IDENTIFYING DRIVERS OF ACCELERATING SEAGRASS LOSS IN THE MEDITERRANEAN: CAUSAL CHAIN AND SCENARIO ANALYSES

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Abstract
The primary causes of loss and degradation of Mediterranean seagrass beds were examined within a Driver Pressure State-Change Impact Response (DPSIR) framework as part of a larger EU project on European Lifestyles and Marine Ecosystems (ELME). Total losses were estimated at over 45 000 ha of seagrass over the last 100 years, with rates of change in the Mediterranean higher than recent global trajectories. Evidence gathered on the causes of loss (of seagrass habitat was used to produce Bayesian belief network (BBN) models to explore impacts of future changes in socio- economic drivers and policy.
Keywords: Posidonia, Coastal Management, Models

Introduction
Mediterranean seagrass meadows (primarily *Posidonia oceanica*) play a crucial role in stabilising sediments, maintaining water quality, protecting sedimentary shores from erosion and represent important fish production areas [1]. However, they are often disregarded during economic and social development, despite a wealth of studies illustrating declines due to anthropogenic pressures [2], and this trend is accelerating [3]. Including marine ecosystems components in policies for sustainable development requires a better understanding on the causal connections between human pressures (and their socio-economic drivers) and the changing state of the systems. This is particularly important at a time when the European Community is expanding, re-examining its agricultural and chemical policies, reforming its fisheries policy and exploring new ways to protect marine systems using an ecosystem-based approach (Marine Strategy Framework Directive). Here we assesses the causes of historical seagrass habitat loss in the Mediterranean and the evidence gathered is used to produce Bayesian belief network (BBN) models to explore the impact of plausible alternative human development scenarios on seagrass habitats.

Methods
The study presented here summarises the information on loss (dates, amount and causes) of seagrass habitat in the Mediterranean over the last 100 years. Data gathering was carried out via three main methods; searching published material, an online questionnaire and via direct contact with key organisations and experts. Results of metadata analyses were used to construct a BBN model of the Driver, Pressure and State-change pathways (using probability density functions derived from data to describe causal relationships between variables). The model was trialled under different scenario outcomes based on plausible future development patterns, policy options and likely social changes at European Community level. The scenarios employed in this study were designed to provide a general overview of alternative states of the world to highlight the differences that result from divergent pathways of socio-economic development [4]. A baseline scenario projecting future trends based on the current situation was contrasted with four Alternative Scenarios, defined at the extremes of two dimensions: governance and values. Each scenario comprises a description of the underlying values and policies that define it, and their broad socio-economic implications [5]. From these characterisations, narrative description of changes in basic socio-economic variables and activity in Driver sectors were developed for each scenario and translated into a simple categorical representation to indicate the direction of change in each of the Driver sectors, which were used to condition the BBN (full description see [6]).

Results and Discussion
We estimated total losses of over 45 000 ha of seagrass over the last 100 years, and identified rates seagrass loss for the Mediterranean which accede recent global trajectories. The causes of loss of seagrass habitat and the activities driving these pressures show patterns over time. The most numerically dominant activity causing past losses throughout the Mediterranean was input of urban sewage. However, there are indications that this activity pressure has been decreasing in frequency since the 1970s, perhaps due to improved wastewater treatment. The second most frequently observed pressure is from the fishing sector. There has been a gradually increasing trend in the loss of seagrass due to trawling, despite bans in the vicinity of seagrass beds in many parts of the Mediterranean. Other activities that are of growing concern are aquaculture (fish cages), tourism and shipping (anchoring, port construction). The BBN model (see Figure 1) was used to examine levels of seagrass loss and degradation under different combinations of pressures observed under different scenarios. Alarmingly under the baseline scenario (and assuming that there is full compliance to policy) the decline of *Posidonia* continues, despite improvements in urban wastewater treatment and a decline in the trawling and dredge fleet, mainly due to increases in finfish aquaculture and coastal urbanisation (affecting turbidity and organic matter enrichment). Continuing upward trends in livestock production and fertiliser carry on loading coastal systems with nutrients indirectly affecting the light received by *Posidonia*. Of the alternative scenarios only local responsibility leads to an improvement in *Posidonia* state, due to a steep decline in destructive fishing practices and a decrease in the drivers of nutrient enrichment and turbidity. National enterprise has devastating effects on the *Posidonia* with all of the major causes of seagrass loss and degradation showing an increasing trend or stabilising at current levels but not declining. The outputs of this study, in terms of transdisciplinary scenario models, are intended to provide scientific support for the implementation of the ecosystem approach in Europe.

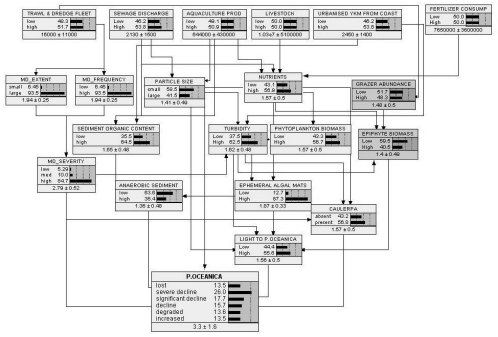

Fig. 1. Fully parameterised Bayesian Belief Network Model for *Posidonia oceanica* loss and degradation in the Mediterranean

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