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ASSESSING THE ENVIRONMENTAL IMPACT OF DEVELOPMENT POLICY LENDING ON

coastal areas

A WORLD BANK TOOLKIT

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Introduction

Coastal areas host a range of diverse habitats, including some of the most productive ecosystems on Earth in terms of goods and services. They are also the most inhabited areas on the planet, which makes them critically important both from an environmental and a human point of view (Martinez and others 2007). Through a combination of direct and indirect impacts, including the effects of global warming, human activities are increasingly threatening coastal areas.

Although there is no single definition to encompass the complexity of coastal environments, they are generally identified with the area delimiting the border between the marine environment and the land. Coastal areas are complex systems with seaward and landward zones of influence that stretch far out into the sea or inland. They are at the receiving end of impacts from both the sea and the land. Impacts can be triggered far from the arbitrary boundaries of coastal areas, and therefore their effects may be delayed. Because of ecological links between coastal areas and upstream environments, as well as horizontal linkages between economic sectors and demographic patterns, a landscape or ecosystem-based approach is helpful in understanding the local dynamics of the system and the impacts of offsite activities or broad economic policies.

The Bank has some tools at its disposal to allow stakeholders to anticipate possible offsite impacts caused by development plans and policies. These instruments—such as country environmental assessments (CEAs), strategic environmental assessments (SEAs), and other sector analytical work—provide valuable information. SEAs typically include an analysis of institutional capacity within a given sector, as well as environmental risk. Due to their complexity, duration, and cost, however, they are not performed on a regular basis.

The Bank is increasingly engaged in supporting country programs through its development policy lending (DPL) instrument. DPLs are subject to OP/BP 8.60, which requires an analysis of potential environmental effects. The fast disbursing nature of the DPL means that the likelihood of significant environmental impacts needs to be appraised within a short time frame. In the absence of supporting analytic work, a rapid assessment toolkit is necessary to help task teams identify and report on the likelihood of any significant coastal impacts emanating from Bank-supported development policies.

This toolkit complements the assessment obtained through the DPL general toolkit. It provides guidance on possible significant effects on coastal natural resources, which will suggest to stakeholders whether or not a full-scale CEA or SEA should be performed to further appraise a proposed package of policy reforms.

Definition of coastal area

A commonly accepted definition of coastal area includes an area that extends inland 100 kilometers from the coastline, and at sea to the EEZ boundary (200 nautical miles) (Martinez and others 2007; Burke and others 2001; Small and Nicholls 2003).

How the Coastal Toolkit Works

Following the approach of the DPL Toolkit, the Coastal Toolkit is divided into three modules. (See the introduction to the DPL Toolkit for a general description of the three modules). The way the modules interact to suggest significant impacts is also based on the system used in the DPL Toolkit.

Organization of the modules

Module I

Module I presents a summary of the major known sources of coastal impacts. It also illustrates the link between DPL policies, sources of coastal impacts, and the indicators presented in Module II.

Module II

Module II provides information on impacts and affected coastal receptors. This is the basis for identifying the “indicators of environmental state,” which provide a measure of the sensitivity to impacts for the coasts in a given country. Eight indicators are illustrated in this module.

Module III

Bayesian belief networks (BBNs) were built for a selection of policies related to the expansion of trade.

BBNs graphically represent the causal relationships between DPL policies, political-economical factors, and sources of coastal impact. They provide a measure of the probability associated with impacts originating from a specific policy.

Analysis through BBNs complements the results from Modules I and II, and delivers an improved estimate of the significance of the impact.

The module also presents a selection of countries where the toolkit could be applied. The selection process is based on the relevance of coastal environments to the market and non-market economy of these countries.

The toolkit mechanism

Figure 1 shows how the different modules integrate with one another to assist the user in identifying the possible impacts and assess their significance:

1. When "Policy A" is suggested for implementation, the task team will proceed to verify whether the specific policy is among those listed in Module I (Tables 2 through 6) as likely to trigger impacts on coasts.

2. If the policy is listed, the first piece of information the team needs is the risk of impact, identified in Tables 2 through 6 through a color code system (red or yellow code).

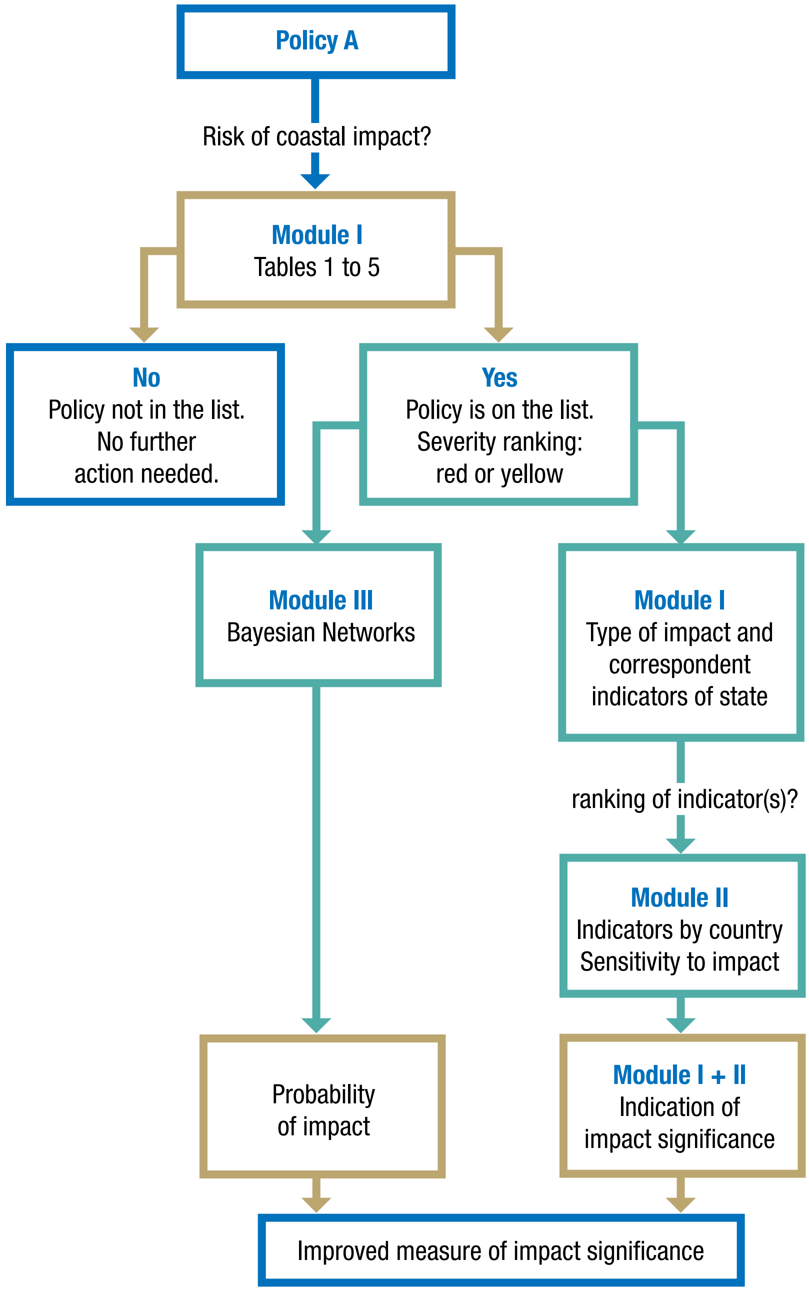
3. Tables 2 through 6 in Module I show the type of impact (according to the classification in Table 1) associated with policy A. They also identify the corresponding indicators of environmental state that measure the sensitivity of coastal areas to that specific impact type (provided in Module II).

4. The task team can now refer to Module II to record the state of the indicators for the specific country under study.

5. The combination of information from Modules I and II provides a general indication of the significance of the impact. Although elementary, this information is useful to set priorities. In fact, it is often the case that not one policy but several policies are suggested for implementation; therefore, an initial measure of significance may allow the users to distinguish those impacts that need to be analyzed more urgently due to their potentially severe risks.

6. When the preliminary data about the likely impacts and their significance is complete, the Bayesian networks (Module III) offer a further level of insight in terms of probability of the impact. This is offered for a subset of the policies presented in Tables 2 through 6 (Module I).

Figure 1. The Coastal Toolkit: Use of the Modules



Module I

This module (a) identifies the major types of environmental impacts affecting coastal areas; and (b) presents tables linking DPL policies with coastal impacts and with the indicators presented in Module II.

Introduction: Impacts on Coastal Areas

Coastal areas include nearshore terrestrial or saltwater coastal ecosystems such as wetlands, salt marshes, and sea-grass beds, along with marine ecosystems and inland agricultural landscapes, grasslands, and forests. All of these environments are threatened both by direct/local impacts and by indirect impacts.

Direct impacts—such as dumping of wastes or the destruction of habitats through landfilling, draining, and conversion to aquaculture—are compounded by indirect impacts triggered far inland (or offshore) within or outside the artificially defined boundaries of coastal areas. The most common and serious indirect impacts on coastal areas are due to changes in water quality and quantity, and to modifications in seasonal water pulses. Along watersheds and river basins, which often extend hundreds of kilometers outside a coastal area, many activities may impact coastal areas. For example, deforestation activities can impact downstream habitats through erosion and modification of runoff. Wastewater emissions from agricultural or industrial activities can affect downstream water quality, threatening biodiversity and habitats. Competing needs for water usage—such as water for irrigation, for energy production, for sanitation and drinking purposes—can modify water quantity and pulses, which disrupts biological cycles and can adversely affect the functioning of coastal areas and the delivery of ecosystem services.

In addition, direct impacts can lower the resilience of coastal areas to indirect impacts. The draining and landfilling of wetlands deprives coastal zones of the important filtering services operated by these ecosystems, which reduces buffering of indirect impacts like increased pollution loads from upstream activities (Burke and others 2001).

Given these considerations, a "transboundary" management method—extending across river basins, coastal areas, and marine ecosystems—is critical in order to integrate competing uses and manage resources sustainably. The new approach should extend assessment and management beyond the current jurisdiction of an integrated coastal area management (ICAM) project (FAO 1998). For example, Switzerland is far from any coastline or sea, but is nonetheless an important participant in ministerial meetings on the protection of the North Sea because of the impact of wastewater emissions by Swiss industries on the Rhine River. The present coastal tool represents an effort in this new direction.

Loss of goods and services

Adverse impacts on the coasts translate into a loss of ecosystem goods and services. The range of goods and services affected include:

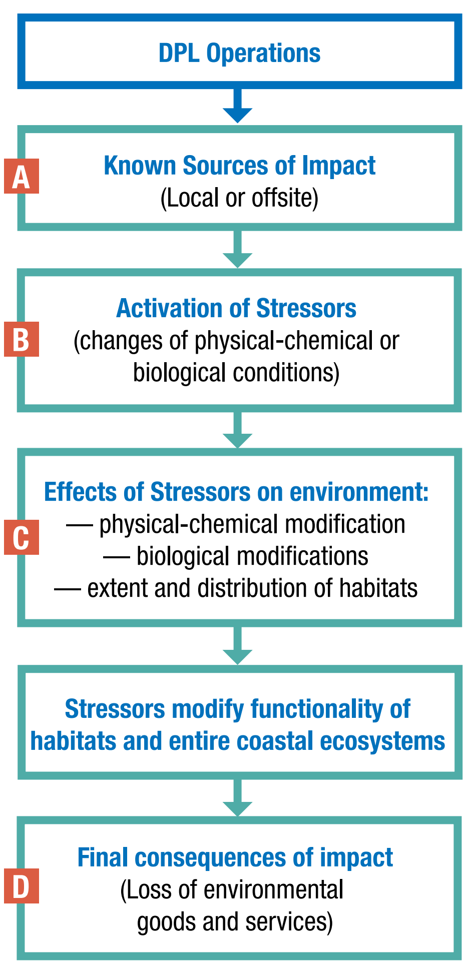
- food from fisheries and aquaculture
- nursery habitats for aquatic species
- storage and cycling of nutrients
- waste processing, detoxification/sequestration of compounds (water filtration)
- recreational opportunities, tourism, and ecotourism
- storm protection and erosion control

Summary of impacts and receptors

The *Guide to Estuarine, Coastal and Marine Indicators* produced by the Australian Cooperative Research Centre (Scheltinga and others 2004) identified three general types of changes in the conditions of coastal natural resources as a result of local and/or upstream (offsite) impacts: (1) changes in physical-chemical conditions; (2) changes in biological conditions; and (3) changes in extent and/or location of estuarine, coastal, and marine habitats. These changes can depend on the release of a stressor, or they can be the result of a direct impact.

A stressor is defined as a change in physical-chemical or biological conditions, triggered by events external to the ecosystem. Examples of stressors can be a change in the concentration of dissolved nutrients, a change in the sediment load, or even a change in the size of a specific habitat as a result of a direct impact such as habitat removal or replacement due to development projects. A stressor can also be a completely new component introduced in the ecosystem, such as litter or invasive species. The activation of a stressor results in the transfer of an impact to other components of the ecosystem (Scheltinga and others 2004) and ultimately leads to modifications in the biotic community and in the functionality of habitats and ecosystems (Figure 2).

Figure 2. Scheme of Progression from Causes of Impact to Final Environmental Consequences



Note: Red-boxed letters refer to the columns in Table 1.

The most significant impacts that affect coastal areas include changes in water flow quality (pollution), quantity, and pattern (seasonal pulsing of freshwater flow to estuaries). All three aspects alter the physical-chemical conditions of estuarine-coastal waters to the detriment of local flora and fauna (Table 1). Pollution (Impact 1, Table 1) includes nutrient and toxic chemical inputs, as well as changes in pH, temperature, and turbidity (due to sediments) that can reduce survival of various organisms, therefore modifying the biotic community and hence impairing the functionality of habitats and entire ecosystems. Erosion, which leads to changes in both water quality (sediment load) and quantity (alteration of the flow), is exacerbated particularly by upstream construction and road building (Impact 4, Table 1). These activities remove ground cover and alter the drainage pattern, while soil compaction increases the risk.

Major data sources

Information on sources of impact, stressors, type of impact, and final consequences on coastal environment were gathered from the following sources: Burke and others 2001; Carter 1988; Daily 1997; Hirji and Ibrekk 2001; Martinez and others 2007; Scheltinga and others 2004; Small and Nicholls 2003; and UNEP/GPA 2006.

Link Between DPL Policies and Coastal Impacts

Purpose and data

Analysis of the link between macroeconomic or sectoral adjustments and environmental impacts are numerous and their results quite varied. While reforms promote long-term economic growth, some of them may induce some type of environmental damage in the short term. The extent and type of impact is often dependent on country-specific environmental, institutional, economic, and social conditions.

This section illustrates the link between specific DPL policies and the known sources of impact illustrated in Table 1. To identify the policies that may present a risk for coastal areas and to understand which impacts they trigger, we relied mainly on data from studies on environmental impacts of macro and sectoral policies. The relevance of the information was validated through the analysis of experts.

Table 1. Causes of Impacts, Stressors, and Damages to Coastal Areas

(A) Sources of Impact	(B) Stressors	(C) Ecosystem Conditions Indicators	(D) Final Impacts
(1) Water Pollution • Point and nonpoint sources • Wastewater release from local or upstream urban settlements (raw sewage dumping or outfall from wastewater treatment plants) • Agricultural and industrial wastes disposed into surface waters or aquifers • Stormwater outfalls • Road runoff (mainly hydrocarbons) • Harbor activities and runoff • Oil spills and slicks • Aquaculture wastes (ex: residual feed) • Thermal pollution • Solid waste (litter)	Changes in concentration of dissolved compounds: nutrients, organic matter, chemical toxic compounds, including heavy metals and POC. Bacteria/pathogens (bacteria, viruses, protozoa, fungi) Changes in water temperature and pH. Changes in aquatic sediment load	Physical-chemical (dissolved oxygen for eutrophication, concentration of chemicals and sediments load) BOD/COD Biological (animal & plant species abundance, bacterial load)	• Deterioration of both estuarine surface waters and groundwater reserves in shallow aquifers • Eutrophication + following hypoxia or anoxia • Reduced water quality affects biota; it may reduce biodiversity by increasing mortality (or reducing survival) of both animals and plants • Possible damages to commercial sea species or sport species, and aquaculture activities • Possible damages to estuarine habitats such as wetlands, mangroves, sea grass • Possible damages to offshore habitats (e.g. coral reefs). • Risks to human health (waterborne diseases + toxic chemicals) affect both general health and tourism
(2) Pressure on Natural Resources • Abstraction and regulation of surface freshwaters (domestic or for commercial activities) • Abstraction of groundwater • Small-scale/artisanal fisheries or large-scale/industrial fisheries • Aquaculture	Changes in water flow quantity and pattern (changes in salinity) Removal of biota	Physical-chemical (water salinity) Biological (Changes in abundance of fish populations or other taxa exploited through fishery)	• Changes in stream and groundwater flow modifies estuary and wetlands salinity and negatively affects biota, both flora and fauna (increased mortality) • Reduction of biodiversity and commercial fish stocks through overfishing practices • Repercussions on human economic activities (fisheries and aquaculture) • Seepage of seawater into water table (salinization)
(3) Habitat Conversion (loss/degradation) • Local development, density human population • Aquaculture • Agriculture • Coastal urban development (e.g. transport infrastructure and settlements for tourism) • Extraction activities (timber, mining)	Changes in land use and land cover, causing habitat removal or disturbance	Biological (abundance/ richness of plant and animal species) Habitat extent (extent/ distribution of key habitat types)	• Displacement and loss of flora and fauna • Destruction of wetlands and other habitats (with repercussions on water quality) • Repercussions on human economic activities (fisheries) • Coastal erosion • Impact on water table due to water abstraction • Salinization

Table 1. Causes of Impacts, Stressors, and Damages to Coastal Areas, continued

(A) Sources of Impact	(B) Stressors	(C) Ecosystem Conditions Indicators	(D) Final Impacts
(4) Upstream Destructive Land Use • Forestry (deforestation) • Poor cultivation practices • Overgrazing • Construction and roadbuilding	Changes in water flow quantity and patterns Depletion of vegetative cover can alter runoff and infiltration rates: • Increased frequency and intensity of floods • Changes in groundwater recharge Increased erosion and sediment transport and deposition: increased sediment load in the water	Physical-chemical (water salinity) Biological Habitat extent (extent/distribution of key habitat types)	• Changes in stream and groundwater flow affects estuary and wetlands salinity and biota • Affects stream sediment load, estuary sedimentation, siltation, and effects on habitats and biota (habitat suffocation effects) • Sediment accumulation can change geology and energy fluxes and impact flora and fauna • Reduced water quality, as the plants have a filtering action (e.g. wetlands)
(5) Introduction of Exotic Species • From ballast water of ships or boat hulls • From aquaculture (escapees) • From coastal terrestrial habitats	New presence of exotic invasive species (Including pathogens & parasites)	Biological (density and distribution of pest species and species affected by it)	• Displacement and extinction of local species • Loss of biodiversity • Possible damage to human commercial activities through pest outbreaks
(6) Hydrodynamics • Aquaculture • Canals, breakwaters, artificial opening/closing estuary mouth • Overgrowth of invasive plant species • Levees, retention walls, and water barriers • Mining • Saltwater intrusion • Climate change	Change in hydrodynamics (change in patterns of wave, currents, tides)	Physical-chemical (salinity, water current patterns) Biological (algal blooms, biomass algae)	• Algal blooms • Decreased abundance of flora or fauna species (loss biodiversity) • Sediment accumulation • Habitat loss due to erosion or sediment accumulation • Reduced water quality, anoxia, hypoxia
(7) Climate Change • Changes in precipitation patterns • Increase in extreme weather events • Sea level rise • Temperature rise	Coastal erosion Modification of water flow pattern and water quantity Modification/loss of habitats	Biological Habitat extent and location	• Changes in water flow pattern and quantity negatively affect biota (increased mortality) • Salinization and loss of habitat • Coral bleaching-increase in SST • Ocean acidification → decrease in calcification • Diseases
(8) Air Pollution • Atmospheric emissions from all sources			• Affects human health and biota

Tables 2 to 6 show the types of impacts (as reported in Table 1) that could be triggered by each policy. Since there are both direct and indirect impacts, the policies taken into consideration do not need to be obviously linked to coastal resources; for instance, trade policies may (1) trigger impacts directly on aquaculture and fisheries, or (2) they may affect agriculture or forestry activities in ways that produce impacts on aquaculture and fisheries on the coasts.

The last column in the tables presents the indicators of state that should be taken into consideration to measure the significance of the impact. The indicators will be described in Module II. To understand how to use this framework and measure the significance of an impact, see the toolkit mechanism.

The correspondence between type of impact and indicator is shown in Table 7.

Major data sources

Major data sources included Iannariello and others 2000; Munasinghe, Cruz, and Warford 1996; Panayotou and Hupe 1996; Reed 1996; and World Bank 2004.

Table 2. Policies Designed to Ensure Macroeconomic Stability

Expand and deepen international trade			
Policy Action	**Impact**	**Type of Impact (Summary Table)**	**Relative Indicators (Module II)**
(1) Trade policy reforms; liberalization of trade regime, tariff and nontariff regulations		Pollution (Impact type 1) Overexploitation of marine resources (Impact type 2) Habitat loss (Impact type 3) Upstream land use (Impact type 4) Exotic species (Impact type 5)	• Fertilizer intensity use • Marine trophic index • % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species • % deforestation • % introduced species established in the wild
(2) Expand market access for domestic exports			

Table 3. Policies Designed to Increase Production and Competitiveness in Agriculture

Policy Action	Impact	Type of Impact (Summary Table)	Relative Indicators (Module II)
Increase production and productivity			
(3) Improve access to markets (trade liberalization)		Pollution (Impact type 1) Overexploitation of water resources (Impact type 2) Habitat loss (Impact type 3) Upstream land use (Impact type 4)	• Fertilizer intensity use • % population within 100 km • % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species • % deforestation
(4) Reform of land tenure laws and land acts			
(5) Product price and input price reforms			
(6) Maintenance and expansion of irrigation		Overexploitation of water resources (Impact type 2)	• % population within 100 km
Increase competitiveness in specific commodities (coffee, tea, cotton, etc.)			
(7) Provide better incentives and institutional arrangements to farmers to increase returns		Pollution (Impact type 1) Habitat loss (Impact type 3) Upstream land use (Impact type 4)	• Fertilizer intensity use • % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species • % deforestation
(8) Improve marketing arrangements for improved seeds and fertilizers		Pollution (Impact type 1)	
(9) Improve trade and marketing of agro-processed products		Pollution (Impact type 1) Habitat loss (Impact type 3) Upstream land use (Impact type 4)	

Table 4. Policies Designed to Improve Infrastructure

Policy Action	Impact	Type of Impact (Summary Table)	Relative Indicators (Module II)
Implement general transport sector reforms			
(10) Rehabilitation of rural tracks and roads in production centers		Habitat loss (Impact type 3)	• % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species
(11) Development and maintenance of road network			
Development of ports			
(12) Private sector participation in port development		Pollution (Impact type 1) Habitat loss (Impact type 3) Exotic species (Impact type 5)	• Fertilizer intensity use • % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species • % introduced species established in the wild

Table 5. Policies Designed to Improve Energy Supply and Distribution

Policy Action	Impact	Type of Impact (Summary Table)	Relative Indicators (Module II)
Tariff structure reforms			
(13) Reform of tariff structure to reflect costs, cover costs of generation		Habitat loss (Impact type 3) Upstream land use (Impact type 4)	• % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species • % deforestation
Improve operational efficiency and fiscal sustainability of utilities			
(14) Remove subsidies to utilities in the power sector		Habitat loss (Impact type 3) Upstream land use (Impact type 4)	• % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species • % deforestation
Increase competition in the electricity market			
(15) Reinforce power sector deregulation		Pollution (Impact type 1) Habitat loss (Impact type 3)	• Fertilizer intensity use • % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species

Table 6. Policies Designed to Promote Tourism and Tourism Revenue

Policy Action	Impact	Type of Impact (Summary Table)	Relative Indicators (Module II)
Promote tourism and tourism revenue			
(16) Increase the number of tourist destinations in coastal areas		Pollution (Impact type 1) Habitat loss (Impact type 3) Upstream land use (Impact type 4)	• Fertilizer intensity use • % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species • % deforestation

Table 7. Type of Impact and Indicator

Type of Impact*	Indicators
(1) Pollution/water quality	• Fertilizer intensity use (kg/ha)
(2) Pressure on natural resources	• Marine trophic index (sustainability fisheries) • % population within 100 km
(3) Habitat conversion	• % surface area covered by marine protected areas • % mangrove loss • % endangered or critically endangered marine species
(4) Upstream destructive land use	• % deforestation
(5) Introduction of exotic species	• % introduced species established in the wild

* Impacts from Table 1

Module II

This module presents a list of indicators of environmental state for those DPL countries that have direct access to the sea.

Analysis of impacts and their sources (Module I) is critical to uncover the possible link between these impacts and specific DPL policies, while identification of the affected coastal receptors serves as a rationale for the choice of coastal indicators.

Indicators of Coastal Environment Status

Introduction to the indicators

This section provides Task Teams with indicators of state that estimate the sensitivity of coastal receptors to different impacts.

The indicators are chosen to cover the main impacts described in the introduction to Module I. They represent either the conditions of coastal environmental receptors affected by those impacts, or reflect the status/level of specific pressures on the coasts.

Table 8 presents the eight chosen indicators. Table 8 explains the system used to rank the indicators. A three-color coding system was adopted in keeping with the general DPL Toolkit. Green indicates that the country is not particularly affected with respect to the indicator, yellow somewhat affected, and red seriously affected. Table 10 shows the ranking of the indicators for all of those DPL countries that have direct access to the sea.

A note on the marine trophic index

In a study published in *Science* in 1998, and based on the FAO database of fish landings, Pauly and others revealed a declining abundance of the larger fish on top of marine food webs. The phenomenon, known since as "fishing down marine food webs," is demonstrated by a decreasing mean trophic level of the landed fish. The measure of the mean trophic level of fishery landings has been considered (with some controversy) as an indicator of the impact of fisheries on aquatic ecosystems and marine biodiversity, and thus as a possible measure of the sustainability of fisheries.

Table 8. Indicator Categories, Measures, and Sources of Data

Indicator category	Indicator definitions and measures	Source
Agricultural inputs: proxy for water quality	Fertilizer intensity—kg/ha of agricultural land	Earthtrends database: amount of fertilizer consumed per hectare of arable and permanent cropland
Impacts on biodiversity	% endangered or critically endangered species in marine environment	IUCN Red List
Sustainability of fisheries	Marine trophic index[a] (cutMTI = 3.25)	Sea Around Us Project
Pressure on coastal resources	% population within 100 km of coasts	Earthtrends WRI database
Status of coastal habitats	Marine protected areas as a % of surface area	World Development Indicators
Pressure on coastal habitats	Mangrove annual % loss	World Atlas of Mangroves (FAO)
Upstream destructive land use	Annual % deforestation	Little Green Data Book
Invasive species	% of introduced aquatic species established in the wild or very likely to be established in the wild	DIAS (database on introduction of aquatic species, FAO)

Note: [a] The lower limit for the marine trophic index is set at 3.25 in order to exclude from the analysis lower trophic levels that may be more easily influenced by natural/cyclical changes in environmental conditions (rather than by the impact of fishery operations) (Pauly and Watson 2005). Pauly and Watson also provide a clear definition of trophic level.

Table 9. Coding of Indicators

Indicator category	Indicator definitions and measures	Coding
Agricultural inputs: Proxy for water quality	Fertilizer intensity—kg/ha of agricultural land	Red when a country has a score more than twice the median;[a] yellow when the score is above the median of the group; green otherwise
Impacts on biodiversity	% endangered and critically endangered species in marine environment	Red when a country has a score above the median; green when the score is below half of the median; yellow when the score is between half of the median and the median
Sustainability of fisheries	Marine Trophic Index (cutMTI = 3.25)	Red when the slope of the regression line of the mean trophic values is negative (index decreasing); green when the slope is positive[b]
Pressure on coastal resources	% population within 100 km coasts	Green with population between 10% and 30%; yellow between 31% and 60%; red between 61% and 100%
Status of coastal habitats	Marine protected areas as a % of surface area	Red when a country has a score more than twice the median; yellow when the score is above the median of the group; green otherwise
Pressure on coastal habitats	Mangrove annual % Loss	Red with mangrove loss, green otherwise; + sign indicates growth, - sign indicates loss of mangroves
Upstream destructive land use	Annual % deforestation	Red with deforestation, green otherwise; + sign indicates deforestation, - sign growth (the opposite of the mangrove indicator)
Invasive species[c]	% of introduced aquatic species established in the wild or very likely established in the wild	Red when country score is over the median; green when it is below

Notes:

a This is the median of 49 countries supported by DPLs that actually have access to the sea (selection of DPL countries just based on access to the sea would give a list of 51 countries. Iraq and Montenegro were excluded from this list because of a lack of available and reliable data).

b The values of the marine trophic index for landed catch are regressed across time (from 1950 to 2003).

c This is a measure of how much the country is affected by invasions. This can be due to several factors, including malpractice and lack of controls and regulations.

Table 10. Ranking of the Coastal Tool Indicators for all the DPL Countries with Access to the Sea

	Impact 1: Pollution/ water quality	Impact 2: Pressure on nat resources	Impact 2: Pressure on nat resources	Impact 3: Habitat destruction	Impact 3: Habitat destruction	Impact 3: Impact on biodiversity	Impact 4: Upstream destructive land use	Impact 5: Exotic species introduction
Country	Agricultural inputs: Fertilizer intensity kg/ha of agricultural land	% Pop within 100 km coasts	Marine trophic index: Slope of regression line	Mangrove annual % loss period 1990-2000	Marine protected areas 2004 % of surface area	% Endangered or critically endangered species in marine environment	Average annual % deforestation 1990-2005	% Introduced species established and species probably established in the wild
Albania	50.6	97		0	1	17.9	0	61.5
Argentina	25.6	45	-0.0004	0	0.3	12.3	0.4	66.7
Bangladesh	168.9	55		+0.2	0.2	10.7	0.1	100.0
Benin	17	62	0.0117	-2.6		17.6	1.9	50.0
Brazil	115.4	49	0.001	-1.3	0.6	14.2	0.5	42.1
Bulgaria	46.3	29	0.0032	0	0	12.3	-0.6	75.0
Cambodia	2	24		-1.6	1.1	10.3	1.3	42.9
Cameroon	4.9	22	0.0044	-0.8	0.8	12.9	0.9	25.0
Capo verde	4.5	100				13.3	-3	
Chile	197.2	82	-0.011	0	15.1	5.5	-0.4	76.0
Colombia	179.6	30	-0.0033	-1.1	0.7	12.2	0.1	73.9
Cote d'Ivoire	15.8	40	0.0022	-10.8	0.1	11.7	-0.1	30.8
Croatia	108.3	38	0.0005	0	4.4	12.5	-0.1	100.0

Table 10. Ranking of the Coastal Tool Indicators for all the DPL Countries, continued

	Impact 1: Pollution/ water quality	Impact 2: Pressure on nat resources	Impact 2: Pressure on nat resources	Impact 3: Habitat destruction	Impact 3: Habitat destruction	Impact 3: Impact on biodiversity	Impact 4: Upstream destructive land use	Impact 5: Exotic species introduction
Country	Agricultural inputs: Fertilizer intensity kg/ha of agricultural land	% Pop within 100 km coasts	Marine trophic index: Slope of regression line	Mangrove annual % loss period 1990-2000	Marine protected areas 2004 % of surface area	% Endangered or critically endangered species in marine environment	Average annual % deforestation 1990-2005	% Introduced species established and species probably established in the wild
Dominican Rep.	56.2	100	0.0037	-3.4	17.6	9.1	0	69.6
Ecuador	76.9	61	-0.0034	-1.2	49.7	8.8	1.4	42.9
El Salvador	60.8	99	0.006	-3.9	0.4	12.5	1.4	63.6
Georgia	26.7	39	0.0096	0	0.1	26.7	0	100.0
Ghana	4.9	42	0.0041	-2		11.7	1.7	66.7
Guatemala	92	61	0.0011	-1.2	0.1	11.7	1.1	61.5
Guinea-Bissau	4.4	95	0.0019	no changes		12.9	0.4	
Haiti	12.7	100		-4		10.3	0.6	50.0
Honduras	35.2	65	0.0011	-7	1.7	10.3	2.5	80.0
India	95	26	-0.0033	-0.3	0.5	10.9	-0.4	75.0
Indonesia	88.8	96	0.0005	-1.8	6.8	14.0	1.6	43.8
Kenya	27.7	8	0.0032	-0.3	0.5	7.5	0.3	57.7
Liberia	0.5	58	0.004	no changes	0.5	11.3	1.5	0.0
Madagascar	2.6	55		-0.2	0	8.7	0.4	65.4
Mauritiius	235.8	100	0.0111	no changes	4.4	10.7	0.3	60.9
Mexico	62.7	29	0.0007	-2.1	4.2	12.0	0.5	68.8
Morocco	43	65	-0.0019		0.1	11.5	-0.1	63.2
Mozambique	5.6	59	0.0238	-0.2	2.8	9.9	0.2	10.0
Namibia	0.4	5	-0.0031		9	11.8	0.8	72.7
Nicaragua	24.9	72	0.0014	-2.6	1	13.7	1.4	80.0
Pakistan	133	9	-0.0029	-1.6	0.3	9.5	1.6	80.0
Panama	41.3	100		-0.5	13.3	11.9	0.1	60.7
Peru	63.6	57	-0.001	-0.6	0.3	8.7	0.1	84.2
Philippines	67.6	100	0.0028	-1.2	5.5	10.3	2.2	76.9
Romania	32.9	6	0.0088	0	2.6	12.1	0	
Senegal	13.4	83	-0.00111	+0.1	0.4	12.7	0.5	
Sierra Leone	0.5	55	-0.0021	-1.1		11.6	0.6	0.0
Sudan	4.2	3		-1.4	0	4.3	0.8	66.7
Tanzania	1.4	21	0.0063	+0.7	0.2	7.3	1	66.7
Tonga	3.4	98		no changes		12.1	0	17.6
Tunisia	20.8	84	0.0016	0	0.1	13.0	-4.3	53.3
Turkey	65.6	58	-0.0022	0	0.6	15.9	-0.3	68.2
Ukraine	17.6	21	-0.0019	0	0.5	13.7	-0.2	100.0
Uruguay	91.3	78	0.0006	0	0	15.8	-4.4	80.0
Vietnam	224.1	83		-4.5	0.2	7.3	-2.5	80.0
Yemen Rep.	7	63	-0.0011	-2		3.7	0	100.0

Major data sources

World Bank. 2006. *The Little Green Data Book,* 2006. Washington, DC: World Bank.
The *Little Green Data Book,* which is produced by the Environment Department in collaboration with the Development Economics Data Group, provides data on agriculture, forests and biodiversity, energy, emissions and pollution, water and sanitation, environment and health, and national accounting aggregates. It is available at: http://siteresources.worldbank.org/INTEEI/936214-1146251511077/20916989/LGDB2006.pdf

World Bank. 2007. *World Development Indicators 2007*. Washington, DC: World Bank.
WDI is the World Bank's official annual compilation of data on development. The 2007 edition contains 900 indicators organized in six sections: World View, People, Environment, Economy, States and Markets, and Global Links

World Resources Institute. *Earth Trends*
Earth Trends is a comprehensive online database maintained by the World Resources Institute. It focuses on the environmental, social, and economic trends that shape our world. It provides information on coastal and marine ecosystems; water resources and freshwater ecosystems; climate and atmosphere; population, health, and human well-being; economics, business, and environment; energy and resources; biodiversity and protected areas; agriculture and food; forests, grasslands, and drylands; and environmental governance and institutions.

Source: http://earthtrends.wri.org/

Food and Agriculture Organization of the United Nations (FAO). 2006. *Global Forest Resources Assessment 2005*. Rome: FAO.
FAO has been coordinating global forest resource assessments every five to ten years since 1946. *Global Forest Resources Assessment (FRA) 2005* is the latest and most comprehensive assessment of forests and forestry to date. It provides information on the current status and recent trends for about 40 variables covering the extent, condition, uses, and values of forests and other wooded land. The key findings are presented under six themes: extent of forest resources, forest health, biological diversity, productive, protective, and socioeconomic functions of forest resources.

The FRA has global tables, country tables, country reports, and the background documents used in the preparation of the report. The global tables present information for 229 countries and territories grouped into six regions. The country tables provide data on all the reporting countries in a set of 15 national reporting tables. In addition, the assessment has seven thematic studies, which provide complementary information on specific topics like planted forests, mangroves, bamboo, wildland fires, forest pests, forests and water, and forest ownership and resource tenure.

Source: http://www.fao.org/forestry/site/fra/en/

Food and Agriculture Organization of the United Nations (FAO). *FAO Database on Introductions of Aquatic Species (DIAS)*. Rome: FAO.
"The FAO Database on Introductions of Aquatic Species was initiated by R. Welcomme in the early 1980s. It considered primarily only freshwater species of fish and formed the basis for the 1988 FAO Fisheries Technical Paper no. 294. The database has been expanded to include additional taxa, such as mollusks and crustaceans and marine species. In the 1990s a questionnaire was sent to national experts to gather additional information on introductions and transfers of aquatic species in their countries. The database includes records of species introduced or transferred from one country to another and does not consider movements of species inside the same country. DIAS can provide a registry of where aquatic species have been introduced and some summary statistics, as seen in the accompanying figures. Some example maps demonstrate the extent of introductions." (from DIAS website)

Source: http://www.fao.org/fi/website/FIRetrieveAction.do?dom=collection&xml=dias.xml

Using the available database, a by-country indicator was built providing the % of those introduced aquatic species that are known to be established in the wild and very likely to be established in the wild.

Food and Agriculture Organization of the United Nations (FAO). 2005. *FAO World Atlas of Mangroves*. Rome: FAO.
Data on mangrove loss were obtained from Wilkie and

Fortuna 2003 (Wilkie, M.L., and S. Fortuna. 2003. “Status and trends in mangrove area extent worldwide.” Forest Resources Assessment Working Paper No. 63. Forest Resources Division. Rome: FAO. Available at: http://www.fao.org/docrep/007/j1533e/j1533e00.htm). The data on mangrove status per country can be accessed directly from the website of the FAO World Atlas of Mangroves, which is available at: http://www.fao.org/forestry/site/20067/en/

Sea Around Us Project

“The Sea Around Us Project is a Fisheries Centre partnership with Philadelphia’s Pew Charitable Trusts. It was started in July 1999 and is led by Daniel Pauly. The aims of the project are to provide an integrated analysis of the impacts of fisheries on marine ecosystems, and to devise policies that can mitigate and reverse harmful trends while ensuring the social and economic benefits of sustainable fisheries.”

Source: http://www.seaaroundus.org/Project.htm?date=4%20Feb%202005&title=Project%20home

Among other services, the project provides fisheries and biodiversity data by EEZ zone, including estimates of the marine trophic index, which is used as a measure of the sustainability of fisheries.

IUCN Red List

“The IUCN Red List provides a framework to classify species according to their extinction risk. The searchable online database contains the global status and supporting information on about 40,000 species. Its primary goal is to identify and document the species most in need of conservation attention and provide an index of the state of degeneration of biodiversity.”

The list was used to build a by-country indicator of the % of endangered and critically endangered species in the marine environment. The DD (Data Deficient) species were excluded from the analysis.

Source: http://www.iucn.org/themes/ssc/redlist.htm

Module III

This module has two sections. First, it selects a number of countries as an initial subset upon which the toolkit can be tested. The second section illustrates the Bayesian belief network approach, which has been tailored to be used for the analysis of impacts on coastal areas. These approaches can be integrated with a number of other approaches presented in Module III of the general DPL Toolkit.

Selection of Countries

Introduction to the selection process

The Coastal Toolkit focuses on a subset of the countries supported by the DPL (see general DPL Environmental Toolkit for complete list of countries). The initial selection identifies only those countries with direct access to the sea. A further reduction of the list is justified with the intention of testing the approach on a limited number of subjects; this makes it easier to determine possible issues for further development and optimization.

About 20 countries were selected based on their dependence on coastal resources, both for market and nonmarket goods and services. "Dependence" is measured using indicators that function as selection criteria.

The following selection criteria (or rules) were used:

1. Coastline length in km
2. Percentage of population within 100 km of the coast
3. Value of marine fishery production in the EEZ[1] (million $)
4. Coastal ecosystem services value per km of coastline (million $)

1 EEZ = Exclusive Economic Zone. Under the law of the sea, the EEZ is a zone in the sea over which a state has special rights of resources use and exploration. Usually it extends to 200 nautical miles from the coastline (http://www.un.org/Depts/los/convention_agreements/texts/unclos/part5.htm).

Description of selection criteria

Rule 1 — Length of coastline

Length of coastline provides an indication of the likely reliance of the country on coastal resources. Data per country has been obtained through the CIA *World Factbook* online database (https://www.cia.gov/library/publications/the-world-factbook/index.html). The "coastline" entry in the database provides the total length of the boundary between land area and sea. It includes islands. In the case of Vietnam, the data on length of coastline did not include the coastline of islands belonging to Vietnam. For consistency, the total length (including islands) was obtained through the online database of Earthtrends-WRI (http://earthtrends.wri.org).

Rule 2 — Percent Population within 100 km

This criterion is a proxy for the intensity of use of coastal resources. Data comes from the online database of Earthtrends-WRI (http://earthtrends.wri.org).

Rule 3 — Value of marine fishery production

Total value of fishery production is used as an indicator of the economic-market importance of coastal resources. Data was obtained through the online database of the Sea Around Us Project (www.seaaroundus.org). It reports the real value (in US $) of total marine reported landings in the EEZ zone in 2003. The website explains that the reported catch (and value) comes exclusively within the EEZ, and any catch outside this boundary is excluded.

Rule 4 — Coastal ecosystem services product per km coast (million $)

This indicator provides an estimate of the nonmarket value of coastal ecosystem services. It includes both terrestrial and marine ecosystems considered part of the coastal areas. It is a proxy for the value of coastal biodiversity and ecosystems for each country. Data for ecosystem services product (ESP) comes from Martinez and others (2007). In order to compare the values across countries with various coastal extents, the value of ESP for each country was divided by the length of the coastline.

Normalization and selection

Data sets with different metrics—for example, monetary values, length data, and percentages—need to be made comparable by bringing them to the same scale.

Values for each of the four variables were normalized to the mean of 0 and standard deviation (std) of 1, by subtracting the mean from each data point and dividing it by the std.

Normalization equation [2]: $(x-\mu)/std$

The values obtained through this operation are both positive and negative in sign. Due to the type of calculation, values are negative when the original raw number is smaller than the mean, and positive when the raw number is greater than the mean. Once the normalization process has brought all the variables to the same scale, data across variables can be selected based on a common cutoff value or based on a common rule. It is therefore possible to establish a thorough criterion of choice for the countries.

As we are particularly interested in countries that depend heavily on their costal areas in terms of resources and contribution to the economy, it is reasonable to choose countries that present the highest values in all of the four indicators selected for this analysis. A way to do this is by choosing countries according to the number of positive values after the normalization process, starting with those that have four positive values, and then, if needed, selecting those with three positive and one negative. If this were still not enough, we would need to select countries with two positive values and two negative values.

Table 11 presents the output of the selection process described above. No countries had four positive values, therefore the ones to be chosen were the ones with three and two positive values.

Bayesian Networks for the Coastal Toolkit

Introduction to Bayesian networks

Bayesian networks, also called Bayesian belief networks (BBNs) or causal maps, are probabilistic graphical models based on the concepts of conditional probability and on the Bayes theorem of probability. Readers can refer to readily available literature and to web resources to find out more about Bayesian statistics. In general, Bayesian statistics use both previous knowledge and updated new evidence to measure the probability of an event.

BBNs are technically defined as direct "acyclic graphs"—that is, graphs representing a set of variables linked by causal relationships that are expressed in terms of probability. As such they consist of a qualitative and a quantitative layer. The former is the graphical representation of the relations between some variables (as in an influence diagram), whereas the latter informs about the strength of these relations by way of probability.

Introductory example

The Bayesian network in Figure 3 is a simplified model that tries to capture the factors contributing to the risk of an oil spill—for instance, from an oil tanker—and to the ensuing loss of marine fauna.

Key elements

The basic components of Bayesian networks are (a) a set of nodes (the variables, or events that populate the map); and (b) edges or arcs (the connecting arrows that specify the direction of the causal relation between nodes). The combination of nodes and edges forms the graph. A probability is attached to each node—either prior unconditional probability, if the nodes have no parents, or a conditional probability if the nodes have parents. These probabilities are introduced through the use of raw data, expert opinion, or information from other sources, including research literature.

What can they be used for?

The main feature of Bayesian networks is to allow decisions in the face of uncertainty—for example, about the way a system works, or the factors involved.

Bayesian networks emerged from the field of artificial intelligence (AI). Their use then spread to the risk assessment field. Since the early 1990s, they have been applied to the environmental sciences, in particular in water management and wildlife management studies, in the fisheries sector, and lately they have been extended to climate change studies.

What do they tell you?

Bayesian maps can provide a measure of probability for the coastal impacts identified through the tables presented in Module II. They indicate the likelihood of

2 x = any data point, μ = mean of the values of each variable

Table 11. Raw Data Value and Normalized Value for 17 Selected Countries

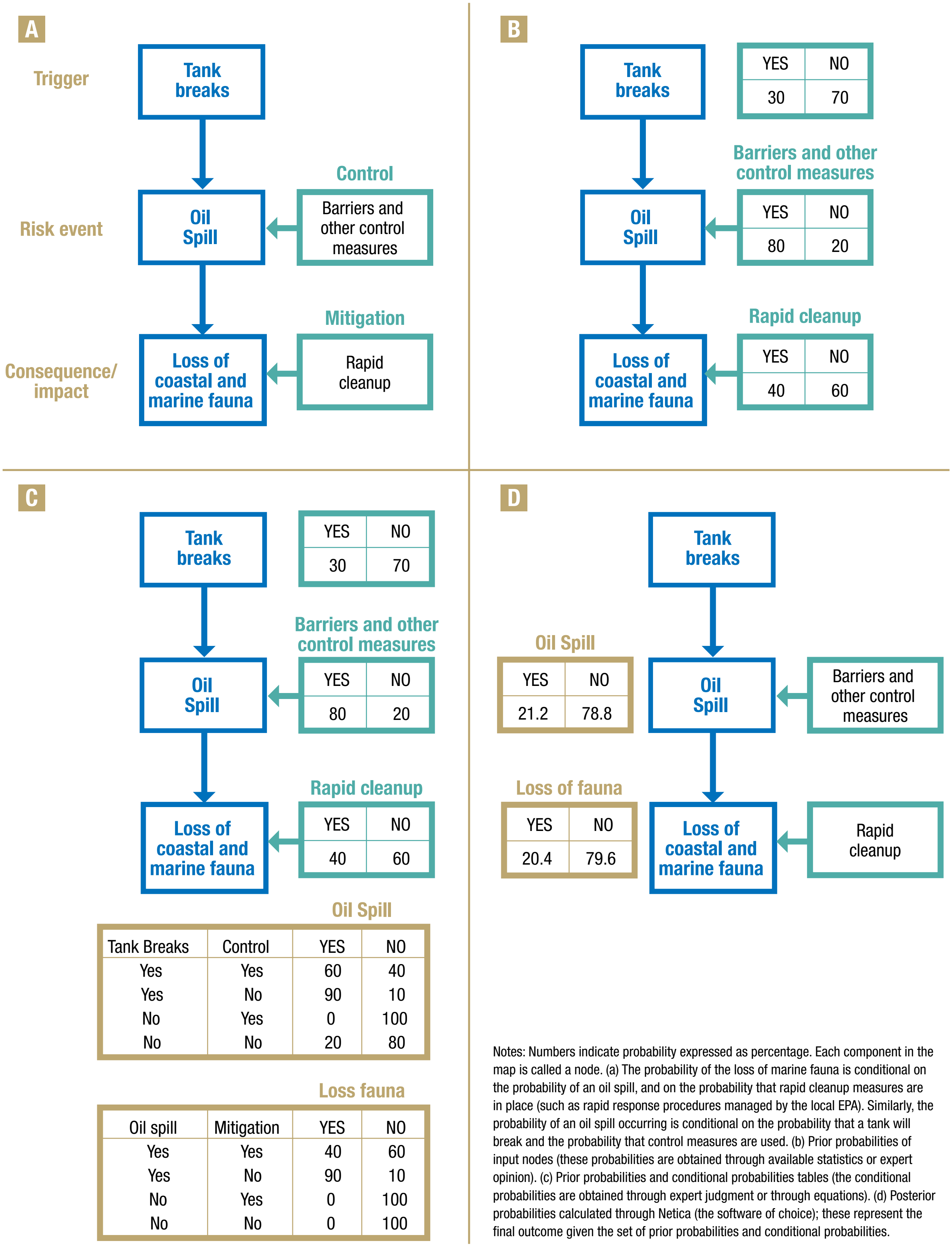
Country	Grouping[a]	Km of coasts	Population (%)	EEZ value (mil $)	ESP per km coast (mil $)
		RAW VALUES [NORMALIZED UNDERNEATH][b]			
Brazil	3+	7491 [+0.38]	49 [-0.28]	1030 [+1.08]	8.3 [+0.26]
Chile		6435 [+0.27]	82 [+0.79]	657 [+0.50]	1.9 [-0.64]
Indonesia		54716 [+5.49]	96 [+1.25]	3270 [+4.54]	5.1 [-0.19]
Philippines		36289 [+3.50]	100 [+1.38]	1425 [+1.69]	0.6 [-0.81]
Turkey		7200 [+0.35]	58 [+0.01]	401 [+0.11]	0.6 [-0.82]
Vietnam		11409 [+0.80]	83 [+0.82]	2069 [+2.68]	0.8 [-0.79]
Argentina	2+	4989 [+0.11]	45 [-0.41]	783 [+0.70]	1.4 [-0.70]
Benin		121 [-0.42]	62 [+0.14]	4 [-0.51]	11.3 [+0.68]
Guatemala		400 [-0.39]	61 [+0.11]	20 [-0.48]	8.8 [+0.33]
Guinea-Bissau		350 [-0.39]	95 [+1.22]	13 [-0.49]	13.9 [+1.05]
Honduras		820 [-0.34]	65 [+0.24]	27 [-0.47]	9.7 [+0.45]
India		7000 [+0.33]	26 [-1.03]	1991 [+2.56]	3.3 [-0.44]
Liberia		579 [-0.37]	58 [+0.01]	2 [-0.51]	9.9 [+0.49]
Mauritius		177 [-0.41]	100 [+1.38]	3 [-0.46]	27.9 [+3.02]
Mexico		9330 [+0.58]	29 [-0.94]	987 [+1.01]	6.0 [-0.06]
Nicaragua		910 [-0.33]	72 [+0.47]	64 [-0.42]	12.4 [+0.83]
Senegal		531 [-0.37]	83 [+0.82]	145 [-0.29]	14.7 [+1.17]

Notes:

a Indicates the grouping method used in the selection process (see text).

b Normalization of the raw data is enclosed in brackets. Data are presented to show positive and negative data in the corresponding grouping.

Figure 3. Example of a Bayesian Network



Oil Spill

Tank Breaks	Control	YES	NO
Yes	Yes	60	40
Yes	No	90	10
No	Yes	0	100
No	No	20	80

Loss fauna

Oil spill	Mitigation	YES	NO
Yes	Yes	40	60
Yes	No	90	10
No	Yes	0	100
No	No	0	100

Notes: Numbers indicate probability expressed as percentage. Each component in the map is called a node. (a) The probability of the loss of marine fauna is conditional on the probability of an oil spill, and on the probability that rapid cleanup measures are in place (such as rapid response procedures managed by the local EPA). Similarly, the probability of an oil spill occurring is conditional on the probability that a tank will break and the probability that control measures are used. (b) Prior probabilities of input nodes (these probabilities are obtained through available statistics or expert opinion). (c) Prior probabilities and conditional probabilities tables (the conditional probabilities are obtained through expert judgment or through equations). (d) Posterior probabilities calculated through Netica (the software of choice); these represent the final outcome given the set of prior probabilities and conditional probabilities.

an impact actually taking place given the cascade of events that led to the impact, and given our knowledge about the probability relation between the interacting nodes.

Three Bayesian belief networks have been developed to measure the probability of impacts originating from the implementation of policies related to improved access to markets and reduction of tariffs.

Network 1 analyzes the effects originating from the agriculture sector; networks 2 and 3 refer to the aquaculture and fishery sectors respectively. All the networks are available as Netica files (Netica is the supporting software application for BBNs).

Complementary tools

Quantitative tools
Network diagrams
GIS

Data/Information

Bayesian maps are knowledge-intensive during the building phase. Once the maps are correctly laid out, data is required to establish the relation between nodes. Where there is a lack of quantitative data, expert opinion is equally valid. The power of the system is such that expert opinion produces very strong results.

Time

Time is dependent on data-gathering for the nodes of the maps. This should be fairly quick as the maps have been designed such that data should be readily available through online databases. Interpretation of the results may involve some discussion within the team and therefore the time requested could be longer.

Skills

Experience with the concepts of Bayesian statistics, probability. Experience with Netica and Excel.

Supporting software

Netica software (www.norsys.com)

Limitations

Bayesian networks are acyclic graphs, and as a result they cannot contain feedback loops (which in some cases are useful in environmental modeling). It is also fairly time-consuming to represent changes in time and space, as these would need to be modeled through separate networks.

Sources of information and references on BBNs

Sources of information and references on BBNs include Cain 2007; Charniak 1991; Drudzel and van der Gaag 2000; Marcot and others 2006; Nyberg, Marcot, and Sulyma 2006; Uusitalo 2007, and van der Gaag 1999.

Also refer to the following websites of companies producing software for BBNs:
www.agena.co.uk
www.norsys.com

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Annex A. Description of the Bayesian Belief Networks

Introduction

This Annex is divided in three sections:

1. Description of the structure and variables in the Bayesian belief networks (BBNs). This section is designed to help task teams interpret the BBNs provided with the Coastal Toolkit.
2. Qualitative and quantitative definition of all nodes and of their relative states.
3. Methodology

Goal of the BBNs

BBNs take into consideration a subset of the DPL policies presented in Module I and analyze the link between these policies on some of the sources of coastal impacts.

The policies under scrutiny are mostly trade liberalization policies—for example, expansion of market access and elimination of tariffs—directed at increasing trade openness by enhancing the profitability of exports. The goal of the networks is to rapidly assess the probability of environmental impacts on coasts following the implementation of these policies.

The qualitative layer of the BBNs—that is, the graphical map—shows the possible environmental impacts and the major factors that interact with DPL policies to influence the triggering of these impacts. The quantitative layer (i.e. the probabilities) illustrates *how* these factors interact with one another. In the language of environmental policy and economics, these factors (or variables) are referred to as "channels." [3] They can be assigned to specific categories: (a) institutions and governance, (b) markets and economics, and (c) policy. Two BBNs also integrate factors that have to do with physical conditions (erosion).

The question driving the identification of the specific factors is the following: "Which factors are most important in determining a change in the level of the impact when interacting with trade policies?" The final choice reflects the results of peer-reviewed literature integrated with discussions with several domain experts.

Section 1 - Description of BBNs

BBN 1: Agricultural extensification

The BBN model illustrates how the implementation of a DPL policy affects the rate of deforestation, and how the conversion of land to agricultural production influences erosion. The DPL policies from Module I considered in the map are: (policy 1) implementation of trade policy reforms, including liberalization of trade regimes, tariffs and nontariff regulations; (policy 2) expand market access for domestic exports; (policy 3) improve access to markets (trade liberalization); (policy 7) provide better incentives and institutional arrangements to farmers to increase returns; and (policy 9) improve trade and marketing of agro-processed products (see Tables 2 through 6, Module I).

The fundamental assumption is that the DPL policies under consideration affect the level of trade openness; this is why trade openness is the variable of choice to represent quantitatively the implementation of the DPL policies.

Two aspects must be made clear before describing the nodes and relationships represented in this BBN:

1. The model implies that increased openness will make agricultural exports more profitable. Agricultural exports refer to "changes in the aggregate terms of trade for agriculture with respect to other sectors" (Angelsen and Kaimowitz 1999). As such, we are modeling a simplified system that does not take into consideration changes in the price of single crops, or whether these are under an extensive or more intensive cultivation system (Chomitz 2007).

2. The specific deforestation rate in a country is determined by many internal and external factors

3 The literature often analyzes the "channels" through which trade policies exert their effect on the environment.

that compose an intricate web of conditions leading to the final figure. However, sectoral research and models on the impact of trade policies have shown that a few specific variables can be used to explain the deforestation rate in a country in combination with the level of openness (Ferreira 2004; Mendelsohn 1994).

Interpretation of the network
The causal relationships between nodes tell us the following:

The level of the deforestation rate [4] following implementation of the policies is dependent on the status of property rights and the pressure on the land. [5] The status of property rights is dependent on the combination of two governance variables: (1) "control of corruption," and (2) "government effectiveness." A number of governance variables were considered from the Governance Matters list (Kauffmann and others 2007). The final choice was informed both by the analysis of relevant literature (Deacon 1994; Ferreira 2004) and from a correlation analysis between the variables.

Pressure on land is a summary node that combines the level of transportation infrastructure (roads) with total population density. Population density may affect the deforestation rate because of a greater need for food and sources of income, and because of an increased availability of labor. The degree of "physical access" is represented by road density, which is often used as an indication of proximity to markets. Greater ease of physical access (that is, high road density) translates into lower transportation costs, and therefore into higher "farmgate prices" (output prices) and lower input prices, both of which have been reported as promoting deforestation (Chomitz 2007; Angelsen and others 1999). The "road density" node in the map reflects these findings and determines the ease to "exploit new areas for timber and agricultural products" (Chomitz 2007). The state of this node may be affected by DPL policies 10 and 11 (Table 4, Module I), which directly address the maintenance and expansion of rural roads.

The bottom part of the BBN focuses on the state of erosion following land conversion (deforestation node). Erosion (increased, constant, or decreased) is dependent on the deforestation level, on the vulnerability to erosion (high or low), and on whether land-management practices are sustainable or not (good, sufficient, poor). The latter factor is the most critical; deforestation may represent a trigger for increased erosion, but the extent of this actually happening depends on whether or not the soil is appropriately managed (i.e. conservation of soil cover and of the top layer of organic matter.)

The "vulnerability to erosion" node is a summary node, a technical artifact that is used to simplify the calculations in the network and also to help visualize groups of similar variables. This node is dependent on the status of changes in rainfall (significant, moderately significant, or not significant), and on the slope and composition of the terrain (the variables were chosen following the RUSLE equation for the measurement of erosion levels, available at: www.iwr.msu.edu/rusle).

Notes on property rights
There is a proven link between the quality of property rights and rate of deforestation (Deacon 1994). For a private landowner, either an individual or a community, insecure tenure means a higher risk of eviction; in economic terms this translates into a high discount rate, which discourages investments in standing forest, in agricultural intensification, and in sustainable long-term management of the land. The result is a trend toward higher deforestation rates. The outcome is the same when the land is state-owned; weak tenure means that the government is unable to enforce its property rights and control the use of its land and forests.

The quality of property rights is the result of performance measured in several areas of governance. Indicators of government stability and effectiveness, the rule of law, control of corruption, and the level of democratic representation and accountability have been associated with the quality of property rights (Deacon 1994; Ferreira 2004).

4 Deforestation rate is used rather than land cover measures. The choice is motivated also by the fact that we are not considering factors such as climate and environmental conditions when talking about deforestation (Deacon 1994).

5 The current understanding of the relation between trade policies and deforestation is that an increase in trade openness is likely to increase the deforestation rate; however, models and empirical studies demonstrate that openness affects deforestation not independently, but through the interaction with a few major factors, in particular institutional factors (which determine the state of property rights), population density, and the level of access to the forests (for instance, expressed as density of roads.)

Climate change node

The DPL countries were assigned to one or more Köppen climatic zones based on an updated Köppen-Geiger climate classification map (http://koeppen-geiger.vu-wien.ac.at).

BBN 2: Aquaculture map

The DPL policies taken into consideration for both the aquaculture and fishery BBN are the following:

- *Policy 1*. Trade policy reforms: liberalization of trade regime, tariff, and nontariff regulations
- *Policy 2*. Expand market access for domestic exports

This BBN focuses specifically on commercial aquaculture developed in land-based ponds within coastal areas. The network captures the effect of trade policies on the expansion of aquaculture and whether this may have significant environmental impacts.

The policies described above and represented by the DPL policy node constitute an incentive to increase production; in fact, the efficiency of markets is recognized as the first driver of aquaculture expansion, both in terms of productivity and the number of players entering the field (World Bank 2007; FAO 2006).

Good governance (property rights node) and a high level of communication/transportation (road density-node) are the other major contributing factors.

Good governance allows for the establishment of a solid tenure system, which is critical to the expansion of production. Secure tenure is a prerequisite for access to credit (World Bank 2007). A good property rights system—that is, the recognition and formalization of both individual and community property rights—provides stronger assurance of the equitable allocation of land and water resources (World Bank 2007).[6]

Expansion of production is also critically dependent on the quality of communication/transportation (road density node). This determines the accessibility of markets, a vital aspect for the success of commercial aquaculture (FAO 2006). In summary, the DPL policies represent the trigger, the main incentive, while the status of property rights and the physical access state regulate whether the concurring conditions are facilitating the process or thwarting it.

Options to increase production include improving the management of the farm, making it more efficient and productive, or intensifying the use of inputs and/or land. The former option is usually related to more sustainable practices, which are helped by the presence of secure property rights. In fact, when property rights are strengthened it is expected that aquaculture practitioners will try to gain a stronger control over all aspects of production—from the type of feed used, to harvest technology, to effluent management—with benefits to the production level (reduced impact of diseases) and sustainability of the business. "With relatively strong property rights in shrimp farming, there is expected to be an increased effort to internalize the externalities related to pollution and diseases transmission with investments in research on feed, disease, and site management" (Leal 2004). This important aspect is represented in the network by the link connecting the property rights node and the incentives node.

Thus the property rights system influences the level of impacts on the environment; however, this is in combination with government control (rule of law) and the type of aquaculture system.

As shown in the "type of aquaculture" node in Table A-1, the aquaculture sector is generally divided into extensive, intensive, and semi-intensive operations; the definitions are based on the intensity of use of land and inputs, and on the stocking density. They are also related to the production level.

In general, intensive aquaculture requires heavy investments and availability of capital. The probabilities entered in the BBN reflect this; intensive aquaculture is thus given a lower probability of being developed compared to the other options. Given the general characteristics of the different aquaculture systems, these will have different impacts on the environment.

Aquaculture requires considerable amounts of water, both seawater and freshwater, along with land. The

6 As a counterexample, it is thought that poor institutions and deficient access to financial resources have been significant factors in the failure of African aquaculture.

Table A-1. Types of Aquaculture and Definitions

Type of aquaculture	Main characteristics	Most likely practitioner
Extensive	Open*	Families
	Low inputs	Small business/holders
	High use of land	
	Low stock density	
Intensive	Closed (open at times)	Big commercial companies
	High inputs	
	Low use of land	
	High stock density	
Semi-Intensive	Open/Closed	All of the above
	Medium inputs	
	High/Medium use land	
	Medium stock density	

Note: * Open or closed refer to the extent to which water is re-used within the system.

availability of water and land are therefore two important factors. Given the scale of analysis required for the toolkit, this BBN assumes that land and water are available. This is too dependent on local conditions to be represented in the map.

BBN 3: Fishery map

The effects of trade liberalization on fisheries depend heavily on subsidies and management systems (World Bank 2004; Leal 2004). These aspects are captured in the BBN in three nodes: subsidies, access status (open/closed), and fishery management practices (management regime node).

The network assesses the risk to the sustainability of stocks due to an expansion of the fishing industry following the implementation of a DPL policy. It is intended that the risk for the stock comes from an expansion that may occur either through the access of new players, or by increasing the fishing intensity, for instance through technological advances.

The entry of new players is dependent on the interaction of the DPL policy with other factors, including the level of incentives (in terms of subsidies and regulatory quality provided by the government), profitability of the field, and access regime. The access regime can be either open or closed. By plugging different probabilities in the map, it is possible to represent a degree of openness, so that we do not have "completely open" or "completely closed" as only options. The changes in fleet size are used as a proxy to represent the profitability of the sector (see nodes' definitions): an increase in fleet implies high profitability.

The sustainability of the stock (high, low, no) is dependent on the level of expansion of the industry, on the presence of good management practices[7] as part of the sector policies, and on the quality of governance. It is commonly accepted that poor governance is the main cause of overfishing (World Bank 2004). Even where sustainable practices are integrated in the official policy, their implementation and success depend on the quality of governance, which is represented here as a function of rule of law and control of corruption.

Section 2 - Description of Nodes and Relative States

Introduction: Use of the nodes

The factors that form the structure of a Bayesian belief network are technically called nodes. Each node is a discrete or a continuous variable that can be

7 In this BBN we are assuming that the country has access to knowledge and data to take into consideration the implementation of these practices.

described through a finite number of states. BBNs are part of the DPL Toolkit mainly as an instrument to assess the probability of a specific impact, but they are commonly used to structure/formalize available knowledge and guide decision making in terms of management actions. Consequently, the nature of the node needs to represent opportunities for intervention, and the states of the nodes must reflect the aspects of the node that are relevant to the user for management purposes (Cain 2001).

This annex provides a definition of the nodes included in the BBN maps, along with a description of their specific states in qualitative or (more often) quantitative terms.

Agri-extensification BBN: Description of nodes

Climate change: The node represents the impact of changes in extreme rainfall events on the level of erosion. The change in rainfall is measured comparing the period 1980–90 to forecasts for the period 2090–2100 (Climate Change Group – The World Bank). We use a proxy indicator currently used in the ADAPT tool developed by the World Bank's climate change team. The indicator refers to the maximum rainfall in a 5-day period (expressed as % of change between the two time periods mentioned above).
States of the node: Significant increase/moderate increase/no increase. For a quantitative description, see classification adopted by the Bank's climate change group in the ADAPT tool. The three states represent a different percentage change depending on the affiliation of a country to a specific climate category as identified by the CC team (based on a combination between Holdridge zones and Köppen climate classification).

Control of corruption: It is represented through an indicator belonging to the Worldwide Governance Indicators 2006 (http://info.worldbank.org/governance/wgi2007). The specific indicator is "control of corruption," defined as: "Control of Corruption (CC)—measuring the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests."
States of the node: Good/sufficient/poor.
Good = values > -0.2
Sufficient = values between -0.7 and -0.2
Poor = values below -0.7
This is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1996 and 2006 (see also Module II).

Government effectiveness: The node is represented through a proxy indicator belonging to the Worldwide Governance Indicators 2006 (http://info.worldbank.org/governance/wgi2007). The specific indicator is "government effectiveness" with this formal definition: "Government effectiveness (GE)—measuring the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies." Table B3 (Governance Matters VI, 2007) allows us to obtain further details related to this aggregate indicator by exploring the single sub-indicators.
States of the node: Good/sufficient/poor.
Good = values > -0.2
Sufficient = values between -0.7 and -0.2
Poor = values below -0.7
This is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1996 and 2006.

Land-management practices: The management regime is the key factor in determining the level of erosion. This node is a qualitative measure of whether the topsoil is protected through practices like intercropping, agroforestry, use of perennials rather than seasonal crops, or use of cover crops. The states of the node are good/sufficient/poor. The states shed light on whether the practices in place may contribute to increase erosion (poor practices), have no effect (baseline erosion is maintained), or mitigate erosion. It could be interpreted as: erosion mitigation = use of several sustainable practices; erosion normal = use of only 1 practice; erosion enhancing=intensive agriculture with no sustainable practice (e.g. use of intensive tillage).

Land use conversion (Deforestation): The BBN measures the likelihood of a specific level of deforestation following the introduction of policy A

and the conversion of land into crops. It answers to the question: given policy A along with other factors, what is the likelihood of deforestation being high, low, or none (none or forest growth)? Deforestation, in accordance with the FAO definition, is measured as the percentage of annual deforestation ("Natural forest area, average annual percent change"). Data are from the WRI searchable database (http://earthtrends.wri.org/searchable_db/index.php?theme=9), and are adapted from FAO *Global Forest Resources Assessment 2005*.
The states of the node are high/low/no, where high indicates an average annual % of deforestation below -1, low an annual deforestation between 0 and -1, and no an increase in forest cover (therefore a number greater than 0). Negative numbers indicate forest loss; positive numbers indicate an increase in forest area.

Physical factors: Summary node that brings together "climate change," "soil texture," and "terrain incline."
States of the node: high/low. The state depends on the combination of the states of the parent nodes. High indicates that the characteristics of the three parent nodes lead to high vulnerability to erosion.

Pressure on land: Summary node that brings together road density and total population density. States of the node: high/low. The state is determined solely by the combination of the states of the parent nodes.

Property rights: It is a summary node determined by the combination of the nodes "government effectiveness" and "control of corruption."
The states of the node are adequate/inadequate. The choice of state depends on the combination of the states of the parent nodes.

Road density: It is expressed as km of road per 100 km^2 of land area. "Road density refers to the ratio of the length of the country's total road network to the country's land area. The road network includes all roads in the country—motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads." (WDI 2007, World Bank)
The states of the node are high/medium/low, where high = density ≥ 30, medium = from 15 to 30, and low = density from 0 to 15. Road density is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1990 and 2006.

Soil texture: States of the node are coarse/medium/fine. They refer respectively to sandy, silty, and clay soils. If the assessment is nationwide, then the project team should have knowledge of the basic % soil composition of the country (soil maps are easily available). Clay soils are more vulnerable to (water) erosion compared to sandy soils. Silts tend to have characteristics in between the two. Vulnerability to erosion depends on the fact that larger particles are more likely to let the water seep through, whereas the more sticky structure of clay makes soils more prone to mechanical erosion.

Soil erosion: Research on soil erosion has produced what is known as the Revised Universal Soil Loss equation (RUSLE). The equation's parameters have been developed for all climates, soil types, topography, and land uses in the United States. The equation is expressed as follows: A=R*K*LS*C*P, where A is the estimated average soil loss in tons per acre, R is a rainfall erosivity factor, K is a soil erodibility factor, L a slope length factor, S a slope steepness factor, C a cover-management factor, and P a support practice factor. The soil erosion node follows conceptually the RUSLE equation: rainfall, soil composition, and slope are summarized into a "physical factors" parent node. The other parent nodes are "land use conversion" and "sustainable land management practices." The node represents the likelihood of erosion increasing, remaining stable (maintained), or decreasing compared to previous conditions. The states of the "soil erosion" node are increased/maintained/decreased. They depend directly on the combination of the states of the parent nodes.

Terrain incline: States of the node are flat/sloping. The definition is general and qualitative, but acquires strength in combination with the soil texture node.

Total population density: Deforestation models commonly use estimates of either total population density or urban population density as a measure of population pressure on forest resources. The

data of total population density for this node was obtained from the WRI searchable database. "Population density is the number of persons per square kilometer of land area. This dataset is calculated by WRI using population data from the United Nations Population Division and total land area data from FAOSTAT" (http://earthtrends.wri.org/searchable_db/index.php?theme=4).
Total population density is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1990 and 2006.
The states of the node are:
High = over 120
Medium = 60 to 120
Low = 0 to 60

Trade openness: As described in the Introduction, trade openness is used as a measure of implementation of DPL policies. Openness is measured using exports+imports/GDP. This is a common indicator of trade intensity/openness (see Ferreira 2004).
States of the node: very high/high/low/very low.
Very High = above 0.9
High = between 0.6 and 0.9
Low = between 0.4 and 0.6
Very Low = between 0 and 0.4
This is a continuous variable; discretization into intervals was based on examination of data for DPL countries between 1990 and 2006.

Marine fisheries BBN: Description of nodes

Improved access to market: Implementation of the policies: yes/no

Access regime: Control of fishing grounds either by the state, communities, or private parties. As a result, the fishery can be open or closed. There will always be a number of conditions ranging from completely closed to completely open; this can be taken into account with the use of probabilities (also, if we know that a country has 10 different fisheries and of these 6 are closed, we can translate this into a 60% for the closed state). This node controls decisively the entrance of new players.
States of the node: open/closed.

Control of corruption: It is represented through an indicator belonging to the Worldwide Governance Indicators 2006 (http://info.worldbank.org/governance/wgi2007). The specific indicator is "control of corruption," with this formal definition: "Control of corruption (CC)—measuring the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests."
States of the node: good/sufficient/poor.
Good = values > -0.2
Sufficient = values between -0.7 and -0.2
Poor = values below -0.7
This is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1996 and 2006.

Expansion of fishery: Expansion can happen through entrance of new players or through improvements in technology.
Expansion is measured through a proxy indicator. Data for capture production by area (marine waters) was obtained for the years 2000 and 2005 for coastal DPL countries, through the WRI searchable database (http://earthtrends.wri.org/searchable_db/index.php?theme=1). The % annual change was then calculated in Excel (see Fishery production.xls file).
States of the node: high/low/no, where no indicates negative growth (i.e. a reduction in production) and low means an annual % growth rate below the median of the coastal DPL countries for which an increase in marine fishery production was registered between 2000 and 2005. High indicates a growth above this median.

Enforcement of regulations for the fishery sector: The node represents the capacity of enforcing regulations to control catch. A proxy indicator is used belonging to the Worldwide Governance Indicators 2006 (http://info.worldbank.org/governance/wgi2007). The specific indicator is "Rule of law" with this formal definition: "Rule of Law (RL)—measuring the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence." Table B5 (Governance Matters VI, 2007) allows us to obtain further details related to this aggregate indicator by

exploring the single sub-indicators.
States of the nodes: good/sufficient/poor.
Good = values > 1
Sufficient = values between -1 and 1
Poor = values below -1
This is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1996 and 2006.

Laws effectiveness: This is a summary node built to facilitate processing of the information. It combines the two nodes “enforcement of regulations” and “control of corruption.”
States of the nodes: good/sufficient/poor, depending on the combination of states of the parent nodes.

Incentives: Summary node to combine effects of subsidies and regulatory quality of the government. States of the node: high/low, where each state is dependent on the combination of states of the parent nodes

Profitability of the sector: The node is rendered by using as proxy the historic fleet size change. Data is from the WRI searchable database and it considers the change in fishing decked vessels between 1995 and 1998 (the only dates available). (http://earthtrends.wri.org/searchable_db/index.php?theme=1).
States of the node: profitability high/medium/low. Medium refers to no changes in the fleet size, high to an increase, and low to a decrease.

Regulatory quality: It is represented through an indicator belonging to the Worldwide Governance Indicators 2006 (http://info.worldbank.org/governance/wgi2007). The specific indicator is “regulatory quality” with this formal definition “Regulatory Quality (RQ)—measuring the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.”
States of the node: good/sufficient/poor.
Good = values > -0.2
Sufficient = values between -0.7 and -0.2
Poor = values below -0.7
This is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1996 and 2006.

Subsidies for fishery: The node is defined based on the data available through the governance section of the Sea Around Us website. “The subsidy intensity in the form of total subsidy as a percentage of landed (fish) value is … given” (http://www.seaaroundus.org). The node takes into consideration only what are called “bad” and “ugly” subsidies for year 2006 (the only available data). “Bad subsidies are defined as those that lead to ‘disinvestments’ in the natural capital of the fishery resources. Excessive disinvestment can lead to outright destruction of the natural resources (Bjorndal and Munro 1998). Bad subsidies include all forms of capital inputs and infrastructure investments from public sources that reduce cost or enhance revenue. They include the following types: (a) boat construction renewal and modernization programs; (b) fishery development projects and support services; (c) fishing port construction and renovation programs; (d) marketing support, processing and storage infrastructure programs; (e) tax exemptions; (f) foreign fishing access agreement payments; and (g) fuel subsidies. Ugly subsidies are defined as those that have the potential to lead to either ‘investment’ or ‘disinvestment’ in the fishery resources. These subsidy programs can lead to resource enhancement or to resource overexploitation. Subsidies in this category include controversial ones such as: (a) fisher assistance programs; (b) vessel buyback programs; and (c) rural fisher community development programs” (http://www.seaaroundus.org/eez/eez.aspx, then choose country/governance/subsidies).
States of the node: high/medium/low, where high indicates values above twice the median value for bad+ugly subsidies of the DPL maritime countries, medium indicates values between median and twice the median, and low indicates values below the median.

Sustainable fishery management practices: This control factor refers to the use of practices like maximum economic yield as upper limit of harvest, total allowable catch (TACs), closed seasons and fishing bans, gear modification to limit bycatch, and individual transferable fishing quotas (ITFQs). These practices should take into consideration a

whole range of variables, including the effects of climate and environmental changes.
States of the node: yes/no, where yes necessitates at least one of the measures from the above list (unless it is gear modification, in which case it needs an additional measure).

Sustainability of stocks: This node is defined only qualitatively, based on the combination of states of the parent nodes.
States of the node: high/low/no.

Pond aquaculture BBN: Description of nodes

Accountability and representation: The node is represented by an indicator belonging to the Worldwide Governance Indicators 2006 (http://info.worldbank.org/governance/wgi2007). The specific indicator is "voice and accountability," with this formal definition: "Voice and accountability (VA)—measuring the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media." Table B1 (Governance Matters VI, 2007) allows us to obtain further details related to this aggregate indicator by exploring the single sub-indicators.
States of the node: good/sufficient/poor.
Good = values > -0.2
Sufficient = values between -0.7 and -0.2
Poor = values below -0.7
This is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1996 and 2006.

Control of corruption: It is represented through an indicator belonging to the Worldwide Governance Indicators 2006 (http://info.worldbank.org/governance/wgi2007). The specific indicator is "control of corruption," with this formal definition: "Control of corruption (CC)—measuring the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests."
States of the node: good/sufficient/poor.
Good = values > -0.2
Sufficient = values between -0.7 and -0.2
Poor = values below -0.7
This is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1996 and 2006.

Damage from escapees: Includes exotic (invasive) species, engineered species, and diseases (parasites, virus, bacteria). Exotic species may be invasive and outcompete native species; native species reared in aquaculture facilities and either engineered through use of biotechnology or through targeted selection processes may cause damage too. Interbreeding of selected/native escapees with the wild population may reduce diversity and threaten local populations.
States of the node: yes/no, depending on the combination of the parent states.

Destruction of habitats: It refers to the loss of coastal habitats due to the expansion of aquaculture activities.
States of the node: yes/no, depending on the state of the parents' nodes.

DPL policy: Implementation of the policies: yes/no.

Expansion of production: Summary node; it is the direct result of the combination between the parent nodes (property rights, DPL policy, and physical access).
States of the node: yes/no.

Government effectiveness: The node is represented through a proxy indicator belonging to the Worldwide Governance Indicators 2006 (http://info.worldbank.org/governance/wgi2007). The specific indicator is "government effectiveness," with this formal definition: "Government effectiveness (GE)—measuring the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies." Table B3 (Governance Matters VI, 2007) allows us to obtain further details related to this aggregate indicator by exploring the single sub-indicators.
States of the node: good/sufficient/poor.
Good = values > -0.2
Sufficient = values between -0.7 and -0.2

Poor = values below -0.7
This is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1996 and 2006.

Groundwater abstraction: The node refers to the abstraction of groundwater to achieve brackish water conditions suitable for some specific organisms. This practice may lead to salinization and/or depletion of groundwater depending on the nature (semi-intensive or intensive) of the aquaculture enterprise.
States of the node: yes/no.

Incentives toward sustainability: incentives to obtain expansion of production through technological innovations, better knowledge of the system, higher control over the operations, and in general more sustainable practices.
States of the node: high/low.

Increased pollution: States of the node: yes/no; it depends on the combination of the parents.

Property rights: This node is determined by the combination of government stability, rule of law, and government effectiveness nodes.
The states are adequate/inadequate. The choice of state depends on the combination of the states of parent nodes.
A few considerations about the node. This is one of the nodes affecting the "expansion of aquaculture" node. Inadequate property rights (for instance short-term concessions, or lack of ownership) may favor the subtraction of the land by the government. The government may then sell it to companies for large-scale commercial aquaculture development, which may either go toward an intensive or extensive culture approach. On the other hand, adequate property rights may foster an extensive rather than intensive development, but on a smaller scale, with a reduced use of land compared to the first case. Strong property rights are an incentive for farms to gain a stronger control over all aspects of production, and care about all of them.

Road density: It is expressed as km of road per 100 km^2 of land area. "Road density refers to the ratio of the length of the country's total road network to the country's land area. The road network includes all roads in the country—motorways, highways, main or national roads, secondary or regional roads, and other urban and rural road." (WDI 2007, World Bank).
The states of the node are high/medium/low, where high = density ≥ 30, medium = from 15 to 30, and low = density from 0 to 15. Road density is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1990 and 2006.

Rule of law: The node is represented through an indicator belonging to the Worldwide Governance Indicators 2006 (http://info.worldbank.org/governance/wgi2007). The specific indicator is "rule of law," with this formal definition: "Rule of law (RL)—measuring the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence." Table B5 (Governance matters VI, 2007) allows us to obtain further details related to this aggregate indicator by exploring the single sub-indicators.
States of the node: good/sufficient/poor.
Good = values > -0.2
Sufficient = values between -0.7 and -0.2
Poor = values below -0.7
This is a continuous variable; discretization of the variable into intervals was based on examination of data for DPL coastal countries between 1996 and 2006.

Type of aquaculture: This node indicates the types of aquaculture systems that can drive the expansion in production: extensive, intensive, or semi-intensive.

Section 3 - Methodology of BBN Development

Aquaculture and fisheries

These maps were developed through discussions with experts in ARD. The BBN represents a formalization of expert knowledge both in the structure and in the probabilities associated with the different nodes. These networks have not been trained and tested because of lack of a data; they provide a possible model that can be adopted and modified for the purposes of a specific DPL project. The nodes included in the maps guide the choice of the necessary data.

Agriculture extensification

The structure of the BBN, including nature of the variables and their causal relations, was initially built by analyzing relevant literature and subsequently optimized through rounds of discussions carried on with experts in the ENV and ARD departments. An initial alpha model was generated, then a Beta version was produced through a combination of review by new experts and analysis of past data available for the various nodes.

Once the structure of a BBN is completed, states have to be assigned to each node and parameters have to be established for the network; that is, probability values are entered in the conditional probability tables (CPTs) of each node. In general, CPTs can be obtained simply through use of expert opinion (probability elicitation), by using past existing data, or by a combination of the two. The status of data availability for this particular case prompted the following choice: the CPTs for the top part of the network, between the openness node and the deforestation node, were generated by training the BBN using past data, whereas for the bottom part relating to the erosion process, CPTs were entered after discussions with experts in ENV and ARD.

BBN construction and training process

Data was collected for the six variables included in the top part of the BBN: openness, total population density, roads density, control of corruption, government effectiveness and deforestation. Sources of data and states of the nodes are described in Section 2. The property rights and pressure on land nodes are summary nodes; their data originates from a combination of the data of input nodes and they do not need an independent source of data. Their function is both to simplify the mathematical calculations and to make the structure of the BBN more readily understandable.

Most of the variables are continuous, but the majority of the software applications available for Bayesian networks can only work with discrete variables. The application of choice for this work, Netica (Norsys Software Corporation, Vancouver) is no exception. Therefore, the first step consisted in properly establishing discrete intervals for the nodes (discretization of the variable). Discretization was informed both by descriptive statistics (mean and median of the data) and by the need to have enough data for each of the states of a node. The subsets (i.e. the states of each node) should actually contain enough data to "allow for reliable identification of probabilistic relationships among the variables…." (Drudzel and van der Gaag 2000). If one or more states of some variables are not represented by enough data, this will damage the probabilistic assessment.

Training and test data

The data collected for the six variables was used to train the BBN to correctly predict a certain range of deforestation rate (output node) given a combination of values attributed to the input variables (openness, population density, roads density, control of corruption, and government effectiveness).

The data was arranged as follows: data for openness, population density, road density, and governance were gathered for all the DPL countries for the years 1996, 1998, 2000, 2002, 2003, and 2004. Deforestation data were available only for the periods 1990–2000 and 2000–05 as annual percent change in deforestation. Data for the input variables and all DPL countries for the years 1996/1998/2000 were matched with the average deforestation rate data for the same countries for the period 1990–2000. Similarly, the data for 2002, 2003, and 2004 were matched to the average deforestation rate for the period 2000–05. The choice is based on the assumption that governance, openness, population, and road density are the main determinants of deforestation. Collection of data started from 1996, since this was the first available year for the governance data used for this exercise (Governance Matters VI, 2007).

The lack of some openness data reduced the overall number of DPL countries to 58. The entire dataset of 348 cases (58 countries by 6 groups, due to the available years, 1996 to 2004) was reduced further by eliminating the cases that had more than one missing value (e.g. roads and population density), and those that did not have a value for the output node (deforestation node). The automatic training process built into Netica can tolerate missing data in the input nodes and middle nodes, not in the output node, which is fundamental for the predicting ability of the BBN. After the selection process, 304 cases were left. The cases in the dataset were randomized using the Excel Rand function. After the randomization, the first 35 cases were taken aside as test data, to be used to verify the precision of prediction of the BBN. The remaining 269 cases were moved in a separate Excel file to be uploaded into Netica as training data. The BBN was trained using the expectation maximization algorithm according to the procedure described in Netica.

Testing of the BBN using the 35 set-aside cases was performed in two different ways. Initially, taking one case at a time, the values for the input variables (openness, population density, roads density, control of corruption, and government effectiveness) were entered in the corresponding node in the BBN; the BBN was then compiled to obtain the probabilities associated with each of the states of the deforestation node (high, low, or no deforestation). The state with the highest probability was taken as the main result and compared with the value of deforestation provided in the case being examined.

As a second validation, the automatic function *Test with case* was used in Netica to test the predictive power of the BBN using the 35 test cases.

Both methods gave a result of between 70 and 75 percent accuracy.

Figures

The numbers in RED at the top indicate the relative DPL policies, whereas the GREEN triangles indicate the type of impacts.

Figure A-1. Agriculture

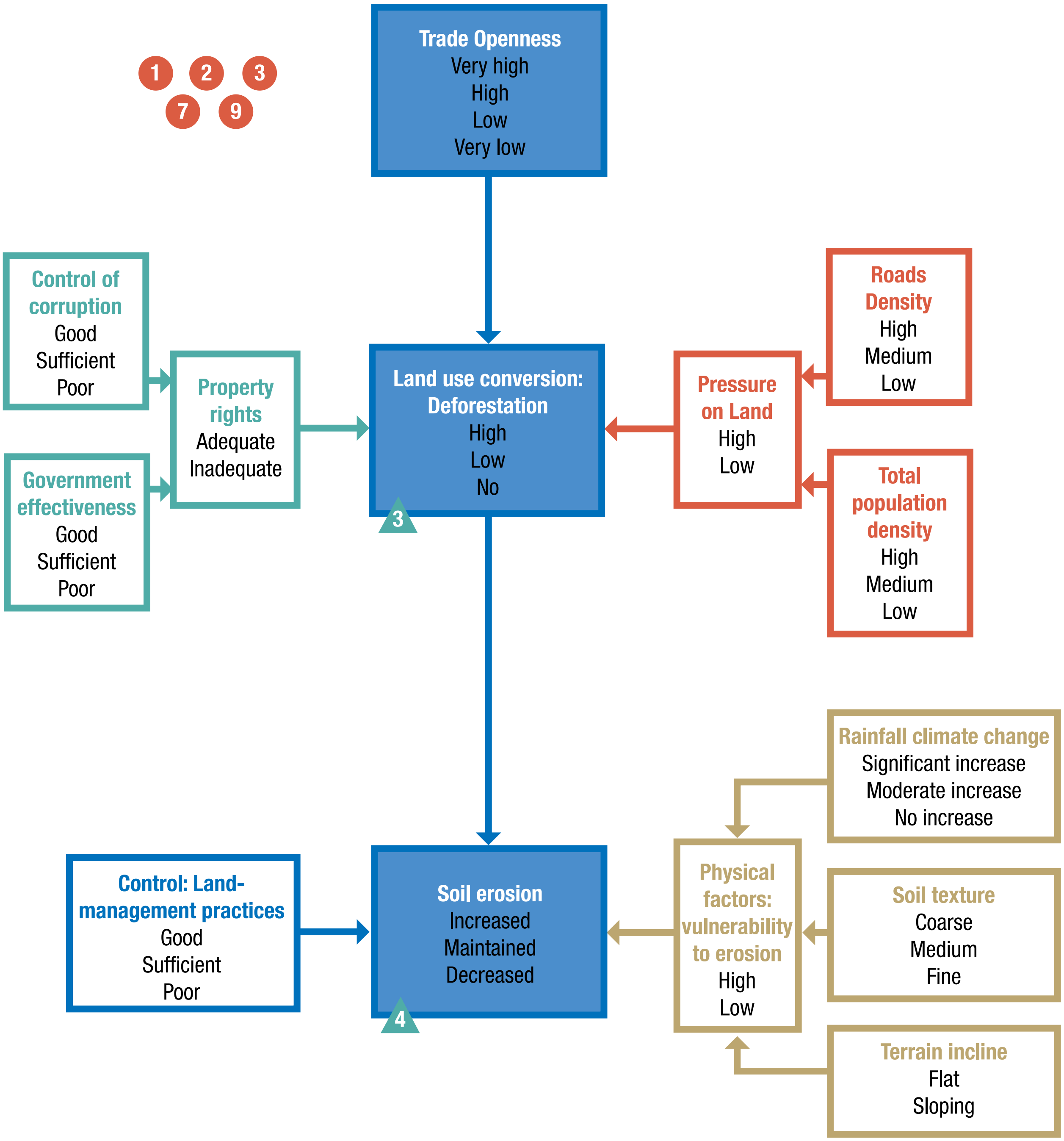


Figure A-2. Fisheries

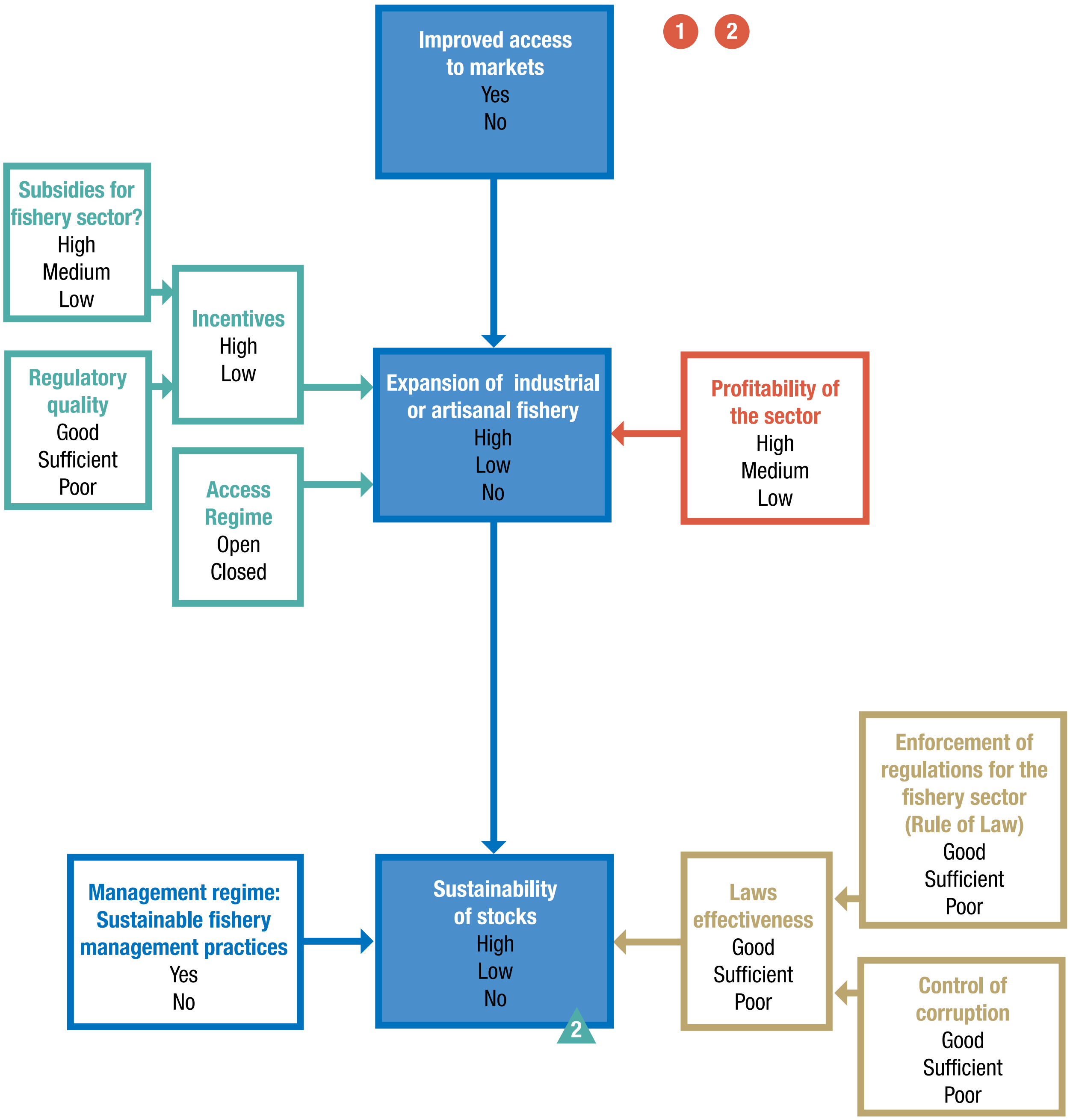
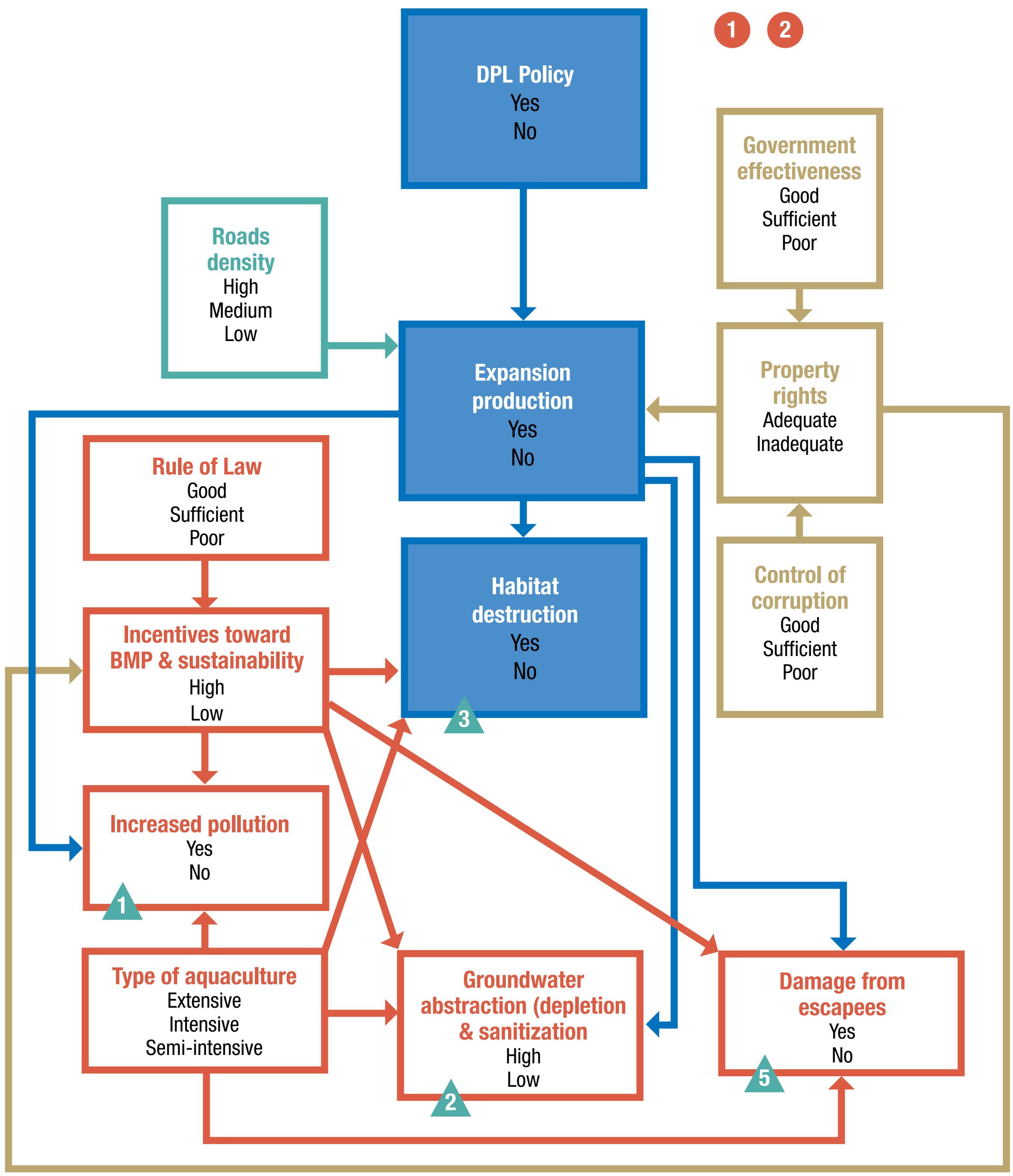


Figure A-3. Aquaculture



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Annex B. Coastal Tool Example

This section illustrates a practical example of how to use the Coastal Toolkit. The case does not necessarily reflect the situation of a specific country.

Step 1. Environmental Risk Associated with Proposed Policies (Module I)

The project team will examine the policies proposed in the DPL program document and identify the corresponding policies among those listed in Module I. The module shows the environmental risk associated with specific policies through a color code system.

Impacts on the environment are predicted to be serious following policy 1 (Table B-1, “Impact Risk” column, red code), and of some concern following policy 2 and policy 3 (Table B-1, “Impact Risk” column, yellow code). The remaining policies are not going to be analyzed further; they are not included in the list of policies in Module II, which indicates that they are not considered to be of concern for coastal areas.

Step 2. Finding the Right Indicators (Module II)

Module I also provide details about the impacts possibly originating from the policies, and helps to select the most appropriate indicators of environmental concern among the ones listed in Module II. Table B-1 (“Indicators” column) shows the chosen indicators and their ranking (color code).

Step 3. Analysis of Policies — Preliminary Significance of Impacts

At this stage the user will pull together the information from Modules I and II in order to obtain an initial indication of the significance of impacts associated with the proposed policies.

Table B-1. Policies, their Impact Risk (from Module I) and the Relative Indicators of Environmental Concern (from Module II)

Policy Action in Program document	Impact Risk Module I [a]	Indicator(s) Module II [b]
(1) Expand market access for domestic exports	Corresponds to Policy 2 Module I	Fertilizer intensity use
		Marine trophic index
		% surface area covered by marine protected areas
		% mangrove loss
		% endangered or critically endangered marine species
		% introduced species established in the wild
		% deforestation
(2) Agriculture sector – Improve marketing arrangements for improved seeds and fertilizers	Corresponds to Policy 8 Module I	Fertilizer intensity use
(3) Agriculture sector – Maintenance and expansion of irrigation	Corresponds to Policy 6 Module I	% population within 100 km
Improve debt management	*Not among Coastal impact policies*	
Regulatory and institutional mechanisms to fight corruption	*Not among Coastal impact policies*	

a Color coding of Module I: Yellow = impact may be of some concern ; Red = impact may be serious

b The color coding for the indicators of Module II is indicator-specific. Refer to the specific sections and tables in Module II to interpret. In general green indicates good environmental conditions, red critical conditions, and yellow is in between.

Policy 1 and associated impacts
This policy may have serious effects (red in "Impact Risk" column in Table B-1). The impacts may be in the agriculture, aquaculture, and fisheries sector. For each sector, different impacts may be triggered, hence different indicators are going to be used as a measure of sensitivity to these impacts.

Expansion of market access may make agriculture more attractive, thereby increasing land use, and ultimately leading to deforestation and to an increase in use of fertilizers (when available). "Deforestation" and "fertilizer intensity use" are therefore the indicators to check in relation to impacts from the agriculture sector.

The same policy may influence the production of aquaculture and fisheries. Additional pressure could be exerted on fish stocks; the table suggests using the marine trophic index as an indicator. Increased aquaculture activity could instead affect the environment in different ways: (a) through more intense use of resources (land and freshwater); (b) by increasing pollution through the use of fertilizers, feed, and therapeutants; and (c) by raising the risk of escapees. Table B-1 reports the indicators suggested in Module I in relation to these impacts:

- For expansion of area under aquaculture: "% surface area covered by protected areas," "% mangrove loss," and "% endangered or critically endangered marine species." The mangrove loss indicator will obviously be used only in countries where mangroves are present. Percent of endangered species is very relevant since the conversion of natural habitat and habitat reduction are the principal causes of biodiversity loss.

- For use of resources (especially freshwater): "% population within 100 km"

- For pollution: "Fertilizer intensity use"

- For introduction of exotic species: "% introduced species established in the wild"

For the purposes of this example, the status of the indicators is assigned randomly. In a real situation, at this stage the user would open Module II and record the status of these indicators for the country under study.

For our hypothetical country, Module II shows the following (represented in the indicators column of Table B-1):

1. High concern (red) for deforestation, introduced species, mangrove loss, and for area covered by marine protected areas.
2. Some concern (yellow) for pollution (fertilizer intensity) and endangered species.
3. No concern for (green) concerns about the sustainability of fisheries (marine trophic index).

Policy 2 and associated impacts
As suggested in Module I, this policy has some likelihood to lead to uncontrolled runoff (e.g. excess fertilizer), perhaps partly dependent on mismanagement of chemicals due to lack of training on proper use. A relevant indicator from Module II is "fertilizer intensity use," whose color code for our hypothetical country is yellow. This indicates that the country is already affected by activities that impinge on environmental receptors represented through this indicator.

Policy 3 and associated impacts
The risk associated with this policy is for an uncontrolled use of water resources. The relevant indicator from Module II is "% population within 100 km," which is a proxy for pressure on water resources. The color code for this indicator for our hypothetical country is green, which means that the resource is presently not under significant stress.

Impact significance
Table B-3 shows that based on the significance matrix in Table B-2, the possible impacts from policy 1 are of high significance for the agriculture sector and of medium significance for the fishery sector. It appears that the aquaculture sector may produce a range of high significance impacts.

Furthermore, impacts originating from policy 2 in the agriculture sector are of medium significance, whereas the impact from policy 3 has low significance.

This preliminary assessment helps set priorities, as some policies need to be examined more urgently than others due to their higher potential severity. In general our judgment is that all impacts that are either of medium or high significance should be analyzed more in depth by using a selection of the tools offered in Module III and the Bayesian networks when applicable.

Table B-2. Significance Matrix

Risk (Module I)	Indicator of environmental state for the specific country	Significance
Yellow	Green (not particularly affected)	Low
Red	Green (not particularly affected)	Medium
Yellow	Yellow (affected)	Medium
Red	Yellow (affected)	High
Yellow	Red (very affected)	High
Red	Red (very affected)	High

Note. The table does not contain Low Risk (first column) as green represents no changes and blue positive impacts. In the latter case the analysis can be furthered through tools provided in Module III and designed to learn how to enhance the possible positive impacts.

Step 4. Further Analysis through BBNs

The Coastal Toolkit offers three Bayesian belief networks (BBNs) to allow a further level of study for some of the policies and impacts presented in Module I.

Among the policies presented in this example, only policy 1 has BBNs associated with it. In fact policy 1 (corresponding to Policy 2 in Module I) is considered in all the BBNs offered: agricultural extensification, fisheries, and aquaculture.

This means that the user, after having obtained a measure of the significance of each impact through the procedure illustrated in this example, can get a measure of the probability that these impacts will actually take place. This information helps to refine the assessment of significance of the impacts.

In Annex A, the user will find for each node of the BBNs (1) a general description, (2) definition of the states of the node, and (3) the data source from which the node was built. In order to run the BBN and obtain a probability measure, the user will need to enter an observation (a value) specific for the country under study for each of the nodes. The values can be found in readily available databases, which report values of the variables (nodes) for each of the DPL coastal countries.

In order to enter an observation for each node, the user will need to go to the database and find the value corresponding to the country of interest. Once the value is found, the definition of the states provided in Annex A will allow the user to determine the state of the country of interest for that particular node (variable).

Table B-3. Significance of the Possible Impacts from Policy 1 and 2

Policy Action in Program document	Impact Risk Module I	Indicator(s) Module II	Significance of impact
(1) Expand market access for domestic exports		Fertilizer intensity use	High
		Marine trophic index	Medium
		% surface area covered by marine protected areas	High
		% mangrove loss	High
		% endangered or critically endangered marine species	High
		% introduced species established in the wild	High
		% deforestation	High
(2) Agriculture sector – Improve marketing arrangements for improved seeds and fertilizers		Fertilizer intensity use	Medium
(3) Agriculture sector – Maintenance and expansion of irrigation		% population within 100 km	Low

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