FAIRSEA (ID 10046951)

“Fisheries in the AdriatIc Region - a Shared Ecosystem Approach”

D.4.8.3 – Report on the preference modelling approach developed (MCDA)

Work Package:	WP4 “Implementation of a shared and integrated platform” Activity 4.8 “Development of an integrated platform for an Ecosystem Approach to Fisheries”
Type of Document	Report on the preference modelling approach developed (MCDA).
Use	Public
Responsible PP	PP5
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Version and date	Version 1, 28/08/2021

Deliverable 4.8.3

Report on the preference modelling approach developed (MCDA)

FAIRSEA – Fisheries in the Adriatic Region – a shared Ecosystem Approach

FAIRSEA is financed by Interreg V-A IT-HR CBC Programme (Priority Axis 1 – Blue innovation)

Start date: 01 January 2019

End date:31 August 2021

Contents

Acronyms used

AHP	Analytical Hierarchy Process
CFP	Common Fisheries Policy
D	Discards
DFN	Drift and/or fixed netters
EAF	Ecosystem Approach to Fisheries
EAFM	Ecosystem Approach to Fisheries Management
EMPL	Employment
F	Fishing mortality
FAIRSEA	Fisheries in the AdrIatic Region – a Shared Ecosystem Approach
FMSY	Fishing mortality at the Maximum Sustainable Yield
GFCM	General Fishery Commission for the Mediterranean
GVA	Gross value added
HOK	Vessels using hooks
LP	Lead Partner
Y	Yield
MAUT	Multi-attribute utility theory
MCDA	Multi-Criteria Decision Analysis
NGO	Non-Governmental Organization
PGP	Vessels using polyvalent passive gears only
PP	Project Partner
RBER	Ratio of revenue to break-even revenue
SSB	Spawning Stock Biomass
TAC	Total Allowable Catches
WAGE	Salary
WP	Work packages

INTRODUCTION

About FAIRSEA Project

The FAIRSEA is a European Territory Cooperation project financed under the priority 1 “Blue innovation”, Specific Objective 1.1 “Enhance the framework conditions for innovation in the relevant sectors of the blue economy within the cooperation area” of the INTERREG V-A Italy –Croatia Programme 2014-2020. The project focuses on the fisheries sector, key driver for the blue growth of the Adriatic communities, towards a sustainable co-management of resources and marine ecosystem protection. The transboundary nature of marine resources requires a cross-border cooperation and a shared “vision” to properly tackle and address the different socio-economic and environmental challenges related to fisheries activities management. In this context, FAIRSEA Project aims at enhancing transnational capacity and cooperation in order to promote the sharing of knowledge and good practices between regional and transnational key actors in the sector of sustainable fisheries management in the Adriatic Sea as well as to implement innovative approaches adopting an ecosystem approach to fisheries (EAF). Coordinated by the OGS of Trieste (IT), the project involves a consortium of 12 strategic and operational partners from Italy and Croatia making the best use of their complementary expertise to address and support the application of the EAF ensuring a strong and interactive engagement of institutional, technical and socio-economic stakeholders in project activities.

BIOECO – A multi-fleet and multi-stock platform for mixed fisheries

BIOECO is a module of the integrated platform for an Ecosystem Approach to Fisheries, developed in the WP4, which provides a multi-fleet and multi-stock platform to simulate mixed fisheries using the BEMTOOL model.

BEMTOOL includes 6 modules: a) biological; b) impact; c) socio-economic; d) policy/harvest rules; e) fleet behaviour.; f) Multi Criteria Decision Analysis - MCDA.

The ALADYM simulation model is the core model for the components a), b) and partially d) of BEMTOOL (more details can be found in “D4.6.1 - Calibrated BEMTOOL applications to the Adriatic Region”).

These tools allow to set scenarios for evaluating how changes/shifts in population traits (e.g. natural mortality, growth), fishery-driven impacts (e.g. fishing mortality, population and gear selectivity) and management or fishing strategies (e.g. closed season, changes in fishing

opportunity), affect stock and fisheries dynamics in terms of landings, discards and economic performance.
Results of model calibration and scenario modelling for the target species, by fleet segment (and fisheries), for the Adriatic basin have been produced, providing outputs in terms of biological, fishing impact and economic indicators. The definition of management scenarios has been object of a participatory process developed in WP5, by mean of the MCDA module of BEMTOOL.

Participatory process & preference modelling methods

Participatory management is widely recognized as a working method of paramount importance, based on the principles of knowledge sharing, accountability and legitimacy, for addressing the sustainable development of the fishery sector.
Industry–science cooperation could ensure more coherent information, enhance credibility, as well as contribute to the progressive implementation of an Ecosystem Approach to Fishery Management (EAFM).
This process entails the integration of stakeholder's local and traditional knowledge on both research-based advice and identification of management directions (e.g., Garcia and Cochrane, 2005; Cochrane et al., 2007; Rochet et al., 2008; Röckmann et al., 2012).
In Mediterranean fisheries, actions are urgently needed to reverse the unsustainable exploitation of most stocks (75% of assessed stocks remain overexploited in 2018, six years previously, that figure was at 88 % FAO, 2020).
A cooperative approach, involving stakeholders with different backgrounds, could help to increase collective awareness of this issue. It is thus fundamental to facilitate good governance and policy implementation, reducing conflicts and distrust in the advice and decision-making processes (e.g., Delaney et al., 2007; Shelton, 2007; Linke et al., 2011).
However, participatory management requires that stakeholders are enabled to express their qualitative and quantitative perceptions about the current situation, being aware of the objectives and indicators used to assess the fishery's impact, the information these are able to convey, the advice procedures, and the range of applicable management options with estimates of their biological, economic, and social consequences.
Multi Criteria Decision Analysis (MCDA; e.g., Belton and Stewart, 2002) is an area of growing interest in fisheries management, and there are several applications worldwide (e.g., Soma, 2003; Leung, 2006; Bevacqua et al., 2009; Innes and Pascoe, 2010; Aanesen et al., 2014; Kavadas et al., 2015; Rossetto et al., 2015; Lembo et al., 2017). MCDA models are powerful

for addressing specific problems characterized by multiple and often conflicting objectives, something that is common in fishery systems.

However, MCDA assessments can be affected by a range of uncertainties due to the imperfect knowledge of the specific system under study and the subjectivity of expert judgments (e.g., Banuelas and Antony, 2004; Rossetto et al., 2015). Incorporating uncertainty in the MCDA has been achieved using probabilistic judgments (e.g., Levary and Wan, 1998), fuzzy sets (Lee et al., 2001), and ranking intervals (Arbel and Vargas, 1993) to test the statistical significance of the final score and to facilitate consensus when a large number of stakeholders is involved.

In FAIRSEA project, we applied a preference modelling method that allows the transformation of qualitative judgments into quantitative judgments in order to ease their evaluation and practical use: the Analytical Hierarchy Process - AHP (e.g. Lembo et al., 2017).

Material and methods

We implemented the AHP to understand how stakeholders rank the importance of the economic, social, and biological factors affecting the fisheries, as well as to quantify how stakeholders perceive a set of management options.

The decision-making process needs to be decomposed to generate priorities in a specific way, defining the problem and structuring the decision hierarchy from the goal on top to the objectives at the intermediate level and down to the indicators/management options. A decision tree was thus identified for a survey design.

Two international meetings with stakeholders were organised by MEDAC (PP 11) and a final one by RERA (PP7) for discussing decision trees and administrate specific questionnaires to elicit preferences for the MCDA. During the final meeting the results of the case studies were discussed, particularly regarding the impact of the different management scenarios simulated with the BEMTOOL model, taking into account the spatial and temporal dimensions.

The participants to the MCDA survey were 32 (18 from Croatia, 13 from Italy, 1 from Slovenia). 13 of them belonged to fishermen/associations/cooperatives, 8 to researchers, 4 to public authorities, 2 to NGOs and 5 to other.

In the AHP survey the participants were asked to express their opinion on the relevance of a) economic, b)social, c)bio-ecological and d) productivity objectives to achieve the fishery sustainability, by giving a preference according to a scale of semantic scores.

Indeed, the participants were asked to rank the importance of the objectives showed in fig 2 by making pairwise comparisons and assigning a semantic score chosen from the following: "equally important", "moderately important", "more important" and "extremely important" (see fig. 1).

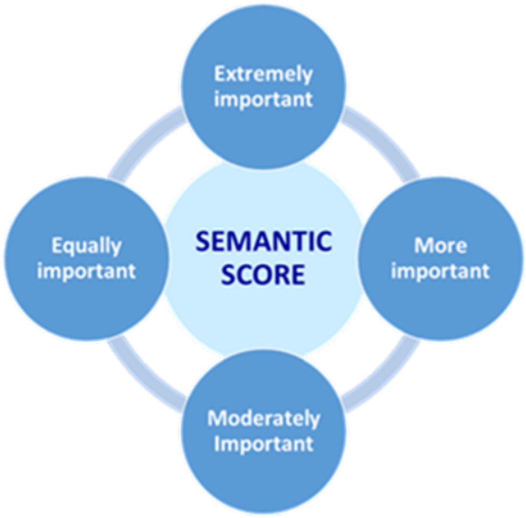

Fig. 1 – Semantic score for the AHP

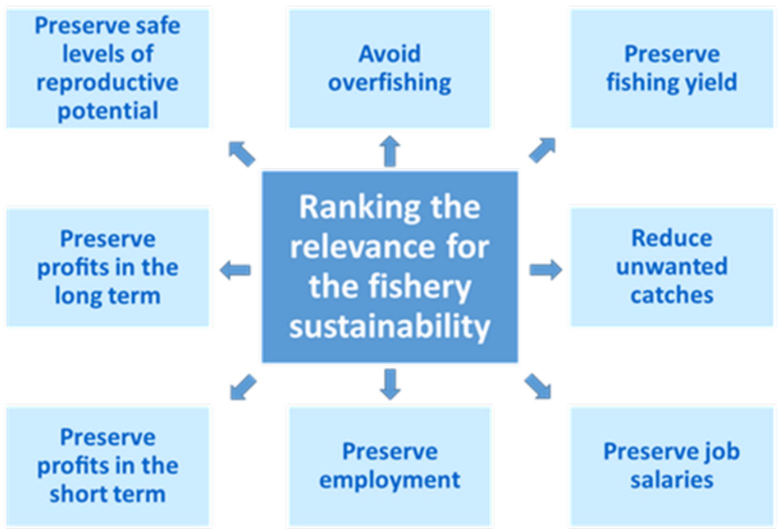

Fig. 2 – Pairwise comparison of the relevance of the relevance of the fishery sustainability objectives

The results were elaborated using a pairwise comparison matrix:

$$A = (a_{i,j})_{i,j=1,2,\ldots N}$$

where N is the number of alternatives (objectives or indicators) and $a_{i,j}$ is the score assigned by the stakeholder in the pairwise comparison between the i-th and jth alternatives. A is a positive reciprocal square $N \times N$ matrix, where a square matrix is reciprocal if: $a_{i,j} = \frac{1}{a_{j,i}}$.

It was possible to calculate a measure of consistency (Consistency Ratio) for each matrix of preferences using the following formula: $CR = \frac{CI}{RI} = \frac{\frac{\lambda_{max} - N}{N-1}}{RI}$, where CI is the consistency index, computed using the principal eigenvalue λmax and the number of alternatives N; the random index RI is a randomly generated value, computed assuming that the numbers in pairwise comparison matrix A are completely random (Saaty, 2008).

A similar process of pairwise comparison of the relevance of the fishery sustainability objectives was followed to determine the stakeholder's perception of the level of importance of the different management scenarios simulated using the BEMTOOL model.
Actually, the MCDA component implemented in BEMTOOL combines two multi-criteria techniques: a) the multi-attribute utility theory (MAUT) and b) the Analytic Hierarchy Process (AHP) (Rossetto et al., 2015).
MAUT relies on the idea that decision-makers attempt to maximize their utility with respect to a number of independent attributes (Keeney et al., 1993), each one representing a management objective.
The biological and socioeconomic indicators are identified and organized into an appropriate hierarchy; the utility functions are defined to express the level of satisfaction associated with different values of the indicators; the weights, representing the relative importance of each indicator to the overall utility, is derived through the pair-wise comparison of the indicators and/or objectives.
The flexible structure of this framework allows the incorporation of different management criteria and utility functions to adapt it to different decision problems.

Sensitivity

A sensitivity analysis was carried out to evaluate the robustness of the results, with respect to the uncertainty associated to the weights expressing the relative importance of the elements considered in the AHP. To this end, the Monte Carlo approach was applied, according to the following steps:

1. Application of uncertainty to the normalized vector of weights at each hierarchical level for each stakeholder, multiplying the deterministic local weights by the factor (1 + ε), where ε is a normally distributed error with mean 0 and standard deviation 0.15 (so that 90% confidence bounds encompass the original value of the weight±20%). A total of 1,000 extractions were made;
2. The perturbed local weights were normalized to add up to 1;

3. On the 1,000 vectors of weights for each hierarchical level, and for each element, relevant percentiles (0.05, 0.25, median, 0.75, 0.95) and statistics (minimum, maximum, mean, standard deviation and CV) were calculated;
4. For each statistic and percentile, the corresponding global vector was derived as a geometric mean among all stakeholders; this was carried out at each level of the hierarchical tree.

Estimates

First, an exploratory analysis on the perturbed weight vectors was carried out to detect possible differences between rankings. Then a global frequency was computed, taking all the runs of all the stakeholders as a whole and estimating the frequency to be the first, the second, etc. on the total perturbed rankings. This frequency has been interpreted as a proxy of the probability to get the higher preference, that is, a synthesis of the frequency of the ranking for a given objective, based on its weight and taking into account the judgment of each stakeholder (empirical probability).
The results of this exploratory analysis are affected by both the uncertainty introduced in the process and the natural variability among the stakeholders' preferences. Then, ranking preferences over stakeholders were estimated using geometric means. These global means and other associated statistics are only affected by the uncertainty introduced in the process, because the variability due to the different perceptions of stakeholders is smoothed by the mean. All the algorithms and computations were performed using an ad hoc routine developed in R language.

Results and Conclusions

According to the stakeholders perspective, the objective to "preserve a safe level of reproductive potential" had the maximum empirical probability to be ranked first preference (60%, see fig. 3), followed by "avoid overfishing" (18%).

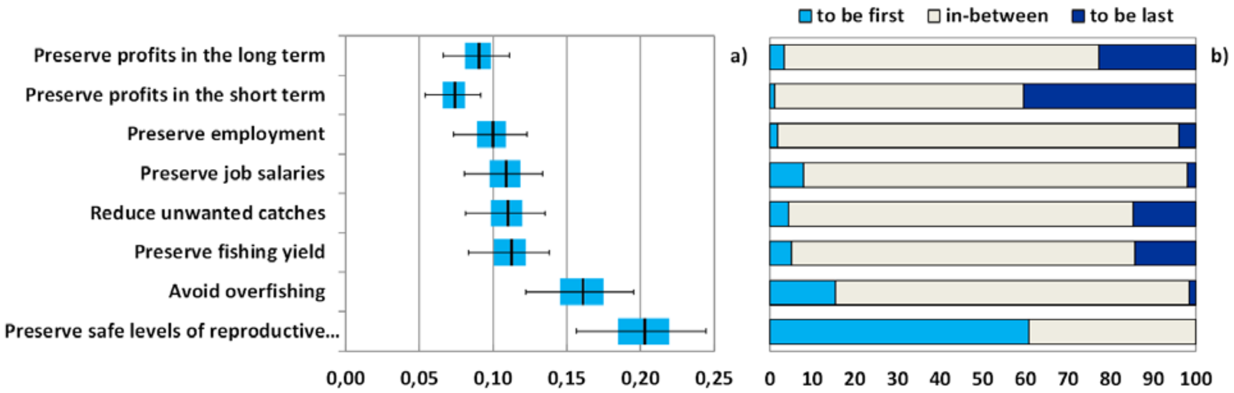

Fig. 3 – a) Ranking the stakeholders' preference (box plot percentiles: 0.05, 0.25, 0.5, 0.75, 0.95). b) Empirical probability (in percentage) to be ranked as first, in-between or last preference.

The other objectives of the fishery sustainability reached lower level of preference (empirical probability).

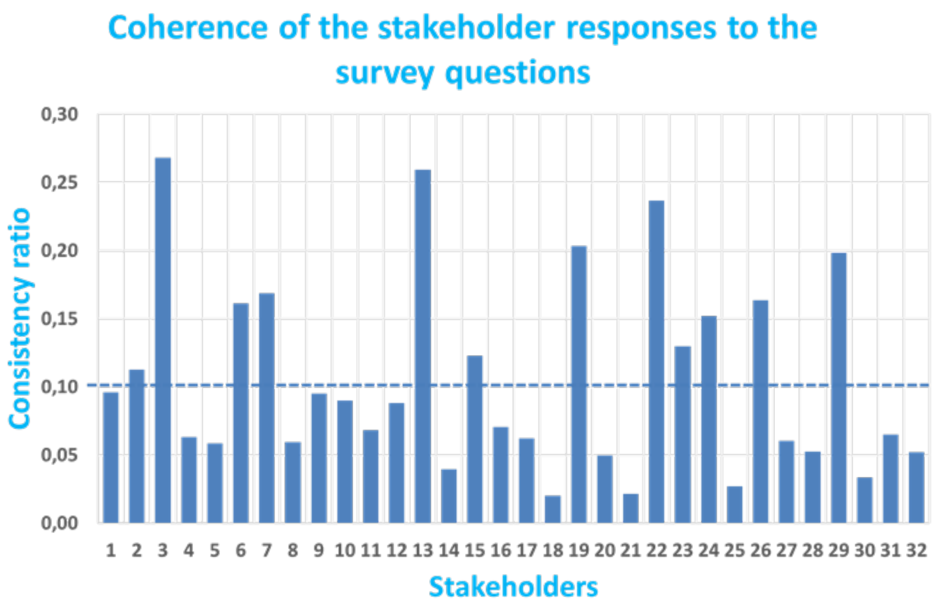

Fig. 4 – Consistency ratio of the stakeholder's answers

Among all the objectives, "preserve profits in the short terms" had the higher probability to be ranked as the last preference (40%; see fig. 3).

The Consistency Ratio (CR) identifies any possible inconsistency between the answers of each stakeholder to the survey, possibly due to e.g. an incorrect understanding of the question or a random compilation. Thus, the CR expresses the level of coherence, and values that are generally considered satisfactory should be within the threshold limit of 0.1 (Saaty 2008). Actually, the majority of the consistency ratios of the 32 stakeholders were below 0.1 (see fig. 4), which can be considered an appropriate achievement in order to minimize the risk of bias in the survey results.

A second survey was carried out among stakeholders, in order to rank their preference about possible scenarios based on sustainable fishing practices, aimed at achieving the F_{MSY}, improving the fishing pattern and guarantee durability of the results when the stocks overexploited rebuilt but, at the same time, preserving sustainable socio-economic conditions.

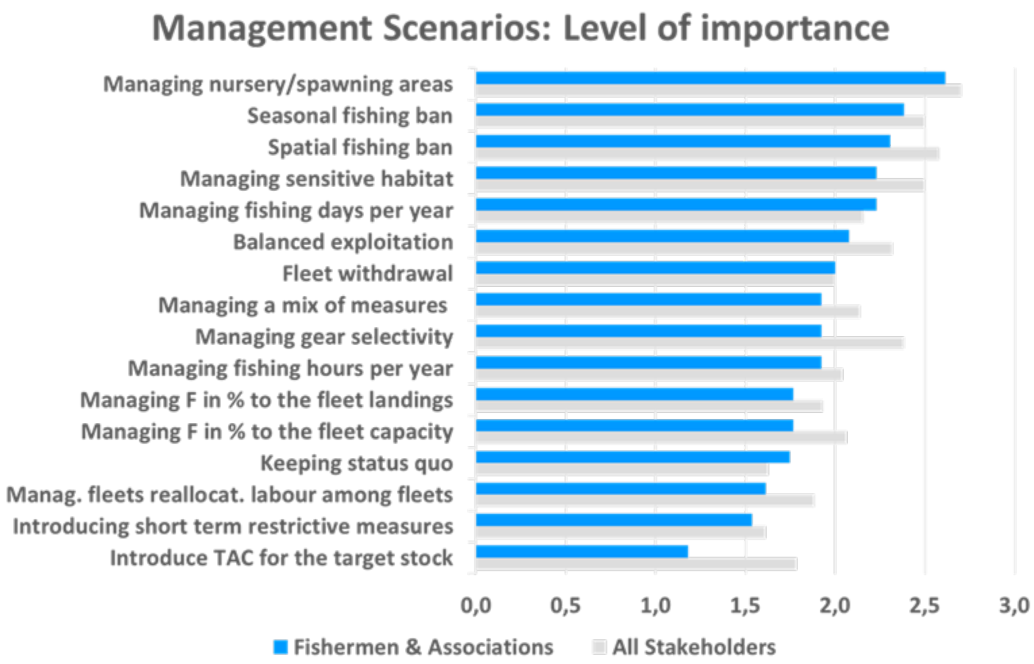

Fig. 5 – Management scenarios to achieve the fishery sustainability

Among the 16 possible scenarios evaluated, the most appreciated were those based on the management of spatial and temporal measures (i.e. managing nursery/spawning areas; seasonal fishing ban; spatial fishing ban; managing sensitive habitat). While, the less appreciated scenario was that based on the introduction of TAC for target stocks (see fig. 5). What is worth to point out is that similar results were obtained both considering the preferences expressed by the categories “fishermen & associations” and by “all categories of

stakeholders together", which suggests that there are no significant differences of opinion between the different categories interviewed (see fig. 5).
The stakeholders' most appreciated management scenarios were designed and fed into the BEMTOOL model, that was parameterised for the simulations and forecast scenarios taking as basis the GFCM Recommendation (Rec. GFCM/43/2019/5; MAP demersal fisheries in the Adriatic Sea; GSAs 17 and 18) and the management targets therein.
To this end, the first step was the model calibration, based on the stock assessments of the target stocks considered in the above mentioned GFCM Recommendation with their life history traits and indicators (spawning stock biomass, recruitment), the time series of total landings, discards, effort, costs, revenues, by fleet segment (and fisheries) for the Adriatic and Ionian basin, on the basis of the data available from 2004 to 2019.
At the second step, management scenarios were implemented at different spatial and time scales, following the loop of inputs from stakeholders' meetings. Specifically: three scenarios were implemented (see deliverable "D4.6.2 Management scenarios of policy using BEMTOOL outputs"):

1. (S0) Status quo (no variations compared to 2021).
2. (S1) Linear reduction of 40% in fishing days until 2026, for trawlers and "rapido", toward the F_{MSY} combined (0.35 value). We used a combined reference point of the target species included in the GFCM Recommendation (GFCM/43/2019/5), instead the one of European hake F_{MSY} (0.18 value), in order to avoid the risk of underutilisation for the less exploited species.
3. (S2) A combination of measures selected by stakeholders, based on fleet selectivity improvements + spatial closure areas (within 6 nautical miles, until December), taking into account the presence of nurseries of the main target species in the areas + 2 months of fishing bans for other gears (PGP 17-18 and DFN Croatia fishing ban in Feb and May; HOK GSA 18 March and May) + linear reduction of 25% in fishing days for trawlers and "rapido" fleets.

At the third step, the BEMTOOL scenario modelling module was used to assess the biological, economic and social consequences of the three selected management scenarios.
The best performing scenario was assessed by considering a) the utility functions associated to the different indicators and b) the weights representing the relative importance of each indicator (i.e. GVA, RBER, WAGE, EMPL, SSB, F, Y, D), to the overall utility, provided by the stakeholders.

Indeed, while in the BIOECO module of the FAIRSEA integrated platform the utility functions associated with the various indicators are default values (see fig. 6), the weights representing the relative importance of each indicator can be assigned directly by the stakeholders by operating on the BIOECO module (see fig. 7).

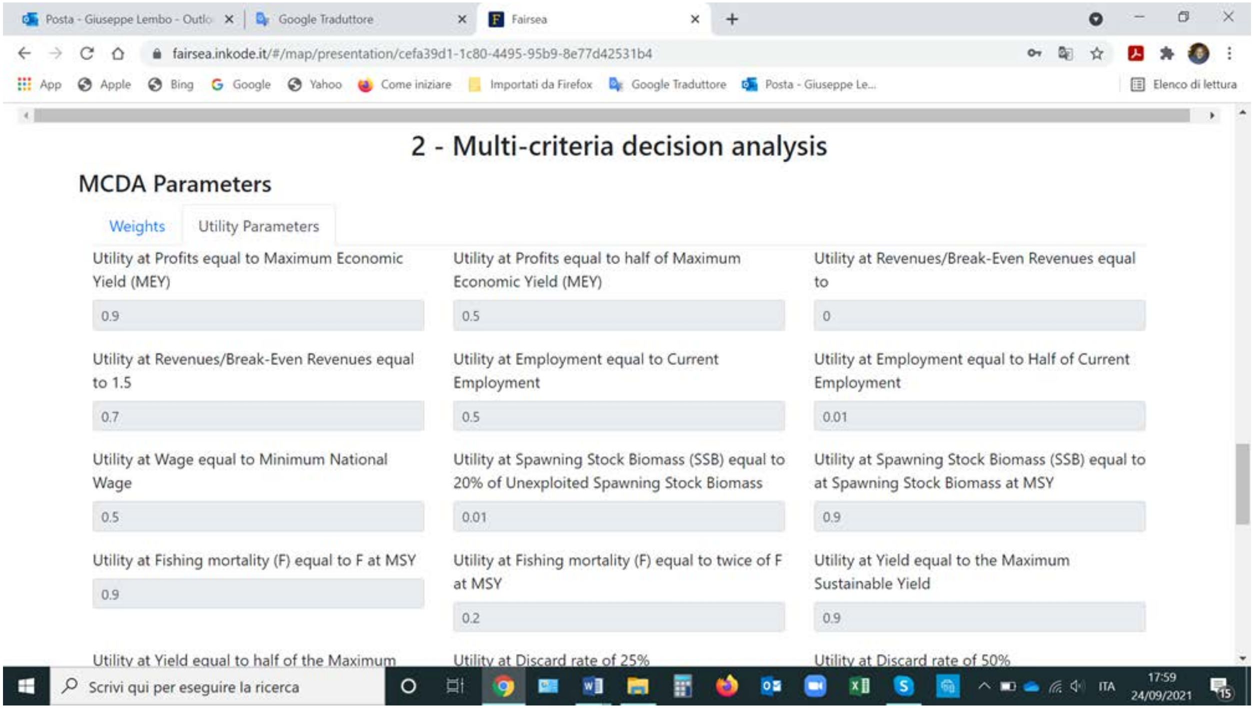

Fig. 6 – FAIRSEA integrated platform. Screenshot of the page in the MCDA menu, reporting the default values of the utility function

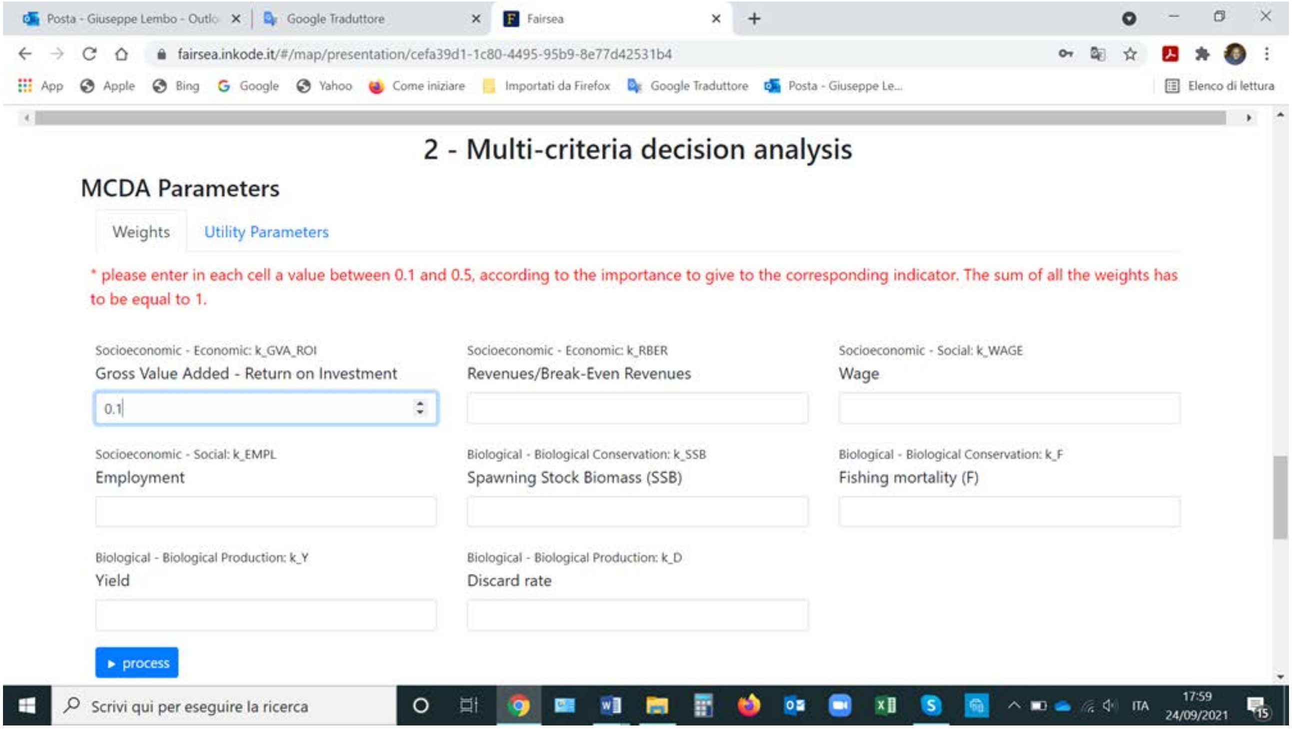

Fig. 7 – FAIRSEA integrated platform. Screenshot of the page in the MCDA menu, where stakeholders can introduce weights, which represent the relative importance of each indicator

The S0 scenario, which was the only one not based on the GFCM Recommendation for the period following the transition phase, showed the worst performances of all the indicators.
The S1 scenario, which was based on the GFCM Recommendation, but mainly implemented through a fishing days reduction, showed better performances of the biological indicators compared to scenario S0.
Finally, the S2 scenario, also based on the GFCM Recommendation, but implemented through a combination of the following measures:

a) spatial closure areas (within 6 nautical miles, until December),
b) taking into account the presence of nurseries of the main target species in the areas,
c) considering 2 months of fishing bans for other gears (PGP 17-18 and DFN Croatia fishing ban in Feb and May; HOK GSA 18 March and May),
d) a linear reduction of 25% in fishing days for trawlers and “rapido” fleets

showed the best performances of all the indicators (see fig. 7).

Thus, a combination of measures, less depending on the reduction of the fishing days and more addressed to improve the fishery exploitation pattern, seems to perform better, especially if social and economic considerations are taken into account.

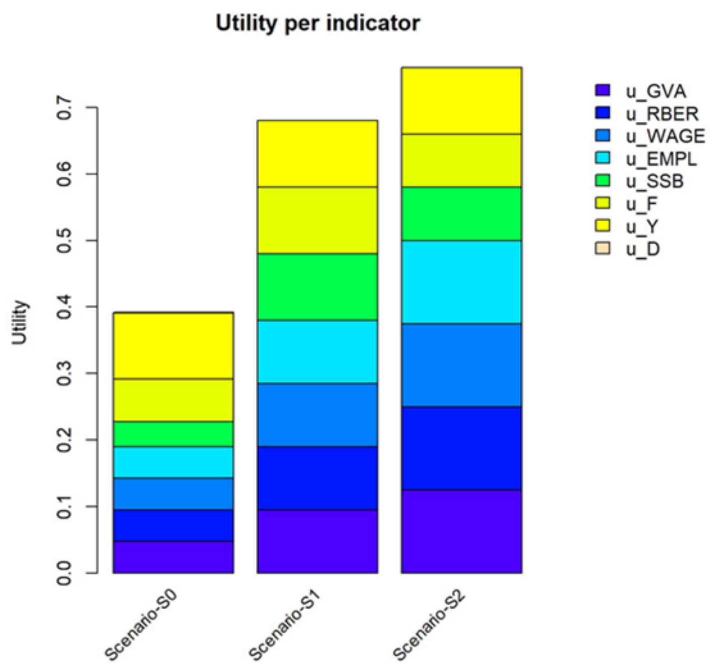

Fig. 8 – Utility function of the three scenarios simulated

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