DIACHRONIC EVOLUTION OF THE COASTLINE OF BORDJ EL KIFFANE (ALGIERS, ALGERIA) IN ABSENCE AND PRESENCE OF COASTAL PROTECTION STRUCTURES

Ismahane KADRI [1], Farid ATROUNE [1]
[1]Laboratory Geo-environment – University of Science and Technology Houari Boumedienne, Algiers, (Algeria),
phone +213 668997044, e-mail: minakadri.ik@gmail.com, faridatroune@gmail.fr

Abstract – The coastline is one of the country's most important environmental and economic resources. However, it is a delicate and highly coveted environment on which many factors of evolution interact, both anthropogenic and natural [1].The anthropization of the shoreline accelerates the trends of evolution which lead to other human interventions by implanting hard protective structures that can cause other impacts and even accelerate erosion rates. [2]

The coastal area of Bordj El Kiffane, located in the central part of Algiers Bay in Algeria, has experienced an artificialisation of its shoreline translated by the strong urbanization since 1980 and development of several anthropogenic activities on its coast. This caused a remarkable decline of the shoreline. To remedy this, the solution recommended by the Maritime Studies Laboratory is the combination of several protection methods: shore-connected break-waters, groins, seawalls and nourishment of the sandy beach on the west of the study area. [2]

In order to determine the consequences of the implementation of these protective structures, a study of the historical evolution of the coastline was performed with ArcGIS and its extension Digital shoreline Analysis System (DSAS) as a means of monitoring. The methodology followed consists of the application of automatic analytical techniques, based on a geomatics approach using multi-temporal photo-interpretation on a period of 38 years. The change rates using the End Point Rate EPR and Net Shoreline Movement NSM were calculated by the DSAS tool and mapped to facilitate their interpretation. The surface evolution has been also estimated to quantify the sediment budget in case of erosion or accretion of the shoreline.

The Diachronic evolution of the coastline of Bordj El Kiffane area allowed determining its evolutionary rates and comparing the evolutions on different periods in absence and presence of the protection structures.

Introduction

The coastline in general is characterized by its extreme diversity and by the speed of its evolution. It is an environment that depends at the same time on the nature of the substratum, on the quantity of sedimentary contributions and on marine dynamics, continental and / or anthropic factors. [3]

In general, the coastline of Algiers Bay is in decline. Erosion is due to natural factors governing coastal dynamics and anthropogenic action, in particular, the extraction

FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Ismahane Kadri, Farid Atroune, *Diachronic Evolution of the Coastline of Bordj El Kiffane (Algiers, Algeria) in Absence and Presence of Coastal Protection Structures,* pp. 422-431,
DOI 10.36253/978-88-5518-147-1.42

of sand and urbanization close to the coast. The sum of all these factors results in the alteration of the natural balance of the coast. [4]

The Bordj El Kiffane area was the subject of a detailed study of its sedimentary dynamics as a part of my engineer degree project entitled: ‘Consequences of the establishment of protective structures on the coastal fringe of Bordj El Kiffane (Algeria)’ in 2017, followed by an article publication in the Revue Paralia in 2018. In addition, Bordj El Kiffane is one of the areas studied in my doctoral work entitled: ‘Mapping of surface sediments of the Algerian continental platform of the central region of Algeria’ since 2018.

Study area

The region is marked by a predominance of winds from the East-North-East and West-South-West directions, with maximum speeds reaching 20 m/s for the directions between 240° and 270° north. Also for directions between 45° and 90° north, wind speeds are reach 16 m/s. [4]

The Northeast swells are the most frequently observed. Storms mainly come from the western sector.The North sector has a fairly regular distribution during the year [4]. The most energetic swells are those of the Northeast, which generate currents with speeds of the order of 1.65 m/s. They induce coastal drift currents with dominance from east to west, eddy currents inside the breakwater basins as well as a weak rip current. [2]

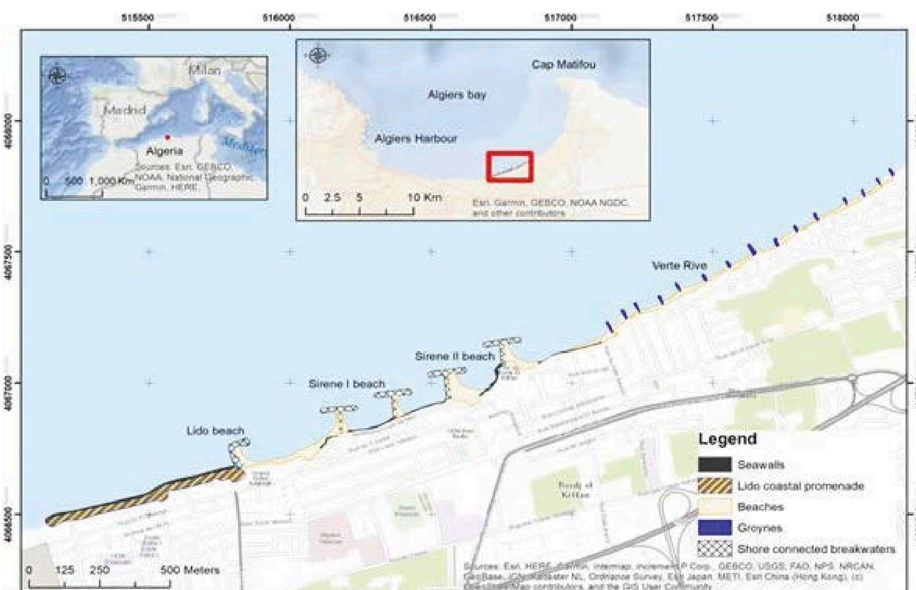

Figure 1 - Map of the location of the study area.

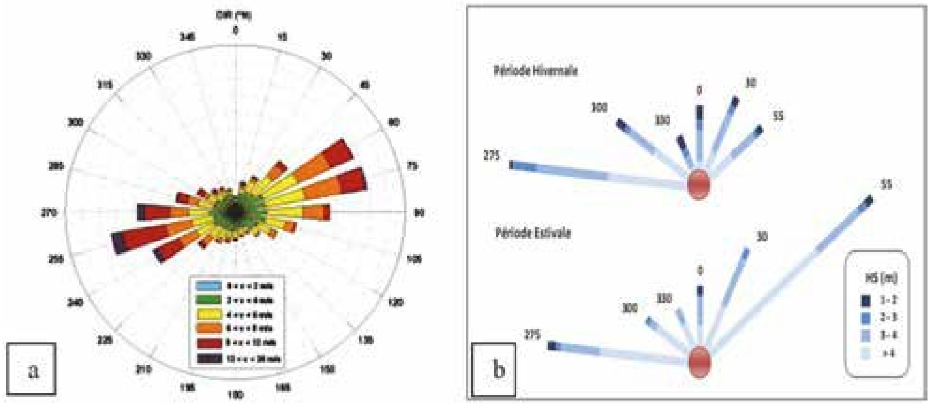

Figure 2 - a: Wind direction rose of Algiers Bay [4] and b: Swell direction roses on the offshore of Algiers Bay [5].

Erosion factors

Among the factors aggravating erosion on the study area, the natural factors (activity of winds and swells) combined with human factors such as the excessive extraction of aggregates, the construction of dams upstream rivers and urbanization. The region of Bordj El Kiffan was a commune with agricultural and tourist vocation but its urbanization reduced it to a very urbanized commune. Agricultural land has been sacrificed in favor of urbanization.

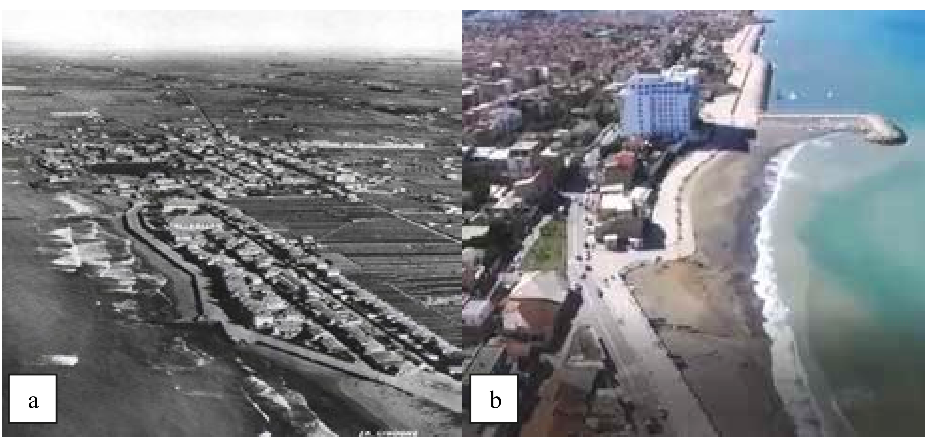

Figure 3 - Illustration of urbanization in the Bordj El Kiffane area between 1960 [6] and 2018 (Credits Anonymous).

The first touristic potential in this city is the beaches, which once made the glory of the town, are in a deplorable state now, the situation of the beaches in the sixties and after the artificialization of the coastline is illustrated by the photos below. These photos show the great loss of in width of the beaches and the change in their profiles and slopes with the disappearance of some of them and theirs replacement with seawalls.

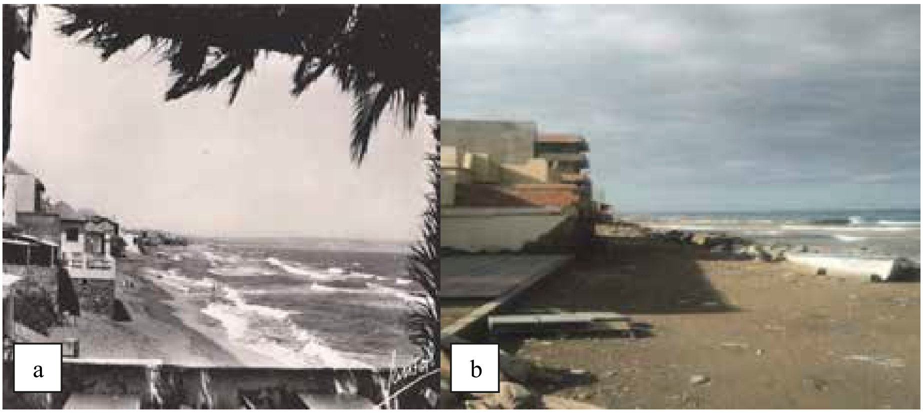

Figure 4 - Verte Rive a : in 1960 [6], b : in 2019 (Credits :KADRI I.).

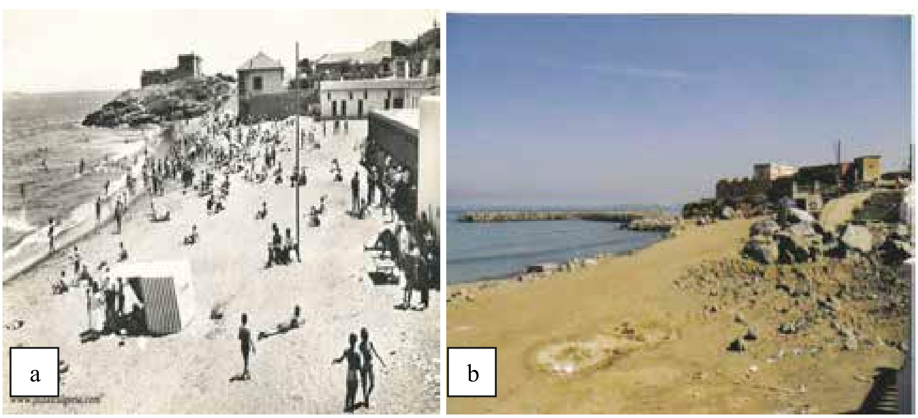

Figure 5 - Sirene II a: in 1960 [6], b: in 2018 (Credits: KADRI I.).

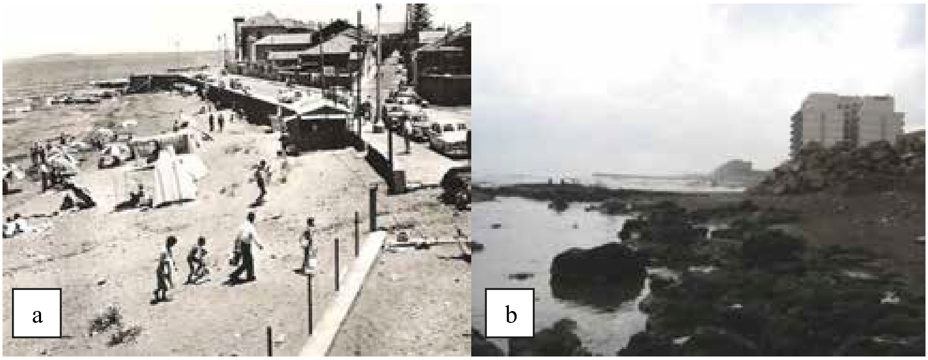

Figure 6 - Lido a: in 1960 [6], b in 2009 (Credits: LEM).

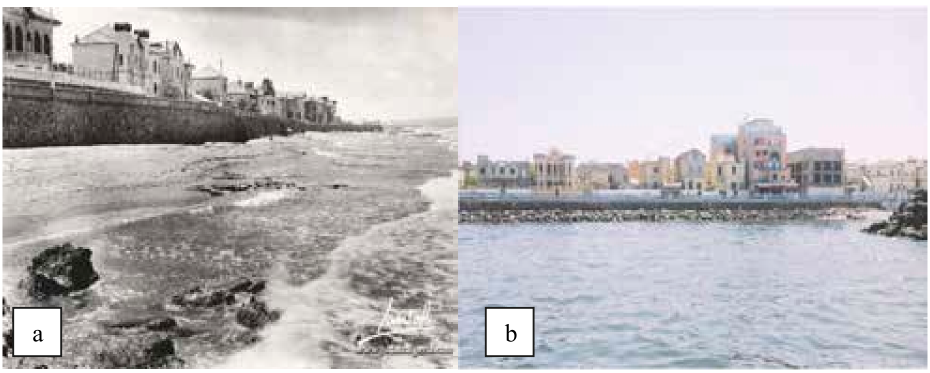

Figure 7 - Sirene I a: in 1960 [6], b: in 2017 (Credits: KADRI I.).

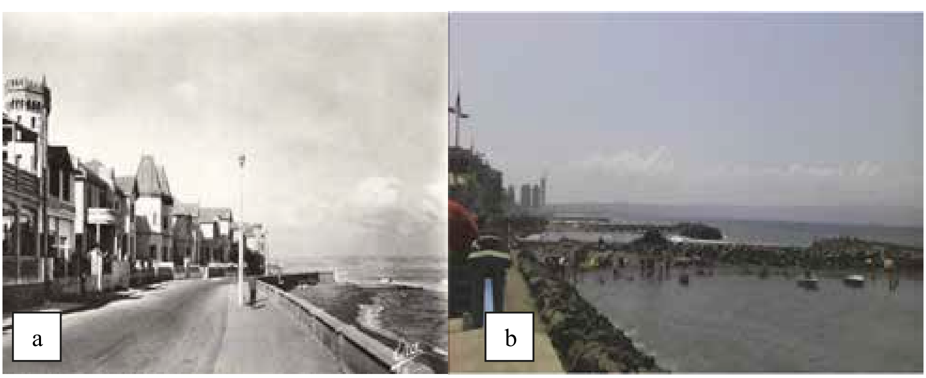

Figure 8 - Sirene I and Sirene II and the coastal promenade a: in 1960 [6] , b: in 2017 (Credits KADRI I.).

History of management of Bordj El Kiffane

The vulnerability of the study area to the erosion hazard necessitated its protection by the installation of different types of hard and soft protective structures: a battery of 15 groynes on the Verte Rive site in 2002, seawalls and rock fill to protect the beaches and the houses from wave action, T-shaped mixed protection structures, on a length of 1560 m on the Sirene I and Sirene II sites in 2007 and the creation of an L-shaped breakwater to keep the reloading carried out at the Sirene I beach as well as the realization of a promenade on the site of Lido in 2012. This was in order to protect the bordering houses by reducing the hydrodynamic energy as well as by widening the beach.

Figure 9 - Illustration of protective structures at the study site (Photo taken by a drone in 2019, Credits: Anonymous).

Material and methods

The analysis of the coastline evolution was carried out by the combination of different types of data and it consists of the application of automatic analysis techniques based on a geomatic approach. The documents used are summarized in the following table:

Table1 - Summary of the data used.

Date	1980	2003	2007	2012	2018
Type	2 aerial photographes	2 aerial photographes	2 aerial photographes	Ortho-photographe	Field survey

These documents were treated in several steps with:

- The treatment of aerial photographs and satellite images under ArcMap
- After correcting the aerial photographs, the step of digitizing the coastlines is applied, this was done using the ArcMap module of the ArcGis 10.4 software, where a new personalized database containing the shoreline features and the baseline was created.
- The estimation of global correction errors using the following formula:

$$E_g = \pm \sqrt[2]{E_p^2 + E_r^2 + E_d^2 + E_s^2} \qquad 1$$

Using: the resolution of the photos, the error due to the rectification E_r, the error of digitization Ed and the error due to the seasonal variations [7].

Table 2 - Estimated errors induced when treating shorelines data.

Period	1980	2003	2007	2012	2018
Error (m)	3.12	3.12	1.62	0.62	2.12

- Another feature class for transects has been created and evolution rates have been calculated on nearly 250 transects 10 meters apart along the coast.

Figure 10 - Digitizing of the shoreline and the baseline as well as the realization of the transects using the DSASv5 tool.

- Analysis of the diachronic evolution of the coastline using the DSAS v5 extension and the estimation of eroded surfaces and those accreted as well as the calculation of the statistics of evolution of the coastlines using the Net Shoreline Movement NSM and the End Point Rate EPR as follows:

$$R = {}^{D}/_{T_e} \qquad 2$$

Where: R: is the speed in meters per year (m/year), D: is the distance in meters (m) and Te: is the time between the most recent and the oldest coastline (years) [8].

Results and discussion

Evolution between 1980 and 2003 (23 years)

This period is marked by an average accretion of 0.24 m/year in the eastern part. On the other hand, in the western part, erosion has taken advantage over accumulation with an average decline estimated at -0.12 m/year. These evolutions on the coast are, on the one hand, the result of manifestation of hydrodynamic factors and on the other hand, the intervention of the human factor by the strong urbanization of the shore and its anthropization. [9]

Evolution between 2003 and 2007 (4 years)

During a period of 4 years, our study area was marked by an alternation of erosion and accretion zone. Erosion has been triggered in the eastern sector and has been accentuated in the West sector with an average rate of -1.17m/year. We note that the accumulation zones are located in the same direction of the coastal with an average change of 2.73 m/year. These short-term changes are due to the combination natural and artificial factors, by the hydrodynamics and by the implantation of four T-shaped breakwaters which promote erosion downstream and progradation upstream of the coastal drift. [9]

Evolution between 2007 and 2012 (5 years)

From 2007 to 2012, erosion rates were significantly reduced to an average of -0.26 m/year. We notice the continuation of the fattening especially in the West sector with an average of 5.98m/year. The spectacular fattening in the West sector is caused by the beginning of the emplacement of a promenade and an artificial beach at Lido. [9]

Evolution between 2012 and 2018 (6 years)

During a period of 6 years, erosion started again in the eastern sector in upstream of the last breakwater and at the Lido with an average speed of -0.72 m/year. Progradation in the West sector continues with an average of 3.45 m/year. The phenomenal accretion in Lido Beach is artificial and is due to the artificial sand nourishment as well as the installation of an L-shaped breakwater to maintain it. [9].

Global evolution between 1980 and 2018 (38 years)

Analysis of the evolution of the study area over the medium term (38-year period) shows that our study area has gone through many changes. On the one hand, we note the formation of small beaches in pockets sheltered by the breakwaters which are fattening at an average speed of 0.8 m/year; this caused blocking of the sedimentary transit from the East to west as well as preventing the sediments from going offshore. On the other hand, there are small areas which are eroding at low rates of -0.51 m/year in the eastern sector downstream of the last right groyne of the Verte Rive as well as downstream from the promenade of Lido.

The analysis of surface changes is illustrated in the table 3. The general balance sheet of the evolution of surfaces in a period of 38 years is positive and estimated at 1490.133 m² with a gain of 61561.48 m² and a loss of -4936.439 m².

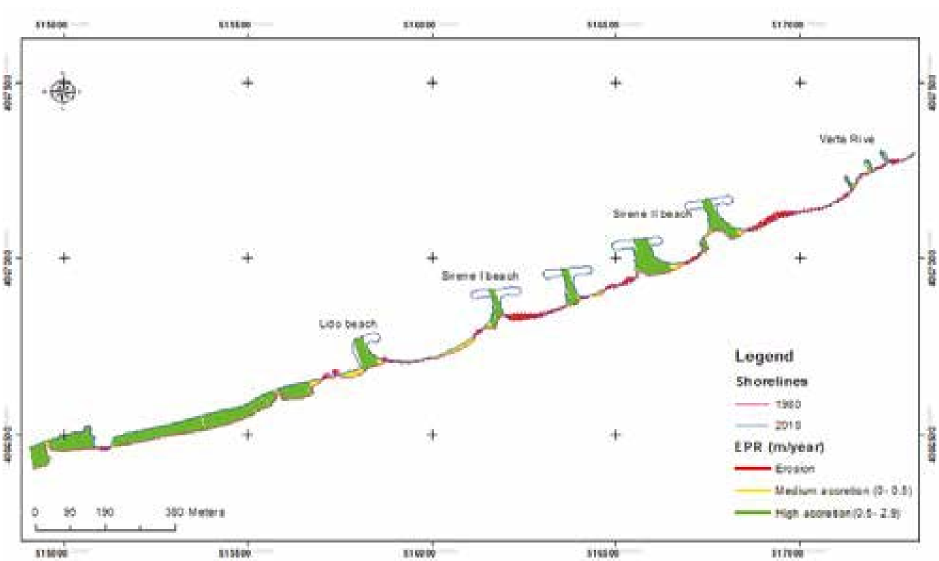

Figure 11 - Coastline evolution rates between 1980 and 2017.

Table 3 - Assessment of eroded and accumulated surfaces in the Bordj EL Kiffane area from 1980 to 2018.

Period	Accretion (m²)	Erosion (m²)	Balance (m²)	Annual evolution (m²)
1980-2003	8269.17	-9633.44	-1364.27	-59.32
2003-2007	26197.96	-6488.92	19709.03	4927.26
2007-2012	32924.74	-289.13	32635.62	6527.12
2012-2018	16153.77	-2766.31	13387.47	2677.49
1980-2018	61561.48	-4936.439	56625.04	1490.133

Conclusion

The Diachronic evolution of the coastline of Bordj El Kiffane area allowed determining its evolutionary rates and comparing the evolutions on different periods in absence and presence of the protection structures. The action of hydrodynamic factors with the strong anthropization of the shoreline and the construction of houses along the coastline of the area combined with human activities since 1980, have motivated the beginning of erosion and the retreat of the coastline. Besides, the implementation of various protection structures on the coastal area of Bordj El Kiffan has led to significant changes in the shoreline where there were high rates of accretion and low rates of erosion locally where accretion took the advantage over the retreat.

Finally, we can judge the impact of the protection structures on the city of Bordj El Kiffane as positive.

References

[1] Salim, F.Z., El Habti, M.Y., Hamman, L.-H.K.B., Raissouni, A. and El Arrim, A. (2018) - *Application of a Geomatics Approach for the Diachronic Study of the Meditterannean Coastline Case of Tangier Bay,* International Journal of Geosciences, pp. 320-336.

[2] Kadri I. (2017) - Impacts de l'implantation des ouvrages de protection sur la frange cotiere de Bordj El Kiffane. ENSSMAL 108 .

[3] Benali H. And El Moutchou B. (2016) - *Evolution diachronique de la ligne de rivage et de l'occupation des espaces de la zone côtière de Ksar Esghir entre 1966 et 2005 (Tanger - Maroc),* Innovative Space of Scientific Research Journals, International Journal of Innovation and Applied Studies, Vol. 16 No. 1. ISSN 2028-9324.

[4] LEM (2009) - *Etude de protection du site de "Lido" commune de Mohammadia, Collecte et analyses des données de base*, Laboratory of Marine Studies, p. 79.

[5] Zemenzer (2004) - Ensablement du port par transport sédimentaire simulation et application du modèle de Gao et Collins (1994) au port de Sidi Fredj. *Mémoire d'ingéniorat* : ISMAL, pp. 6-7, 31-41.

[6] Garcia C., *fortdeleau.* [Online] http://www.fortdeleau.net.

[7] Samat O. (2007) - *Effiacité et impacts des ouvrages en enrochement sur les plages microtidales. Le cas du Languedoc et du Delta du Rhone,* Université d'Aix-Marseille I, Thèse de doctorat en Géographie physique et humaine, aménagement, urbanisme, 376.

[8] Himmelstoss, E.A., Henderson, R.E., Kratzmann, M.G., and Farris, A.S. (2018) - *Digital Shoreline Analysis System (DSAS) version 5.0 user guide: U.S. Geological Survey Open-File Report 2018–1179*, 110. ISSN 2331-1258. https://doi.org/10.3133/ofr20181179.

[9] Ismahane, KADRI, Cherif, Aoudj (2018) - *Conséquences de l'implantation des ouvrages de protection sur la frange côtière de Bordj El Kiffan (Algérie,* La Rochelle : Editions Paralia CFL, DOI:10.5150/jngcgc.2018.017.