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EXPANSION OF THE INVASIVE ALGAE *CAULERPA RACEMOSA* VAR. *CYLINDRACEA* (SONDER) VERLAQUE, HUISMAN & BOUDOURESQUE, 2003 ON THE REGION OF VALENCIA SEABED

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Key words: *Caulerpa racemosa*, invasive algae, expansion, Region of Valencia, Spain, Mediterranean.

ABSTRACT

The present study contains the results gathered from the programme monitoring the implantation of invasive species of algae in the Region of Valencia. The programme has been in operation since 1993 and consists of an annual inspection at 40 points considered to be at most risk along the coast, as well as responding to warnings given by entities and individuals. The programme was initially designed to detect the presence of *Caulerpa taxifolia* (Vahl) C.Agardh 1817, which has not been detected during any of the inspections carried out in the last 15 years. However, *C. racemosa* var. cylindracea (Sonder) Verlaque, Huisman & Boudouresque, 2003 was detected in 1999, more specifically on the approaches to the Port of Castellón de La Plana and since then it has expanded exponentially and is now present along the coast of all three Valencian provinces, with the area colonised being estimated at 168 Km^2 in late 2008. The programme has also detected the presence of other invasive species of algae, namely *Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon, 1845 and *Lophocladia lallemandii* (Montagne) F. Schmitz, 1893, currently present exclusively in the Islas Columbretes archipelago.

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INTRODUCTION

Of the more than 70 known species of the genus *Caulerpa*, only a small number are present in the Mediterranean. *Caulerpa taxifolia* (Vahl) C.Agardh, 1817 is a tropical species that was first seen in the Mediterranean in Monaco in 1984. Since then it has propagated and covered large areas of the Western and Adriatic areas of the Mediterranean, mainly on the French Cote D'Azur, Monaco and Italy, although colonies have also been detected in Spain (Balearic Islands), Croatia and Tunisia. Since its appearance, the species has expanded rapidly, with the areas occupied multiplying 3 to 10 times a year (Boudouresque, *et al*., 1996). *C. taxifolia* is a highly invasive species and has become a serious threat to most Mediterranean marine algae and phanerogamae (Meinesz & Hesse, 1991; Villele & Verlaque, 1994, Verlaque & Frytaire,

Figure 1:
Monitoring stations in the Region of Valencia.

1994). Highly diverse ecosystems in the invaded areas have been replaced by monospecific populations of *C. taxifolia* (De Torres *et al*., 1996). The significant capacity of the species for expansion, either naturally or due to human activities (Meinesz & Hesse, 1991; Meinesz *et al*., 1993), as well as the cost of eradication (Avon *et al*., 1994; Escoubet & Brun, 1994; Riera *et al*., 1994) make the early detection of new colonies essential, as this is currently the best way of slowing the expansion of *C. taxifolia* in the Mediterranean.

In this sense and after the location in 1991 of a colony of *Caulerpa taxifolia* at Saint-Cyprien (France), very close to the border with Spain, the *Direcció General de Qualitat Ambiental* (Department of the Environment of the Regional Valencian Government) started a programme to monitor the coasts of the Region of Valencia to detect the presence or possible implantation of *Caulerpa taxifolia*. The programme was in force from 1993-1994 and 1996-1998 within the framework of the European Commission LIFE

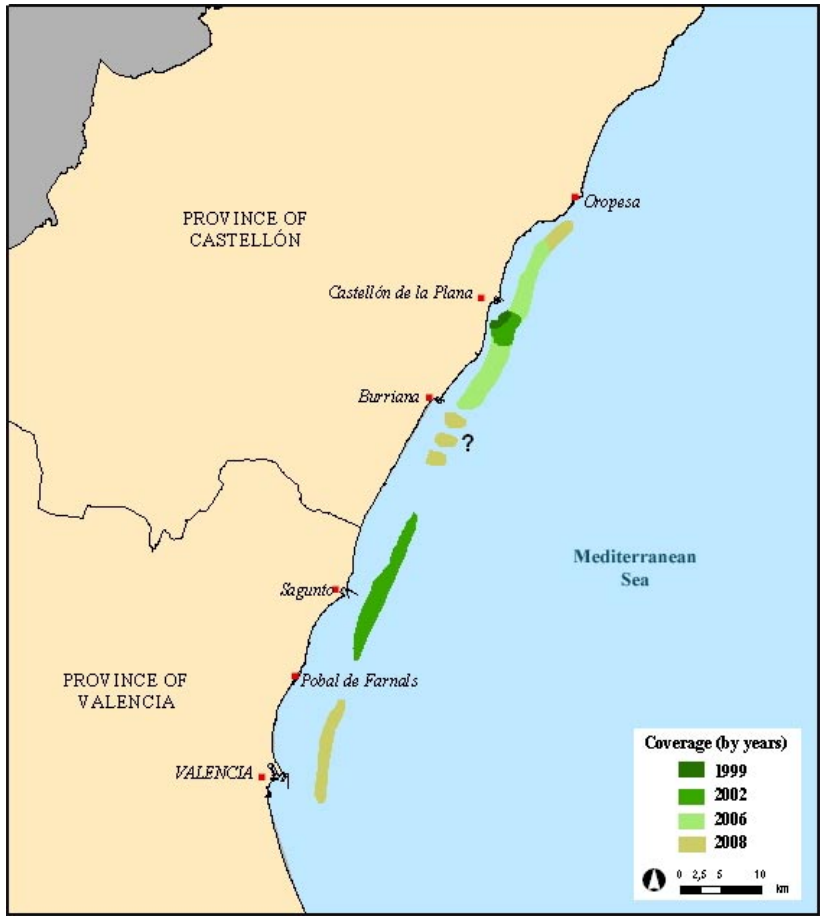

Figure 2:
Presence of Caulerpa racemosa in the coasts of Castellón and Valencia.

programmes. Since then, the Region of Valencia Government has remained vigilant and the sale, distribution and commercialisation of algae have been prohibited in the Region of Valencia since May 1994 in order to prevent and reduce the risk of introducing *C. taxifolia* (Region of Valencia Government Decree 89/1994, dated May 10th).

At the same time, another species of the genus *Caulerpa*, *C. racemosa*, is also spreading in many parts of the Mediterranean even faster than *C. taxifolia*. Although *C. racemosa* has not been as widely studied as *Caulerpa taxifolia*, the meeting in Heraklion (Crete) on invasive species of *Caulerpa* in the Mediterranean (Report UNEP(OCA)/MED WG. 139/4 dated March 20th 1998) concluded that the strain of *C. racemosa* that is currently colonising the Mediterranean could show morphological characteristics that differ from one zone to another as well as the specimens described in the same region at the beginning of the century. A molecular study confirmed the hybrid origin of this species (Durand *et al*., 2002), initially originating from Southwest Australia (*C. cylindracea*) (Harvey, 1858; Womersley, 1984), recognising this taxon as *C. racemosa* var. *Cylindracea* (Verlaque *et al*., 2003).

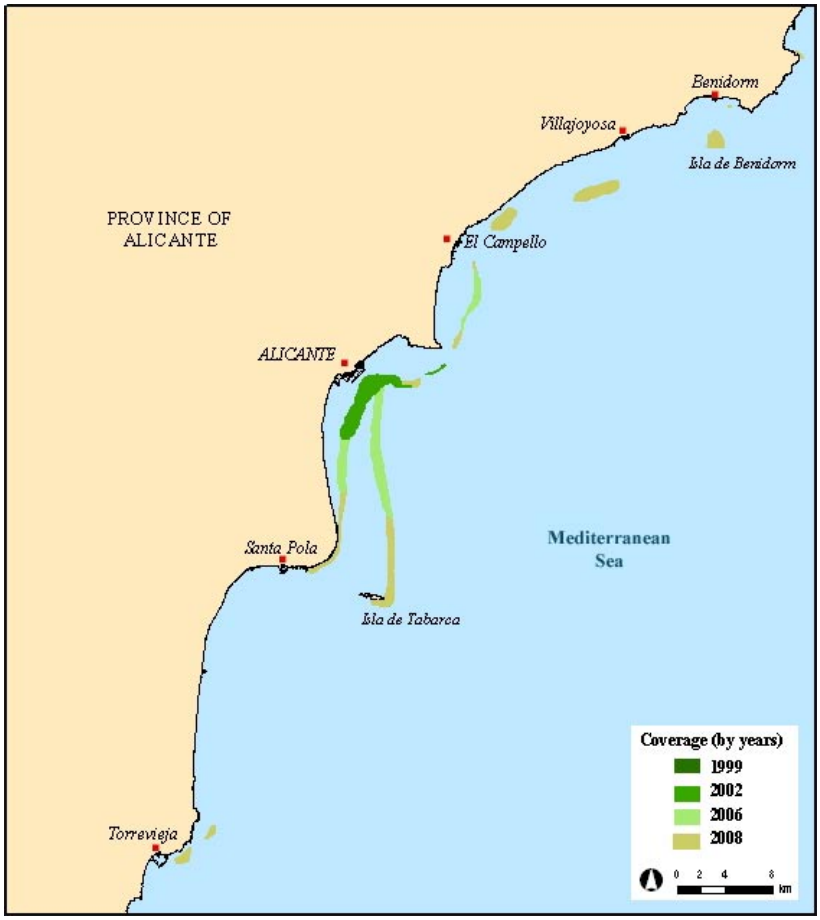

Figure 3: *Presence of Caulerpa racemosa in the coast of Alicante.*

This species is distributed widely over all the warm regions of the planet (Verlaque *et al*., 2000). In the Mediterranean, *Caulerpa racemosa* colonises all kinds of substrate (rock, sand, mud) as well as the dead growth of *Posidonia* up to 60 metres deep, upsetting coastal marine biocenosis. This successful colonisation is based on its ability to propagate, whether by sexual reproduction or by fragments and propagules that are spread by vessels (ballast water, anchors), fishing (dredging, trawling, trammels) and also by currents (Klein & Verlaque, 2008). The recommendations of the 1998 meeting in Crete highlighted the need to *i)* give any official instructions needed to prevent those using the sea from using practices that contribute towards the dissemination of these species, particularly *in situ* cleaning of anchors, fishing tackle and diving material, to avoid disseminating fragments of these algae in the sea; *ii)* carry out an inventory and cartographic monitoring of the colonised areas; *iii)* monitor the evolution of the biocenosis of the affected areas; *iv)* maintain scientific research into all aspects relating to the species: evolution of consequences and control of their dynamics; *v)* control, as far as possible, the expansion of the two species, mainly by eradicating small colonies in areas of high patrimonial worth and in regions distant from strongly colonised areas.

Figure 4: *Presence of Caulerpa racemosa in 2008.*

The Monitoring Plan carried out in the Region of Valencia has been designed to follow said recommendations.

MATERIALS AND METHODS

Detection and cartography

The species are monitored annually, coinciding with the period of maximum density and growth of the algae between June and October (Klein & Verlaque, 2008), along the 450-kilometre coastline of the Region of Valencia, at 41 stations regarded as being at risk of the implantation of invasive algae (presence of tourist vessels, merchant shipping, fishing activities) (Figure 1). Most stations correspond to fishing ports, marinas and nearby areas. As well as the ports, the programme monitors traditional anchoring areas along the Alicante coast and areas where the algae have been detected in previous years, as well as acting on any information received from volunteers, divers and fishermen who receive regular information about invasive algae.

Two types of methodology are used: *i)* Large areas are examined to detect the presence of invasive algae and their bionomic composition is assessed, with a file being drawn up for each of them every year in risk areas nearby to harbours, bays and coves. Transects were surveyed both perpendicular and parallel to the shoreline in deeper areas (from 4 to 35 meters). These tracks are used to establish the spatial distribution of *Caulerpa racemosa* and to characterise the marine benthic habitats occupied. Video transects are recorded by towing a camera behind a boat along the same courses. The CCD digital camera records the time, date, speed and geographic coordinates on screen; *ii)* scuba dives in areas of difficult access for the boat, acting on information received. During the inspections, images of the surface affected by the new colonies are taken using a video or still camera. The boundaries of *C. racemosa* were estimated by interpolation, assuming data transects and benthic habitat map.

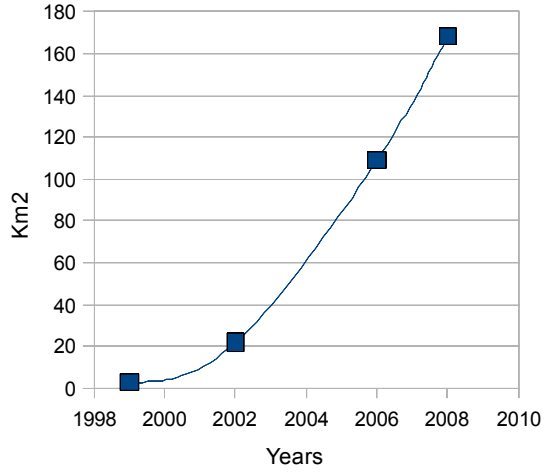

Figure 5:
Areas colonised by Caulerpa racemosa in the Region of Valencia.

Eradication

Eradication of species in a marine environment is difficult, and can only be carried out in closed or semi-closed areas (Bax *et al*., 2001). Despite this, between 2005 and 2007 action was taken to control and eradicate the shallowest and smallest colonies of *Caulerpa racemosa*, this being the case with the colonies located in Alicante, La Cala de La Mina (Alfaz del Pí), Torrevieja, Jávea and Tabarca. The method used consists in diluting copper sulphate, according with McEnnulty *et al*. (2001). Laboratory experiments show that copper concentration of >10 ppm applied for 30 minutes causes complete mortality. Concentrations of copper ions required to cause 100% mortality were 10,000 times lower than those of potassium and sodium ions (Uchimura*et al*., 2000). In this case we used a solution of 1 to 5 mg/l of copper, sufficiently saturated in sodium chloride (70‰) to ensure that its increased density meant that it remained in the seabed at the same depth as the colony treated. The solution was prepared in advance and injected over the colonies, which had previously been covered with a plastic sheet weighted along the edges and fitted with valves for the solution to be injected. The algae remained in contact with the solution for 45 minutes before the plastic was removed.

The effectiveness of the treatment was assessed after four days, rating it in accordance with densities of fronds and stolons fallen in comparison with their state before being treated (100%: total elimination – 0%; no effects). The process was repeated whenever part of a colony was seen to have survived in the treated areas.

RESULTS

Evaluation of the monitoring stations

Every year approximately 50 kilometres of video transects were filmed. The results for 2008 are shown on Table I, where the expansion of *Caulerpa racemosa* already affects 39% of the stations (16), 51% if we take into account the cases denominated “highly probable” (21 stations). *Lophocladia lallemandi* and *Asparagopsis taxiformis* were only detected at one station (2.4%). Only ten years ago, none of the stations had detected any of these algae.

Presence of *Caulerpa racemosa*

Caulerpa racemosa was first detected in the waters off the Iberian Peninsula (Castellón) in 1999 (Aranda *et al*., 1999). Since then, colonisation has progressed at an exponential rate, with no withdrawal having been detected in the areas colonised. The depths at which it is found range from practically on the shore (Cabo de Huertas -Alicante, Playa de los Locos -Torrevieja, Cala de La Mina -Alfaz del Pí and Cabo de Santa Pola), to depths of over 30 metres: 34 metres in Alicante, 32 metres in Benidorm, Elche and Santa Pola.

The size of the areas affected by the invasion of this species on the infralittoral level differs due to their different extent in the north and south of the Region of Valencia: up to 15 metres deep off the coast of Castellón and Valencia, and up to 20 – 25 metres deep in Alicante. It prefers to grow on hard substrates on the biocenosis of calm infralittoral photophilic rock, although it is also frequent in shallow areas where the sea beats against rock. It has also been seen colonising areas of *Posidonia oceanica* in degradation with scarce coverage and density, as well as on the dead matter of *Posidonia oceanica*, in this case frequently together with *Caulerpa prolifera*. This association has also been observed in dense meadows of *Cymodocea nodosa*. However, in areas with fine sand, where the friction of the sediment can be significant, *C. racemosa* has not been found. Neither is it found in areas with significant sedimentation of silt, such as inside ports, areas where *C. prolifera* is frequent.

The circalittoral level is where larger areas have been colonised by *Caulerpa racemosa*, the biocenosis in which this algae has spread most is the detritic coastal biocenosis, both in its facies of sedimentation and in that of typical appearance. It is also frequent, especially on the Alicante coast, at the lower level of distribution of *Posidonia oceanica*, when the latter is degraded, largely due to illegal trawling in the area.

The morphologies of colonisation by *Caulerpa racemosa* are very different at the infralittoral and circalittoral levels. The first sees very rapid growth of stolons with long fronds (up to 12 cm). In this area we have seen types of growth creating a “shrub” some 10 cm thick, due to the superimposition of stolons. In these cases the *C. racemosa* meadow favours sedimentation and reduces the number of species enormously, especially the macrophytes (Klein & Verlaque, 2008).

However, at depth, at the circalittoral level, *Caulerpa racemosa* is more conspicuous (fronds no longer than 7 cm) and their density is much less than that seen at the infralittoral level, although it is at this level where we see the greatest surface areas colonised on the coast of the three provinces.

a) Situation on the Castellón coast.

The first zone affected was discovered in July 1999 in waters close to the Grao de Castellón, this being the first mention of this species in the waters around the Iberian Peninsula (Aranda *et al*., 1999), and was found at the same time in the waters around the Balearic Islands (Ballesteros *et al*., 1999). It was detected in the Region of Valencia thanks to the many awareness campaigns carried out by the programme aimed at detecting the presence of *Caulerpa taxifolia*, and which led to the warning being given by recreational divers who notified the presence of the species on the seabed close to Castellón oil refinery. The area was searched thoroughly during the first two weeks of August. A colony was initially located 9 metres deep on dead *Posidonia oceanica* and precoralligenous communities, the community extended over some 3 m^2, largely in a single block, although a search of the surrounding area revealed the presence of numerous small colonies close to the main block over 337 hectares, indicating that the algae had been present for no more than 1 or 2 years and that it was expanding rapidly, probably through the dispersion of fragments from the main colony.

Said colonies have continued to propagate, mainly in the deeper areas, as more superficial coastlines with a predominance of sandy substrates hinder the expansion of the algae. Currently, the colonies of *Caulerpa racemosa* cover an area of 72.5 km^2. (Figure 3). The presence of the algae has been detected from the shores of Benicàssim to Burriana, although the invaded area is likely to be much greater. The algae are found from the shore and to a depth of 28 metres on bottoms that were previously occupied by meadows of *Posidonia oceanica* and are now detritic biocenosis with facies of sedimentation. Large amounts of the species are caught in seine nets and even get caught in paternoster lines, making it very difficult to fish in the area.

The presence of the species was also detected four years ago on the Isla Grossa island in the Islas Columbretes.

b) Situation on the Valencian coast.

Along the coast of the province of Valencia, the invasive strain of *Caulerpa racemosa* has been located close to the Port of Sagunto, with the first colonies being found in 2001. The southward expansion was probably related to the proximity of the colonies of Castellón, and factors as the effect of sea currents and fishing activities.

Caulerpa racemosa is found at mid-depth along muddy detritic coastal bottoms, and dead *Posidonia oceanica* meadows, areas where seine netting activities are carried out. They currently cover an area of approximately 51 km^2 (Figure 3) and have not yet been detected in shallower waters, possibly, as with Castellón, because of the predominance of open, sandy coastlines. Its presence has not yet been detected in the few rocky coastal areas or cliffs (e.g.: Cabo de Cullera).

c) Situation on the Alicante coast.

In early 2000, different colonies of algae were identified south of the port, at depths of 10-12 metres. In 2001, the species was discovered at Cabo de Santa Pola (Aranda *et al*., 2003; Aranda, 2004) in shallow water on bottoms with *Posidonia oceanica* meadows in the degradation stage. The most probable origin in this case is linked to oil tanker mooring points, which coincides with the discovery off the coast of Castellón – oil refinery terminal - and off other ports, such as Marseille. In this case, the first colonies were found around the gas terminal. It could have been spread by the anchors and chains and/or ballast water of the vessels.

A later cartographic survey carried out in late 2002 from the Port of Alicante to Cabo de Huertas, and another in early 2003 towards the southern part of the port, showed that almost 10 km^2 were affected by the species, affecting over 18 km of the coast between Cabo de Huertas and Cabo de Santa Pola, as well as the sector with degraded *Posidonia oceanica* at a depth of 25 to 30 metres between Cabo de Huertas and El Campello. In Alicante Bay, the algae has colonised both degraded Posidonia meadows with a low density of shoots – due to cargo vessels mooring in the bay - and muddy detritic bottoms. Its depth varies from 15 to 34 metres. It has propagated both to the south, on the coast of Santa Pola, reaching the Tabarca Marine Reserve (2006), and to the north, also on detritic bottoms, from 32 to 25 metres deep facing the San Juan and Muchavista beaches (2004), Isla de Benidorm (2005) and the deep coast off Villajoyosa (2006).

The above-mentioned areas account for most of the colonisation of *Caulerpa racemosa* along the coast of Alicante (almost 45 km^2 in 2008) (Figure 4). Its morphology consists of a reduced density of short fronds with long stolons. As well as these colonies, every year since 2003 the coastlines with cliffs in Alicante have seen the appearance of colonies of *C. racemosa*, with these having a very different morphology, much more invasive growth, and higher density of very long (up to 12 cm) fronds that cover and grow on the algae substrates that characterise the

Table 1: *Evaluation of the Monitoring Plan.. 1 mean presence, 0 absence, y 0* presence without confirmation.*

Station. Year 2008	*C. taxifolia*	*C. racemosa*	*A. taxiformis*	*L. lallemandi*
1. Vinaroz	0	0	0	0
2. Benicarló	0	0	0	0
3. Peñíscola	0	0	0	0
4. Oropesa	0	0	0	0
5. Castellón	0	1	0	0
6. Burriana	0	1	0	0
7. Sagunto	0	1	0	0
8. Pobla de Farnals	0	1	0	0
9. Valencia	0	1	0	0
10. Cullera	0	0	0	0
11. Gandía	0	0	0	0
12. Denia	0	0	0	0
13. Jávea	0	1	0	0
14. CalaSardinera (Jávea)	0	1	0	0
15-16. San Martín Cape (Jávea)	0	1	0	0
17. Ambolo Island (Jávea)	0	0*	0	0
18. Cala Granadella (Jávea)	0	0	0	0
19. Moraira (Teulada)	0	0	0	0
20. Calpe	0	0	0	0
21. Puerto Blanco (Calpe)	0	0	0	0
22. Mascarat (Altea)	0	0	0	0
23. Altea	0	0*	0	0
24. Cala La Mina (Altea)	0	1	0	0
25-26. Sierra Helada (Alfaz del Pí)	0	0	0	0
27. Benidorm	0	1	0	0
28. Cala de Finestrat	0	0*	0	0
29. Racó del Conill (Villajoyosa)	0	0*	0	0
30. Villajoyosa	0	0	0	0
31. El Campello	0	1	0	0
32. La Albufereta (Alicante)	0	1	0	0
33. El Postiguet (Alicante)	0	0*	0	0
34. Port of Alicante	0	1	0	0
35. Santa Pola	0	0*	0	0
36. Tabarca Island (Alicante)	0	1	0	0
37. Torrevieja	0	1	0	0
38. Cabo Roig (Torrevieja)	0	0	0	0
39. Campoamor (Orihuela)	0	0	0	0
40. Pilar de la Horadada	0	0	0	0
41. Columbretes Islands Castellón)	0	1	1	1
Total presence	0	16 (21 incl. probables)	1	1
% stations	0	39,00% (51% probables)	2,40%	2,40%

Table 2: *Location of Caulerpa racemosa colonies (surface of less than 10.000 square meters). State after algaecides treatment.*

Location	***Detection (year)***	***Surface***	***State and Response***
Cala de La Mina (Alfaz del Pí)	2004	400 m^2	Treatments in 2004, 2005 and 2006, eliminated in the shallow area, now on the cliff.
Huertas Cape (Alicante)	2004	8000 m^2	Located in very shallow bays. Continuity in the deep grass to -19 m deep.
Benidorm (Island)	2005	120.000m^2	Initially around trains anchoring subsequently colonized all funds detrital around the island
Tabarca (colonies and areas near the village, and "La Galera" area) (Alicante)	2005	2.000 m^2	Expanding
Tabarca ("la Llosa" area) (Alicante)	2005	4.000 m^2	Areas of degradation in Posidonia oceanica meadow (areas affected by the dragging effect of the buoy's chain).
Cala Blanca (Jávea)	2006	1.500 m^2	Treatments in 2006. The expansion continues.
Torrevieja (Bays of: El Cura, La Calita, and Los Locos)	2006	100 m^2	2006. Partially removed.
Isla del Portitxol (Jávea)	2007	500 m^2	Very irregular relief.
Benidorm (Rincón de L'Oix)	2007	50 m^2	Low growth.
El Amerador (El Campello)	2008	100 m^2	In areas with degradated *Posidonia oceanica* meadow.
Torres River (Villajoyosa)	2008	200 m^2	In areas with degradated *Posidonia oceanica* meadow.

biocenosis of the infralittoral rock, or the blanket of *Posidonia oceanica*, especially when the latter is receding. These colonies are listed in Table II.

The expansion of the colonies at infralittoral levels is sometimes spectacular, as was the case of the Isla de Benidorm, where it started with a colony of less than 30 m^2 close to the mooring lines at a depth of 15 metres in 2005. By 2006, the colonies had colonised part of the southwest sector of the island to a depth of approximately 8 metres, especially in depths of up to 20 metres, covering an area of 13,000 m^2. A year later, the surface colonised extended from 8-10 metres to 30 metres in depth, over the whole west-southwest sector, especially from a depth of 15 metres, covering an area of almost 120,000 m^2. In 2008, the colonies made special progress at the deeper levels, being found from 15 to 30 metres, and in the northern and southern parts.

Eradication actions

In accordance with the recommendations of the Crete Meeting, concerning "Controlling, as far as possible, the expansion of the two species, mainly by eradicating small colonies in areas of high patrimonial

worth and in regions distant from strongly colonised areas", from 2004 to 2007, a number of steps were taken to eradicate small colonies at infralittoral levels in reserves, natural parks and areas of interest. The eradications consisted of the controlled diffusion of algaecides over areas measuring 1 m^2. The results can be seen in Table III, and were highly effective, with an average 92.7% success rate for eradication. However, the high cost and length of time involved in using this technique, when compared with the high colonisation rate of *Caulerpa racemosa*, mean that these kinds of measures are not viable at present.

Other species of invasive algae

Other species of algae regarded as invasive as a result of their potential negative effects on the biocenosis of the areas where they settle, as they displace other members of the algal community, were: *i) Asparagopsis taxiformis*: detected in the Islas Columbretes in 2007: L'Illa Grossa, Foradada and Ferrera, at over 20 metres deep, both in rocky areas corresponding to hemiphotophilic and sciaphilic communities of the infralittoral rock and in areas of coarse sand and gravel, as well as communities at circalittoral levels; *ii*) *Lophocladia lallemandi*: detected in the Islas Columbretes in 2007, covering bottoms with communities of superficial photophilic algae of the infralittoral rock in the area of L'Ila Grossa. Colonisation of these algae is massive and this species also coexists with *Caulerpa racemosa*.

CONCLUSIONS AND DISCUSSION

Since the start of the Plan for monitoring the presence of invasive algae in the Region of Valencia, *Caulerpa taxifolia* has not been located as yet. On the contrary, since its detection in 1999, *C. racemosa*, has continued to expand along the Valencian coast, especially in large areas at circalittoral levels, as well as at numerous points at infralittoral levels of the Alicante coast in shallow waters. We currently estimate that the area covered by the algae is approximately 168 Km^2 (Figure 5, Table IV), with differing density. This means that the greatest density occurs at depths of less than 20 metres, while greater areas are covered at greater depths, but with lower density.

The increase in awareness thanks to the publication of leaflets and reports aimed at divers, rangers, fishermen and volunteers has been very useful for obtaining information about such a large area, given the apparently random appearance of new colonies.

Of the 16 stations in the Region of Valencia that have detected the presence of *Caulerpa racemosa*, there are stations close to major cities (Castellón, Alicante) and ports with sea traffic (Sagunto), as well as in areas of high environmental value (Tabarca, Columbretes). This means that there is no direct correlation between polluted areas and the presence of *C. racemosa*. Neither has it been found inside dense *Posidonia oceanica* meadows, but it has been found around their edges, in line with other sightings made in the Mediterranean (Klein & Verlaque, 2008).

The increase of bottom surface covered or colonized by *Caulerpa racemosa* was estimated in 17 km^2/year. These rates being higher than those seen on the French coast, where the area affected doubled every year (Ruitton *et al*., 2005; Javel & Meinesz, 2006). We have recently seen the sudden collapse of *C. racemosa* meadows in certain areas of France and Turkey, although these variations could be due to unfavourable situations, such as extreme temperatures, abrasion by sediment, high hydrodynamics or even massive reproduction (Klein & Verlaque, 2008). This means that we cannot at present define any guideline to indicate stabilising the colonisation curve of *C. racemosa* in either the Mediterranean or the Region of Valencia.

In the region of Valencia, as in other areas of the Mediterranean, the areas where the algae are implanted are often degraded or degrading biocenoses, mainly Posidonica oceanica meadows with limited coverage of degraded or dead matter – and detritic coastal biocenoses, mainly in their

facies of sedimentation, except for the colonies in the Tabarca marine reserve and the Islas Columbretes, where we can also see colonisation by *Lophocladia lallemandi* and *Asparagopsis taxiformis*, both recently, since 2007. Several studies have confirmed a decrease in the total number of species and the total coverage of macrophytes in all the biocenoses where *Caulerpa racemosa* has installed itself, but especially in rock biocenoses, with the effects being very similar to those caused by hypersedimentation stress, showing that one of the most damaging effects is that sedimentation processes over rocky substrates are favoured (Piazzi *et al*., 2005).

The first introductions nuclei are related with harbours and ballast water (Castellón and Alicante). However, nowadays the main dissemination vectors of *Caulerpa racemosa* are related to fishing activities and sea currents. We can see a clear correlation in its expansion with seine net fishing, with the deep areas where the algae are implanted, close to the lower limit of *Posidonia oceanica* meadows or in the detritic biocenosis, largely corresponding to the grounds for this type of fishing, which disturbs the bottom and moves through the area, thus favouring the re-implantation of the fragments adhered to the nets. The fragmentation of *Caulerpa racemosa* favours its spread, with fragments surviving for several days until they are fixed in the substrate (Cecherelli & Piazzi, 2001). Paradoxically, this association with seine net fishing is very harmful for the latter, as Italian experience has shown that the fishermen can suffer severe injuries when raising nets full of algal stolons (Magri *et al*., 2001).

Other areas where colonies have been found include coves and mooring buoys, where the fragments broken off can settle in the mooring areas. This effect has also been seen near mooring sites located near meadows that had been degraded in this way, this being the case of La Cala de La Mina and La Isla de Benidorm, and on other occasions, without meadows, as is the case with the Islas Columbretes.

Despite the success of the eradication programmes, with 92.17% of the algae eliminated after treatment, these control measures are not enough to limit or eliminate the colonisation and expansion of *Caulerpa racemosa*. This is due to the high cost of eradication that demands at least 2 divers plus support vessels working for no less than 2 hours to eradicate some 10 m^2, as opposed to the high growth rate of the algae and the many new outbreaks. This means that we cannot yet use control mechanisms, due to the diffuse limits of the meadows, the difficulty in finding new colonies and the significant capacity for expansion of the species. Some writers believe that more research should be done on the populations originating from Australia to identify their predators, diseases and parasites and build a knowledge base to acquire tools for controlling the algae in the Mediterranean (Klein & Verlaque, 2008).

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