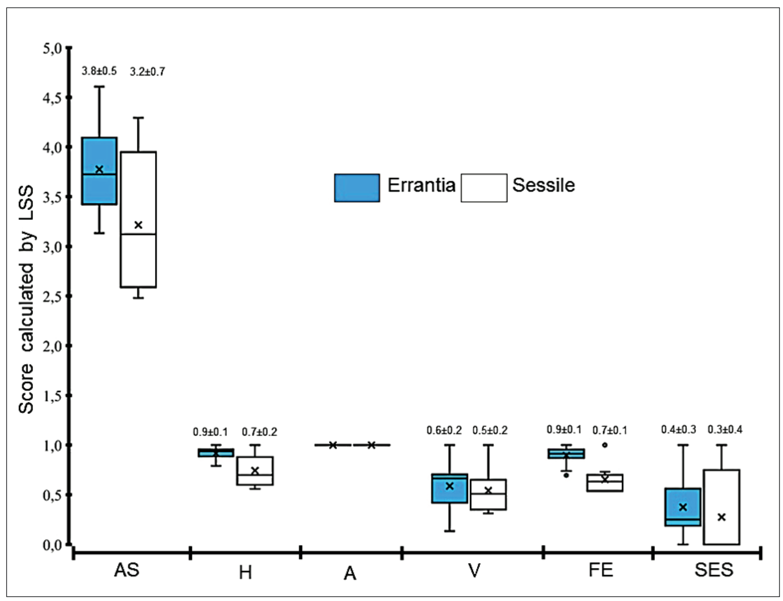


Figure 3 – Box-whisker plots of values of candidate species of errantia groups (Blue; N = 10) and sessile (White; N =10), including mean values (± SD) on top of each box plot. Aggregate score (AS), Heterogeneity (H), area requirements (A), Vulnerability (V) Ecological Functionality (FE), and Scio-economic significance (SES)

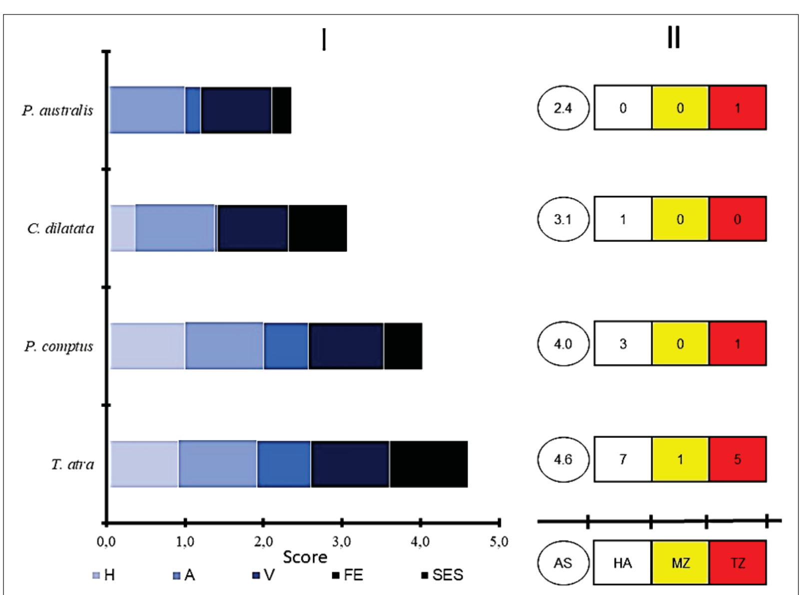


Figure 4 – Four errantia species selected as target species and their respective scores of Heterogeneity (H), Area requirements (A), Vulnerability (V) Ecological Functionality (FE), and Scio-economic Significance (SES) (I). The aggregate score (AS), score based on habitat (HA), management zones (MZ) and threats zones (TZ) for each conservation object (II)

2.2 Sessile target species

The LSS analysis selected four species (Figure 4), and the encrusting coralline algae *Lithothamnium* sp. presented the highest score (4.3). The sea anemone *A. chilensis* accumulated a score of 3.9, becoming the second selected conservation object. The other selected species were the parchment worm *C. variopedatus* and the encrusting ascidia *Didemnum sp.*, both obtaining an accumulated score of 3.5 and 1.7 respectively. Regarding the habitat occupation, the management areas, and the threats, *Lithothamnium* sp. showed values of 5.0, 1.0 and 6.0 respectively. All remaining species showed lower values (Figures 5 and 6).

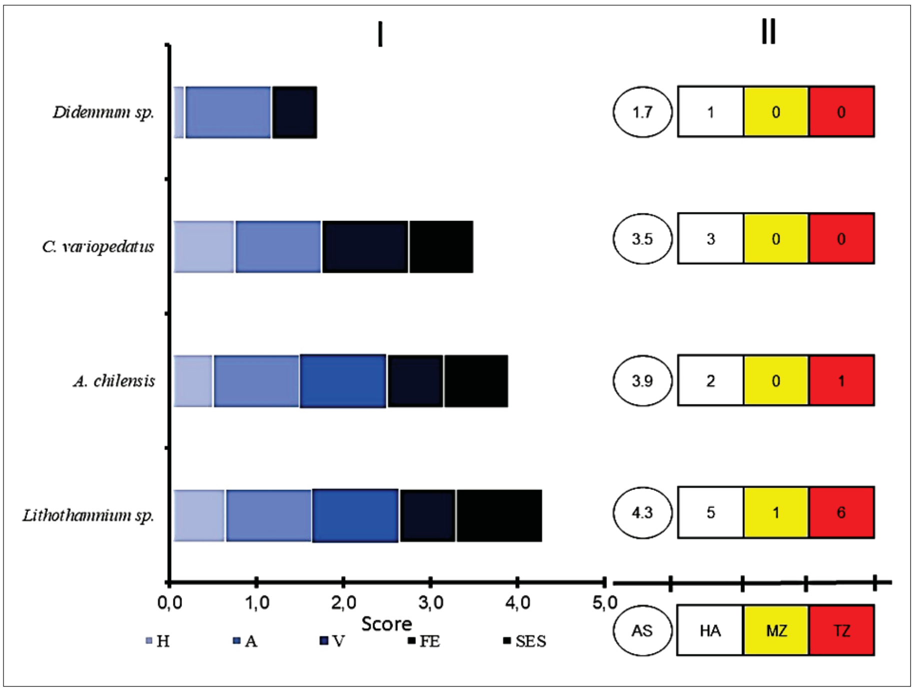


Figure 5 – Four sessile species selected as target species and their respective scores of Heterogeneity (H), Area requirements (A), Vulnerability (V) Ecological Functionality (FE), and Scio-economic Significance (SES) (I). The aggregate score (AS), score-based habitat (HA), management zones (MZ) and threats zones (TZ) for each conservations object (II)

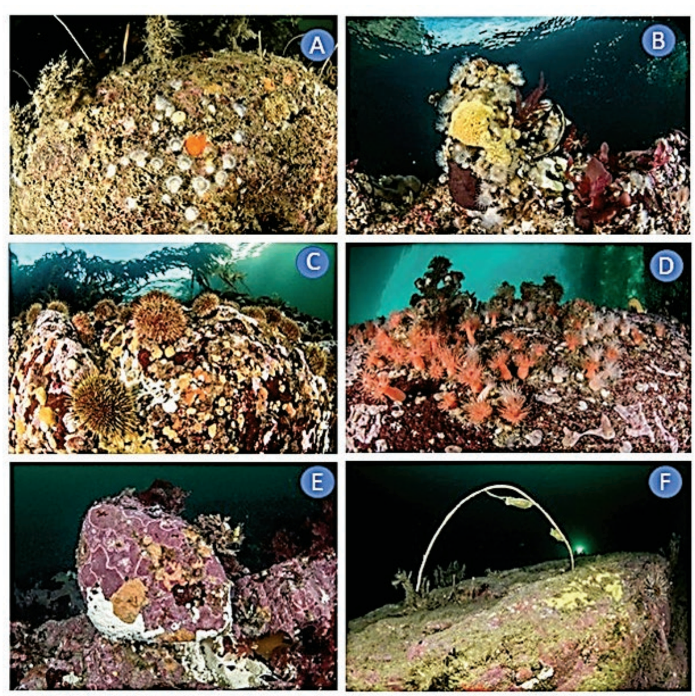


Figure 6 – Underwater photographs showed the seascape of the rocky reefs from de KNR Photographs: M. Gorny | M. Altamirano OCEANA.

DISCUSSION

In recent years, the percentage of marine protected areas has increased considerably (Jones; Murray & Vestergaard, 2019). However, biodiversity loss is still an ongoing process at global scales and with alarming rates due to contamination, overexploitation and habitat loss (Worm *et al*., 2006; McCauley *et al*., 2015; Eddy *et al*., 2021). Obviously, the current conservation and environmental management strategies are insufficient to halt or reverse the continuous and escalating degradation of ecosystems characterizing the Anthropocene (Jones; Murray & Vestergaard, 2019; He & Silliman, 2019). Since the percentage of protected areas is not enough to stop the defaunation in the oceans (McCauley *et al*., 2015), it was suggested that at least 30% of the world ocean surfaces need to be protected by 2030 (Salas *et al*., 2021). Therefore, the selection of optimal targets species is an important issue that should be improved urgently to define and manage protected marine areas in the future.

Currently, selection of targets species is mainly focused on marine vertebrates and excluding MBO, although they are major contributors to marine biodiversity and play a key role in trophic web. Unfortunately, benthic organisms are poorly represented on red lists, leaving unprotected benthic marine organisms worldwide. Our approach proposes is to broaden the spectrum of organisms to be considered as conservation target in marine realm. In this context, our result show that the errant target species (*T. atra*, *P. comptus*, *C. dilatate* and *P. australis*) are high frequent species of benthic communities characterizing the marine ecosystems of southern Chile (Cárdenas & Montiel, 2015; Cárdenas & Montiel, 2017; Betti *et al*., 2017; Försterra; Häussermann & Laudien, 2017). Therefore, these four target species may represent a reliable indicator for successful conservation of the Chilean fjords and channels. Since sessile species are sensitive to changes of temperature and pH (Peck, 2005; Andersson; Mackenzie & Gattuso, 2011), these organisms are extremely vulnerable to allochthonous oceanographic changes, even when threats come from outside the boundaries of area MPA. Therefore, sessile target species as defined by our study (*Lithothamnium* sp., *A. chilensis*, *C. variopedatus* and *Didemnum* sp. (Figure 6)) may represent usefully sentinels to monitor impacts caused by climate change.

Considering the ecological importance of MBO as target species, and the fact that they are permanently exposed to environmental conditions of a MPA, compared to highly migrating vertebrates, it would be advisable for decision makers to incorporate MBO in any future conservation planning and management.

In the case of the KNR, recently, systematic research efforts contributed significantly to determine the diversity and to complete the taxonomic inventory of this low protected area. Our results may motivate to include MBO in the list of future conservation objects when the still lacking management plan for this comparable low protected area is devolved or when the level of protection of these still pristine waters may be raised in future times. Finally, our study is an example that not only corals, but also many other species of marine invertebrates such as snails, crustaceans and even worms are important target species for successful conservation planning.

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