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ARTICLE

# Status stock and Sustainable Management Measures for Moroccan Sardines

**Abdelaziz Mounir[1,2*] Mohammed Znari[1,2] Hayat Elmghazl[1,2] Hassan Alahyane[3] Noreddine chouikh[4] Nawal Hichami[5]**

1. Laboratory of Water, Biodiversity & climate change, Department of Biology, Faculty of Sciences, Semlalia, Cadi Ayyad University, Marrakech, 40000, Morocco
2. The Natural History Museum of Marrakech, Research Centre on Biodiversity, Cadi Ayyad University, Bd Allal El Fassi, Marrakech, Morocco
3. Laboratory of Molecular and Ecophysiology Modelling, Faculty of Sciences Semlalia, University Cadi Ayyad, Marrakech, 40000, Morocco
4. Laboratory of Aliments, Environnement and health, Faculty of Sciences and Techniques, University Cadi Ayyad, Marrakech, Morocco
5. Laboratory of Biotechnology & sustainable development of Natural Ressources, Polydisciplinary faculty of Beni Mellal, Sultan Moulay Slimane University, Mghila, Beni Mellal, 23000, Morocco

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ABSTRACT

This article summarizes the state of stocks of sardine, *sardina pilchardus* in Moroccan waters at the end of 2016 and 2018. These stocks varies according to the region,They are now in a sustainable exploitation situation: Atlantic sardine, but also stocks that have reached or are still in over-exploitation levels: Mediterranean sardine. The fishing pressure exerted on the sardine stock exceeds the optimal level by 40%. Due to the degradation of the fragile marine environment of the Mediterranean region, generated by pollution of various origins, the overexploitation of juveniles in the coastal strip, non-responsible practices and the use of non-fishing gear selective, it is imperative to take the necessary measures to protect the marine environment and ensure rational and sustainable exploitation of the resource. (High commission plan 2006 report).

## 1. Introduction

The northwest African upwelling system of Morocco, is the most productive in the world, in terms of primary productivity. This productivity results in large fish biomass mainly dominated by small pelagic fish, which are the main exploited living resources of the region. In a context of shared management by several countries of the region's fishery resources, understanding the factors that control the spatial distribution of small pelagic popula-

**Corresponding Author:*
*Abdelaziz Mounir,*
*Laboratory of Water, Biodiversity & climate change, Department of Biology, Faculty of Sciences, Semlalia, Cadi Ayyad University, Marrakech, 40000, Morocco; The Natural History Museum of Marrakech, Research Centre on Biodiversity, Cadi Ayyad University, Bd Allal El Fassi, Marrakech, Morocco;*
*Email: mnraziz1980@gmail.com*

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tions and the evolution of their abundance is crucial for fisheries and the region's socio-economic development.

Morocco has two maritime frontages of approximately 3,500 km of coastline, supported by an Exclusive Economic Zone1 (EEZ) of 200 nautical miles in the Atlantic. These advantages, combined with the existence of a upwelling2 zone, considered among the most important in the world, make the Moroccan coast one of the most fish-rich zones, with an annual production potential that exceeds 1.5 million tons of fish. A relatively large specific diversity characterizes this reservoir of fishery wealth. The fishing sector represents between 2% and 3% of gross domestic product (GDP) and generates around 170,000 direct jobs and 500,000 other indirect ones while providing sources of income for around 3 million people [1]. In 2015, national fishery production exceeded 1.35 million tons (worth 10.8 billion dirhams), mainly small pelagic (84% in volume and 25% in value). Thanks to this production, Morocco ranks 17th among producer countries (capture fishing) and first on the African continent [2]. This production is mainly generated by a fishing fleet of coastal and artisanal vessels (56% in volume; 54% in value) and deep-sea vessels (34% in volume; 44% in value). However, despite the importance of national fishery production, Moroccans' consumption of fishery products remains limited to levels below the world average (13.3 kg/inhabitant against 19.3 kg/inhabitant on the scale in 2012). Morocco has set itself the strategic objective, within the "Halieutis" Plan framework, of bringing this average to 16 kg/inhabitant/year around 2020. Starting from producers' objective aiming to maximize their income and facing demand for fishery products that continues to grow, especially in a context of increasingly imposed globalization, the fishery sector has become particularly dependent on the rest of the world and other sectors of the economy. This strong dependence on the rest of the world places the fishing sector in a situation of vulnerability in the face of various hazards in the international economic environment.

The availability of fishery resources is one of the factors driving the dynamics of the fishery production system. This resource is dynamic in nature and constantly interacts with the bio-physicochemical system, characterizing its natural environment and the socio-economic and regulatory subsystems in which fishing activities are carried out. If the socio-economic conditions are favorable, the abundance of the exploited resource can potentially lead to fishing efforts. On the other hand, the increase in the latter beyond biologically sustainable limits can ultimately lead to a decrease in the availability of resources, thus affecting the balance between supply, demand and price of fish.

The sustainability of fishery resources will only be ensured through management systems that can adapt fishing pressure to the optimal level of stocks. The main control variable for this is fishing effort. The context and fishery issues have changed a lot, going from questions of prospecting and development of new fisheries to issues of biodiversity conservation, conservation in the face of over-exploitation, development, understanding of the effects of climate change or security marine

## 2. Fluctuations in Small Pelagic

The environnemet factors influence the distribution and fisheries abundance. This is the case for small pelagic fish, which are essential elements of marine ecosystems due to their intermediate food web position and large biomass. In upwelling ecosystems, the total biomass of fish is generally dominated by small pelagic, often a species of anchovy and/or a species of sardine or sardinella. We speak of ecosystems structured in "wasp-waist" [3,4], because of the small number of small pelagic species that constitute this intermediate trophic level. In this case, control of the trophic chain would be carried out by the intermediate link, the small pelagic. Thus, this intermediate-level will play a central role in the structure and the dynamics of the ecosystem, both by "top-down" type control (control of upper predators on the lower trophic links) on the plankton which it feeds and by bottom-up control on the many marine predators that consume them" [5]. Fluctuations in the abundance of pelagic fish stocks reflect significant changes in structure and functioning in upwelling ecosystems. Significant mortalities have been observed at higher trophic levels (birds, marine mammals, large predatory fish) in response to the decrease in the abundance of their prey.

Pelagic resources consist mainly of sardines, mackerel, anchovies, horse mackerel and tuna. These highly displaced and unstable resources experience more or less significant fluctuations in their abundance and distribution. The southern area of the Kingdom has known, in recent years, variations in their abundance and their composition by species.

Studying the effects of environmental change on fish populations, especially sardines, is complicated because environmental factors can affect various processes at different levels of biological organization" [6-9]. Fish has complex life cycles, including several different life stages (egg, larva, juvenile and adult), each of which can be affected in different ways by environmental changes. In fish populations, changes induced by changes in the environment

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can result from four mechanisms, often linked together: (i) a physiological response to changes in environmental parameters, such as temperature, (ii) a response behavioral, for example, by avoiding unfavorable conditions and displacement to new more favorable habitats, (iii) population dynamics, resulting from changes in the balance between mortality, growth and reproduction rates, (iv) productivity changes and/or trophic interactions in the ecosystem. In addition, (v) commercial exploitation greatly affects the abundance and distribution of fish and can interact with the effects of environmental change.

## 3. Sardines are an Important but Unstable Resource

World production of small pelagic represents around 39 million tons, or more than a third of the catches total, making small pelagic the most fished species group in the world (FAO). Over the past 60 years, catches have largely evolved according to variations in the resource. Small pelagic constitute the largest group of species targeted by the "milling fishery," whose catches are intended to manufacture fish meal and fish oils, mainly consumed by the aquaculture sector. With the development of intensive aquaculture to meet ever-increasing needs, small pelagic are diverted from their primary vocation to feed the poorest populations directly. In many countries of the world, and particularly in developing countries, small pelagic are an important source of protein and nutrients at affordable prices. These small pelagic fish thus occupy an important weight in the food and the world economy.

Instability is one of the major characteristics of small pelagic resources. Significant changes (by a factor of 1000) in abundance over a few decades are characteristic in small pelagic. Long-term alternations of dominant species are observed in most upwelling ecosystems, such as the alternation between sardines and anchovies in the Humboldt, Benguela and Kuroshio currents off Japan" [10]. The scientific community widely accepts that this high variability is caused by the synergy of different factors, including main overfishing and environmental conditions. The biological characteristics of small pelagic (short lifespan, high fertility, high natural mortality rate, dependence of plankton for their food) make them very sensitive to environmental forcing" [11,12]. In addition, because they are very mobile and good swimmers, pelagic fish can react quickly to changes in their environment. Small pelagic have a so-called "r" reproduction strategy (favoring a high growth rate) and can potentially double their populations within a few months, the age of first reproduction generally being between 6 and 18 months" [13]. Finally, their gregarious behavior facilitates their detection, and their catches contribute to their variability in abundance. Also, several stocks of small pelagic have suffered historical collapses, such as anchovies in Peru in 1972, sardines in South Africa between 1965 - 1966 " [14] and in Namibia between 1970 - 1971" [15].

The small pelagic resources, consisting of fish species on the surface or between the two water's layers (Sardine, Mackerel, Horse mackerel, Anchovies and sardinella), represent the main fishery potential of the Moroccan EEZ. Small pelagic fishing occupies an important place in the fishing sector in Morocco due to the size and the dynamism of the fleet which practices it, the quantities sold in the various sectors supplied with the products of this fishing and the number of 'direct and indirect jobs generated. Fishing for small pelagic extends across the entire Moroccan, Atlantic and Mediterranean continental shelf. The national fleet mainly leads it from different ports in the Kingdom and a foreign fleet operating under charter or fishing agreements. The fishery for small pelagic has developed along the Moroccan Mediterranean and Atlantic coast with a historic shift in the fishing area to the south at the Atlantic coast. Indeed, after exploitation of the northern sardine stock (Tangier-El Jadida) during the 1930s, fishing developed further south and the port of Safi became the first sardinian port during the 1970s. Then, 80, with the opening of Tan-Tan, Laâyoune and that of Tarfaya, the fishery moved further south, making the Sidi Ifni - Cap Boujdour area (area B) the main area of activity of the Moroccan sardine fleet. This development was reflected, notably from the 1990s, by a change in the evolution of landings, with a decrease in sardine catches in the North zone and the Safi-Sidi Ifni zone (zone A) and a continuous increase in sardine catch in zone B. The increase in sardine catches in zone B was accompanied by a change in the destination of production; the by-product industry absorbed the large share of landings, intended before the 1990s mainly for canned.

South of Cap Boujdour (zone C), an area historically exploited by a foreign fleet, the national small pelagic fishery began during the 1980s, with large-scale purse seiners (Thona type fishing) and from the 1990s with a coastal sardine fleet. This development of activity in zone C is supported by the opening of the port of Dakhla in 2001 and by the arrival of modern vessels which have added to the traditional purse seiners and have supported the development of the freezing sector. In addition, authorizations to charter foreign vessels (freezer pelagic trawlers, purse seiners and pelagic trawlers RSW type) were granted, from 1997 to operators of the Dakhla and Laayoune oc-

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topus freezing sector, as part of the program assistance in the conversion of excess processing overcapacity in this sector and also in the context of the development of the national small pelagic fishery in this area. Artisanal fishing activity has also emerged since 2008; this fishing is practiced by boats that operate from fishing sites in the region on mackerel, generally during the closed periods of octopus fishing.

Potentials currently offered for small pelagic species are available in the area south of Cap Bojdour and are variable depending on stocks. Certain populations (sardinella, mackerel, horse mackerel) form part of the straddling stocks exploited in the Moroccan EEZ and in the EEZs of the other countries of the Northwest African region. Sardines remain the dominant species in Morocco, while the availability of other species varies from one area to another and from year to year.

### Sardine, the dominant pelagic species in upwelling ecosystems

The Moroccan Atlantic ecosystems are characterized by upwelling that promotes nutrient enrichment of the coastal strip, making these ecosystems very productive areas that support the most abundant fisheries in the world. In fact, despite a relatively modest area of less than 3% of the surface of the oceans, these regions concentrate a significant part of the fishing volume, representing 40% of the world catches of marine species" [5,10]. However, these upwelling ecosystems are very dynamic and show high variability at all spatial and temporal scales. Small pelagic fish are dominant in biomass in these ecosystems, mainly sardine and anchovy species, whose population dynamics are often linked to the very high physical variability of upwelling. Understanding the mechanisms linking environmental fluctuations to the recruitment of these species is one of the major challenges for fisheries in these regions.

A striking example is the large-scale fluctuations in sardines and anchovies observed in the main upwelling zones of the world" [16-18]. When one species has high biomass, the other species have relatively low biomass and vice versa. Changes in species biomass are generally accompanied by an expansion and/or contraction of their distribution areas" [19,20]. However, there is no general theory yet, shifts in ecosystem shifts [21]. That has occurred in response to climate change have been suggested as the main cause of fluctuations in sardines and anchovies" [22,23]. Many studies have suggested that these regime changes are associated with structural changes in the ecosystem (temperature, wind, upwelling but also the size of plankton particles), leading to favorable environmental conditions for a species rather than '' another" [18,19,24]. This is the case for the Peruvian anchovy (Engraulisringens), characterized in the 1960s by very large landings reaching 13 million tons in 1970, which collapsed during the 1970s and 1980s. Since the early 1990s, landings of anchovies from Peru have resumed and have hovered around 7 million tonnes, with a drop observed in recent years. In parallel, catches of Chilean sardinops (Sardinopssagax) have exploded in 15 years (1978-1992), reaching 10 million tons per year. Since 1992, landings have almost disappeared" [25]. The causes of large variations in the biomass of small pelagic fish, whether mainly due to natural variability (due to environmental changes and/or interactions between species), exploitation, or both, are still long-discussed [10,20].

## 4. Canary Upwelling

The Canary Islands' upwelling is located along the northwest coast of Africa, from Gibraltar (36°N) to southern Senegal (10°N) and runs along the coasts of Morocco, Mauritania, Gambia and Senegal. It results in a general surface current running along the coast from north to south. In this region, three upwelling zones have been described [26,27]. Upwelling has a strong seasonality between 11 ° N and 21 ° N and between 26 ° N and 35 ° N, and remains intense all year round between 20 ° N and 26 ° N. At high latitudes (26 ° N-35 ° N), the intensity of upwelling is low and intensifies in summer and autumn and weakens in winter and spring. At low latitudes (11 ° N-21 ° N), it disappears completely during the summer months. The distribution of water bodies in the region has been summarized by Barton et al [28]. From a biogeographic point of view, the area can be divided into two main areas: to the north, the southeastern limit of the North Atlantic subtropical gyre (NACW) and to the south, the north of the northeast tropical Atlantic gyre (SACW). The area includes part of the eastern edge of the subtropical gyre with the Azores Current (AC, for Azores Current) whose southern branch feeds the Canary Current (CC, for Canary Current), which flows along the African coasts. Arrived at the Cap Blanc level (21°N), the CC branches off to the east to form the Courant Nord Equatorial (NEC, for North Equatorial Current). South of Cap Blanc, we find the North Equatorial Counter Current (NECC) [29,30]. The two current systems in the region carry the water of very different temperatures. A frontal zone at their meeting point separates them with a strong thermal gradient [31]. This front is located at Cap Blanc in the hot season and at Cap Roxo in the cold season.

The coastline of the northwest African system is characterized by a succession of capes (Cape Ghir (31 ° N),

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Cape Yubi (28 ° N), Cape Bojador (26 ° N), Cap Blanc (21 ° N) and Cape Verde (15 ° N) and bays. The continental shelf is generally wide (50 km) compared to other large upwelling systems, reaching 150 km in the central part, around 25 ° N offshore Western Sahara [32]. Two groups of islands are found off the coast, the Canary Islands at 27 ° - 29 ° N and the Cape Verde islands at 14 ° - 18 ° N. The coasts senegalo-mauritaniennes are appreciably oriented in the meridian direction; the transport of Ekman to the broad one is produced there by the trade winds of north, northeast and northwest having a component parallel to the coast. These winds prevail in the region in winter and spring and are responsible for a vertical supply of nutrient-rich waters by virtue of the principle of mass conservation [33]. The movement of the Intertropical Convergence Zone (ITCZ) causes a clear alternation between a dry season which generally extends from November to May and a wet season from June to October. During the dry season, corresponding to winter in the northern hemisphere, the ITCZ reaches its southernmost position, while it oscillates north during the wet season - boreal summer. This area is characterized by high spatial and seasonal variability in sea surface temperatures (SST) and primary productivity. The southern part of the area is characterized by warmer and richer Chlorophyll-a waters than the northern part. Seasonal variations are also very marked. The temperature can vary from 16-18 °C in February-March (cold season) to 30 °C in July-October (hot season). Strong latitudinal temperature gradients exist in the region with a larger and narrower temperature change between 20 ° -22 ° N. These latitudinal variations in temperature depending on heat exchanges with the atmosphere and the intensity of the upwelling. The NW African ecosystem's nutrients distribution is typical of a coastal upwelling zone where cold waters rich in nutritive salts are advected in the euphotic layer where primary production develops. The fertilization mechanisms of the marine environment change according to the season and the region depending on the situation of the climatic action centers and the morphology of the underwater coast [34]. The two main bodies of water (NACW and SACW) have different nutrient contents. A significant southern-north gradient is observed with waters clearly richer in nutrients in the south [35]. In the North West African upwelling system, it is recognized that there are two types or phases of organic production: a so-called "balanced" phase where the phytoplankton and zooplankton peaks are simultaneous, and another so-called "unbalanced" phase where these two peaks are offset in time (the zoo succeeds - to the phyto) [34] and this has significant impacts on the productivity of the region. South of Cap Blanc, seasonal maximums of phytoplankton and zooplankton are in phase [36,37]. Further north and especially in Morocco, there is a significant gap between the development of phytoplankton which takes place in summer during the upwelling and that of zooplankton which is maximum in autumn or winter [38]. The NW African upwelling system is the most productive in terms of primary production of the four EBUS (> 5 gC $m^2$ $d^{-1}$ and> 10 mg $m^{-3}$ of Chl-a) [29,39]. This high productivity supports a wide variety of pelagic fish species.

## 5. Operating Modes

### Fishing fleet

The exploitation of small pelagic resources in the Moroccan EEZ is carried out by three main types of means of production, which operate under different regimes legal access to the resource (fishing license and fishing agreement). These fleets differ according to their size and their fishing strategies.

The coastal fleet operates along the Atlantic and Mediterranean coast and is made up of: • Moroccan coastal purse seiners with a gross tonnage ranging from 50 tons (tx) to 130 tons and a variant power between 300 hp and 550 hp. The gear used is the purse seine, the characteristics of which vary according to the size of the fishing units, the fishing area and the size of the catch. The length varies between 350 and 460 fathoms and the fall between 40 and 60 fathoms. The bulk storage system in the holds, traditionally used in the Atlantic, has been gradually replaced by the use of plastic boxes for handling small pelagicin order to control the quantities caught and promote their quality. This system is almost generalized in the main ports (a limited percentage of bulk is still admitted, ie 30% at the level of the southern ports). • Spanish coastal purse seiners classified in the "artisanal pelagic fishing" section at the level of the 2014-2018 protocol of the Morocco-European Union fishing agreement. These vessels are authorized to fish beyond 2 nautical miles calculated from the baseline. Their fishing area is limited to the south by the parallel 34 ° 18'N. Fishing units with the possibility of fishing are of a tonnage less than 100 tx and use the purse seine as fishing gear. This fleet, which used to target anchovy (Engraulisencrasicolus) in the past, has now directed its effort towards fishing for sardines (Sardina pilchardus). An extension of the fishing zone to the south, up to parallel 33 ° 25'00''N is planned for 5 purse seiners. This measure is subject to regular evaluation in order to examine the possible interactions between the European Union fleet and the Moroccan fleets. 3.1.2 The offshore

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fleet This fleet operates south of Cap Boujdor and is made up of: • Pelagic trawlers Type RSW, flying the Moroccan flag, equipped with a conservation system on board type RSW (Refregerated Sea Water). The average Gross Tonnage (GRT) is 762 tons and the average engine power is 2524 hp. These trawlers are authorized to fish between Cap Boujdor and Cap Blanc (26 ° 07'N- 20 ° 46'N), beyond 8 nautical miles calculated from the baseline. The fishing gear used is the pelagic or semi-pelagic trawl, the size of the smallest mesh of which must be equal to or greater than 40 mm of stretched mesh. These trawlers operate under an individual quota system per boat. • Russian freezer pelagic trawlers with an on-board freezing system and devices for processing and processing fish into flour. They operate under the Morocco Russia fishing agreement. Russian trawlers have an average capacity of 6,334 tons and an average engine power of 6,515 hp. Resources and Fisheries for Small Pelagictock and Moroccan Fisheries Report 2016 30 • European pelagic trawlers: classified under the heading "industrial pelagic fishing" at the level of the 2014-2018 protocol of the Morocco-EU fisheries agreement. The gear used is the pelagic trawl, the mesh of the pocket of which is fixed at 40 mm targeting small pelagic, sardines and sardinella, as well as horse mackerel and mackerel. The units authorized to fish are of three categories: vessels of a tonnage greater than or equal to 3000 Gross tonnage (GT), vessels of a tonnage less than or equal to 3000 GT greater than or equal to 150 GT and vessels of '' a gauge of less than 150 GT. The accessible fishing area is located south of parallel 29 ° N These freezer trawlers should operate beyond 15 nautical miles calculated from the baseline. Concerning fresh fishing trawlers, they can exercise their activity up to 8 nautical miles from the baseline. These pelagic trawlers have an average capacity of 6,560 GT and an average driving power of 5,220 KW.

The artisanal fleet This fleet operates between Saidia and Boujdor. It is made up of small boats whose gross tonnage generally exceeds 2 tx for the majority while it can reach 8 tx in certain regions. This artisanal fleet is targeting small pelagic has constantly been developing in recent years. In fact, by the end of 2014, approximately 2,000 boats employing more than 10,340 fishermen had practiced the fishing activity for small pelagiceasonally or permanently. The majority were identified in the central area between Safi and Boujdor. In the Mediterranean zone, two regions are distinct according to the type of fishing unit used and the fishing methods for small pelagic:

- Eastern Mediterranean: the small seine is used by boats operating at night and essentially targeting the sardines and horse mackerel. The fishing operation is done by means of two units: (1) the active boat (Mampara) having the design of a large boat (5 to 7m) decked with inboard engines from 60 to 120 CV, (2) the boat au feu (lamparo) is used to attract pelagic fish by the light of lamps. Fish gather near the boat before surrounding them with the purse seine. There are two types of lamparo, electric and gas.
- Western Mediterranean: the small seine is used by fishing units locally called "Chebbaks". The fishing unit is composed of three boats: (1) the boat whose length can reach up to 9 m and a maximum tonnage of 5 GRT, (2) the fireboat (lamparo) and (3) a small rowboat to hold the front of the seine. • Atlantic: in the Atlantic zone, the small seine is used by boats, particularly at the level of the ports because of the existence of a port infrastructure favoring safe exits and returns, but also with the availability and the ease of fuel and ice supply. Fishing is practiced by a single boat in the entire region north of Safi and by two to three boats in the Resources and Fisheries of Small Pelagictate of stocks and Moroccan Fisheries 2016, 31 regions south of Safi. The period of use of the small seine varies from one port to another. It is dependent on the climatic conditions and the availability of the caught product. The small seine called "Swilka" has a length that varies from 60 to 350 fathoms and a width of 8 to 50 fathoms. The stretched mesh of the net is 9 mm. Fishing activities generally take place near the coast at depths between 10 and 50 fathoms.

## 6. Conclusions

The sardine stocks located along the Moroccan Atlantic coast live and breed in seasonal or permanent upwelling areas. Upwelling is by its very nature a dispersive, fluctuating process that varies widely from year to year, from area to season and from season to season. For sardines, it seems difficult to satisfy the retention constraint, which is an important process conditioning the existence and long-term maintenance of a population in a given environment [40]. Sardines are, however, capable of developing huge biomass. This is the result of an adaptation of the reproductive strategies to the environmental characteristics of the upwellings in order to offer optimal conditions for the development of the larvae. In the central zone (28-32 ° N) of the Atlantic coast of Morocco, the main spawning season is offset from the upwelling season.

In short, a responsible attitude towards this resource requires the conservation not only of specific diversity but

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also that of the entire genetic heritage. Therefore, responsible management must have as a preliminary stage the definition of management units that necessarily involve identifying population units constituting a stand, particularly when it comes to small pelagic known for their instability as well in time than in space. Therefore, the need to improve scientific knowledge on the biology of the species (area and spawning period, diet, stock unit, etc.), on migration, and the conditions of its exploitation s' is gradually imposed.

The importance of respecting the biological rest period of the agarophyte G. sesquipedale which provides economic benefits for rural communities along the coasts where the algae form important deposits; - Adopting responsible behavior in harvesting and encouraging the uprooting of gelidium thalli whose size is greater than 10 cm. Indeed, a thallus that does double weighs twice as much and contains more agar; - Respect for the ecosystem including not only marine plants but also other forms of marine life; - Raising the awareness of divers as to the danger which threatens the resource if the rocky substrate is destroyed or degraded, it represents the support and the point of fixation of the algae.

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