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The coasts of our world: Ecological, economic and social importance

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ABSTRACT

We integrated the emerging information of the ecological, economic and social importance of the coasts at a global scale. We defined coastal regions to range from the continental shelf (to a depth of 200 m), the intertidal areas and adjacent land within 100 km of the coastline. We used the 1 km resolution Global Land Cover Characteristics Database and calculated the area covered by 11 different land cover classes (natural and human-altered ecosystems) within the 100 km limit [Burke, L., Kura, Y., Kasem, K., Revenga, C., Spalding, M., McAllister, D., 2001. Coastal Ecosystems. Washington DC World Resource Institute. 93 pp.]. Cover of aquatic ecosystems was calculated based on several world databases. Our results show that the coasts of the world comprise a wide variety of geomorphological characteristics of which mountainous coasts with a narrow shelf are the most abundant. Sandy shores are found on 16% of the coastal countries. The coasts are located in every weather regime and the number of biomes is equally variable. Within the 100 km limit, 72% still is covered by natural ecosystems and 28% have been altered by human activities (urban and croplands). Open shrubs and evergreen broadleaf forests are the most abundant terrestrial ecosystems. Canada has the largest area of natural and relatively well preserved terrestrial ecosystems. Indonesia and China have the largest percentages of cropland area near the shore, and Japan and the US have the largest coastal urban areas. Indonesia, Australia, Brazil, Bahamas and New Caledonia have the largest areas of aquatic ecosystems. The calculated economic value of goods and services provided by coastal ecosystems showed that altogether, coastal ecosystems contribute 77% of global ecosystem-services value calculated by Costanza et al. [Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R.V., Raskin, R., Sutton, P., ven den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260]. According to 2003 data, 2.385 million people live within the coastal limit, which represents 41% of world global population. More than 50% of the coastal countries have from 80 to 100% of their total population within 100 km of the coastline. Twenty-one of the 33 world's megacities are found on the coast. Multivariate analyses grouped coastal countries according to their ecological, economic and social characteristics. Three gradients

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explained 55% of the variance: degree of conservation, ecosystem service product and demographic trends. Given the current scenario and the climate change prediction, the coastal environments will be confronting serious environmental issues that should be worked in advance, in order to achieve a sustainable development of the most valued locations of the world. Several recommendations are made.

1. Introduction

Planet Earth is a coastal planet. It comprises 361.13 million km^2 of water (71% of total planet surface) and 148.94 million km^2 of land area (29% of total planet surface). They both interact intensively and extensively along the world's total 1,634,701 km of coastline (Burke et al., 2001). The coastline of the world is so long that if we could stretch it, it would go 402 times around the equator. Furthermore, 84% of the countries of the world have a coastline either with the open oceans, inland seas or both.

The extensive distribution of the coasts results in an ample variety of geomorphological features, weather regimes and biomes. The coasts include soft-shores, rocky shores and cliffs, hilly or flat coastal plains, narrow or wide coastal shelves and a wide variety of wetlands (estuaries, saltmarshes, deltas) (Schwartz, 2005). The weather types found on the coasts are equally variable, ranging from tropical dry or humid to temperate and polar (Bailey, 1998). The great heterogeneity in terms of weather and geomorphological characteristics results in an equally large variety of biomes found along the coasts. On the terrestrial part there are different kinds of forests (tropical and temperate, evergreen and deciduous), shrubs, and savannas, while the aquatic ecosystems comprise mangroves, saltmarshes, estuaries, coral reefs, sea grasses and the coastal shelf (van der Maarel, 1993a,b; Burke et al., 2001; Spalding et al., 2001; FAO, 2003; Green and Short, 2003).

Human beings have not been insensitive to the wide array of opportunities provided by the coasts and have been attracted to them, making the coasts the most favored locations to either live permanently, for leisure, recreational activities, or tourism (Culliton et al., 1990; Miller and Hadley, 2005). The coasts have been centers of human activity for millennia and host the world's primary ports of commerce.

The ecological, economic and social importance of the oceans of the world has been analyzed before (Costanza, 1998). However, the same is not true for the coasts, probably because of their vastness, and general lack of information. Only recently, within the last decade, has global information of the coasts been generated via remote sensing technologies and satellite imagery. This provides the opportunity to integrate and summarize the available information to develop a comprehensive picture of the status of coastal ecosystems and to evaluate their relative importance in terms of their ecological, economic and social attributes.

1.2. Aims of the study

This study aims at summarizing and integrating the emerging information of the ecological, economic and social importance of the coasts. Our goal is to analyze quantitative and qualitative information to assess the relative importance of the coasts beyond their traditional economic value as sources of commerce, fisheries and human populations. This study of the world's shorelines begins with an examination of their ecological features. We then analyze the economic importance of the coasts, specifically in terms of the ecosystems services they provide. Finally, we examine global demographic trends and discuss the social relevance of the coasts. We have integrated the ecological, economic and social information of most coastal countries through a multivariate analysis which grouped countries according to shared trends of coastal features.

1.2. Definition

What exactly is the coast? Even though the coasts are an important feature of our planet it has been difficult to define precisely what "the coast" really is. The Webster Dictionary defines the coast as the "margin of land bounded by the sea". This definition strictly refers to that part of an island or continent that borders an ocean or its saltwater tributaries. Other authors refer to the coast as the "area where aquatic and terrestrial ecosystems interact" (Carter, 1988). Although the scope of the latter definition is broader, it still presents some practical difficulties, because setting clear-cut limits between coastal aquatic and terrestrial interactions is not a simple task. How far inland are terrestrial ecosystems influenced by the ocean? How far into the ocean are aquatic ecosystems affected by the land processes?

In this study we consider that the coasts cover broad scale aquatic–terrestrial interactions, beyond the limited single-point area where water and land meet physically. Terrestrial processes (such as upland erosion and pollution) have a clear impact on the aquatic ecosystems. Marine phenomena, such as storms and hurricanes clearly have an impact beyond the beach. Thus, in this study we will consider the coast as that "part of land most affected by its proximity to the sea, and that part of the ocean most affected by its proximity to the land" (Hinrichsen, 1998). We defined coastal regions to be the

Table 1 – Worldwide percent covered by each of the 11 ecosystem types as determined by the World Resource Institute within 100 km from the coastline

Ecosystem type	%
Evergreen needleleaf forest	11
Evergreen broadleaf forest	21
Deciduous needleleaf forest	1
Deciduous broadleaf forest	4
Mixed forests	7
Closed shrubs	5
Open shrubs	23
Woody savannas	12
Savannas	9
Grasslands	7
Permanent wetlands	2

Table 2 – Biodiversity of dry coastal ecosystems of the world (from van der Maarel, 1993a,b)

	Polar regions and Europe	Africa, America, Asia and Oceania
Plants	921	1477
Chlorophyta	4	
Phaeophyta	4	2
Rhodophyta	11	
Lichens	61	14
Bryophyta	95	27
Pteridophyta	23	20
Gymnospermae	9	21
Angyospermae	714	1393
Monocots	186	226
Dycots	528	1167
Fungi	6	3
Animals	504	428
Annelida	1	
Arthropoda	110	79
Insecta	70	61
Arachnida	40	7
Mollusca	39	8
Chordata	244	273
Amphibia	7	9
Reptilia	16	44
Aves	174	136
Mammalia	47	84
Carnivora	11	15
Artiodactyla	8	10

Estimated number of genera reported in the literature for different taxa (blank spaces = missing information).

intertidal and subtidal areas on and above the continental shelf (to a depth of 200 m); areas routinely inundated by saltwater; and adjacent land, within 100 km from the shoreline. Our definition is based on those used by Burke et al. (2001) and Small and Nicholls (2003), whose work on coastal land use and population estimates respectively, followed the same limits. Thus, this definition enabled us to cover most of the interactions between the contrasting aquatic and terrestrial ecosystems that co-occur at the coast and to use the information available.

2. Ecological importance

2.1. *Methods and data*

Terrestrial ecosystems were located within 100 km of the coastline. We based our calculations on the database generated by the World Resource Institute (Burke et al., 2001). They used the 1 km resolution Global Land Cover Characteristics Database (GLCCD, 1998) which was derived from the Advanced Very High-Resolution Radiometer (AVHRR), satellite covering the period between 1992 and 1993. We used their 11 different land cover classes (including natural, semi-altered and fully altered ecosystems) and calculated the area covered by each one within the 100 km limit. Natural ecosystems referred to locations with minimal human intervention; semi-altered were defined as those ecosystems with a mosaic of natural and human-altered ecosystems (croplands and urbanizations) and fully altered ecosystems were those fully covered by croplands and urban developments. Per country area covered by aquatic ecosystems (mangroves, coral reefs, sea grasses and coastal shelf) was obtained from different databases: World Atlas of Coral Reefs (Spalding et al., 2001), World Atlas of Sea Grasses (Green and Short, 2003), World Mangrove Atlas (Spalding et al., 1997; FAO, 2003), and Coastal Ecosystems (Burke et al., 2001).

Table 3 – Ecosystem goods and services offered by coastal ecosystems

Ecosystem types	Ecosystem services																	
	GR	CR	DR	WR	WS	EC	SF	NC	WT	P	BC	H	FP	RM	Gen	Rec	Cul	SP	ES
Evergreen needleleaf forest		x					x		x		x		x	x		x			302
Evergreen broadleaf forest		x	x	x	x	x	x	x	x				x	x	x	x	x		2007
Deciduous needleleaf forest		x					x		x		x		x	x		x	x		302
Deciduous broadleaf forest		x	x	x	x	x	x	x	x				x	x	x	x	x		302
Mixed forests		x	x	x	x	x	x	x	x				x	x	x	x	x		728
Closed shrublands	x			x		x	x		x	x	x		x		x	x			232
Open shrublands	x			x		x	x		x	x	x		x		x	x			232
Woody savannas	x	x		x		x	x		x	x	x		x	x	x	x			267
Savannas	x	x		x		x	x		x	x	x		x	x	x	x		x	232
Grasslands	x	x		x		x	x		x	x	x		x	x	x	x		x	232
Permanent wetlands	x		x	x	x				x			x	x	x		x	x	x	14,785
Sandy shores			x			x				x		x		x		x	x	x	No data
Coral reefs			x						x		x	x	x	x		x	x	x	6075
Mangroves			x					x	x			x	x	x		x		x	9990
Sea grass								x						x				x	19,004
Coastal shelf								x			x		x	x			x		1610
Swamps–floodplains	x		x	x	x				x			x	x	x		x	X		19,580
Estuaries			x					x			x	x	x	x		x	x	x	22,832

GR = gas regulation; CR = climate regulation; DR = disturbance regulation; WR = water regulation; WS = water supply; EC = erosion control; SF = soil formation; NC = nutrient cycling; WT = waste treatment; P = pollination; BC = biological control; H = habitat/refugia; FP = food production; RM = raw material; Gen = genetic resources; Rec = recreation; Cul = cultural; SP = storm protection. Ecosystem service values (ES) ($ US per ha per year) are given according to Costanza et al. (1997) and Sutton and Costanza (2002).

2.2. General trends

The coastlines of the world are quite diverse in terms of their physiographical characteristics. Fifty-five percent of the countries with a coast that were analyzed by Burke et al. (2001) have a narrow shelf, and from these, 38% are either mountainous or hilly, while 17% have coastal plains. Twenty-nine percent of the countries have a wide shelf (14% hilly and 15% with a coastal plain) and 16% of all the coastal countries include soft-shores, and barrier islands within their shorelines (from Burke et al., 2001). However, the latter have not been mapped in detail. Coral reefs and mangroves are abundant in the Middle East, Southeast Asia, and Australia. Mangroves line nearly 8% of the world's coastline (Spalding et al., 1997; FAO, 2003).

Within the 100 km of near-shore terrestrial vegetation, the analysis performed by Burke et al. (2001) revealed that 72% of the coastline can be considered as natural and 28 as altered by human activities such as croplands and urban development. Terrestrial natural ecosystems cover a larger area (69%) than aquatic (3%). Within altered terrestrial ecosystems, croplands (12%) are more extensive than either urban developments (6%) or the mosaic of natural vegetation and croplands (10%).

Terrestrial natural ecosystems within the 100 km boundary encompass a wide variety of habitats that were classified into 11 ecosystem types: evergreen needleleaf forest, evergreen broadleaf forest, deciduous needleleaf forest, deciduous broadleaf forest, mixed forests, closed shrubs, open shrubs, woody savannas, savannas, grasslands and permanent wetlands (Table 1). Together, forests comprise 44% of global natural coastal vegetation within the 100 km inland boundary. Of these, evergreen broadleaf forests are the most abundant. Shrubs (28%) and savannas (21%) are almost equally abundant. In contrast, deciduous needleleaf forests, broadleaf forests, mixed forests, closed shrubs, savannas and permanent wetlands cover each less than 10% but 35% if added altogether (from Burke et al., 2001) (Table 1).

The countries with the longest coastline are Australia, Canada, Chile, Finland, the Russian Federation and the United States (Table A1 in the Appendix). Canada, the Russian Federation, the United States and Australia contain the largest areas of most of the terrestrial ecosystems defined above. An exception to this trend is Finland with the second largest area of deciduous needleleaf forest on the coast. Overall, Canada is the country with the largest area of natural and relatively well preserved terrestrial ecosystems and is followed by the Russian Federation and Australia. Brazil, China and the Philippines showed the largest percentages of near-shore land covered by a mosaic of cropland and natural vegetation. Indonesia and China have the largest percentages of cropland area near the shore, and the United States and Japan are the countries with the largest coastal urban areas (Table A1 in the Appendix). These trends are different for aquatic ecosystems. Indonesia and Australia are by far the countries with the largest extension of coral reefs and sea grasses. These countries also contain the largest areas of mangroves, together with the Brazilian coast. The Bahamas, New Caledonia and Qatar have the largest cover values of coastal shelf (Table A1 in the Appendix).

Based on the global characterization presented above, it becomes obvious that the coastal environment includes a wide variety of ecosystems, many of which are considered as the most diverse of the world (i.e. coral reefs and tropical rain forests) (Reaka-Kudla, 1997; Groombridge and Jenkins, 2002). To our knowledge, the only global analysis of the biodiversity of coastal terrestrial ecosystems is that integrated for dry coastal ecosystems (van der Maarel, 1993a,b). In this extensive revision, a total of 3484 plant and 417 animal species have been reported for the Americas, Africa and Asia and 714 plants and 398 animals for the European and Arctic regions. These terrestrial coastal ecosystems include the ecosystem types mentioned in Table 1. The coasts of the polar regions and Europe have the largest number of genera of Fungi, Lichens, Bryophyta, Pteridophyta, Insecta, Archnida and Aves, whereas more genera of Gymnospermae, Angyospermae, Amphibia, Reptilia and Mammalian have been reported for Africa, America, Asia and Oceania (Table 2).

Unlike the amply distributed dry coastal ecosystems, mangroves are restricted to the tropics and are located along sheltered shores and in estuarine environments. In terms of species richness mangroves are considered homogeneous, but some coasts are more diverse than others: species diversity in

Table 4 – Ecosystem Service Product calculated for natural (terrestrial and aquatic separately), and altered coastal ecosystems at a global scale

Ecosystem	$ US ($\times 10^9$) per km^2 per year	% from total coastal ESP
Evergreen needleleaf forest	44.59	0.17
Evergreen broadleaf forest	560.81	2.18
Deciduous needleleaf forest	3.93	0.02
Deciduous broadleaf forest	17.9	0.07
Mixed forests	76.59	0.30
Closed shrublands	16.12	0.06
Open shrublands	73.12	0.28
Woody savannas	45.9	0.18
Savannas	28.1	0.11
Grasslands	21.42	0.08
Permanent wetlands	436.3	1.69
Total terrestrial	1324.78	5.14
Coral reefs	172.41	0.67
Mangroves	161.03	0.62
Sea grass	299.1	1.16
Coastal shelf	52.18	0.20
Swamps–floodplains	19,580	75.94
Estuaries	4100	15.90
Total aquatic	24,364.72	94.50
Cropland/natural vegetation mosaic	41.6	0.16
Croplands	51.45	0.20
Total altered	93.05	0.36
Total natural (aq and terr)	25,689.48	99.64
Total semi-altered	41.6	0.16
Total altered	51.45	0.20
Total coastal ESP	25,782.53	100.00

Table 5 – Ecosystem Service Product (ESP) of coastal ecosystems per country

Country code	Country	Natural			Modified	
		Terrestrial (T) (million $US)	Aquatic (A) (million $US)	Total (T + A) (million $US)	Semi-altered (million $US)	Altered (million $US)
1	Albania	132.43	0.98	133.42	211.04	140.91
2	Algeria	3435.66	1.56	3437.23	500.26	318.67
3	Angola	7179.03	613.51	7792.54	39.84	56.65
	Anguilla		30.38	30.38		
	Antigua and Barbuda	64.18	493.21	557.39		0.65
	Antilles Netherlands		255.15	255.15		
4	Argentina	6992.59	130.46	7123.05	890.92	1214.53
	Aruba		143.24	143.24		
5	Australia	90,112.63	222,762.36	312,875.00	3.27	3306.55
6	Azerbaijan	300.72	12.56	313.28	175.49	129.91
	Bahamas	5078.26	14,767.87	19,846.12		50.61
	Bahrain		1628.96	1628.96		
7	Bangladesh	7009.79	6258.47	13,268.26	45.94	595.17
	Barbados		95.04	95.04		
8	Belgium	0.53	0.58	1.11	43.66	97.17
9	Belize	2651.27	4316.99	6968.26	3.06	95.64
10	Benin	1348.58	17.43	1366.02	13.67	
	Bermuda	193.72		193.72	225.13	58.71
11	Bosnia–Herzegovina		247.64	247.64		
12	Brazil	51,292.51	10,957.19	62,249.70	5090.20	272.00
	Brunei–Darussalam	576.33	1437.32	2013.65	1.12	28.17
13	Bulgaria	126.28	1.75	128.04	177.57	313.91
	Caiman Islands	3.18	259.84	263.03		0.08
14	Cambodia	3077.25	763.57	3840.82	13.27	396.67
15	Cameroon	7186.99	2274.83	9461.83	15.71	1.17
16	Canada	123,574.62	577.32	124,151.94	234.93	45.64
17	Chile	12,204.33	39.04	12,243.37	962.90	360.61
18	China	4198.84	2023.69	6222.53	2088.39	4310.12
19	Colombia	10,966.60	4369.40	15,335.99	1067.08	128.73
	Comoros	169.39	515.18	684.57	2.64	0.29
20	Congo	1856.26	121.07	1977.33	18.81	6.59
21	Congo Dem		225.90	225.90		
22	Costa Rica	4452.26	1004.92	5457.18	19.76	277.33
23	Cote d'Ivoire	11,093.31	151.23	11,244.54	136.76	0.16
24	Croatia	340.54	7.23	347.77	193.85	43.97
25	Cuba	7469.18	7277.09	14,746.27		711.55
26	Denmark	11.38	453.58	464.96	204.10	265.02
	Djibuti	157.38	831.73	989.11	0.02	
	Dominica	24.61	109.79	134.41		5.14
27	Dominican Rep	6452.02	583.46	7035.48		139.03
28	Ecuador	2497.84	1530.83	4028.67	500.79	270.10
29	Egypt	211.44	2321.38	2532.82	8.94	194.55
30	El Salvador	774.82	270.58	1045.40	1.02	85.11
31	Equatorial Guinea	4374.74	258.13	4632.86	6.01	0.66
32	Eritrea (Red Sea)	732.69	2052.03	2784.72	6.72	4.08
33	Estonia	341.81	5.83	347.64	362.15	25.61
34	Fiji		6514.50	6514.50		
35	Finland	3092.63	32.29	3124.92	16.93	98.32
36	France	1007.00	6568.01	7575.01	1120.81	1158.25
37	Gabon	12,920.49	1154.77	14,075.27	28.97	12.96
38	Gambia	805.18	596.32	1401.50	29.42	29.00
39	Georgia	666.19	0.43	666.63	97.86	44.24
40	Germany	17.25	8.94	26.18	681.70	358.23
41	Ghana	9948.68	102.81	10,051.50	231.60	0.03
42	Greece	1301.30	15.18	1316.49	749.28	388.46
	Grenada	3.86	194.94	198.80		0.94
	Guadeloupe	44.34	844.26	888.60	0.02	2.96
	Guam		134.35	134.35		
43	Guatemala	3303.80	217.19	3521.00	2.88	229.72
44	Guinea	2853.48	2968.04	5821.52	140.00	0.66
45	Guinea Bissau	2377.14	2487.51	4864.64	53.22	3.48
46	Guyana	7237.38	811.05	8048.43	282.92	10.59

Table 5 (*continued*)

		Natural			Modified	
Country code	Country	Terrestrial (T) (million $US)	Aquatic (A) (million $US)	Total (T + A) (million $US)	Semi-altered (million $US)	Altered (million $US)
47	Haiti	5424.46	424.17	5848.63		182.56
48	Honduras	6878.49	1044.00	7922.49	18.01	282.88
49	Iceland	2874.65	17.50	2892.15	5.95	0.99
50	India	14,371.98	8517.56	22,889.54	1322.52	4144.35
51	Indonesia	154,563.42	123,200.30	277,763.72	1636.51	6099.75
52	Iraq	64.45	0.16	64.61	0.62	
53	Ireland	1165.89	24.46	1190.35	790.93	136.18
54	Islamic Rep. Iran	3429.19	657.84	4087.03	261.69	235.87
55	Israel	101.53	8.49	110.02	43.01	4.55
56	Italy	2510.62	4483.78	6994.40	1147.11	784.63
57	Jamaica	557.44	852.36	1409.80		9.02
58	Japan	14,644.63	2755.42	17,400.05	691.21	256.35
59	Jordan	163.34	30.39	193.73	25.94	6.71
60	Kazakhstan	2430.98	22.40	2453.38	33.32	16.01
61	Kenya	1036.91	977.27	2014.18	174.73	120.17
	Kiribati		2217.85	2217.85		
62	Korea Dem	1990.57	4.23	1994.81	649.77	399.49
63	Korea Rep	1411.83	169.46	1581.29	668.07	145.78
64	Kuwait	81.69	67.89	149.58		
65	Latvia	283.17	4.51	287.68	389.22	51.92
66	Lebanon	80.24	5867.01	5947.25	53.70	18.53
67	Liberia	5557.37	192.21	5749.58	262.36	0.10
68	Libya	423.41	10.24	433.65	0.31	93.81
69	Lithuania	71.26	0.92	72.18	164.62	64.36
70	Madagascar	22,784.97	4622.64	27,407.61	733.55	92.26
71	Malaysia	22,241.84	8113.89	30,355.74	356.25	1666.59
	Maldives		10,185.95	10,185.95		
	Marshall Islands		3815.19	3815.19		
	Martinique	2.37	372.79	375.15	0.03	1.57
72	Mauritania	725.57	5.61	731.19	0.03	10.35
	Mauritius		4935.65	4935.65		
	Mayotte	30.88	352.95	383.83	1.05	
73	Mexico	36,557.30	19,577.24	56,134.54	420.50	1786.10
	Micronesia		3764.68	3764.68		
	Montserrat	1.77	0.05	1.82		0.31
74	Morocco	3431.52	11.33	3442.86	242.50	384.64
75	Mozambique	6082.10	5899.67	11,981.76	448.97	237.59
76	Myanmar (Burma)	15,998.01	5691.26	21,689.27	30.62	988.96
77	Namibia	1026.22	15.30	1041.52	0.53	0.28
	Nauru		30.38	30.38		
78	Netherlands	8.53	656.90	665.44	122.00	202.99
	New Caledonia	1404.31	11,282.52	12,686.84	10.82	108.82
79	New Zealand	15,880.06	1262.62	17,142.67		334.04
80	Nicaragua	7989.99	3264.11	11,254.10	2.14	224.19
81	Nigeria	24,775.24	9973.75	34,748.99	87.08	0.70
	Northern Marianas	3.81	30.44	34.26	0.02	0.31
82	Norway	6273.58	35.18	6308.76	61.24	97.33
83	Oman	539.69	349.47	889.17	2.07	19.86
84	Pakistan	586.87	2105.34	2692.21	1.94	99.86
	Palau	13.21	77.41	90.62	0.02	3.32
85	Panama	6459.73	2023.94	8483.67	60.49	376.84
86	Papua New Guinea	47,077.80	13,064.48	60,142.28	48.58	85.31
87	Peru	2955.23	61.51	3016.75	283.71	32.98
88	Philippines	4719.45	18,396.73	23,116.18	2036.89	1948.55
89	Poland	71.93	4.83	76.76	274.96	431.37
90	Portugal	691.80	3.24	695.03	227.46	123.70
	Qatar	60.85	5446.36	5507.21	0.05	
	Réunion and Eparses		337.62	337.62		
91	Romania	63.23	2.99	66.23	57.32	167.36
92	Russian Federation	276,080.86	666.06	276,746.92	1196.01	1276.03
	Samoa		399.21	399.21		

(*continued on next page*)

Table 5 (*continued*)

Country code	Country	Natural			Modified	
		Terrestrial (T) (million $US)	Aquatic (A) (million $US)	Total (T + A) (million $US)	Semi-altered (million $US)	Altered (million $US)
93	Saudi Arabia	1204.71	4765.01	5969.72	1.07	1.70
94	Senegal	5997.52	1825.56	7823.08	142.32	270.12
	Seychelles		6114.77	6114.77		
95	Sierra Leone	5219.89	1567.17	6787.06	112.25	
96	Singapore		65.86	65.86		
97	Slovenia	184.57	0.03	184.60	95.11	5.70
98	Solomon Islands	2733.77	4021.77	6755.54	5.46	89.34
99	Somalia	5093.38	537.73	5631.11	292.78	8.85
100	South Africa	6689.49	76.44	6765.93	537.74	554.28
101	Spain	1718.74	1948.41	3667.14	856.98	727.74
102	Sri Lanka	1433.65	502.98	1936.63	441.68	394.96
	St. Kitts and Nevis	12.32	110.14	122.46		0.11
	St. Lucia	4.62	142.83	147.45		1.41
	St. Vincent and Grenadines	39.73	258.47	298.20	0.06	1.18
103	Sudan	126.61	1659.95	1786.56	0.23	0.58
104	Suriname	5451.27	989.39	6440.66	156.12	0.02
105	Sweden	4680.72	271.81	4952.53	143.81	78.62
106	Syria	215.09	0.14	215.23	176.19	111.23
107	Tanzania	1842.25	3892.30	5734.55	177.29	298.63
108	Thailand	9502.02	3940.87	13,442.89	77.61	1054.81
109	Togo	462.00	10.09	472.09	23.90	
	Tonga		1438.04	1438.04		
110	Trinidad–Tobago	479.33	137.72	617.04	5.10	0.10
111	Tunisia	1243.34	10.51	1253.86	42.57	237.78
112	Turkey	4408.60	8.58	4417.18	1794.85	1201.70
113	Turkmenistan	440.48	11.66	452.13	1.17	1.00
	Turks and Caicos Island	109.35	679.24	788.59		1.25
	Tuvalu		431.72	431.72		
114	Ukraine	186.07	1817.94	2004.00	512.63	1142.52
115	United Arab Emirates	52.48	771.16	823.64	0.06	0.13
116	United Kingdom	15,943.79	2473.03	18,416.81	943.29	1519.77
117	United States	69,617.19	27,340.94	96,958.13	1611.50	1633.77
118	Uruguay	580.28	11.08	591.36	318.75	536.30
119	Uzbekistan		131.27	131.27		
	Vanuatu	0.42	4.20	4.62		
120	Venezuela	21,870.75	3759.20	25,629.95	630.86	46.27
121	Vietnam	4823.53	4186.91	9010.44	731.14	1423.80
	Virgin Islands UK	1533.02	4708.69	6241.72	6.72	29.58
	Virgin Islands US		408.72	408.72		
122	Yemen	1961.49	445.02	2406.51	10.47	32.97
	Total	1,324,763.43	684,717.99	2,009,481.42	41,596.79	51,451.77

Ecosystem Service Product (ESP) was calculated according to Costanza et al. (1997) for natural (terrestrial and aquatic), semi-altered and altered ecosystems. See Tables 1 and 4 for detailed information of ecosystem types. Blank spaces indicate missing information. Countries were assigned a numerical code (country code) that was used in the multivariate analyses (Fig 2). Countries without a code were not included in the analyses because of missing information.

the Indonesian Archipelago and Southeastern Asia is highest and is lowest in the Americas and Africa (Burke et al., 2001). It is estimated that about 70 species are found in mangroves worldwide (Spalding et al., 1997; FAO, 2003). Seagrasses in turn, are widely distributed in both tropical and temperate seas. Similar to mangroves, seagrasses are not particularly diverse. The World Atlas of Seagrasses reports 59 species in these ecosystems (Green and Short, 2003).

In contrast with the above, the availability of data describing patterns of species richness is poor for most littoral habitats although some data are available for the better known groups such as pinnipeds (sea lions and seals), turtles and birds. Groombridge and Jenkins (1996) report 283 seabirds, 34 pinnipeds and 7 marine turtles.

Coral reefs occupy less than 1% of the global benthic environment and yet, they are the most diverse and productive ecosystems. The so far incomplete inventory of species reveals that some 93,000 species inhabit coral reefs (Burke et al., 2001). However, Reaka-Kudla (1997) suggests that this number may increase to almost 1 million if the species yet to be discovered, named and classified are included. The Indo-Pacific region contains the largest species richness, especially the Philippines, Malaysia and Indonesia (Spalding et al., 2001).

Based on the information available, an educated guess would be that over one million species can be found on the world's coasts, considering aquatic, intertidal and terrestrial ecosystems. In fact, Reid and Miller (1989) stated that nearly 1 million species have been described for the coasts, but they estimate that the total number of species living at or near the coasts can be as high as 10 millions, once all the coastal species have been found, described and named. This is a relatively large percentage of the world's global biodiversity, considering the different estimates of global diversity that range from 5–10 million (Gastón, 1991) to 14 (Groombridge and Jenkins, 2002) and even 30 millions (Erwin 1988).

3. Economic importance

The coastal zone provides goods and services highly valuable to human society (Table 3). The goods from marine and coastal habitats include food for humans and animals, salt, minerals and oil resources, construction materials (sand, rock, lime and wood) and biodiversity, including the genetic stock that has potential application for biotechnology and medicine. The services provided by coastal terrestrial ecosystems are less readily quantified in absolute terms, but are also invaluable to human society and to life on Earth. These include shoreline protection against extreme events such as storms and hurricanes, storing and cycling nutrients, sustaining biodiversity, water capture. They also offer a highly valued habitat to live as well as areas for recreation and tourism (Carter, 1988; Costanza et al., 1997; van der Meulen et al., 2004). In the following section we estimate coastal Ecosystem Service Product by considering a broader and more ample definition of the coast which includes terrestrial ecosystems occurring within the 100 km limit.

3.1. *Methods and data*

To estimate the "non-market" economy of the coasts we used Ecosystem Service Product (ESP) as a proxy measure. ESP can be defined as the total value of ecosystem services and products of the different ecosystem types. ESP is used as a measure of the area of terrestrial and aquatic ecosystems of a country with the corresponding ecosystem service value calculated by Costanza et al. (1997). The values of the different ecosystem services and products are based on an estimate of the "willingness to pay" of individuals for the different ecosystem services (Costanza et al., 1997). Costanza et al. (1997) already estimated the value of the world's ecosystem services.

After having the total area covered by each of the terrestrial and aquatic ecosystems, we calculated Ecosystem Services Product (ESP) based on unit ecosystem-service values calculated by Costanza et al. (1997) and the ecosystem equivalence made by Sutton and Costanza (2002). With this we obtained ESP per square kilometer per ecosystem per country in terms of $US per year. The addition of ESP values per ecosystem per country yielded total dollar value of ecosystem services per country. The total ESP for all the countries generated total ESP provided by coastal ecosystems. In addition to our calculations, we used the information produced by Costanza et al. (1997) to include estuaries and floodplains in the global estimation of ESP values of coastal ecosystems.

3.2. *ESP value of coastal ecosystems*

The total value calculated for the Ecosystem Services Product (ESP) provided by coastal ecosystems of the world, including natural (terrestrial and aquatic) and human-transformed ecosystems added 25,782.53 × 10^9 $US per year. Of this, natural ecosystems contributed the most (Table 4). Within the natural ecosystems, aquatic provided a larger ESP than terrestrial, even though aquatic ecosystems only represented 5% of total natural coastal ecosystems. This apparent discrepancy is probably due to the high ecosystem service value attributed to swamps–floodplains and estuaries (Costanza et al., 1997).

In terms of per country ESP, Australia and Indonesia reached the highest values of terrestrial, aquatic and total natural ESP. The U.S., Mexico, Canada and the Philippines were also amongst the countries with highest natural ESP values (Table 5). In contrast, high ESP values for human-altered ecosystems were calculated for Brazil, China and India. These values are high because, in comparison with others, altered and semi-altered ecosystems cover a large area in the above-mentioned countries. In the past, certainly land use change into agriculture and development was beneficial to society as a whole. However, evidence shows that at present, further conversion does not lead to regional (or global) sustainability (Balmford et al., 2002).

4. Social importance

4.1. *Population density within 100 km of the coast*

The beauty of coastal ecosystems coupled with a rather high accessibility and the many services offered by these ecosystems makes the coasts a magnet for the world's human population. People gravitate to the coasts to live as well as for

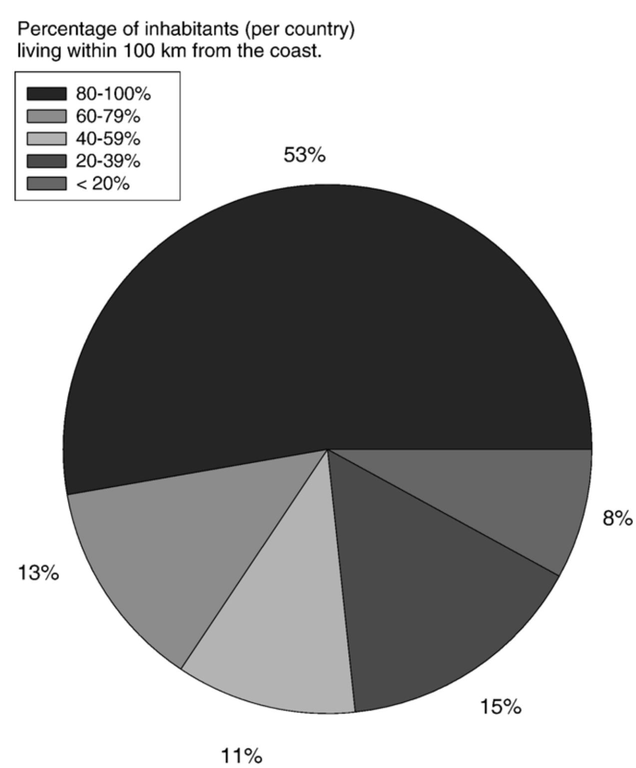

Fig. 1 – Relative frequency of countries with different proportions of inhabitants living within 100 km from the coast.

Table 6 – Demographic trends of the coastal countries of the world

	Total (millions)[a]	Coastal (millions)[a]	Percent from total[a]	Coastal density (000 people/ 100 km^2)	Projected population growth rate[b]	Total (millions)[b]	Coastal (millions)[b]	Coastal density (000 people/ 100 km^2)	Coastal density increment (%)
	2003	2003	2003	2003	2000–2015	2015	2015	2015	2003–2015
Albania	3.10	3.01	97.1	4.6	0.6	3.3	3.2	4.9	6.45
Algeria	31.90	21.95	68.8	14.1	1.5	38.1	26.2	16.8	19.44
Angola	15.00	4.41	29.4	2.0	2.8	20.9	6.1	2.7	39.33
Anguilla	0.01	0.01	100.0						
Antigua and Barbuda	0.10	0.10	100.0	0.3	1.2	0.1	0.1	0.3	0.00
Antilles Netherlands	0.21	0.21	100.0						
Argentina	38.00	17.23	45.3	2.1	1.0	42.7	19.4	2.3	12.37
Aruba	0.11	0.11	100.0	1.0					
Australia	19.70	17.69	89.8	0.3	1.0	22.2	19.9	0.3	12.69
Azerbaijan	8.30	4.62	55.7	5.3	0.7	9.1	5.1	5.8	9.64
Bahamas	0.30	0.30	100.0	0.0	1.3	0.4	0.4	0.0	33.33
Bahrain	0.70	0.70	100.0	2.7	1.6	0.9	0.9	3.5	28.57
Bangladesh	136.60	74.86	54.8	22.6	1.7	168.2	92.2	27.9	23.13
Barbados	0.30	0.30	100.0	3.1	0.2	0.3	0.3	3.1	0.00
Belgium	10.40	8.63	83.0	113.6	0.1	10.5	8.7	114.7	0.96
Belize	0.30	0.30	100.0	0.2	1.8	0.3	0.3	0.2	0.00
Benin	7.90	4.93	62.4	32.2	2.9	11.2	7.0	45.7	41.77
Bermuda	0.06	0.06	100.0						
Bosnia–Herzegovina	3.90	1.82	46.6	79.0	−0.1	3.9	1.8	79.0	0.00
Brazil	181.40	88.16	48.6	2.6	1.2	209.4	101.8	3.0	15.44
Brunei-Darussalam	0.40	0.40	100.0	1.5	2.0	0.5	0.5	1.9	25.00
Bulgaria	7.80	2.28	29.2	5.0	−0.8	7.2	2.1	4.6	−7.69
CaimanIslands	0.04	0.04	100.0						
Cambodia	13.50	3.21	23.8	2.9	1.9	17.1	4.1	3.6	26.67
Cameroon	15.70	3.44	21.9	1.9	1.6	19.0	4.2	2.3	21.02
Canada	31.60	7.55	23.9	0.0	0.9	35.1	8.4	0.0	11.08
Chile	16.00	13.04	81.5	0.2	1.0	17.9	14.6	0.2	11.88
China	1300.00	312.00	24.0	10.4	0.6	1393	334.3	11.1	7.15
Colombia	44.20	13.22	29.9	2.2	1.4	52.1	15.6	2.7	17.87
Comoros	0.80	0.80	100.0	1.7	2.5	1.0	1.0	2.1	25.00
Congo	3.80	0.93	24.5	4.5	3.1	5.4	1.3	6.5	42.11
Congo Dem	54.20	1.46	2.7	8.3	3.0	78.0	2.1	11.9	43.91
Costa Rica	4.20	4.20	100.0	2.0	1.5	5.0	5.0	2.4	19.05
Cote d'Ivoire	17.60	6.99	39.7	8.8	1.7	21.6	8.6	10.8	22.73
Croatia	4.50	1.71	37.9	0.3	0.0	4.5	1.7	0.3	0.00
Cuba	11.20	11.20	100.0	0.8	0.2	11.4	11.4	0.8	1.79
Denmark	5.40	5.40	100.0	1.0	0.2	5.6	5.6	1.1	3.70
Djibuti	0.80	0.80	100.0	1.8	1.6	0.9	0.9	2.0	12.50
Dominica	0.10	0.10	100.0	0.7	0.9	0.1	0.1	0.7	0.00
Dominican Rep	8.60	8.60	100.0	5.3	1.3	10.1	10.1	6.3	17.44
Ecuador	12.90	7.80	60.5	1.7	1.4	15.1	9.1	2.0	17.05
Egypt	71.30	37.86	53.1	6.4	1.8	88.2	46.8	7.9	23.70
El Salvador	6.60	6.52	98.8	8.6	1.6	8.0	7.9	10.5	21.21
Equatorial Guinea	0.50	0.36	72.3	0.6	2.2	0.6	0.4	0.7	20.00
Eritrea (Red Sea	4.10	3.01	73.5	0.9	3.0	5.8	4.3	1.2	41.46
Estonia	1.30	1.12	85.9	0.4	0.0	1.3	1.1	0.4	0.00
Fiji	0.80	0.80	99.9	0.2	0.7	0.9	0.9	0.2	12.50
Finland	5.20	3.79	72.8	0.1	0.2	5.4	3.9	0.1	3.85
France	60.00	23.76	39.6	3.2	0.3	62.3	24.7	3.4	3.83
Gabon	1.30	0.82	62.8	0.4	1.5	1.6	1.0	0.5	23.08
Gambia	1.40	1.27	90.8	2.5	2.3	1.9	1.7	3.4	35.71
Georgia	4.60	1.78	38.8	4.7	−0.7	4.2	1.6	4.3	−8.70
Germany	82.60	12.06	14.6	3.3	0.0	82.5	12.0	3.3	−0.12

Table 6 (*continued*)

	Total (millions) [a]	Coastal (millions) [a]	Percent from total [a]	Coastal density (000 people/ 100 km^2)	Projected population growth rate [b]	Total (millions) [b]	Coastal (millions) [b]	Coastal density (000 people/ 100 km^2)	Coastal density increment (%)
	2003	2003	2003	2003	2000–2015	2015	2015	2015	2003–2015
Ghana	21.20	9.01	42.5	11.9	1.9	26.6	11.3	14.9	25.47
Greece	11.10	11.01	99.2	0.7	0.1	11.2	11.1	0.7	0.90
Grenada	0.10	0.10	100.0	0.4	1.3	0.1	0.1	0.4	0.00
Guadeloupe	0.43	0.43	100.0	0.7					
Guam	0.16	0.16	100.0						
Guatemala	12.00	7.34	61.2	16.5	2.3	15.9	9.7	21.9	32.50
Guinea	9.00	3.68	40.9	2.3	2.3	11.9	4.9	3.0	32.22
GuineaBissau	1.50	1.42	94.6	0.4	3.0	2.1	2.0	0.6	40.00
Guyana	0.70	0.54	76.5	0.5	−0.1	0.7	0.5	0.5	0.00
Haiti	8.30	8.27	99.6	4.2	1.4	9.8	9.8	4.9	18.07
Honduras	6.90	4.52	65.5	2.4	2.0	8.8	5.8	3.1	27.54
Iceland	0.30	0.30	100.0	0.0	0.8	0.3	0.3	0.0	0.00
India	1070.80	281.62	26.3	16.4	1.4	1260.4	331.5	19.3	17.71
Indonesia	217.40	208.49	95.9	2.2	1.1	246.8	236.7	2.5	13.52
Iraq	23.10	1.32	5.7	12.5					
Ireland	4.00	4.00	99.9	0.6	1.3	4.7	4.7	0.7	17.50
Islamic Rep. Iran	68.20	16.30	23.9	2.8	1.3	79.9	19.1	3.2	17.16
Israel	6.50	6.28	96.6	30.6	1.6	7.8	7.5	36.8	20.00
Italy	58.00	45.88	79.1	5.0	0.0	57.8	45.7	5.0	−0.34
Jamaica	2.60	2.60	100.0	2.9	0.4	2.7	2.7	3.0	3.85
Japan	127.70	122.98	96.3	4.2	0	128	123.3	4.2	0.23
Jordan	5.40	1.57	29.0	58.0	2.1	7.0	2.0	75.2	29.63
Kazakhstan	14.90	0.54	3.6	0.1	0.0	14.9	0.5	0.1	0.00
Kenya	32.70	2.49	7.6	1.6	2.5	44.2	3.4	2.1	35.17
Kiribati	0.09	0.09	100.0	0.0					
Korea Dem	23.90	21.99	92.0	5.5					
Korea Rep	47.50	47.50	100.0	3.8	0.3	49.1	49.1	3.9	3.37
Kuwait	2.50	2.50	100.0	3.3	2.4	3.4	3.4	4.5	36.00
Latvia	2.30	1.73	75.2	3.1	−0.5	2.2	1.7	2.9	−4.35
Lebanon	3.50	3.50	100.0	11.9	1.0	4.0	4.0	13.6	14.29
Liberia	3.30	1.91	57.9	2.3		3.3	1.9	2.3	0.00
Libya	5.60	4.41	78.7	2.2	1.8	7.0	5.5	2.7	25.00
Lithuania	3.50	0.80	22.9	3.1	−0.4	3.3	0.8	2.9	−5.71
Madagascar	17.60	9.70	55.1	1.0	2.5	23.8	13.1	1.3	35.23
Malaysia	24.40	23.91	98.0	2.6	1.6	29.6	29.0	3.1	21.31
Maldives	0.30	0.30	100.0	0.1	2.4	0.4	0.4	0.2	33.33
Marshall Islands	0.07	0.07	100.0	0.0					
Martinique	0.40	0.40	100.0	1.1					
Mauritania	2.90	1.15	39.6	0.9	2.7	4.0	1.6	1.2	37.93
Mauritius	1.20	1.20	100.0	2.4	0.8	1.3	1.3	2.6	8.33
Mayotte	0.20	0.20	100.0						
Mexico	104.30	29.93	28.7	1.3	1.1	119.1	34.2	1.4	14.19
Micronesia	0.10	0.10	100.0	0.1					
Montserrat	0.01	0.01	100.0						
Morocco	30.60	19.92	65.1	9.9	1.4	36.2	23.6	11.7	18.30
Mozambique	19.10	11.27	59.0	1.6	1.8	23.5	13.9	2.0	23.04
Myanmar (Burma)	49.50	24.26	49.0	1.6	0.9	55	26.9	1.8	11.11
Namibia	2.00	0.09	4.7	0.1	1.0	2.2	0.1	0.1	10.00
Nauru	0.01	0.01	100.0						
Netherlands	16.10	15.04	93.4	7.9	0.3	16.8	15.7	8.2	4.35
New Caledonia	0.20	0.20	100.0	0.1				0.0	
New Zealand	3.90	3.90	100.0	0.2	0.7	4.3	4.3	0.2	10.26
Nicaragua	5.30	3.79	71.6	2.0	1.9	6.6	4.7	2.5	24.53
Nigeria	13.10	3.37	25.7	1.1	3.3	19.3	5.0	1.6	47.33
Northern Marianas	0.07	0.07	100.0						

(continued on next page)

Table 6 (*continued*)

	Total (millions) [a]	Coastal (millions) [a]	Percent from total [a]	Coastal density (000 people/ 100 km^2)	Projected population growth rate [b]	Total (millions) [b]	Coastal (millions) [b]	Coastal density (000 people/ 100 km^2)	Coastal density increment (%)
	2003	2003	2003	2003	2000–2015	2015	2015	2015	2003–2015
Norway	4.60	4.39	95.4	0.1	0.5	4.8	4.6	0.1	4.35
Oman	2.50	2.21	88.5	0.8	1.9	3.2	2.8	1.0	28.00
Pakistan	151.80	13.81	9.1	5.3	2.0	193.4	17.6	6.8	27.40
Palau	0.02	0.02	100.0						
Panama	3.10	3.10	100.0	0.5	1.6	3.8	3.8	0.7	22.58
Papua New Guinea	5.70	3.49	61.2	0.2	1.8	7.0	4.3	0.2	22.81
Peru	27.20	15.56	57.2	4.6	1.4	32.2	18.4	5.5	18.38
Philippines	80.20	80.20	100.0	2.4	1.6	96.8	96.8	2.9	20.70
Poland	38.60	5.21	13.5	5.0	−0.1	38.1	5.1	5.0	−1.30
Portugal	10.40	9.64	92.7	3.4	0.3	10.8	10.0	3.5	3.85
Qatar	0.70	0.70	100.0	0.8	2.3	1.0	1.0	1.1	42.86
Réunion and Eparses	0.70	0.70	100.0	3.2					
Romania	21.90	1.38	6.3	2.0	−0.4	20.9	1.3	1.9	−4.57
Russian Federation	144.60	21.55	14.9	0.2	−0.5	136.7	20.4	0.2	−5.46
Samoa	0.20	0.20	100.0	0.4	0.3	0.2	0.2	0.4	0.00
Saudi Arabia	23.30	7.04	30.2	0.9	2.3	30.8	9.3	1.2	32.19
Senegal	11.10	9.24	83.2	7.0	2.2	14.5	12.1	9.1	30.63
Seychelles	0.10	0.10	100.0	0.1	0.9	0.1	0.1	0.1	0.00
Sierra Leone	5.10	2.79	54.7	1.7	2.5	6.9	3.8	2.3	35.29
Singapore	4.20	4.20	100.0	15.7	1.1	4.8	4.8	17.9	14.29
Slovenia	2.00	1.21	60.6	29.6	−0.1	1.9	1.2	28.1	−5.00
Solomon Islands	0.50	0.50	100.0	0.1	2.3	0.6	0.6	0.1	20.00
Somalia	11.50	6.30	54.8	1.6				0.0	
South Africa	46.90	18.24	38.9	4.9	0.2	47.9	18.6	5.0	2.13
Spain	42.10	28.59	67.9	3.9	0.4	44.4	30.1	4.1	5.46
Sri Lanka	20.40	20.40	100.0	7.2	0.7	22.3	22.3	7.9	9.31
St. Kitts and Nevis	0.00	0.00	100.0		1.1	0	0		
St. Lucia	0.20	0.20	100.0	1.2	0.8	0.2	0.2	1.2	0.00
St. Vincent and Grenadines	0.10	0.10	100.0	0.4	0.4	0.1	0.1	0.4	0.00
Sudan	34.90	0.98	2.8	0.4	1.9	44.0	1.2	0.5	26.07
Suriname	0.40	0.35	86.9	0.6	0.5	0.5	0.4	0.7	25.00
Sweden	9.00	7.89	87.7	0.3	0.3	9.3	8.2	0.3	3.33
Syria	18.10	6.24	34.5	29.5	2.3	23.8	8.2	38.7	31.49
Tanzania	36.90	7.79	21.1	2.2	1.8	45.6	9.6	2.8	23.58
Thailand	63.10	24.42	38.7	3.5	0.7	69.1	26	3.8	9.51
Togo	5.80	2.59	44.6	48.8	2.5	7.8	3.5	65.6	34.48
Tonga	0.10	0.10	100.0	0.1	0.2	0.1	0.1	0.1	0.00
Trinidad–Tobago	1.30	1.30	100.0	1.8	0.3	1.3	1.3	1.8	0.00
Tunisia	9.90	8.32	84.0	8.1	1.0	11.1	9.3	9.1	12.12
Turkey	71.30	41.00	57.5	5.0	1.2	82.6	47.5	5.8	15.85
Turkmenistan	4.70	0.38	8.1	0.3	1.3	5.5	0.4	0.3	17.02
Turks and Caicos Islands	0.02	0.02	100.0						
Tuvalu	0.01	0.01	100.0						
Ukraine	47.50	9.93	20.9	2.0	−1.1	41.8	8.7	1.8	
United Arab Emirates	4.00	3.40	84.9	1.2	2.7	5.6	4.8	1.7	40.00
United Kingdom	59.30	58.47	98.6	3.0	0.3	61.4	60.5	3.1	3.54
United States	292.60	126.70	43.3	1.0	0.9	325.7	141.0	1.1	11.31
Uruguay	3.40	2.67	78.5	2.4	0.6	3.7	2.9	2.6	8.82
Uzbekistan	25.00	0.65	2.6	0.4				0	

Table 6 (*continued*)

	Total (millions) [a]	Coastal (millions) [a]	Percent from total [a]	Coastal density (000 people/ 100 km^2)	Projected population growth rate [b]	Total (millions) [b]	Coastal (millions) [b]	Coastal density (000 people/ 100 km^2)	Coastal density increment (%)
	2003	2003	2003	2003	2000–2015	2015	2015	2015	2003–2015
Vanuatu	0.20	0.20	100.0	0.1	1.8	0.3	0.3	0.1	50.00
Venezuela	25.80	18.86	73.1	2.8	1.6	31.3	22.9	3.4	21.32
Vietnam	82.00	67.90	82.8	6.0	1.2	95	78.66	6.9	15.85
Virgin Islands UK	0.02	0.02	100.0	0.1				0.0	
Virgin Islands US	0.10	0.10	100.0						
Yemen	19.70	12.51	63.5	4.0	3.1	28.5	18.1	5.7	44.67

Coastal population refers to total population within 100 km from the coast. Empty cells = no information available.
[a] UN (2005).
[b] Burke et al. (2001).

leisure, recreational activities and tourism. Interestingly, the estimates of population density along the coast have changed over time. Small and Nicholls (2003) reported that in 1990, 30% (1.2 billions) of the world human population lived at or near the coast, while this percentage rose to 41% (2.5 billions) by 2002 (UN 2005). In this time period, coastal population increased by 919 millions, which represents 56% from initial population in 1992. Contrastingly, in the same time period world global population rose from 5.4 to 6.2 billions (a total of 783 millions) (NationMaster, 2005), which represents 14%. The above shows that coastal population is growing at a fast rate, probably owing to a combination of population growth and migration. Currently there are no global data on population migration to the coast.

A wide majority of countries have a large percentage of their population (80–100%) living within the 100 km boundary (Fig 1, Table 6). Small and Nicholls (2003) report that worldwide, settlements are concentrated within 5 km of the coastline. They also found that throughout the 100 km width of the near-coastal zone, mean population densities were higher at elevations below 20 m. The number of people living at or near the coast does not seem to be associated with total coast length (coastal availability). For instance, the most uninhabited areas are located in northern latitudes. Countries like Canada and the Russian Federation, with the longest coastlines of the world have a very low number of inhabitants (30 and 200 respectively) every 100 km^2 along the coast (1 km of coastline × 100 km inland) (Table 6). In Mexico,

Table 7 – World's largest coastal cities, with projected populations in 2015 exceeding 8 million

City	Country	Population size (millions)			Expected growth	Rank	Rank	Rank
		1975	2000	2015	2000–2015 (%)	1975	2000	2015
Tokyo	Japan	19.771	26.444	26.444	0	1	1	1
Bombay	India	6.856	18.066	26.138	44.68	9	2	2
Lagos	Nigeria	3.3	13.427	23.173	72.59	20	4	3
Dhaka	Bangladesh	2.172	12.317	21.119	71.46	21	9	4
Karachi	Pakistan	3.983	11.794	19.211	62.89	15	10	5
New York	United States	15.88	16.64	17.432	4.76	2	3	6
Jakarta	Indonesia	4.814	11.018	17.256	56.62	14	11	7
Calcutta	India	7.888	12.918	17.252	33.55	7	6	8
Metro Manila	Philippines	5	10.87	14.825	36.38	13	13	9
Shangai	China	11.443	12.887	14.575	13.10	3	7	10
Los Angeles	United States	8.926	13.14	14.08	7.15	6	5	11
Buenos Aires	Argentina	9.144	12.56	14.076	12.07	5	8	12
Cairo	Egypt	6.079	10.552	13.751	30.32	12	15	13
Istanbul	Turkey	3.601	9.451	12.492	32.18	19	17	14
Rio de Janeiro	Brazil	7.854	10.582	11.905	12.50	8	14	15
Osaka	Japan	9.844	11.013	11.013	0.00	4	12	16
Tianjin	China	6.16	9.156	10.713	17.01	11	18	17
Bangkok	Thailand	3.842	7.281	10.143	39.31	16	20	18
Seoul	Republic of Korea	6.808	9.888	9.923	0.35	10	16	19
Lima	Peru	3.651	7.443	9.388	26.13	17	19	20
Madras	India	3.609	6.648	9.145	37.56	18	21	21

Modified from Klein et al. (2003).

with almost 24,000 km of coastline, coastal population is rather low too (1300 every 100 km^2). Instead, Belgium (113,000), Bosnia–Herzegovina (79,000) and Jordan (58,000) show the highest population densities on the coast in spite of their rather short coastlines. These apparent discrepancies can be understood through different explanations. For instance, the weather regimes in northern Canada and Russia make these coasts difficult to live in. In contrast, the low population density and economic activity along Mexican coasts are probably associated to the country's history and not to the year-round pleasant weather on the coast. The Aztecs and latter on the Spanish gravitated towards the central region of the country, where the capital city has been located for more than 5 centuries (Fermán and Gómez-Morín 1993; Moreno-Casasola 2000). In European countries, humans have gravitated toward the coasts for millennia. Calculations based on projections of population growth rate at current trends show that overall, population density on the coast will increase significantly over the next decade. Largest increments are predicted to occur in African countries, such as Angola, Benin, Congo, Eritrea, Gambia and Nigeria. Asia and the Americas will show lower population increments on the coast while it will decrease in several European countries (Germany, Italy, Latvia, Lithuania, Poland, Romania, Russian Federation and Slovenia), where current population growth rates are negative.

In addition to the above, 21 of the world's 33 megacities (with more than 8 million people) are located within 100 km of the coast (Table 7). Except for Tokyo, most of these cities have increased their sizes significantly over the last three decades. Particularly, Lagos (Nigeria), Dhaka (Bangladesh) and Karachi (Pakistan) show very high population growth rates. Certainly, such human over-population of the coasts requires infrastructure for manufacturing, transportation, energy processing and consumption as well as waste products disposal. If current demographic trends remain, and even without considering migrations to the coast, it seems like the human burden on the coasts will increase dramatically within the next decades (Tables 7 and 8). The result will be an increasing pressure on coastal ecosystems through habitat conversion, increased pollution and demand for coastal resources.

5. Data analyses and results

To integrate the information gathered for all the coastal countries in terms of their natural, economic and social features, we performed a multivariate analysis (Principal Component Analysis) (MVSP, 1985–2000), which is useful to find statistical patterns and trends in very large databases, as was our case. For each of the countries the following attributes were considered: percent of area with natural, semi-altered and altered ecosystems; ESP values for total natural, terrestrial, aquatic, semi-altered and altered ecosystems; and population density on the coast and projected population growth within the next decade. The axes on the figure show vector eigenvalues. Data were standardized and centered, and we applied an orthogonal rotation to maintain perpendicularity between axes.

The multivariate analyses grouped the countries along two axes that, together, explained 55% of total variance (31% in axis 1 and 24% in axis 2). Axis 1 was clearly associated with a conservation gradient, ranging from the least to the most preserved coastal areas. Axis 2 was associated with population density and growth rate on the coast (Fig. 2). In general, countries with high population density on the coast had the lowest coastal ESP values because of intense exploitation of coastal resources. That is, natural ecosystems in these regions are highly degraded.

The specific attributes of each of the groups generated by the multivariate analyses follow (see Table 8).

Group 1. The majority of the countries were inserted in this group. Countries in group 1 showed the largest percentages of natural ecosystems (61–100%).

Group 2. Countries in group 2 also show a high percentage of natural ecosystems (63–100%), but population density at the coast (2–50 thousand inhabitants every 100 km^2) and expected population growth rate (77–140%) are the highest.

Group 3. Is intermediate between groups 2 and 4. Percentage of natural ecosystems is lower (32–64%), and altered and semi-altered ecosystems are higher (55 and 42% respectively) than in the previous groups. Expected population growth rate is smaller and even negative (−5–60%) for countries included in this group.

Table 8 – Characteristics of the group definitions applied to the 163 countries analyzed via PCA

Groups	% natural	% semi-altered	% altered	Maximum coastal density 2000	Maximum coastal density 2025	Expected population growth 2000–2025	Maximum total ESP terrestrial	Maximum total ESP aquatic	Maximum total ESP altered	Maximum total ESP semi-altered
1	**61–100**	0–33	0–32	9	13	0–118	2×10^{10}	6.5×10^{9}	9.8×10^{8}	9.6×10^{8}
2	**63–100**	0–30	0–39	25	**50**	**77–140**	1×10^{10}	10×10^{9}	2.3×10^{8}	2.3×10^{8}
3	32–64	0–42	10–55	11	34	−5–60	2×10^{10}	8×10^{9}	1.6×10^{9}	1×10^{9}
4	28–41	4–43	**15–70**	**29**	**43**	−9–63	7×10^{9}	6×10^{9}	6×10^{8}	5×10^{8}
5	0.8–29	**20–74**	**12–73**	8	8	−12–40	2×10^{10}	1.8×10^{10}	1.9×10^{9}	2×10^{9}
6	16–52	14–38	**10–60**	15	20	16–32	5×10^{10}	1×10^{10}	$\mathbf{4.3\times10^{9}}$	$\mathbf{5\times10^{9}}$
7	65–97	0–7	2–28	2	3	−10–29	$\mathbf{2.7\times10^{11}}$	$\mathbf{2.2\times10^{11}}$	$\mathbf{6\times10^{9}}$	1.6×10^{9}
8	74–97	0.4–3	2–22	1	2	19–57	$\mathbf{1.2\times10^{11}}$	$\mathbf{1.3\times10^{10}}$	1.7×10^{9}	4.2×10^{8}

Groups are shown in Figs. 2 and 3 (coastal density in thousands for every 100 km^2 of coastline −1 × 100 km; expected population growth rate in %; ESP values in dollars per year). Bold highlights highest values in each column.

Groups 4, 5 and 6 contain countries with the largest percentages of semi-altered and altered ecosystems (up to 74%). Additionally, countries in group 4 have the highest coastal density in 2000 (13–29) and second highest expected population densities for 2025 (18–43 thousand inhabitants every 100 km^2).

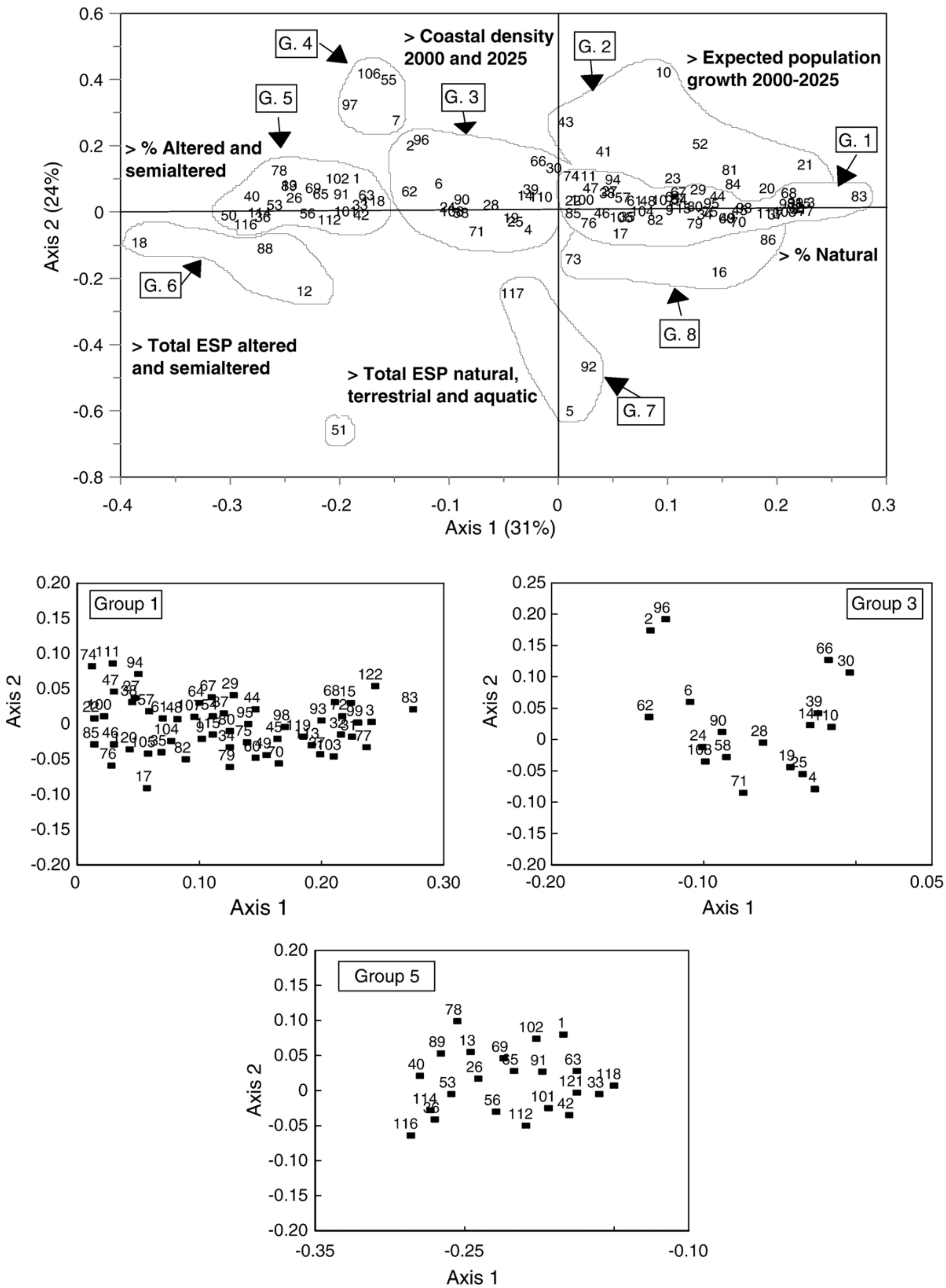

Fig. 2 – Principal Component Analyses performed with natural (% cover of different land use types), economic (Ecosystem Service Product calculated for each ecosystem) and social (population density and population growth rate trends at the coast) attributes from each country. The eight groups (G.) generated by the analyses are shown. Numbers indicate country codes (see Table 5). Groups 1, 3 and 5 are enlarged for clarity.

Group 5. These countries have the largest percentages of semi-altered (20–74%) and altered (12–73%) ecosystems located along their coasts. Population density is moderate (a maximum of 8000 every 100 km^2) and population growth rate is low, even negative in a few countries (−12–40%).

Group 6. Maximum ESP values for altered (4.3×10^9) and semi-altered (5×10^9) ecosystems are highest in those countries belonging to this group. Natural ecosystems are medium to well preserved (16–52%).

The last two groups comprise those countries with the largest ESP values for both terrestrial and aquatic ecosystems and also, a large percentage of natural ecosystems located along their coasts (up to 97%).

Group 7. Those countries grouped here showed the highest maximum ESP values for terrestrial (2.7×10^{11}), aquatic (2.2×10^{11}) and altered ecosystems (6×10^9). In contrast, countries in group 8 also showed high maximum ESP values for aquatic (1.3×10^{10}) and terrestrial (1.2×10^{11}) ecosystems, but altered ecosystems had lower values (1.7×10^9).

Finally, Indonesia could not be allocated in any group because of its extremely high ESP values for aquatic ecosystems (154, 563 million dollars). Similarly, Belgium, Bosnia–Herzegovina, Jordan and Togo had to be excluded from our analyses because of their extremely high coastal density values (higher than 48 thousand people every 100 km^2 of coastline, while the remaining countries had maximum densities less than 40 thousand) which did not allow us to effectively group the other countries.

Global analyses and classification of coastal countries according to their ecological, economic and social features are shown in Fig. 3. Some geographic trends are clear: Most African countries, the Middle East, northern Europe (Sweden, Norway and Finland) and a few countries in Central and South America (Honduras, Nicaragua, Chile, Peru, Venezuela, Guyana and French Guyana) show relatively well preserved coastal ecosystems, with moderate population growth rates. ESP values in these regions tend to be from moderate to high (group 1). However, those countries with the largest population densities and highest expected population growth rates (Nigeria, Benin, Togo, Ivory Coast, Irak, Pakistan and Guatemala) are also located within these regions (group 2). Countries with a lower percentage of natural ecosystems and higher percentage of altered and semi-altered ecosystems are scattered throughout the globe (group 3) (i.e. Cuba, Panama, Colombia, Ecuador, Argentina, Portugal, Argelia, Japan, Thailand, Malaysia). Syria and Bangladesh (group 4) are amongst the countries with the largest percentages of semi-altered and altered ecosystems (up to 70%), with a high coastal density in

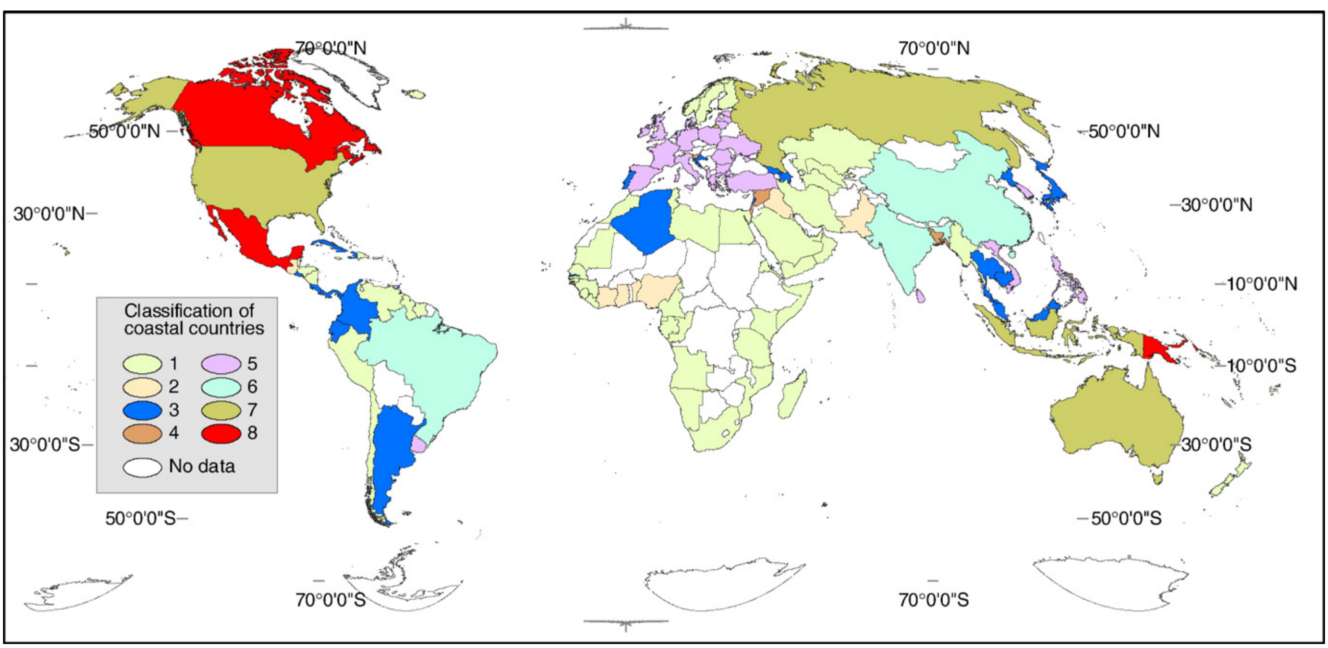

Fig. 3 – Classification of coastal countries according to their ecological, economic and social attributes along the coast. Color codes are: 1.—Largest percentages of natural ecosystems (61–100%); 2.—High percentage of natural ecosystems (63–100%), highest population density at the coast (50 thousand inhabitants every 100 km^2) and highest expected population growth rate (77–140%); 3.—Lower percentage of natural ecosystems (32–64%) and higher semi-altered and altered ecosystems (42–55%); moderate population growth rate (−5 to 60%); 4.—High percentage of altered ecosystems (up to 70%), highest coastal densities in (29–43 thousand per 100 km^2), high population growth rate (up to 60%); 5.—Largest percentage of altered and semi-altered ecosystems (up to 74%). Population density (a maximum of 8000 every 100 km^2) and population growth rate (−12 to 49%) are moderate; 6.—Highest ESP values for altered (4.3×10^9) and semi-altered (5×10^9) ecosystems, medium to well preserved ecosystems (16–52%); 7.—High percentage of natural ecosystems (up to 97%); highest maximum ESP values for terrestrial (2.7×10^{11}), aquatic (2.2×10^{11}) and altered ecosystems (6×10^9); 8.—High percentage of conserved ecosystems (up to 97%), high maximum ESP values for aquatic (1.3×10^{10}) and terrestrial (1.2×10^{11}) ecosystems, but altered ecosystems had lower values (1.7×10^9).

2000 (13–29) and second highest expected population densities for 2025 (18–43 thousand inhabitants every 100 km^2). In turn, most coasts in Europe and a few scattered countries in Asia (Sri Lanka, Vietnam, Philippines) (group 5) also have high percentages of altered and semi-altered ecosystems (up to 74%) (revealing a long-term exploitation of coastal natural resources), but population growth rates are reduced and even negative. Brazil, India, Butan and China (group 6) showed the highest ESP values for altered and semi-altered ecosystems. Lastly, North America (Alaska, Canada, USA, Mexico) Russia and South Eastern Asia (New Guinea, Indonesia and Australia) (groups 7 and 8) showed the highest ESP values for terrestrial, and aquatic ecosystems along their coasts.

6. Discussion

Existing global analyses of the world's coastal ecosystems reveal that 18% of all lands within 100 km are considered altered (urban or agricultural use); 10% are covered by a mosaic of crop and natural vegetation and 72% fall within the least modified category. Twenty-two percent of this lies in uninhabited areas in northern latitudes (Canada and Russia). Besides their large extension, coastal ecosystems comprise a high percentage of global biodiversity, especially because of the occurrence of coral reefs and tropical rain forests (the richest ecosystems of the world) on the coasts. When comparing ecosystem services of inland vs. coastal ecosystems the relevance of the coasts is highlighted. The total value calculated for the Ecosystem Service Product provided by coastal ecosystems of the world, including natural (terrestrial and aquatic) and human-transformed ecosystems represents 77% of world global value calculated by Costanza et al. (1997) (33, 268×10^9 $US per year). Our results are congruent with those of Costanza et al. (1997) who estimated that 63% of the global value of annual ecosystem services was generated in the Ocean, open water and aquatic ecosystems, while the remaining 37% was produced in terrestrial ecosystems. The ESP values calculated for our broader definition of coast were higher because we also included the terrestrial part of the coast. To our knowledge, this is the first time that the economic value of the coast is calculated, considering natural (terrestrial and aquatic), semi-altered and altered ecosystems. The relevance of the world's coastal ecosystems as providers of ecosystem services is obvious.

The coastal area accounts for only 20% of all land area in the world, and yet, it provides housing for 41% of the world population. This demographic trend places more infrastructure and associated economic investment on the coast and therefore, increases human impact on coastal ecosystems. In addition, given that demographic projections predict an even larger population on the coast within the next two decades (Duxbury and Dickinson, 2007), it is likely that human impact will be exacerbated even further. Because of weather harshness, uninhabited coasts (northern latitudes) are likely to remain as such, whereas regions in milder climates (the Mediterranean and the tropics) will have an increased human pressure on the coast.

The countries considered in this study were grouped according to the conservation status of the natural ecosystems located on their coasts, population density on the coast, expected population growth rate and ESP values. Coastal ecosystems of 51 countries (29.5% from total considered) (group 1) (a wide majority are located in Africa) are relatively well preserved. A few of these have a rapidly expanding human population on the coast (group 2). Within the next decades, these countries are likely to experience a much intense human burden along their coasts. In contrast, 27 countries (13.9% from total) (many of them in Europe and Asia) (groups 4 and 5) had a large percentage of altered ecosystems with low or even negative population growth rates. The coasts of these countries have faced a high and intense human impact in the past, but it is not expected to increase in the near future, if current demographic trends remain. In turn, countries from group 6, whose natural ecosystems along the coast have already been degraded (only 16–52% remains unaltered) have a human population that continues expanding. Human influence along these coasts is likely to be exacerbated in the near future. Finally, 7 countries (4% from total) had the highest ESP values, owing to the natural ecosystems (swamps–floodplains and estuaries) and large extensions in them (groups 7 and 8). Current demographic trends, so far, do not pose a threat to the coastal ecosystems of those countries included in these groups.

The above groupings demonstrate the high and contrasting variability of the coasts. Certainly, climate, migration trends, internal growth, water availability, types of coasts, and inland vs. coastal contrasts add to this variability and largely affect the future trends of the coasts of the world. As more information is generated and becomes available, further analyses will help elucidate in more detail how these factors will play out.

6.1. *Human impact on the coast*

Some of the currently recognized human impacts on the coast and coastal ecosystems have been reviewed for over a decade (Groombridge and Jenkins, 1996; García-Novo et al., 1997; Reaka-Kudla, 1997; Andrade, 1998; Burke et al., 2001; Spalding et al., 2001; FAO, 2003; Green and Short, 2003; Martínez et al., 2004; World Resources Institute, 2003) and are summarized next:

6.1.1. *Habitat and shoreline modification*

Human modification of the shoreline has altered currents and sediment delivery, enhancing coasts in some areas and inducing erosion and receding beaches in others (Psuty, 2004). Coastal habitats are being polluted, modified by development and replaced by artificial structures. These activities will increase as human population on the coast grows. No doubt, the human-colonized coasts coupled with a global sea-level rise perspective (IPCC, 1996) and increased frequencies of category 4 and 5 hurricanes (Webster et al., 2005) will threaten a large percentage of human population and infrastructure. Countries with a relatively high population growth will probably be facing intense habitat degradation in the next decades, whereas those countries with an already intensely modified coast will need to restore their natural ecosystems as much as possible (Palmer et al., 2004). Furthermore, the coasts of hurricane-prone countries (such as the USA, Mexico, Central America, India, Bangladesh, Madagascar, Australia, Japan and vicinities) (Pérez-Maqueo et al., 2007) are much more vulnerable to the additional degrading impact of increasingly frequent and intense hurricanes in a climate change scenario (Webster et al., 2005).

6.1.2. *Over-exploitation*

Many important coastal habitats are disappearing at a fast pace, particularly over the last 50 years. Mangroves for instance have disappeared from 5 to 80% (where data are available) (Spalding et al., 1997; FAO, 2003). The capacity of coastal and marine ecosystems to produce fish for human harvest is highly degraded by overfishing, destructive trawling techniques and loss of coastal nursery areas (Burke et al., 2001). Commercial fish species are threatened globally (Atlantic Cod, tuna and haddock) (McGinn, 1999) as are several species of whales, seals and sea turtles. A preliminary estimate of endangered littoral species indicates a total of 85 species at risk (Burke et al., 2001). Certainly, as the extent and functionality of coastal ecosystems declines, the capacity to deliver ecosystem services will become depleted and, eventually, be lost. Some of the negative consequences of these environmental losses will be an increased damage from storm surges, hypoxia areas and eutrophication.

6.1.3. *Invasive species*

Species invasion is one of the most globally pervasive threats to natural ecosystems worldwide (Primack, 1993). Human vectors have exacerbated the otherwise natural movements of species from region to region. Burke et al. (2001) report that the marine ecosystems in the Mediterranean contain 480 invasive species, the Baltic Sea 89, and Australian waters 124 species. Terrestrial ecosystems are also exposed to species invasions, both by intentional and accidental introductions. Multiple experiences have demonstrated that removal of invasive species may be an extremely expensive and time-consuming task that is not always successful. Prevention programs should be enforced.

6.2. *Faint glimmers of hope: conservation of coastal and marine biodiversity*

Growth in the number of marine and coastal protected areas over the last decades indicates an increased awareness toward the protection of coastal environments. There are several international conservation organizations that have focused on coastal ecosystems. Burke et al. (2001) report an increasing number of marine protected areas that peaked in the 1990s. However, information of the actual proportion of the world's coasts and oceans that are protected remains unknown. Furthermore, many "protected" areas lack adequate funding and staff, and thus, there is no guarantee that proper management and protection will actually occur. There are three major protection schemes that operate on coastal ecosystems: Ramsar sites (declared under the convention of wetlands), Biosphere Reserves (declared under UNESCO's Man and the Biosphere Programme) (UN, Millenium Project, 2005) and World Heritage sites. No doubt, there is an urgent need to: 1) identify and describe areas of high conservation importance at genetic, species and ecosystem levels; 2) increase the taxonomic inventory of coastal ecosystems; c) improve distribution maps of species and habitats; d) assess the threat status at a global level. Understanding the links between human pressure and ecosystem condition will improve the assessment of future trends, while the profound effects that human activities have on the coastal habitats, biodiversity and ecosystem services are considered.

7. Conclusions

Humans have been occupying and using the coasts and their multiple ecosystems for millennia and our impact has been very large in some areas and is likely to increase in others. Better-informed decisions on where to build (low-risk areas), what types of constructions are better (in accordance with the environment) (Duxbury and Dickinson, 2007; Dickinson et al., in press) and how to deal best under extreme events such as hurricanes (effective prevention and evacuation programs) (Baker and Refsgaard, 2007) are becoming increasingly necessary and even mandatory.

The extension of natural ecosystems presented here may be underestimated. For instance, Mexico is considered to have 4880 km^2 of mangroves, but recent more detailed estimates (López-Portillo, J. pers. comm.) reveal a total of 9421 km^2. All in all, these calculations are useful for a global estimate of the value of ecosystem services provided by coastal ecosystems.

The abundant coasts of the world are highly heterogeneous in terms of their physical, geomorphological, biotic, social, economic and climatic features. They should all be considered in the decision-making process. Scientific knowledge, informed decisions and creative consensus within the human constituents of the coasts are key elements to achieve economic efficiency, social equity, and ultimately, ecological sustainability. Only through coordinated global and integral efforts will we be able to maintain, live and enjoy our coasts, without exploiting them as if they were infinite.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ecolecon.2006.10.022.

REFERENCES

Andrade, F., 1998. Coastal management research and sustainability. In: Costanza, R., Andrade, F. (Eds.), Ecological Economics and Sustainable Governance of the Oceans. SILVAS-Cooperativa de Trabalhadores Gráficos, Lisboa, pp. 99–106.

Bailey, R.G., 1998. Ecoregions: The Ecosystem Geography of the Oceans and Continents. Springer-Verlag, New York. 176 pp.

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, S.E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K., Turner, K.R., 2002. Economic reasons for conserving wild nature. Science 297, 950–953.

Baker, D., Refsgaard, K., 2007. Institutional development and scale matching in disaster response. Ecol. Econ. 63, 331–343.

Burke, L., Kura, Y., Kasem, K., Revenga, C., Spalding, M., McAllister, D., 2001. Coastal Ecosystems. Washington DC World Resources Institute. 93 pp.

Carter, R.W.G., 1988. Coastal environments. An Introduction to the Physical, Ecological and Cultural Systems of the Coastlines. Academic Press, New York. 617 pp.

Costanza, R., 1998. The ecological, economic and social importance of the oceans. In: Costanza, R., Andrade, F. (Eds.), Ecological Economics and Sustainable Governance of the Oceans. SILVAS-Cooperativa de Trabalhadores Gráficos, Lisboa, pp. 69–98.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R.V., Raskin, R., Sutton, P., ven den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260.

Culliton, T.J., Warren, M.A., Goodspeed, T.R., Remer, D.G., Blackwell, C.M., MacDonough, J.J., 1990. 50 Years of Population Change along the Nation's Coasts, 1960–2010. National Oceanic and Atmospheric Administration, Rockville, MD. 41 pp.

Dickinson, S., Duxbury, J., Lewis, D., in press. Designing a sustainable coastal city: a survey and the future of New Orleans. Ecol. Econ.

Duxbury, J., Dickinson, S., 2007. Principles for sustainable governance of the coastal zone. Ecol. Econ. 63, 319–330.

Erwin, T.I., 1988. The tropical forest canopy. In: Wilson, E.O. (Ed.), Biodiversity. National Academic Press, Washington D.C., pp. 123–129.

FAO, 2003. Status and trends in mangrove area extent worldwide. By Wilkie, M.L. and Fortuna, S. Forest Resources Assessment Working Paper No. 63. Forest Resources Division. FAO, Rome. http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/007/j1533e/J1533E67.htm.

Fermán, J.L., Gómez-Morín, L., 1993. Legal and regulatory aspects to support a Mexican coastal zone management program. In: Fermán, J.L., Gómez-Morín, L., Fischer, D.W. (Eds.), Coastal Management in Mexico. The Baja California Experience. American Society of Civil Engineers, New York, pp. 7–13.

García-Novo, F., Crawford, R.M.M., Díaz-Barradas, M.C. (Eds.), 1997. The Ecology and Conservation of European dunes. Universidad de Sevilla, Sevilla, Spain. 374 pp.

Gastón, K.J., 1991. The magnitude of global insect species richness. Cons. Biol. 5, 283–296.

GLCCD (Global Land Cover Characteristics Database), Version 1.2. 1998. Loveland, T.R., Reed, B.C., Brown, J.F., Ohlen, D.O. Zhu, Z., Yang, L., Merchant, J., 2000. Development of a Global Land Cover Characteristics database and IGBP DISCover from 1-km AVHRR data. Int. J. Remote Sensing 21: 1303–1330. Data available on-line at: http://edcdaac.usgs.gov/glcc/glcc.html.

Green, E., Short, F.T. (Eds.), 2003. World Atlas of Sea Grasses. UNEP-WCMC. University of California Press, USA. 298 pp.

Groombridge, B., Jenkins, M.D. (Eds.), 1996. The Diversity of the Seas: A Regional Approach. Cambridge, UK: World Conservation Press, World Conservation Monitoring Centre. 129 pp.

Groombridge, B., Jenkins, M.D., 2002. World Atlas of Biodiversity. UNEP, WMCM. University of California Press, Berkeley, USA. 340 pp.

Hinrichsen, D., 1998. Coastal Waters of the World: Trends, Threats and Strategies. Island Press, Washington DC. 275 pp.

IPCC (Intergovernmental Panel on Climate Change), 1996. In: Watson, R.T., Zinyowera, M.C., Moss, R.H. (Eds.), Climate Change 1995. Impact, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses (IPCC 1995 WGII). Cambridge University Press, New York, 889 pp.

Martínez, M.L., Maun, A.M., Psuty, N.P., 2004. The fragility and conservation of the world's coastal dunes: geomorphological, ecological and socioeconomic perspectives. In: Martínez, M.L., Psuty, N. (Eds.), Coastal Dunes: Ecology and Conservation. Springer-Verlag, Berlin, pp. 355–370.

McGinn, A.P., 1999. In: Peterson, J.A. (Ed.), Safeguarding the health of oceans. Paper #145, Worldwatch Paper Series. Worldwatch Institute, Washington, D.C. 87 pp.

Miller, M.L., Hadley, N.P., 2005. Tourism and coastal development. In: Schwartz, M.L. (Ed.), Encyclopedia of Coastal Science. Springer-Verlag, The Netherlands, pp. 1002–1008.

Moreno-Casasola, P., 2000. Plan de manejo comunitario de La Mancha-El Llano, un proyecto de desarrollo costero y de creación de un ambiente sustentable. Cuadernos de Biodiversidad no. 3, año II. Universidad de Alicante, España, pp. 4–7.

MVSP, 1985–2000. Multi-Variate Statistical Package, Version 3.11. Kovach Computing Services.

NationMaster, 2005. World Statistics, Country Comparisons. www.nationmaster.com (consulted September 20, 2006).

Palmer, M.A., Bernhardt, E.S., Chornesky, E.A., Collins, S.L., Dobson, A.P., Duke, C.S., Gold, B.D., Jacobson, R., Kingsland, S., Kranz, R., Mappin, M.J., Martinez, M.L., Micheli, F., Morse, J.L., Pace, M.L., Pascual, M., Palumbi, S., Reichman, O.J., Simons, A.L., Townsend, A., Turner, M.G., 2004. Ecology for a crowded planet. Science 304, 1251–1252.

Pérez-Maqueo, O., Intralawan, A., Martínez, M.L., 2007. Coastal disasters from the perspective of ecological economics. Ecol. Econ. 63, 273–284.

Primack, R.B., 1993. Essentials of Conservation Biology. Sinauer Associates Inc., Sunderland Massachusetts, USA. 564 pp.

Psuty, N.P., 2004. The coastal foredune: a morphological basis for regional coastal dune development. In: Martínez, M.L., Psuty, N. (Eds.), Coastal Dunes: Ecology and Conservation. Springer-Verlag, Berlin, pp. 11–28.

Reaka-Kudla, M.L., 1997. The global biodiversity of coral reefs: a comparison with rain forests. In: Reaka-Kudla, M.L. (Ed.), Biodiversity II: Understanding and Protecting our Biological Resources. Joseph Henry Press, Washington D.C., pp. 83–108.

Reid, W.V., Miller, K.R., 1989. Keeping Options Alive: The Scientific Basis for Conserving Biodiversity. World Resource Institute, Washington D.C. 110 pp.

Schwartz, M.L. (Ed.), 2005. Encyclopedia of Coastal Science. Springer-Verlag, The Netherlands. 1211pp.

Small, C., Nicholls, R.J., 2003. A global analysis of human settlement in coastal zones. J. Coast. Res. 19 (3), 584–599.

Spalding, M.D., Blasco, F., Field, C.D. (Eds.), 1997. World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp.

Spalding, M.D., Ravilious, C., Green, E.P., 2001. World Atlas of Coral Reefs. UNEP-WCMC. University of California Press, USA. 424 pp.

Sutton, P., Costanza, R., 2002. Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation. Ecol. Econ. 41, 509–527.

UN, 2005. Human Development Report. International Cooperation at a Crossroads: Aid, Trade and Security in an Unequal World. 372 pp.

UN Millenium Project, 2005. Environment and Human Well-Being: a Practical Strategy. Report of the Task Force on Enviromental Sustainability. EarthScan, United Nations Development Programme, London. 224 pp.
van der Maarel, E., 1993a. Dry Coastal Ecosystems: Polar Regions and Europe. Elsevier Science Publishers, The Netherlands. 600 pp.
van der Maarel, E., 1993b. Dry Coastal Ecosystems: Africa, America, Asia and Oceania. Elsevier Science Publishers, The Netherlands. 616 pp.
van der Meulen, F., Bakker, T.W.M., Houston, J.A., 2004. The costs of our coasts: examples of dynamic dune management from Western Europe. In: Martínez, M.L., Psuty, N. (Eds.), Coastal Dunes: Ecology and Conservation. Springer-Verlag, Berlin, pp. 259–278.
Webster, P., Holland, J., Curry, G.J., Chang, H.-R., 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. Science 309, 1844–1846.
World Resources Institute, 2003. World Resources 2002–2004. Decisions for the Earth: Balance, Voice and Power. United Nations Development Programme, United Nations Environmental Programme, The World Bank, World resources Institute. USA. 315 pp.