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First Report of the Invasive Marine Flora of Oran Coast, Northwestern Algeria (Western Mediterranean)

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Abstract. The Mediterranean flora and fauna are changing. The warming of marine waters leads to changes and modifications in the distribution of species within the Mediterranean. Due to disturbance, more and more species of the tropical Atlantic migrate to the north and some enter the Mediterranean through Gibraltar strait. The objective is to provide a first black list of invasive flora in the marine environment at the regional and national levels by in situ observations made by diving focusing on the presence of the different Exotic Flora of Oran coastline (EFO) these last twenty years. We report a total of 6 species (Macrophyta with 3 Chlorophyceae and 3 Rhodophyceae). Some species are appearing on the Westside of Oran coastline, via the Strait of Gibraltar (for species coming from the Atlantic) and others mark their origin on the East side of the coast, via the Suez Canal (for species coming from the Red Sea) like sea grapes *Caulerpa racemosa* var *cylindracea.* This black list of non-native flora, which has invaded Oran coasts in recent years, must be completed by work on the 14 coastal wilayas (district) in order to draw up a national blacklist and this for contributing to a national and Mediterranean strategy for monitoring and managing non-native species that threaten the marine coastal environment, resources and users.

Key words: Flora, Exotic, Non-native, Alien species, Oran, Western Mediterranean.

INTRODUCTION

In Algeria, the study of biological invasions remains fragmentary, generally characterized by reports of a species in a given region. This study is aiming to provide a black list of non-native flora which in recent years has invaded the Oran coast pushing scientists and sea users to be involved in the elaboration of a blacklist of invasive species.

Some non-native species may under certain conditions become invasive. Indeed, they find all the conditions to develop in their new environment without any limiting factor opposing to their proliferation. Managers are often disarmed face of these complex phenomena that are difficult to stop (Verlaque et al., 2003).

The objective is to provide a black list of invasive species in the marine environment at the regional and national levels, relying on photo-identification for identification and vulgarization of species to sea users and also monitoring and management of this threat in Oran coastline.
Their census and signaling to the specialists' networks thus the follow-up of their development are very useful to improve the knowledge of the mechanisms implicated. Raising sea user awareness and inquiring with specialized networks about the emergence of new species near MPA's should be an important reflex (Unep-Map RAC/SPA, 2005 ; Refes, 2012).
Non-native species (species of fauna or flora found outside their known range) are species for which the Mediterranean Sea is not part of their original range. About 925 non-native species have been counted so far in the Mediterranean represented by 13 phyla. Mollusks are the most important phylum (216 species), followed by fish (127 species), plants (124 species) and crustaceans (106 species) (Streftaris and Zenetos, 2006; Unep-Map RAC/SPA, 2017; Worms editorial board, 2017).

MATERIAL AND METHODS

Study area

The Oranian coastline is located along the southern shore of the Mediterranean basin (Fig.1); also called Alboran Sea is located in North-West of Algeria at 432 km from the capital Algiers. It is made up of 70% of rocky coasts and 30% of sandy coasts; the West sector is characterized by rocky character beaches: Ain Türk, Cape Falcon, la Madrague, les Andalouses, Madagh in the form of steep cliffs sometimes delimited by caps with an island complex (Plane and Habibas Islands) that are clearly visible in this region. In the East, the Macta (Arzew Gulf) is limited to the West by Cape Carbon (35° 45'NW 20' W) and to the East by the Cape Ivi (36° 37'N -0 13'W) where we can find a long arched sandy beach that ends with the large terminal (harbor) of Bethioua for liquefied natural gas. From this last point the rocky character spreads to the North until the islets of Arzew and extends to the West to Cape Carbon (Hussein, 2015). The continental shelf is very small with a steep slope that is interrupted by numerous rocky bottoms deep and not well suited for trawling activity (Hussein, 2015).

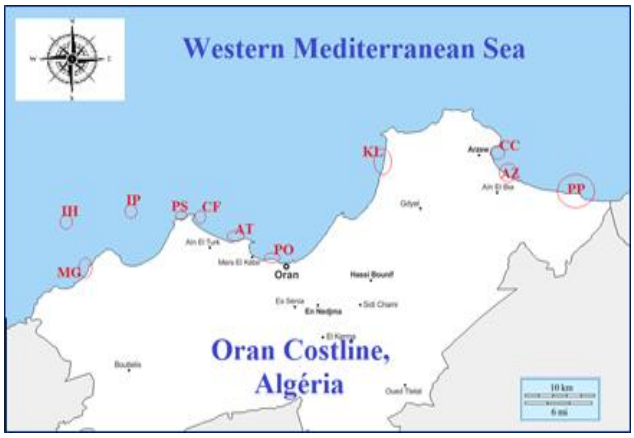

Fig.1. Overview of the coastal and marine environment of Oran coastline and positioning of the sampling stations: 1-Port Au Poules (PP);2-Arzew (AZ) ;3-Cap Carbon (CC) ;4-Kristel (KL) ;5-Oran harbor-Monte cristo (PO) ; 6-Ain Türck (AT); 7-Cape Falcon (CF); 8-Pain Sucre-la Madrague (PS);9- Plane island (IP);10-Madagh (MG) et (IH): 11-Iles Habibas.

Hydrodynamism factors

According to Hydrothermal structures of Western Mediterranean waters and especially Oran coast it appears clear that the cooling of the Atlantic waters at the level of Gibraltar can be incriminated to the brewing of water masses due to the tightening of the Spanish and Algerian

coasts and to the bathymetry which ascents in the Strait. The entry of the Atlantic water flow through the Strait results in the formation of cold water reefs along the Spanish coasts that mix with the Atlantic waters (Millot et al., 2017). This phenomenon is particularly visible in figure 2a (MSG images acquired over the Mediterranean between June and September 2005), the cold waters flowing from the coast of Spain, coming from the Atlantic are deviated to the south-east by the Cape of Gata in the south of Spain to form a beautiful reversed mushroom structure from their encounter with the Moroccan coasts (Taupier-letage, 2008).

a **b**

Fig. 2. Circulation of surface waters and thermodynamics of the Oran coast, North West Algeria, Western Mediterranean (Millot et al., 2017) (adapted).

At the level of Oran, the current of Oran front reflects waters to the west form a second anticyclonic vortex, the eastern Alboran gyre (Hussein, 2015; Hussein and Bouras, 2014) (Fig 2b). In general, these water masses circulations facilitate the biological invasions on Western Algerian waters. These geo-hydro-bathymetric factors in the region considerably accelerate the distribution of non-native species of Atlantic origin in Oran coastline (Hussein and Bensahla Talet, 2019a; Hussein and Bensahla Talet, 2019b).

METHODOLOGY

Oran coastline length is about 124 km which represents 1/10 of Algerian coast. Ten (10) stations were chosen for their ease of access and their environmental characteristics were explored in scuba diving (Fig.1), the work was based on photo-identification (Fig.3) for the invasive species encountered (non-destructive method), between the surface (biological zero) and 30 m of isobaths (photic zone). Since 2004, monitoring was performed and the species identification was done in situ and sometimes from the analysis of video sequences taken during the dives. In total, the study required more than fifty exploratory dives some of which were deep (35m: Plane island, Ain Türk, Cap Carbon) and others were made by snorkeling. The investigation was supported by underwater images (videos and photographs of non-native species) by the transect method according to the protocols of photo-identification Rebent Med, as well as the abiotic parameters (Kantin et al., 2006). The method followed consists in describing the type of substrate and the underwater landscape at the same time, as well as the date and time, usual name of the diving site, location, visibility, water temperature, depth, substrate type and any type of information that may be relevant to the observations (Harmelin-Vivien et al ., 1985).

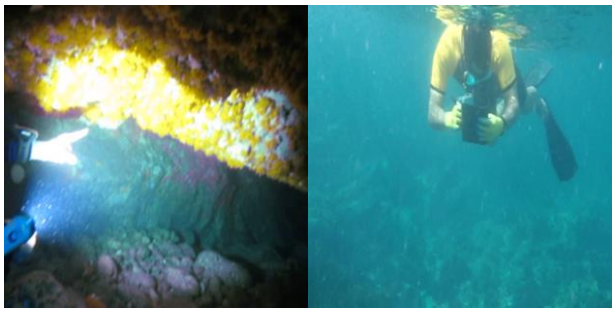

Fig.3. Observation (photography and underwater video) in situ.

The identification and classification of species were done according to FAO species identification sheets, as well as other scientific documents in the field (Boudouresque, 2005; Pergent et al., 2007; Barcelona Convention, 1976). Digital photographs were also taken to facilitate species identification. For species of conservation interest, Annex II and III of the Barcelona Protocol on Specially Protected Areas and Biological Diversity of the Barcelona Convention have been used (Barcelona Convention, 1976). The observations noted in situ and also from underwater photographs analyzed could constitute a basic data to establish a first blacklist of non-native species reported in Oran coast.

RESULTS AND DISCUSSION

Synthesis of in situ surveys and the observations realized allowed us to draw up a list of the different invasive species (EFO) present in Oran coastline. We have inventoried 4 flora species, inventory realized on non-trawable hard and soft substrates at a depth between 0 and 30m. Adding 2 species reported from the bibliography on Oran coast we obtain a blacklist of 6 Macrophytes species cryptogenic or installed (Table 1).

Non-native flora of the Oran coast

The invasive flora frequented Oran coast for a long time that fauna, the totality of the observed floristic species belong to the macroalgae, among which 3 species of Chlorophyceae (*Coduim fragile*, *Ulva lactuca* and *Caulerpa racemose* var *cylinder acea*) and 3 species of Rhodophyceae (*Asparagopsis armata*, *Asparagopsis taxiformis* and *Chondria coerulescens*). All the species encountered are old and their reporting exceeds 20 years of survival. They have adapted perfectly with their new environment, integrating with the different native benthic communities. Their geobathymetric distribution spreads all along the Oran coast, only the caulerpe or sea grape, seems recently introduced (Hussein and Bensahla Talet, 2019a; Hussein and Bensahla Talet, 2019b) and its introduction appears to come from the East coast of Algeria. This presence remains modest for the moment in the form of one or two turfs of 50cm maximum in very limited places. This real and direct threat to the marine coastal ecosystem will, in the very near future, harm this environment already weakened by anthropic actions, which requires priority follow-up with urgent measures to completely eradicate this alga on our coastlines.

Non-native flora species description

Codium fragile (Suringar) (Hariot , 1889). Dead man's fingers or Oyster thief is considered highly invasive. This species native to the Pacific (Japan) was introduced in the Mediterranean in 1940. It frequented the coast of Oran and Algerian between 1985 and 1987 (Verlaque, 1994). This photophilic species is found in the upper infralittoral zone from the surface up to 13 m deep, it is found all along the Oran coast on hard substrate (Hussein, 2015). The species was photographed in 2016 at “Plane Island” (Fig.4) at 35° 46.281'N and 0° 54.11'W.

Caulerpa racemosa var cylindracea (Forsskål J.Agardh, 1873). Caulerpa racemosa var cylindracea is a lessepsian species that by a "step by step" spread in different ports would have

migrated from Australia to the Red Sea and then the Mediterranean in 1990 via the Suez Canal. Called also sea grapes frequented the Algerian coast from the East then the center (Ould-Ahmed and Meinesz, 2007), and then invaded Oran coast where it was first reported in 2012 at Cape Carbon at 0.2m (East coast of Oran) (Hussein and Bensahla Talet, 2019a; Hussein and Bensahla Talet, 2019b). Figure 4 was photographed in 2014 at Cape Falcon at 35° 46 '16.47 N and 0° 47' 33.68 W (West coast of Oran).

Asparagopsis armata (Harvey 1855). The harpoon alga is native to New Zealand and Australia; shortly before the discovery of gametophytes in 1925 (Sauvageau, 1925a; Sauvageau, 1925b). Almost simultaneously, the latter appeared in Algeria in 1923 (Sauvageau, 1925b), then in the Eastern Pyrenees, in Banyuls, in 1926 (Hamel, 1926). This species inhabits the infralittoral stage on hard substrate and often very epiphyteal. Generally, it has been found in the majority of the studied stations to a maximum depth of 27 m in Oran coastline, it was photographed in the same place with Asparagopsis taxiformis at "pain sucre" (la madrague) in 2015 at 350 37 '952 N 'and 000 104' 243 " W (Hussein, 2015) (Fig. 5).

Asparagopsis taxiformis (Delile) (Trevisan de Saint-Léon, 1845). According to Verlaque (1994) (Oceanology Center of Marseille-DIMAR), the species is present in Habibas Islands and is an introduced form coming from Australia and not the Atlantean-Mediterranean form. But it appears to be well integrated in the subtidal coral community up to the upper coralligenous level and is a major feature of the landscape (Dixon, 1964; Grimes, 2000). It also coexists in some places with *Asparagopsis armata*, but this one is more abundant (Hussein, 2015) (Fig.6).

Fig.4.Coduim fragile (2016).

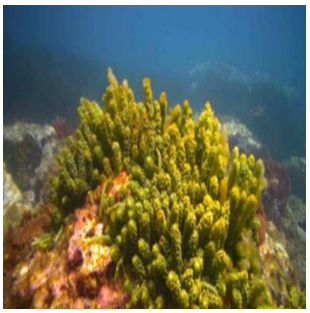

Fig.5.Caulerpa racemosa var cylindracea (2014).

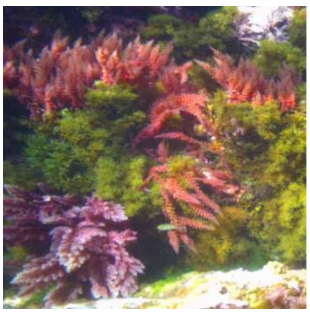

Fig.6. Asparagopsis armata (lower left) and Asparagopsis taxiformis (upper and lower right) (2015).

Black list of invasive species of Oran coast (EFO)

Six exotic species, listed in the black list of invasive, cryptogenic species of flora have established themselves on the Oran coast (Table 1).

Table 1.Black list of Alien marine species introduced in Oran coastline based on *in situ* data and bibliography of signalization with geographic coordinates, origin, locality, year and author of first sighting.

Species	YFRA	Coordinates	Org	Locality	Authors	Success
Ulva lactuca (Linnaeus 1758)	Since 1834	36.773393°; 3.114887°*	IP	Algeria	Steinheil 1834 Montagne, 1846 As U. fasciata	Cas
Caulerpa racemosa (ForsskålJ.Agardh 1873)	Between 2010-2013	35.920824°; -0.340679°*	IP	Cap Carbon	Hussein, 2015	Inv
Coduim fragile (Suringar) Hariot , 1889	Between 1985 et 1987	35.748383°; -0.613843°*	NW. P	Oran Bay	Verlaque, 1994 (	Est
Asparagopsis armata (Harvey 1855)	Since 1923	35.748383°; -0.613843°*	SW. P	NIA	Sauvageau, 1925 a	Est
Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon, 1845	Since1939	35.748383°; -0.613843°*	At-IP	NIA	Verlaque, 1994 (	Inv
Chondria coerulescens (J. Agardh) Falkenberg	Since 1893	NIA	At.E	Oran costline	Debray, 1893	Est

*(Abbreviations: YFRA: Year of first record in Algeria, Org:origine; IP: Indo Pacific; P: Pacific; I: Indian Ocean; RS: Red Sea; At: Atlantic; Tr: Tropical; Circ: Circumtropical; Est: Established; Ques: Questionable; Cas: Casual; Inv: Invasive; E: East; W: West; N: North; S: South ; NIA: Non identified Area; * : First signaling).*

They have been reported along the coast of Oran during the last twenty years, this is due to several natural and anthropogenic factors, as well as the geographical location and underwater topography of the region, favoring a great hydrodynamism, facilitating the propagation and the installation of several non-native species.

Origins and pathways of EFO of Oran

In figure 7 each invasive plant is represented with its probable region of origin. In fact, compiled a list of the likely vectors of introduction of flora and fauna from which we have been inspired (Zibrowius, 1991):

- Maritime traffic and "offshore" activities, either on the hulls of ships, on towed structures (fouling or fouling), or in water for ancient times, on sand and rocks used as ballast;
- The Suez Canal;
-Importation for breeding or cultivation purposes;
-Accidental transport during previous imports;
- The rejection of living organisms imported for other purposes (consumption, bait, packaging, scientific research, aquariums). These anthropogenic vectors are responsible and contribute to the biological pollution and the imbalance of the ecosystems as well as the depletion of their renewable resources.

The lessepsian species recorded at Oran coasts seems to be less represented than those from Atlantic origin (Herculean species), the origin of the exotic species on the black list of the region differs according to the probable origin of the species. EFO seems strongly influenced by Gibraltar strait active hydro dynamism. In fact, we can note four Atlantic alien species coming from the Atlantic Ocean using straight currents as main access way against only two lessepsian species coming from the Red Sea via Suez Canal (Fig.7).

Fig.7. Pathway and origin of the invasive species of Oran.

CONCLUSION

Six EFO or invasive plants species have been recorded during the last 15 years. The reports have been based on bibliographic research, diving exploration and in situ research of non-indigenous species between 0 and 30m depth, along the 124 km of the Oran coast. 3 Chlorophyceae and 3 Rhodophyceae were reported with 4 Atlantic alien species and 2 lessepsian species (red Sea). This EFO black list of non-native flora species, which have invaded Oran coasts in recent years, must be completed by work on the 14 coastal wilayas (province) in order to draw up a national blacklist or EFFO (Exotic Flora and Fauna of Oran) black list, and this for contributing to a national and Mediterranean strategy for monitoring and managing non-native species that threaten the marine coastal environment, resources and users.

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