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Using the DPSIR Framework to Develop a Conceptual Model:

Technical Support Document

Office of Research and Development
National Health and Environmental Effects Research Laboratory

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Using the DPSIR Framework to Develop a Conceptual Model: Technical Support Document

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Foreword

The approach described in this manual reflects procedures developed by EPA ORD during 8 years of ecological and sustainability research, including decision-support workshops conducted in Florida, Puerto Rico, and the US Virgin Islands. The overall objective is to deliver a technical support manual into the hands of decision-makers so they can apply the DPSIR conceptual model in support of complex environmental decision-making.

Table of Contents

Appendices

Figures

Table

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Note: Organizational affiliation is based upon the participant's organization when attending a workshop or otherwise supporting the DPSIR development process.

Chapter 1: Introduction to Systems Thinking Frameworks

Modern problems (e.g., pollution, urban sprawl, environmental equity) are complex and often transcend spatial and temporal scales[1]. Scientific research and decisions are frequently limited to a particular economic concern, level of authority or scientific field and therefore address a single aspect of a problem with insufficient understanding or consideration of short- and long-term consequences to the larger system[2]. Additionally, stakeholders and decision-makers frequently implement multiple, uncoordinated management actions. While each of these management actions may be successfully implemented for a particular purpose, the combined effects may not lead to improved environmental conditions.

Systems thinking is an approach to problem solving that is based on the belief that the component parts of a system are best understood in the context of their relationships and interactions with one another and with other systems[3]. A systems approach considers more than one issue and broadens the decision context. As an example, there are a multitude of issues that affect island communities (**Fig. 1-1**). Decision-makers can follow a structured process to organize this vast number of issues, management options and information in a systems framework that facilitates examination of the decision alternatives and likely tradeoffs.

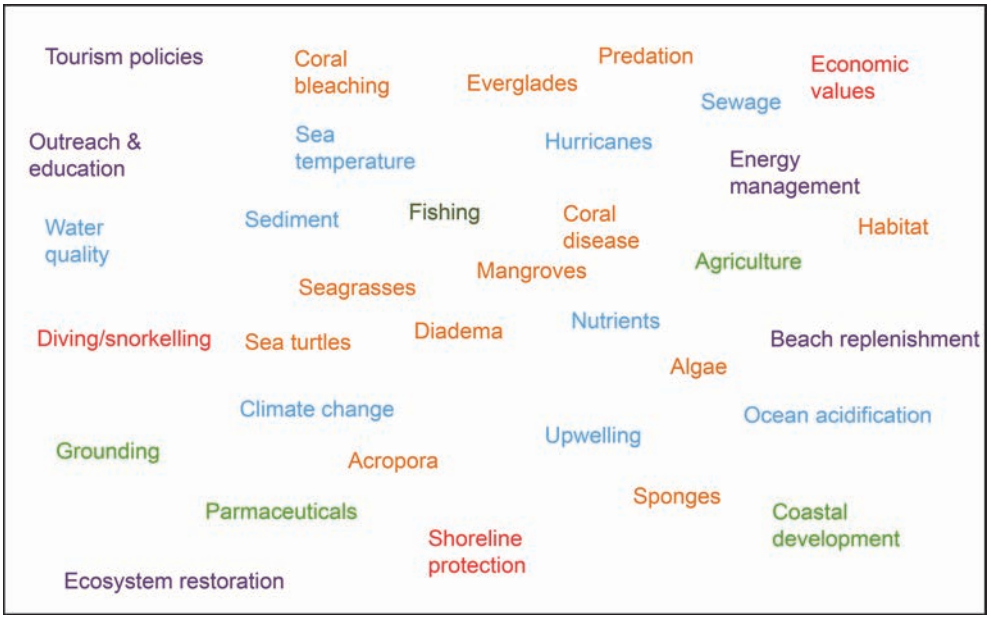


Figure 1-1. Diversity of issues facing coastal communities. These issues are often discussed as single issues, without consideration for how they fit together. This can lead to confusion and frustration among stakeholders

[1] Knol et al. 2010; Yee et al. 2012
[2] O'Connor and McDermott 1997
[3] von Bertalanffy 1972

Conceptual models, which consist of diagrams and accompanying narratives, can be developed to capture, visualize and organize connections between key factors in a complex system[4] and can be used to evaluate consequences of alternative decisions on the provision of ecosystem services by linking anthropogenic and environmental stressors to ecosystem condition[5]. Conceptual models also can form the conceptual foundation for development of predictive mathematical models, performance indicators, or other decision support tools, particularly in the case of complex multi-disciplinary problems such as sustainability.

When decision-makers and stakeholders develop the conceptual model in a collaborative manner, the learning experience contributes to a shared understanding of system dynamics and appreciation of the diversity of information needed to select appropriate management actions and identify a suite of relevant performance indicators[6]. This collaborative learning process is, in itself, a major tangible product of the process[7].

Conceptual models[6]:

- Formalize current understanding of system processes and dynamics
- Identify linkages of processes across disciplinary boundaries
- Identify the bounds and scope of the system of interest
- Contribute to communication
    - Among decision-makers
    - Among scientists and program staff
    - Between scientists and decision-makers
    - With the general public

[4] Joffe and Mindell 2006; Knol et al. 2010; Yee et al. 2011
[5] Yee et al. 2011
[6] Gross 2003
[7] Wright 2002

Chapter 2: The DPSIR Framework

One framework supporting a systems approach is the *Driving Forces – Pressures – State – Impacts – Responses* (DPSIR) framework, which has been a valuable tool for organizing and communicating complex environmental issues. The DPSIR framework was developed by the European Environmental Agency[8], has been used by the United Nations[9], and has been adopted by the US Environmental Protection Agency (EPA) in the Sustainable Puerto Rico initiative.

The DPSIR framework is a systems-thinking framework that assumes cause-effect relationships between interacting components of social, economic, and environmental systems. The DPSIR framework has been used for many environmental resource applications, including management of agricultural systems[10], water resources[11], land and soil resources[12], biodiversity[13] and marine resources[14]. The DPSIR framework also can be used to integrate social, cultural, and economic aspects of environmental and human health into a single framework[15]. DPSIR has most commonly been used in the context of environmental management to link ecological and socioeconomic factors (**Fig. 2-1**). For many types of environmental decision-making, this basic version will suffice. For purposes of this manual, we will refer to this DPSIR as the Eco DPSIR.

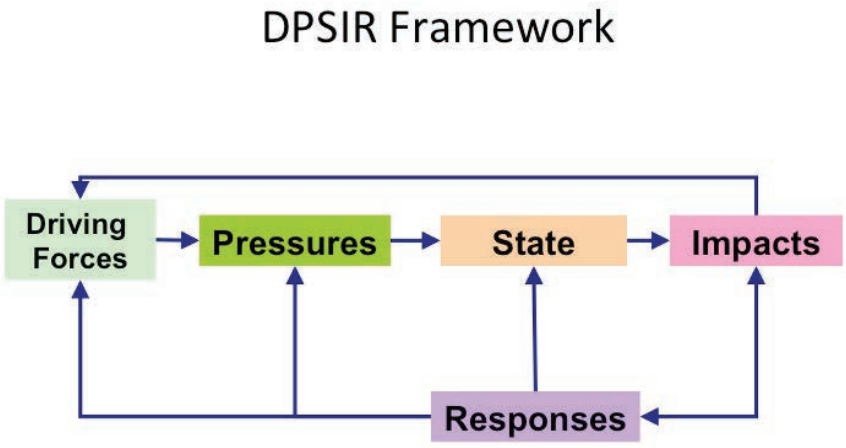


Figure 2-1. The Eco DPSIR framework and conceptual relationships among DPSIR categories

[8] EEA 1999
[9] UNEP 2007
[10] Kuldna et al. 2009; Binimelis et al. 2009
[11] Mysiak et al. 2005; Borja et al. 2006
[12] Gisladottir and Stocking 2005
[13] Maxim et al. 2009; Omann et al. 2009
[14] Mangi et al. 2007; Ojeda-Martinez et al. 2009; Yee et al. 2011; Nuttle and Fletcher 2013
[15] Yee et al. 2012

Many environmental issues include aspects of Human Health and Well-being, and the Eco DPSIR did not adequately capture those aspects. EPA has expanded DPSIR to more explicitly include Human Health, with two parallel tracks, one representing Ecosystem Health (on the left) and the other Human Health (on the right) (**Fig. 2-2**). The Eco-Health DPSIR also captures core concepts of sustainability including equity, natural capital, human well-being and human habitat[16], incorporates social, economic, physical and behavioral risk factors related to human health and well-being (in addition to environmental factors) and integrates the social, cultural and economic aspects of ecosystem health and human health into a single framework. The structure of the Eco-Health DPSIR follows a defined logic sequence; however, for both natural scientists and human health scientists it represents a paradigm shift away from research that focuses on singular aspects of complex issues[17].

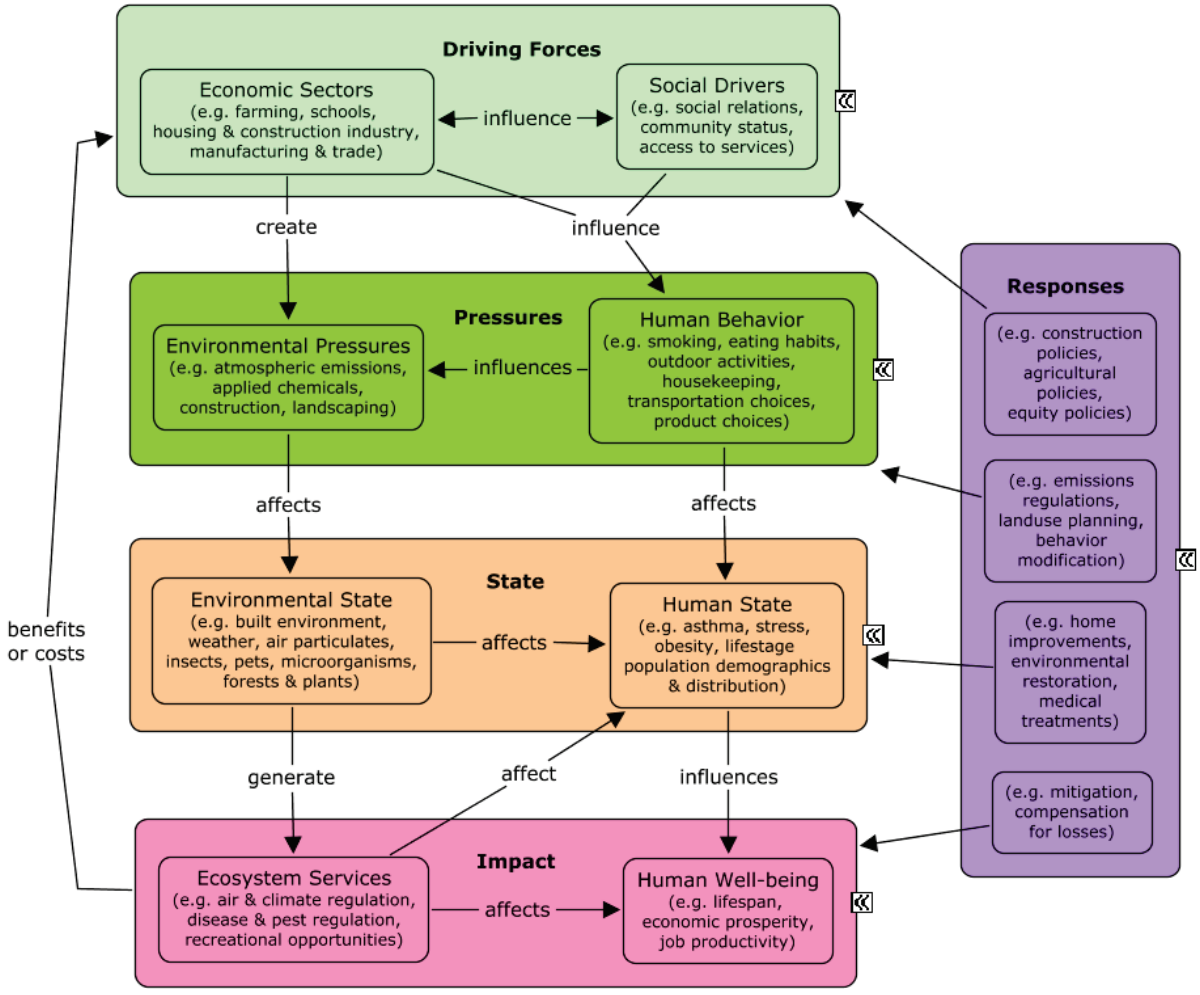


Figure 2-2. The Eco-Health DPSIR framework, with two parallel tracks differentiating ecosystem health (left side) and human health (right side)

[16] Jabareen 2008
[17] O'Connor and McDermott 1997

During EPA-conducted focus groups, participants found it particularly challenging to place some concepts into the appropriate categories[18]. Consequently, EPA developed a rigorous system of definitions that distinguishes social, economic and environmental factors to reduce confusion regarding the meaning of categories and provide a generic process that could be applied broadly across different systems, topics, or decision contexts. Definitions were largely derived from the original intent of DPSIR[19], but include sub-categories to provide clarity and help guide discussions. The generic nature of the categories and sub-categories make this integrating framework easy to transfer and apply across a variety of systems, communities and issues. These detailed descriptions and lists are intended to serve as a quick reference guide for the facilitator and note-taker to use during a DPSIR workshop elicitation.

2.1 *Driving Forces*

Driving Forces are the factors that motivate human activities and fulfill basic human needs, which have been consistently identified as the necessary conditions and materials for a good life, good health, good social relations, security, and freedom[20]. The spatial distribution and intensity of *Driving Forces* varies - they can originate and act globally, regionally or locally. *Driving Forces* are not:

- Climate and weather influences (e.g., hurricanes, sea level rise, global climate change) – these are all part of Environmental State[21]
- Any type of "management" (e.g., water management) – these are responses
- Human population – this is actually reflected in human state, and is a result of Social Driving Forces

Driving Forces describe "the social, demographic, and economic developments in societies"[22]. Many studies specifically refer to economic sectors as drivers, while social factors that influence the structure, characteristics, and functioning of economic sectors, are less frequently described[23]. Social determinants also have a strong influence on human health[24]. Therefore for the purpose of this framework, *Driving Forces* have been divided into two categories, *Economic Sectors* and *Social Driving Forces* (**Fig. 2-3**).

[18] Yee et al. 2011
[19] EEA 2005
[20] Narayan 2000; MEA 2005; EEA 2005; Maxim et al. 2009
[21] Note that because *Driving forces*, in DPSIR terminology, arise from fulfillment of human needs, they do not include the natural external influences (such as climate and weather) typically referred to as *forcing functions* in ecological modeling.
[22] Gabrielsen and Bosch 2003
[23] Maxim et al. 2009
[24] U.S. Department of Health and Human Services 2008; www.healthypeople.gov

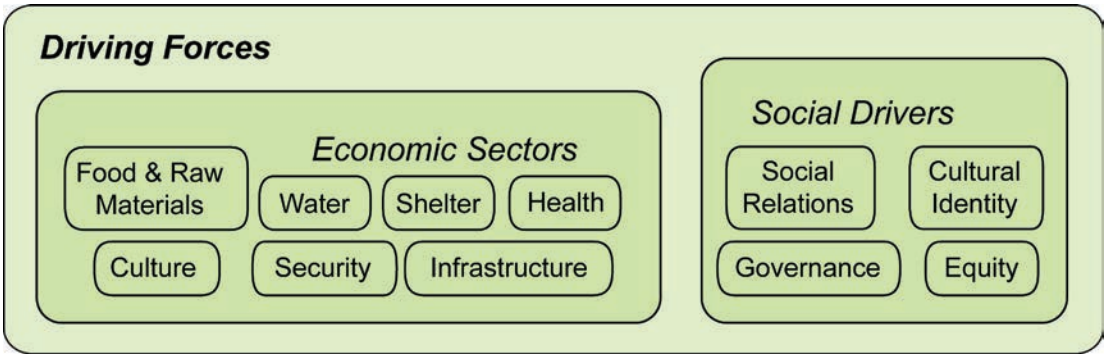


Figure 2-3. DPSIR Category—*Driving Forces*

2.1.1 *Economic Driving Forces*

Economic Driving Forces fulfill human needs for food and raw materials, water, culture, security, health, shelter, and infrastructure (**Fig. 2-4**). EPA uses the North American Industrial Classification System (NAICS), which is the government standard for defining *Economic Sectors*. This connection to NAICS is particularly important because it connects the system model to the tools that the US Census Bureau, Bureau of Labor Statistics, Internal Revenue Service and Social Security Administration use in their reporting.

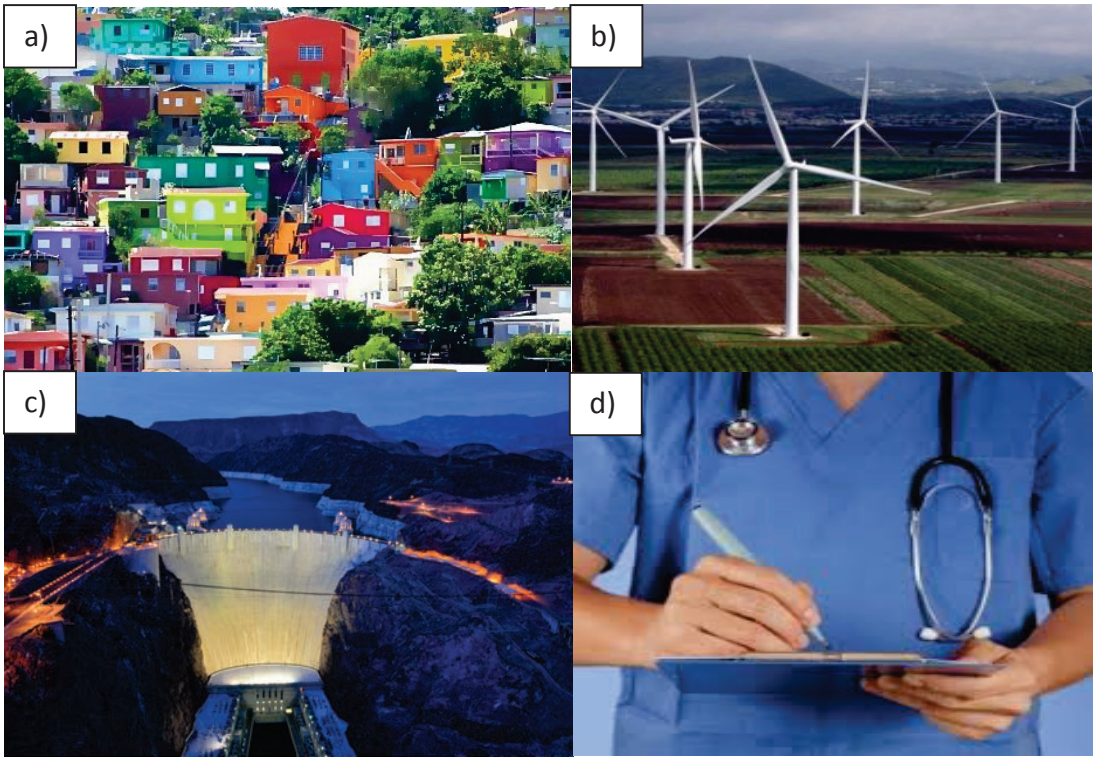


Figure 2-4. Examples of *Economic Driving Forces*: a) residential housing, b) energy, c) water, and d) health industries

In creating a generic DPSIR conceptual model, EPA found it useful to collapse some NAICS sectors and slightly re-categorize others to reflect human needs or to better capture certain issues relevant to environmental management. In some cases, *Driving Forces* may fall into more than one sector (recreational fishing for food and culture). Ambivalent issues should be placed where they will be most relevant to a management issue.

- Sectors providing ***Food and Raw Materials*** include:
  - Agriculture- croplands, rangelands
  - Aquaculture
  - Oil and gas extraction
  - Fishing- commercial fisheries, artisanal fishing, and recreational fishing
  - Forestry
  - Mining and quarrying – coal mining, mineral mining
- Sectors fulfilling human needs for ***Water*** include:
  - Drinking water supply
  - Irrigation
- Sectors fulfilling human needs for ***Shelter*** include:
  - Housing - home construction, real estate, single family and multi-unit housing
  - Textiles and apparel
- Sectors fulfilling human needs for ***Health*** include:
  - Medical care - hospitals
  - Pharmaceuticals and cosmetics
  - Social assistance - child care centers
  - Waste management - sewage treatment facilities and landfills
- Sectors fulfilling human needs for ***Culture*** include:
  - Tourism and recreation – recreational fishing and hunting, beaches and natural lands,
  - Education – primary and secondary education, colleges and universities
  - Information – telecommunications, scientific research, biotechnology research and development
  - Social organizations- churches, outreach groups, families
- Sectors fulfilling human needs for ***Security*** include:
  - National defense – coastal defense, munitions
  - Public administration – government, courts, law enforcement
- ***Infrastructure*** sectors provide the physical, organizational, and technical support for the economy to function and include:
  - Manufacturing and trade
  - Transportation – air and road transportation, ship and boat operation, warehousing
  - Construction and civil engineering – road and utility line construction, building construction, dam construction, pipeline construction
  - Finance and insurance – banks, insurance
  - Technical services – management of companies, repair and maintenance services, personal services
  - Utilities – electric power, natural gas

2.1.2 *Social Driving Forces*

Humans live together in organized communities with shared laws, traditions, and values. ***Social Driving Forces*** fulfill human needs for social relations, equity, governance, and cultural identity[25] (**Fig. 2-5**). ***Social Driving Forces*** broadly capture the suite of social, community, and political characteristics that influence the structure and function of economic sectors, as well as act as key determinants of human health. For example, a lack of equity or repressive governance may influence the ability of economic sectors to function or constrain the ability of individuals to fulfill their basic human needs.

Figure 2-5. Examples of *Social Driving Forces*: a) religion, b) culture, and c) marriage

*Social Driving Forc*es include:

- ***Social Relations*** are the day-to-day interactions and connections within a community, including:
  - Religious affiliations
  - Social groups
  - Marriage
  - Family dynamics

[25] MEA 2005

- ***Equity*** describes the fairness of opportunities in a community, including*:*
  - Access to education
  - Access to health care
  - Access to jobs
- ***Governance*** is the political disposition and characteristics of a community, including*:*
  - Voting patterns
  - Roles of decision-makers
  - Type of government
- ***Cultural Identity*** are the history, social, and cultural attitudes that define a community, including*:*
  - Urban, rural, tribal, or coastal communities
  - Ethnic or religious identity

2.2 *Pressures*

Pressures are defined as human activities, derived from the functioning of Social and Economic *Driving Forces* that induce changes in the environment[26], or human behaviors that can influence human health. *Pressures* are not stressors. Stressors are the components of state that are changed by pressures (e.g., land development [the pressure] - increases sediment [the stressor] in the coastal zone, which then may stress the ecological components of the reef). *Pressures* fall into two classes – Environmental Pressures and Human Behavior Pressures, (**Fig. 2-6**).

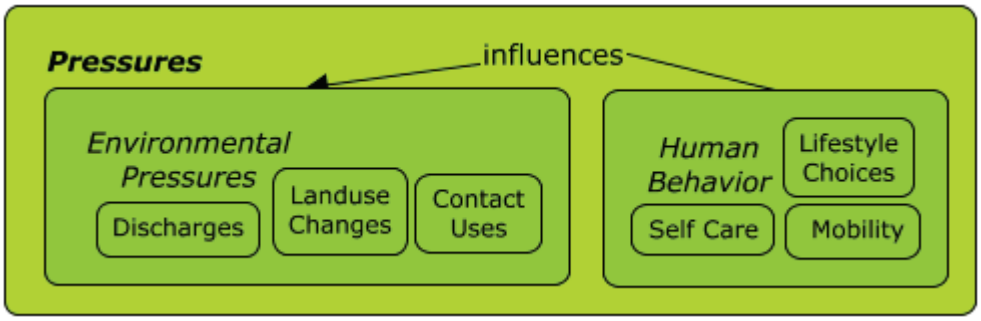


Figure 2-6. DPSIR Category—*Pressures*

2.2.1 *Environmental Pressures*

On the environmental side, identifying a particular activity as a *Pressure* implies a causal relationship between that activity and an environmental change[27]. ***Environmental Pressures*** may include discharges of chemical, physical, or biological agents, land-use changes and direct contact uses (**Fig. 2-7**). The intensity of ***Environmental Pressures*** depends on the technology and extent of source activities and can vary across geographic regions and spatial scales.

[26] EEA 2005; Maxim et al. 2009
[27] Rogers 2003

Figure 2-7. Examples of *Environmental Pressures* facing communities: a) stormwater discharge, b) vegetation clearing and erosion and c) sediment discharge

Environmental Pressures include:

- ***Landuse changes*** resulting from alterations of the natural landscape, typically associated with population growth, including:
  - Coastal development
  - Land development
  - Shoreline alteration
  - Hydrologic modifications
- ***Discharges*** of pollutants as may result from the operation of industries or vehicles, or the diffuse distribution of contaminants from agricultural lands, roads, or lawns through ground-water or storm-water run-off, including:
  - Applied chemicals – use of fertilizers, pesticides, insecticides, and herbicides
  - Atmospheric discharges – vehicle and smokestack emissions including greenhouse gas emissions, sulphur and nitrogen oxide emissions, volatile organic compound emissions
  - Waterborne discharges – point and non-point source discharges including wastewater discharges, contaminant discharges, and impervious surface run-off
- ***Contact uses*** are human activities that lead to a direct alteration or manipulation of the environment, and include:
  - Physical damage – dredging and filling, boat gear and anchor damage, vessel groundings, trampling, movement of boats, deforestation

- Biological addition – ballast discharge, release of non-natives, feeding, creation of artificial habitat
- Biological harvest – harvesting, fishing, accidental by-catch, clear cutting

2.2.2 *Human Behavior Pressures*

Human Behavior is an additional class of *Pressures* that can influence human health independent of *Environmental Pressures*, which influence the physical condition of the environment. We specifically define ***Human Behaviors***, as with all *Pressures*, as human activities that can increase the chances of developing a disease, disability, or syndrome (**Fig. 2-8**). In some cases, the burden of chronic disease is preventable with modifications of these behaviors. However, Social Driving Forces (e.g., social status, exposure to violence) and economic sectors (e.g., health services, government) can both motivate and constrain human actions (e.g., our ability to consume a healthy diet), and are often beyond, or perceived as beyond, personal control[28].

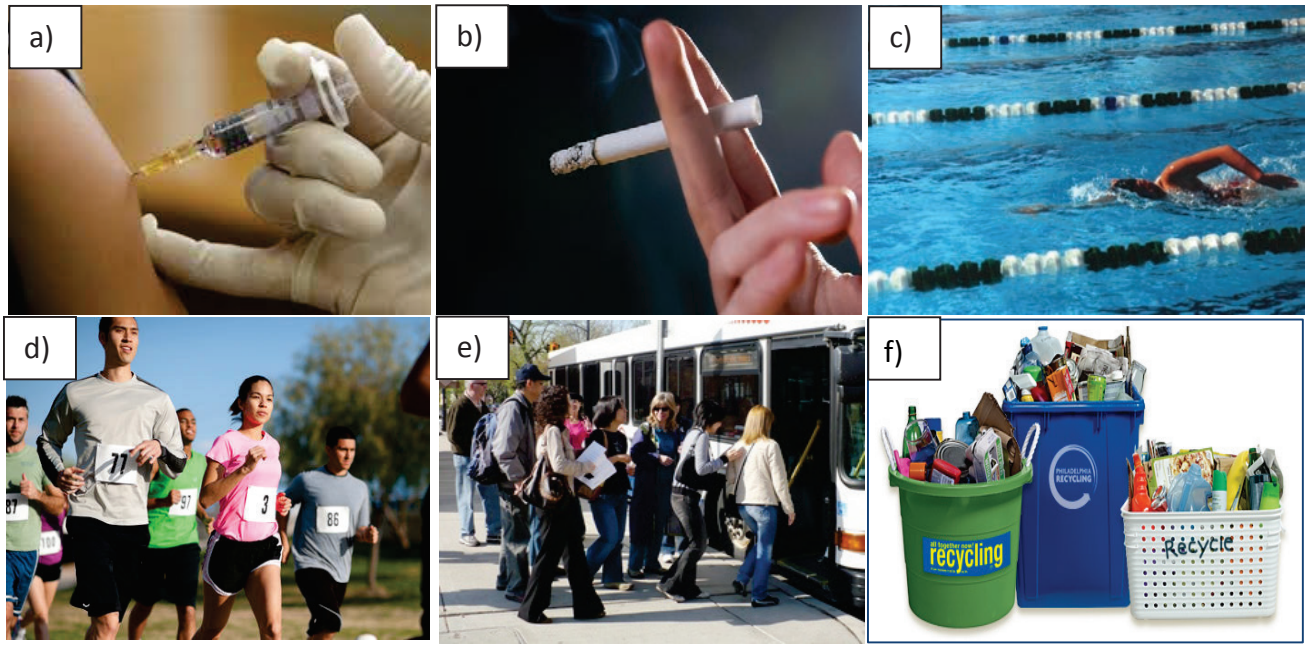


Figure 2-8. Examples of *Human Behavior Pressures*: a) vaccinations, b) smoking, c) swimming, d) running, e) riding public transportation, and f) recycling

Human Behavior Pressures include:

- ***Self-Care*** refers to actions and attitudes that contribute to the maintenance of personal health and well-being. Self-care includes:
  - Nutrition and diet (i.e., healthy eating)
  - Personal hygiene
  - Housekeeping practices
  - Medical care (e.g., disease screening, primary care and vaccinations)

[28] U.S. Department of Health and Human Services 2008; www.healthypeople.gov

- ***Lifestyle*** is the aggregation of personal decisions (i.e., over which the individual has control) that can be said to contribute to, or cause, illness or death. Lifestyle includes:
  - Transportation choice
  - Housing choice
  - Consumptive patterns (e.g., overeating)
  - Resource use and recycling
  - Risky sexual behaviors
  - Tobacco and/or alcohol use
  - Exercise
  - Sun exposure
- ***Mobility*** involves how people choose to get from one place to another. Travel behavior and transportation mode choice, or the decision to drive, use public transit, bike or walk to a destination, is heavily influenced by built and physical environment factors such as community design, land-use mix, residential density, street connectivity and transportation infrastructure.
  - Walking
  - Biking
  - Riding in an automobile
  - Climbing
  - Public transportation

2.3 *State*

State refers to the state of the natural and built environment (e.g., the quantity and quality of physical, chemical, and biological components)[29], and human systems (e.g., population level and individual attributes)[30]. Chemical, physical and biological processes interact to affect different ecosystem components (e.g. chemicals, biological species) that can be measured by their attributes (metrics of quantity or quality). All biota incorporate community and population attributes, but human condition also incorporates individual-level and subpopulation-level attributes (**Fig. 2-9**).

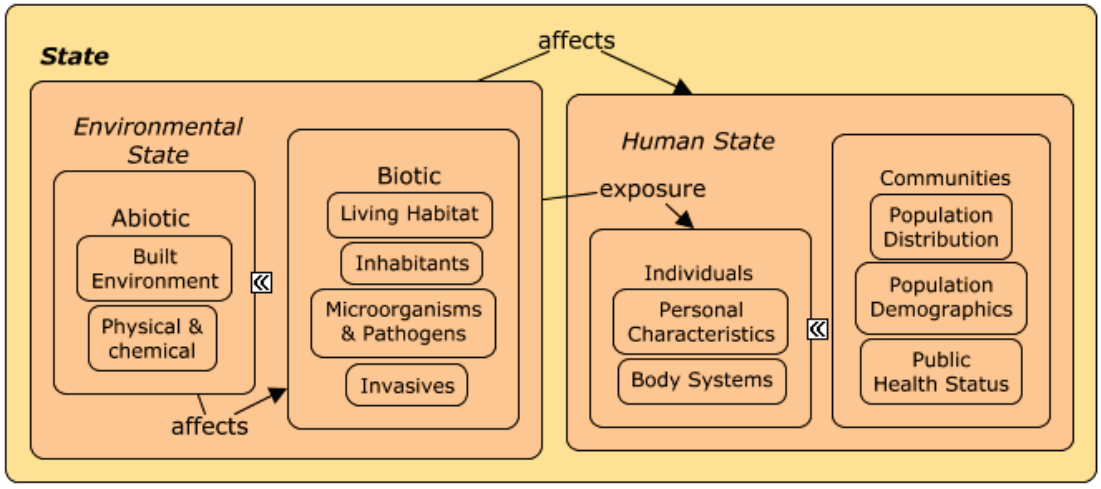


Figure 2-9. DPSIR Category—*State*

[29] Gabrielson and Bosch 2003
[30] Yee *et al.* 2012

2.3.1 *Environmental State*[31]

Environmental State refers to all of the physical, chemical and biological components of the natural and built environment[32](**Fig. 2-10**). *Environmental State* includes:

Abiotic State includes the non-living chemical and physical factors in the environment as well as the built environment (man-made structures), which affect the survival, growth, and distribution of living organisms in the Biological state. Abiotic phenomena are a part of all of biology. The *abiotic state* reflects the magnitude, frequency, and concentration of abiotic components of the environment including:

- Physical environment (e.g., climate, air and sea temperature, precipitation, storms and hurricanes, drought, hydrology, ocean circulation patterns, fire)
- Chemical environment (e.g., nutrients, pH, atmospheric CO_2 levels, salinity, contaminants)
- Built environment - man-made physical structures or extreme modifications of the natural environment (e.g., buildings and roadways) that contribute to human habitat

Biotic State includes the biological components of the ecosystem and their interactions, including humans. In general, this includes sessile plants or animals that provide the living habitat and base of the food web that supports higher trophic levels. Biological condition may be measured by individual- or community-level attributes, including:

- Living habitat (e.g., deserts, forests, grasslands, agricultural lands, wetlands, coral reefs, freshwater lakes and streams, estuaries)
- Inhabitants (e.g., birds, mammals, reptiles, amphibians, invertebrates)
- Invasive/non-native species (e.g., plants, animals, insects)
- Microorganisms and pathogens (e.g., decomposers, mycorrhizae, bacteria, fungi, viruses)

[31] Yee et al. 2012

[32] Gabrielsen and Bosch 2003

Figure 2-10. Examples of *Environmental State*: a) coral reef biota (Hawksbill Turtle), b) built environment, c) hurricane, and d) forest fire

2.3.2 *Human Systems State*

Human health is "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity"[33]. Determinants of health include the structure and function of economic sectors (e.g. health services, education, policy-making), social driving forces (e.g., equity and cultural identity), human behaviors (e.g., diet and mobility), the physical environment (e.g., green space, weather), and individual biology and genetics[34]. These relationships are shown through the influence of *Driving Forces*, *Pressures*, and *Environmental State* on human state (**Fig. 2-2**). As with other biota (e.g., fish, birds), metrics of the ***Human State*** may include population-level attributes, such as distribution or demographics, and individual-level attributes, such as intrinsic personal characteristics including one's age and sex, and the condition or health of individual body systems (**Fig. 2-11**).

[33] WHO 1946

[34] U.S. Department of Health and Human Services 2008; www.healthypeople.gov

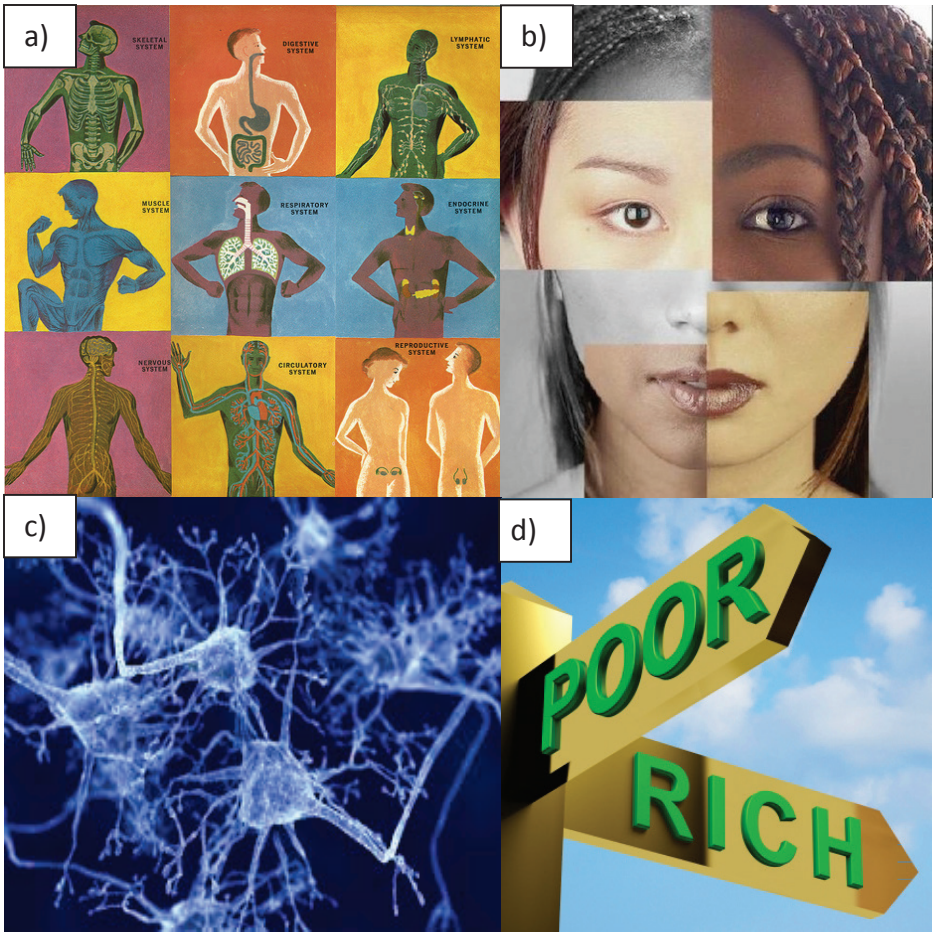


Figure 2-11. Examples of *Human Systems State*: a) body systems, b) race, c) disease (Parkinson's disease), and d) economic status

Human Systems State may be measured by individual- or community-level attributes, including:

- ***Individual level***
    - Personal characteristics
        - Life stage
        - Gender
        - Ethnicity
        - Socio-economic status
    - Body systems
        - Respiratory system
        - Immune system
        - Gastrointestinal system
        - Reproductive system
        - Endocrine system
        - Neurological system
        - Mental health
        - Genetics

- ***Community level***
    - Population distribution – community-level distributions of:
        - Age
        - Economic status
        - Race
        - Education
        - Gender
    - Public health status - community-level metrics of:
        - Disease prevalence
        - Disease incidence

2.4 *Impacts*

Changes in the quality and functioning of the ecosystem have an *Impact* on the welfare of humans, including the production of ecosystem goods and services and ultimately, human well-being[35] (**Fig 2-12**).

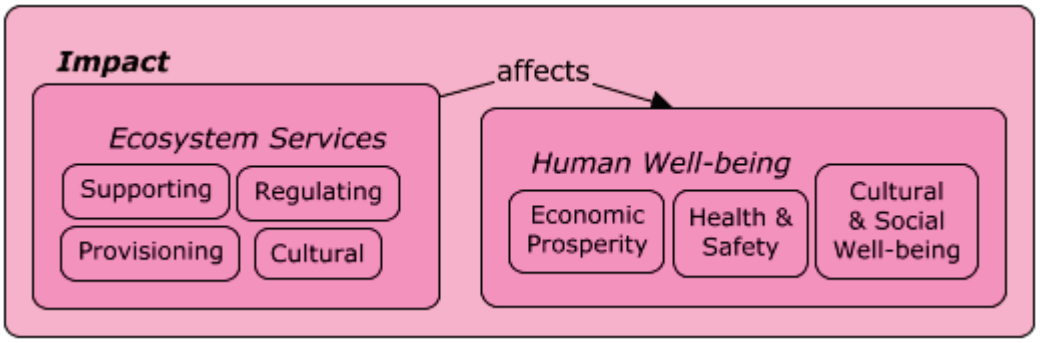


Figure 2-12. DPSIR Category—*Impacts*

2.4.1 *Ecosystem Services*

Ecosystem goods and services have been variously defined as ecosystem processes, or the products of those processes that directly or indirectly benefit humans[36]. As notably defined by the Millennium Ecosystem Assessment, ecosystem goods and services include:

- ***Provisioning services*** - the biological, chemical, or products obtained or harvested from ecosystems for human use including of food, water, biochemical and genetic resources, and raw materials
- ***Regulating services*** – the biophysical processes that regulate the ecosystem, including regulation of air quality, water quality, climate, disease, pollination, and natural hazards
- ***Cultural services*** - the nonmaterial benefits people obtain from the ecological integrity of ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including recreational and educational opportunities, aesthetic value, sense of place, and spiritual or religious value

[35] Gabrielsen and Bosch 2003

[36] Costanza et al. 1997; MEA 2003, 2005; President's Council of Advisors on Science and Technology 2011; Munns et al. 2015

- ***Supporting processes*** - biophysical processes that maintain the functioning of the ecosystem, and are necessary for the production of other ecosystem services, but may not have direct impacts to humans, including nutrient and contaminant cycling, provision of food and habitat to critical species, water cycling and primary production (**Fig. 2-13**)

Figure 2-13. Example *Ecosystem Services*: a) tourism (snorkeling), b) recreational fishing, c) pollination, and d) provisioning (food)

2.4.2 *Human Well-being*

Human Well-being is an abstract concept that captures a mixture of people's life circumstances and quantifies the degree of fulfillment of basic human needs for food, water, health, security, culture, and shelter (**Fig. 2-14**). *Human Well-being* reflects a positive physical, mental and social state[37]. *Human Well-being* can be quantified by metrics reflecting how well human needs are being met, including needs for basic materials, social relations, good health, security, and freedom[38].

Human Well-being includes:

- ***Economic prosperity*** (e.g., productivity, ability to work, income)
- ***Health and safety*** (e.g., life span, medical or insurance costs, sick days, pain and suffering)
- ***Cultural and social well-being*** (e.g., "happiness", sense of belonging, community vibrancy, spiritual fulfillment)

[37] Diener and Seligman 2004; MEA 2005; Clark and McGillivray 2007; Summers et al. 2012; Yee et al. 2012
[38] MEA 2005

Figure 2-14. Examples of *Human Well-being*: a) happiness, b) spiritual fulfillment, c) freedom, and d) safety

2.5 *Responses*

A key benefit in using the DPSIR framework is that it explicitly includes an Action or *Response* component that can be taken at any level of the causal network[39] (**Fig. 2-15**). In the DPSIR framework, *Responses* are actions taken by groups or individuals in society and government to prevent, compensate, ameliorate or adapt to changes in the state of the environment; and to modify human behaviors that contribute to health risks, to directly modify health through medical treatments, or to compensate for social or economic impacts of human condition on human well-being[40] (**Fig. 2-16**).

[39] Smeets and Weterings 1999; Waheed et al. 2009; Yee et al. 2011
[40] Yee et al. 2012

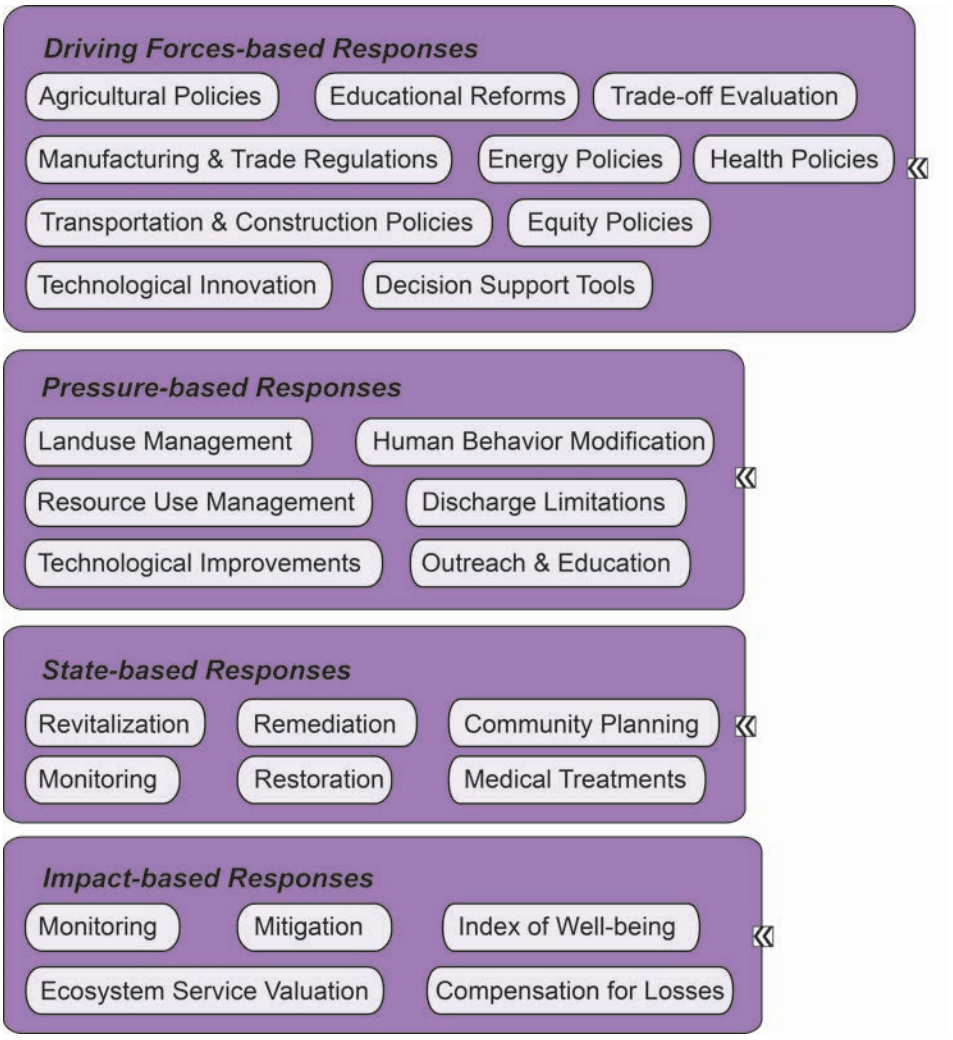


Figure 2-15. DPSIR Category—*Responses*

Figure 2-16. Examples of *Responses*: a) coral nursery, b) technology, c) sediment retention, and d) revitalization

2.5.1 *Driving Forces-based Responses*

Responses may seek to control *Driving Forces* through policies or economic decisions that directly influence sectors, including:

- ***Food and energy policies*** are legislation, restrictions, and guidelines that pertain to sectors that harvest or extract natural resources, including:
  - Agricultural best management practices – including pest and nutrient management, or conservation buffers
  - Fishing and hunting policies – such as catch limitations, consumer preferences for sustainable species
  - Energy policies – including carbon credits, emissions testing, alternative energy sources
- ***Health policies*** are decisions that impact the functioning of health sectors, including:
  - Waste-treatment policies
  - Biomedical research funding
  - Patent laws regarding naturally found bio-chemicals

- ***Cultural policies*** are responses that impact the distribution and functioning of cultural sectors, including tourism, recreation, education, and social organizations. Responses include:
  - Environmental education and outreach – including training, demonstrations, or brochures
  - Tourism policies – including establishing visitor centers or marketing to increase, decrease, or direct tourism activities
- ***Security and public administration policies*** are responses to improve the decision-making and enforcement abilities of government institutions, including:
  - Actions to improve enforcement of existing laws
  - Political pressure by citizens or officials on government
- ***Transportation and construction policies*** are responses to improve the distribution and functioning of sectors that provide infrastructure for buildings and transportation networks, including:
  - Construction codes and policies
  - City ordinances
- ***Manufacturing and trade policies*** are responses to control the production, distribution, and sale of goods and services, including:
  - Actions to encourage competition among businesses
  - Environmental compliance
  - Consumer protections
  - Workplace safety regulations
- ***Education policies*** seek to impact the distribution, function, and quality of educational institutions, including secondary schools and colleges through actions such as:
  - Adopting and enforcing educational standards
  - Grants for research, construction, or supplies
- ***Equity policies*** seek to improve fairness and access to services among populations through:
  - Elimination of barriers to access
  - Programs and actions to enhance diversity
- ***Decision support tools*** are tools that help decision-makers make informed decisions by presenting information in a straightforward, interactive, and scientifically defensible manner, including:
  - Development or application of models, websites, and other tools
  - Statistical analysis
  - Visualization and geospatial analysis
  - Cost-benefit analysis
  - Trade-off evaluations

2.5.2 *Pressure-based Responses*

Responses may also seek to control *Pressures* through regulations or technology that limit human activities, or decisions designed to modify human behavior, including:

- ***Land-use management*** which seeks to plan and control development of lands through:
  - Land-use zoning
  - Building permits
  - Beach re-nourishment
  - Designation of protected areas
- ***Discharge limitations*** which place limits on and monitor pollution including:
  - Non-point source discharge regulations
  - Point or mobile source discharge regulations
- ***Technological innovations***, which involve research and development to improve the use of technology, including leading toward environmentally-sound practices through:
  - Improved technology
  - Alternate energy sources – such as solar or wind power
- ***Resource use management*** is regulations, policies, and actions designed to control the use of natural resources including through
  - Setting designated uses
  - Hunting, fishing, or boating regulations and licenses
  - Coastal zone management, including Marine Protected Areas
  - Designating protected areas

Responses may be designed to modify individual human behaviors that contribute to health risks:

- ***Human behavior modification*** is an attempt by an individual to modify their own behavior, which may be negatively contributing to personal health, such as quitting smoking, dieting, or opting for public transportation
- ***Outreach and Education*** attempts to get an individual or group of individuals to modify their behavior by providing materials and information through presentations, brochures, and other promotional tools

2.5.3 *State-based Responses*

Responses may also directly impact the *State* of the environment, human condition or human health through:

- ***Environmental responses*** which seek to control the physical, chemical, and biological environment including:
  - Water quality monitoring
  - Air quality monitoring
  - Setting water or air quality criteria
  - Biological monitoring
  - Scientific research
  - Setting biological criteria

        - Restoration, remediation, and revitalization activities – including efforts to re-establish native species
    - ***Medical treatments*** designed to directly modify human condition or health including
        - Medications
        - Surgery
        - Physical therapy
    - ***Community planning*** seeks to modify the state of the community by promoting and implementing actions such as
        - Homeowner assistance
        - Expanded economic opportunities

2.5.4 *Impact-based Responses*

Responses may also be designed to quantify or compensate for social and economic impacts of human condition on human well-being:

- ***Monitoring*** involves tracking the success of implemented decisions on one or more indicators measuring environmental or human well-being impacts through
    - Surveys and opinion polls
    - Field observations
- ***Ecosystem Services Valuation*** is the process of estimating the monetary or non-monetary merit of potential or implemented decisions, including:
    - Market valuation
    - Non-market valuation
- ***Mitigation*** is an effort to alleviate burdens on persons or the environment caused by some action by compensating for the loss of environmental benefits, including:
    - Compensatory mitigation
    - Mitigation banking
- ***Compensation for losses*** is an effort to alleviate burdens on individuals caused by some action or offense by compensating for economic, social, or emotional losses with money or other things of economic value, and includes:
    - Financial compensation
    - Statutory environmental damage insurance
- ***Human Well-being Index*** is an effort to quantify the condition of humans and society, defined in terms of the basic material and other natural resource needs for a good life, freedom and choice, health, wealth, social relations, and personal security[41]

2.6 *Summary*

The DPSIR framework provides a flexible, well-defined conceptual model for organizing and communicating complex environmental issues (**Fig. 2-17**).

[41] Smith et al. 2012; Munns et al. 2015

The hierarchy of concepts in social, health, and environmental sciences identified in the generic Eco-Health DPSIR framework (**Table 2-1**) is intended to identify potential places for interactions among multiple stakeholder perspectives and across scientific disciplines.

The strength of the DPSIR approach is that it:

- Is transparent and simple – with 5 concepts that are readily understandable to both scientists and stakeholders
- Enhances communication by simplifying the complex connections between humans and the environment
- Fosters a systems approach
- Is inherently human-centric, appealing to the public and decision-makers
- Implies causal relationships among the factors

Chapter 3 will demonstrate how DPSIR can be used in a workshop setting.

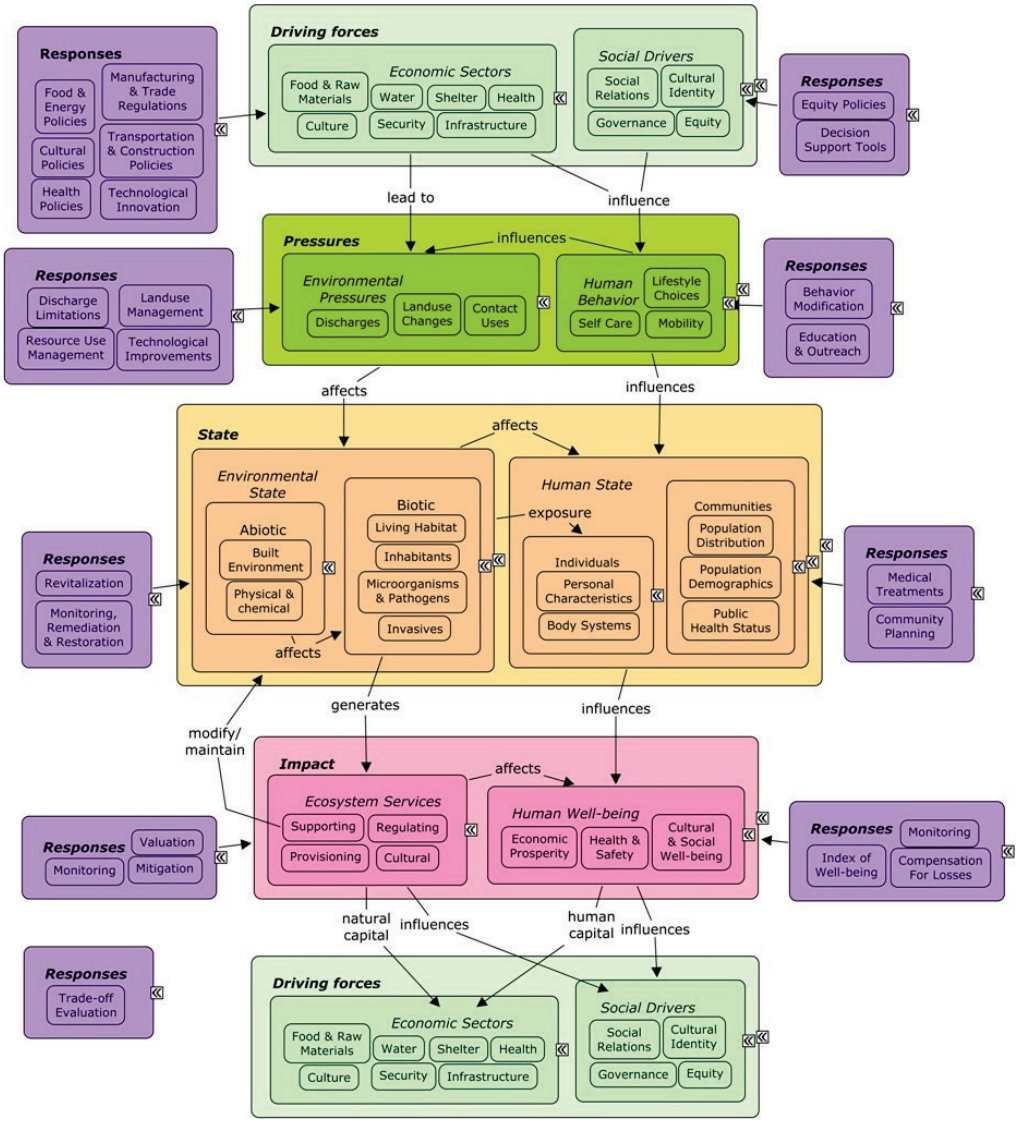


Figure 2-17. The complete Eco-Health DPSIR framework

Table 2-1. Categories, sub-categories, and concepts within the Eco-Health DPSIR

Category	Concepts
Driving Forces	
Economic Sectors	
Food and Raw Materials	agriculture, aquaculture, oil and gas extraction, fisheries, forestry, mining
Water	drinking water supply, irrigation
Shelter	home construction, real estate, textiles and apparel
Health	medical care, pharmaceuticals and cosmetics, social assistance, waste management, public health agencies
Culture	tourism and recreation industry, schools, telecommunications, scientific research, social organizations
Security	national defense, public administration, law enforcement
Infrastructure	manufacturing and trade, transportation, construction and civil engineering, finance and insurance industries, utilities, technical services
Social Driving Forces	
Social Relations	religious affiliations, social groups, marriage, or family dynamics
Cultural Identity	urban, rural, tribal, or coastal communities; ethnic or religious identity;
Governance	voting patterns, roles of decision-makers, type of government
Equity	access to education, access to health care, access to jobs
Pressures	
Environmental Pressures	
Discharges	point/non-point source discharges, agricultural/urban run-off, atmospheric emissions, applied fertilizers/chemicals, wastewater discharges, solid waste disposal
Land-use Changes	coastal development, land development, shoreline alteration, hydrologic modifications, deforestation, devegetation, creation of impervious surfaces
Contact Uses	dredging, filling, trampling, release of non-native species, creation of artificial habitat, harvesting, fishing
Human Behavior	
Self-Care	personal hygiene, housekeeping, smoking, eating habits
Mobility	walking, climbing, utilizing transportation alternatives, time-activity patterns
Lifestyle Choices	transportation or housing choice, consumptive patterns, resource use and recycling
State	
Environmental State	
Abiotic State	
Physical and Chemical Environment	climate, air and sea temperature, precipitation, storms and hurricanes, drought, hydrology, ocean circulation patterns, fire, nutrients, pH, atmospheric CO_2 levels, salinity, contaminants
Built Environment	buildings, roadways, furnishings, landfills, brownfields, parks
Biotic State	
Living Habitat	deserts, wetlands, grasslands, forests, coral reefs, agricultural lands
Inhabitants	birds, mammals, fish, reptiles, amphibians, invertebrates
Invasive species	invasive plants, invasive animals, invasive aquatic species
Microorganisms and Pathogens	decomposers, mycorrhizae; bacteria, fungi, viruses
Human State	
Individuals	
Personal Characteristics	life stage, gender, ethnicity, socio-economic status
Body Systems	respiratory system, immune system, gastrointestinal system, reproductive system, endocrine system, neurological system, mental health, genetics
Communities	
Population Distribution	population density, population spatial distribution
Population Demographics	community-level distributions of age, economic status, race, education, gender
Public Health Status	community-level metrics of disease prevalence or incidence

Category	Concepts
Table 2-1 (continued)	
Impacts	
Ecosystem Services	
Supporting	soil stabilization, wave energy attenuation, nutrient and contaminant processing, water cycling, carbon storage and cycling, and provision of resources and habitat to critical species
Regulating	air and water quality regulation, climate regulation, erosion regulation, water purification, disease/pest regulation, pollination, natural hazard regulation
Provisioning	water resources, food resources, biochemical or genetic resources, fuel, fiber, ornamental resources
Cultural	recreational value and ecotourism, aesthetic value, cultural value, spiritual or religious value, sense of place, educational or knowledge value, research potential, untapped future potential
Human Well-being	
Economic Prosperity	productivity, ability to work, income
Health and Safety	life span, medical or insurance costs, sick days, pain and suffering
Cultural and Social Well-being	"happiness," sense of belonging, community vibrancy, spiritual fulfillment, connection with the natural world
Responses	
Driving Forces-based Responses	
Food and Energy Policies	agricultural best management practices, fishing policies, hunting policies, energy policies
Health Policies	waste-treatment policies, biomedical research funding, biochemical patent laws
Cultural Policies	environmental education and outreach, tourism policies
Transportation and Construction Policies	construction codes, city ordinances
Manufacturing and Trade Regulations	environmental compliance, consumer protections, workplace safety
Education Policies	educational standards, grants
Security Policies	law enforcement, political pressure on government
Equity Policies	elimination of barriers to access, programs to enhance diversity
Decision Support Tools	models, websites, statistical analysis, visualization, geospatial analysis, cost-benefit analysis
Pressure-based Responses	
Land-use Management	landuse management, building permits, beach renourishment, designated protected areas
Discharge Limitations	non-point source regulations, point and mobile source regulations
Technological innovations	improved technology, alternate energy sources
Resource Use Management	setting designated uses, hunting licenses, fishing licenses, boating licenses, designated protected areas
Behavior Modification	quitting smoking, diet modification, opting for public transportation
Outreach and Education	presentations, brochures, promotional tools
State-based Responses	
Environmental Responses	monitoring, restoration, remediation, revitalization
Medical Treatments	medications, surgery, physical therapy
Community Planning	homeowner assistance, expanded economic opportunities
Impact-based Responses	
Monitoring	surveys, opinion polls, field observations
Valuation	market valuation, non-market valuation, multi-attributed utility theory
Mitigation	compensatory mitigation, mitigation banking
Compensation for Losses	financial compensation, statutory environmental damage insurance
Human Well-being index	Methods to quantify and monitor well-being

Chapter 3: DPSIR as a Discussion Tool

The DPSIR conceptual framework is a useful tool in workshops and meetings for motivating discussions and brainstorming among participants. EPA uses a two-person team to elicit and document the brainstormed DPSIR - a DPSIR facilitator and a note-taker who captures the participants' ideas into the conceptual map as they are brainstormed (**Fig. 3-1**).

Figure 3-1. DPSIR elicitation during a workshop held in La Parguera, Puerto Rico. The facilitator is standing in the front of the room, and the Cmap note-taker is seated with a laptop, facing the workshop participants. The computer is being projected onto the screen, so participants can view the DPSIR as it is being developed

Software applications such as the IHMC CmapTools (**Fig. 3-2**) or the EPA SystemSketch tool are useful to construct a DPSIR concept map. Guidance on using CmapTools is provided in Appendix A. Example Cmap files, templates, and DPSIR concept lists and definitions can be found at the EPA DPSIR tutorial website (Appendix B). More information on EPA's SystemSketch tool can be found in Appendix C, along with information on the DASEES decision support system, which can help stakeholders understand where conceptual models fit in the overall decision process. Facilitators and note-takers should be trained in the Eco-Health DPSIR framework and either CmapTools or another conceptual modeling tool prior to the workshop/meeting.

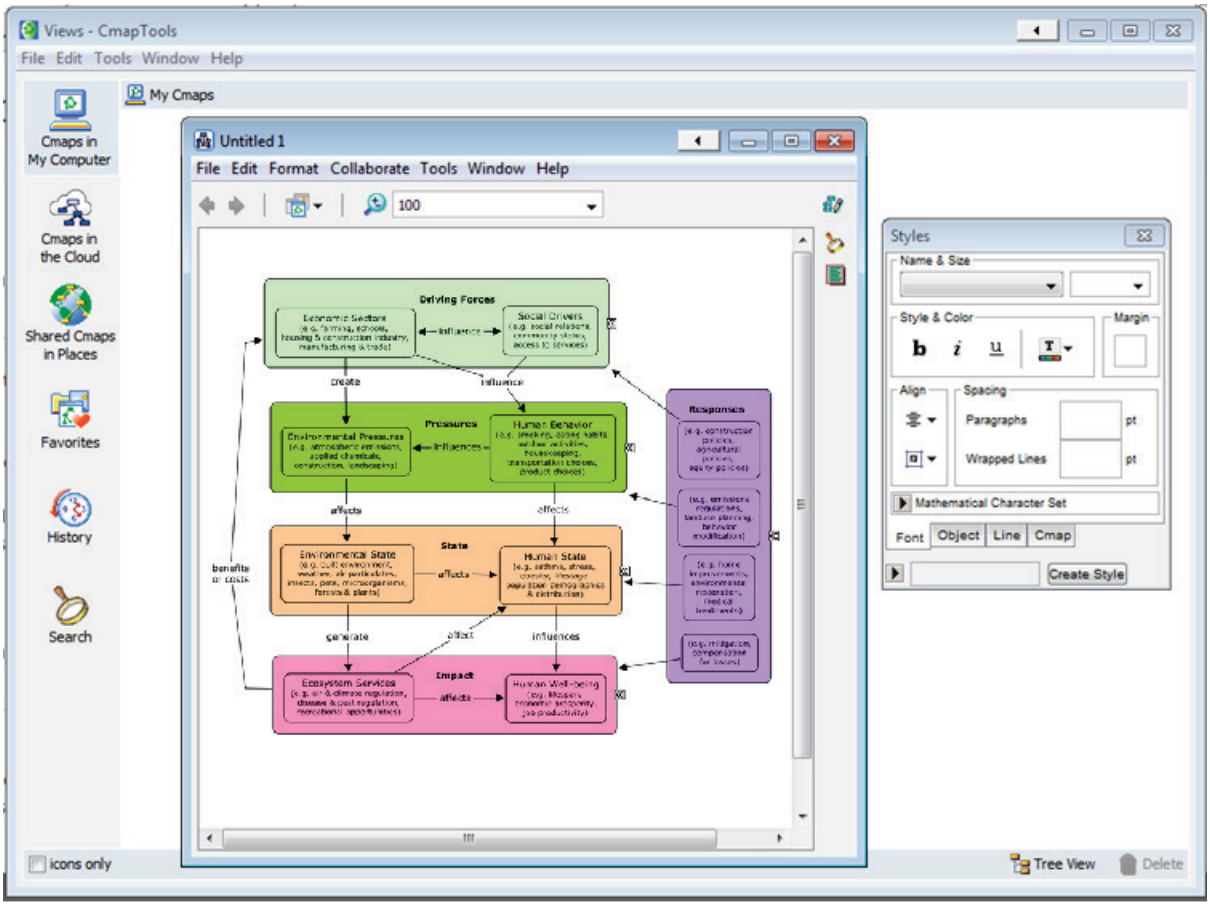


Figure 3-2. Screenshot of CmapTools software. This tool is available from URL: http://cmap.ihmc.us/

Facilitators can start at any point in the DPSIR. Most study areas or communities already have activities in progress (e.g., a watershed management plan, an environment impact assessment, or a set of issues of concern). In that case, facilitators can start with the management options that have been identified in the management plan (*Reponses*) and work their way backwards through the DPSIR framework.

To elicit information, discussion questions are assigned at each level of the DPSIR framework. This provides a step-by-step method to guide participants into thinking about relationships among social, economic and environmental factors relevant to the discussion topic. If the discussion is centered on ecosystems and ecosystem services, then an ecologically focused DPSIR can be developed using only the example questions on the left side of **Fig. 3-3**. However, if the discussion is focused around sustainable communities, including both ecosystem services and human health impacts, then the DPSIR should be developed using the questions from both sides of **Fig. 3-3** (Ecosystem Health and Human Health).

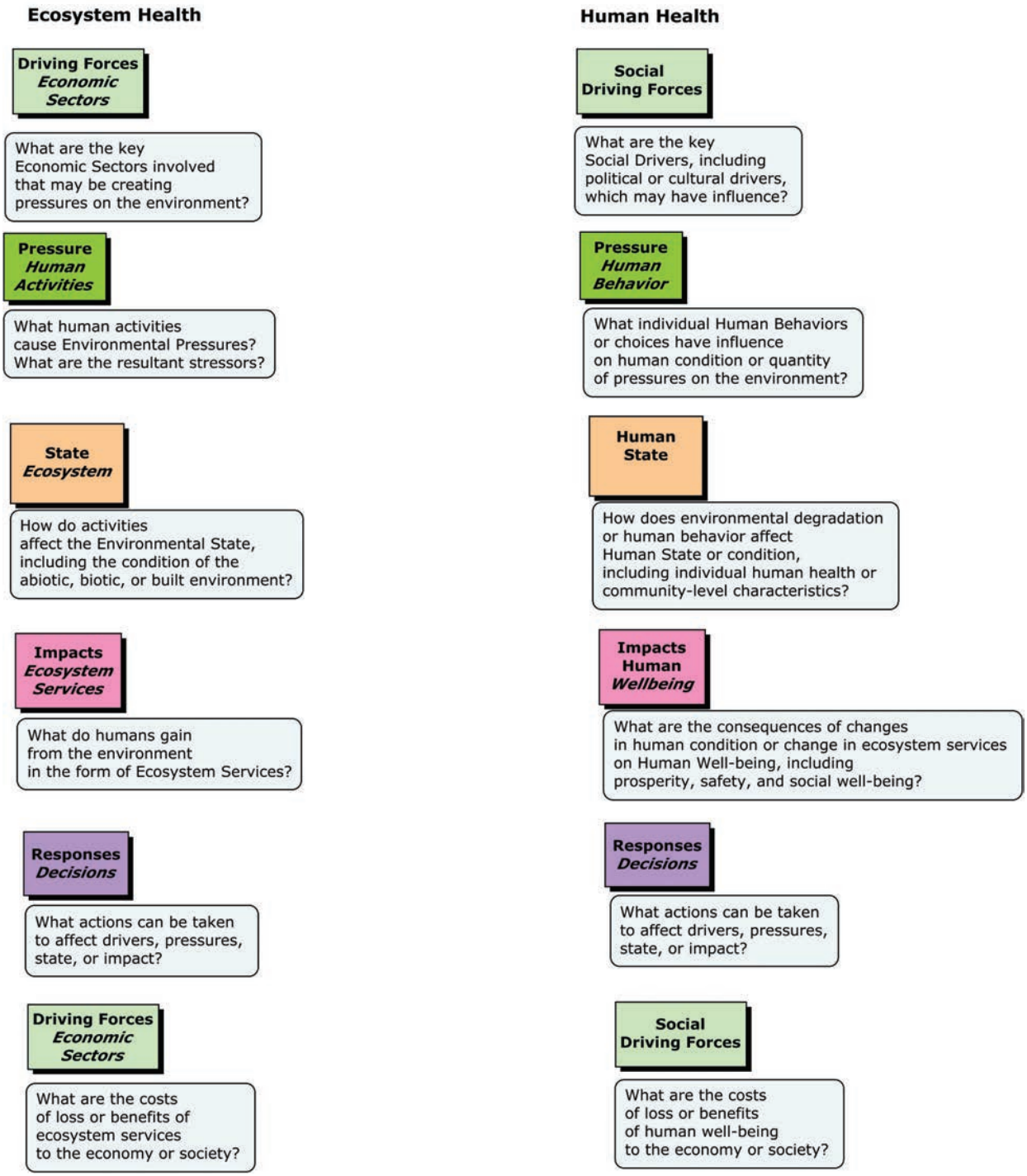


Figure 3-3. Template for DPSIR conceptual map. Questions used during discussion stepping through each generic DPSIR category on the left or right side of the generic framework to elicit more information toward building a detailed conceptual model for a given topic under consideration (Source: Yee et al. 2012)

Participant input for each discussion question is visually captured during the meeting discussion as lists of keywords in a conceptual model[42]. Use of a Cmap template to guide the DPSIR development is also helpful. The template includes the color-coded DPSIR levels and the discussion questions for each level. It is helpful to maintain this color scheme to quickly determine which level a topic falls into. In the examples the following color scheme is used:

Driving Forces – light green

Pressures – dark green

State – peach

Impacts – pink

Responses - purple

The note-takers generate the DPSIR maps real-time using Cmap software and the DPSIR is projected so the group can see what is being developed.

There are several benefits to using the DPSIR process in a workshop elicitation. For participants, it encourages whole-systems thinking, thinking about ecosystem services (benefits they gain from the environment), considering alternative perspectives (e.g. gets the farmer thinking about the perspective of the fisherman), considering the purpose and possible unintended consequences of proposed actions, and considering new management options. Furthermore, as participants see their own contributions added to the conceptual model, it shows them they have a voice in the discussion. For organizers, it provides a way to get the conversation going and allows the facilitator to elicit information on stakeholder priorities and concerns.

Case studies

Although DPSIR has been applied to a wide range of problems[43], here we provide two specific examples, one for an ecological assessment using the ecologically focused DPSIR and the other for an eco-health assessment using Eco-Health DPSIR. Each case study walks through the elicitation process, including the discussion questions and example participant responses.

3.1 Ecological Case Study—Coral Reef and Coastal Ecosystems Linkages with the Tourism and Recreation Sector

This case study begins with the ***Driving Force*** – the tourism and recreation economic sector. It is a fitting example because coral reef-based tourism and recreation is an important industry in many coastal communities.

[42] Canas et al. 2003; Yee et al. 2011

[43] Maxim et al. 2009; http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=235356

The note-taker starts with a Cmap template showing the DPSIR components and respective questions (**Fig. 3-4**). (Note – because this example addresses only ecological condition and not human health, this is just the left side of the Eco-Health DPSIR template.)

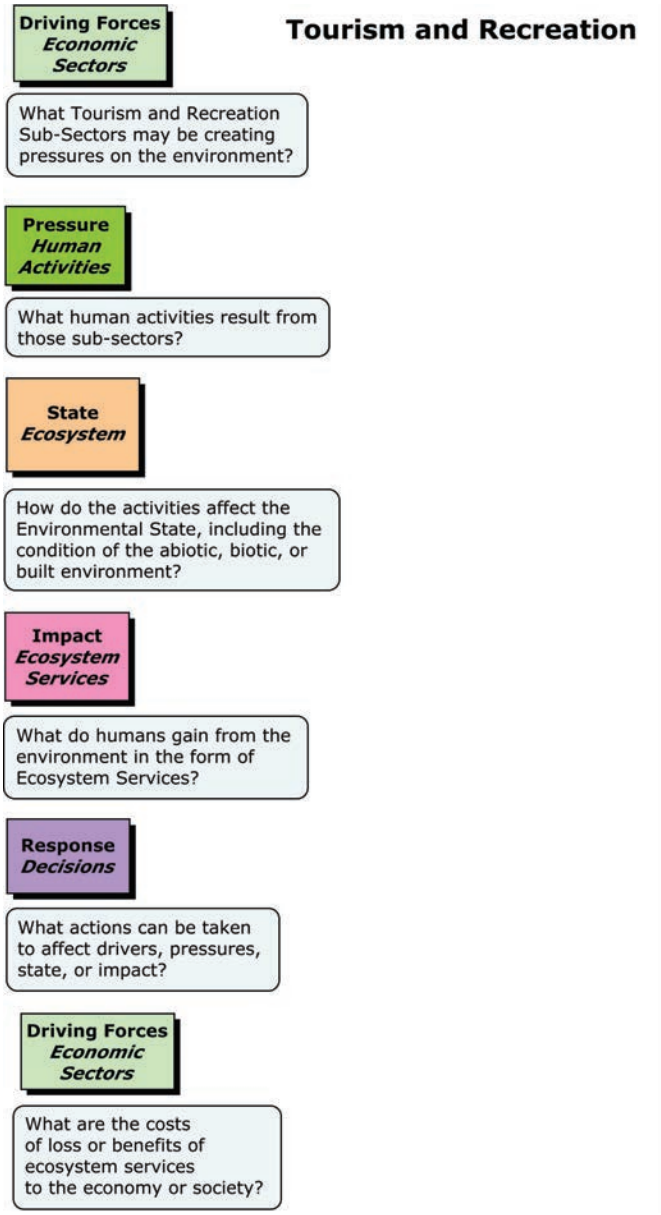


Figure 3-4. Tourism and recreation DPSIR template. Note: the questions are tailored to the starting point–*Driving Forces.*

Question #1: *What Tourism and Recreation **Economic Sectors** may be creating pressures on the environment?*

The facilitator leads a discussion with workshop participants on the *Tourism and Recreation* ***Economic Sectors*** in their community. *Tourism and Recreation* sectors operate facilities and provide services for the varied cultural, entertainment and recreational interests of residents and tourists. Coral reef-based tourism and recreation includes recreational scuba diving, snorkeling, surfing, recreational fishing, beachcombing, beach sunbathing, swimming and viewing nature and wildlife. It also includes the infrastructure needed to support the industry, including hotels, restaurants, marinas and transportation (**Fig. 3-5**).

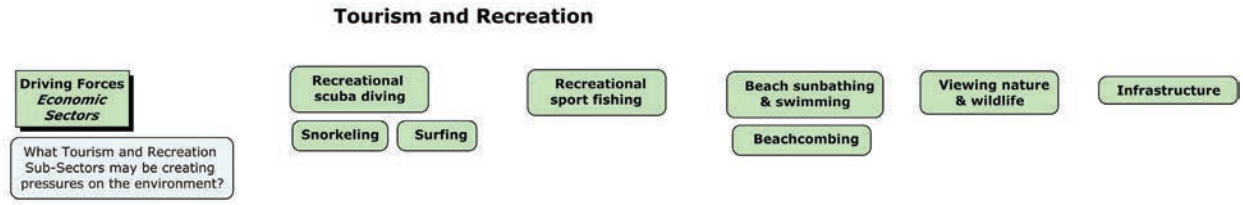


Figure 3-5. ***Driving Forces*****–tourism and recreation economic sector and associated sub-sectors**

Once the participants feel comfortable with this part of the conceptual model, the facilitator moves on to the next question. Note: the participants can re-visit any section throughout the facilitated discussions. The idea is to jointly develop a conceptual model that participants feel truly represents their situation.

Question #2: *What human activities (**Pressures**) result from those economic sub-sectors*?

The facilitator leads a discussion about each economic subsector. For illustration purposes, this example focuses on *Recreational sport fishing*. The ***Pressures*** included harvesting, by-catch and waste; anchor, gear and boat groundings; and oil, metals and sewage discharge (**Fig. 3-6**).

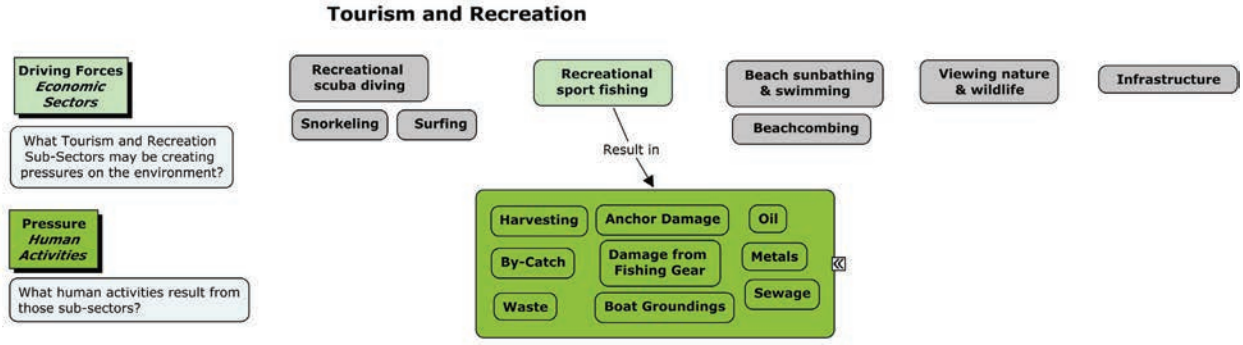


Figure 3-6. ***Pressures*** **associated with recreational fishing and boating**

Question #3: *How do activities affect the **Environmental State**, including the condition of the abiotic, biotic, or built environment*?

The facilitator leads a discussion about each *Pressure*. For illustration purposes, this example focuses on *Harvesting, By-catch and Waste*. There are two components of ***Environmental State*** – *Abiotic* and *Biotic*. The facilitator first focused on *Biotic State* and asked which organisms were being harvested, and the participants identified invertebrates, fish and sponges. The group also defined the relationship – harvesting reduces the populations of these organisms (**Fig. 3-7**).

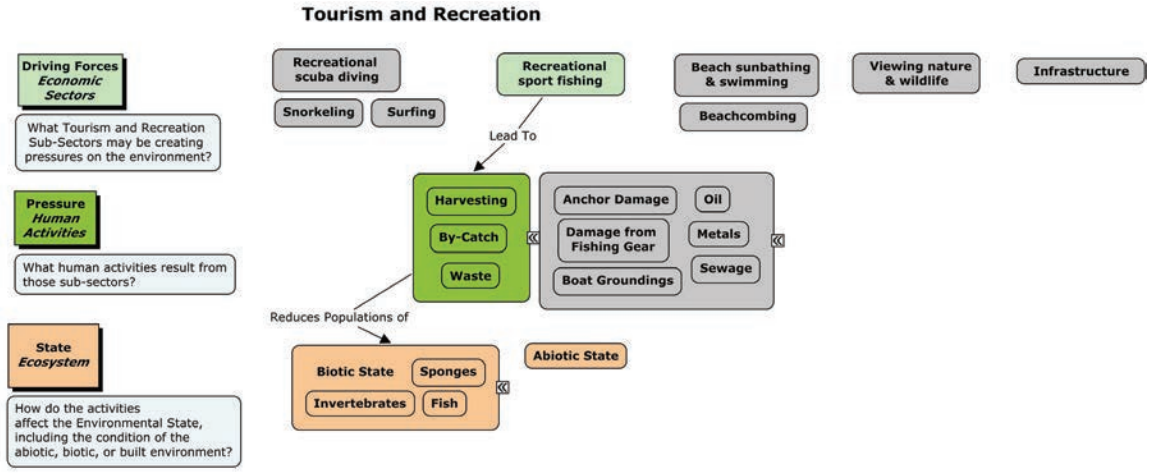


Figure 3-7. Organisms being harvested, resulting in a decreased population (change in *Biotic State*)

The facilitator next focused on how *anchor, gear and boat groundings* would damage sponges, stony corals, octocorals, and seagrasses; and how oil, metals, and sewage discharges would affect *Abiotic State* by increasing contaminants that would influence invertebrates, fish, sponges, stony corals, octocorals, seagrasses, mangroves and macro-algae (**Fig. 3-8**).

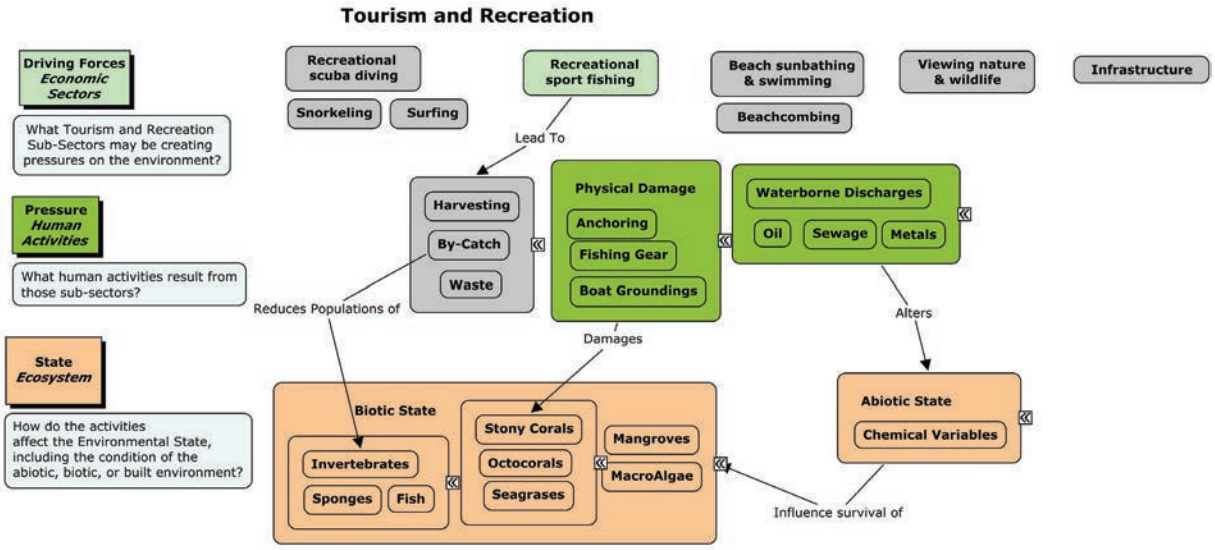


Figure 3-8. Changes in *Abiotic* and *Biotic State* associated with recreational fishing and boating

Question #4: *What do humans gain from the environment in the form of **Ecosystem Services***?

The participants brainstormed a wide range of ***Ecosystem Services*** (*Impacts*) that would be impacted by the changed ecological state. These included services that directly benefit humans (food, erosion control, pharmaceuticals, tourism and recreation), as well as supporting services – the processes and functions that underlie the other ecosystem services (e.g., biodiversity, primary production, and nutrient cycling) (**Fig. 3-9**).

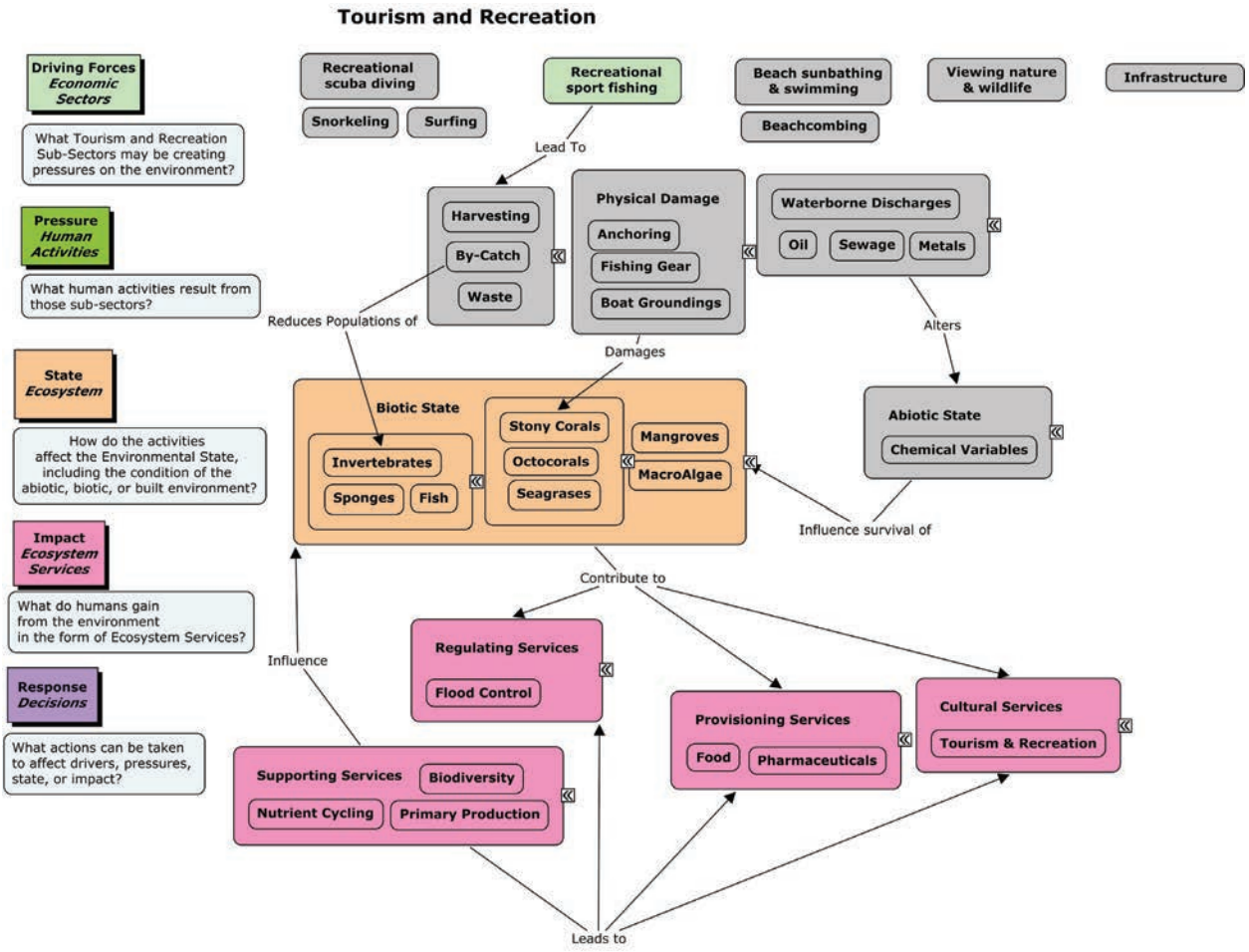


Figure 3-9. ***Ecosystem Services*** **(*Impacts*) affected by recreational fishing and boating**

Once all of the other *Economic Sectors*, and the resultant *Pressures* and *States* associated with those sectors were identified, the discussions moved on to the *Responses*. For the purposes of this case study, the other sub-sectors are not shown.

Question #5: *What actions (**Responses**) can be taken to affect Driving Forces, Pressures, State, or Impacts?*

The participants brainstormed a set of management actions, including permits to regulate sport fishing, law enforcement, coastal zone management, resource management, ecosystem monitoring and restoration and valuation (**Fig. 3-10**).

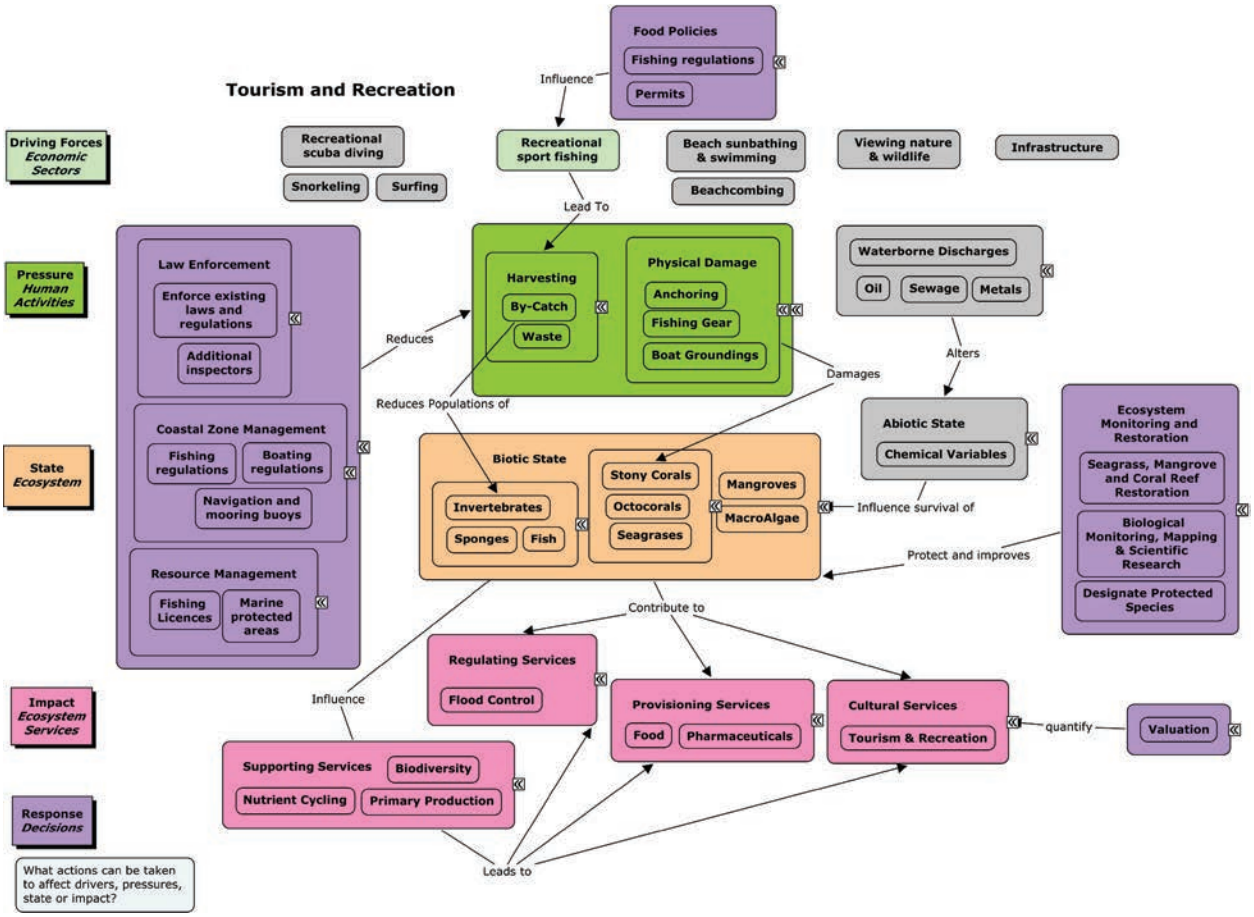


Figure 3-10. *Responses* that could be implemented to mitigate the *Impacts* of the tourism and recreation sector

3.2 Eco-Health Case Study—Asthma

In this example, the facilitator began with a ***Human State***—asthma, which is a public health concern with enormous economic and social consequences for families and communities[44]. An array of interacting environmental, economic and social factors are associated with the prevalence and severity of asthma[45]. Recently there have been efforts to evaluate systems approaches for reducing well-known asthma disparities for children and minorities by combining public health intervention programs with strategic housing, building and maintenance practices[46]. However, prior to Yee et al. 2011, a framework that integrated such approaches with efforts designed to reduce pollution and to evaluate effects on ecosystem services had not been developed.

By incorporating both ecosystem health and human health into a single integrated framework, we are able to obtain a broader systems perspective on how factors related to asthma may have multiple origins and multiple social, economic, and environmental consequences. This perspective can then be applied in decision models to evaluate which interventions to reduce incidence and severity of asthma, provide the greatest benefit and least cost across all sectors.

To begin the process of building an asthma DPSIR, the note-taker would start with a Cmap template showing the DPSIR components and respective questions (**Fig. 3-11**).

[44] Akinbami et al. 2011
[45] Wright and Subramanian 2007
[46] Takaro et al. 2011

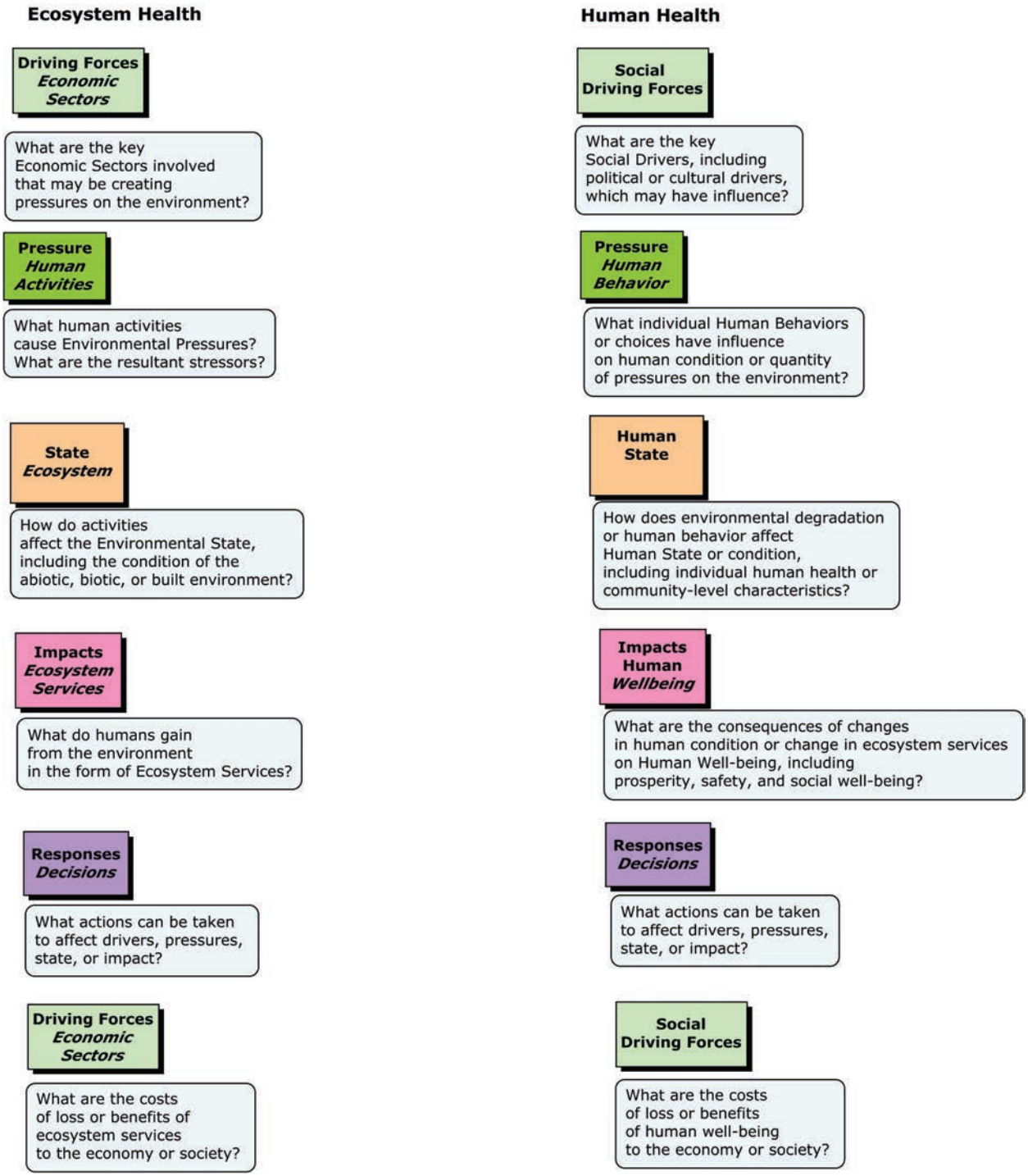


Figure 3-11. Asthma DPSIR template. Note: this is the Eco-Health DPSIR Template with Ecosystem Health on the left and Human Health on the right

Question 1: *What is the human condition of concern (**Human Health State**)?*

Using the template as a guide, we begin with asthma as a condition of the individual human respiratory system in *State* (**Fig. 3-12**).

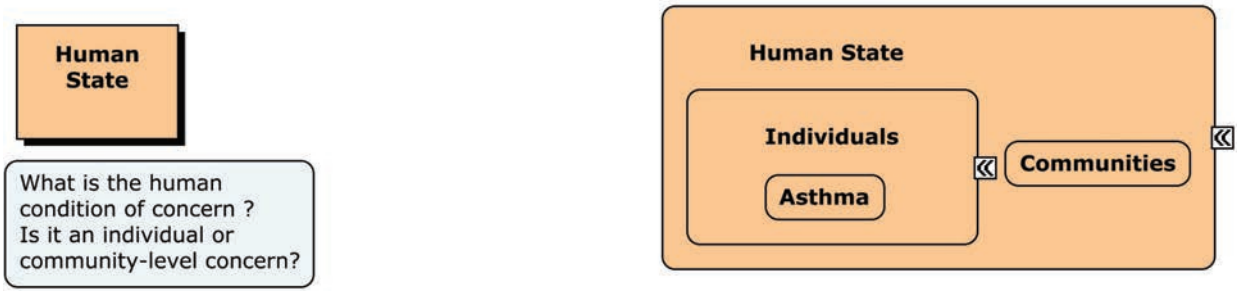


Figure 3-12. *Human State* associated with asthma

Question 2: *What **Human Behaviors** (Pressures) contribute to this condition?*

The facilitator next leads a discussion to identify ***Human Behaviors*** (e.g., smoking, housekeeping, and outdoor activities) influencing asthma risk (**Fig. 3-13**).

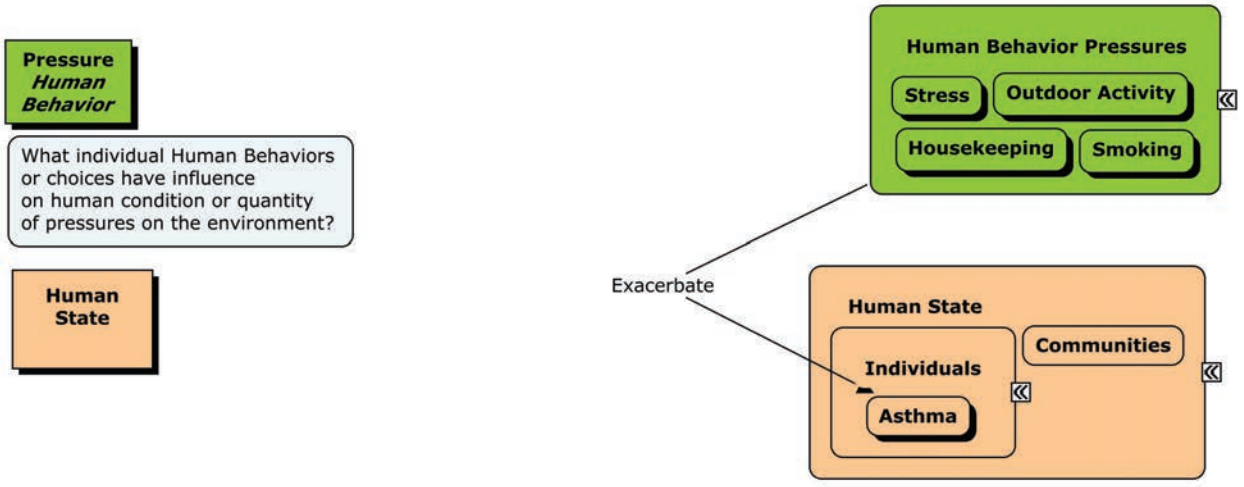


Figure 3-13. *Human Behavior Pressures* that contribute to asthma (*Human State*)

Question 3: *How does the environment contribute to this condition (**Environmental State**)?*

Environmental State can also impact *Human State*. The participants brainstorm the potential environmental influences (e.g., pollen, dander, or mold) that can influence asthma (**Fig. 3-14**)

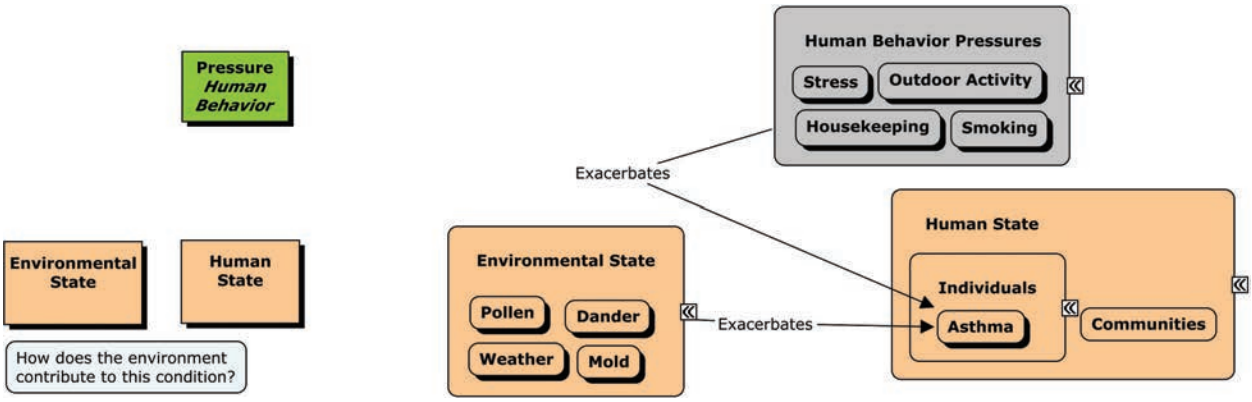


Figure 3-14. *Environmental State* contributes to asthma (*Human State*)

The group next discusses the human activities that exert pressure on the environment, and therefore increase the effect on human state.

Question 4: *What human activities exert **Environmental Pressures**?*

Environmental Pressures, such as air pollution, application of chemicals, or landscaping, can determine the quantity and types of potential allergens in the environment (**Fig. 3-15**).

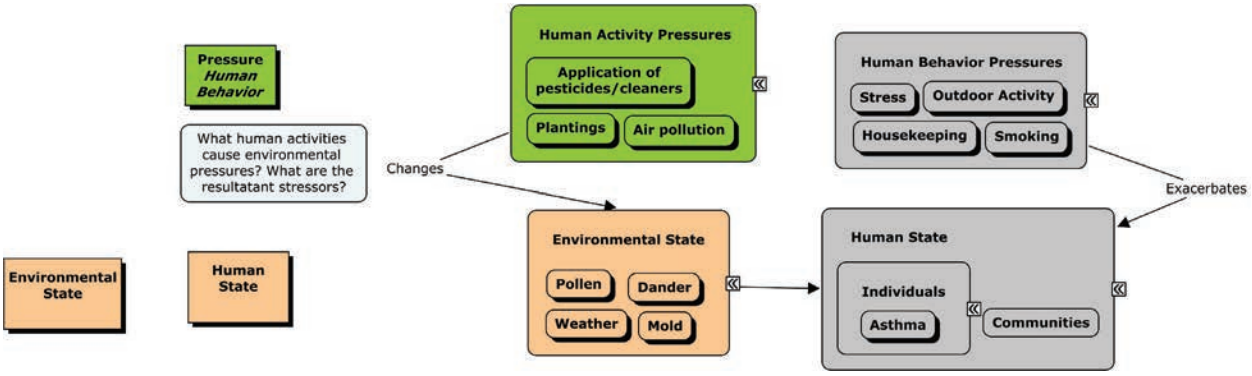


Figure 3-15. Human activities that exert *Pressure* on *Environmental State*

The discussion next moves toward linking *Pressures* and *State* to key social and economic factors (*Driving Forces*).

Question 5: *What **Social Driving Forces** influence human behavior?*

Social Driving Forces such as attitudes and understanding of family and friends, and community economic status (access to and coordination of health care; ability to intervene) can influence human behaviors (**Fig. 3-16**).

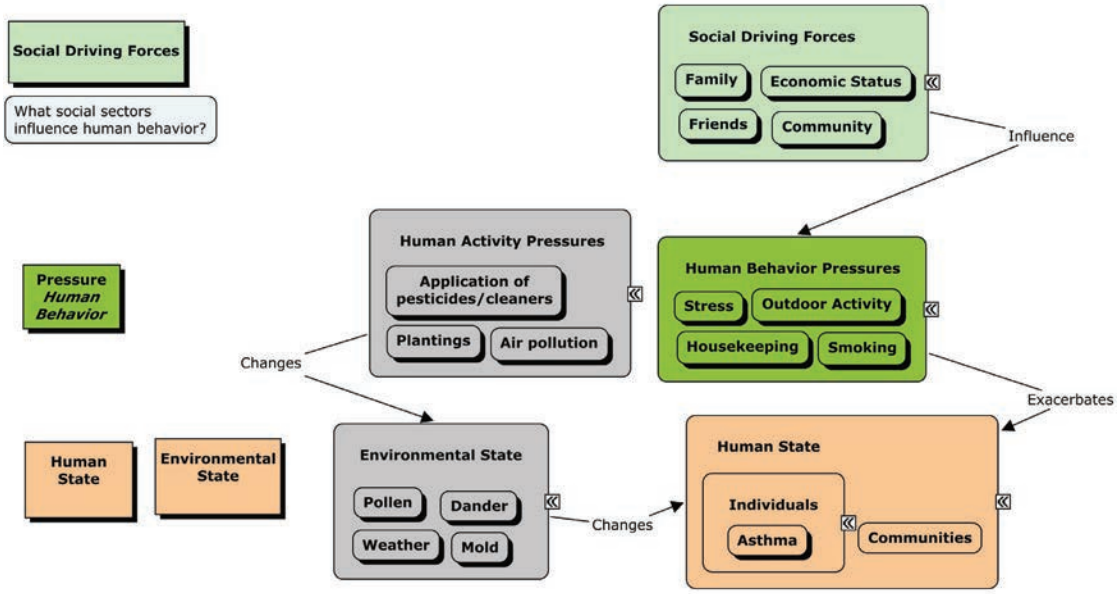


Figure 3-16. Social factors (*Driving Forces*) that influence *Human Behavior* (*Pressures*)

Question 6: *What **Economic Sectors** influence Human Behavior?*

Economic Sectors, such as agriculture, transportation, landscaping services, construction, and manufacturing, also play a role in creating environmental pressures that act as triggers of existing asthma or exacerbate the development of asthma (**Fig. 3-17**).

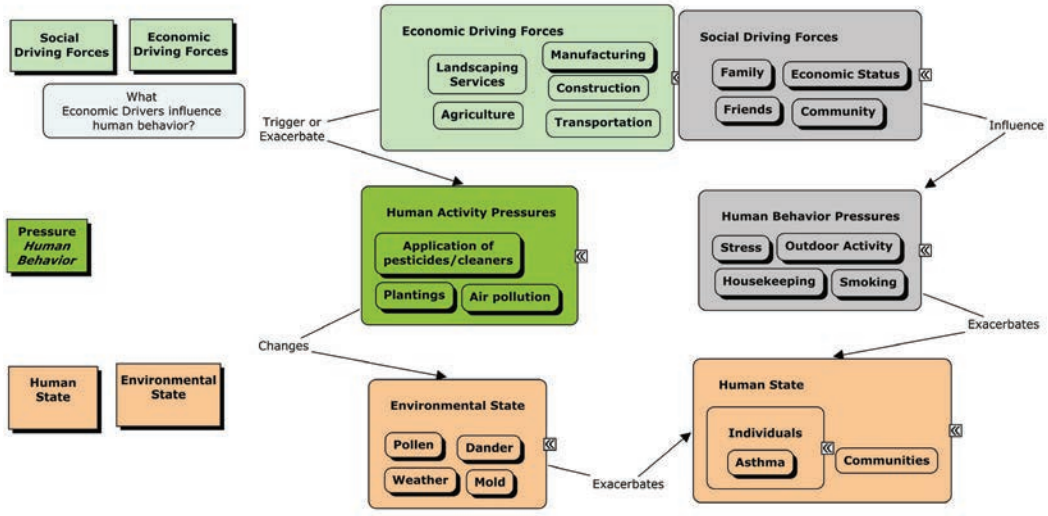


Figure 3-17. *Economic Sectors* (*Driving Forces*) that influence human activities (*Pressures*)

Question 7: *What **Ecosystem Services** (Impacts) do humans gain from the environment?*

Changes in the condition of the environment, due to pressures such as land development, may lead to loss of ***Ecosystem Services*** (*Impacts*) such as air and pest regulation or recreational opportunities, which can help ameliorate potential environment-related asthma triggers (**Fig. 3-18**).

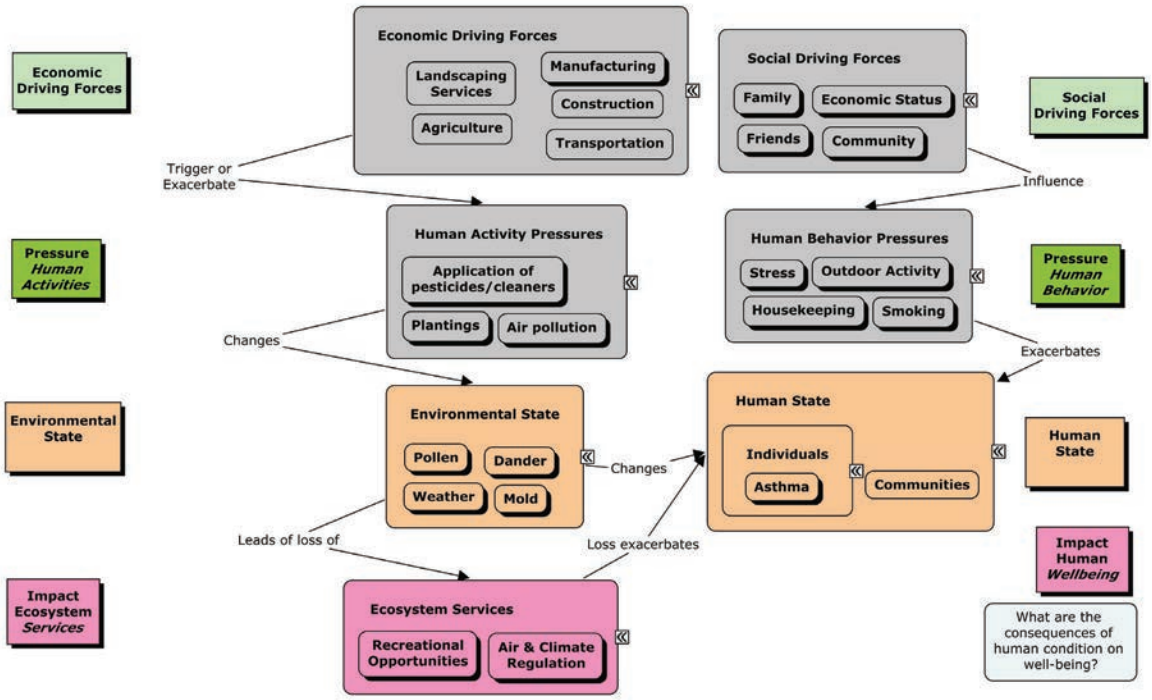


Figure 3-18. Changes in *Ecosystem Services* (*Impacts*). Workshop participants next identify the social and economic consequences of asthma at both the individual and societal levels

Question 8: *What are the consequences of human condition on **Human Well-being** (Impacts)?*

Affected individuals and their families may suffer from loss of productivity from missed work and school, or increased medical costs which may trickle through the broader economy or impact social relations (**Fig. 3-19**).

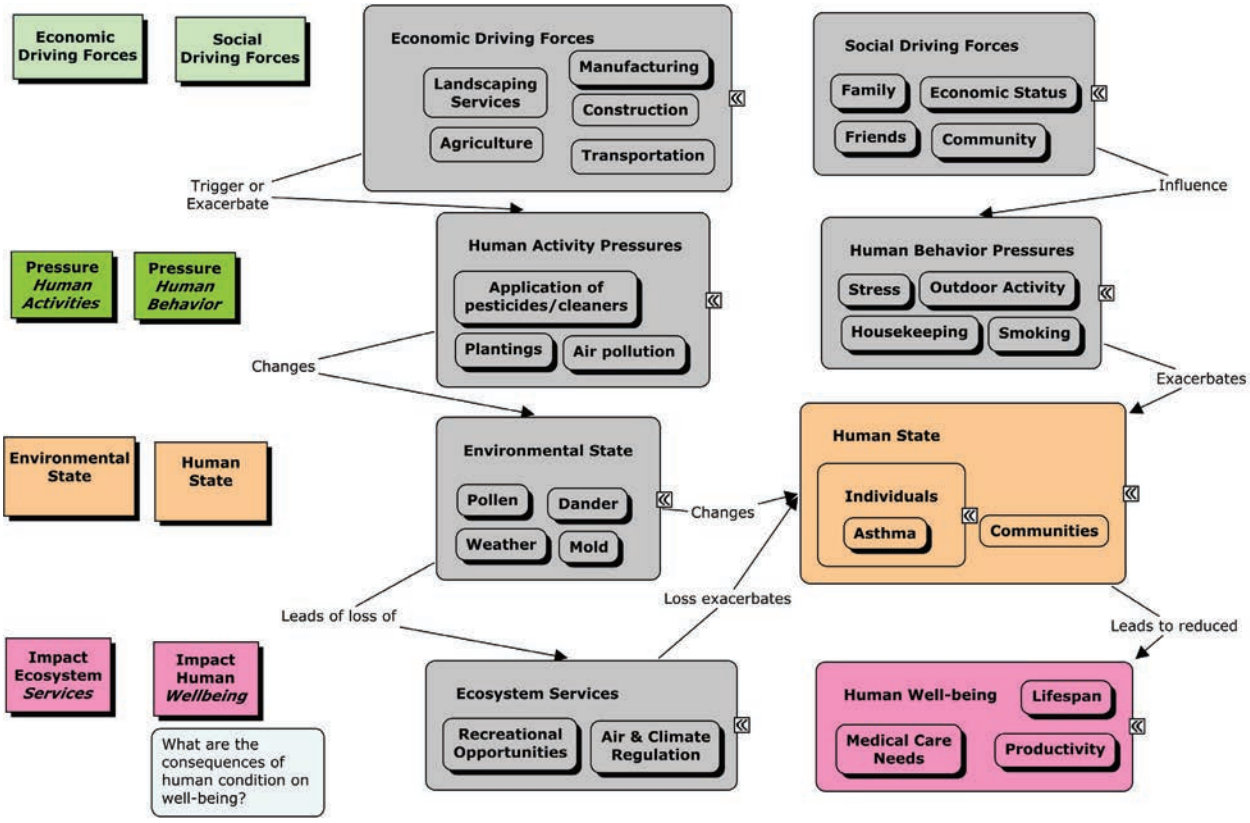


Figure 3-19. The consequences of human condition (*Human State*) on *Human Well-being* (Impacts)

The facilitator next leads discussion to identify potential decision options (*Responses*) for preventing, controlling, or ameliorating asthma.

Question 9: *What are the possible management actions that can be taken (**Responses**)?*

Individuals or society can implement ***Responses*** to asthma in a number of ways, such as trying to influence socio-economic driving forces through policies[47], directly regulating discharges or improving technology to reduce pressures, attempting to modify human behaviors, implementing interventions that modify the environment and/or improve medical care for affected individuals[48], and mitigating or compensating for losses related to asthma (**Fig. 3-20**).

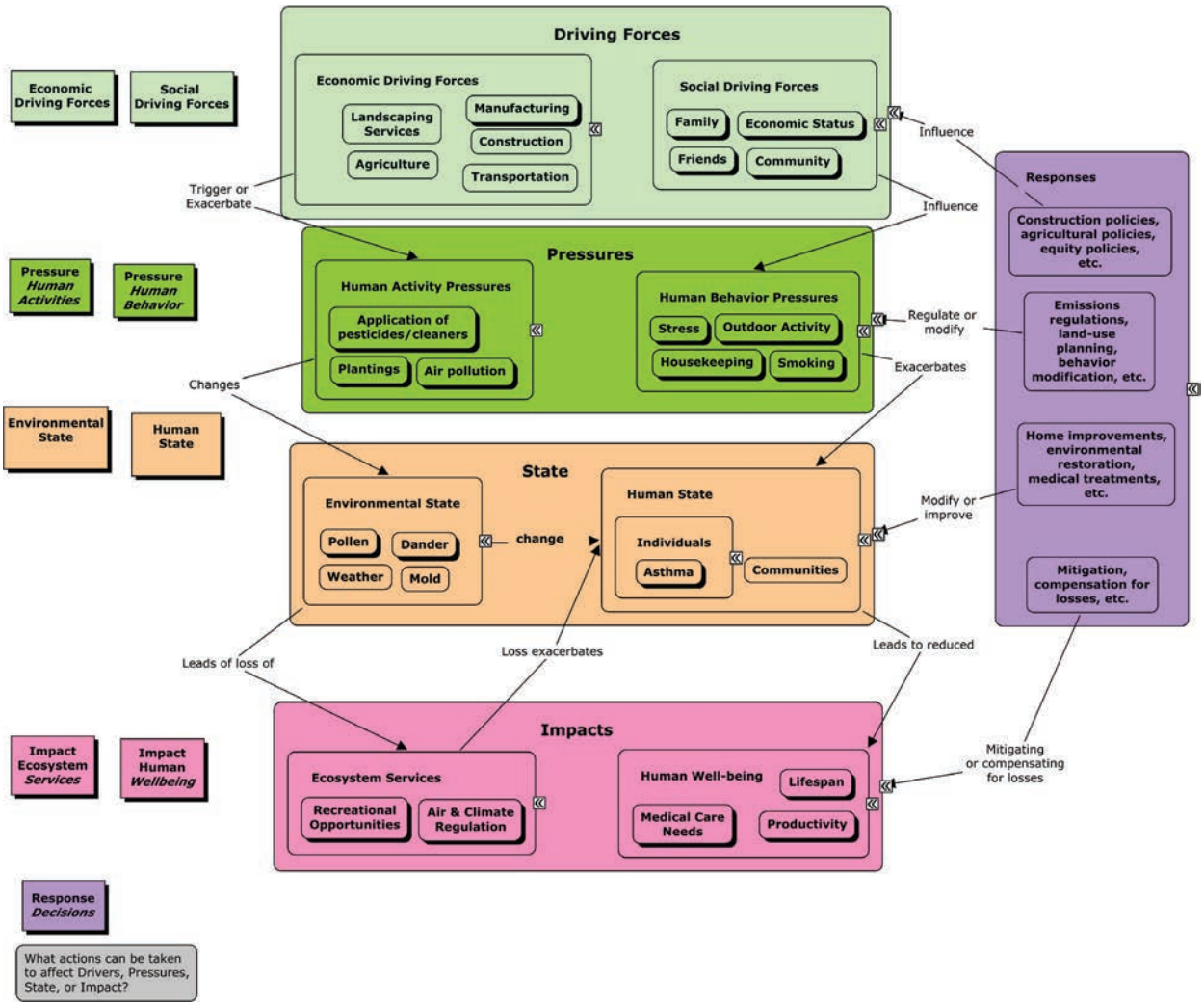


Figure 3-20. Management actions that can be taken to prevent, control or ameliorate asthma

[47] Takaro et al. 2011
[48] Clark et al. 2010

Finally, changes in *Ecosystem Services* and *Human Well-being* have consequences for the socio-economic sectors.

Question 10: *Which **Economic Sectors** (Driving Forces) benefit from Ecosystem Services and Human Well-being?*

The economy in general may benefit from increased worker health and productivity, while specific sectors may be impacted by changes in recreational opportunities (**Fig. 3-21**).

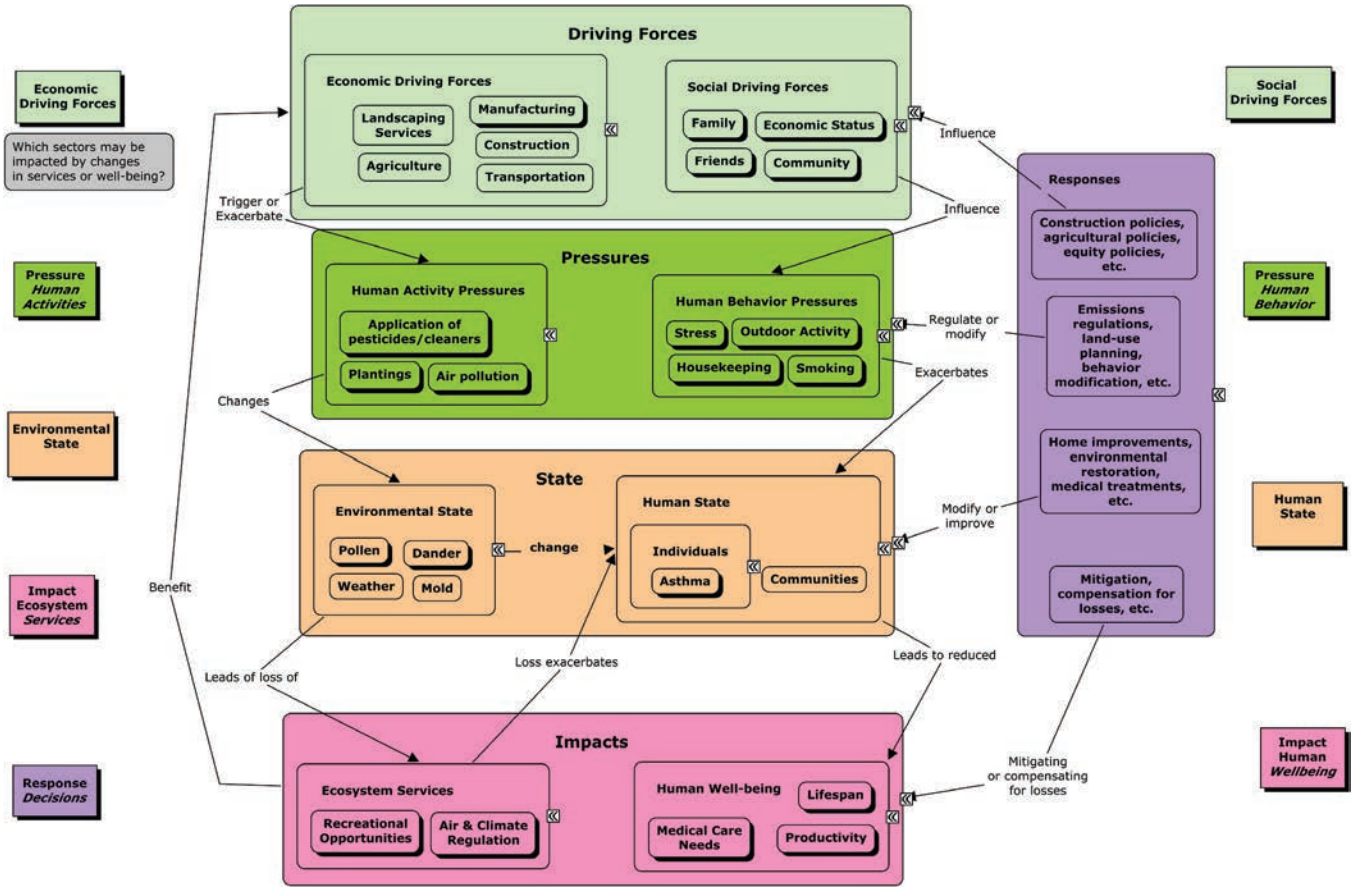


Figure 3-21. *Economic Sectors* (*Driving Forces*) that benefit from *Ecosystem Services* and *Human Well-being* (*Impacts*)

Chapter 4. Summary

Conceptual frameworks such as DPSIR provide a mechanism for planning and organizing information, identifying knowledge gaps or stakeholder concerns, identifying metrics or indicators for assessment, and providing the conceptual basis for mathematical models[49]. The DPSIR framework has been widely lauded as a communication tool among policy makers, scientists, and the public for its ability to simplify in five steps the complex topic of environmental management[50]. To make the DPSIR framework more broadly applicable to issues of sustainability, this report has extended the framework by integrating human health and ecosystem health into a single framework. Furthermore, this report has provided a hierarchical system of DPSIR subcategories and concepts and provided guidelines for discussion.

4.1 Identifying and Conceptualizing the Problem

Stakeholder discussions, structured within an overarching framework, can better define the issue under consideration and help identify concepts and relationships of primary concern to participants[51]. In a formal decision analysis, DPSIR can provide a guided discussion tool, such as described in Chapter 3, for eliciting participant objectives and the means to achieve them[52].

The flexibility of the DPSIR framework allows the initial concept to be anywhere within DPSIR, depending on the specific economic, ecological, or management concerns of the decision maker. Although starting with a narrow set of concerns, framing the problem within DPSIR encourages the decision-maker to adopt a systems approach, and think about the uphill and downhill challenges to the problem within the larger system[53].

Decision-makers are apt to see more options when the major concepts (socio-economic driving forces, human activities, environmental variables, human impacts) are identified and overlaid with potential responses[54]. DPSIR also encourages decision-makers to think about problems and solutions with an eye toward the long view—for example, how might a particular solution play out over the long run? And what unintended consequences might it have?

4.2 Collecting and Analyzing Relevant Data

Once key research areas and science questions have been identified, scientific data can be collected and analyzed to better understand the system[55]. One of the identified advantages of a

[49] Yee et al. 2011
[50] Ojeda-Martinez et al. 2009
[51] Joffe and Mindell 2006; Knol et al. 2010; Yee et al. 2011; Bradley et al. 2013
[52] Yee et al. 2015
[53] http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=235356
[54] Odermatt 2004
[55] Ojeda-Martinez 2009

framework like DPSIR is that it implies causal relationships among the factors[56]. Because DPSIR hints at the dynamics of the system[57], it can provide the conceptual foundation for development of mathematical simulation models for forecasting effects of alternative decision scenarios on long-term sustainability and health of communities.

Development of mathematical simulation models requires integration and coordination across a number of disciplines including social, ecological and health sciences. Computational models for complex systems are inherently more complicated than a conceptual framework, but the Eco-Health DPSIR can serve to highlight key variables and relationships, for which parameter estimates and functions will be needed, and to identify areas where existing models may be appropriate or where new models are needed[58]. When fully parameterized, the DPSIR framework can therefore support economic cost-benefit analysis of various *Responses* (management actions) and the value of the *Impacts* (ecosystem goods and services).

4.3 Appraising Scientific and Assessment Outcomes

Even without development of rigorous mathematical simulation models, the Eco-Health DPSIR is useful for identifying potential unintended consequences of decisions, both beneficial and adverse. Identifying potential side effects of decisions is extremely difficult, particularly when scientific knowledge and data are incomplete[59]. By planning and executing scientific research within a conceptual framework, however, decision-makers will have access to a fuller suite of knowledge, organized in a way that enables tracing interactions among concepts through the system. Thus, through development of a DPSIR, potential tradeoffs among stakeholders begin to emerge.

The Eco-Health DPSIR can also benefit research planning. Even when individual scientific research projects are separate, pieces of the system, a well-designed DPSIR can provide context for linking their objectives and results, and interpreting them collectively[60]. This process, in turn, can identify critical knowledge gaps and needs for additional research.

Additionally, the use of concept mapping software or relational database tools allows direct annotation of DPSIR concepts with literature, science questions, research projects, collaborators, or other information[61]. The systematic organization of information can be used to prioritize research needs through a combination of literature reviews and expert opinion on the concepts and relationships that are likely to be important[62].

[56] Smeets and Weterings 1999
[57] Knol et al. 2010
[58] Joffe and Mindell 2006; Yee et al. 2011
[59] Knol et al. 2010
[60] Joffe and Mindell 2006
[61] Giupponi 2007; Yee et al. 2011
[62] Russell et al. 2011

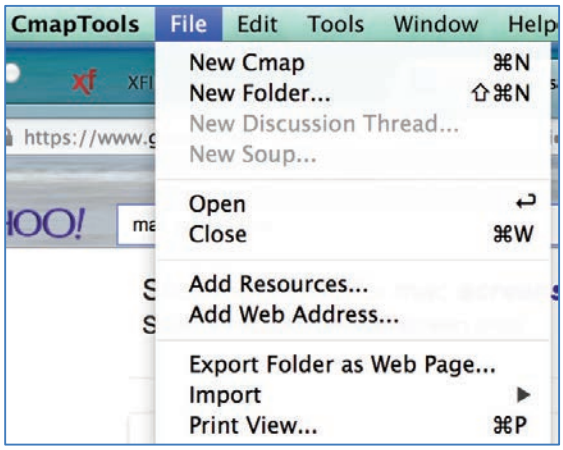
Appendix A: CmapTools Software Guidance

Download and Install Cmap Tools

The CmapTools software can be downloaded from http://cmap.ihmc.us/. Follow the website instructions for downloading and installing the software.

Create a New Cmap

From the "Views - CmapTools" window**:** Select **File**, then **New Cmap**.



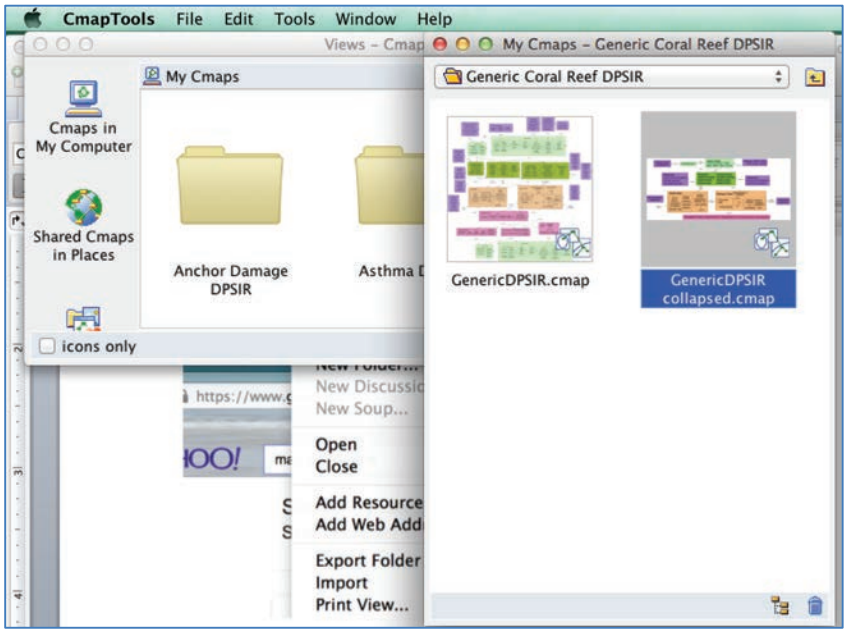
Open an Existing Cmap

From the "Views - CmapTools" window**:** Select **File**, then **Open**.

From **Edit** on the menu bar, select **Preferences**.

Browse to the folder where the existing Cmap is and select **OK**.

Highlight the Cmap that you wish to open.

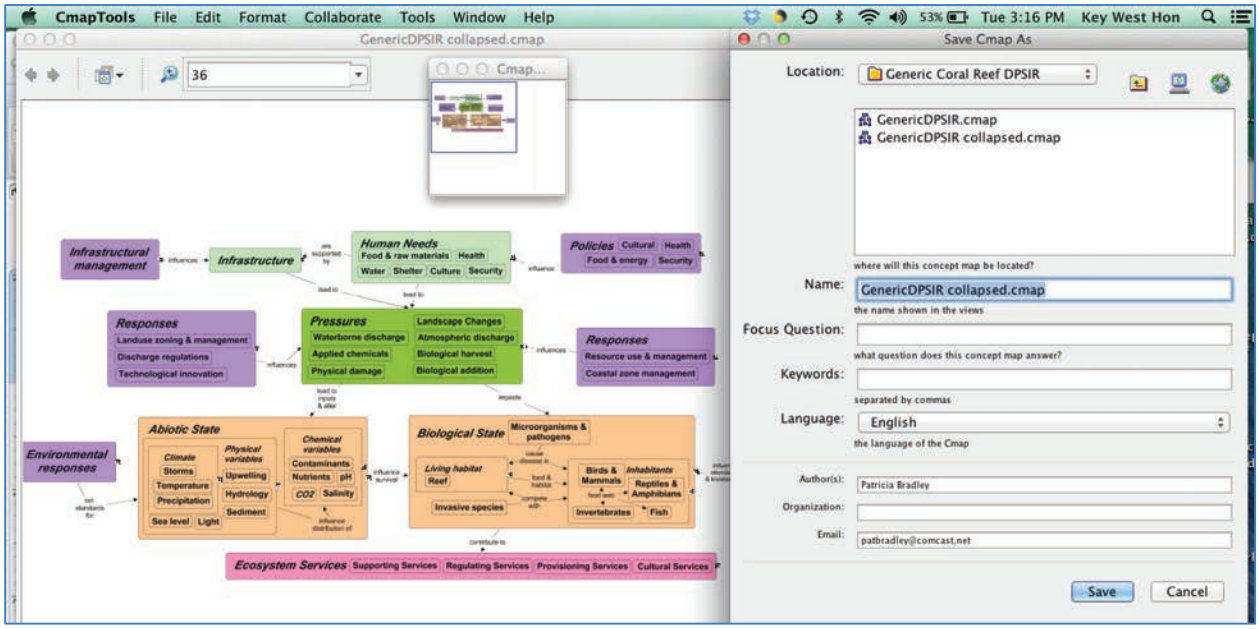


Save a Cmap

To save to a particular folder, first select **Preferences** from the **Edit** menu under the window "Views – CmapTools".

Browse to the folder where you wish to save the Cmap and select **OK**.

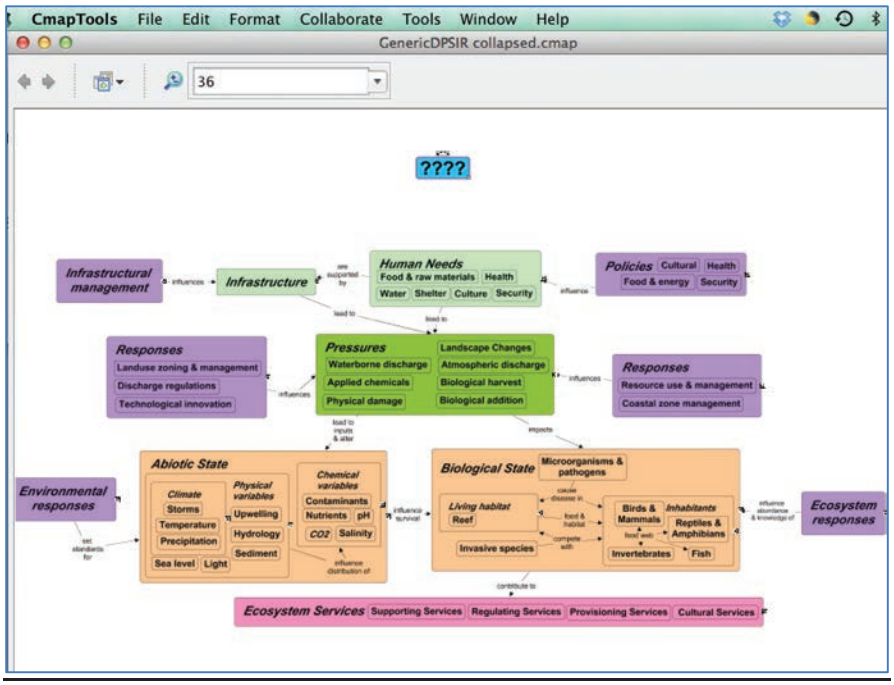
From your Cmap window, select **File**, then either **Save Cmap** if you intend to save editing on an existing Cmap, or **Save Cmap As** to save a new Cmap.



Add a Concept

Using the left mouse button, double-click anywhere on the Cmap.

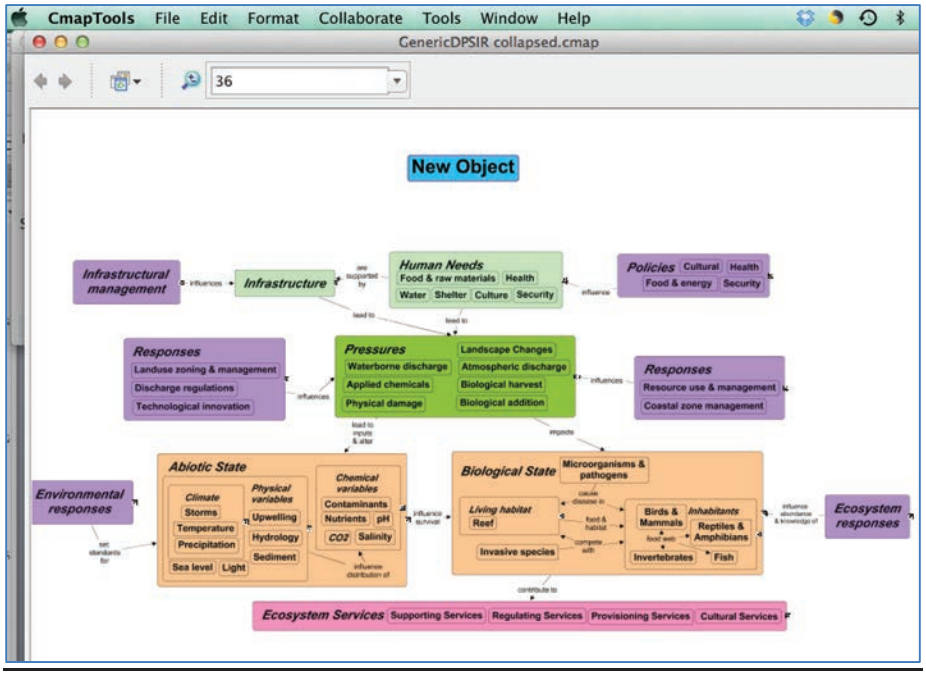
A shape will appear with question marks inside of it (blue box with question marks).



Type in a label to replace the question marks.

Left-click on a white portion of the Cmap outside of the shape to set the label.

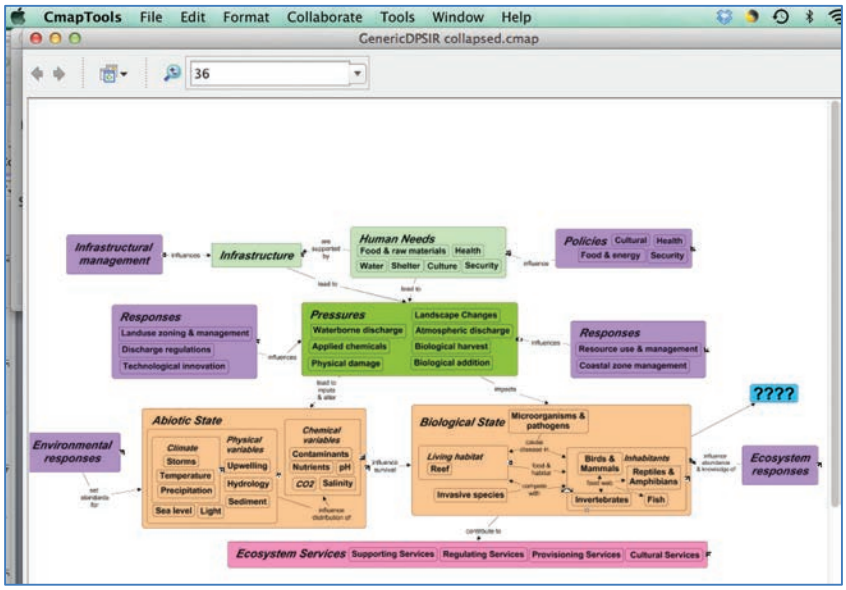
The shape has now become a new **concept** (blue box that says “New Object”).



Create a Proposition from One Concept

Left-click on the concept you would like to make a new proposition from. Left-click and drag from the arrows at the top of the concept.

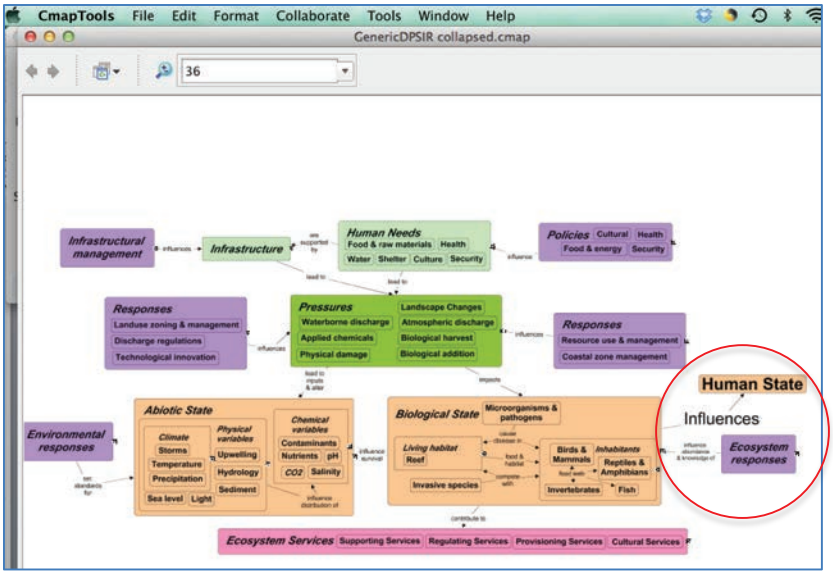
As you continue to hold the mouse button down, notice that an arrow from the selected concept will follow around the mouse pointer.



Drag the arrow some distance away from the concept and release the mouse. A new concept will be created, along with a rectangle that connects the two concepts (blue box with question marks).

Type in a label for the rectangle, then left-click on a white portion of the Cmap to set the label.

A **linking phrase** for the new proposition has now been created. These may reflect a verb that implies causality, such as “causes” or “leads to”. Box is now labeled “Human State” and the linking verb “influences” has been added.



To create only an arrow and prevent the linking phrase box from being created, hold the shift key when you left-click and drag the arrow to a new concept.

Create a Proposition from Existing Concepts

Starting with two or more concepts, left-click on a concept you would like to make a new proposition from.

Left-click and drag from the arrows at the top of the concept.

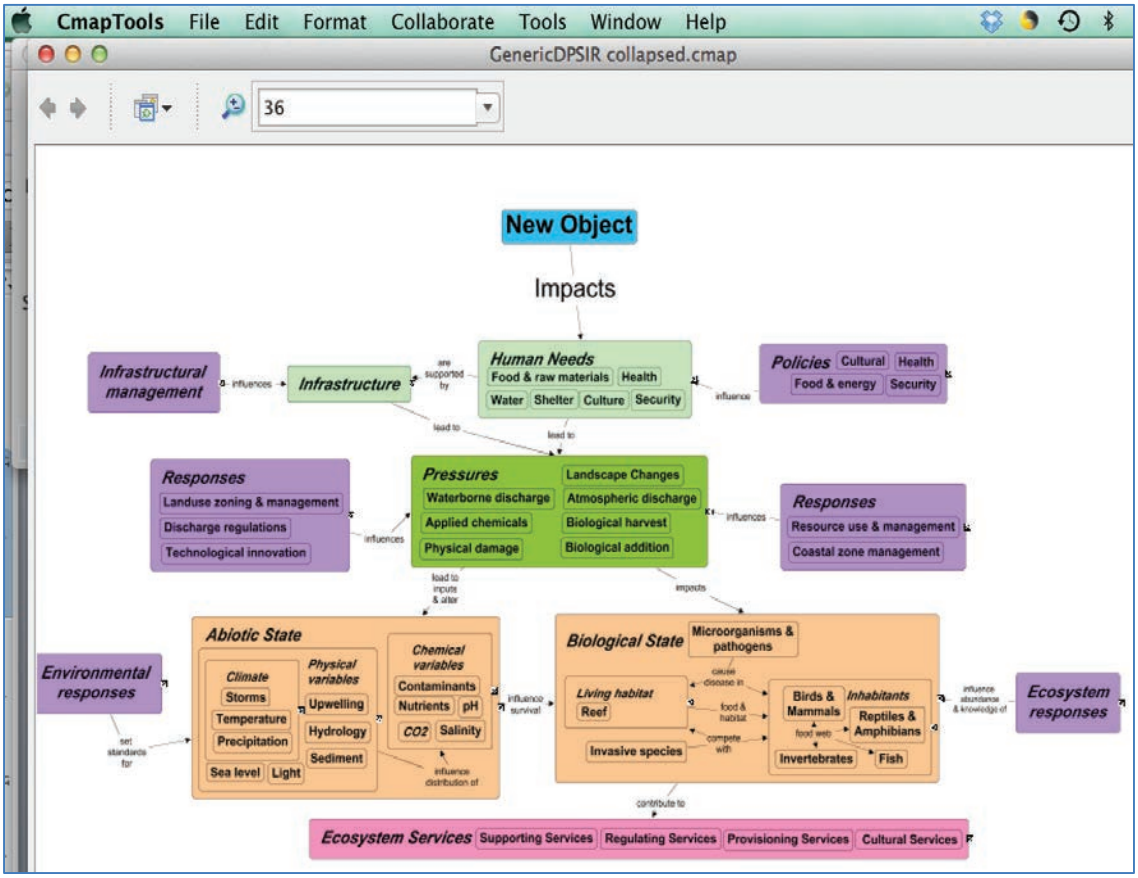
As you continue to hold the mouse button down, notice that an arrow from the selected concept will follow around the mouse pointer.

Select another concept to drag the arrow over and release the mouse. (The selected concept is the blue box entitled “New Object”.)

A rectangle will appear with lines connecting to both concepts.

Type in a label for the rectangle to add a **linking phrase**. (The verb “Impacts” links the concepts).

To create only an arrow and prevent the linking phrase box from being created, hold the shift key when you left-click and drag the arrow between concepts.

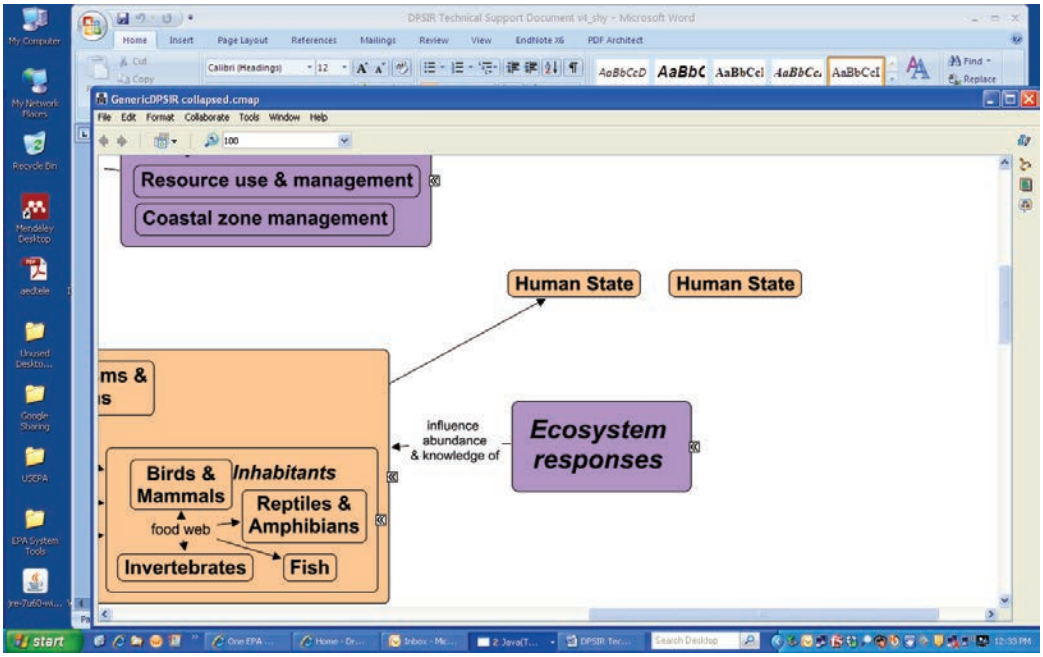


Copy/Paste or Edit an Existing Concept

Right-click on an existing concept.

The concept may be copied by selecting "**Copy**" from the "**Edit**" on the menu-bar or pressing Ctrl+C.

Select the white portion of the Cmap. Select "**Paste**" from the "**Edit**" menu, or Ctrl+V, to paste the concept. The pasted concept will retain the formatting of the copied concept.

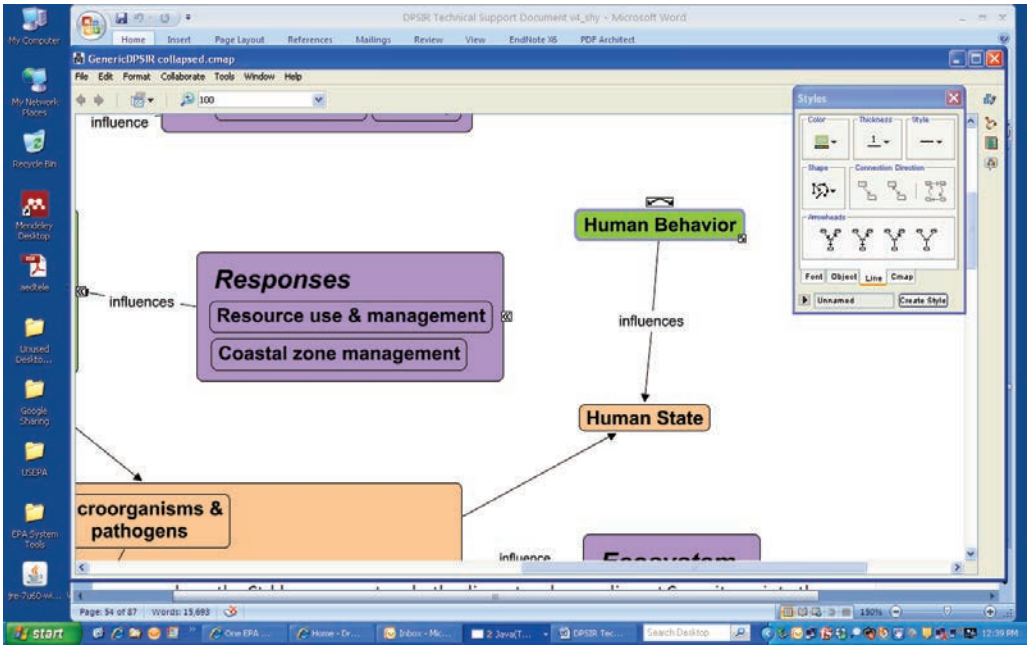


The text may be editing by double-clicking inside the concept box, and replacing the existing text with new text.

Change Colors

To change the color of a concept, select the concept by right-clicking it.

Then left-click **Object...** from the menu that appears. The "Styles" window will open to the **Object** dialog.



<u>Selecting Multiple Cmap Objects</u>. You can change the color of multiple Cmap items at the same time.

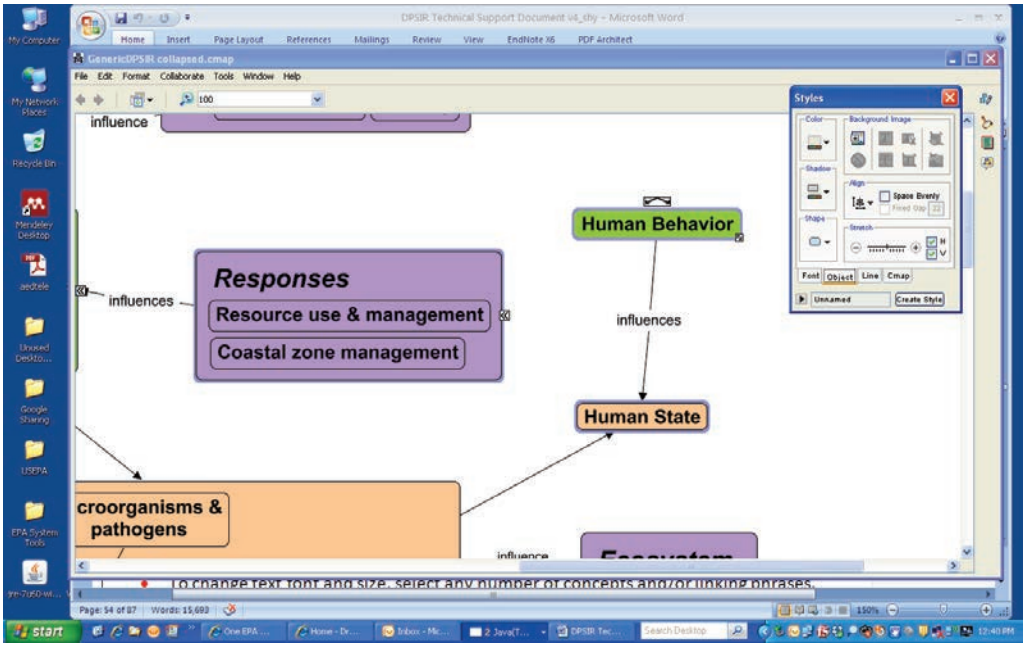
A way to select multiple adjacent Cmap items is by clicking and holding the left mouse button to drag a **selection rectangle** over the items.

By holding down Ctrl and left-clicking on items, more than one non-adjacent item may be selected. A combination of left-clicking and dragging rectangles, all while holding down the Ctrl key, can capture both adjacent and non-adjacent Cmap items into the selection.

You can also use the "**Select**" options under the "**Edit**" menu to select all, concepts only, lines only, or linking phrases only.

Then right-click to set the style for your selection.

Note: Three items have been selected in the image below: The purple box named "Responses", the green box named "Human Behavior' and the orange box named "Human State". You can tell they have been selected, because they are outlined in a thicker purple line.

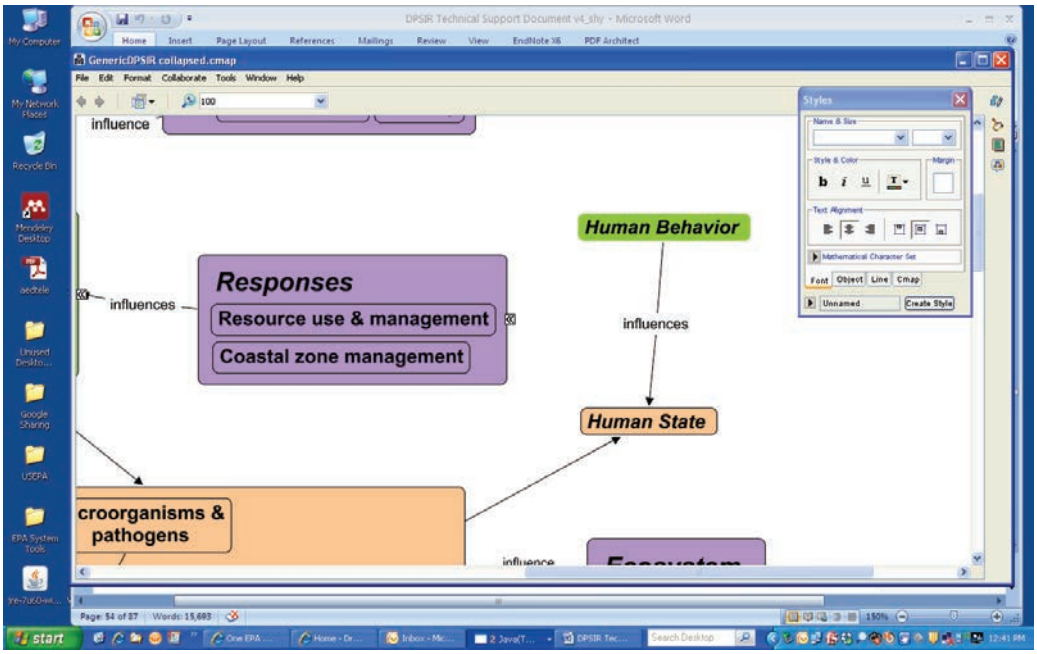


Change Fonts and Sizes

To change text font and size, select any number of concepts and/or linking phrases. Right-click the selection.

Then left-click **Format Style**. A sub-menu appears.

Now left-click the **Font...** menu item. The "Styles" window will open to the **Font** dialog.



Add or Change Direction of Arrows to Linking Lines. You can change the directional emphasis within propositions by using arrows. Right-click the selection.

Then left-click **Line...** from the **Format Style** sub-menu.

The order in which concepts are created for propositions affects the direction that linking line arrows point. Propositions may not appear logical until the arrow direction is reversed.

To reverse the direction that linking line arrows point, begin with a selection that includes these lines.

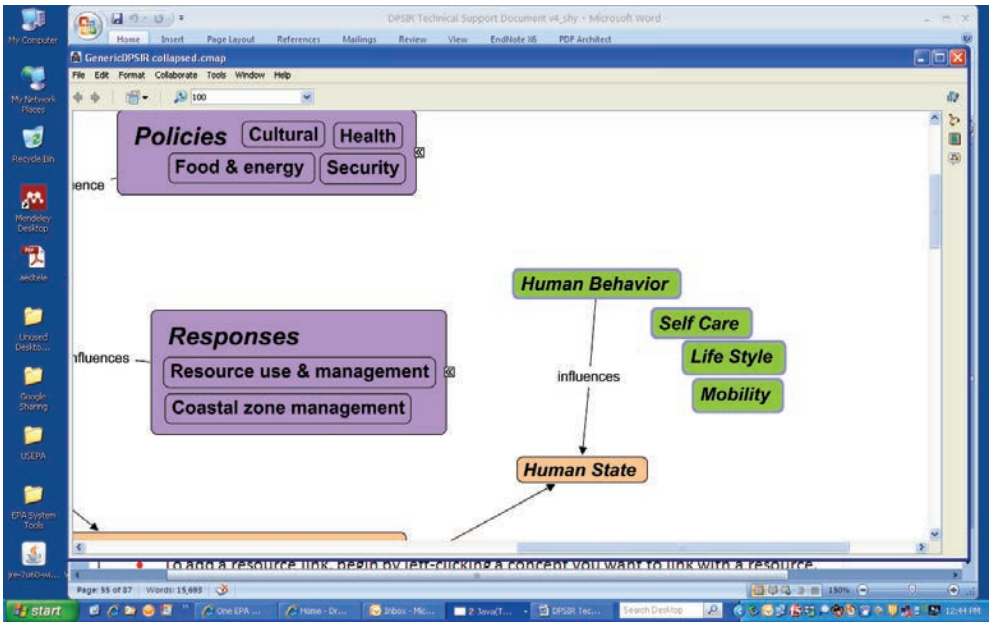
Right-click the selection.

Then left-click **Line...** from the **Format Style** sub-menu. The "Styles" window will open to the **Line** dialog.

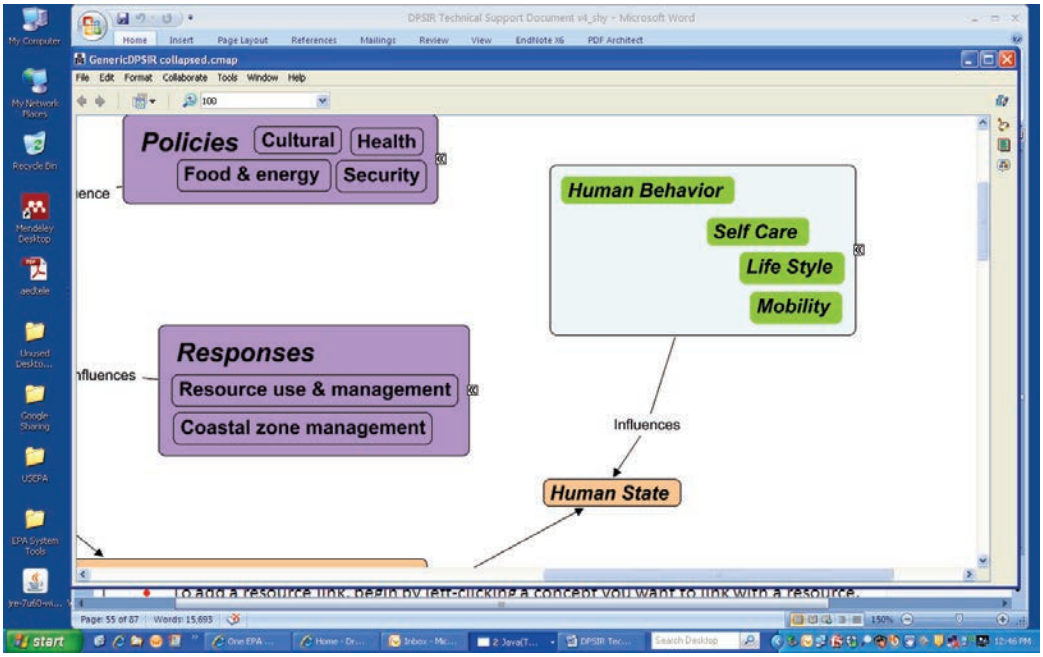
Left-clicking the **Reverse** button (under the **Connection Direction** heading) will reverse the direction that arrows point.

Nested and Merged Nodes. You can provide more detail about a subject by putting Cmap items inside of a ***nested node***. Nested nodes are useful when you want to add extra information to an expandable concept, and wish to be able to quickly access or hide it as needed.

To create a nested node, begin by right-clicking a selection of Cmap items you want to include in the node. All Cmap items may be selected by pressing Ctrl+a. In the image below, the green items “Human Behavior” “Self Care”, “Lifestyle” and “Mobility” have all been selected.

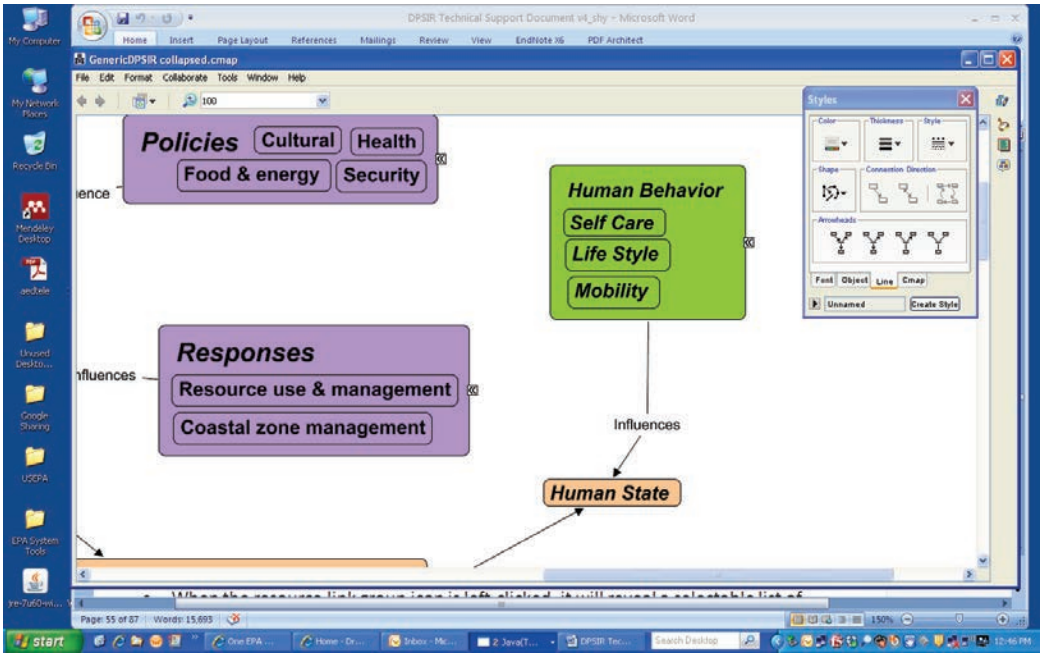


Left-click **Nested Node**, then left-click **Create** from the sub-menu. The nested node initially appears in its ***expanded mode*** with a set of arrows on the right.



You can expand or collapse a nested node by left-clicking the set of arrows (<<) on the right of the node. A nested node enters ***label mode*** once it is collapsed. In label mode, the nested node may be labeled just as a normal concept would.

Cmap items located inside nested nodes may be arranged just the same as if the items were located in their own Cmap.



To reveal other Cmap items that may be covered up by an expanded nested node, return the node to its label mode.

To add existing Cmap items to a nested node, hold shift while dragging the selection of items into the node.

Add and Edit Links to Resources

To add a resource link, begin by left-clicking a concept you want to link with a resource.

Select **Edit.**

Then select **Add and Edit Links to Resources...** from the menu bar.

You can also perform this action by right-clicking the selected concept.

Then left-click on **Add and Edit Links to Resources...** from the menu that appears.

Using the "Editing Resource Links for [...]" window, you can manually navigate through folders to add resource links to concepts in Cmaps. Now when viewing the Cmap, a **resource link group icon** will appear attached to the concept.

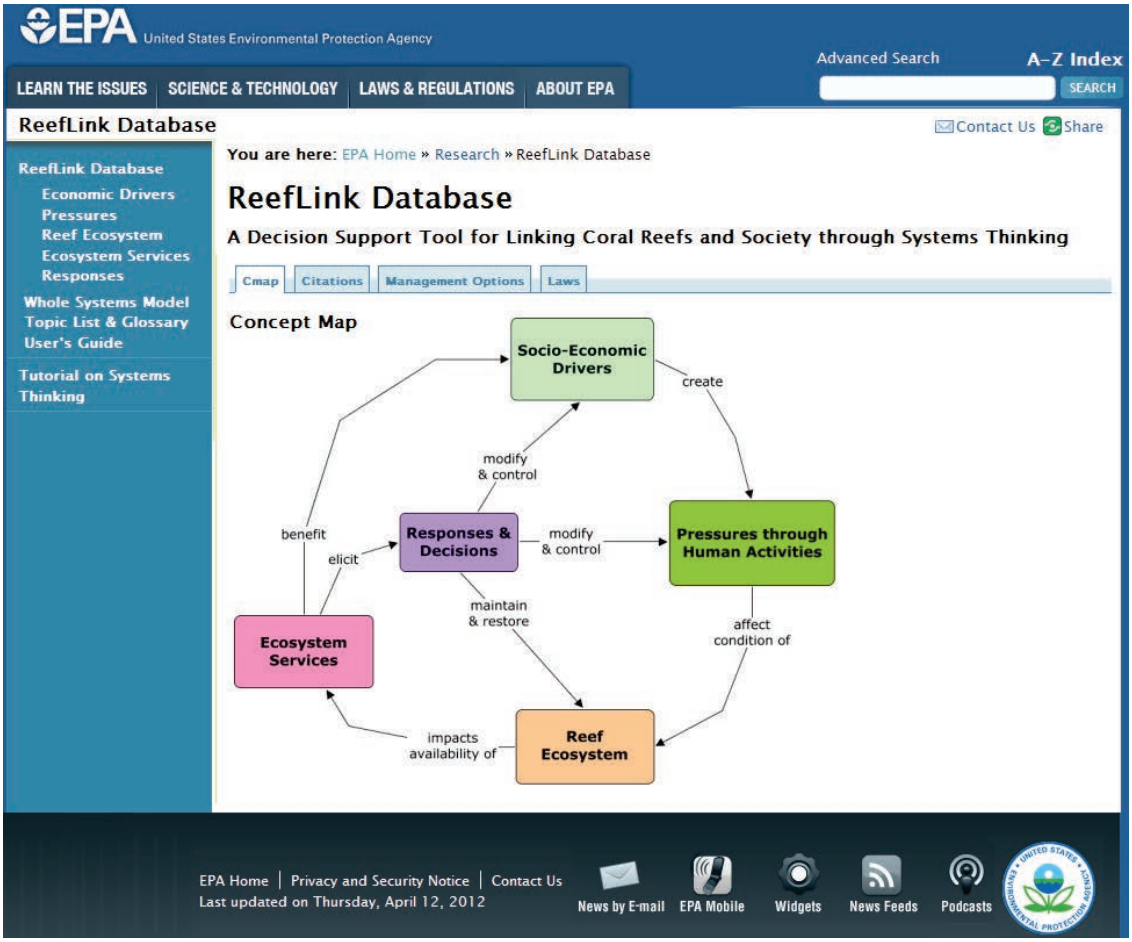
When the resource link group icon is left-clicked, it will reveal a selectable list of resources that have been added to the concept.

Appendix B: Operational Systems-Thinking Tools–The ReefLink Database, Tutorial on Systems Thinking and the Eco-Health Relationship Browser

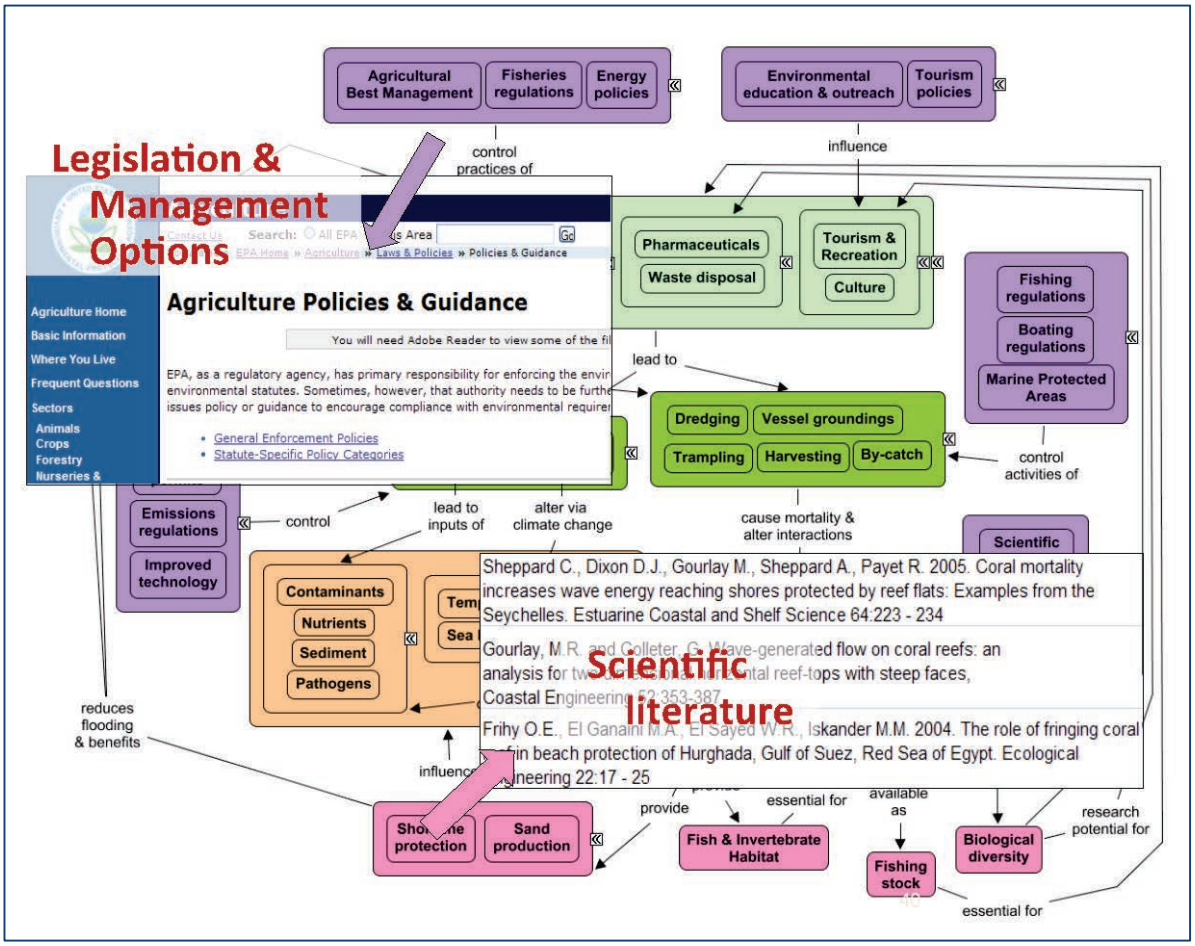
EPA scientists have developed several tools to transfer the information: the ReefLink Database, a Tutorial on Systems Thinking and the Eco-Health Relationship Browser.

The ReefLink Database

The ReefLink Database utilizes the DPSIR framework to describe the linkages between decisions, human activities, and provisioning of coral reef ecosystem goods and services.



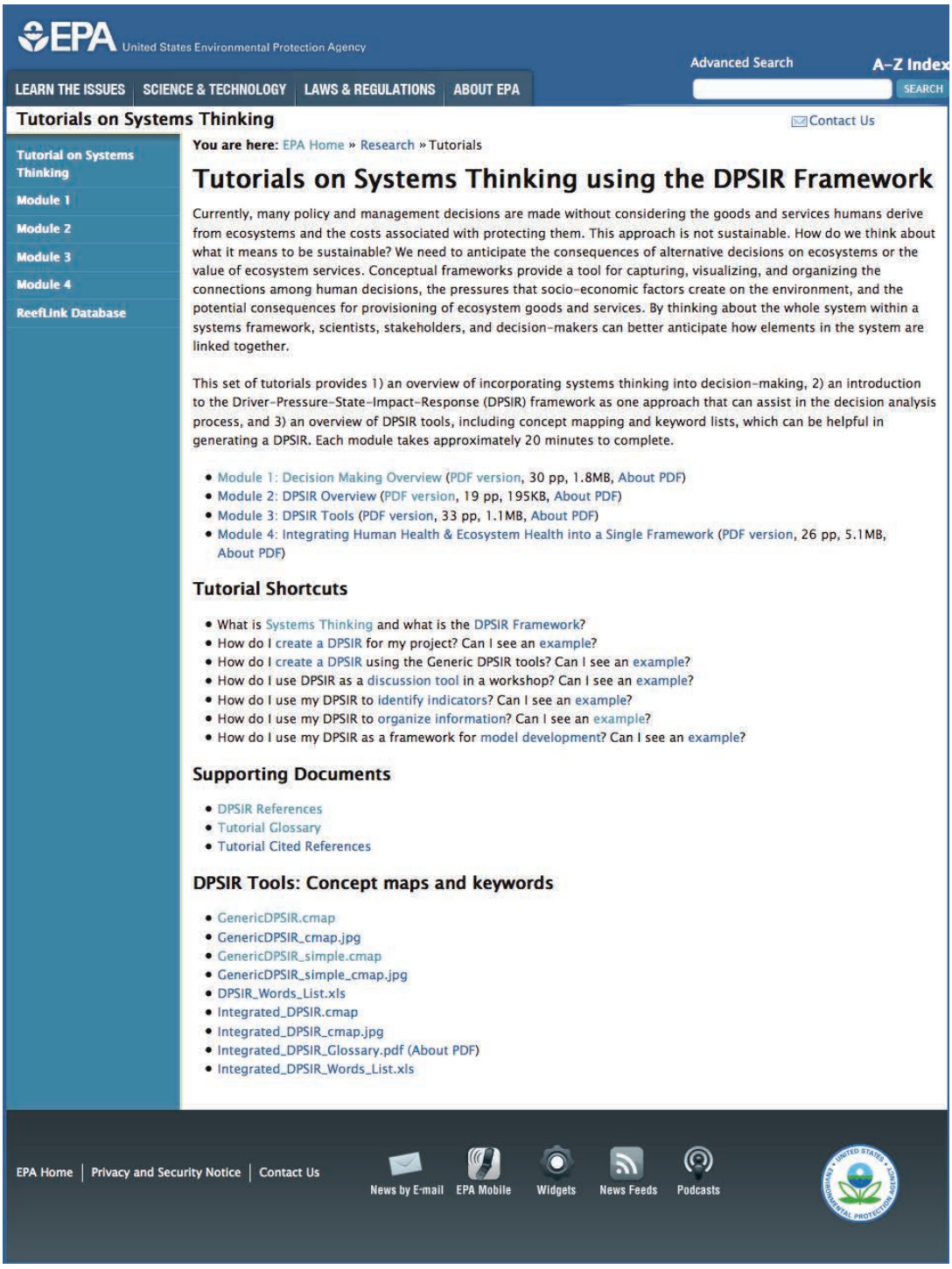
This database provides a navigable hierarchy of related topics and information for each topic including concept maps, scientific citations, management options, and laws.



The database can be used by: 1) the public to learn how their community may affect or benefit from coral reefs, 2) scientists to identify decision scenarios for which their research may be relevant, and 3) reef managers to understand how systems thinking can aid in identifying alternative management options. The ReefLink Database can be accessed at: http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=242306

Tutorial on Systems Thinking

The Tutorial on Systems Thinking provides: 1) an overview of how to incorporate systems thinking into decision-making, 2) an introduction to the DPSIR framework for linking socioeconomic and environmental factors in decision-making, 3) an illustration of several tools, including concept mapping and keyword lists, which can be helpful in generating a DPSIR, and 4) an example of using DPSIR to integrate human health and ecosystem health into a single framework. The tutorial can be accessed at: http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId =235356.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Module 2
Module 3
Module 4
ReefLink Database
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Tutorials on Systems Thinking using the DPSIR Framework
Currently, many policy and management decisions are made without considering the goods and services humans derive from ecosystems and the costs associated with protecting them. This approach is not sustainable. How do we think about what it means to be sustainable? We need to anticipate the consequences of alternative decisions on ecosystems or the value of ecosystem services. Conceptual frameworks provide a tool for capturing, visualizing, and organizing the connections among human decisions, the pressures that socio-economic factors create on the environment, and the potential consequences for provisioning of ecosystem goods and services. By thinking about the whole system within a systems framework, scientists, stakeholders, and decision-makers can better anticipate how elements in the system are linked together.
This set of tutorials provides 1) an overview of incorporating systems thinking into decision-making, 2) an introduction to the Driver-Pressure-State-Impact-Response (DPSIR) framework as one approach that can assist in the decision analysis process, and 3) an overview of DPSIR tools, including concept mapping and keyword lists, which can be helpful in generating a DPSIR. Each module takes approximately 20 minutes to complete.
Module 1: Decision Making Overview (PDF version, 30 pp, 1.8MB, About PDF)
Module 2: DPSIR Overview (PDF version, 19 pp, 195KB, About PDF)
Module 3: DPSIR Tools (PDF version, 33 pp, 1.1MB, About PDF)
Module 4: Integrating Human Health & Ecosystem Health into a Single Framework (PDF version, 26 pp, 5.1MB, About PDF)
Tutorial Shortcuts
What is Systems Thinking and what is the DPSIR Framework?
How do I create a DPSIR for my project? Can I see an example?
How do I create a DPSIR using the Generic DPSIR tools? Can I see an example?
How do I use DPSIR as a discussion tool in a workshop? Can I see an example?
How do I use my DPSIR to identify indicators? Can I see an example?
How do I use my DPSIR to organize information? Can I see an example?
How do I use my DPSIR as a framework for model development? Can I see an example?
Supporting Documents
DPSIR References
Tutorial Glossary
Tutorial Cited References
DPSIR Tools: Concept maps and keywords
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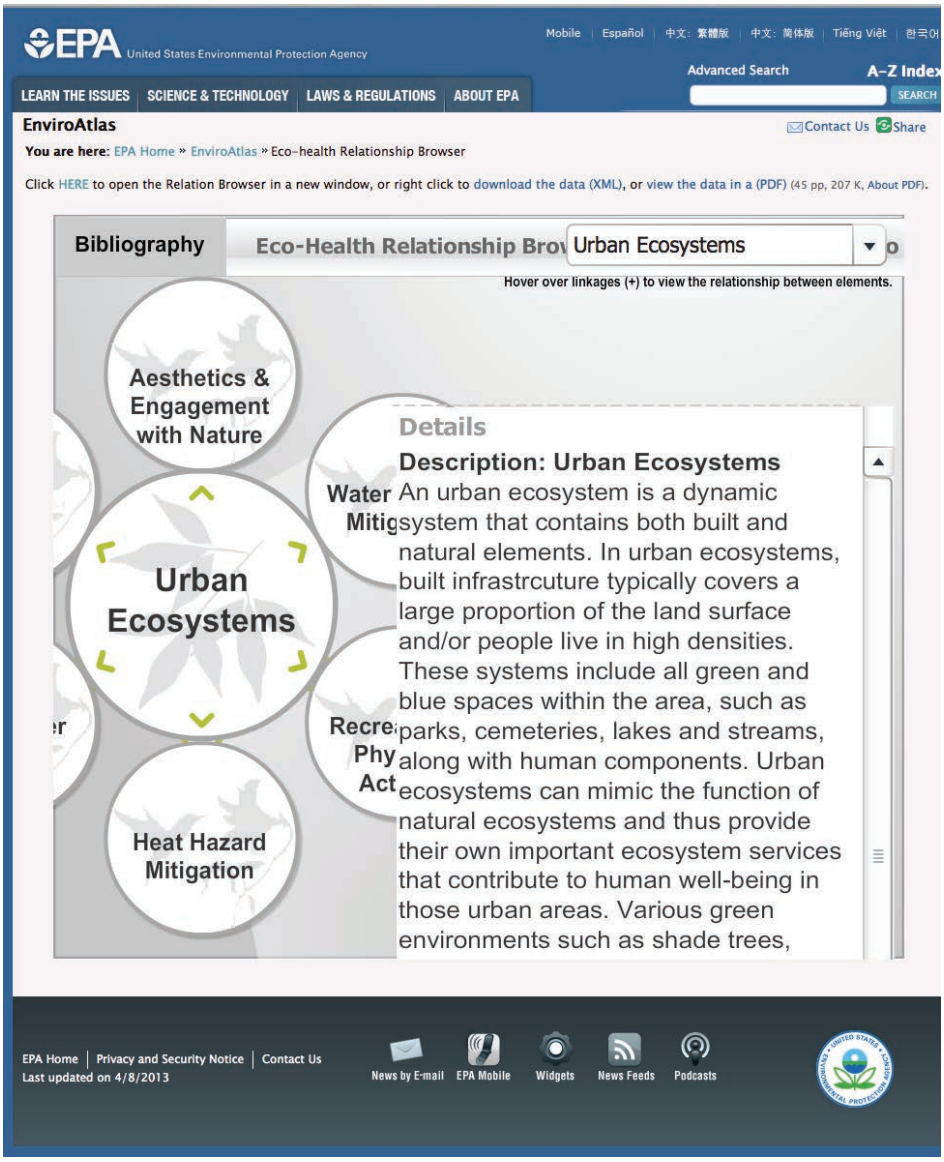
GenericDPSIR_simple.cmap
GenericDPSIR_simple_cmap.jpg
DPSIR_Words_List.xls
Integrated_DPSIR.cmap
Integrated_DPSIR_cmap.jpg
Integrated_DPSIR_Glossary.pdf (About PDF)
Integrated_DPSIR_Words_List.xls
EPA Home | Privacy and Security Notice | Contact Us
News by E-mail
EPA Mobile
Widgets
News Feeds
Podcasts

The Eco-Health Relationship Browser

The Eco-Health Relationship Browser illustrates scientific evidence for linkages between human health and ecosystem services—benefits supplied by Nature. While not DPSIR-based, this interactive tool does provide information about several of our nation's major ecosystems, the services they provide, and how those services, or their degradation and loss, may affect people. The Eco-Health Relationship Browser can be accessed at: http://enviroatlas.epa.gov/enviroatlas/Tools/EcoHealth_RelationshipBrowser/introduction.html.



Appendix C: Systems-Thinking Tools under Development at EPA–DASEES and SystemSketch

EPA is developing an open-source, web-based decision analysis framework called DASEES: Decision Analysis for a Sustainable Environment, Economy and Society. DASEES integrates guidance and decision support tools to implement a five step iterative Bayesian decision process:

Step 1 - Understand Context
Step 2 - Define Objectives
Step 3 - Develop Options
Step 4 - Evaluate Options
Step 5 - Take Action

DASEES provides guidance and software tools that can be used to support decision-making by applying a Structured Decision Process. DASEES provides a suite of tools to assist users to establish the context within which the management problem is contained – the Decision Landscape (DL) Suite.

A **Decision Landscape** Section allows users to summarize the political, regulatory, social, institutional and scientific context of the decision.

A **Social Network Analysis (SNA)** tool provides a visual insight into who is, and more importantly, who is not sharing in the information flow for the decision at hand.

A ***Driving Forces-Pressures-States-Impacts-Response*** **(DPSIR)** model (**SystemSketch**) enables causal understanding in the decision context. SystemSketch provides a dynamic, graphic visualization tool to help stakeholders better understand system context and access to information resources.

GIS-based visualization tools.

A “sandbox” area for exploring and recording thoughts and ideas that arise during deliberation.

DASEES is still a prototype and has not yet been released for public use.

Appendix D: Glossary

Brainstorming - a group problem-solving technique in which members spontaneously share ideas and solutions.

Coral reef – a complex tropical marine ecosystem dominated by soft and hard (stony) corals, anemones and sea fans. Stony corals are small animals with an outer skeleton of calcium carbonate that form colonies and are responsible for reef building.

Decision landscape – a decision support framework for capturing the physical, legal, and institutional environment in which a particular management choice is made; it includes identification of management and policy options, outcomes of interest, and stakeholder valuation of outcomes, as well as the key participants involved in making the decision (decision makers, information collectors, and stakeholders), the information they use to inform the decision and that information's associated uncertainty, and the methods of assessment they use to evaluate outcomes.

Decision maker – a person(s) entrusted with the responsibility to make a decision. Decision makers include federal, territorial and government managers, corporations, non-governmental organizations and the general public.

Decision-making – an outcome of mental processes leading to the selection of a course of action among several management options.

Decision support tools – software, models, data sets, maps, etc. to support decision-making.

DPSIR – a decision support framework for capturing the physical and human processes in a decision process; it includes the identification of the ***D****riving Forces* (socioeconomic sectors that drive human activities), ***P****ressures* (human activities that stress the environment), resulting environmental and ecological ***S****tates* (reflect condition of the natural and living phenomena), ***I****mpacts* on services and values (effects of environmental degradation of ecological attributes and ecosystem services), and ***R****esponses* to those impacts (policies and responses).

Drivers (*Driving Forces*) – the economic and social factors that motivate human activities and fulfill basic human needs for materials for a good life, good health, good social relations, security, and freedom.

Eco-Health DPSIR – an extended version of DPSIR that includes parallel tracks for ecosystem health and human health (Yee et al. 2012)

Ecosystem - includes the plant and animal communities in an area together with the non-living physical environment that supports them. Ecosystems have physically defined boundaries, but they are also dynamic: their boundaries and constituents can change over time. They can import and export materials and energy and thus can interact with and influence other ecosystems. They can also vary widely in size.

Ecosystem Goods and Services **–**are outputs of ecological processes that directly (final ecosystem service) or indirectly (intermediate ecosystem service) contribute to social welfare (Munns et al. 2015).

Human Well-being - the condition of humans and society, defined in terms of the basic material and other natural resource needs for a good life, freedom and choice, health, wealth, social relations, and personal security.

Impacts **–** changes in the quality and value of ecosystem services, and ultimately human well-being, caused by changes in environmental or human condition.

Management options –alternatives that are under the control of decision makers and from which one or a combination of several (to be implemented as a strategy) can be chosen.

Market valuation – an economic assessment of the price at which an asset would trade in an auction setting.

Model – a physical, mathematical, or logical representation of a system of entities, phenomena, or processes; i.e. a simplified abstract view of the complex reality.

Non-market valuation – an economic assessment of willingness to pay for environmental goods and services, such as clean water or healthy wildlife, which are not revealed in market prices.

Outcomes – the results, impacts or consequences of making a decision.

Pathogen – microorganisms (e.g., bacteria, viruses, or parasites) that can cause disease in humans, animals and plants.

Pressures **–** human activities that stress the condition of the environment or humans.

Social network – a decision support framework for capturing the people involved in a decision making process and the relationships between them, such as who has authority to make decisions and who they work or interact with. Social relationships are typically depicted in terms of nodes (individuals within networks) and ties (relationships between the individuals).

Stakeholders – individuals, groups, or organizations impacted by a management choice.

State **–** condition of humans and the environment, including physical, chemical, and natural living components

Uncertainty – inability to predict outcomes due to random variability (for example, streamflow is sometimes high and sometimes low) or incomplete scientific knowledge regarding causal relationships (for example, how does a given concentration of sediments in the harbor affect coral reef growth rates).

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