Coastal and marine landscape ecology based on marine geospatial data infrastructure for analysis of marine resources and fishing effort

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Introduction

Researchers, resource managers and policy makers deal with a plethora of data for the coastal and maritime space. They know that the coastal zone and continental shelf are difficult areas to manage due to the 3-dimension of space, the overlapping of offshore, near-shore, shoreline and inshore physical geography, hydrography-bathymetry, as different type and quality of data, as well as jurisdictional and organizational overlaps. The needs of governance of coast and continental shelf resources, the management of high economic value of activities, and to the social value of coastal zones for quality of life, are drivers for planning and management of the socio-economic framework (Longhorn 2004). These complex physical and institutional relationships require the creation of a Coastal - continental Shelf Spatial Data Infrastructure (CSSDI) or marine geospatial data infrastructure (MGDI). MGDI is developed in close cooperation with the more generic SDI initiatives of countries, and partially exists in the form of the numerous data collection, formatting, and exchange within the framework of policy standards and guidelines set by UNESCO's Intergovernmental Oceanographic Commission (IOC) *via* the International Oceanographic Data and Information Exchange (IODE) Committee (Longhorn 2002). This data set permits a geographic information system (GIS) classification of marine areas based on seascapes. This method implemented the approach of Day and Roff (2000) that is based on the definition and the classification of physical habitat types. With this approach it is possible construct and use some indices (e.g. emergy, and exergy) representing the distribution in space and time of species biomasses and community dynamics of different ecosystem. We applied this method in studying a benthic ecosystem of the north-western Mediterranean shelf, by considering fluxes of energy and biomass among species of the pelagic and the benthic realms that are preyed by the Norway lobster, *Nephrops Norvegicus*, populations.

Materials and methods

The study area is the continental shelf and slope of the south-western margin of Gulf of Lyon (Catalan Sea). The measure were made in at 100-110 m depth off the Ebro River delta (latitude and longitude ranges: 40° 39' N, 1° 13' E; 40° 38' N, 1° 11' E) and 400-430 m depth off Tarragona (41° 1' N, 1° 37' E; 40° 55' N, 1° 31' E). Consecutive trawl were carried out at 1-h interval during 4 days in October 1999 and June 2000 (Aguzzi et al., 2003). All crustacean decapod species were sorted and individual were counted. In the approach presented here, physical nektobenthic habitat types were characterized based on a suite of relatively enduring and recurrent characteristics that are known to influence the distribution of species and biological communities (Roff et al., 2003). The data set required by MGDI included characteristics of the seawater, composition of the seafloor, depth and reported light intensity. This data set, represent an ecosystem but also a trophic spectra, which represents the distribution of biomass, abundance, or catch by trophic level, and may be used as indicators of the trophic structure and functioning of aquatic ecosystems in a fisheries context (Gascuel et al, 2005). Methodology of trawling and light intensity measurements were already detailed by Aguzzi et al. (2003).

Marine environment can be chiefly represented as a three-dimensional space. Roff & Taylor (2002) indicated that the different strata of the water column and seabed are equivalent to patches when these present recurrent oceanographic features in selected habitat parameters such as the water temperature, depth/light, stratification/mixing regimes, substrate types and exposure/slope. They denominated these habitat types as the fundamental units of marine seascapes. Accordingly, the seascape ecology uses recurrent oceanographic features to discriminate different types of marine habitats (Roff & Taylor 2000). In the fluid three-dimensional marine ecosystem, seascapes are more dynamic, intermittent and with a more fuzzy geography in comparison to landscapes (Longhurst, 2007). The combination of all these physical factors results in a horizontal gradient of change in habitat conditions from deep-sea to the coastal lines: along that gradient seascape patches change in form, dimension and components, the size of different habitats decreases while their diversity increases (Grimm et al. 2003). Because seascapes are fluids and spatially heterogeneous entities, their structure, function and dynamics are scale-dependent. In fact, moving across marine ecological processes, abiotic and biotic interactions have families of scales (i.e. eddies, fronts, internal waves), which exhibit emerging properties, but also relations among resources and population (Farina 2006). A possibility of modelling and quantify parameters, within a biophysical approach, is possible trough the integration of landscape ecology and ecological indicators as emergy and exergy (Marotta et al. 2007; 2008).

Results

Considering the seascape and the community, *Nephrops norvegicus* and others crustacean decapod species (*Munida iris, Alpheus glaber,* and *Liocarcinus depurator*) are correlated in rhythmicity (as resulting from corresponding diel catch patterns). The integration among data and indicators appears to be a promising way of analysing and modelling marine ecosystem dynamic at the diel base in relation to local trawl fishery.
It is possible with available data to individuate seascape features as Mesochores and Ecotypes (sensu Naveh and Lieberman, 1994). The used data are available for the identification of a major bottom water mass influence (temperature, salinity), depth, and finally, substrate. In figures 1 and 2 shows the results. According to our preliminary data the spatial resolution of Macrochores was mapped according to the order set by Roff *et al.* (2003), i.e. around five minutes (5') or 1/12th of a degree. This approximately corresponds to anywhere between 6-7 Km by 8-9 Km, approximately an area of 50-60 Km^2. The studied communities of *Nephrops* was considerably more finer being the scale data of 1-2 Km, approximately an area of 2-4 Km^2. The distance between the two areas was 38,96 km. However the construction of an operational data set is needed in order to build a real seascape model. This should be based on oceanographic data sets integrating and modelling information as described by Pinardi *et al.,* 2002.

The two studied communities have the follow descriptors, following Jørgensen *et al.* 2005.

The analysis shows that *Nephrops* at 400 m need an energetic input from other species or from detritus (Marotta et al. 2008).
The community (*Nephrops* and its food items) eco-exergy is ≈. 2.0-2.3*10^7 J/day and emergy ≈.3.4*10^8 sej/day.
Integrating available data in fishing effort (Bastianoni, 2002; Brown and Bardi, 2001; Ziegler and Valentinsson, 2008) is possible calculate the Emergy balance of fishing, and the maximum quantity of trawling effort, measured in sej/day.

Conclusions

In this study emergy and exergy were preliminarily computed on the shelf (100 m) and slope (400 m) for *Nephrops* and the whole benthic community inhabiting its fishing grounds. In order to do so we considered the trophic relationship of decapods and then we extended our analysis to the whole community within a seascape ecology approach. First results show the evidence of a turnover among patches and this oblige toward a more rigorous approach within marine geospatial data infrastructure. Considering an adequate data set, a general model of data integration in seascape can be discussed. A seascape model can be build and the system has to be improved with a more operational approach.

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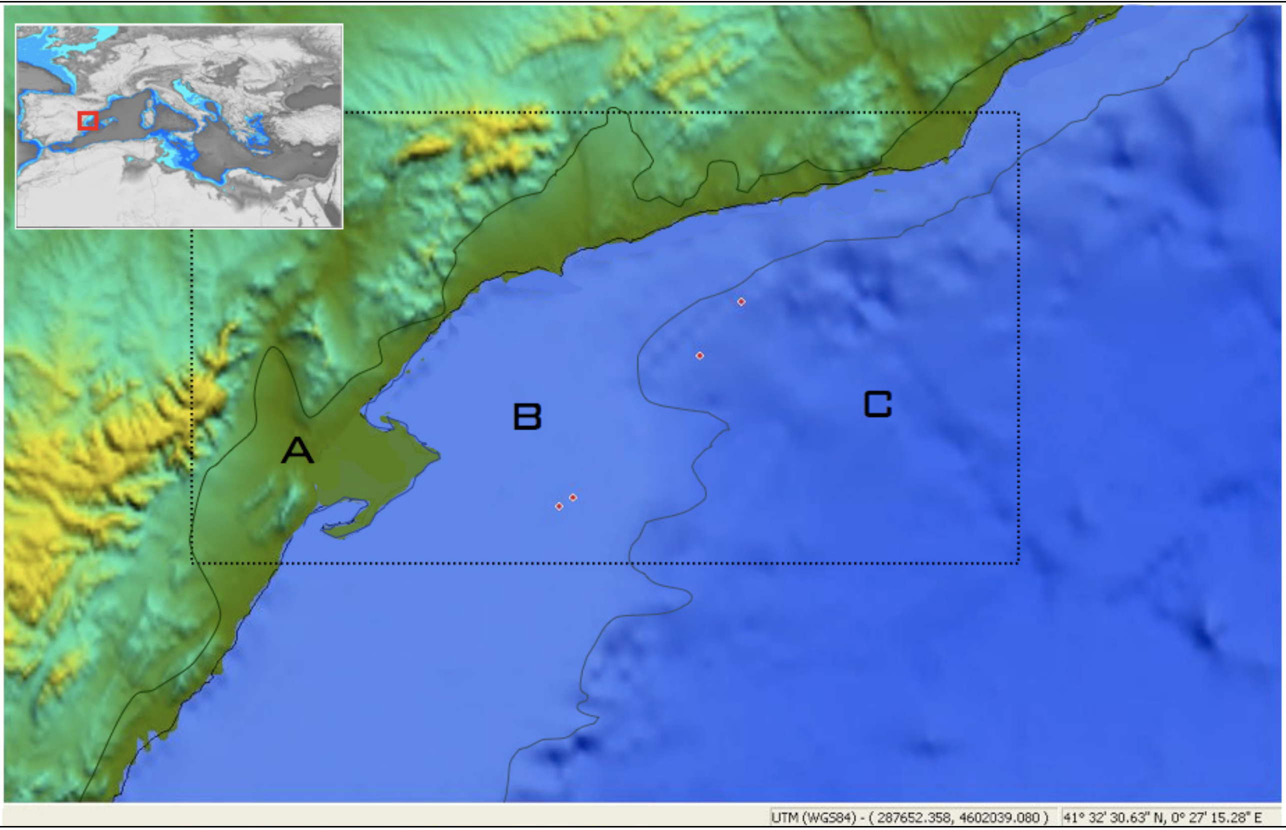

Figure 1. Individuation of Macrochores in Mediterranean Sea and individuation of Mesochores in study areas. Capital letters individuate the Macrochores.

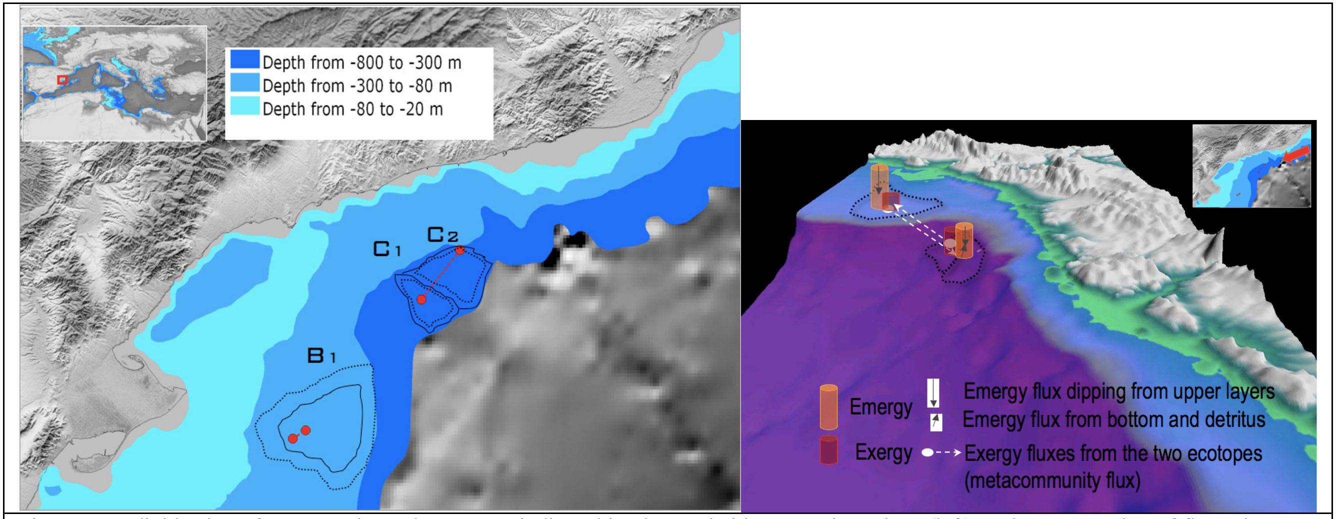

Figure 2. Individuation of Ecotopes in study areas, as indicated by the Capital letters and numbers (left), and representation of fluxes between seascapes and communities (right). Topography resolution is 60 m and the vertical dimension is exaggerated.

		Shelf	Slope	Shelf	Slope
		Emergy sej/day	Emergy sej/day	Exergy J	Exergy J
Annual average, Community		4,62E+09	2,30E+09	3,21E+08	1,58E+08
Annual average, *Nephrops* and community		3,48E+08	3,40E+08	2,32E+07	2,04E+07
Nephrops and community		8,00E-02	1,50E-01	7,00E-02	1,30E-01
Detritus input need for individual of *Nephrops*	October	-7,03E+05	2,58E+04	-	-
	June	-2,56E+04	2,42E+04		
Metacommunity		9,96E+07	2,23E+08	5,73E+06	1,22E+07

Table 1. Table of Emergy and Ecoexergy in the community. Detritus input is the input necessary to account the missing flux. This was calculated from catch data.

		fishing effort transformity			EMERGY FLOW (Shelf)		EMERGY FLOW (Slope)
	Unit of measure	sej/unit	SOURCE	Flux (unit/day)	sej/day	Flux (unit/day)	sej/day
Human Labour	J	$1.24*10^{6}$	(a)	$1.99*10^{5}$	$5.89*10^{7}$	$3.99*10^{5}$	$1.18*10^{8}$
	J	$4.30*10^{4}$	(a)	$7.58*10^{6}$	$2.24*10^{9}$	$1.52*10^{7}$	$4.50*10^{9}$
capital cost	euro	$2.22*10^{12}$	(b)	1.89	$5.61*10^{2}$	3.80	$1.12*10^{3}$
maintenance cost	euro	$2.22*10^{12}$	(b)	1.52	$4.49*10^{2}$	3.04	$9.00*10^{2}$
total Emergy flow	sej/yr				$2.30*10^{9}$		$4.62*10^{9}$

Table 2. Emergy evaluation for fishing effort, as emergy flow in sej (transformity values are taken from following sources: (a), Bastianoni, 2002, (b), Brown and Bardi, 2001).