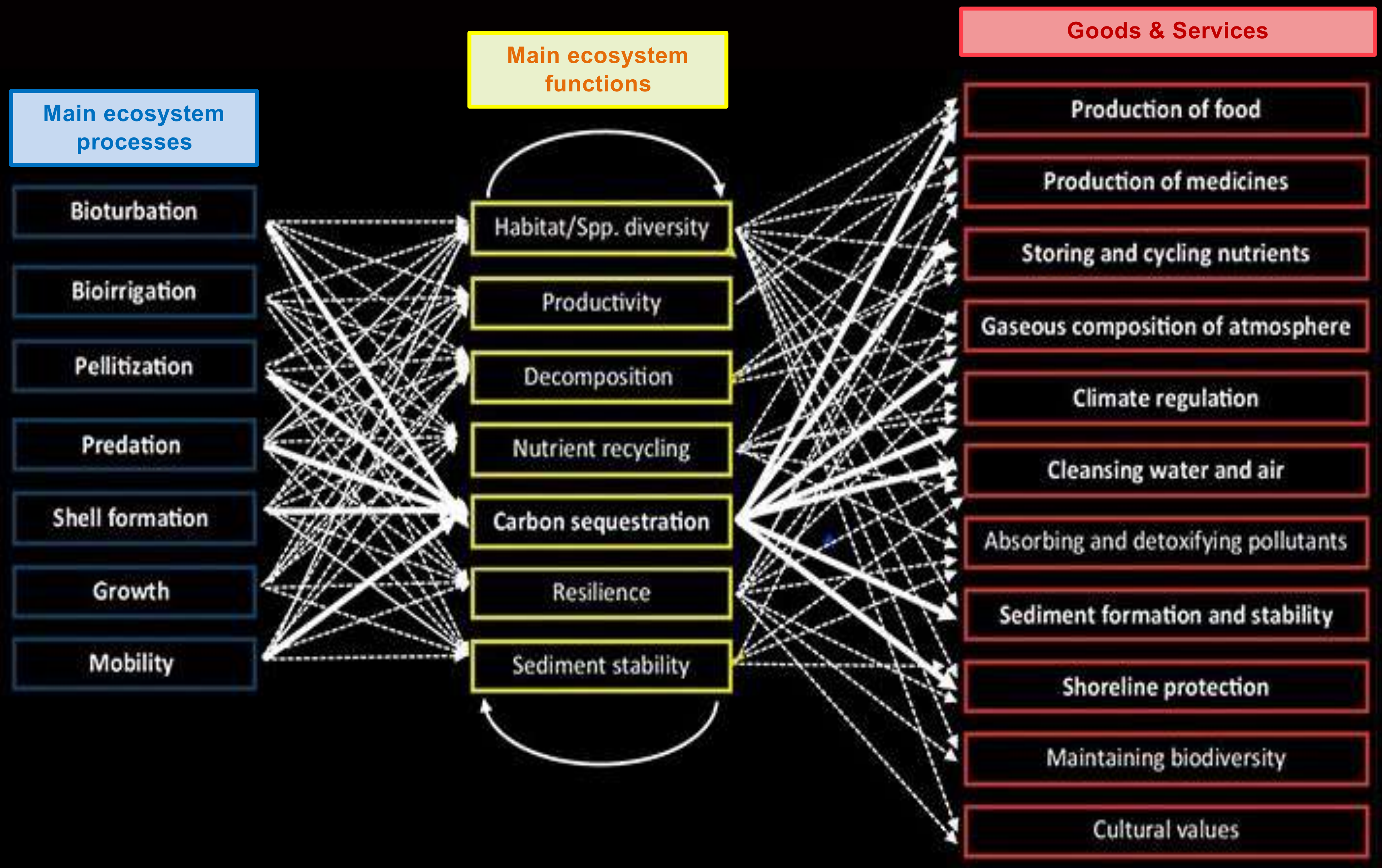
Biodiversity, functioning, and goods and services

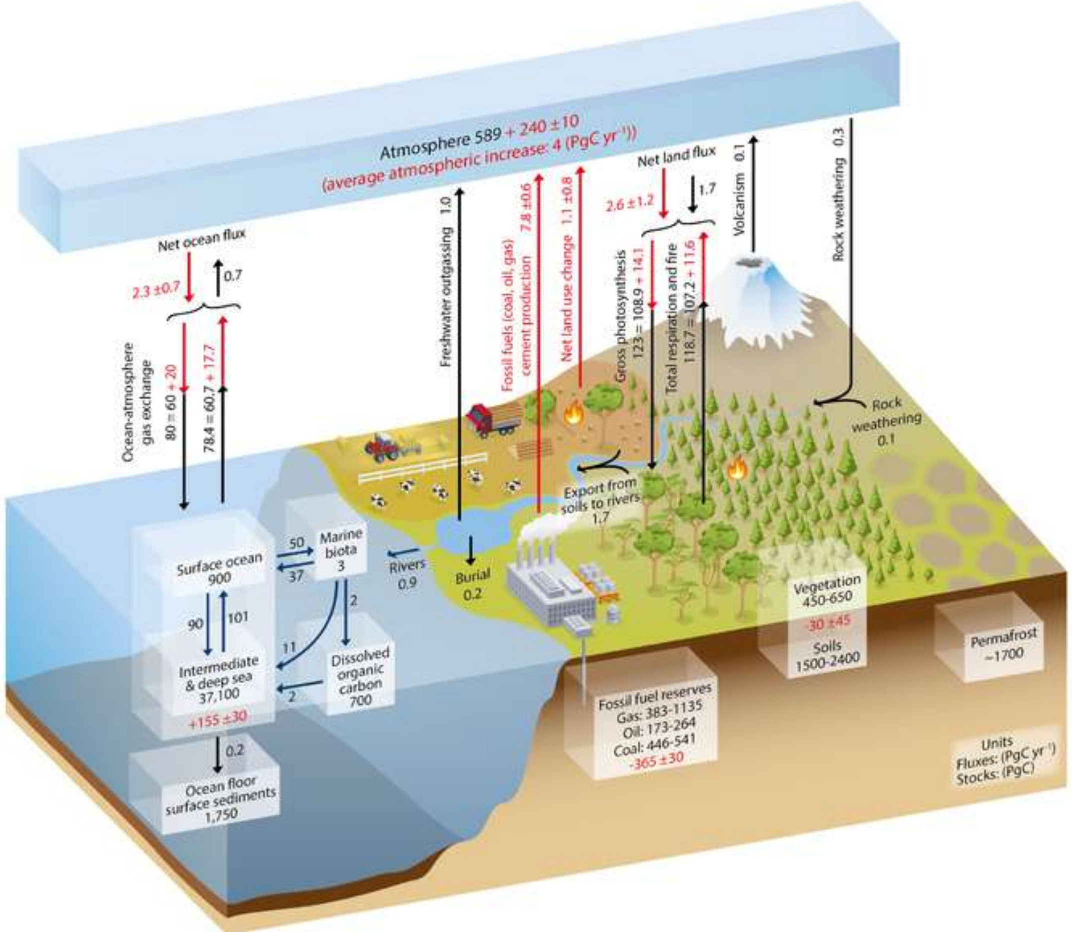


Snelgrove et al. 2014

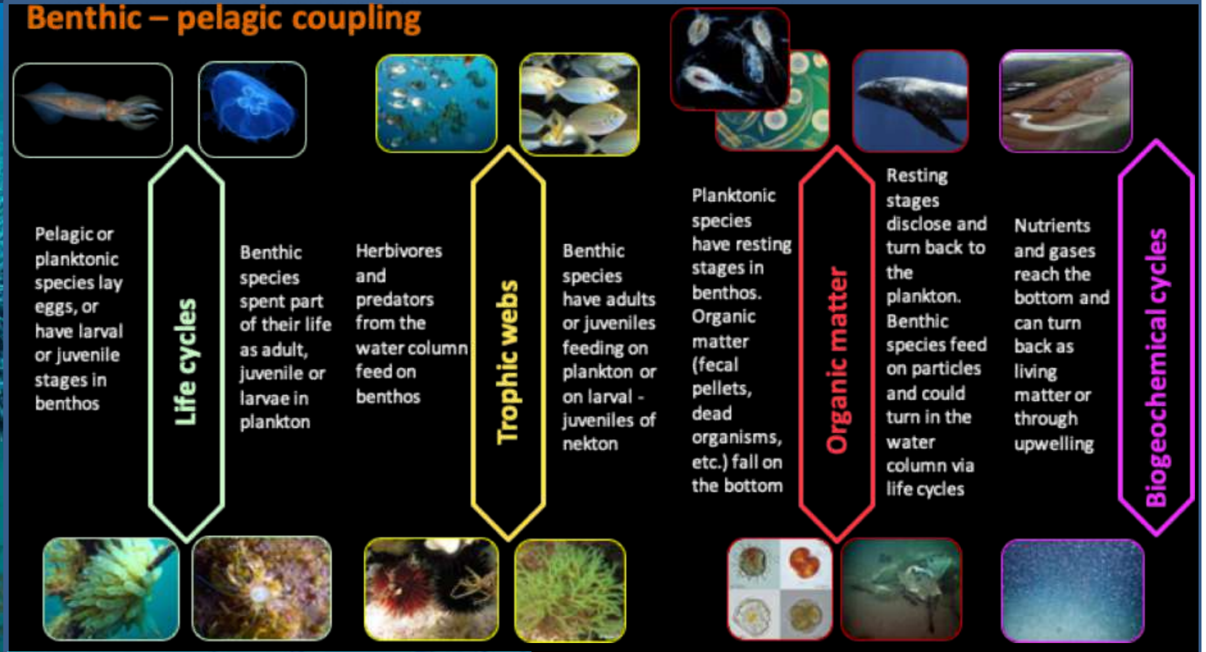
Regulation functions

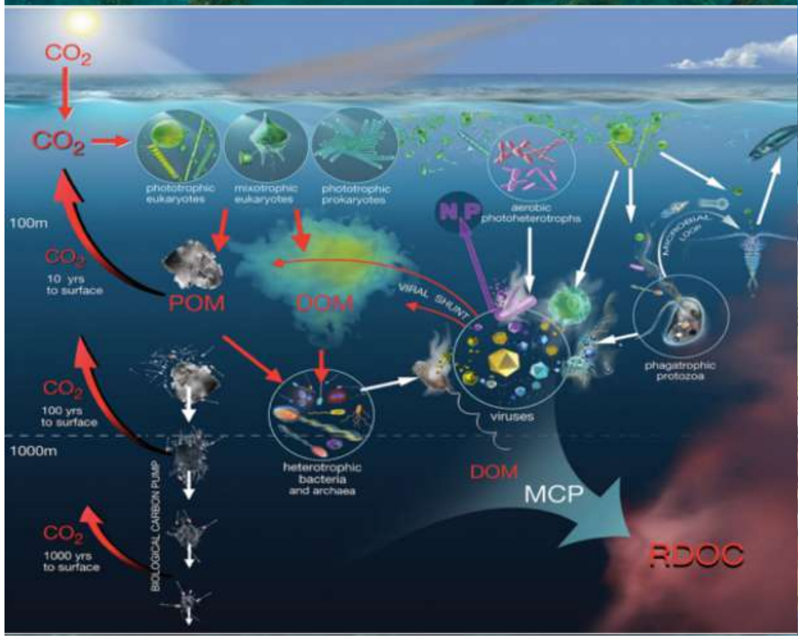
	Functions	Ecosystem processes and components	Goods and services (examples)
	Regulation Functions	*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	1.1 UVb-protection by O_3 (preventing disease). 1.2 Maintenance of (good) air quality.
2	Climate regulation	Influence of land cover and biol. mediated processes (e.g. DMS-production) on climate	Maintenance of a favorable climate (temp., precipitation, etc) for, for example, human habitation, health, cultivation

De groot et al. 2002



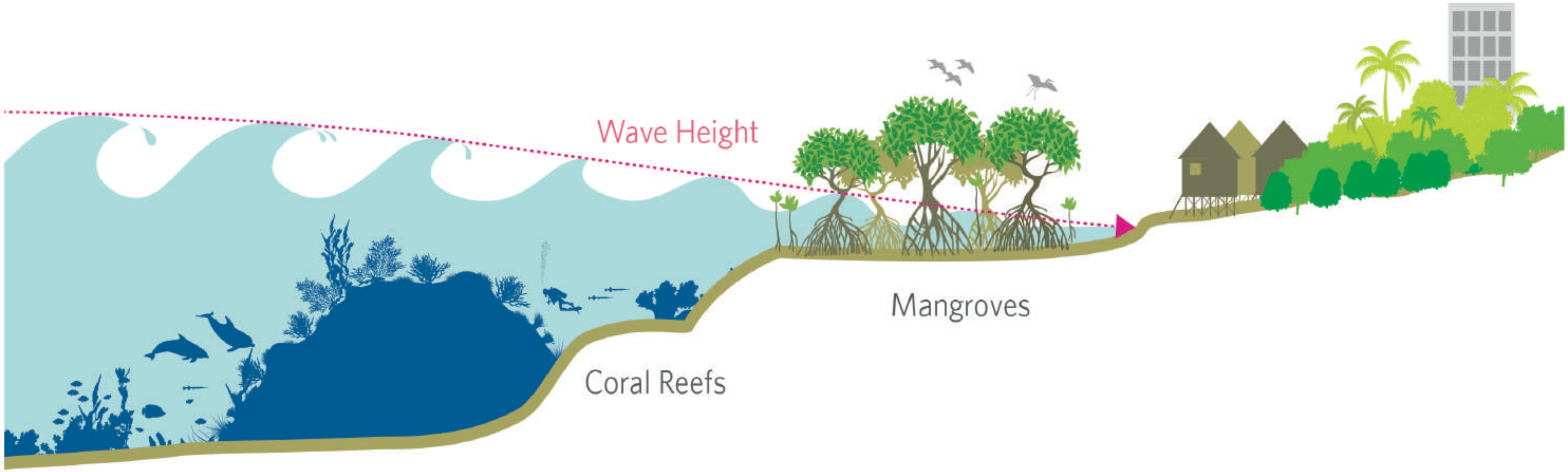
Services: carbon storage

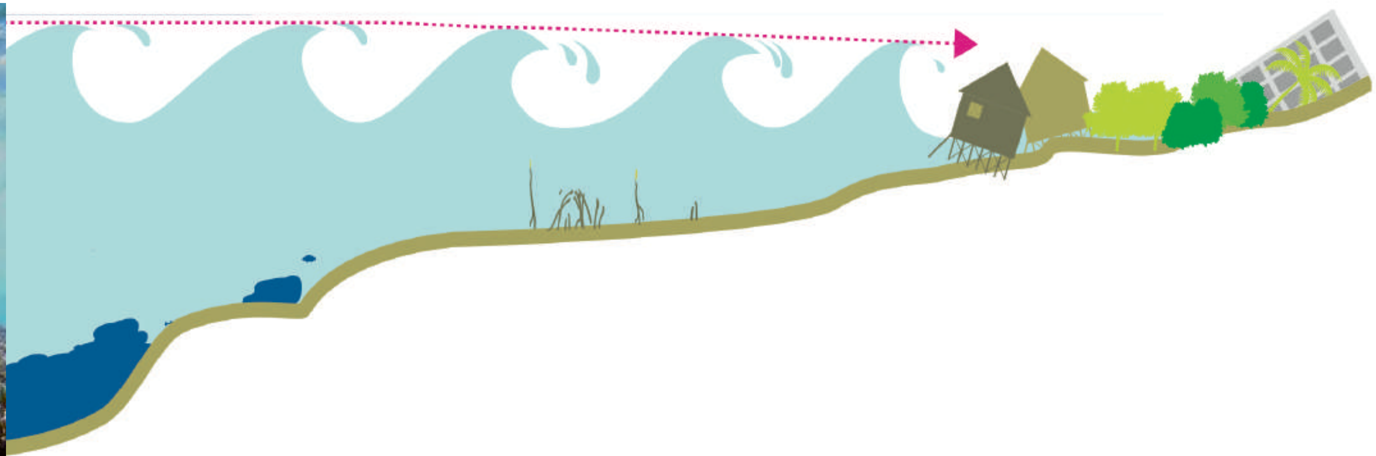




Regulation functions

3	Disturbance prevention	Influence of ecosystem structure on dampening env. disturbances	3.1 Storm protection (e.g. by coral reefs). 3.2 Flood prevention (e.g. by wetlands and forests)



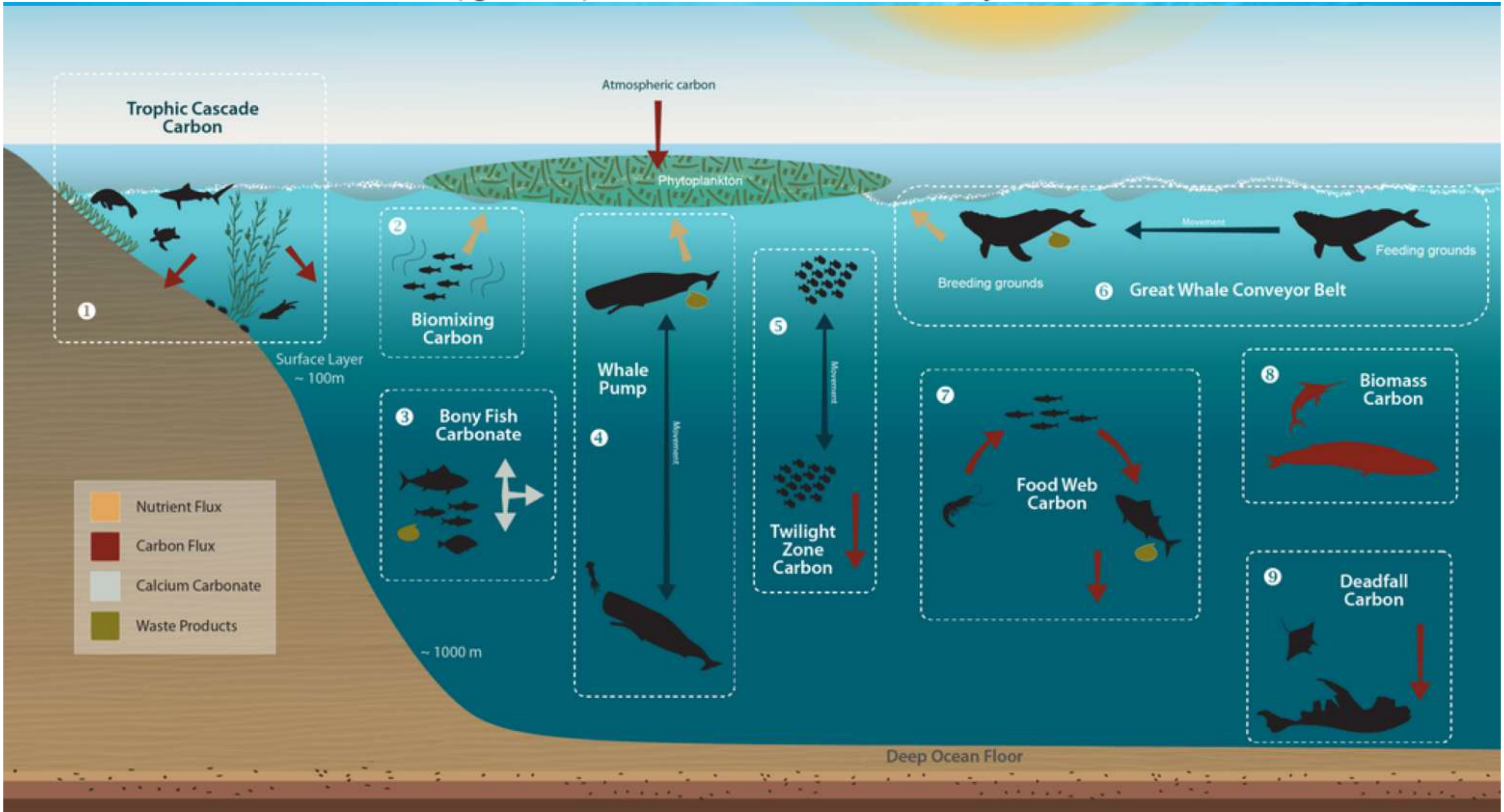


Regulation functions

6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land. 6.2 Prevention of damage from erosion/siltation
7	Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land.

Regulation functions

8	Nutrient regulation	Role of biota in storage and re-cycling of nutrients (eg. N,P&S)	7.2 Maintenance of natural productive soils Maintenance of healthy soils and productive ecosystems



Reference: Lutz, S.J., Pearson, H., Vatter J., Bhakta D. (2018): Oceanic Blue Carbon. Arendal: GRID-Arendal

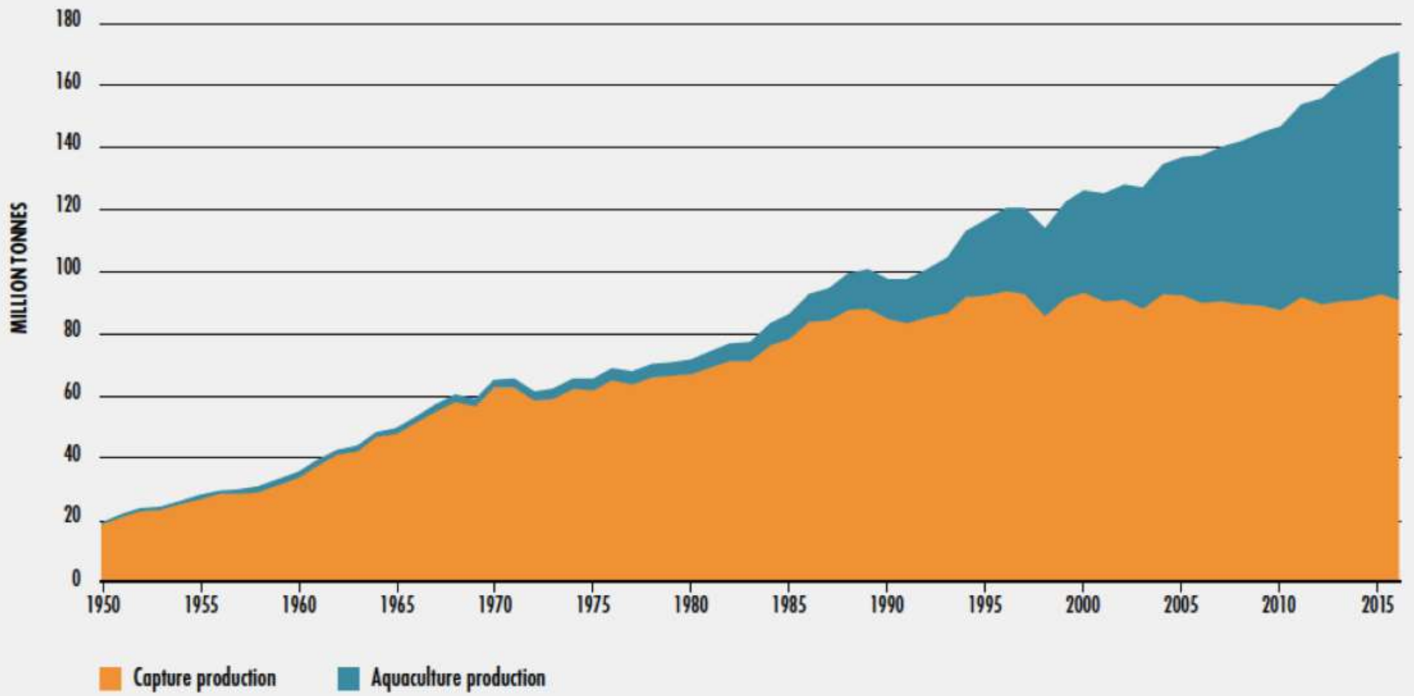
Habitat and production functions

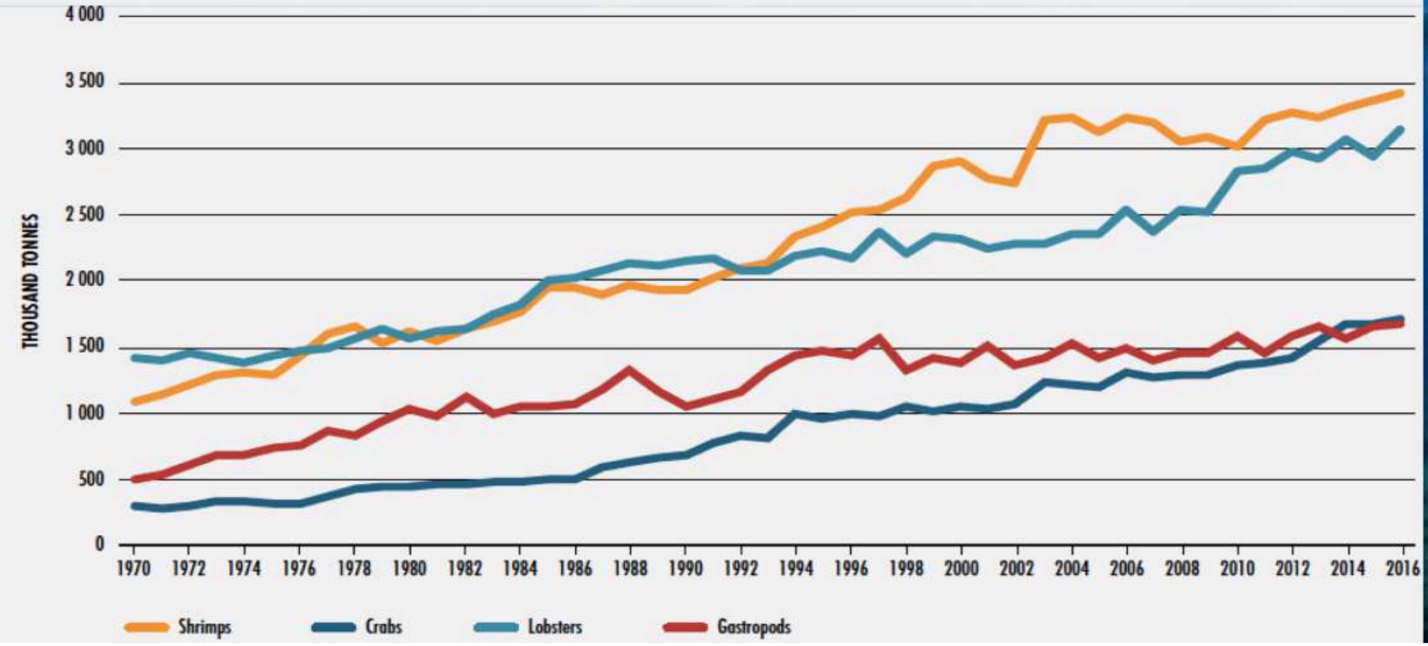
	Habitat Functions	*Providing habitat (suitable living space) for wild plant and animal species*	Maintenance of biological & genetic diversity (and thus the basis for most other functions)
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of commercially harvested specie
13	Nursery function	Suitable reproduction habitat	13.1 Hunting, gathering of fish, game, fruits,

Habitat and production functions

14	Food	Conversion of solar energy into edible plants and animals	14.1 Building & Manufacturing (e.g. lumber, skins). 14.2 Fuel and energy (e.g. fuel wood, organic matter). 14.3 Fodder and fertilizer (e.g. krill, leaves, litter).

Goods: food





About 90 million tons of wild fish were captured for food in 2016. Additional 80 million tons were from aquaculture.

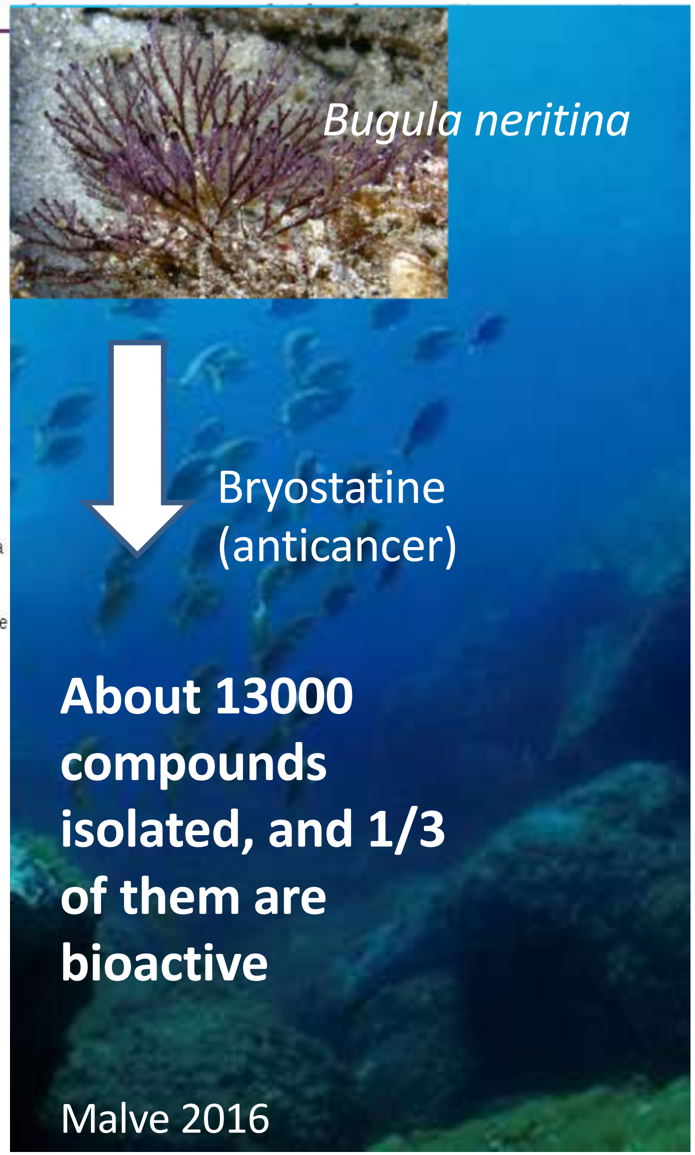
1/3 of world human population base their diet basically on seafood

FAO, 2018

Habitat and production functions

16	Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Drugs and pharmaceuticals. 16.2 Chemical models & tools. 16.3 Test- and essay organisms
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Resources for fashion, handicraft, jewelry, pet worship, decoration & souvenirs (e.g. furs,

Clinical status	Compound name	Marine organism	Chemical class	Disease area
Approved	Cytarabine, ara-C	Sponge	Nucleoside	Cancer, leukemia
	Brentuximab vedotin (SGN-35)	Mollusk/cyanobacterium	ADC (MMAE)	Cancer, lymphoma
	Vidarabine, ara-A	Sponge	Nucleoside	Anti-viral
	Omega-3-acid ethyl esters	Fish	Omega-3 fatty acid	Hypertriglyceridemia
	Ziconotide	Cone snail	Peptide	Pain
	Eribulin mesylate (E7389)	Sponge	Macrolide	Breast cancer
	Trabectedin (ET-743)	Tunicate	Alkaloid	Cancer
Phase III	Plitidepsin	Tunicate	Depsipeptide	Cancer
	Tetrodotoxin	Pufferfish	Guanidinium alkaloid	Chronic pain
	Soblidotin (TZT 1027)	Bacterium	Peptide	Cancer
Phase II	DMXBA (GTS-21)	Worm	Alkaloid	Cognition, Alzheimers disaese, schizophrenia
	Plinabulin (NPI-2358)	Fungus	Diketopiperazine	Cancer
	Glembatumumab vedotin	Mollusk/cyanobacterium	ADC (MMAE)	Breast cancer, melanoma
	Elisidepsin	Mollusc	Depsipeptide	Cancer
	PM1004	Nudibranch	Alkaloid	Cancer
	Tasidotin, synthadotin (ILX-651)	Bacterium	Peptide	Cancer
	Pseudopterosins	Soft coral	Diterpene glycoside	Wound healing
Phase I	Bryostatin 1	Bryozoa	Polyketide	Cancer
	Pinatuzumab vedotin (DCDT-2980S) and (DCDS-4501A)	Mollusk/cyanobacterium	ADC (MMAE)	Non-Hodgkin lymphoma, chronic lymphocytic leukemia
	Hemiasterlin (E7974)	Sponge	Tripeptide	Cancer
	HuMax®-TF-ADC	Mollusk/cyanobacterium	ADC (MMAE)	Cancer for ovary, endometrium, cervix, prostate
	Marizomib (salinosporamide A)	Bacterium	Beta-lactone-gamma lactam	Cancer
Preclinical	Chrysophaentin A	Alga *Halobacillus salinus*	Shikimate	Bacterial infections
	Phenethylamine	Bacterium lyngbyoic acid	Shikimate	Bacterial infections
	Geodisterol sulfates	Sponge	Peptide	Fungal infections
	Pseudoalteromonas sp. metabolites	Bacteria	Polyketide	Bacterial infections
	Peziza vesiculosa β-carboline	Bryozoa	Alkaloid	Fungal infections
	Bromophycolides	Alga	Terpene	Malaria
	Plakortin	Sponge	Polyketide	Malaria
	Homogentisic acid	Sponge	Shikimate	Malaria
	Cladonia cervicornis diterpene	Alga	Terpene	Protozoal infections
	Hymenidin	Sponge	Alkaloid	Tuberculosis
	Ggyrosanols	Soft coral	Terpene	Viral infections
	Dysidine	Sponge	Terpene	Diabetes
	Arenamides A and B	Bacteria	Peptide	Inflammation
	Capnellene	Soft coral	Terpene	Inflammation
	Floridosides	Alga	Glycolipid	Inflammation
	Grassystatins A-C	Bacteria	Peptide	Immunity
	Callyspongidiol	Sponge	Polyketide	Immunity
	Calyculin A	Sponge	PKS/NRPS	Nervous system
	Pulicatin A	Bacteria	Alkaloid	Nervous system
	Dysideamine	Sponge	Terpene	Nervous system



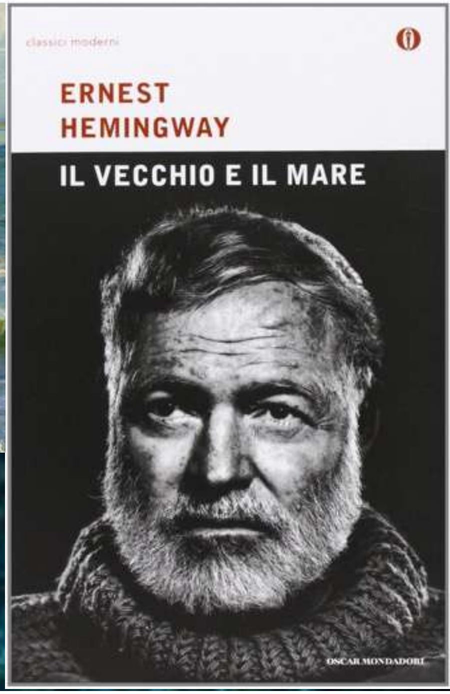
Habitat and production functions

18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	feathers, ivory, orchids, butterflies, aquarium fish, shells, etc.)

Information functions

	Functions	Ecosystem processes and components	Goods and services (examples)
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architect., advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

(V. Van Gogh 1888, E. Hemingway 1952, Iron Maiden 1984, J. Cameron 1989)

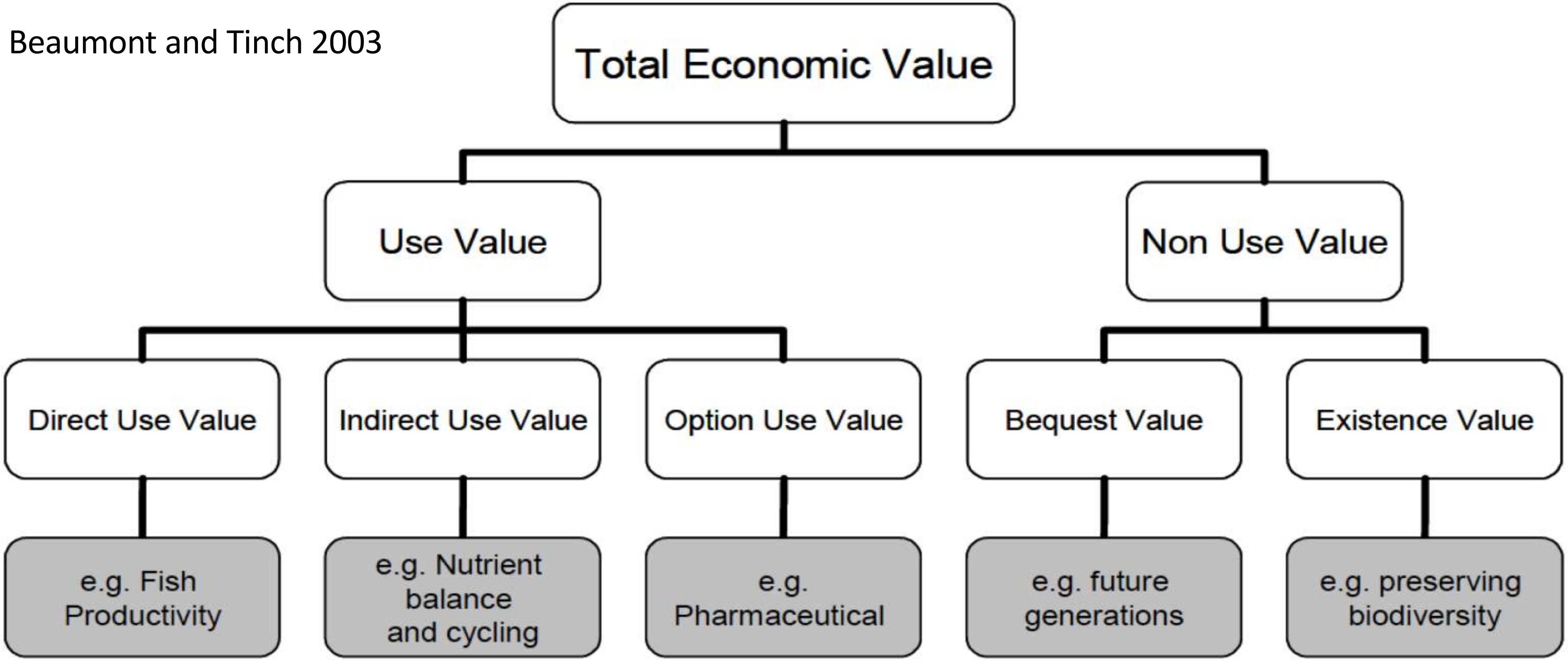


Services: aesthetic, cultural, and spiritual

Natural ecosystems provide an essential 'reference function' and contribute to the maintenance of human health by providing opportunities for reflection, spiritual enrichment, cognitive development, recreation and aesthetic experience

Valuing ecosystem goods and services

Beaumont and Tinch 2003



Direct use value: value given to natural resources which are directly exploited (mostly goods)
Indirect use value: value of natural indirect benefits (mostly services)
Option use: not used now but potentially useful in the future (chemicals, materials, living space, information)
Bequest value: the value given to the fact the we are passing natural capital to future generation
Existence value: value given simply for the fact that species, ecosystems, seascapes exist

Examples: fisheries

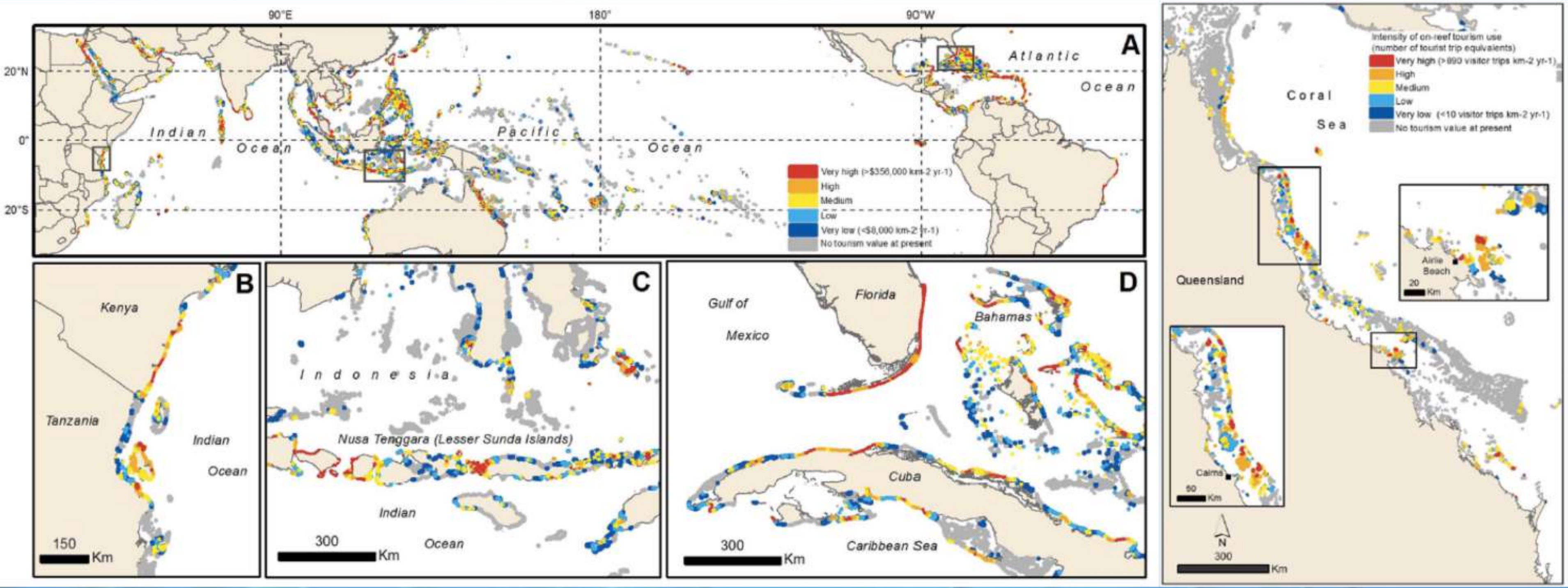
	Landed value (USD billions)	Economic impact (USD billions)
Africa	2.10	5.46
Asia	49.89	133.31
Europe	11.45	35.78
Latin America	7.20	14.78
N. America	8.23	28.92
Oceania	5.22	17.06
World total	84.10	235.31

Dyck and Sumaila 2010

Global fisheries account for 84 billion US$ (2003) just considering the economic value of landed fish. This sustains, on average, an income from related economic activities with an economic impact 2-3 times its value.

Most of landed fish exports go from poor to rich countries…

Examples: tourism related to coral reefs



Total tourism value In million US dollars per year

Spalding et al. 2017

Egypt	5467.3
Indonesia	3097.5
Mexico	2999.9
Thailand	2410.2
Australia	2176.1
China	1435.1
Philippines	1385.1
USA (Hawaii)	1230.9
Japan	1177.5
USA (Florida)	1156.8

Putting a price on nature

Biome	Area (ha × 10^6)	1 Gas regulation	3 Disturbance regulation	8 Nutrient cycling	9 Waste treatmer	11 Biological control	12 Habitat/ refugia	13 Food production	14 Raw materials
Marine	36,302								
Open ocean	33,200	38		118		5		15	0
Coastal	3,102		88	3,677		38	8	93	4
Estuaries	180		567	21,100		78	131	521	25
Seagrass/ algae beds	200			19,002					2
Coral reefs	62		2,750		58	5	7	220	27
Shelf	2,660			1,431		39		68	2

Higher values for goods and services related to nutrient cycling, disturbance regulation and food provision for coastal ecosystems. Nutrient cycling and gas regulation for open ocean. Note that some services, such as biological control and habitat provision have low value despite their important implications on other services.

Global value of ecosystem goods and services (!)

Biome	16 Recreation	17 Cultural	Total value per ha ($ ha^{-1} yr^{-1})	Total global flow value ($ yr^{-1} × 10^9)
Marine			577	20,949
Open ocean		76	252	8,381
Coastal	82	62	4,052	12,568
Estuaries	381	29	22,832	4,110
Seagrass/ algae beds			19,004	3,801
Coral reefs	3,008	1	6,075	375
Shelf		70	1,610	4,283

The global value of marine ecosystem goods and services is estimated as about 21 trillions US dollars per year.

About 33,5 trillions including terrestrial and freswater environments.

Issues

Incomplete estimation of value, which is likely to be higher (!!!) (some important biomes were not evaluated, as well as some services)

Ecosystem serivces (1994 US$ $ha^{-1} yr^{-1}$)

Biome	Area (ha × 10^6)	1 Gas regulation	2 Climate regulation	3 Disturbance regulation	4 Water regulation	5 Water supply	6 Erosion control	7 Soil formation	8 Nutrient cycling	9 Waste treatment	10 Pollination	11 Biological control	12 Habitat/ refugia	13 Food production	14 Raw materials	15 Genetic resources	16 Recreation	17 Cultural	Total value per ha ($ $ha^{-1} yr^{-1}$)	Total global flow value ($ yr^{-1} × 10^9)
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Open ocean	33,200	38							118			5		15	0			76	252	8,381
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Shelf	2,660								1,431			39		68	2			70	1,610	4,283
Terrestrial	15,323																		804	12,319
Forest	4,855		141	2	2	3	96	10	361	87		2		43	138	16	66	2	969	4,706
Tropical	1,900		223	5	6	8	245	10	922	87				32	315	41	112	2	2,007	3,813
Temperate/boreal	2,955		88		0			10		87		4		50	25		36	2	302	894
Grass/rangelands	3,898	7	0		3		29	1		87	25	23		67		0	2		232	906
Wetlands	330	133		4,539	15	3,800				4,177			304	256	106		574	881	14,785	4,879
Tidal marsh/ mangroves	165			1,839						6,696			169	466	162		658		9,990	1,648
Swamps/ floodplains	165	265		7,240	30	7,600				1,659			439	47	49		491	1,761	19,580	3,231
Lakes/rivers	200				5,445	2,117				665				41			230		8,498	1,700
Desert	1,925																			
Tundra	743																			
Ice/rock	1,640																			
Cropland	1,400										14	24		54					92	128
Urban	332																			
Total	51,625	1,341	684	1,779	1,115	1,692	576	53	17,075	2,277	117	417	124	1,386	721	79	[illegible]	3,015		33,268

Marine

Terrestrial

Climate and gas regulation, genetic diversity

11% of Earth surface

Costanza et al. 1997

Issues

Most of the functions arising from the marine environment are services.

Other than fish production there are not many direct uses for marine biodiversity, and thus it is rarely used as a good.

It is the action, or service, of keeping the rest of the system functional that it is particularly valuable. The provision of services tends to overlooked in comparison to provision of goods, particularly in the management context.

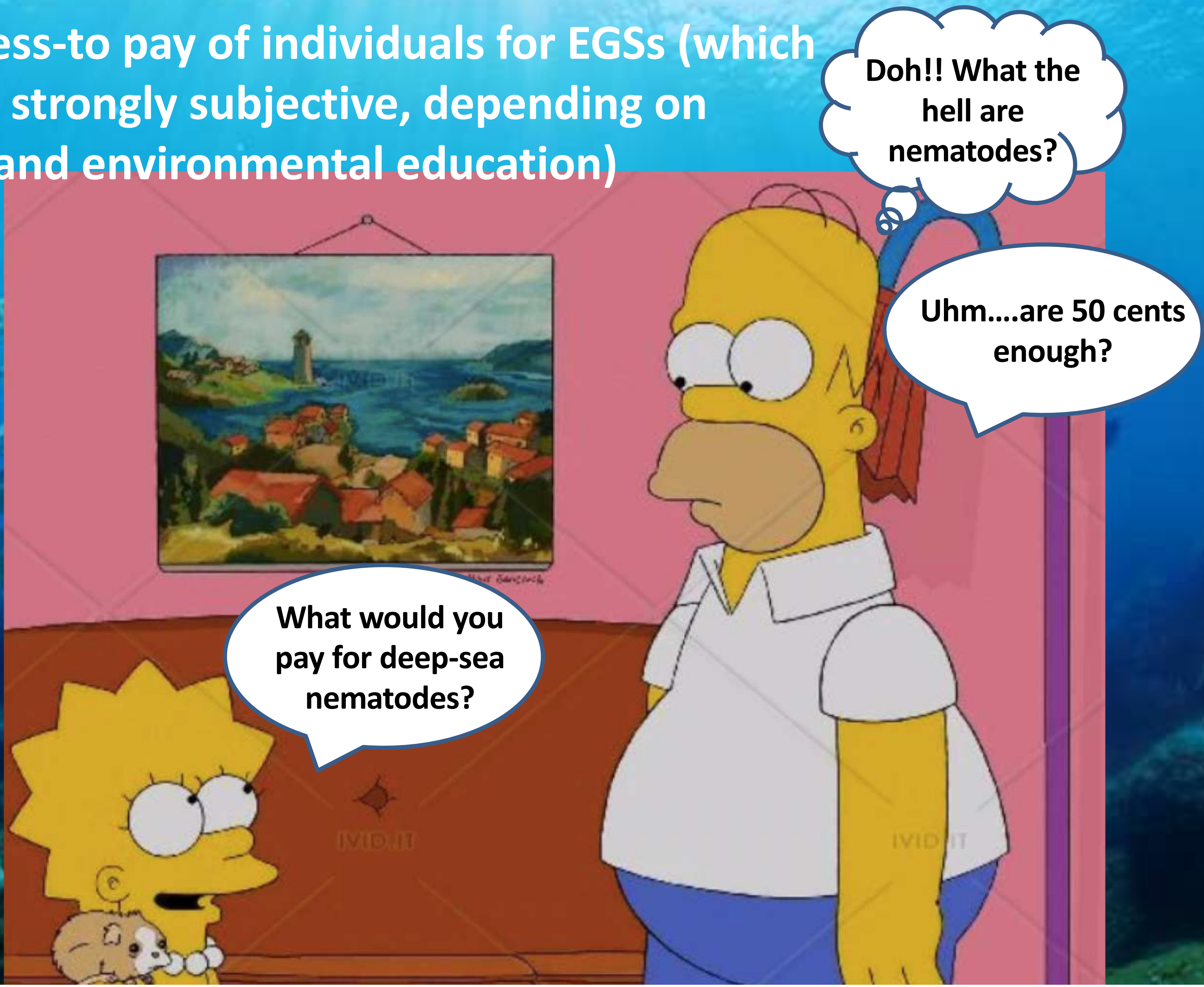
Services cannot be seen or held, and often do not yield immediate market value, and as a result are often taken for granted, however, these functions are fundamental to providing humanity with a healthy and suitable planet, and are thus just as critical to our well being as tangible goods.

It is critical that the services provided by the marine environment are well documented and included in management decisions, and not overlooked as they may have been in the past.

Beaumont and Tinch 2003

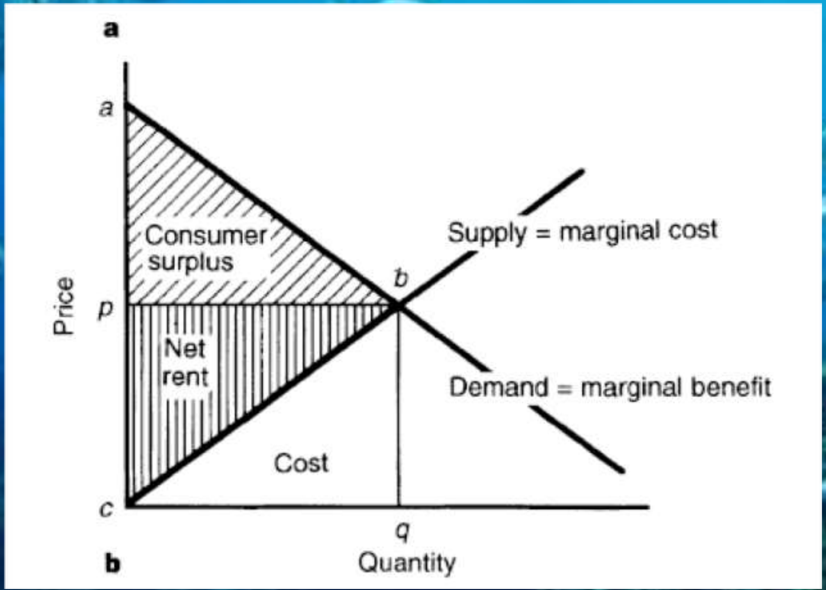
Issues

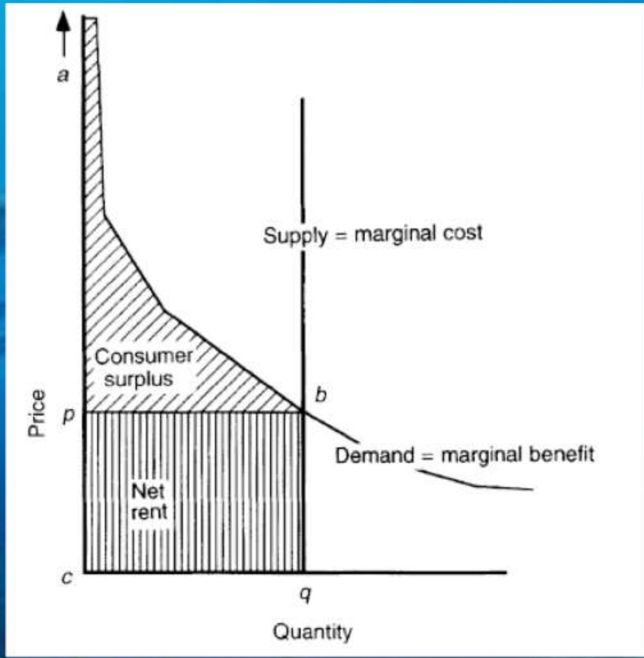
In many cases the values are based on the current willingness-to pay of individuals for EGSs (which could be strongly subjective, depending on cultural and environmental education)



Issues

Values are calculated based on the demand-supply model of real economy…However, for many EGSs, supply is limited by carrying capacity and we cannot implement action to increase "production". Moreover, demand (and price) will increase drastically if supply is reduced, because everyone needs this supply.





Continuity of supply and reversibility of supply reduction is assumed, which is not always the case for EGSs…at least in the short-medium term. Also, values are contingent, being subject to variation (increase) in the future.

Costanza et al. 1997

Can we rely on market to value nature?

Service	Obs.	Mean	Min	Max	Median
Fisheries	51	23,613	10.05	555,168	627
Forestry	35	38,115	18.00	1,287,701	576
Coastal protection	29	3,116	10.45	8,044	3,604
Recreation & tourism	14	37,927	1.74	507,368	1,079
Nutrient retention	1	44	-	-	-
Carbon sequestration	7	967	39.89	4,265	211
Nonuse	6	17,373	3.77	50,737	15,212
Biodiversity	1	52	-	-	-
Water and air purification/ waste assimilation	4	4,748	12.43	7,379	5,801
Traditional uses	1	114	-	-	-
Total	149				

Aspects underlying the whole functioning (e.g. biodiversity) are those with lower value. Evaluation biased towards more practical, and easy-to-quantify EGSs. Often those of major interest for economy.

(US dollars ha per year)

Salem and Mercer 2012

Value based on market and economy can be extremely variable, rising uncertainty on actual value. In 2012, mangrove EGSs estimated as 128000 US $ ha per year, in 1997 about 10000.

Often, EGSs estimated based on costs to provide equivalent good or service based on present cost to reproduce them. What about advance in technology leading to reduce costs?

NEWS · 07 JUNE 2018

Sucking carbon dioxide from air is cheaper than scientists thought

Estimated cost of geoengineering technology to fight climate change has plunged since a 2011 analysis.

Jeff Tollefson

Moral question…or moral conflict?

Zero natural capital implies zero human welfare because it is not feasible to substitute, in total, purely 'non-natural' capital for natural capital. Manufactured and human capital require natural capital for their construction. Therefore, it is not very meaningful to ask the total value of natural capital to human welfare.

It is trivial to ask what is the value of the atmosphere to humankind, or what is the value of rocks and soil for infrastructure as support. Their value is infinite in total.

However, it is meaningful to ask how changes in the quantity or quality of various types of natural capital and ecosystem services may have an impact on human welfare. And we value welfare economically every day…

Costanza et al. 1997

Moral question? Moral conflict?

Biodiversity offsetting

The aim has been to convert environmental problems into a narrow mainstream economic and financial discourse supporting market governance. Ideally Nature can be bought and sold to boost corporate profits.

This is the same logic supporting biodiversity offsetting because developers are expected to make gains that exceed costs allowing them to claim:

(i) a legitimate political reason for destroying habitat based on the creation of jobs, growth and economic value;

(ii) an efficiency gain can result because a net economic surplus will be created (use space efficiently based on preferences);

(iii) conservation will benefit from trading habitat by capturing some of this surplus.

"Offsets by definition are about destruction of ecosystems, species habitat and local Nature in order to benefit developers. They redefine human–Nature relationships as value capture and capital maintenance, where Nature becomes a malleable constructed human artefact. In the capital accumulating growth economy such creative destruction is the mantra of progress and development. Roll on the bulldozers." (Spash 2015)