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A bibliographic survey of applications of the DPSIR framework to coastal zones

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A bibliographic survey of applications of the DPSIR framework to coastal zones

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1. Introduction

The development of management programs and the adoption of improved policies by stakeholders must be based on credible, organised and actualized information. However the lack of data is many times a problem in the coastal zones context. The Driving force – Pressure – State – Impact – Response (DPSIR) framework is a good methodology to help the selection of proper indicators. In this research the applications of the DPSIR framework into coastal zones systems are reviewed. The LOICZ (Le Tissier *et al*. 2006) classification of coastal zones was adopted, which define seaward boundaries as the continental shelf edge delineated by the 200 m isobaths, and the landward boundaries as the area 200 m above mean sea level. The DPSIR applications with focus on a marine environment, coastal industries and coastal problems were also considered, although they have a more specific perspective under analysis.

This study is organized as follows. An overview of DPSIR concepts is made in section 2, a bibliographic review of DPSIR applications into coastal zones is presented in section 3, and finally some conclusions are presented in section 4.

2. DPSIR concepts: an overview

The DPSIR framework, presented by the European Environment Agency (EEA, 1999), enables the establishment of communication paths between stakeholders, simplifying data into comprehensible indicators. All indicators included in each of D, P, S, I and R categories are *describing indicators* (EEA, 1999). The main motivation of this methodology is not the construction of an analytical tool neither the description of the complexity of the real world. Instead, it is concerned with the selection of suited indicators which can describe the system under analysis. After the process of indicators definition, the data available can be organized and the missing data can be collected. Involved stakeholders can later create more complex indicators and indexes, as well as management models and policy actions. Figure 1 exhibits the DPSIR framework.

According to the original FAO guidelines (FAO, 1999), driving forces describe the social, demographic and economic developments in society. Pressures are the human actions that can induce unwanted environmental change. In the review of DPSIR definitions performed by Maxim *et al*. (2009), pressure indicators are linked to those human actions with potential to

damage and degrade the exploited ecosystem. State indicators aim to illustrate the environmental changes, with chemical, physical and biological parameters (FAO, 1999). Depending on the focus of the study, the state can also belong to a social or economic dimension. Impacts are the negative effects of human activities, perceived into the environment and society. Responses are all the preventive, adaptive or restorative actions performed by society with the aim to improve the system.

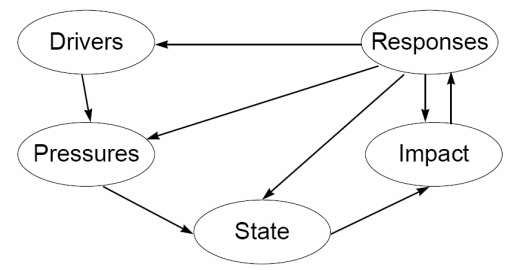

Figure 1. DPSIR framework (EEA, 1999).

3. DPSIR applications for coastal zones

This section attempts to perform a synoptic review of the DPSIR indicators used in papers published in scientific journals where the DPSIR framework is applied to coastal zones. The reported DPSIR applications have focus on several points of view: the coastal zones as a whole, the marine areas, the terrestrial areas, a specific coastal industry or a specie coastal issue. The indicators adopted in the reviewed applications are summarized in Table 1, which organizes them into the respective DPSIR category (i.e., D-P-S-I-R). The application area of each study is also presented in the last column of Table 1.

Table 1 – DPSIR indicators of coastal zones applications.

Driving Forces	Pressures	State	Impact	Response	Application area
Borja *et al.*,2006					
•Populations; •Industry; •Ports; •Fisheries; •Agriculture;	•Nutrient discharge (nitrogen); •Water pollution (%); •Sediment pollution (%); •Water abstraction; •Dredged sediments; •Shoreline reinforcement; •Interdital losses;	(None)	•Eutrophication; •Toxicity; •Pollution of the ecosystems; •Saline intrusion; •Changes in flow regime; •Residence time; •Smothering of the sea bed; •Alteration of invertebrate assemblages; •Loss of habitats;	(None)	Estuarine and coastal water bodies of Basque Country (Spain)

Driving Forces	Pressures	State	Impact	Response	Application area
	•Number of berths within each water body; •Introduction of benthic alien species;		•Introduction of pollutants to the ecosystem; •Flow regime; •Habitat alteration; •Substitution of populations; •Destruction of habitats; •Food competition; •Loss of genetic pools;		
Bowen *et al.* (2003) •Resident coastal population; •Coastal land-use /land cover; •Coastal zoning patterns;		(the same indicators as driving forces)			**Population dynamics**
•Annual GDP growth; •Environmentally adjusted net domestic product; •Economic value / employment in coastal industry;		(the same indicators as driving forces)			**Economic conditions**
•% population with potable water; •Cultural stability / integrity;			•The change in user conflict;		**Social conditions and cultural traditions**
	•% of altered coastal land; •% of impermeable surface in coastal zone; •Coastal fill acres/year;		•Cost of coastal flooding / hazards and savings provided by coastal habitat; •Dredging costs driven by sediment contamination;		**Development pressure / capital construction**

Driving Forces	Pressures	State	Impact	Response	Application area
	•Service value of coastal habitat; •Value of habitat driven manufactured products;		•Social costs of invasive species; •Service value changes from habitat alteration; •Changes to non-use values of coastal habitat;		**Habitat change / ecological value**
	•% of population with wastewater treatment; •Fertilizer use in coastal watershed; •Industrial inputs of POPs/metals;		•% of coastal harvesting areas under environmental restrictions;		**Contaminant introduction**
	•Oil spills from extraction /transportation; •Commercial fishery landings; •Seafood consumption patterns;		•Seafood value changes from seafood risk / habitat alteration;		**Resource extraction activities**
	•Coastal aquaculture; •Beach attendance;		•Marine – vectored disease; •Beach closing costs;		**Human uses / activities**
Caeiro *et al.* (2004)					
•Urban areas near the estuary; •Industry types; •Dunghills / sanitary landfills; •Rice-fields; •Saltpans; •Aquacultures; •Fishing; •Ships traffic; •Harbours; •Tourism areas;	•Population density; •Toxic substances spill; •Pesticides in rice-fields; •Commercial species captured; •Dredging; •Dredged material disposal; •Urban wastewater discharges without suitable treatment; •Solid waste disposal; •Solid industrial waste disposal; •Non source pollution;	(None)	(None)	(None)	Sado estuary (Portugal).
Cave *et al.* (2003)					
•Population; •Agriculture; •Industry; •Port development; •Climate	•Land use / emissions: sewage, agricultural, industrial; •Contaminated	•High nutrient input to coastal waters; •High contaminant input to coastal	•Reduced water quality in the Humber Estuary; •Export of nutrients and contaminants to	•Upgrading of STWs; •Designation of NVZs; •Changes to agricultural	Overview of the current state of Humber Estuary catchment

Driving Forces	Pressures	State	Impact	Response	Application area
change; •Fisheries;	sediments; •Oil pollution; •Dredging; •Coastal squeeze;	waters; •Raised temperature of water in tidal rivers; •Low oxygen zone at head of estuary; •Disturbed bed sediment; •Reduced intertidal area;	the North Sea; •Damage to aquatic ecosystems; •Passage of migratory fish upriver blocked; •Habitat loss;	practices; •Remediation of contaminated land; •Cleanup of industrial effluent; •Cessation of sewage dumping in N. Sea; •Creation of intertidal areas by setback of coastal defences;	from natural science, social and economic perspectives.
Crossland *et al.* (2001)					
Natural forcings •Global systems and climate patterns; •Sea level; •CO2 concentration changes in atmosphere; **Human forcings** •Land-based resources uses (agriculture, Foresty / deforestation, damming & irrigation);	•Urbanisation and industrial development (industrialization, urbanization, wastes, reclamation & shoreline development); •Transportation; •Mining and shoreline modification; •Tourism; •Fisheries;	(none)	(none)	(none)	World's coastal zones. State, impact and responses are also commented, although no indicator was defined.
Henriques *et al.* (2008)					
•Population;	•Runoff waters; •Sewage discharges;	•Toxic contamination; •Degradation of water / sediment quality; •Habitat loss; •Eutrophication;	•Diversity; •Dominance; •Biomass; •Abundance; •Ocurrence of massive death; •Reproductive inhibition or failure; •Trophic structure;	•Treatment of sewage; •Gathering and treatment of runoff waters; •Assess the water quality; •Implement environmental monitoring plans;	DPSIR application to assess the ecological status of marine environment.
•Fishing;	•Selective catch; •Overfishing; •Bycatch; •Ghost-fishing; •Destructive fishing methods;	•Selective mortality; •Substrate destruction;	•Diversity; •Dominance; •Biomass; •Mean size; •Mean thophic level; •Thophic structure;	•Implement environmental monitoring plans (relating assessments to policy developments); •Revision of	

Driving Forces	Pressures	State	Impact	Response	Application area
			•Reproductive inhibition or failure; •Age structure; •Abundance; •Proportion of demersal and benthic species;	fisheries acts (legal fishing nets, daily boats limit, minimum legal length, closed catch seasons, number of fishing licenses, etc); •Intensity of control of fishing activities; •Network of Marine Protected Areas (MPAs); •Sport fishing regulation; •Critical habitat protection.	
•Dredging activity;	•Contaminants and sediments suspension; •Sediments removing;	•Toxic contamination; •Degradation of water / sediment quality; •Biological pollution; •Substrate destruction; •Bathymetric alteration; •Increased in turbidity;	•Diversity (benthic species); •Dominance (opportunistic species); •Abundance (benthic species); •Occurrence of massive death; •Occurrence of exotic species (macroinvertebrate); •Genetic variability; •Proportion of demersal and benthic species; •Trophic structure;	•Use adequate methodologies and equipment to dredge; •Minimize the duration of dredging operations; •Assess the sediments quality; •Implement environmental monitoring plans; •Select a dumping site and disposal technique that promote dispersal and assimilation of the dragged; •Take account of important activities for aquatic organisms;	
•Port activity;	•Ballast waters; •Boats pressure;	•Toxic contamination; •Degradation of water / sediment quality; •Biological	•Diversity; •Dominance; •Abundance; •Occurrence of massive death; •Occurrence of	•Minimize the dredging operations; •Minimize the cleaning ships to the strict	

Driving Forces	Pressures	State	Impact	Response	Application area
		pollution; •Noise perturbance;	exotic species; •Genetic variability; Behaviour; •Reproductive dysfunction; •Trophic structure;	necessary ones; •Regular maintenance of the main engine, generators and boilers; •Strict inspection of ships; •Control and management of ships ballast water and Sediments; •Reduction of cruising speed where appropriate (emissions control); •Hull and propeller cleaning;	
•Agriculture;	•Ferterlizer; •Biocides;	•Eutrophication; •Degradation of water/sediment quality; •Toxic contamination;	•Diversity; •Dominance; •Abundance; •Occurrence of massive death; •Reproductive inhibition or failure; •Trophic structure;	•Gathering and treatment of runoff waters; •Assess the water quality; •Implement environmental monitoring plans; •Composition control of the fertilizer and biocides;	
•Aquaculture;	•Effluent discharges; •Individuals leak; •Exotic species; •Pathological vectors;	•Eutrophication; •Degradation of water/sediment quality; •Toxic contamination; •Habitat loss; •Biological pollution;	•Trophic structure; •Dominance; •Abundance; •Occurrence of massive death; •Reproductive inhibition or failure; •Genetic variability; •Diversity;	•Keep fish density at moderate levels to reduce disease risk and need for antibiotics; •Pump air to the water to speed up decomposition; •Release pond water to water body with adequate dilution and dispersal capability; •Dilute pond water prior to release;	

Driving Forces	Pressures	State	Impact	Response	Application area
				•Use local wild species rather than introduced species as seed stock; •Implement environmental monitoring plans; •Revision of aquaculture legislation;	
•Industry;	•Industrial effluents discharges;	•Toxic contamination; •Degradation of water/sediment quality; •Habitat loss; •Eutrophication;	•Diversity; •Dominance; •Biomass; •Abundance; •Occurrence of massive death; •Reproductive inhibition or failure; •Trophic structure;	•Industrial effluent treatment; •Assess water quality; •Implement environmental monitoring plans;	
Holman *et al.* (2008)					
•Social change; •Economic change; •Climate change (sea level; storms; temperature);	•Sea level; •Population; •Urbanisation; •Tourism; •Port and harbour development;	•Coastal build environment (areas, totals); •Spatial distribution of coastal built environment (landscape quality); •Tourism arrivals (at coast); •Trade through ports and harbours (annual tonnage);	•Loss of landscape quality; •Loss of accommodation space for wetland migration (coastal squeeze); •Average annual damages from erosion /flooding;	•Spatial planning; •Improve flood defences; •Soft engineering for wetlands;	Suggested indicators for coasts
•Social change (consumer preferences); •Climate change; Economic change (supply and demand); •EU and international policy change;	•Climate (temperature, precipitation, etc.); •Prices of goods; •Cost of production inputs (labour, fuel, chemicals, etc.); •Subsidies; •Fossil fuel energy costs;	•Crop yields; •Farm profit; •Crop areas; •Irrigation water demand; •Workable days; •Nitrate leaching; •Pesticides; •Area of biofuels;	•Unacceptable farm profits; •Crop production below self-sufficiency level; •Irrigation water demand not achievable; •Land abandonment; •Water pollution; •Biofuel target;	•Increase subsidies; •Promote rural diversification; •Extensification or intensification; •Encourage new crops; •Limit chemical inputs; •On-farm reservoirs;	Suggested indicators for agriculture
•Climate change; •Environmental consciousness; •Concern for	•Climate; •Number and size of protected sites; •Land cover; •Agri-	•Spatial distribution of species (presence / absence); •Species and	•Species or habitat vulnerability index increases; •Habitat degradation	•Expand protected areas; •Agri-environmental schemes to	Suggested indicators for biodiversity

Driving Forces	Pressures	State	Impact	Response	Application area
environmental sustainability; •European nature conservation policy; •Recreation trends;	environmental schemes; •Local policy / management of protected sites;	habitat vulnerability index; •Biodiversity stewardship index (combining attributes of land use, land management and intent to maintain biodiversity);	occurs when land use / management changes reach a critical level (represented by a change in the biodiversity stewardship index);	reduce stresses; •Habitat re-creation; •Managed retreat in coastal habitats;	
•Climate change; •Economic change (wealth, employment); •Environmental consciousness; •Concern for environmental sustainability; •European water policy;	•Water climate; •Land cover; •Irrigation demand; •Domestic demand (household no., per capita usage); •Catchment abstraction management; •Industrial demand; •Leakage control; •Environmental flow objectives;	•River flows; •Recharge;	•River flow below environmental flow objective; •Degree of water supply-demand imbalance;	•Irrigation abstraction limits; Water conservation (per capita demand); •Restrict new housing development;	Suggested indicators for water
Karageorgis *et al.* (2006)					
•Political reasons; •Floods; •Human health; •Population growth; •Economic development; •Transport; •Port siltation;	•Refugees rehabilitation; •Draining; •Axios R. diversion; •Arable land; •Drinking water demand; •Damming; •Construction materials; •Aquaculture;	•Accretion status; •Net sedimentation rate ($10^6 m^3 yr^{-1}$);	•Reduction of wetlands; •Biodiversity loss; •Reduction of river loads; •Coastline retreat; •Aquifer and soil salinization; •Subsidence;	**1st half of 20th century** •Axios River diversions; •Drainage of the lakes and swamps; •Construction of roads and bridges; •Dams contruction; **2nd half of 20th century** •Master plan for the Thessaloniki plain and the Thermaikos Gulf catchments; •Protected areas; •Wastewater treatment plants for domestic and industrial	Application of DPSIR in the Axios River Delta Area to assess the changes of the last 100 years, and to provide a base for management options.

Driving Forces	Pressures	State	Impact	Response	Application area
				effluents;	
Langmead *et al.* (2008) •Gross tonnage of dredging and trawling fleet (dredging and trawling effort); •Gross tonnage of fleet (fishing effort); •Tanker traffic through •Bosphorus Strait (shipping activity); •SST (ºC, climate change); •Meat production (livestock production);	•Anchovy and sprat landings (pelagic catch); •Turbot landings (demersal catch); •Area of hypoxia; •Secchi depth (transparency).	•Total summer density (phytoplankton); •Number of introduced species; •Mackerel, bonito, and bluefin biomass (pelagic predador stocks); •Sprat and anchovy spawning biomass during early May (small pelagic stocks); •Turbot spawning stock biomass (demersal stocks);	(None)	(None)	DPSIR framework application to marine environment of the north-western Black Sea.
Lin *et al.* (2007) •Human population Gross domestic production (GDP);	•Coastal reclamation area; •Commercial fishery production; •Aquaculture production; •Industrial use water; •Domestic use water;	**Physical** •Loss of coastal wetland area Influx volume; •Suspended solid (S.S.); •Siltation and sediment changes; **Chemical** •DIN concentration; •DRP concentration; •COD_{Mn} concentration; •DO concentration; •Organic pollutants; •Heavy metal pollutants; **Biological** •Concentration of Chl-a; •Mangrove area; •Species abundance; •Species diversity;	•Number of red tides; •Commercial fishery production; •Aquaculture area; •Population of white dolphin; •Distribution area of egret; •Siltation in navigation channel;	•Rational use of coastal wetland; •Waste water emission control; •Waste water treatment capacity; •Natural conservation area •Public involvement; •Scientific support ability;	DPSIR application to assess changes in coastal wetlands in Xiamen (China).
Mangi *et al.* (2007)					

Driving Forces	Pressures	State	Impact	Response	Application area
Population dynamics •Unemployment; •Tradition and culture; •Tourism and poverty;	•Number of fishers; •Excessive exploitation; •Use of destructive fishing gears;	•Fish abundance; •Live coral cover and topographic complexity; •Sea urchin populations; •Coral bleaching and mortality;	•Declining fish catch (kg / fisher); •Livelihood benefits compromise (% dependence on coral reef resources); •Increased exclusion / conflicts;	•Legislation; •Planning regulations; •Education and awareness;	DPSIR application in Kenyan coral reef artisanal fisheries.
Ojeda-Martínez *et al.* (2009)					
Fisheries •Number of fishing boats; •Number of fishers; •Fishing sector profit; •GDP produced by the sector; •Number of investments done in the sector; •Fishing boats power; •Per capita income in the area; •Per capita income of the sector; •Fishing boats with a kind of gear;	**Fisheries** •Fishing ground; •Boats fishing / day; •CPUE (catch per unit effort); •Length of net; •Number of hooks; •Fishing time; •Total biomass extracted; •Biomass extracted by specie; •Individuals fished / total capture; •Number of species caught; •Hydrocarbons consumed; •Organic matter thrown; •Gears lost;	**Fisheries** •Abundance (of key species); •Biomass (weight of key species); •Density (abundance per unit of area); •Size structure; •Diversity; •Relative abundance; •Richness (number of species); •Dominance; •Community structure; •Coverture (of key species); •Trophic categories; •Recruitment; •Occupied surface;	**Fisheries** •Surface affected by a gear; •Surface affected; •Changes in density; •Changes in covertures; •Changes in community structure; •Species size variation; •Relative abundance; •Changes in abundance; •Changes in diversity; •Changes in richness; •Changes in dominance; •Changes in sediment; •Species substitution; •Families substitution; •Changes in recruitment; •Breaking index; •Rugosity; •Changes in habitat heterogeneity; •Changes in thophic levels; •Opportunistic species; •Sensitive species;	**Fisheries and tourism** •Marine protected area; •Integral reserve; •Zoning surface; •Sport fishing surface; •Diving surface; •Budget; •Budget for surveillance; •Budget for each pressure; •Budget for educational programs; •Budget for waste programs or actions; •Budget for anchoring points; •Budget for duties of management of anchoring points; •Budget for improvement actions; •Budget for participant organisms; •Participation budget; •Budget for research programs for each pressure; •Research budget; •Budget for	DPSIR framework application to assess elements affecting marine protected areas.
Tourism •GDP produced by the sector; •Number of	**Tourism** •Tourist angling in coast; •Tourist angling	**Tourism** •Abundance; •Biomass; •Density;	**Tourism** •Changes in covertures; •Changes in		

Driving Forces	Pressures	State	Impact	Response	Application area
investments done in the sector; •Per capita income in the area; •Per capita income in the sector; •Recreational boats; •Spear fishing/coast; •Angling/coast ; •Fishing rods sold; •Specialised shops; •Spear guns sold/habitant; •Number of divers; •Diving club number; •Diving incomes; •Diving licences number; •Influx visitants; •Guided activities in the area; •Recreational boats sold; •Jet sky sold; •Nautical activities offered; •Hotel accommodatio n offer;	in boat; •Spear fishers; •Density of recreational fishers; •Recreational fishing surface; •Recreational boats; •Boating or Jet sky; •Divers; •Visitants; •Littoral itinerary; •Hydrocarbons consumed; •Organic matter; •Recreational boats;	•Size structure; •Diversity; •Relative abundance; •Richness; •Dominance; •Community structure; •Coverture; •Trophic categories; •Recruitment; •Occupied surface; •Key species; •Hydrocarbons concentration; •Chemical products concentration; •Solid waste; •Species broken; •Nests;	abundance; •Changes in diversity; •Changes and richness; •Species size; •Species weight; •Mortality rate; •Captures; •Recruitment rate; •Extracted biomass; •Extracted biomass by specie; •Fragile species; •Protected species; •Sediment; •Opportunistic species; •Filter species; •Anchoring; •Diving activities; •Whale watching; •Sea mammals; •Trampling; •Water quality;	management actions for each pressure; •Littoral itinerary budget; •Surveillance hours; •Anchoring surveillance; •Licences for sport fishing; •Denounces; •Educational programs; •Number of actions done; •Anchoring points; •Anchoring points for diving; •Evolution of diving in the MPA; •Visitants surface; •Littoral itineraries; •Improvement actions; •People contracted; •Publications; •Research projects; •Meetings between the actors; •People working in projects; •Legislation changes;	
Pacheco *et al.* (2007)					
•Dredging activity •Sand mining; •Shipping; •Fishing; •Urban / industrial wastewater discharges; •Spilling of petrol;	•Quantity of dredged sediment (m^3);	•Channel physic properties; •Channel hydrodynamic; •Coastal hazards; •Environment and socio-economic factors;	(None)		DPSIR application to backbarrier system, with focus on dredging operations.
Pirrone et al. (2005)					
Agriculture	**Catchment**	**Coast - Ecology**	**Coast - Ecology**	**Catchment**	DPSIR

Driving Forces	Pressures	State	Impact	Response	Application area
and land use change; •Production pattern; •Consumption pattern; •Amount agricultural production; •Degree of innovation in agricultural practices; Fisheries; •Amount of sold catch; •Fishing quotas per year; •Tonnage of fishing vessels; Urbanization; •Rate of population growth; •Demand for waste disposal; •Population density; •Innovation in waste water treatment techniques; •Industrial development; •Degree of industrial activity; •Tourism and recreation; •Types of recreation; •Recreation demands; Demand for Nature Protection; •Political pressure for nature protection; •Human behaviour in nature; Socio-economic framework and governance;	Agriculture; •Fertilizer use; •Pesticide use; •Agricultural land use; •Livestock units; Urbanization; •Growth of urban areas; •Demand for waste disposal; •Volume of waste water; •Volume of sewage; •Type of waste water treatment plants; •Classes of waste water treatment plans; •Industrial production; •Volume of industrial effluent; •Energy demand for industry; Climate change; •Change in seasonal weather patterns; •Floods; •Droughts; Demand for Nature Protection; •Area demand for nature protection; **Coast** Riverine input; •Nitrogen load; •Phosphorus load; •Atmospheric input; •Nitrogen deposition; Fisheries; •Fish catches; •By-catch; •Trawling; Urbanization; •Demand for waste disposal; •Volume of waste water;	Water quality TRIX; •Concentration of: •Chlorophyll-a; •Nitrogen species; •Phosphorus species; •BOD; •COD; In river; •Ecological quality: EBI; •Chemical quality: LIM; •Dissolved Oxygen rate (% sat); •BOD_5 COD; •$N\text{-}NH_4$; •$N\text{-}NO_3$; •Ptot; •Escherichia Coli; Climate change; •Catchment discharge; •Local sea level change; •Frequency of storm; •Events; **Coast Socio-economic** Bathing water quality; •Freq. of failure to Meet bathing WQ; •Extended of blue flag beaches; Nature protection; •% habitat-related tourism (e. g. bird watching); •Area of nature reserve open to public; Tourism; •No. of tourist; •Income from tourism;	Water quality Changed; •Concentration of: •Chlorophyll-a; •Nitrogen species; •Phosphorus species; •BOD; •COD; •Dissolved oxygen; Change of ecosystem functions and Health; •Eutrophication; •Mucilage; •Oxygen depletion; •Enhanced oxygen demand (BOD, COD); •Bloom frequency, intensity and duration; •Fish Kills; •Sediment degradation; Nature protection; Habitat loss; •Change in area of Inter-tidal habitat; •Change in area of coastal habitat; Bathing water quality; •Change in bathing WQ; Climate change; •Flooding (habitat loss / gain); •Coastal erosion; **Coast Socio-economic** Policy; •Problems to reach QOs of WFD; Tourism; •Reduced tourism; •Reduced recreation Facilities;	•Regulation of discharge; •Optimisation of Nitrate Directive; •Increase of protected areas; •Agri-environmental schemes; •Regulation on farming practices; •Optimisation of the Urban Waste Water; •Directive Optimisation of Water Framework Directive; •Increased effluent treatment; •Inducement to create / use energy from renewable sources; •Economic incentive for clean technologies use; •Ban on fossil fuel burning; **Coast** •Creation of buffer; •Sink zones for nutrients; •Zonation of land to preserve habitat; •Increased conservation areas; •Regulation of commercial traffic; •Creation of recreation zone (land and marine);	framework applied to design strategies to reduce and control the eutrophicatio n issue in the Po River Catchment and North Adriatic coastal zone.

Driving Forces	Pressures	State	Impact	Response	Application area
•Type of governance; •Political priorities; •Economic structure; •Lifestyle;	•Volume of sewage; •Industrial production; •Volume of industrial effluent; •Tourism and recreation; •No. of tourist; •No. of holiday home; •Seasonal population change; •Private maritime traffic; Climate change; •Sea-level rise; •Flood-storm events;	•No. of holiday home; •Seasonal population change; •Importance of tourism for local economy; Fisheries; •Stock of commercial Shelfish; •Stock of commercial fish; •Fishing quotas; •Tonnage of fishing Vessels; •Local demography; •Size of current population; •Rate of population growth; Climate change; •Length of coastal defence; •Size of area prone to flooding; •Population living in flood risk area;	Fisheries; •Change in fisheries benefit; Climate change; •Increased insurance Claims; •Reduction in quality / value of farmland from excess water / salt; •Increased spend on coastal defence; •Forced realignment of coastal defense;	•Special areas of conservation; •Promotion of eco-tourism; •Economic incentive for clean technologies use; •Ban on fossil fuel burning; •Change in planning laws to take account sea-level rise; •Realignment of coastal defence where suitable; •Enhancement of defences in urban areas;	
Scheren *et al.* (2004)					
•Domestic activities; •Industrial activities; •Agricultural activities;	•Domestic effluents; •Industrial effluents;	•N and P concentrations in the lagoon;	•Eutrophication problem (biological oxygen demand, BOD); •Organic pollution loads (N and P);	•Pollution reduction;	DPSIR framework used to assess the pollution of a lagoon.
Trombino *et al.* (2007)					
•Agriculture; •Population; •Livestock activity; •Waste water discharge; •Civil and industrial sectors;	•Nutrients loads of N (t/year); •Nutrients loads of P (t/year);	(none)	(none)	(none)	DPSIR is used for to characterize the river basin and coastal zones, with integration of other conceptual approaches.

The driving forces normally associated to coastal zones are related to the social and economic activities that directly depend on natural resources of the areas analysed. These

activities include agriculture, urbanization, tourism, fisheries, aquaculture, industry, harbours and population development. The DPSIR application to estuaries and coastal areas developed by Borja *et al.* (2006), applied population, industry, ports, fisheries and agriculture as driving forces indicators. Similar viewpoint is applied to the Humber estuary in the Cave *et al.* (2003) study, or in the assessment of the marine environment status performed by Henriques *et al.* (2008).

The DPSIR applications to assess a specific issue or industry tend to be more detailed in the indicators selected. In the assessment of elements that affected a marine protected area developed by Ojeda-Martínez *et al.* (2009), driving forces were developed considering fisheries and tourism separately. Analogous perspective was assumed by Mangi *et al.* (2007), where DPSIR was used to assess artisanal fisheries, and tourism, poverty and unemployment were selected as driving forces.

Regarding pressure indicators, a detailed description of possible harmful activities is generally assumed. Borja *et al.* (2006) selected water pollution and nutrient discharge as pressure indicators. In the DPSIR application suggested by Bowen *et al.* (2003), commercial fisheries landings and % of population with wastewater treatments were suggested as pressure indicators.

State indicators aim to describe the status of the natural resources of the system, and normally they are biological, chemical and physical factors. Toxic contamination and habitat loss were state indicators selected by Henriques *et al.* (2008). In the Ojeda-Martínez *et al.* (2009) study, abundance of key species and diversity were selected as state indicators. In the assessment of coastal wetlands performed by Lin *et al.* (2007), loss of coastal wetland area and sediment changes are proposed as physical indicators. This study also suggests the concentrations of pollutants as chemical indicators of the state.

Some authors also presented a social and economic vision of the state. The resident coastal population and the economic value of employment in coastal industry are state indicators suggested in Bowen *et al.* (2003) research, with focus on the population dynamics and economic conditions of coastal zones.

Impacts can be perceived from an environmental perspective. In the Ojeda-Martínez *et al.* (2009) study, changes in abundance, changes in diversity and species substitution are impacts considered. Reduction of wetlands and biodiversity loss were impact indicators selected by Karageorgis *et al.* (2006), in a river delta area context. Some authors also identified impacts as the negative effects of human actions, from social and economic perspectives. Pirrone *et al.* (2005) applied DPSIR framework to reduce and control an eutrophication issue, where impacts were divided into two main groups: the coast-ecologic impacts and the coast socio-economic impacts. Mangi *et al.* (2007) considered the increase exclusion, conflicts and livelihood benefits compromised as impact indicators.

Responses indicators aim to describe the social measures that can reduce or minimize the negative effects of human activities. In the Pirrone *et al.* (2005) research, increase of protected areas and regulation of farming practices were selected as response indicators. Ojeda-Martínez *et al.* (2009) suggested response indicators related to the budget available for improvement activities.

4. Conclusions

A literature review over DPSIR applications within the context of coastal zones was performed. The present study is a good contribution for the comprehension of the DPSIR framework and it can help future studies, mainly in the process of DPSIR indicators selection. The identification of a coherent set of indicators is dependent of the particular context of each case study. The DPSIR framework integrates environmental issues, economic sectors, and social topics, from the most understandable and simple way.

Driving forces are the social and economic motivations for the existence of some activity. Pressures are all the human actions performed directly into the environment. State can be related with the environmental dimension using biological, chemical or physical factors. It can also contemplate social and economical features. Impacts, the negative effects of the activity, can be perceived in the exploited ecosystem and in the society as well. Finally, responses are the actions of the society which aim to improve the analysed system in any of the former categories (i. e. - D, P, S, I).

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