STRP
Scientific and Technical Review Panel

Briefing Note

Number 5, December 2012

Ramsar Convention on Wetlands

Evaluating the risk to Ramsar Sites from climate change induced sea level rise

Purpose of this BN

To provide a preliminary assessment of coastal Ramsar Sites that are at risk to inundation as a consequence of sea level rise, in order to provide site managers with information that may assist them in assessing adaptation strategies.

Background information

CIESIN, through its NASA-supported Socioeconomic Data and Applications Center (SEDAC), conducted a global analysis of Ramsar Sites and developed this report in response to a request by the Ramsar Convention's Scientific and Technical Review Panel (STRP), as part of its wetlands and climate change work area, for "information for wetland managers and decision-makers on the extent of land use and population in the vicinity of wetlands in specific areas, e.g., deltas, and current and likely impacts."

To access the map client or to download the spreadsheet and shapefile that includes assessment results, visit http://www.ciesin.columbia.edu/data/ramsar-slr/

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This Briefing Note and the accompanying web map service and data sets, developed by the Center for International Earth Science Information Network (CIESIN) of Columbia University, provide a preliminary assessment of the risk to coastal wetlands designated as Wetlands of International Importance (Ramsar Sites) under the Ramsar Convention on Wetlands from rising sea levels due to climate change. Two scenarios are evaluated, 0-1 meter sea level rise (SLR), which is close to what the Intergovernmental Panel on Climate Change (IPCC) predicts for this century, and 0-2 meter SLR, which is an upper bound for SLR in this century if land-based ice sheets respond faster than expected to temperature changes (AMAP 2011, Pfeffer et al. 2008). It has to be recognized that sea level rise will not be consistent globally, but is affected by coastal bathymetry and local topography and tides, while the extent of areas periodically submerged will also be affected by storm surges (Strauss et al. 2012, Tebaldi et al. 2012). There will also be many secondary impacts of sea level rise, such as the displacement of human populations and agricultural activities, which could have additional consequences for wetland and biodiversity loss (e.g., Wetzel et al. 2012). Time and resources did not permit this level of analysis globally, so this report represents a first-order risk assessment.

Key messages and recommendations

- This global approach provides a first-order assessment of the relative risk of Ramsar Sites to sea level rise, and likely impediments to their landward migration.
- Analyses of this kind can alert decision makers to possible wetland losses and assist in priority setting for localized, more detailed studies.
- Local adaptation plans and assessments will still need to be conducted at the site level, preferably using LIDAR data, accurate global positioning satellite (GPS) units, and/or aerial photography to assess local topography. These assessments can also incorporate more accurate spatial data and local knowledge of impediments to site migration.
- For further global assessments, it could be useful to assess Ramsar Site vulnerability through a composite score covering a broader range of risks, and incorporating the size of the site, population data, urban extent, slope

or elevation behind the site, and possibly other factors like poverty or government capacity[1].

- The analysis underscores the importance of having accurate geospatial data on boundary locations of all Ramsar Sites (as called for in Ramsar Resolutions X.26 and XI.8) for use in spatial analyses that can contribute to *inter alia* site management planning and monitoring and climate change adaptation measures.

Introduction

In this analysis the risk of wetland loss is first assessed by evaluating proximity to the coast and elevation of Ramsar Sites to see what percentage of a Site's area that is currently not inundated is at risk of inundation under different sea level rise scenarios. The second step in this assessment is evaluating a Site's ability to migrate inland given human populations and activities in and around a Site, which are considered to be the primary impediments to landward migration (topographical barriers were not directly considered here). The variables included in this analysis were population density and population growth within the Site and in areas surrounding the Site, and the degree of urbanization within the Site and in a buffer zone around it.

Suncheon Bay Ramsar Site, Republic of Korea ©*Suncheon-si*

It is important to emphasize that this work was constrained by the spatial accuracy limitations of globally available data sets, so there remain uncertainties that would need to be resolved by local-level assessments. For example, current mean sea level as defined by the Shuttle Radar Topography Mission (SRTM) has a vertical accuracy in low slope areas of approximately +/- 4-5 meters (Gorokhovich and Voustianiouk 2006) and cannot depict sea level at different tide states. The primary value of this assessment is its comparative nature. What this report and its associated data sets provide is a first-order assessment of Ramsar Sites at risk from sea level rise that can alert decision makers to possible wetland losses and assist in priority setting for further localized study.

1 See also *Ramsar Technical Report* No. 5 (2011) *A Framework for assessing the vulnerability of wetlands to climate change*, on: http://www.ramsar.org/pdf/lib/lib_rtr05.pdf

RELATED DOCUMENTS

1) Center for International Earth Science Information Network (CIESIN)/Columbia University. 2012. Low Elevation Coastal Zone: Urban-Rural Population and Land Area Estimates. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://www.ciesin.columbia.edu/data/lecz-urban-rural-population-land-area-estimates/

2) Strauss, B., Ziemlinski, R., Weiss, J., Overpeck, J. 2012 Tidally-adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States. *Environmental Research Letters* 7 014033. http://dx.doi.org/10.1088/1748-9326/7/1/014033

Data and Methods

CIESIN utilized the best available Ramsar Sites data, building on the official site boundaries from the Ramsar Sites Information Service (RSIS) (http://ramsar.wetlands.org/) accessed in October 2010, and adding to these additional sites for which boundary data is available from the 2010 World Database on Protected Areas (WDPA). This yielded 466 official boundaries from the RSIS, and 557 unofficial boundaries from the WDPA. A further seven boundary delineations were added from Bermuda's Department of Conservation Services, and 113 from Mexico's Comisión Nacional de Áreas Naturales Protegidas (CONANP). In total, 1,143 Ramsar Sites had delineated boundaries. Of the 1,882 Ramsar Sites with latitude and longitude coordinates available from the RSIS (downloaded in October 2010), 739 did not have geospatial boundaries. Thus, approximately 60% of the 1,882 Sites used in our analysis had geospatial boundaries. For the 739 Sites without geospatial boundaries available, we estimated boundaries based on centroids (latitude-longitude coordinates) by creating buffers equivalent to the site area. But since their levels of risk can only be approximated, we calculated and reported statistics on these Sites separately.

Ramsar Sites were treated as coastal sites if the boundary polygon intersected with the coastal zone, which was defined as the zone from the coastline up to and including 5 meters above mean sea level (AMSL). Coastal elevation data was derived from Shuttle Radar Topographic Mission (SRTM) remote sensing data processed to a global 90m grid by ISciences LLC, and a coastal boundary using a Landsat-derived coastline product developed by ISciences LLC.[2] The coastal subset of Ramsar Sites used in this analysis contained 613 sites with boundary data and 251 sites with estimated boundaries.

The population density and urban extent data sets used in this analysis are from the NASA SEDAC Global Rural-Urban Mapping Project (GRUMPv1) (CIESIN 2011a and 2011b). Note that population density for 2000 was based on census data observations, whereas the population density for 2010 is based on projections of the GRUMP population density grids using the History Database of the Global Environment (HYDE) population distribution for 2010 (Klein Goldewijk 2010). The HYDE data are extrapolations on trends and are not based on circa 2010 census data.

All geospatial analyses were conducted using ArcGIS 10. The first measure of exposure was to calculate land area at risk from sea level rise. SRTM coastlines were used to demarcate what portion of coastal sites are already inundated and to determine those portions of the sites that are either tidal or above the high tide mark, and are therefore considered at risk of sea level rise. Risk increases with a higher proportion of the Site area in both the 0-1 meter and the 0-2 meter band. These proportions were calculated by intersecting Ramsar Sites with a 0m, 1m and 2m elevation band and calculating the area of each intersection in square kilometers.

The second type of risk assessed was the ability of a Ramsar Site to migrate inland in response to rising sea levels. Population density was evaluated within and around a Ramsar Site by using zonal statistics, along with the proportion of the area in and around a site that is urbanized.

Results

Sites with and without delineated boundaries were analyzed separately. In the first phase, we ranked wetland sites with boundaries by percent land area at risk, and then looked at a subset of the sites most at risk to assess impediments to landward migration using the population data and satellite images from Google Earth to understand the pattern and extent of built infrastructure in the vicinity of the wetland (see Figures 1-6 in Annex 1). It is noteworthy that many Sites also have population settlements, roads, and agricultural activities within their boundaries.

Areas already inundated can also be affected by sea level rise

"Deeper coastal waters will have a multitude of effects on seagrasses. Deeper water will reduce sunlight penetration to the seafloor, change tidal variation, and result in increased seawater flooding of rivers and estuaries. These changes will alter seagrass distribution and reduce the quality of a variety of seagrass habitats" (quoted from the Pacific Islands Climate Change Virtual Library).

For the coastal Ramsar Sites with boundaries, we found that while 85% will be affected in some way by a 0-1 meter rise in sea level, only 28% of all such Sites would have greater than 50% of their area at risk, and only 9% have greater than 90% of their area at risk.[3] The numbers for 0-2 meter sea level rise are similar: 88% of these coastal Ramsar Sites would be affected, with 37% of such Sites having greater than 50% of their area at risk and 13% of Sites with greater than 90% of their area at risk. The percent of the total area at risk across all coastal Ramsar Sites as a result of 0-1 meter sea level rise would be about 3.5% of their total land area. The total area at risk as a result of 0-2 meter sea level rise is about 4.7% of their total land area.

The statistics generated for Ramsar Sites without boundaries (251 sites), for which we created buffered points, suggest that fewer of these Sites are at risk from sea level rise. We found that 80% of these estimated Sites will be affected by a 0-1 meter rise in sea level. Only 4% of these would have greater than 50% of their area at risk, while only 1 Site would have over 90% of its area threatened. The numbers increase slightly for a 0-2 meter rise in sea level, where we found 85% of Sites would be exposed, 6% would suffer at least 50% of their area at risk, and still only 1 Site would have over 90% of its area threatened. The percent of the total area at risk across all those coastal Ramsar Sites without boundaries would be about 4% total area from 0-1 meter seal level rise, and 6% for 0-2 meter sea level rise. However, these lower figures probably reflect error inherent in the estimated boundaries, rather than a real significantly lower risk.

2 Available from http://www.terraviva.net/spotlight/spotlight_global_coastline.html.

3 Note that some Sites are already below sea level according to the SRTM data. These sites are reported in Table 7 of Annex 1.

For Sites with boundaries, we assessed the ability to migrate inland using population density, population growth, and urban extent data. Population density and population growth were evaluated within a 1km and a 5km buffer around each site to look at the density of settlement and the change from 2000-2010. Mean, minimum and maximum population density statistics within the buffer zones were generated. Urban extent was evaluated in a 1km buffer around each site, with each site assigned a percent buffer area classified as urban. For each part of the world, we report the top 10 sites in terms of level of exposure to a 0-1m SLR in Tables 1-6 of Annex 1.

Figures 7-9 provide regional views of the relative risk of Ramsar Sites to SLR in Mexico, northwestern Europe (from the Netherlands to Scandinavia and the Baltic), and the Black Sea and the eastern Mediterranean. In Mexico (Figure 7), Sites on the Yucatan Peninsula face considerable risks, together with Sites surrounding the Gulf of California and many smaller Sites along the Pacific coast. Figure 8 shows that the Netherlands, Germany, and Denmark have many Sites at risk, although Sites in the Netherlands are generally behind seawalls and therefore are not technically in immediate inundation danger. The Baltic and Scandinavian countries (Figure 8) have a large number of Sites with greater than 71% of their areas at risk. For the Black Sea and eastern Mediterranean (Figure 9), there are few Sites at risk, but some of them are large, such as the Danube Delta (see also Figure 3), which has 80% of its area at risk to a 0-1m SLR.

Limitations

The biggest limitation for this study has been the lack of boundary data for the complete set of Ramsar Sites. The Sites with complete boundary data tend to be located in developed countries, with disproportionately few Sites with boundary data from developing countries. The Ramsar Sites with estimated boundaries based on buffered points have large uncertainties in terms of their level of exposure to sea level rise, since Ramsar Sites along the coast often tend to be elongated or of irregular shape.

A second issue is that in many cases the Sites may be tidal or partially submerged, and therefore the assessment of percent area at risk to SLR actually included areas of Sites that are already fully or partially submerged. In Table 7 we provide a list of Sites that are, according to the SRTM data, already wholly below 0m in elevation. As noted in the introduction, tides and storm surge will affect that amount of area inundated under various SLR scenarios, and that would need to be taken into account in any local assessment.

The importance of digital boundary information

Ramsar Contracting Parties have been encouraged to provide digital boundary information for existing Ramsar Sites (e.g., Resolution X.26, paragraph 24), but for many Sites this information is still currently not available. For the Ramsar Site Information Sheet (RIS) – 2012 revision adopted by Resolution XI.8, which comes into force in January 2015, digital boundary information will become a required element of the information provided when designating a new Ramsar Site or updating information on previously designated Sites. This is important because of the increasing analytical constraints that the lack of this information is causing and will further cause, making it more to ensure wide access to clear, reliable information for all stakeholders about the location of Ramsar Sites, including through other mechanisms such as the World Database on Protected Areas (WDPA).

A third issue is the inaccuracies in the SRTM data (see Introduction) and the quality of the SRTM elevation data, particularly in mangrove or other heavily forested coastal areas. As Table 7 indicates, the reported (in Ramsar Information Sheets) maximum elevation above sea-level of some of those Ramsar Sites identified by the SRTM data as being wholly below 0m elevation is higher than the +/- 4-5m SRTM accuracy. Currently, all satellite-derived (SRTM and ASTER) global digital elevation models generally capture the elevation of the canopy cover and not the ground level, thereby overestimating the elevation in these zones and underestimating the exposure of sites in those areas to SLR.

References

Arctic Monitoring and Assessment Programme (AMAP). 2011. *Snow, Water, Ice and Permafrost in the Arctic*. Oslo: AMAP.

Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IFPRI); The World Bank; and Centro Internacional de Agricultura Tropical (CIAT). 2011a. Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Population Density Grid. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. Available at http://sedac.ciesin.columbia.edu/data/sets/browse?contains=grump.

Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IFPRI); The World Bank; and Centro Internacional de Agricultura Tropical (CIAT). 2011b. Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Urban Extents Grid. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. Available at http://sedac.ciesin.columbia.edu/data/sets/browse?contains=grump.

Gorokhovich, Y., Voustianiouk, A. 2006. Accuracy assessment of the processed SRTM-based elevation data by CGIAR using field data from USA and Thailand and its relation to the terrain characteristics. *Remote Sensing of Environment* 104:409–415.

Klein Goldewijk, K., Beusen, A., Janssen, P. 2010. Long term dynamic modeling of global population and built-up area in a spatially explicit way: HYDE 3.1. *The Holocene* 20: 565-573.

Pfeffer, W., Harper, J., O'Neel, S. 2008. Kinematic constraints on glacier contributions to 21st-century sea-level rise. *Science* 321(5994): 1340-1343.

Strauss, B., Ziemlinski, R., Weiss, J., Overpeck, J. 2012. Tidally-adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States. *Environmental Research Letters* 7 014033. http://dx.doi.org/10.1088/1748-9326/7/1/014033

Tebaldi, C., Strauss, B., Zervas, C. 2012. Modelling sea level rise impacts on storm surges along US coasts. *Environmental Research Letters* 7 014032.

Wetzel, F.T., Kissling, W.D., Beissmann, H. 2012. Future climate change driven sea-level rise: secondary consequences from human displacement for island biodiversity. *Global Change Biology* doi: 10.1111/j.1365-2486.2012.02736.x

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Vulnerability to sea level rise: fishermen's homes on the island of Burano in the Venice Lagoon. ***Photo: Tobias Salathé, Ramsar*.**

Annex 1

Figures and Tables

Figure 1. Sea level rise risk and impediments to Ramsar Site migration: Yangcheng National Reserve, China (Ramsar Site 1156)

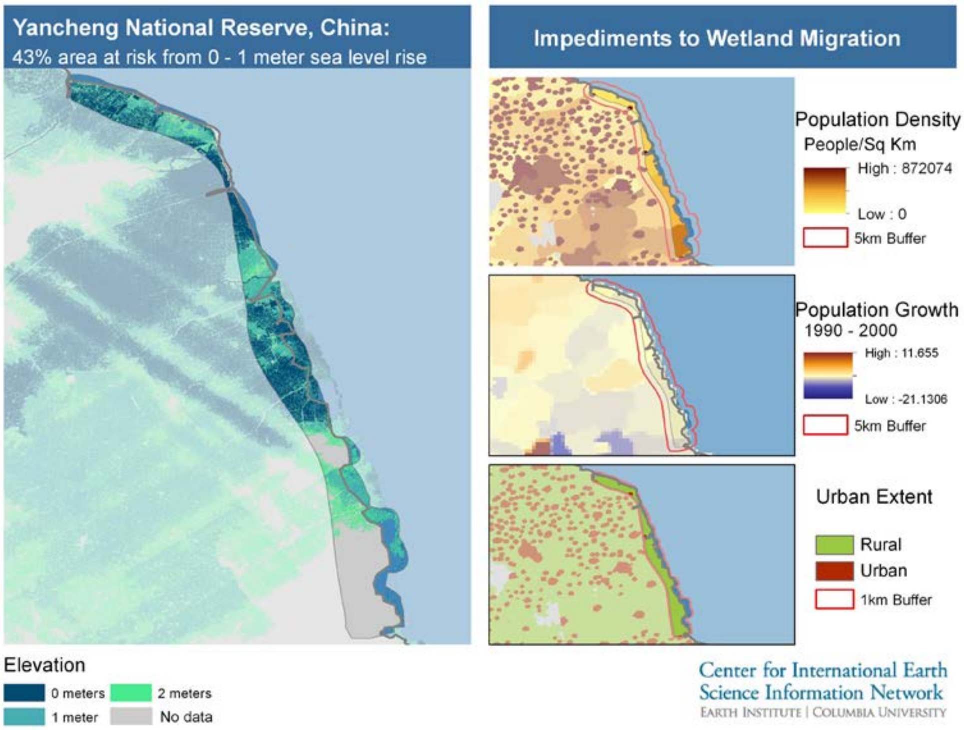

Figure 2. Population density and Google Earth images: Yangcheng National Reserve, China

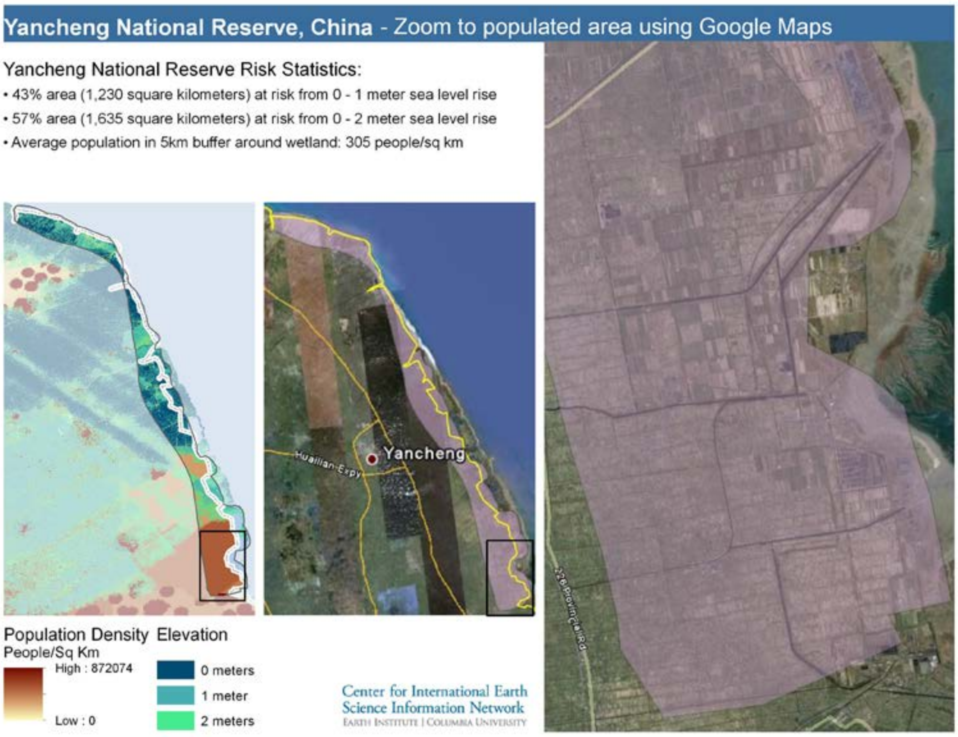

Figure 3. Sea level rise risk and impediments to Ramsar Site migration: Danube Delta, Romania (Ramsar Site 521)

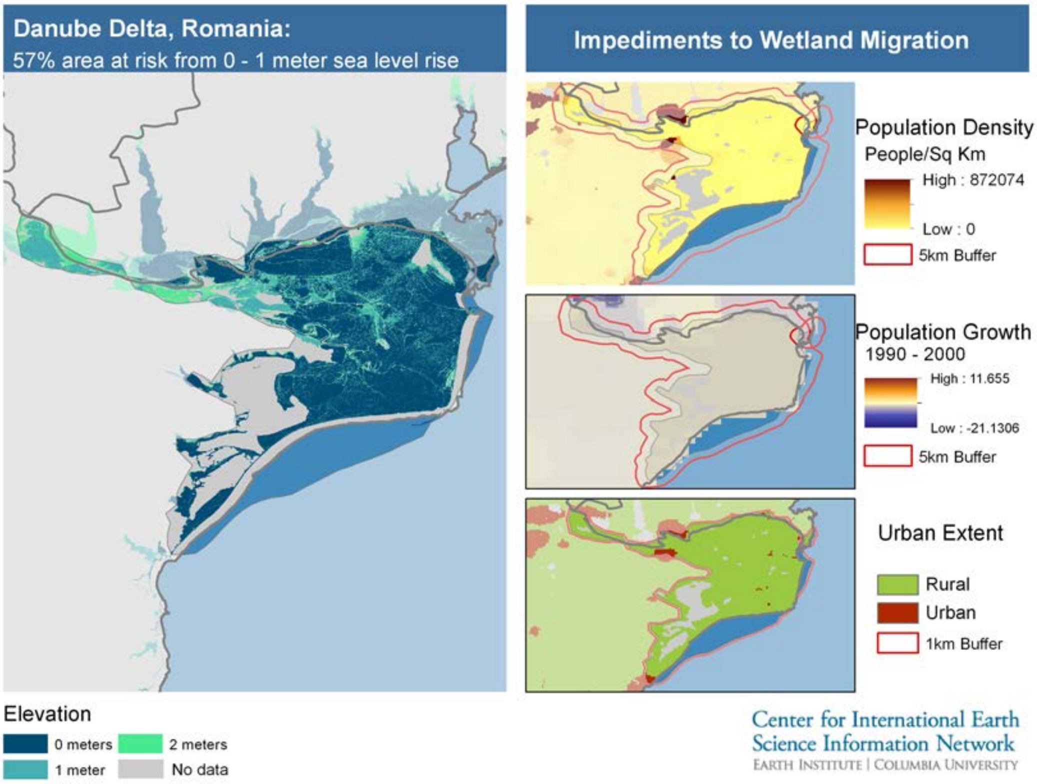

Figure 4. Population density and Google Earth images: Danube Delta, Romania

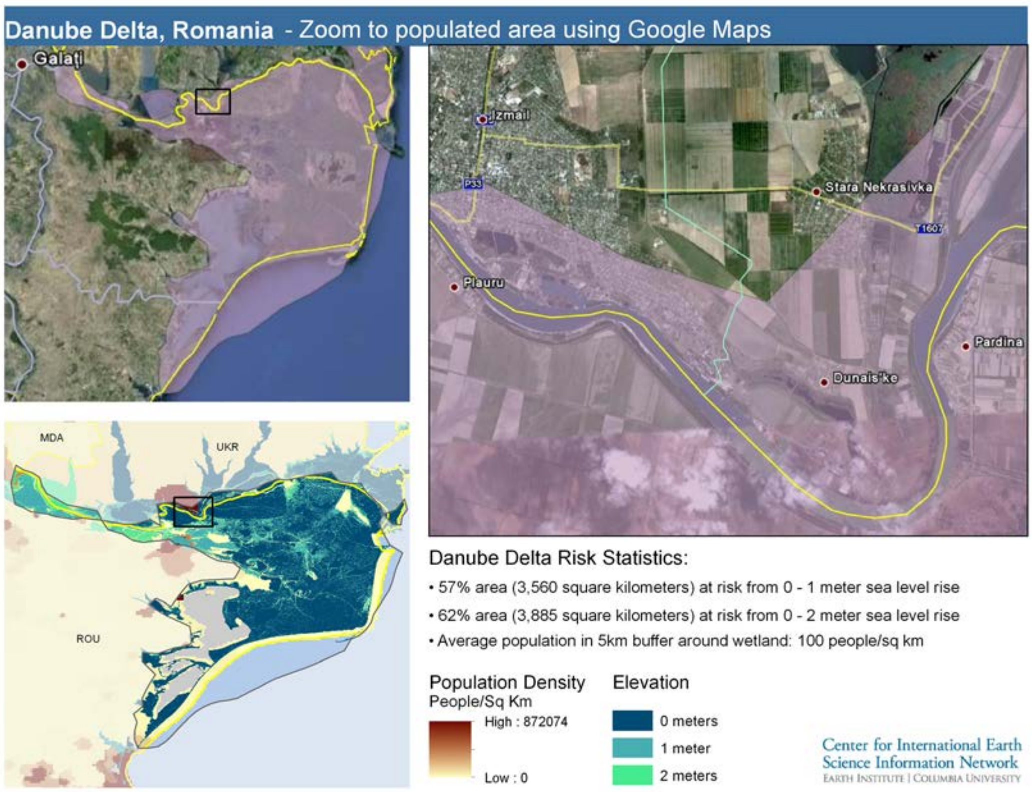

Figure 5. Sea level rise risk and impediments to Ramsar Site migration: Anlo-Keta Lagoon Complex, Ghana (Ramsar Site 567)

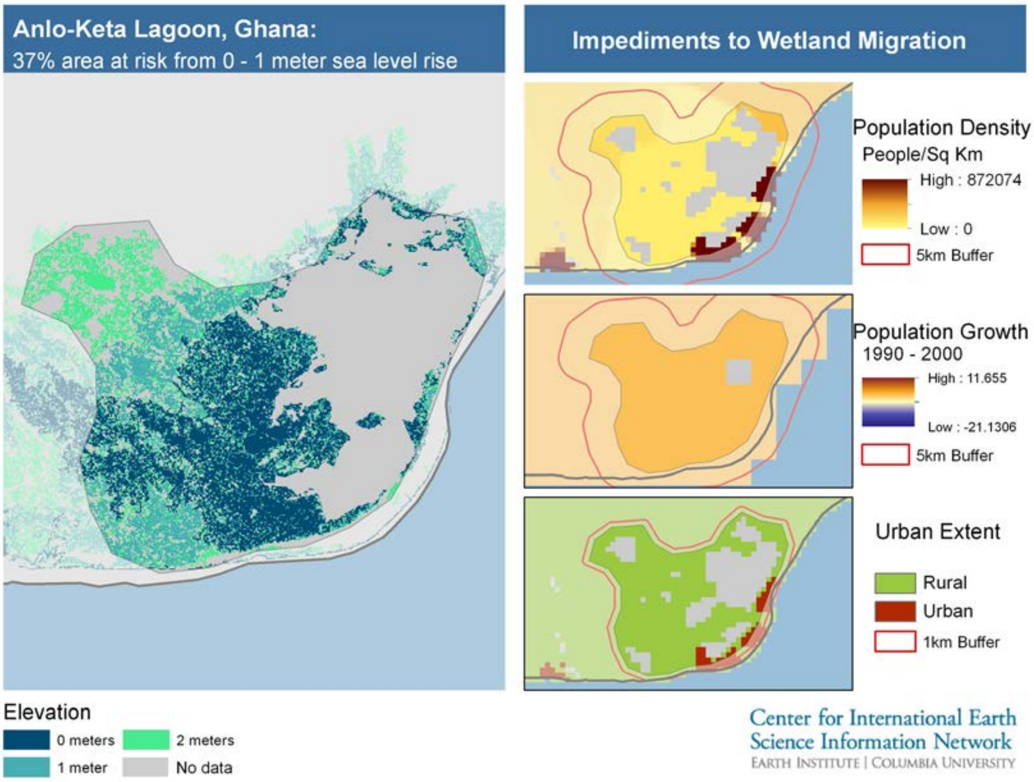

Figure 6. Population density and Google Earth images: Anlo-Keta Lagoon Complex, Ghana

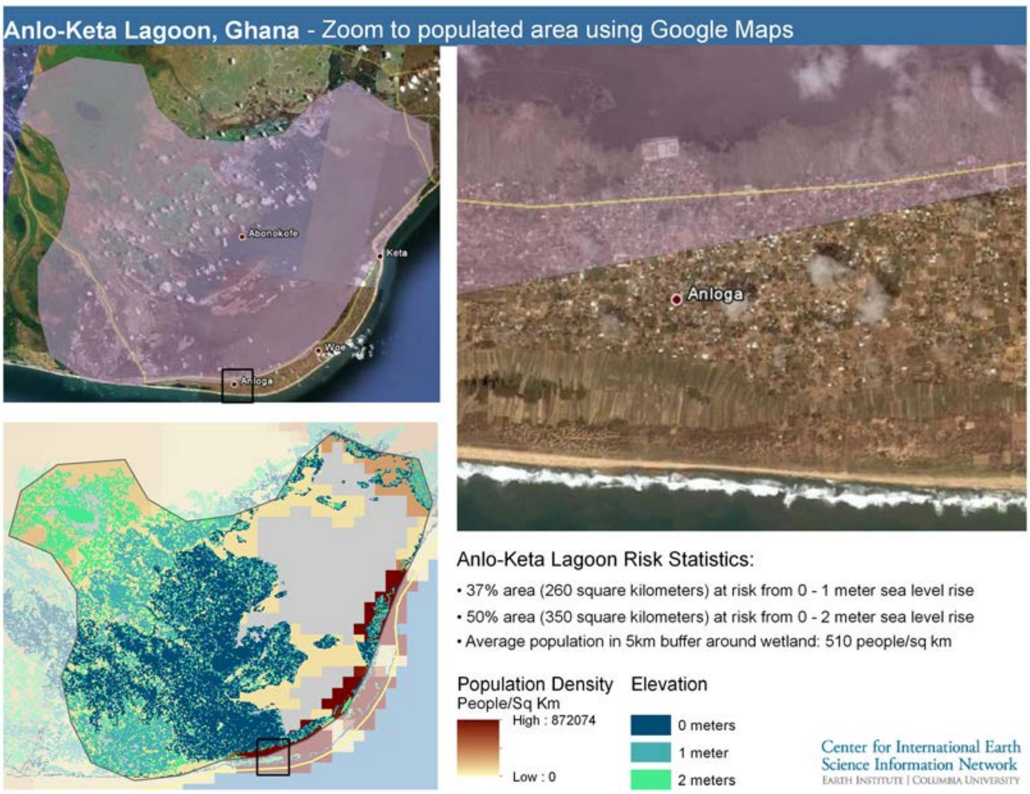

Figure 7. Relative risk of coastal Ramsar Sites in Mexico from a 0-1m sea level rise

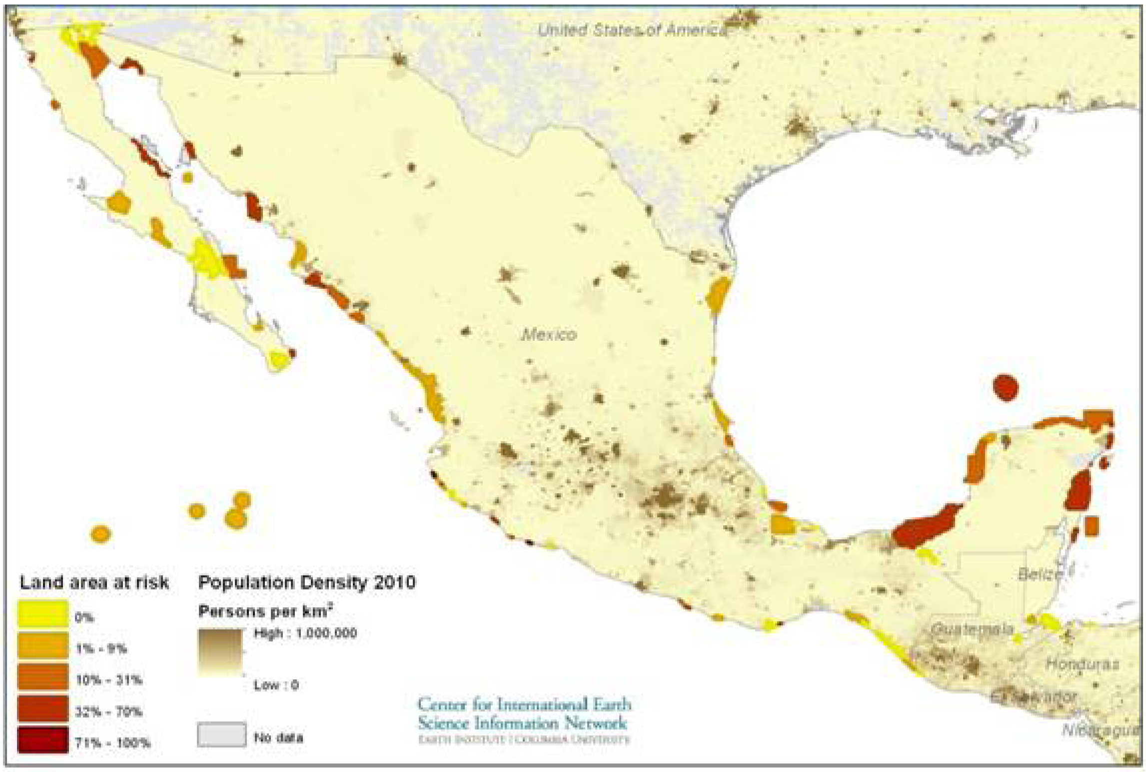

Figure 8. Relative risk of coastal Ramsar Sites in northern Europe from a 0-1m sea level rise

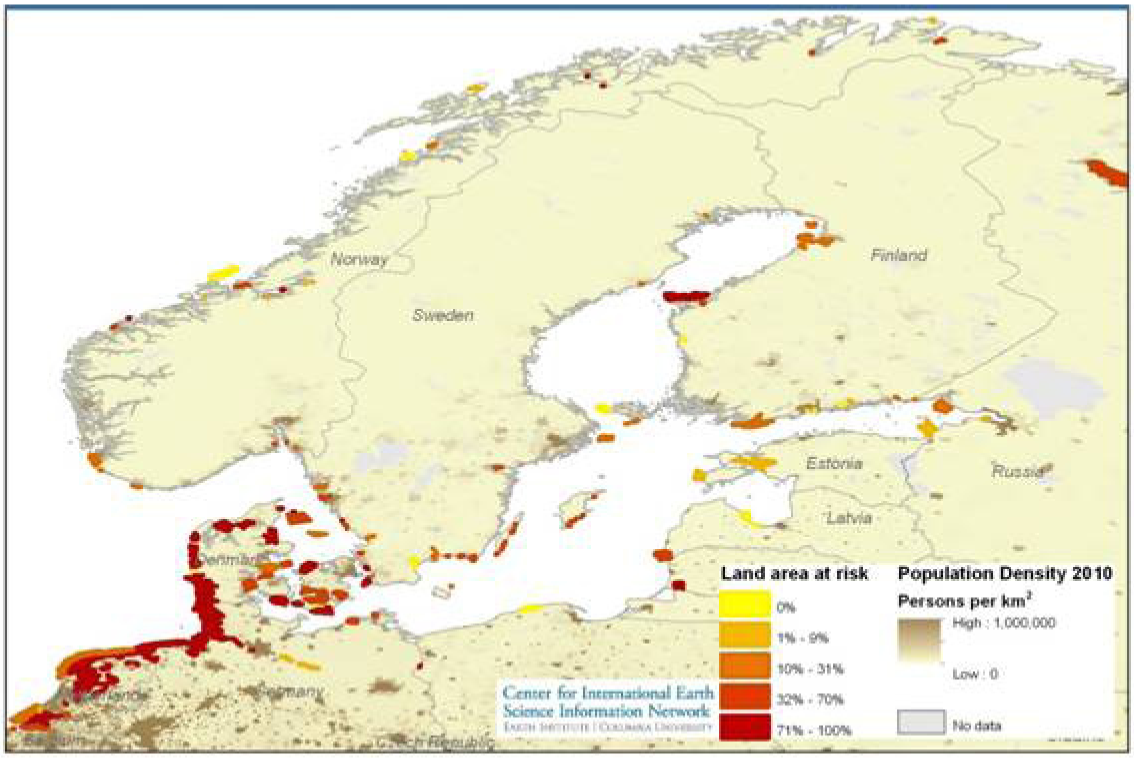

Figure 9. Relative risk of coastal Ramsar Sites around the Black Sea and north-eastern Mediterranean from a 0-1m sea level rise

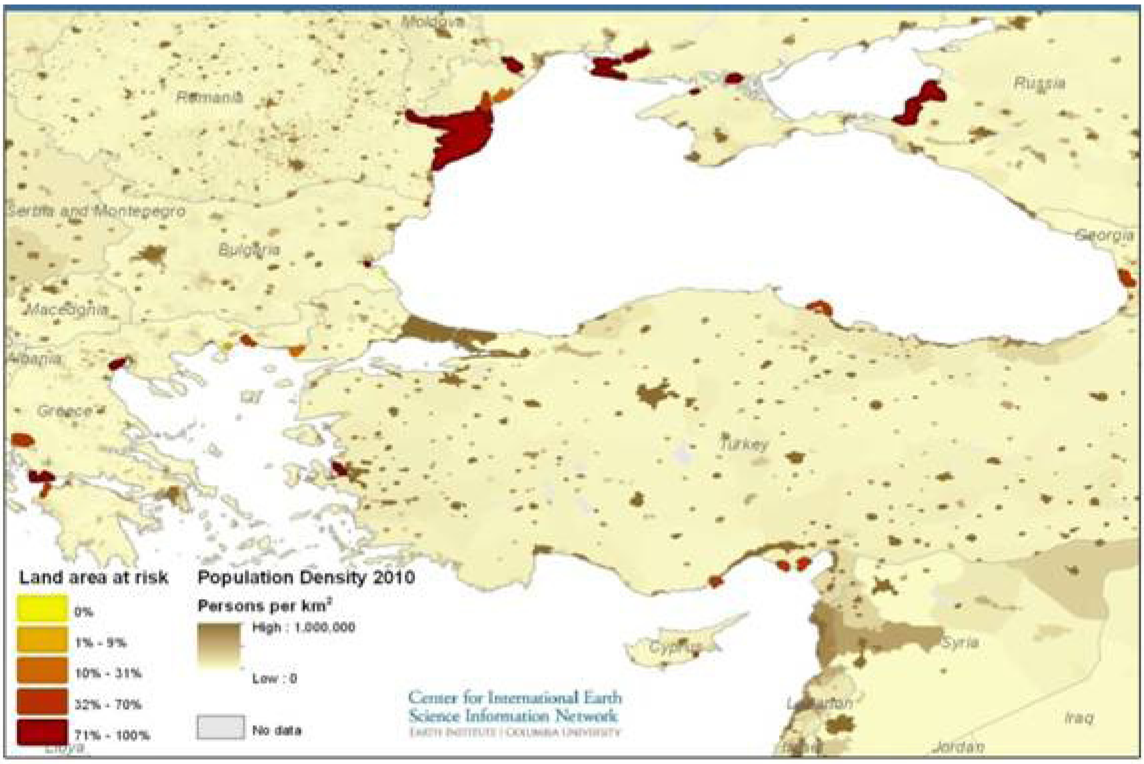

Table 1. Estimated current extent of submergence, area at risk from sea level rise and human population statistics for the 10 Ramsar Sites in Africa most at risk in terms of exposure to 0 – 1 Meter Sea Level Rise (SLR)

Ramsar Site Name	Country	Ramsar Site no.	Total area of Ramsar Site (km^2)	Non-submerged area of site (km^2)	% of Site Inundated	% land area at risk from 0-1m SLR	% land area at risk from 0-2m SLR	0m Area within site (km^2)	1m Area within site (km^2)	2m Area within site (km^2)
Ichkeul	Tunisia	213	63.41	63.41	0.00	86.99	87.33	0.00	55.16	0.22
Turtle Beaches/Coral Reefs of Tonga-land	South Africa	344	749.31	3.07	99.59	80.25	83.35	2.40	0.06	0.10
Baie de Khnifiss	Morocco	209	44.78	44.78	0.00	66.51	69.92	27.70	2.08	1.53
Ile Blanche	Guinea	618	1.59	0.16	90.09	62.35	73.11	0.08	0.02	0.02
Anlo-Keta lagoon complex	Ghana	567	698.57	469.61	32.77	55.67	74.48	160.74	100.70	88.33
Langebaan	South Africa	398	55.24	16.82	69.55	19.60	47.47	1.35	1.95	4.69
Delta du Saloum	Senegal	288	3205.77	2190.17	31.68	16.31	27.14	215.33	141.94	237.10
De Mond (Heuningnes estuary)	South Africa	342	9.81	8.67	11.62	12.45	13.29	1.02	0.06	0.07
Parc National du Banc d'Arguin	Mauritania	250	11924.97	5500.95	53.87	11.95	16.44	391.92	265.47	246.98
Konkouré	Guinea	575	299.93	170.67	43.09	10.92	16.41	9.61	9.03	9.37

	% land area that is urban		Maximum Pop Density 2010			Average Pop Density 2010			Avg Pop Density 2000	
Ramsar Site Name	**Site**	**1km buffer**	**Site**	**1km buffer**	**5km buffer**	**Site**	**1km buffer**	**5km buffer**	**1km buffer**	**5km buffer**
Ichkeul	0.00	0.00	87	87	1074	87	87	219	80	202
Turtle Beaches/Coral Reefs of Tonga-land	0.00	0.00	123	136	344	26	24	24	22	21
Baie de Khnifiss	0.00	0.00	2	2	2	2	2	2	1	1
Ile Blanche	0.00	0.00	0	3	3	0	3	3	2	2
Anlo-Keta lagoon complex	0.05	0.17	5425	5425	5604	297	647	367	532	299
Langebaan	0.00	0.13	439	969	3961	16	33	102	25	86
Delta du Saloum	0.00	0.05	1105	1145	1309	89	128	146	102	117
De Mond (Heuningnes estuary)	0.00	0.00	2	2	2	2	2	2	1	1
Parc National du Banc d'Arguin	0.00	0.00	0	0	0	0	0	0	0	0
Konkouré	0.00	0.00	51	51	51	51	48	45	40	37

Table 2. Estimated current extent of submergence, area at risk from sea level rise and human population statistics for the 10 Ramsar Sites in eastern Europe and Asia most at risk in terms of exposure to 0 – 1 Meter Sea Level Rise (SLR)

Ramsar Site Name	Country	Ramsar Site no.	Total Area of Ramsar Site (km^2)	Non-submerged area	% of Site Inundated	% land area at risk from 0-1m SLR	% land area at risk from 0-2m SLR	0m Area within site (km^2)	1m Area within site (km^2)	2m Area within site (km^2)
Gediz Delta	TURKEY	945	152.94	83.18	45.61	81.13	88.90	57.12	10.37	6.46
Yumurtalik Lagoons	TURKEY	1619	198.76	99.45	49.97	62.23	84.09	36.78	25.10	21.74
Goksu Delta	TURKEY	657	142.82	82.60	42.16	57.01	81.34	17.40	29.68	20.09
Larnaca Salt Lake	CYPRUS	1081	10.95	10.95	0.00	52.71	56.96	5.20	0.57	0.47
Sheedvar Island	IRAN	1015	2.58	0.92	64.48	52.13	67.99	0.15	0.33	0.15
Central Kolkheti	GEORGIA	893	313.50	274.73	12.37	50.92	66.30	87.98	51.90	42.26
Kizilirmak Delta (Kizilirmak Deltasi)	TURKEY	942	215.15	145.24	32.49	48.30	64.81	22.28	47.87	23.98
Yancheng National Nature Reserve	CHINA	1156	2879.29	2691.07	6.54	45.71	60.75	686.43	543.67	404.67
Mai Po Marshes and Inner Deep Bay	HONG KONG	750	6.83	3.33	51.33	39.29	48.78	0.95	0.36	0.32
Akyatan Lagoon	TURKEY	943	163.97	77.57	52.69	36.22	50.66	9.83	18.26	11.20

	% urban land		Maximum Pop Density 2010			Average Pop Density 2010			Avg Pop Density 2000	
Ramsar Site Name	**Site**	**1km buffer**	**Site**	**1km buffer**	**5km buffer**	**Site**	**1km buffer**	**5km buffer**	**1km buffer**	**5km buffer**
Gediz Delta	0.01	0.12	2087	2087	2087	84	341	752	312	686
Yumurtalik Lagoons	0.00	0.00	62	62	62	62	62	62	56	56
Goksu Delta	0.23	0.54	1208	1208	1218	312	690	984	625	890
Larnaca Salt Lake	0.71	0.87	1084	1084	1084	718	656	457	804	560
Sheedvar Island	0.00	0.00	10	10	10	10	10	10	9	9
Central Kolkheti	0.02	0.16	1056	1056	1056	75	228	161	262	185
Kizilirmak Delta (Kizilirmak Deltasi)	0.00	0.00	82	82	853	82	81	110	73	99
Yancheng National Nature Reserve	0.02	0.08	1827	1827	5490	264	325	400	306	376
Mai Po Marshes and Inner Deep Bay	0.40	0.60	3318	3318	33074	3318	3303	8871	3124	8235
Akyatan Lagoon	0.00	0.00	62	62	62	62	62	62	56	56

Table 3. Estimated current extent of submergence, area at risk from sea level rise and human population statistics for the 10 Ramsar Sites in northern and western Europe* most at risk in terms of exposure to 0 – 1 Meter Sea Level Rise (SLR)
***Sites in the Netherlands are excluded from this ranking (see text)**

Ramsar Site Name	Country	Ramsar Site no.	Total Area of Ramsar Site (km^2)	Non-sub-merged area of site (km^2)	% of Site Inundated	% land area at risk from 0-1m SLR	% land area at risk from 0-2m SLR	0m Area within site (km^2)	1m Area within site (km^2)	2m Area within site (km^2)
Laguna di Marano: Foci dello Stella	ITALY	190	30.73	4.58	85.11	99.88	100.01	4.53	0.04	0.01
Laguna di Venezia: Valle Averto	ITALY	423	2.48	2.48	0.18	99.47	100.00	2.45	0.02	0.01
Kuban Delta	RUSSIAN FED-ERATION	675 and 674	1920.04	1821.11	5.15	99.41	99.70	1789.56	20.78	5.24
Breydon Water	UNITED KING-DOM	821	11.73	11.73	0.00	98.77	99.04	11.20	0.39	0.03
Nordre Ronner	DENMARK	148	29.85	0.34	98.85	98.65	100.00	0.26	0.07	0.00
Niederelbe, Barnkrug - Otterndorf	GERMANY	83	100.34	79.40	20.87	98.31	98.76	75.32	2.74	0.36
Valle Cavanata	ITALY	169	4.78	4.63	3.11	98.30	99.22	4.48	0.07	0.04
Valli residue del comprensorio di Comacchio	ITALY	225	119.25	119.25	0.00	97.40	97.87	114.54	1.62	0.56
Muhlenberger Loch	GERMANY	561	7.79	7.79	0.00	97.04	98.43	7.38	0.19	0.11
Delta del Ebro	SPAIN	593	19.26	18.17	5.62	96.74	98.63	16.66	0.92	0.34

	% land area that is urban		Maximum Pop Density 2010			Average Pop Density 2010			Avg Pop Density 2000	
Ramsar Site Name	Site	1km buffer	Site	1km buffer	5km buffer	Site	1km buffer	5km buffer	1km buffer	5km b uffer
Laguna di Marano: Foci dello Stella	0.29	0.34	219	411	411	29	87	94	83	90
Laguna di Venezia: Valle Averto	0.00	0.00	91	91	643	91	91	234	87	225
Kuban Delta	0.02	0.08	378	378	653	28	51	61	53	64
Breydon Water	0.59	0.70	530	530	530	352	376	474	357	450
Nordre Ronner	0.00	0.00	20	0	21	20	0	20	0	20
Niederelbe, Barnkrug - Otterndorf	0.07	0.16	313	313	313	58	74	86	74	86
Valle Cavanata	0.00	0.00	16	16	737	16	16	117	15	112
Valli residue del comprensorio di Comacchio	0.12	0.17	599	599	599	85	114	93	109	90
Muhlenberger Loch	1.00	1.00	2416	2416	2416	2416	2263	1931	2281	1947
Delta del Ebro	0.00	0.00	112	112	140	78	79	87	71	79

Table 4. Estimated current extent of submergence, area at risk from sea level rise and human population statistics for the 10 Ramsar Sites in North America and Greenland most at risk in terms of exposure to 0 – 1 Meter Sea Level Rise (SLR)

Ramsar Site Name	Country	Ramsar Site no.	Total Area of Ramsar Site (km^2)	Non-submerged area of site (km^2)	% of Site Inundated	% land area at risk from 0-1m SLR	% land area at risk from 0-2m SLR	0m Area within site (km^2)	1m Area within site (km^2)	2m Area within site (km^2)
Kitsissunnguit (Gronne Ejland)	DENMARK	384	77.59	4.08	94.74	100.02	100.02	0.00	4.08	0.00
Playa Tortuguera Mexiquillo	MEXICO	1350	0.26	0.00	99.22	100.00	100.00	0.00	0.00	0.00
Kilen	GREENLAND	391	503.72	363.23	27.89	100.00	100.00	0.00	363.23	0.00
Sistema Lagunar Estuarino Agua Dulce - El Ermitano	MEXICO	1825	12.89	12.89	0.01	70.24	71.42	8.99	0.06	0.15
McConnell River	CANADA	248	107.24	107.24	0.00	65.69	83.54	0.00	70.44	19.15
Playa Tortuguera Chenkan	MEXICO	1348	1.22	0.21	83.10	63.85	71.06	0.10	0.03	0.01
Reserva de la Biosfera Pantanos de Centla	MEXICO	733	3045.29	3044.89	0.01	63.78	83.82	550.05	1392.01	610.27
Parque Nacional Arrecife de Puerto Morelos	MEXICO	1343	92.38	0.99	98.93	61.56	63.53	0.60	0.01	0.02
Canal del Infiernillo y esteros del territorio Comcaac	MEXICO	1891	292.38	26.50	90.94	60.89	81.72	7.84	8.30	5.52
Parque Nacional Arrecife Alacranes	MEXICO	1820	3353.34	0.87	99.97	58.18	78.18	0.48	0.03	0.18

	% land area that is urban		Maximum Pop Density 2010			Average Pop Density 2010			Avg Density	2000
Ramsar Site Name	**Site**	**1km buffer**	**Site**	**1km buffer**	**5km buffer**	**Site**	**1km buffer**	**5km buffer**	**1km buffer**	**5km buffer**
Kitsissunnguit (Gronne Ejland)	0.00	0.00	0	0	0	0	0	0	0	0
Playa Tortuguera Mexiquillo	0.00	0.00	10	10	110	10	10	20	9	19
Kilen	0.00	0.00	0	0	0	0	0	0	0	0
Sistema Lagunar Estuarino Agua Dulce - El Ermitano	0.00	0.00	13	13	13	12	12	12	11	11
McConnell River	0.00	0.00	0	0	0	0	0	0	0	0
Playa Tortuguera Chenkan	0.00	0.00	9	9	9	9	9	9	8	8
Reserva de la Biosfera Pantanos de Centla	0.01	0.05	320	320	517	29	40	54	36	49
Parque Nacional Arrecife de Puerto Morelos	0.18	0.36	314	318	545	314	315	330	286	300
Canal del Infiernillo y esteros del territorio Comcaac	0.00	0.00	5	5	5	2	3	3	3	2
Parque Nacional Arrecife Alacranes	0.00	0.00	0	0	0	0	0	0	0	0

Table 5. Estimated current extent of submergence, area at risk from sea level rise and human population statistics for the five Ramsar Sites in Oceania most at risk in terms of exposure to 0 – 1 Meter Sea Level Rise (SLR)

Ramsar Site Name	Country	Ramsar Site no.	Total Area of Ramsar Site (km^2)	Non-submerged area of site (km^2)	% of Site Inundated	% land area at risk from 0-1m SLR	% land area at risk from 0-2m SLR	0m Area within site (km^2)	1m Area within site (km^2)	2m Area within site (km^2)
Ashmore Reef National Nature Reserve	AUSTRALIA	1220	537.26	17.17	96.80	15.77	39.76	0.84	1.87	4.12
Corner Inlet	AUSTRALIA	261	676.82	159.77	76.39	12.97	24.98	10.54	10.18	19.19
The Coorong, Lakes Alexandrina and lake Albert	AUSTRALIA	321	1041.96	226.30	78.28	9.90	23.76	11.35	11.05	31.35
Ord River floodplain	AUSTRALIA	477	553.90	497.87	10.10	4.55	7.69	10.42	12.24	15.62
Western Port	AUSTRALIA	267	728.87	223.21	69.38	1.99	4.40	2.48	1.96	5.40

	% land area that is urban		Maximum Pop Density 2010			Average Pop Density 2010			Avg Pop Density 2000	
Ramsar Site Name	Site	1km buffer	Site	1km buffer	5km buffer	Site	1km buffer	5km buffer	1km buffer	5km buffer
Ashmore Reef National Nature Reserve	0.00	0.00	0	0	0	0	0	0	0	0
Corner Inlet	0.00	0.00	5	5	5	4	4	5	4	4
The Coorong, Lakes Alexandrina and Albert	0.02	0.01	18	18	18	7	4	4	4	4
Ord River floodplain	0.00	0.00	0	0	0	0	0	0	0	0
Western Port	0.01	0.12	132	132	569	24	61	67	54	59

Table 6. Estimated current extent of submergence, area at risk from sea level rise and human population statistics for the 10 Ramsar Sites in the Neotropics (including overseas territories in this region) most at risk in terms of exposure to 0 – 1 Meter Sea Level Rise

Ramsar Site Name	Country	Ramsar Site no.	Total Area of Ramsar Site (km^2)	Non-submerged area of site (km^2)	% of Site Inundated	% land area at risk from 0-1m SLR	% land area at risk from 0-2m SLR	0m Area within site (km^2)	1m Area within site (km^2)	2m Area within site (km^2)
Cienaga de Los Olivitos	VENEZUELA	859	300.14	271.08	9.68	70.61	76.34	172.96	18.45	15.53
Humedal Rio Maximo-Caguey	CUBA	1237	225.95	135.45	40.06	45.04	57.89	42.04	18.97	17.41
Lagoa do Peixe	BRAZIL	603	231.01	230.72	0.13	36.63	42.15	65.45	19.07	12.74
Banados del Este y Franja Costera	URUGUAY	290	3990.22	3913.05	1.93	28.51	34.83	1095.11	20.62	247.26
Klein Bonaire Island and adjacent sea	NETH. ANTILLES (NL)	201	7.20	5.51	23.36	14.01	43.87	0.39	0.38	1.65
Manglares Churute	ECUADOR	502	450.51	450.51	0.00	12.13	15.47	27.40	27.24	15.07
Carlos Anwandter Sanctuary	CHILE	222	64.67	64.67	0.00	9.68	43.53	4.76	1.50	21.89
Gran Humedal del Norte de Ciego de Avila	CUBA	1235	2514.06	1089.36	56.65	7.68	13.10	51.29	32.43	59.01
Buenavista	CUBA	1233	3152.71	938.13	70.25	7.57	15.20	54.68	16.32	71.57
Grand Cul-de-Sac Marin de la Guadeloupe	GUADELOUPE (FR)	642	211.26	21.34	89.90	4.88	9.99	0.82	0.22	1.09

	% land area that is urban		Maximum Pop Density 2010			Average Pop Density 2010			Avg Density 2000	
Ramsar Site Name	Site	1km buffer	Site	1km buffer	5km buffer	Site	1km buffer	5km buffer	1km buffer	5km buffer
Cienaga de Los Olivitos	0.00	0.00	2	16	355	2	3	37	2	31
Humedal Rio Maximo-Caguey	0.00	0.00	14	14	14	14	12	12	12	12
Lagoa do Peixe	0.00	0.00	30	30	30	18	18	16	16	14
Banados del Este y Franja Costera	0.00	0.02	357	357	357	4	8	6	7	6
Klein Bonaire Island and adjacent sea	0.43	0.44	42	42	42	42	42	42	37	37
Manglares Churute	0.00	0.04	29	984	2003	9	72	81	51	53
Carlos Anwandter Sanctuary	0.11	0.15	808	808	808	106	137	162	122	145
Gran Humedal del Norte de Ciego de Avila	0.01	0.06	739	739	739	23	58	66	57	66
Buenavista	0.06	0.06	635	248	730	48	33	35	33	34
Grand Cul-de-Sac Marin de la Guadeloupe	0.53	0.85	1096	1096	3622	278	337	402	309	368

Table 7. Ramsar Sites which SRTM Data indicate are wholly below 0 meters elevation

Name	Country	Continent	Ramsar Site no.	Total Area (km^2)	Elevation range in Ramsar Information Sheet (RIS)
Tubbataha Reefs National Marine Park	Philippines	Asia	1010	1007.82	Mostly subtidal, but up to +4m
Soderskar and Langoren Archipelago	Finland	Europe	3	204.16	0- +13 m
Vlaamse Banken	Belgium	Europe	326	52.29	“sea-level”
Pelican Island National Wildlife Refuge	United States	North America	590	13.62	No information
Ile Alcatraz	Guinea	Africa	571	0.42	0 to +8 m
Parque Nacional Arrecife Alacranes	Mexico	North America	1820	3353.34	0 to +3 m
Parque Nacional Arrecife de Cozumel	Mexico	North America	1449	124.12	Max +10 m
Froan Nature Reserve and Landscape Protection Area	Norway	Europe	809	491.47	Max +10 m
Turtle Beaches/Coral Reefs of Tongaland	South Africa	Africa	344	749.31	Min 0 m (no max. elevation)
Voordelta	Netherlands	Europe	1279	886.16	-20 to 0 m
IJsselmeer	Netherlands	Europe	1246	1080.40	-6 to -2 m
Reserva de la Biosfera Banco Chinchorro	Mexico	North America	1353	1452.44	Max +3 m (most <0 m)
Signilskar-Market Archipelago	Finland	Europe	5	223.69	0 to +20 m
Northumbria Coast	United Kingdom	Europe	1019	4.39	0 m (intertidal)
Playa Tortuguera Mexiquillo	Mexico	North America	1350	0.26	0 m
Parque Nacional Sistema Arrecifal Veracruzano	Mexico	North America	1346	524.79	0 m
Parque Nacional Cabo Pulmo	Mexico	North America	1778	71.38	0 m
Markermeer	Netherlands	Europe	1249	610.21	-8 to -1 m

Livelihoods in the coastal zone, Venezuela. ***Photo: Julio Montes de Oca***

Briefing Notes series

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The Convention on Wetlands (Ramsar, Iran, 1971) – called the Ramsar Convention – is an intergovernmental treaty that embodies the commitments of its member countries to maintain the ecological character of their Wetlands of International Importance and to plan for the "wise use", or sustainable use, of all of the wetlands in their territories.

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