

# Marine Ecosystem Services

Definitions and Classification Systems

# Many definitions for “ecosystem services”

- Generally: The direct or indirect contributions ecosystems make to the well-being of human populations

**Table 1**  
Definitions of ecosystem services and their sources commonly cited in the literature. The Philosophy column indicates whether the definition used in the article is that ecosystem services lead to (→) or are the same as (=) benefits.

Definition of ecosystem services	Citation	Philosophy
...“the benefits human populations derive, directly or indirectly, from ecosystem functions.”	(Costanza et al., 1997)	Ecosystem services = benefits
...“the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life.”	(Daily, 1997)	Ecosystem services → benefits
...“the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly.”	(de Groot et al., 2002)	Ecosystem services → benefits
...“the set of ecosystem functions that is useful to humans.”	(Kremen, 2005)	Ecosystem services → benefits
...“the benefits people obtain from ecosystems.”	(MEA, 2005)	Ecosystem services = benefits
...“components of nature, directly enjoyed, consumed, or used to yield human well-being.”	(Boyd and Banzhaf, 2007)	Ecosystem services → benefits
...“the aspects of ecosystems utilized (actively or passively) to produce human well-being.”	(Fisher et al., 2009)	Ecosystem services → benefits
...“a range of goods and services generated by ecosystems that are important for human well-being.”	(Nelson et al., 2009)	Ecosystem services → benefits
...“Benefits that humans recognize as obtained from ecosystems that support, directly or indirectly, their survival and quality of life.”	(Harrington et al., 2010)	Ecosystem services = benefits
...“a collective term for the goods and services produced by ecosystems that benefit humankind.”	(Jenkins et al., 2010)	Ecosystem services → benefits

Source: Nahlik, Kentula, Fennessy, and Landers (2012, Ecological Economics)

# Operationalizing ecosystem services

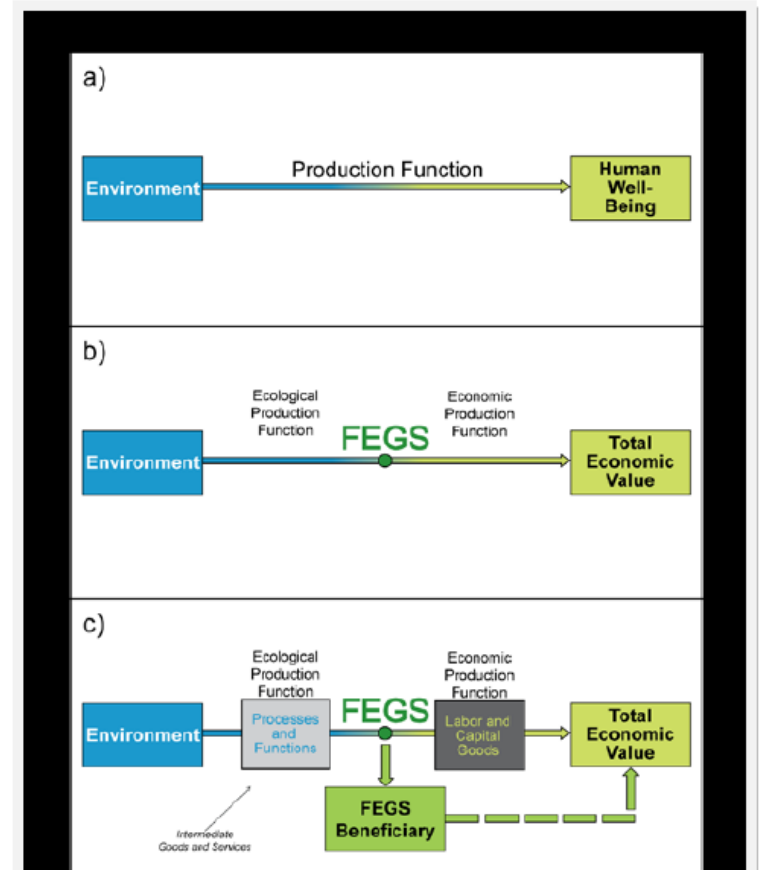
- Key problem: How can we define ecosystem services so that they can be clearly identified, quantified, and valued?

# Final vs. Intermediate Ecosystem Services

- Boyd and Banzhaf (2007, Ecological Economics) focus on final ecosystem services to avoid double-counting in environmental accounting
  - “Final ecosystem service units”
  - Final ecosystem services occur at the handoff between natural systems (i.e., ecosystems) and human systems (producers and consumers; alt. social-cultural-economic systems)
  - Intermediate ecosystem services are inputs to natural processes that produce final ecosystem services
- Nahlik et al. (2012, Ecological Economics) review the different ways of defining and classifying ecosystem services and evaluate them in terms of which are most appropriate for moving concepts to practice (towards operationalization)

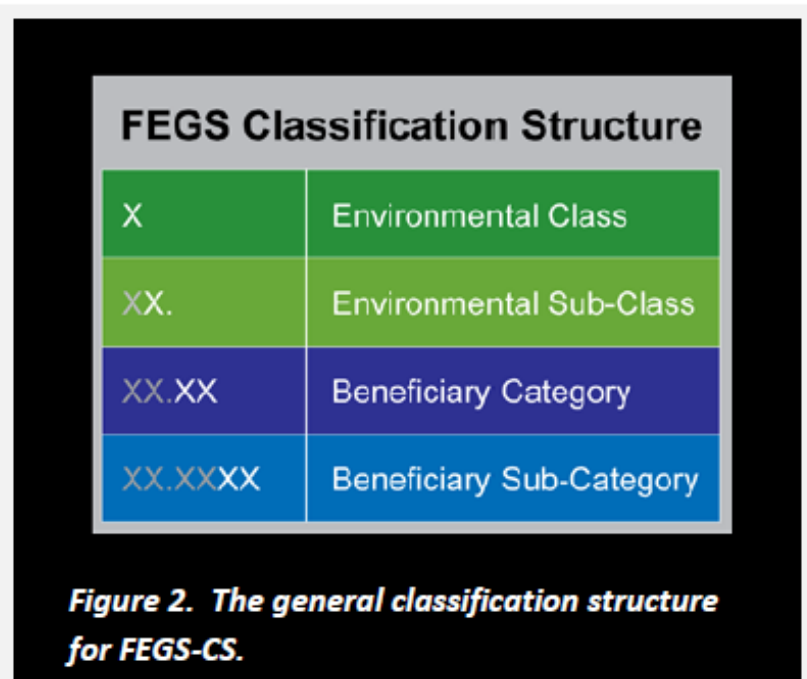
# Final Ecosystem Goods and Services – Classification System (FEGS-CS)

- Landers and Nahlik (2013) develop a consistent classification scheme with 4 goals
  1. Avoid ambiguity inherent in other ecosystem service definitions
  2. Minimize or avoid double-counting
  3. Provide a bridge between natural and social sciences that facilitates direct communication and collaboration
  4. Be **beneficiary-specific** and may be understood by people without translation or interpretation

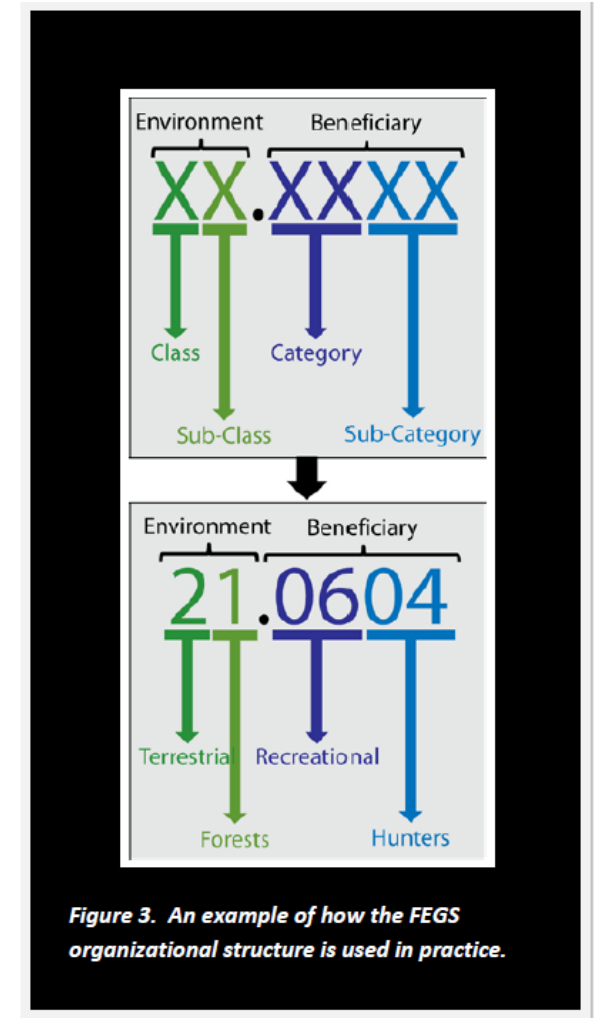


*Figure 1. Illustration of a) a production function between the environment and human well-being, b) how FEGS can be used to delineate the ecological production function from the economic production function, and c) examples of inputs for both production functions. The beneficiary is specific and inherent to the FEGS in the production function.*

# Basic elements of FEGS-CS



1. Clearly define Environmental Class (and sub-class)
2. Identify the Beneficiary categories
3. For a specific Beneficiary category and Environmental Class, hypothesize FEGS received



Source: Landers and Nahlik (2013), [https://cfpub.epa.gov/si/si\\_public\\_record\\_Report.cfm?Lab=NHEERL&dirEntryId=257922](https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NHEERL&dirEntryId=257922)

# Defining the Environmental Class of the Ecosystem Service under FECS-CS

There are 3 main Environmental Classes

***Text Box 3. Environmental Classes and Sub-Classes used in the FECS-CS.***

**1. AQUATIC**

- 11. Rivers and Streams
- 12. Wetlands
- 13. Lakes and Ponds
- 14. Estuaries and Near Coastal and Marine
- 15. Open Oceans and Seas
- 16. Groundwater

**2. TERRESTRIAL**

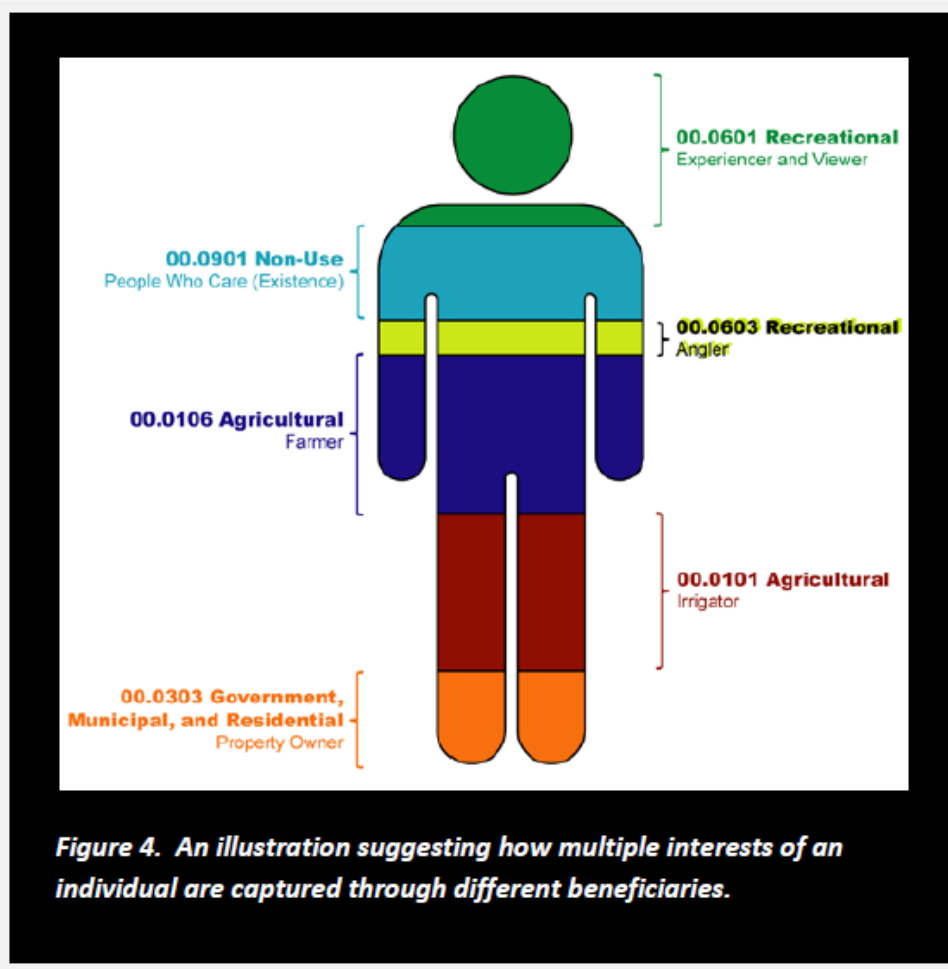
- 21. Forests
- 22. Agroecosystems
- 23. Created Greenspace
- 24. Grasslands
- 25. Scrubland / Shrubland
- 26. Barren / Rock and Sand
- 27. Tundra
- 28. Ice and Snow

**3. ATMOSPHERIC**

- 31. Atmosphere

# One person may be multiple beneficiaries!

In Landers and Nahlik (2013), there are 10 Beneficiary Categories and 38 Beneficiary Sub-Categories in the FECS-CS



**Text Box 4.** Guiding questions for determining FECS, including examples of questions (Q) and answers (A).

- For a specific Environmental Sub-Class, which Beneficiary Sub-Categories are present?
  - **Q:** Do Recreational Food Pickers and Gatherers utilize Estuaries and Near Shore Marine environments? **A:** Yes.
- For a specific Beneficiary Sub-Category interested in a specific Environmental Sub-Class, what are the FECS? Or, what does the beneficiary utilize or care about (to receive a benefit) that is directly provided by the environment?
  - **Q:** What do Recreational Food Pickers and Gatherers utilize from Estuaries and Near Shore Marine environments that result in a benefit? **A:** Flora and fauna, such as seaweed, kelp, mussels, crabs, etc.
- What is the importance of this [set of] FECS to the beneficiary?
  - **Q:** Why do Recreational Food Pickers and Gatherers in Estuaries and Near Shore Marine environments care about flora and fauna? **A:** These are edible organisms that can be picked or gathered for personal use.



# FEGS-CS Beneficiary Sub-categories

## Beneficiary [Sub-]Categories:

### AGRICULTURE (all)

- Irrigators
- CAFO Operators
- Livestock Grazers
- Agricultural Processors
- Aquaculturists
- Farmers
- Foresters

### COMMERCIAL/INDUSTRIAL TRANSPORTATION (all)

- Transporters of Goods
- Transporters of People

### COMMERCIAL / INDUSTRIAL (all)

- Food Extractors
- Timber, Fiber, and Ornamental Extractors
- Industrial Processors
- Industrial Dischargers
- Electric and other Energy Generators
- Resource-Dependent Businesses
- Pharmaceutical and Food Supplement Suppliers
- Fur / Hide Trappers and Hunters

### SUBSISTENCE (all)

- Water Subsisters
- Food Subsisters
- Timber, Fiber, and Fur / Hide Subsisters

### GOVERNMENT, MUNICIPAL, and RESIDENTIAL (all)

- Municipal Drinking Water Plant Operators
- Waste Water Treatment Plant Operators
- Residential Property Owners
- Military / Coast Guard

### RECREATIONAL (all)

- Experiencers and Viewers
- Food Pickers and Gatherers
- Hunters

# Categories of FEGS

- “Categories of FEGS” are not FEGS
- They are heuristics used to classify FEGS in the FEGS-CS system

***Text Box 5. Twenty-one categories used to organize FEGS in the FEGS-CS.***

- 01 water
- 02 flora
- 03 presence of the environment
- 04 fauna
- 05 fiber
- 06 natural materials
- 07 open space
- 08 viewscapes
- 09 sounds and scents
- 10 fish
- 11 soil
- 12 pollinators
- 13 depredators and (pest) predators
- 14 timber
- 15 fungi
- 16 substrate
- 17 land
- 18 air
- 19 weather
- 20 wind
- 21 atmospheric phenomena

# Determining a FEGS from an intermediate one

Principles for assessing whether an ecosystem service/good can be considered a “final ecosystem good or service” or not

FEGS Boundary Principles	
1	Intermediate goods and services (e.g., photosynthesis, carbon sequestration, biodiversity, etc.) are generally ecosystem structural components, functions, and processes that are not directly used or appreciated by individuals and, thus, are not FEGS. Moreover, most humans do not recognize or understand the importance of these entities. However, intermediate goods and services are vitally important and need to be understood in order to construct process models that can project FEGS into the future under different management scenarios, eventually informing trade-off analyses.
2	FEGS are components of the natural, not the built, environment; therefore, a FEGS must be connected to the lithosphere, hydrosphere, and atmosphere. For example, a tree in a city planter is not a FEGS because it is isolated from the earth (the lithosphere). Likewise, aquariums, [botanical] conservatories, and high-tech athletic fields do not qualify as FEGS.
3	Policy endpoints do not create FEGS. Policies are generally created as a reflection of a) what individuals value and b) processes or features that can be regulated - not necessarily those environmental components with which humans interact (Ringold et al. 2009). Services associated with policy are taken into consideration through specific beneficiaries (i.e., endangered bird species protection is taken into account via bird watchers x presence of endangered bird species) or in connected environments.
4	Human-made infrastructure (e.g., roads, boardwalks), buildings (e.g., marinas, welcome centers), or goods and services with a large input of labor and capital goods (e.g., agricultural row crops, stocked (i.e., put-and-take) fish, lumber from tree plantations, orchard produce, Christmas trees) are not FEGS or considered in the FEGS-CS. Many of these items are accounted for in industrial classification systems (i.e., NAICS or NAPCS). FEGS are provided directly and predominantly by the ecosystem itself and are minimally dependent upon human inputs of labor, energy, capital or other enhancements.
5	Incidental non-marketed environmental by-products of intensively produced goods and services (see principle number 4, above) may be considered FEGS. These may include vistas of agricultural lands, game associated with farmland or tree plantations (e.g., deer, pheasants), etc.
6	Increased value (i.e., property value) or sense of happiness is not a FEGS as it reflects human valuation and not something the ecosystem provides itself (see principle number 4; Ringold et al. 2009).
7	The environment itself can be a FEGS (e.g. for a marina owner – a Resource Dependent Business (14.0206), the presence of the estuary provides the FEGS).

# Some benefits of FEGS-CS identified by Landers and Nahlik (2013)

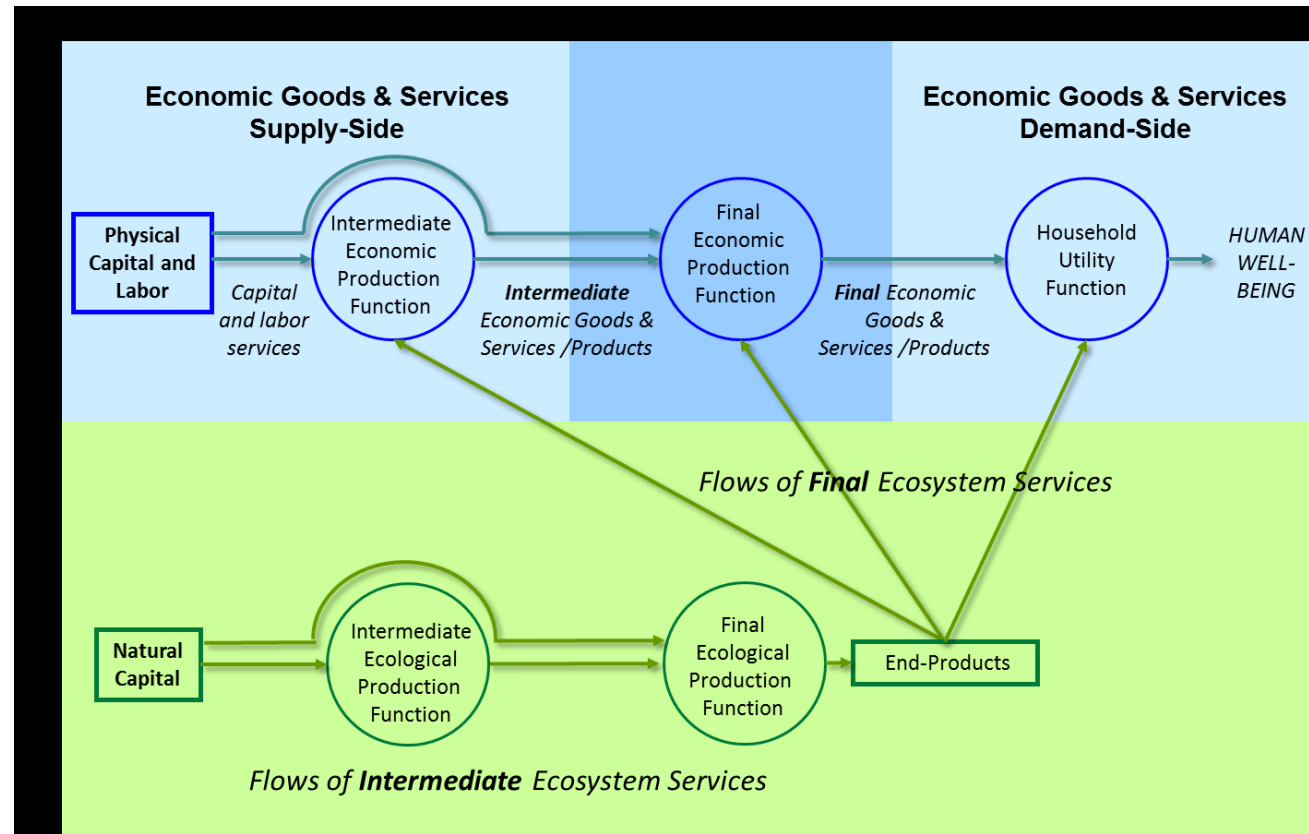
- For communication
  - Makes transparent the role of the natural environment/ecosystem in affecting humans
  - Makes clear that an individual may benefit in multiple ways from the ecosystem and in multiple roles as a beneficiary
- For economic valuation
  - Cannot be used directly for valuation, but may be helpful
  - The clear and systematic identification of FEGS
  - The minimization of double counting\* (excl. value of intermediate ES)
  - The linkage to explicit first-order depictions of specific beneficiaries

# Limitations of FEES-CS

- Doesn't distinguish between stocks and flows
  - Many FEES identified in the classification system are actually ecosystem stocks, not flows
- Double-counting of FEES may occur to the extent the same person can benefit from the same FEES but in different beneficiary roles

# Final flows of ecosystem services (FFES)

*The direct contributions made by nature to **human production processes** or to **human well-being***



Source: United States Environmental Protection Agency. 2015. *National Ecosystem Services Classification System (NESCS): Framework Design and Policy Application*. EPA-800-R-15-002. United States Environmental Protection Agency, Washington, DC.

# National Ecosystem Services Classification System

Table ES-1. NESCS Example

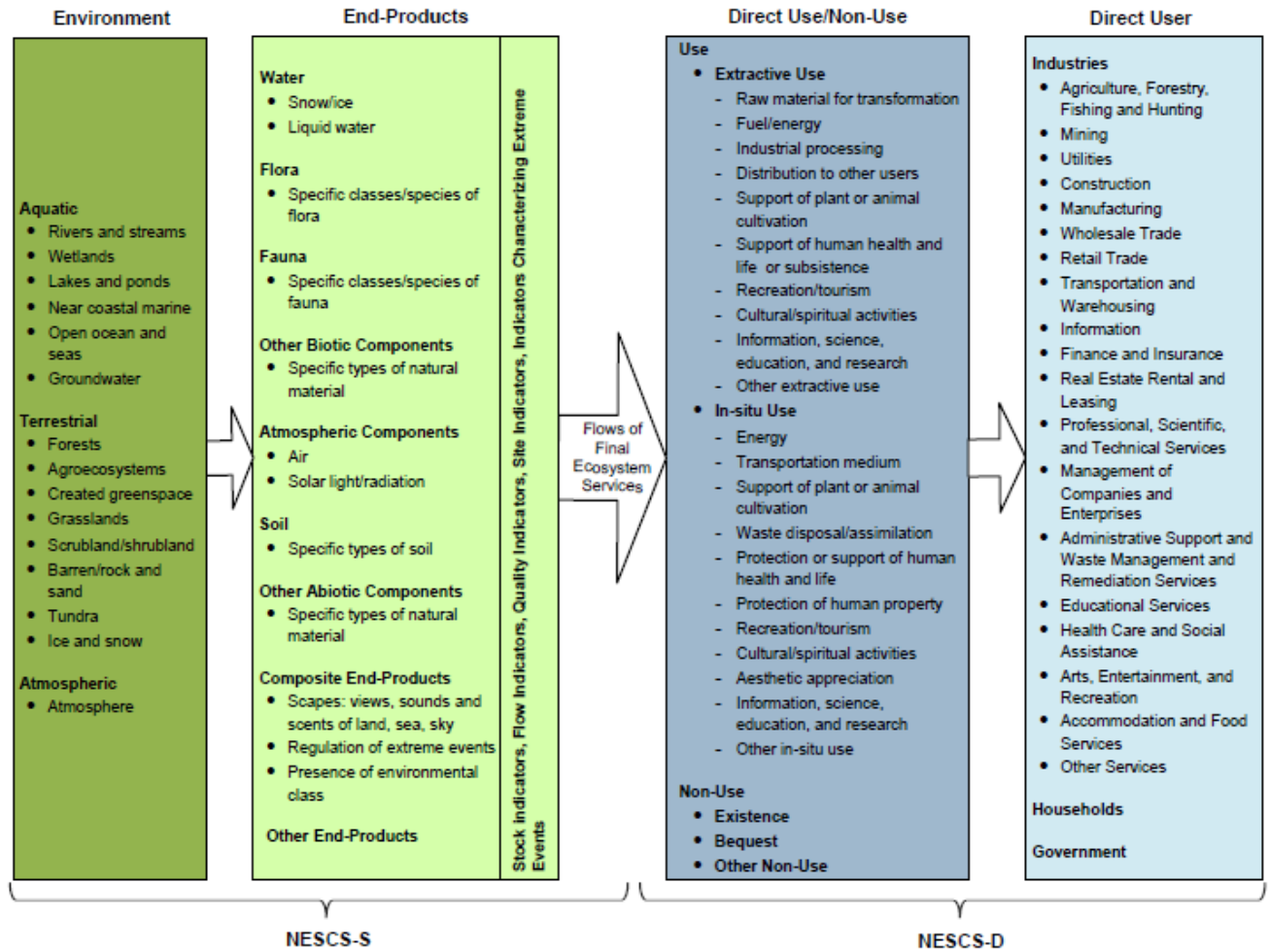
Group	NESCS-S		NESCS-D	
	Environment	End-Product	Direct Use/Non-Use	Direct User
Definition	Spatial units, with similar biophysical characteristics, that are located on or near the Earth's surface and that contain or produce "end-products"	Biophysical components of nature that are directly used or appreciated by humans	Different ways in which end-products are used or appreciated by humans	Entities that directly use or appreciate the end-products
Hierarchy and Coding System NESCS Code for FFES*: <b>WW.XX.YYYY.ZZZZZZ</b>				
Class	<b>W</b>	<b>WW.X</b>	<b>WW.XX.Y</b>	<b>WW.XX.YYYY.Z</b>
Subclass	<b>WW</b>	<b>WW.XX</b>	<b>WW.XX.YY</b>	<b>WW.XX.YYYY.ZZZ</b>
Detail			<b>WW.XX.YYYY</b>	<b>WW.XX.YYYY.ZZZZZZ</b>
Example 1: Water in the ocean being used as a medium for freight transportation NESCS Code for FFES: 15.12.1202.1483111				
Class	Aquatic: 1	Water: 1	Direct Use: 1	Industry: 1
Subclass	Open Ocean and Seas: 15	Liquid Water: 12	In-Situ Use: 12	Transportation and Warehousing: 148
Detail			Transportation medium: 1202	Deep Sea Freight Transportation: 1483111
Example 2: Water in rivers being extracted for household gardening purposes NESCS Code for FFES: 11.12.1105.201				
Class	Aquatic: 1	Water: 1	Direct Use: 1	Households: 2
Subclass	Rivers and Streams: 11	Liquid Water: 12	Extractive Use: 11	Households: 201
Detail			Support of plant or animal cultivation: 1105	

\* Note that this 15-digit code is the most disaggregated level of representation. Different levels of aggregation can be used depending on the context (See Examples 1 and 2 for different levels of aggregation for users)

- In the United States, the two main classification systems for **economic goods and services** are the North American Industry Classification System (NAICS) and the North American Product Classification System (NAPCS)
  - NAICS: How and by whom are goods and services produced
  - NAPCS: How and by whom are goods and services used
- NESCS is a parallel system that focuses on the flow of final ecosystem services (FFES)

# NESCS Structure

Figure ES-2. Proposed Four-Group NESCS Structure

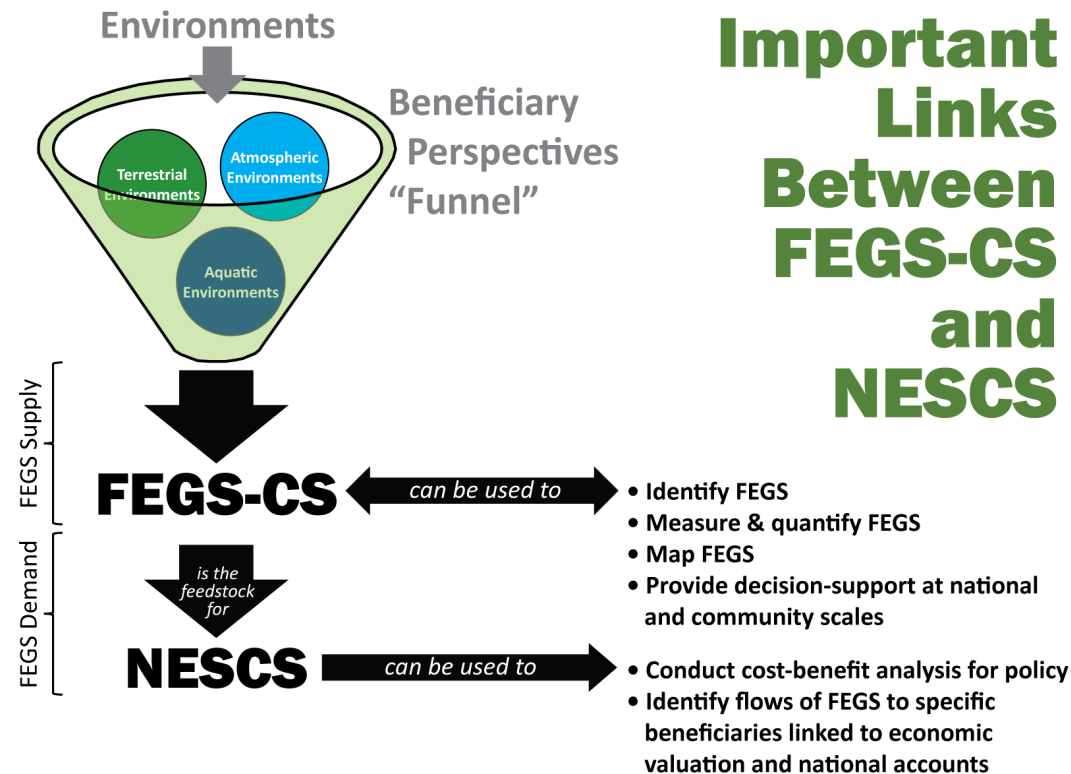




# National Ecosystem Services – Classification System (NESCS) *definitions*

- **End-products** are biophysical components of nature that are either directly used by humans to produce goods and services or directly enjoyed or used to yield human well-being. They can usually (but not always) be interpreted as stocks of ecological goods.
  - Example: Stocks of clean water in an aquifer
- **Flows of Final Ecosystem Services (FFES)** are the **contributions of nature (1) directly to human production processes or (2) directly to households and human well-being**. FFES occur at the point of hand-off between natural systems (ecosystems) and human systems (producers and households). They are represented as service flows between ecological end-products and direct human uses. Note that by definition, ecosystem services only exist when they contribute to human well-being.
  - Example: Water directly extracted from freshwater sources to support plant cultivation, food processing, and human health/well-being (as drinking water)
- **Intermediate ecosystem services** are inputs to the natural processes that ultimately produce FFES. Example: Wetlands' removal of contaminants from water flowing into aquifers
- **Intermediate economic goods and services** are produced using human inputs (physical capital and labor) and ecological inputs (FFES) and are sold to other producers. They are the outputs produced by one sector of the economy, which are then used as production inputs in another sector.
  - Example: Agricultural crops used as inputs in food processing such as corn used to produce ethanol
- **Final economic goods and services** are produced using human inputs (physical capital and labor), intermediate economic goods and services (e.g., corn) and ecological inputs (FFES) and are sold to households who use them as consumption inputs to support their own well-being. They are not used to produce other goods and services for the market economy.
  - Example: Food products sold to consumers, such as cornflakes
- **NOTE: Flows of final ecosystem goods are not included or defined in the NESCS framework. The main reason for this exclusion is that the process of transferring physical ecosystem products from nature to humans, which is necessary to generate flows of goods, typically requires human inputs. For example, transferring portions of existing timber or fish stocks to humans for their use requires human labor for harvesting. In our framework, the involvement of human inputs implies that the transferred goods are classified as economic rather than ecosystem goods.**

# Linking the FEGS-CS and NESCS

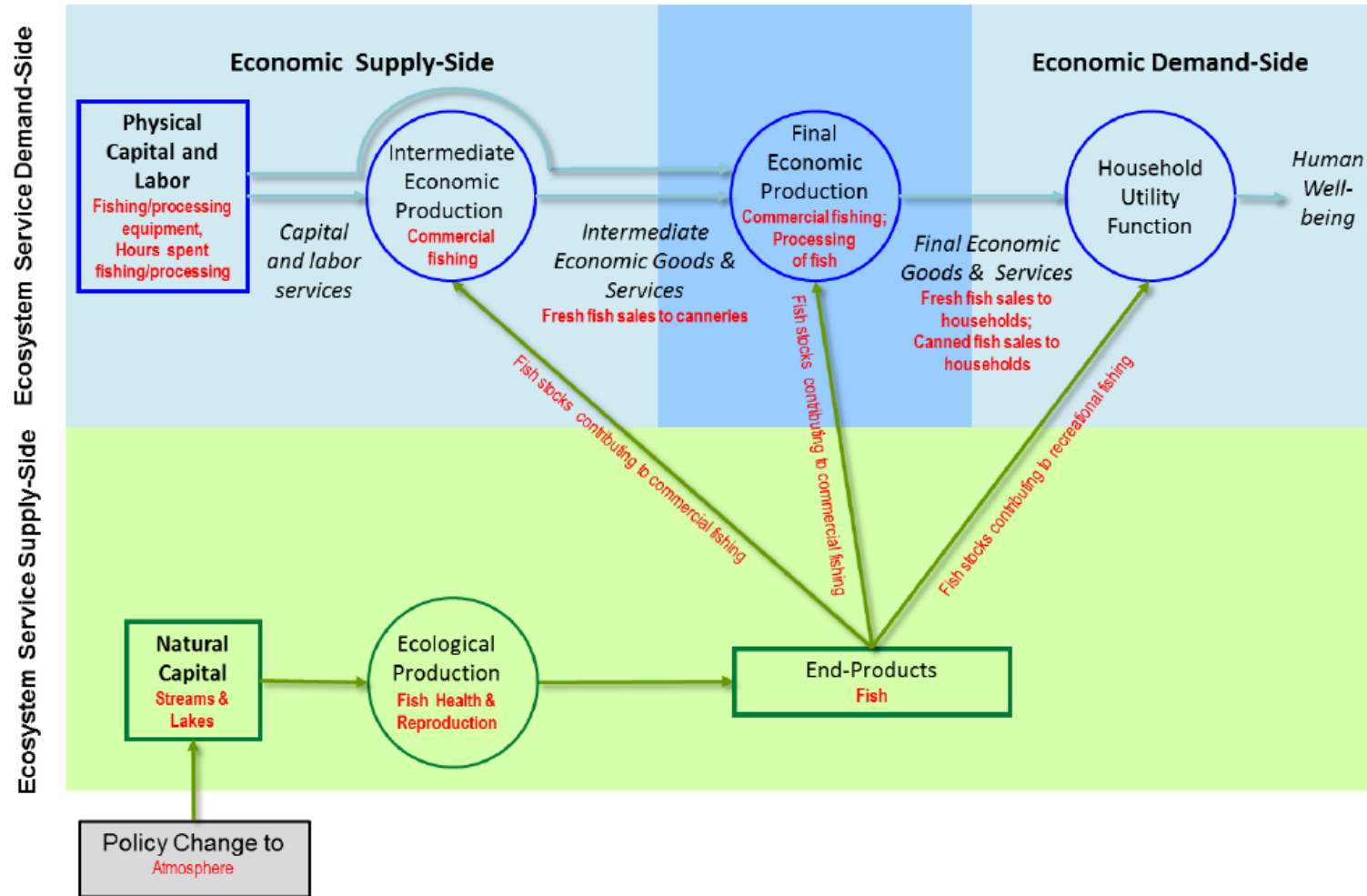


- **Figure 1** (left) FEGS-CS classifies FEGS by their environmental source and by their specific beneficiary use. The output from FEGS-CS can be used for different natural science objectives, such as the quantification of ecosystem services. The environmental categories and metrics from FEGS-CS are essential inputs to NESCS.

- Source: [https://www.epa.gov/sites/production/files/2015-09/documents/shc\\_2015\\_fegs-cs\\_and\\_nescs\\_poster.pdf](https://www.epa.gov/sites/production/files/2015-09/documents/shc_2015_fegs-cs_and_nescs_poster.pdf)

# An Example from EPA (2015)

Figure 5-3. Applying Framework: Identify Potential Pathways Impacted by Aquatic Acidification



# Other Ecosystem Services Classification Systems

- Millennium Assessment (MA) - <https://www.millenniumassessment.org/en/index.html>
- The Economics of Ecosystems and Biodiversity (TEEB) - <http://www.teebweb.org/>
- Common International Classification of Ecosystem Services (CICES) - <https://cices.eu/> (closely linked to UN Statistical Division's System of Environmental-Economics Accounting)
  - “The aim of CICES is not to replace other classifications of ecosystem services but to enable people to move more easily between them and to understand more clearly how people are measuring and analyzing information. You can see the broad equivalences between CICES and the MA, TEEB and IPBES Classifications here. There is also a spreadsheet tool available that provides broad equivalences for the US-EPA Final Ecosystem Goods and Services Classification System (FEGS-CS).”

# A Comparison of MA, TEEB, and CICES v4.3

MA categories	TEEB categories	CICES v4.3 group*
Food (fodder)	Food	Biomass [Nutrition] Biomass (Materials from plants, algae and animals for agricultural use)
Fresh water	Water	Water (for drinking purposes) [Nutrition] Water (for non-drinking purposes) [Materials]
Fibre, timber	Raw Materials	Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
Genetic resources	Genetic resources	Biomass (genetic materials from all biota)
Biochemicals	Medicinal resources	Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
Ornamental resources	Ornamental resources	Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
Air quality regulation	Air quality regulation	Biomass based energy sources Mechanical energy (animal based) [Mediation of] gaseous/air flows
Water purification and water treatment	Waste treatment (water purification)	Mediation [of waste, toxics and other nuisances] by biota Mediation [of waste, toxics and other nuisances] by ecosystems
Water regulation	Regulation of water flows Moderation of extreme events	[Mediation of] liquid flows
Erosion regulation	Erosion prevention	[Mediation of] mass flows
Climate regulation	Climate regulation	Atmospheric composition and climate regulation
Soil formation (supporting service)	Maintenance of soil fertility	Soil formation and composition
Pollination	Pollination	Lifecycle maintenance, habitat and gene pool protection
Pest regulation Disease regulation	Biological control	Pest and disease control

From:  
<https://biodiversity.europa.eu/maes/ecosystem-services-categories-in-millennium-ecosystem-assessment-ma-the-economics-of-ecosystem-and-biodiversity-teeb-and-common-international-classification-of-ecosystem-services-cices>

# From Ecosystem Services to Ecosystem Service Values

- What is “value”?
  - Economic
  - Intrinsic
  - Socio-cultural
  - Ecosystem/ecological
- How do we measure it?