EO8 Coastal Ecosystems and Landscapes Common Indicator 16 - Length of coastline subject to physical disturbance due to the influence of human-made structures – Lebanon

Prepared by:
Ali Fadel
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TITLE
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CONTRACTING AUTHORITY
PAP/RAC
Kraj sv. Ivana 11,21 000 Split, Republic of Croatia Contacting person: Zeljka Skaricic

CONTRACTOR
Ali FADEL

AUTHOR
Ali FADEL, PhD Environmental Remote Sensing

REVIEWERS
Adel YACOUB, Ministry of Environment of Lebanon

Ivan SEKOVSKI, UNEP MAP PAP/RAC

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1. Introduction

Barcelona Convention is the first-ever Regional Seas Programme under UNEP's umbrella that addresses specific aspects in an aim to protect the Mediterranean marine and coastal environment while boosting regional and national plans to achieve sustainable development. This convention includes 21 Mediterranean countries (plus the European Union), including Lebanon.

Monitoring the length of coastline subject to physical disturbance due to the influence of human-made structures and its trend is of high importance to conserve habitat, biodiversity and avoid coastal erosion phenomena, as well as for its importance in land-sea interactions. Until now there has not been systematic monitoring in Mediterranean regarding this, not quantitatively based monitoring, or any major attempt to homogenously characterize coastal ecosystems on a wider Mediterranean basis. The status assessment of Ecological Objective 8 Coastal Ecosystems and Landscapes is done by monitoring of the Common Indicator (CI) 16 “Length of coastline subject to physical disturbance due to the influence of human-made structures”.

The EC-funded EcAp MED III project will be implemented by UNEP/MAP in the framework of the GPGC Priority Area 1 – Component 4: International environment and Climate governance. It will support the delivery of a data-based 2023 Mediterranean Quality Status Report (2023 MED QSR) through support to the implementation of national IMAPs in the respective countries. It will also support harmonized assessment at national level through the preparation of national assessment factsheets. As such, the EcAp EMD III project is directly linked to the implementation of the COP 19 Decision IG.22/7 on IMAP, and of the COP 20 Decision IG.23/6 and COP 21 Decision IG.24/4 on the 2023 MED QSR Roadmap and Implementation Plan. Monitoring of CI 16 makes part of Activity 1.3.1 of the EcAp MED III Project.

Therefore, the objective of this work is to prepare the report on monitoring of the Common indicator 16 for the whole Mediterranean coastline of Lebanon by using the guidance fact sheet (UNEP/MED WG 467/6) where the method is presented as well as the Information standards (Data Standards and Data Dictionaries – UNEP/MED WG 467/10) for the format of results to be uploaded to the IMAP info system.

The outputs of this work include:

- Narrative Report with the presentation of the main characteristics of Lebanon coastline and its coastal area; the main results of monitoring, difficulties encountered while monitoring, experiences. The main indicator units are:
  - Km of artificial coastline and % of total length of coastline.
  - Km of natural coastline and % of total length of coastline.
- GIS layer (polyline; WGS 84 decimal degree): Artificial_structures with location and extend of artificial structures, with attribute table; in a format suitable for upload directly to IMAP Info system coordinated by INFO/RAC
- GIS layer: Coastline_AN: Artificial/Natural coastline with attribute table.

2. General description of study site

As part of the Levantine Sea, the Lebanese coast is in the eastern part of the Mediterranean basin (Figure 1). It is characterized by a high geomorphological diversity (i.e. rocky beach, sandy beach cliff and low cliff). The rocky coasts occupied 110.44 km (30.7 %) of the coastline of 2003 while sandy beach occupied 81.9 km (22.86 %). About 12.35% of rocky beaches (equivalent to 13.64 km) were artificialized. The rocky coasts are in a state of instability, composed mainly of chalk coasts generally fragile and nonresistant to erosion (Faour and Rizk, 2014).

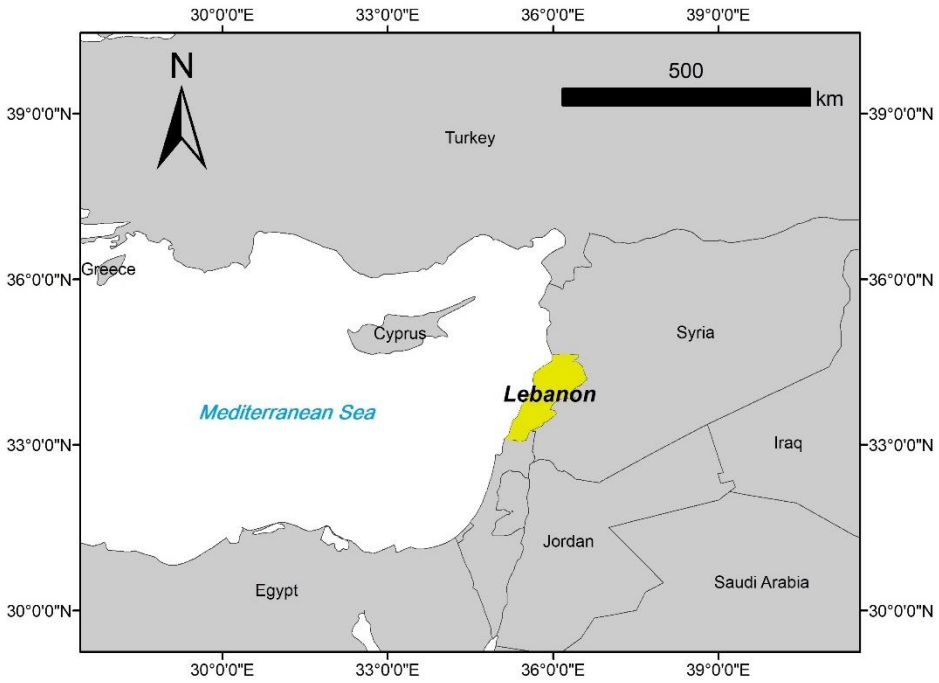

Figure 1 Location of Lebanon on the Mediterranean Sea

The Lebanese coast is characterized by high ecological importance. The dominant sandy beaches are natural habitat of the two endangered species of sea turtle: Green Turtle (*Chelonia mydas*) and Loggerhead Turtle (*Caretta caretta*) (Ghoussein et al., 2018). A significant population growth was documented in the coastal areas. Using topographical maps and satellite images, Faour (2015) found that between 1963 and 2005 the highest urban expansion occurred on the coastal cities with Beirut agglomeration increasing from 63 to 121 km^2 followed by Jounieh agglomeration (from 5.3 to 38 km^2) and Tripoli agglomeration (from 4.3 to 14 km^2). Moreover, according to the UNEP GRID (2017) report, Lebanon had the second highest built-up area in the

150 m coastal belt (38.3%) and the third highest built-up area in the 1 km coastal belt (46.1%) among the Mediterranean countries. This expansion has led to an increase of the anthropic pressure exerted on the coast. However, the trophic status is still considered as oligotrophic (El Hourany et al., 2017; Kanj and Fadel, 2020). A significant increasing trend of sea surface temperature was found on the Lebanese coast over 27 years, between 1986 and 2013. Annual averages increased from 22°C in 1986 to 23.1°C in 2013 with the highest recorded average temperature of 23.7 °C in 2010 (Fadel et al., 2020).

3. Methods and input data

Monitoring of the Common indicator 16 focuses on measuring the length of artificial coastline and its share in total coastline of Lebanon. Primary input data for the research was “Geoeye-1” and “WorldView-2” satellite imageries, taken in June and July 2020, respectively. There approximate spatial resolution is 0.5 m.

The length of artificial coastline was calculated as the sum of segments on reference coastline identified as the intersection of polylines representing human-made structures with reference coastline ignoring polylines representing human-made structures with no intersection with reference coastline. As recommended by the fact sheet (annex 2), the minimum distance between coastal defence structures was set to 10 m in order to classify such segments as natural, i.e. if the distance between two adjacent coastal defence structures is less than 10 m, all the segment including both coastal defence structures is classified as artificial.

The information in the attribute table associated with the GIS information layer, according to the information standards for the Common indicator 16, for the coastline of Lebanon are:

- **CPCODE:** (Two-letter code of Country) LB
- **ART_NAT**: Code for type of segment of coastline.
  - 0 Natural coastline
  - 1 Artificial coastline
- **ASCODE**: Code of type of artificial infrastructure.
  - 1 Breakwaters
  - 2 Seawall/Revetements/Sea dike
  - 3 Groins
  - 4 Jetties
  - 5 River mouth structures
  - 12 Port and marinas
- **Year**: Year of production of the information layer
- **Length**: (Length of coastline segment in km, calculated through Arcmap)

In Lebanon, there are some unlegalized irregular urban construction zones on the coastline as shown in Figure 2. These were classified as ASCODE= 2. Other urban constructions on the coastline like the airport runaway were classified ASCODE= 2 as they often consisted of sea revetments. However, when the built structure had a breakwater protection purpose, it was classified as (ASCODE:1), as shown in Figure 3.

Figure 2 Unlegalized irregular urban construction on the sea classified as ASCODE: 2 in Ouzaai, Lebanon

Figure 3 Airport runway (in blue; classified as ASCODE:2), protected by breakwater (in black; ASCODE:1).

The “Sea revetements” (ASCODE=2) coinciding with the purpose of the seaports or nautical tourism ports, were classified as classified as Port and Marinas (ASCODE 12) as shown in Figure 4.

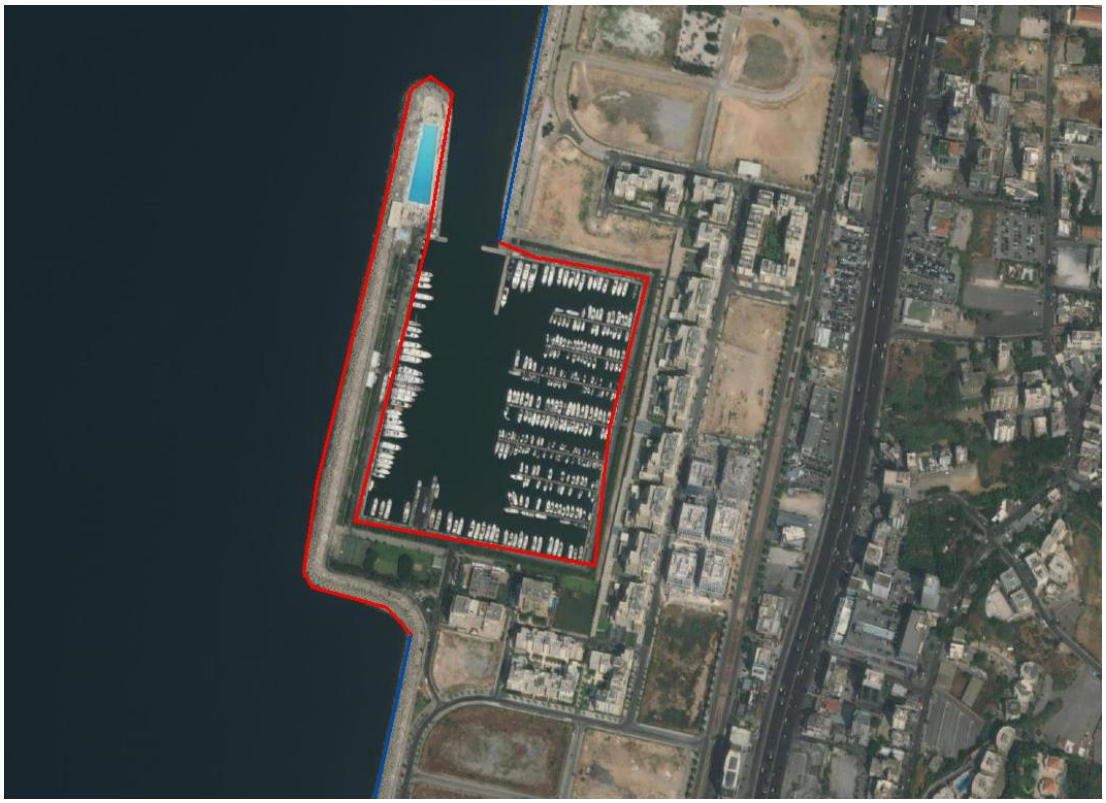

Figure 4 Sea revetements around a Marina (in redline), classified as Port and Marinas (ASCODE 12).

4. Results

The following results are according to indicator guidance factsheet for EO8 Coastal Ecosystems and Landscapes Common Indicator 16 "Length of coastline to physical disturbance due to the influence of human-made structures available in Annex 2 at the end of this report. The results are available in digital version as "shp" file with required attributes. Digital data is a part of this report and are uploaded to INFO/RAC IMAP Info System.

Total length of Lebanese coastline is approximately 342 km. The natural part of the Lebanese coast represents 36,59 % of the total Lebanese coast with a length of about 125 km, and the artificial coastline represents 63,41 % with a length of about 217 km (Figures 5 and Table 1).

Table 1 Classification of the Lebanese coastline following delineation

Type	Class	Length (km)	Percentage (%)
Artificial coastline	Port and marinas	65,6	19,20
	River mouth structures	3,03	0,89
	Jetties	15,77	4,62
	Groins	3,7	1,08
	Seawall/Revetments/Sea dike	110	32,06
	Breakwaters	18,99	5,56
Natural coastline		125	36,59
Total		342	100

The spatial presentation of coastal delineation by type of the Lebanese coastline (natural vs artificial) is presented in Figure 5. The coastline surrounding the capital Beirut is artificial, extending more to the North of Beirut than its South (Figure 6b). Much of the natural coastline length is in the Southern part of Lebanon. It is worth to mention that in the Southern coastline contain one of the most important Coast Nature Reserves to the southern of Tyre city. This Tyre Coast Nature Reserve is an important nesting site for migratory birds and the endangered Loggerhead and green sea turtles (Figure 6a). On the other hand, to the north of Beirut, there are also 2 coastal nature reserves (Palm

islands and cliffs of Ras Ech-Chakkaa). These three mentioned coastal nature reserves were designated in the RAMSAR list.

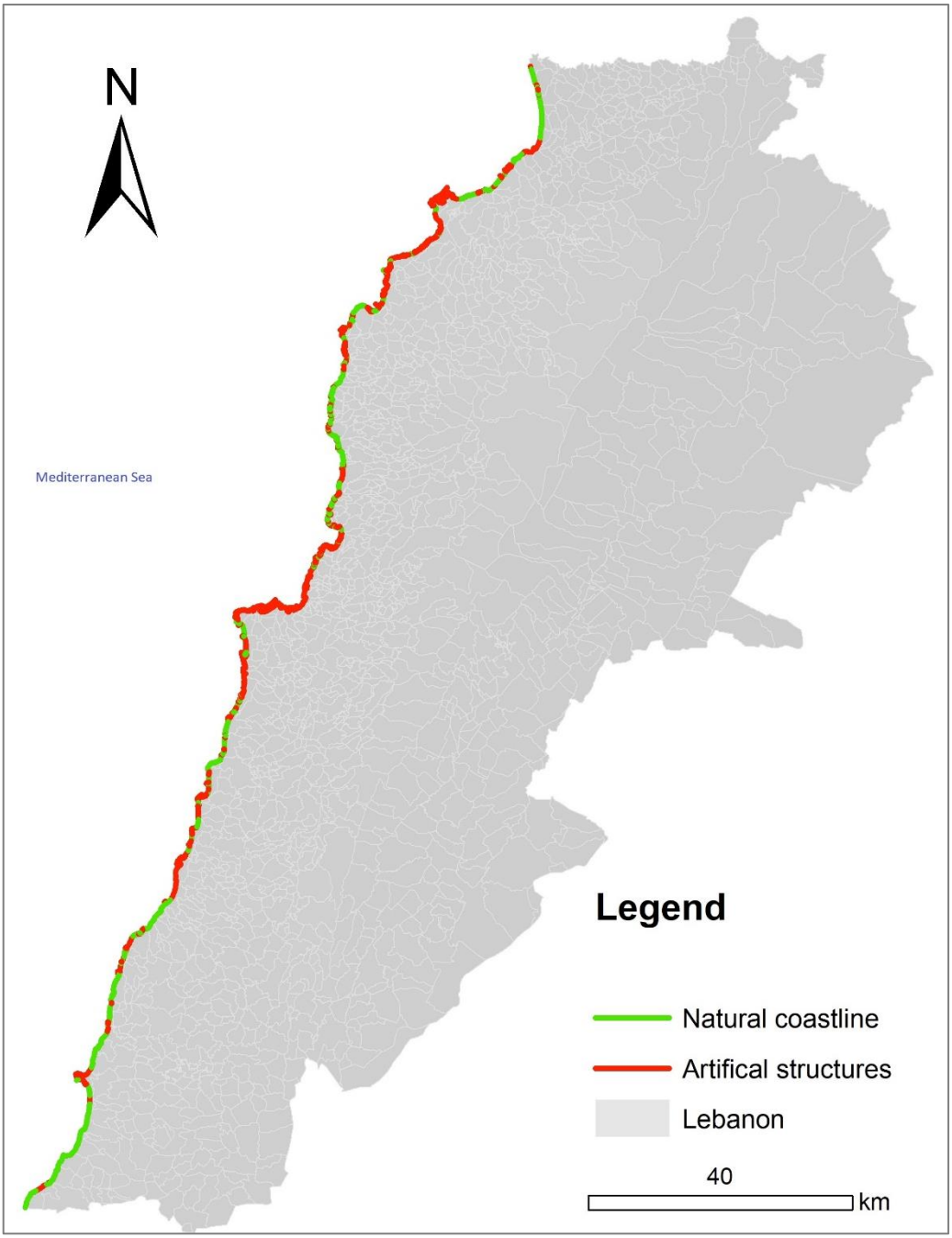

Figure 5 Spatial presentation of coastal delineation by type of coastline in Lebanon

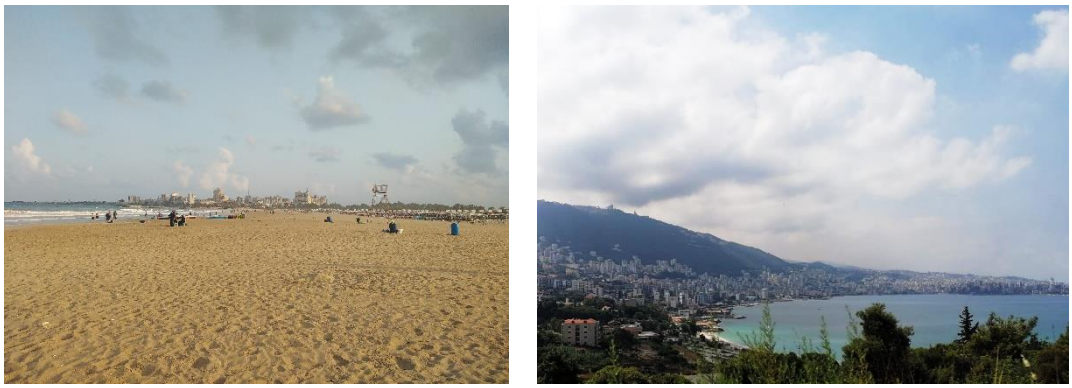

Figure 6 Tyre sandy beach (left) and a photo showing the dense urbanization to the north of the capital Beirut (right).

Spatial distribution of different type of artificial infrastructure is shown in Figure 7.

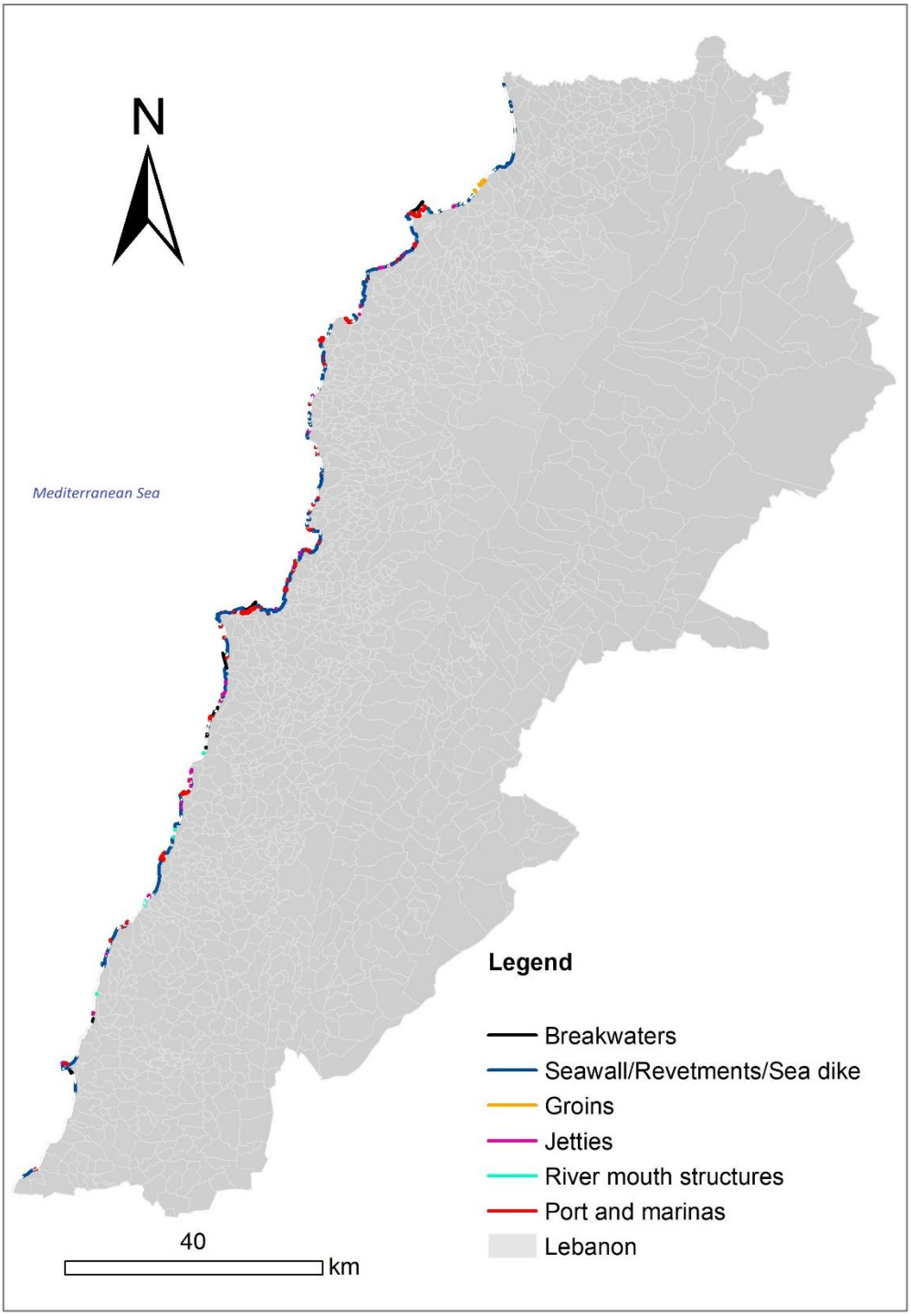

Figure 7 Spatial distribution and types of artificial coastline in Lebanon

As mentioned above, the length of the artificial structures is 217 km. These 217 km are partitioned as the following (Figure 8):

- Seawall/ Revetments/Sea dikes (ASCODE 2): 50,56 %

- Port and Marinas (ASCODE 12): 30,28 %
- Breakwaters (ASCODE 1): 8,77 %
- Jetties (ASCODE 4): 7,28 %
- Groins (ASCODE 3): 1,71 %
- River Mouth Structures (ASCODE 5): 1,40 %

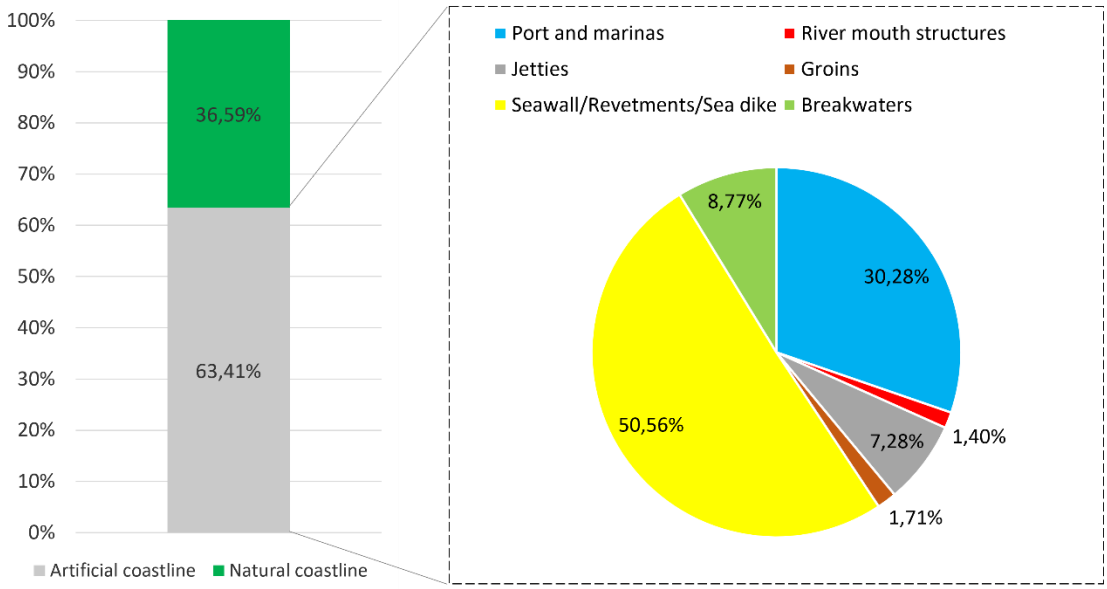

Figure 8 Percentage of Natural coastline and the different types of artificial coastline in Lebanon

No wonder ASCODE 2 represented half of the artificial coastline in Lebanon. As mentioned in the methods section, irregular constructions were classified as Seawall/ Revetments/Sea dikes (ASCODE 2). Moreover, the main highways in Lebanon are located on the coastal side. These are the only way to connect the largest cities to the

capital Beirut. As shown in Figure 9, revetments are often added to protect these coastal highways.

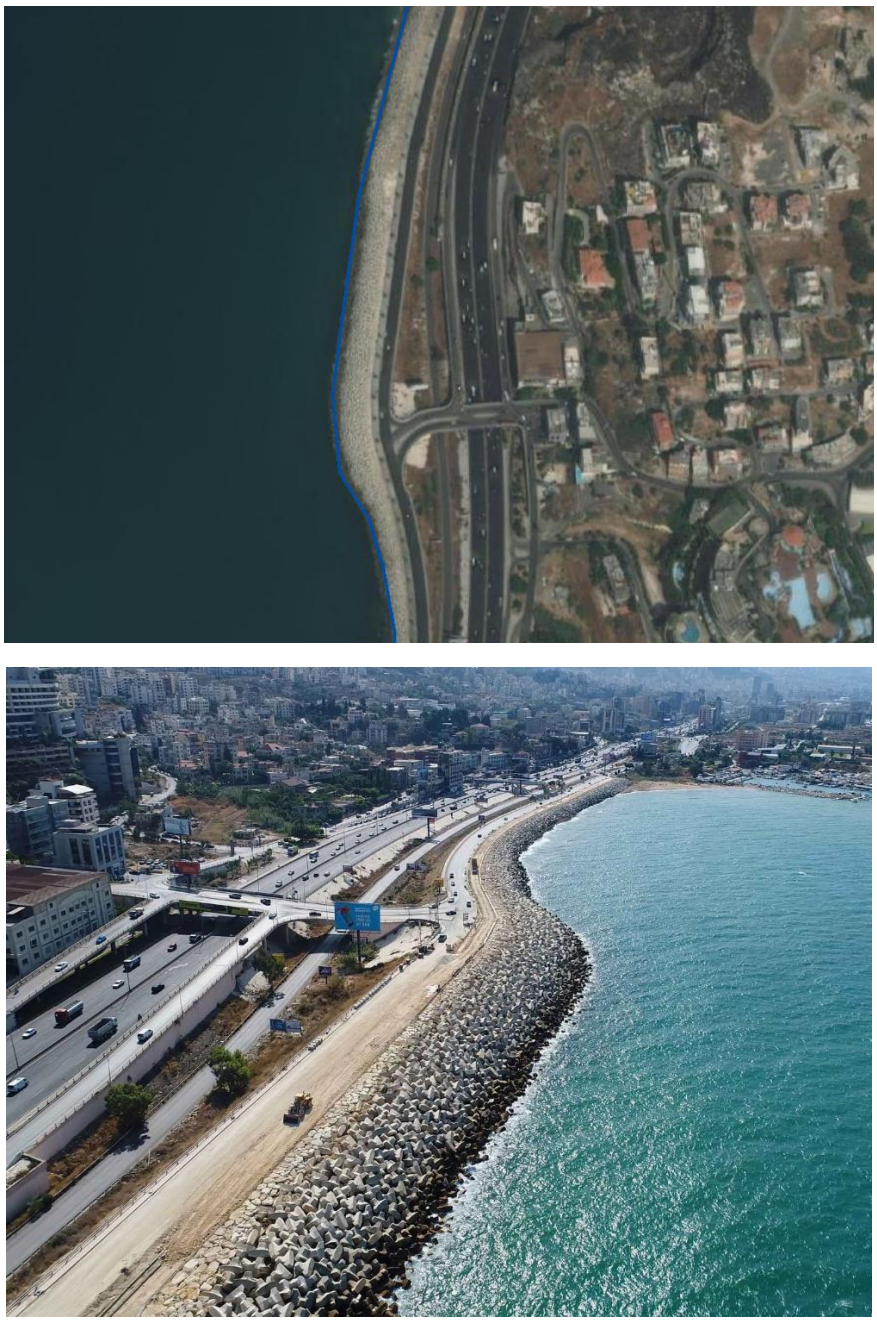

Figure 9 Upper image showing coastal highway protected by concrete Accropodes Blocks Type I armor layer (classified as ASCODE 2). Location Dbayeh, Lebanon. Lower image showing an arial photo of the same location[1]

[1] (Lower image source: http://seatec-sarl.com/project.php?id=110)

5. Conclusion

In this report, information for Common Indicator 16 “Length of coastline to physical disturbance due to the influence of human-made structures” for Lebanese coast was produced.

The total length of Lebanese coastline is 342 km, of which natural part represents 125 km (i.e. 36,59 % of the total coastline), and the artificial coastline represents 217 km (i.e. 63,41 % of the total coastline). The artificial structures are dominated by "Seawalls/ Revetments/Sea dikes", (ASCODE 2: 50,56 %) followed by "Port and Marinas", (ASCODE 12: 30,28 %), Breakwaters (ASCODE 1: 8,77 %), Jetties (ASCODE 4: 7,28 %), Groins (ASCODE 3: 1,71 %), and River Mouth Structures (ASCODE 5: 1,40 %). The results are a part of digital spatial data, which are a part of this report and sent to INFO/RAC IMAP Info system.

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Annexes

Annex 1: Information standards for the Common Indicator 16

GIS information standards:

- Coastline_AN (artificial/natural)
- Artificial structures

Name of GIS layer: Coastline_AN
Type of GIS Layer: polyline
Geographical Reference Systems: WGS 84 decimal degree
Attribute table:

Content	Description
Ecological Objective	**EO8. Coastal ecosystem and landscape**
IMAP Common Indicator	**CI16. Length of coastline subject to physical disturbance due to the influence of manmade structures**
Parameter	**Artificial/Natural coastline**

Attribute table	Specify the following information in the attribute table associated with the GIS information layer:
	• CPCODE: Two-letter code of Country
	• ART_NAT: Mandatory. Integer. Code for type of segment of coastline. Use the following code list:
	  ○ 0 Natural coastline
	  ○ 1 Artificial coastline
	• Municipal: Optional. Text. Name of municipality or local administrative region where the polygon/polyline of segment of coastline is located
	• Year: Mandatory. Text. Year of production of the information layer
	• Ref_Year: Mandatory. Year of the reference coastline used to represent natural and artificial segments

Variables	Segment of artificial/natural of coastline
Spatial resolution	10 m or higher as produced by photo digitalization and interpretation
Vertical coverage	1 level at sea surface
Coordinate Reference System	WGS 84 or ETRS 89 decimal degrees
Temporal coverage	Every 6 years
Data format	GIS Layer: polyline

Name of GIS layer: Artificial_structures
Type of GIS Layer: polyline
Geographical Reference Systems: WGS 84 decimal degree
Attribute table:

Content	Description
Ecological Objective	**EO8. Coastal ecosystem and landscape**
IMAP Common Indicator	**CI16. Length of coastline subject to physical disturbance due to the influence of manmade structures**
Parameter	**Location and extend of artificial structures**
Attribute table	Specify the following information in the attribute table associated with the GIS information layer: • CPCODE: Two-letter code of Country • ASCODE: Mandatory. Integer. Code of type of artificial infrastructure. The following code list should be used: ○ 1 Breakwaters ○ 2 Seawater/Revetments/Sea dike ○ 3 Groins ○ 4 Jetties ○ 5 River mouth structures ○ 12 Port and marinas • ASDES: Optional. Text. Description of type of artificial infrastructures • Municipal: Optional. Text. Name of municipality or local administrative region where the polygon of impervious surface is located • Year: Mandatory. Text. Year of production of the information layer
Variables	Border on the sea side of coastal artificial structures

Annex 2: Indicator guidance factsheet for EO8 Coastal Ecosystems and Landscapes Common indicator 16 "Length of coastline subject to physical disturbance due to the influence of manmade structures"

UNEP/MED WG.467/6
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2. Indicator guidance factsheet for EO8 Coastal Ecosystems and Landscapes Common Indicator 16 "Length of coastline subject to physical disturbance due to the influence of human-made structures"

Ecological Objective 8:	The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved	
Indicator Title	Length of coastline subject to physical disturbance due to the influence of human-made structures	
Relevant GES definition	**Related Operational Objective**	**Proposed Target(s)**
Physical disturbance to coastal areas induced by human activities should be minimized.	The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved.	Negative impacts of human activities on coastal areas are minimized through appropriate management measures.
GES, targets and measures cannot be expressed quantitatively (as a threshold value) but due to country specific circumstances (socio-economic, cultural, historical) should be defined by the countries themselves. In doing so the CPs should take their spatial development and planning policies into account, as well as the legal obligations of the Barcelona Convention, in particular the ICZM Protocol. The above GES definition and Proposed target(s) are just examples.		
Rationale		
Justification for indicator selection Mediterranean coastal areas are particularity threatened by coastal development that modifies the coastline through the construction of buildings and infrastructure needed to sustain residential, commercial, transport and tourist activities. The land, intertidal zone and near-shore estuarine and marine waters are increasingly altered by the loss and fragmentation of natural habitats and by the proliferation of a variety of built structures, such as ports, marinas, breakwaters, seawalls, jetties and pilings. These coastal human-made infrastructures cause irreversible damage to landscapes, losses in habitat and biodiversity, and strong influence on the configuration of the shoreline. Indeed, physical disturbance due to the development of artificial structures in the coastal fringe can disrupt the sediment transport, reduce the ability of the shoreline to respond to natural forcing factors, and fragment the coastal space. The modification of emerged beach and elimination of dune system contribute to coastal erosion phenomena by lessening the beach resilience to sea storms. Coastal defence infrastructures have been implemented to solve the problem together with beach nourishment but preserving the natural shoreline system with adequate sediment transport from river has proved to be the best solution. Monitoring the length of coastline subject to physical disturbance due to the influence of human-made structures and its trend is of paramount importance to preserve habitat, biodiversity and prevent coastal erosion phenomena, as well as for its importance in land-sea interactions. Until now there has not been systematic monitoring in Mediterranean regarding this, in particular not quantitatively based monitoring or any major attempt to homogenously characterize coastal ecosystems on a wider Mediterranean basis. The status assessment of EO8 aims to fill this gap.		
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Ecological Objective 8:	The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved
Indicator Title	Length of coastline subject to physical disturbance due to the influence of human-made structures

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Policy Context and targets

Policy context description

ICZM Protocol (Article 8, point 3):

The Parties shall also endeavour to ensure that their national legal instruments include criteria for sustainable use of the coastal zone. Such criteria, taking into account specific local conditions, shall include, inter alia, the following:

(a) identifying and delimiting, outside protected areas, open areas in which urban development and other activities are restricted or, where necessary, prohibited;
(b) limiting the linear extension of urban development and the creation of new transport infrastructure along the coast;
(c) ensuring that environmental concerns are integrated into the rules for the management and use of the public maritime domain;
(d) providing for freedom of access by the public to the sea and along the shore;
(e) restricting or, where necessary, prohibiting the movement and parking of land vehicles, as well as the movement and anchoring of marine vessels, in fragile natural areas on land or at sea, including beaches and dunes.

Targets

Ecological Objective 8:	The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved
Indicator Title	Length of coastline subject to physical disturbance due to the influence of human-made structures

Negative impacts of human activities on coastal areas are minimized through appropriate management measures.

Additional country-specific criteria should be taken into account for definition of targets, measures and interpretation of results regarding this indicator due to strong socio-economic, historic and cultural dimensions in addition to characteristic geomorphological and geographical conditions in each respective country (reflected in policy documents, strategies and other country-specific documents). Interpretation of results should be left to the countries taking above criteria into account.

Policy documents
Protocol on the ICZM in the Mediterranean - http://www.pap-thecoastcentre.org/pdfs/Protocol_publikacija_May09.pdf

Indicator analysis methods

Indicator Definition

The monitoring aim of the EO8 common indicator is twofold: (i) to quantify the rate and the spatial distribution of the Mediterranean coastline artificialitsation and (ii) to provide a better understanding of the impact of those structures to the shoreline dynamics. It has an operational target on impact, thus it is associated to concrete implementation measures related to specific human activities (i.e. appropriate management measures) to minimize negative impacts and to inform about progress towards GES.

Methodology for indicator calculation

The monitoring of this Common Indicator entails an inventory of the length and location of human-made coastline (hard coastal defence structures, ports, marinas (see Figure 1). Soft techniques e.g. beach nourishment are not included.

With regard to the coastline to be considered: the fixed reference official coastline as defined by responsible Contracting Party should be considered. The optimal resolution should be 5 m or 1: 2000 spatial scale.

Once a proper geographic scale has been established, monitoring should focus, in particular, on the location, the spatial extent and the types of coastal structures taking into account the minimum coastal length that can be classified as artificial or natural.

The identification procedure of human-made structures should be carried on based on typical situations added to the indicator guidance factsheet, including the minimum size (length, width of human-made structures) to be taken into account.

As monitoring should be done every 6 years, every CP should fix a reference year in the time interval 2000-2012 in order to eliminate the bias due to old or past human-made infrastructures.

Ecological Objective 8:	The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved
Indicator Title	Length of coastline subject to physical disturbance due to the influence of human-made structures

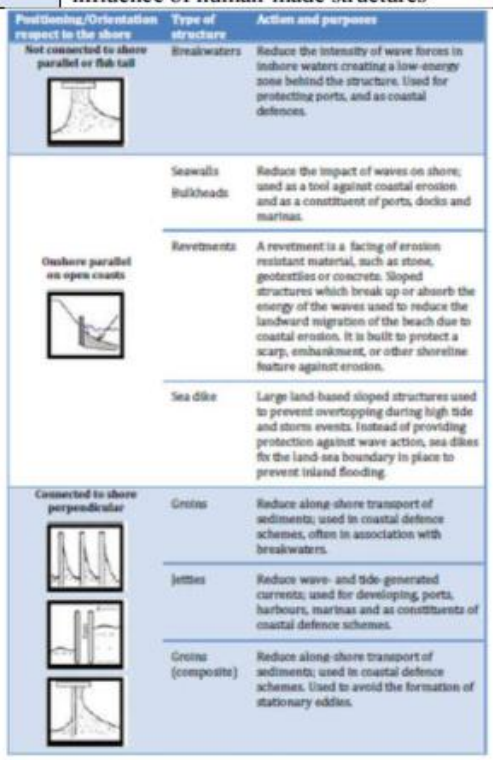

Figure 1. Hard coastal defence structures, modified from the EUROSION Shoreline Management Guide, EU, 2004. Taken from IMAP guidelines, page 134, Table 1.

Indicator units

- Km of artificial coastline and % of total length of coastline.
- Percentage (%) of natural coastline on the total coastline length.

The length of artificial coastline should be calculated as the sum of segments on reference coastline identified as the intersection of polylines representing human-made structures with reference coastline ignoring polylines representing human-made structures with no intersection with reference coastline. The minimum distance between coastal defence structures should be set to 10 m in order to classify such segments as natural, i.e. if the distance between two adjacent coastal defence structures is less than 10 m, all the segment including both coastal defence structures is classified as artificial.

List of Guidance documents and protocols available

Monitoring and assessment methodological guidance on EO8: coastal ecosystems and landscapes (within IMAP guidelines)

Ecological Objective 8:	The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved
Indicator Title	Length of coastline subject to physical disturbance due to the influence of human-made structures
EUROSION Shoreline Management Guide (European Commission and Directorate General Environment, 2004, Annex 2)	
Data Confidence and uncertainties Regarding data confidence, both geographic scale and resolution of images have to be properly selected depending on type and density of coastal human-made structures. A specific cost/benefit analysis has to be carried on to choose the right balance among resolution, an acceptable level of uncertainties and the necessity to assure comparability of results at Mediterranean level.	
Methodology for monitoring, temporal and spatial scope	
Available Methodologies for Monitoring and Monitoring Protocols Space and airborne earth observation systems are the most suitable tool to conduct the monitoring strategy of the EO8 common indicator, i.e. very high resolution (VHR) satellite imagery, aerial photographs, laser scanners etc. Beyond earth observation data, identification techniques and procedures used through GIS tools also have to be described	
Available data sources CORINE land cover, national spatial plans, World Imagery Basemap feature (in ArcGIS 10.1), Landsat satellite imagery, Google earth, aerial photographs surveys.	
Spatial scope guidance and selection of monitoring stations The exact territorial extent of the monitoring should be presented. The optimum spatial scale for a proper identification of human-made structures should be 5 m by satellite imagery or aerial photographs.	
Temporal Scope guidance Monitoring human-made structures data should be updated at least every 6 years, while shoreline survey of sandy coastline under anthropogenic pressure should be, if possible, repeated annually (at the same time of the year)	
Data analysis and assessment outputs	
Statistical analysis and basis for aggregation The total length of coastline estimated as being subjected to physical disturbance due to the influence of human-made structures should be summed. In addition, the share of this coastline in total country's coastline should be determined. If an official coastline is available, i.e. an institutional body provides a GIS polyline, then such coastline can be used to "project" the identified human-made structures in order to classify parts of the coastline as being subjected to physical disturbance due to the influence of human-made structures. Geographic scale of maps and cartography used to identify human-made structures could be different but not too much form the ones used for the official coastline. In case if such official coastline is not available or its geographic scale is too coarse with respect to one needed to properly identify human-made structures, then coastline will be defined by the same maps/cartography used for human-made structures identification.	
Expected assessments outputs	

Ecological Objective 8:	The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved
Indicator Title	Length of coastline subject to physical disturbance due to the influence of human-made structures

The total length of coastline influenced by human-made structures and the share of this coastline in total country's coastal length should be provided on a map showing the coastline subject to physical disturbance due to human-made structures (artificial segments) in red line and the rest (natural segments) in green line.
The assessment output should be reported as a common shape file format with GRS as WGS84. Shape file with other GRS will also be accepted if provided with a complete .prj file that allows GRS transformations by standard GIS tools.

Known gaps and uncertainties in the Mediterranean

In order to implement EO8 indicator with an acceptable level of accuracy, recent data sources with proper spatial resolution and complete coastline coverage should be used jointly with adequate GIS tools and expert team.
Capacity building can be readily assessed for each CP as such resources are generally available for the Mediterranean Region also taking into account the increasing efforts on satellite imagery products (ESA Sentinels constellation). So, once a common framework of data sources, GIS procedures and way of representing the output of EO8 indicator are agreed, a common implementation work for all CPs could be in principle settle down.

Contacts and version Date

Key contacts within UNEP/MAP for further information

Version No	Date	Author
V.1	27/6/16	PAP/RAC & Giordano Giorgi
V.2	27/7/16	Giordano Giorgi
v.3	23 March 2018	PAP/RAC