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Massive decline of *Cystoseira abies-marina* forests in Gran Canaria Island (Canary Islands, eastern Atlantic)

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Summary: Brown macroalgae within the genus *Cystoseira* are some of the most relevant "ecosystem-engineers" found throughout the Mediterranean and the adjacent Atlantic coasts. *Cystoseira*-dominated assemblages are sensitive to anthropogenic pressures, and historical declines have been reported from some regions. In particular, *Cystoseira abies-marina*, thriving on shallow rocky shores, is a key species for the ecosystems of the Canary Islands. In this work, we analyse changes in the distribution and extension of *C. abies-marina* in the last decades on the island of Gran Canaria. This alga dominated the shallow rocky shores of the entire island in the 1980s; a continuous belt extended along 120.5 km of the coastline and occupied 928 ha. In the first decade of the 21st century, fragmented populations were found along 52.2 km of the coastline and occupied 12.6 ha. Today, this species is found along 37.8 km of the coastline and occupies only 7.4 ha, mainly as scattered patches. This regression has been drastic around the whole island, even in areas with low anthropogenic pressure; the magnitude of the decline over time and the intensity of local human impacts have not shown a significant correlation. This study highlights a real need to implement conservation and restoration policies for *C. abies-marina* in this region.

Keywords: marine forests; habitat-forming species; human pressures; Fucales; regression; Atlantic Ocean.

Regresión aguda de los bosques de *Cystoseira abies-marina* en la isla de Gran Canaria (Islas Canarias, Atlántico este)

Resumen: Las algas pardas pertenecientes al género *Cystoseira* se distribuyen a lo largo del Mediterráneo y las costas atlánticas adyacentes, siendo uno de los "ingenieros ecosistémicos" más relevantes. Los bosques constituidos por especies de *Cystoseira* son sensibles a perturbaciones de origen antropogénico y, por esta razón, se han registrado declives históricos en distintas regiones. Concretamente, *Cystoseira abies-marina*, una especie que habita en costas rocosas someras, es clave para la buena salud de los ecosistemas costeros de las Islas Canarias. En este trabajo, analizamos los cambios en la distribución y extensión de *C. abies-marina* en las últimas 4 décadas en la isla de Gran Canaria. Esta especie dominaba las costas rocosas poco profundas de toda la isla en la década de los 80; una banda continua se extendía a lo largo de 120.5 km de costa, ocupando 928 ha. A comienzos del siglo XXI, poblaciones fragmentadas cubrían 12.6 ha, a lo largo de 52.2 km de la línea de costa. Hoy en día, se distribuye a lo largo de 37.8 km del perímetro costero, en su mayoría como parches dispersos, ocupando una extensión de tan sólo 7.4 ha. Esta regresión ha sido drástica en toda la isla, incluso en zonas con baja presión antropogénica; no encontramos una correlación significativa entre el número de impactos locales y la magnitud del declive en el tiempo. Este estudio señala la necesidad real de implementar políticas de conservación y restauración para *C. abies-marina* en esta región.

Palabras clave: bosques marinos; especies formadoras de hábitats; presiones humanas; Fucales; regresión; Océano Atlántico.

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INTRODUCTION

Coastal ecosystems are suffering severe impacts worldwide due to excessive human pressure. Habitat destruction, pollution, eutrophication, species introduction, overfishing and global warming, which often act synergistically, are affecting species, ecosystems and their ability to provide ecosystem services (Halpern et al. 2008). For example, the Canary Islands are a “hot spot” of marine biodiversity in the North Atlantic (Sansón et al. 2001), which is threatened by human impacts, e.g. pollution, overfishing, occupation of the coast and progressive tropicalization (Riera et al. 2015).

Along rocky shores of temperate and subtropical areas, large canopy-forming brown algae, in particular kelps (Laminariales, Phaeophyceae, Ochrophyta) and fucoids (Fucales, Phaeophyceae, Ochrophyta), are the dominant species in pristine environments (Schiel and Foster 2006). These large perennial macroalgae are considered as “engineering species” (Jones et al. 1994), because their three-dimensional structure dramatically alters the physical, chemical and biological environment. These forests provide shelter, food, habitat and nurseries for a multiplicity of species (Cheminée et al. 2013). The decline of kelps and fucoids is a global phenomenon due, directly or indirectly, to human-mediated activities (Wernberg et al. 2011, Lamela-Silvarrey et al. 2012, Franco et al. 2015). Some species have even been driven to regional and local extinction (Thibaut et al. 2005, Franco et al. 2015, Thibaut et al. 2016a). The loss of these well-structured and diverse ecosystems facilitates the appearance of less complex habitats, such as filamentous algal turfs, ephemeral seaweed assemblages and barren grounds dominated by encrusting algae and sea urchins (Benedetti-Cecchi et al. 2001, Ling et al. 2015).

The genus *Cystoseira* C. Agardh (Fucales, Phaeophyta) is distributed in temperate and subtropical coasts around the world, although 80% of the species live in the Mediterranean Sea (Oliveras and Gómez 1989). In the Mediterranean and the adjacent Atlantic Ocean, species of the genus *Cystoseira* are the main group of habitat-forming macroalgae, from the littoral to the lower limit of the euphotic zone (Giaccone et al. 1994, García-Fernández and Bárbara 2016). Losses of *Cystoseira* forests have been reported all around the Mediterranean and attributed to habitat destruction, eutrophication and overgrazing by herbivores (Thibaut et al. 2005, Iveša et al. 2016, Blanfuné et al. 2016a). Due to their high sensitivity to anthropogenic impacts, several species of *Cystoseira* indicate high quality waters and facilitate the implementation of the EU Water Framework Directive (2000/06/EC) (Ballesteros et al. 2007, Blanfuné et al. 2016b, 2017). All the Mediterranean species of the genus *Cystoseira*, except *C. compressa*, have been protected under the Annex II of the Barcelona Convention (2010). Five species, *Cystoseira amentacea*, *Cystoseira mediterranea*, *Cystoseira sedoides*, *Cystoseira spinosa* and *Cystoseira zosteroids*, are protected under the Berne Convention (Annex I, 1979). In addition, all Mediterranean *Cystoseira* species are under surveillance by international organizations, such as IUCN, RAP/ASP and MedPan (Thibaut et al. 2014). All species of *Cystoseira* are “habitat-forming” and are therefore considered EU habitats of interest (Micheli et al. 2013).

The brown alga *Cystoseira abies-marina* (S. G. Gemelin) C. Agardh has been considered the most abundant fucoid species on rocky shores of the Canarian Archipelago (Wildpret et al. 1987, Tuya and Haroun 2006), and its populations typically form extensive stands in both the eulittoral and shallow sublittoral, mainly on rocky wave-exposed zones (Wildpret et al. 1987, Medina and Haroun 1993). *C. abies-marina* is a caespitose plant with large numbers of erect branches, up to 50 cm long. Similar to other species in the genera *Cystoseira*, this species undergoes an annual thallus loss at the end of summer, when a high proportion of the fronds break down at the base. The holdfasts overwinter and regrow the next year. Therefore, although individuals are perennial, the thalli are annual (Buonomo et al. 2017). However, the plant never goes through a total rest phase: during unfavourable months, branches from different seasons coexist (González-Rodríguez and Afonso-Carrillo 1990). This alga spreads through both vegetative propagation and sexual reproduction (Medina 1997). Similar to other species of the genus, thalli are negatively buoyant and propagules normally settle at <20-40 cm from the source population (Mangialajo et al. 2012), which gives the species a low-dispersal ability (Bulleri et al. 2002). This is one of the most productive macroalgae in the Canary Islands (Johnston 1969), and at the end of summer, after the maximum reproductive peak, it is possible to find a large amount of wrack on beaches from nearby forests (Portillo-Hahnefeld 2008).

In the last few decades, *Cystoseira abies-marina* forests have declined significantly at certain points of the Canaries (Medina and Haroun 1993, Rodríguez et al. 2008). In order to analyse the long-term patterns in the distribution and extension of *C. abies-marina* along the entire coastal perimeter of the island of Gran Canaria, we collected all available data to reconstruct historical distributions. The aims were: (i) to provide an up-to-date assessment of the current distribution and extent of *C. abies-marina*, (ii) to facilitate a comparison with historical data, including populations from certain sites, and (iii) to evaluate the influence of local anthropogenic pressures, as drivers of regression.

MATERIALS AND METHODS

Study area

The island of Gran Canaria (28°51'N, 15°36'W) is located 200 km off the northwest African coast, in the middle of the Canary Islands (east Atlantic) (Fig. 1). The island has a circular shape of 256 km of coastal perimeter. Abrupt cliffs mostly dominate the north and west sides of the island, with coastal platforms and beaches predominating in the east and south. Although 76.02% of the coastal perimeter is rocky (Ramírez et al. 2008), rocky reefs only account for 17% of the shallow-water bottoms (up to 50 m). Gran Canaria is

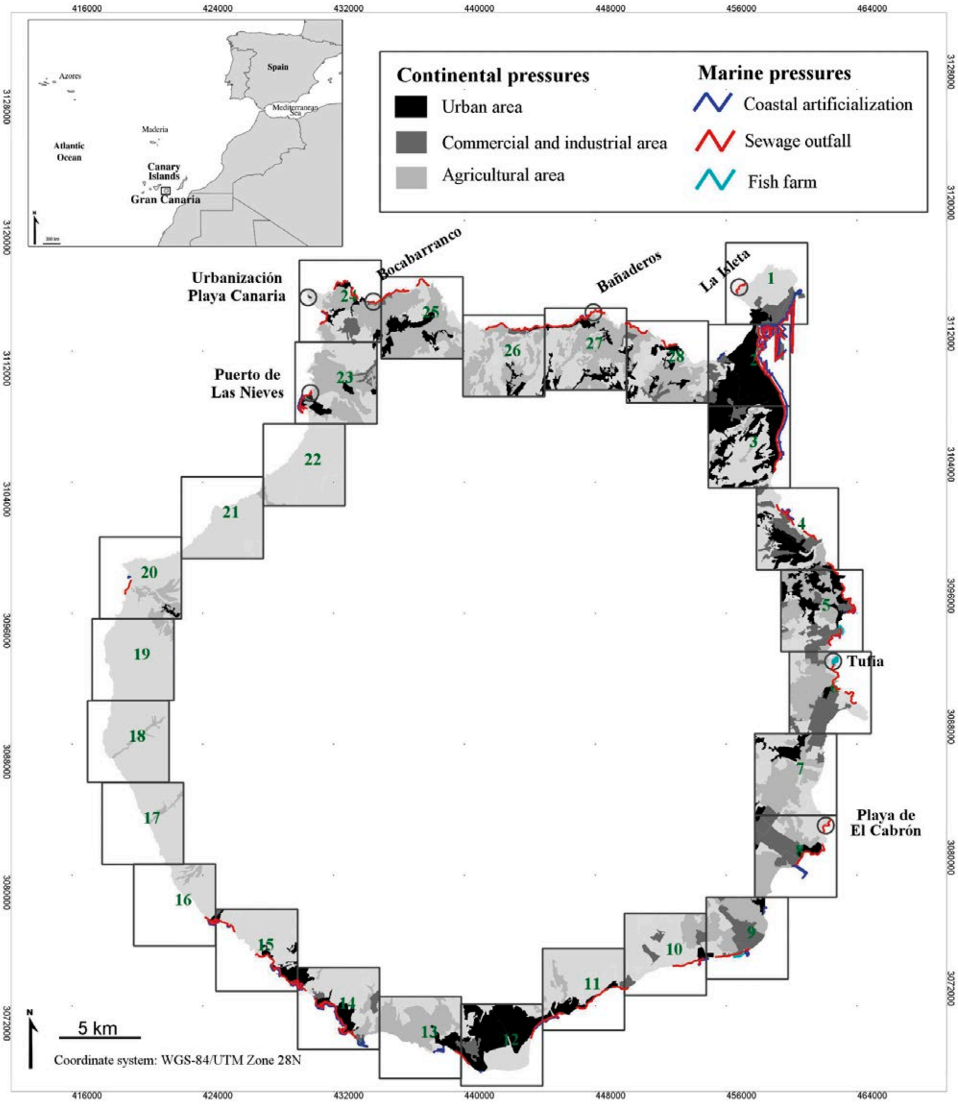

Fig. 1. – Map of Gran Canaria Island, including the 28 sectors (grids of 5×5 km) encompassing the entire coastal perimeter. The location of the seven analysed populations is also shown, with the circular area (500 m radius) where the HAPI index was calculated.

situated at the centre of a west-east oceanographic gradient along the Canarian archipelago, because of the varying proximity from the upwelling of the African coast (Tuya et al. 2006). The waters are typically oligotrophic and the surface temperature varies between 18°C in March and 24°C in October.

Mapping historical and current distribution: GIS analysis

Changes in the distribution (km of coastal perimeter) and extent (occupied area in ha) of *Cystoseira abies-marina* over time were analysed with the open-source GIS (gvSIG) and Sextante tools, using a 1:2500 scale and a WGS-84/UTM Zone 28N coordinate system.

Historical records concerning *Cystoseira abies-marina* distribution in the Canary Islands are scarce (Table 1). To reconstruct long-term patterns of change, we used unpublished reports from the late 1980s and 2000s, and oral scientific contributions. However, we did not take into account herbarium vouchers. The first map dates back to 1985, when Wildpret et al. (1987) defined and mapped 15 types of vegetation between 0 and 10 m depth: 12 correspond to stands of macroalgae, two to seagrass meadows and one to a mixed community of seagrass and algae. Additionally, they mapped three ecosystems devoid of vegetation. We digitalized six of these types of vegetation, in which *C. abies-marina* was the principal floral component (Supplementary material Table S1, Fig. S1A). We used complementary sources to enlarge this map from the 1980s, focusing mainly on the eastern side of the island. Information provided by scientists and technicians, which was contrasted with historical orthophotos (Vuelos históricos: 1989-1991 Costas, Instituto Geográfico Nacional),

Table 1. – Cartographic sources on the distribution of *Cystoseira abies-marina* in Gran Canaria Island.

1980s	1987	Wildpret et al. (1987)
	1989	Oral scientific communications
2000s	2008	Rodríguez et al. (2008)
2010s	2016	Current study

supplied additional populations to those provided by Wildpret et al. (1987) (Supplementary material Table S1, Fig. S1B).

The first digitalized map of *Cystoseira abies-marina* was undertaken in 2008 by Rodríguez et al. (2008), who mapped the distribution of *C. abies-marina* according to three levels of abundance: as continuous belts, as discontinuous belts and as isolated individuals (Fig 2B).

Field surveys were carried out between 2015 and 2016, during the maximum development of *Cystoseira abies-marina* (spring to autumn). The entire coast of Gran Canaria was explored on foot or by boat, and the shallow subtidal by snorkelling. Locally, populations were categorized, following Rodríguez et al. (2008), as C1, rare scattered patches; C2, abundant patches; and C3, continuous belts. All the *C. abies-marina* populations were geo-localized and recorded on A4 format aerial photographs from the IGN (Instituto Geográfico Nacional, 1:2500 scale).

Comparison of populations: 2008 vs 2016

Rodríguez et al. (2008) studied seven populations (Fig. 1), providing the average coverage and belt width of *Cystoseira abies-marina* forests. In 2016, we repeated the study in the same locations, carrying out three transects (ca. 10 m apart), which covered the entire eulittoral and the shallow subtidal. Along each transect, the coverage (n=3) of *C. abies-marina* was obtained with a square (50×50 cm), divided into 25 sub-squares of 10×10 cm; the belt width was measured with a transect. We tested for differences in average coverage and belt width between 2008 and 2016 using a Wilcoxon test (i.e. all populations were pooled).

Human pressures as drivers of change

We assessed the Human Activities and Pressures Index (HAPI) (Blanfuné et al. 2017) on the coast of Gran Canaria. Five water bodies (WD) surround the island, according to the Water Framework Directive (WFD, 2000/60/EC). We divided these WD into 28 coastal sectors (grid cells of 5×5 km, Fig. 1) to identify more precisely the relationship between levels of anthropogenic pressures and the decline of *Cystoseira abies-marina* forests. For this study, we adapted the information available for the Canary Islands, following the method of Blanfuné et al. (2017).

The HAPI index has three metrics to estimate both continental and marine pressures. For continental pressures (urban, industrial and agricultural areas), the three metrics were expressed as the percentage of land area covered (data from Corine Land Cover 2012, available at centrodedescargas.cnig.es) within each coastal sector. For marine pressures, we estimated (i) the level of artificialization of the coast, expressed as the percentage of the artificialized coastline, (ii) fish farms, expressed as the percentage of rocky coastline potentially impacted (within a 500 m radius), and (iii) sewage outfalls, expressed as the percentage of rocky coastline potentially impacted (within a 500 m

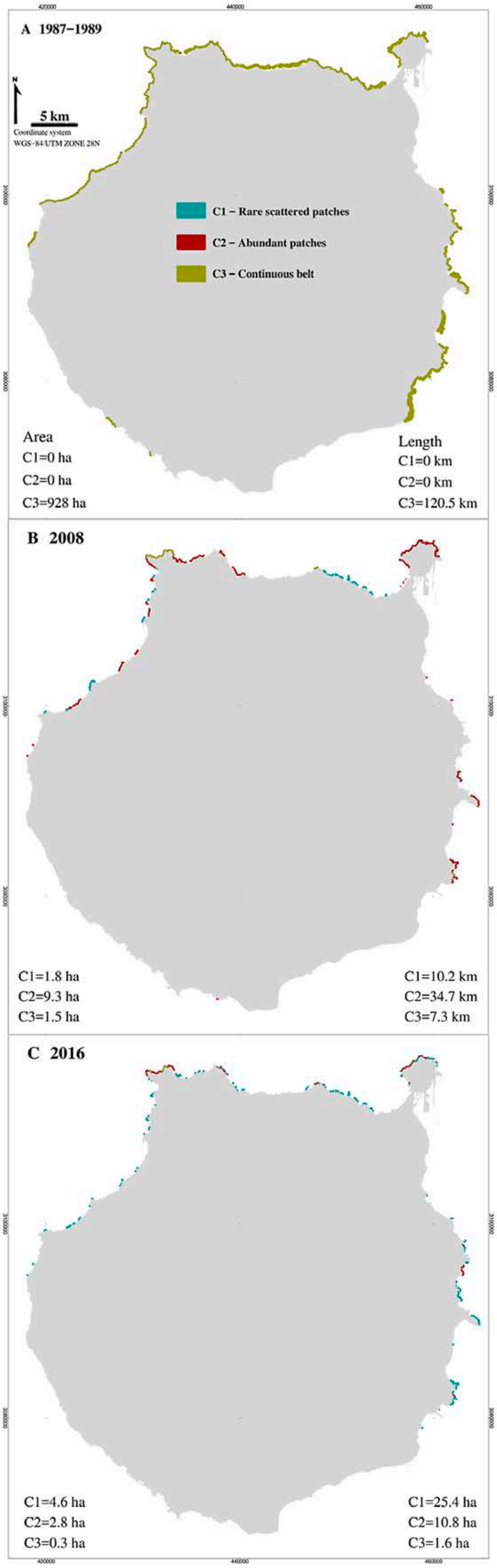

Fig. 2. – Distribution of *Cystoseira abies-marina* around Gran Canaria Island in the 1980s (A), 2008 (B) and 2016 (C). The area (ha) and length (km) of the three types of stands is included (C1, scattered patches; C2, abundant patches; C3, continuous belt).

radius). This information was provided by the on-line GIS of the Canary Islands Autonomous Government (www.idecanarias.es). For each sector, we calculated the change in the extent of *C. abies-marina* between 1980s (i.e. Wildpret et al. 1987) and 2016 (i.e. this study). We applied a linear regression to test whether varying levels of human pressures explained the magnitude of changes in surface area over time at the island scale. Additionally, the HAPI index was calculated for each of the seven populations under study; we calculated the level of human pressures using a 500 m radius circular buffer from the centre of each population (Fig. 1), following a similar approach to that of Tuya et al. (2014).

RESULTS

Distribution and extent

During the 1980s (Fig. 2A), *Cystoseira abies-marina* dominated the rocky coasts of Gran Canaria, along 120.5 km of coastal perimeter, covering 928 ha. It was abundant on most rocky substrates and the populations were mainly composed of continuous belts (Fig. 2A). Subtidal populations reached up to 9 m depth in many places of the north coast; in the east and southeast coast, stands reached up to 20 m depth in some places. The species was absent from the south and southwestern coast, mainly due to a lack of suitable hard substrates. At the start of the 21st century (Fig. 2B), populations were clearly fragmented, occupying 52.2 km of the coast (19.45% of the coastline) and covering 12.6 ha; this corresponds to a regression of 98.64% in 20 years. Populations rarely get down into the subtidal, except in a few locations in the north and east, where populations go down to 8-10 m. Between 2014 and 2016, *C. abies-marina* was present along 37.8 km (14.08% of the coastline) and occupied an area of only 7.4 ha. Populations forming continuous belts have practically disappeared (0.3 ha). Fragmented populations are becoming more prominent and sublittoral populations have totally disappeared. As a result, *ca*. 99% of the area formerly covered by *C. abies-marina* has been lost in a few decades (Fig. 3).

Comparison of populations: 2008 vs 2016

Overall, the seven *Cystoseira abies-marina* populations studied in 2016 have suffered a significant decline relative to 2008, in terms of coverage (V=231, P=0.00006, Fig. 4A) and belt width (V=231, P=0.0000001, Fig. 4B). In 2008, all populations had high cover (>50%) and formed continuous belts; in some localities, belts extended to the subtidal down to 8-10 m depth.

Human pressures as drivers of regression

Values of the HAPI index were calculated for the 28 coastal sectors and 7 populations of Gran Canaria Island (Tables 2 and 3, Supplementary material Table S3). There was no significant effect of varying

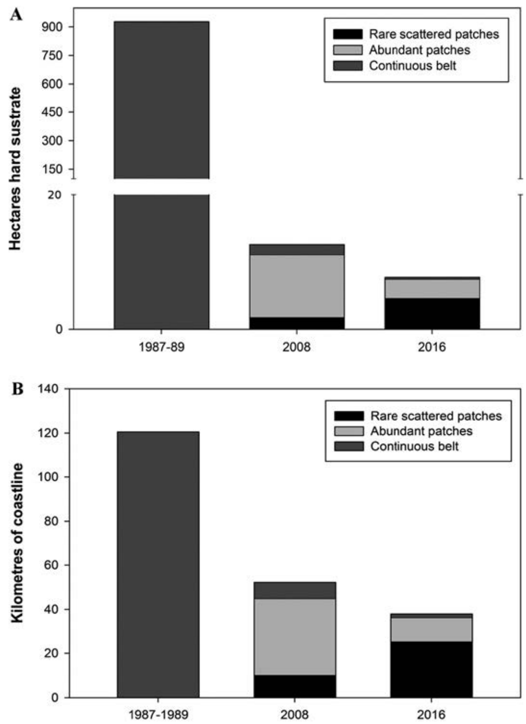

Fig. 3. – Temporal changes in the extent of *Cystoseira abies-marina*, in terms of the surface in hectares (A) and length in kilometres (B) of the coastline occupied at different times.

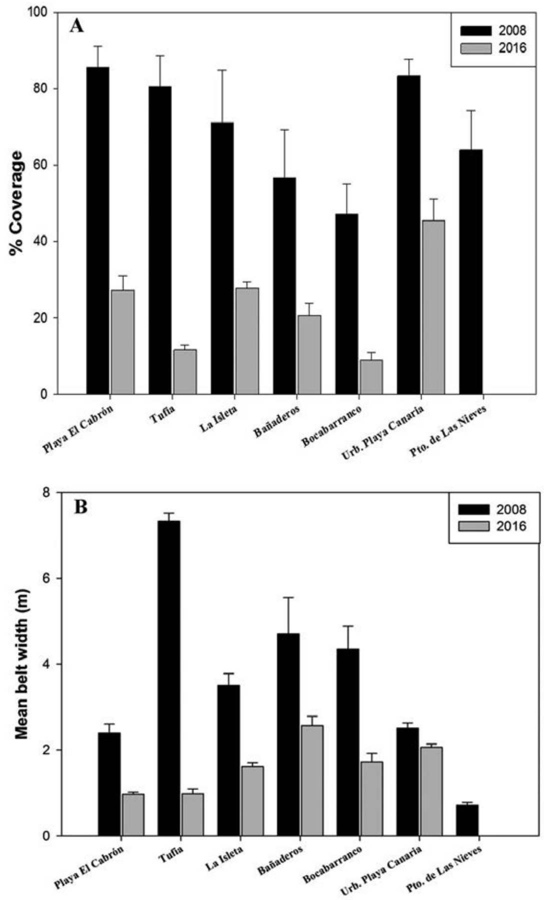

Fig. 4. – Average coverage in percentage (A) and belt width in metres (B) of the seven populations of *Cystoseira abies-marina* in 2008 and 2016.

Table 2. – Values of the HAPI index, area covered and rate of temporal change of *Cystoseira abies-marina* in each of the 28 sectors along the coastal perimeter of Gran Canaria.

Sector	HAPI index	Area (ha) 1980s	Area (ha) 2016	% Change
1	3.24	83.86	0.81	–99.03
2	5.48	31.72	0	–100
3	4.09	0	0	0
4	3.58	6.73	0.06	–99.11
5	4	30.51	1.75	–94.26
6	2.81	62.65	0.55	–99.12
7	0.83	77.07	0.075	–99.9
8	4.55	131.23	0.46	–99.65
9	4.85	118.9	0	–100
10	3.13	0	0	0
11	4.09	0	0	0
12	4.19	0	0	0
13	3.84	0	0	0
14	4.09	6.6	0	–100
15	4.44	5.66	0	–100
16	4.37	0	0	0
17	0.07	0	0	0
18	0.06	0	0	0
19	0.06	8.61	0.05	–99.42
20	1.8	12.39	0.12	–99.03
21	0.04	29.95	0.09	–99.7
22	0.04	16.53	0.07	–99.58
23	2.44	13.5	0.14	–98.97
24	1.93	42.85	1.5	–96.5
25	1.53	50.64	0.53	–98.96
26	1.42	95.03	0.06	–99.99
27	2.55	58.68	0.47	–99.2
28	1.52	45.04	1.01	–98.99

Table 3. – Values of the HAPI index, coverage and rate of temporal change for each of the seven studied *Cystoseira abies-marina* populations.

	HAPI index	% Coverage 2008	% Coverage 2016	% Change
Playa de El Cabrón	1.66	85.56	27.22	–68.19
Tufia	1.88	80.56	11.66	–85.53
La Isleta	1.2	71.11	27.77	–60.95
Bañaderos	2.51	56.67	20.55	–63.74
Bocabarranco	2.19	47.22	8.88	–81.19
Urbanización Playa Canaria	0.11	83.33	45.55	–45.34
Puerto de Las Nieves	2.32	63.89	0	–100.00

levels of human pressures on temporal changes for either extent (1980s vs 2016; R^2=0.048, F=0.0423, df=18, P=0.839) or coverage of *C. abies-marina* (2008 vs 2016; R^2=0.53, F=5.77, df=5, P=0.06). In general, the magnitude of regression, in terms of both extent and coverage, has been high in all sectors and for all populations, even in areas with low or no human pressure.

DISCUSSION

Changes in the distribution and extent of *Cystoseira abies-marina* on the island of Gran Canaria over the last few decades are evident and dramatic. In the late 1980s, *C. abies-marina* occupied 928 ha (12.84% of the rocky bottoms) and now it only covers 7.4 ha (0.1%). Existing *C. abies-marina* populations have been reduced to narrow belts in the lower eulittoral, i.e. as scattered patches with underdeveloped branches. Our results are in agreement with those found for other *Cystoseira* species from the Mediterranean Sea (Thibaut et al. 2005, Mangialajo et al. 2008, Sales et al. 2011), for other fucoids from the Canary Islands (Rodríguez et al. 2008, Riera et al. 2015) and, in general, for habitat-forming brown algae worldwide (Wahl et al. 2015). Our data show a similar trend to that observed for *C. brachyccarpa* var. *brachycarpa*, a species having the same depth range and ecological function as *C. abies-marina*, including a massive decline from the sublittoral to a narrow fringe immediately below the surface (Thibaut et al. 2015, 2016b).

It is plausible that the area occupied by *Cystoseira abies-marina* in the 1980s is not entirely accurate, because of the lack of technical procedures to accurately trace communities at this time. The map of Wildpret et al. (1987) only reached 10 m depth, so they may even have underestimated the area occupied by *C. abies-marina*. Even assuming these inaccuracies, the regression of *C. abies-marina* is acute, in particular because all sublittoral populations have been lost.

In our study, we found no direct relationship between local levels of anthropogenic pressures and the magnitude of local regression; the decay has been dramatic from almost pristine environments to highly altered coasts. This result contrasts with the disappearance of some *Cystoseira* species only from highly artificialized areas (harbours, marinas, piers, etc.) and waters severely polluted in the Mediterranean (Thibaut et al. 2014, 2015, Iveša et al. 2016). However, a similar decline has been observed in the pristine environments of the National Park of Port-Cros in France (Thibaut et al. 2016b). In a similar study, the temporal decay in the vitality of the seagrass *Cymodocea nodosa* in Gran Canaria was connected with an increase in local anthropogenic impacts (Tuya et al. 2014).

The decline of *C. abies-marina* in Gran Canaria has occurred in a period of pronounced urban and tourism development and, therefore, of many local impacts (Tuya et al. 2014, Ferrer-Valero et al. 2017). Today, the population, urbanization and infrastructure are heavily concentrated on the coast of the island, particularly in the northeast, east and south (Fig. 1). Gran Canaria currently has 847830 inhabitants and a very high population density (543 inhabitants km^{-2}) (ISTAC 2015); 87% of the population is located along the littoral perimeter, giving a coastal population density of 3142 ind km^{-1}. In addition, about 2 million tourists visit the island every year (e.g. 1805058 tourists in 2015, ISTAC 2015). This has led to the occupation and degradation of most coastal areas (Ferrer-Valero et al. 2017). Importantly, however, populations of *C. abies-marina* in poorly impacted areas have also suffered significant regressions. Hence, it remains elusive to unravel the reasons for the loss of *C. abies-marina*.

The possible causes of the decline may be multiple and cumulative, as happens around the world (Thibaut et al. 2005, Wahl et al. 2015, Franco et al. 2015). Potentially, both local and global stressors are interacting to explain the severe regression of *Cystoseira abies-marina* in Gran Canaria, as is the case with the disappearance of other fucoids from the study region (Riera at al. 2015). In the Canary Islands, sea surface temperature has increased about 1°C in recent decades (Lima and Wethey 2012, Riera et al. 2015). Global warming is a key factor in the ongoing decline of fucoids and their displacement to colder waters (Wernberg et al. 2011). There is recent regional evidence of the adverse effect of warming on species of both brown and red macroalgae (Sansón et al. 2013). The decrease in the size of thalli of these seaweeds, and in their reproductive success (Zhang et al. 2009), have also been correlated with the warming of the Canarian waters (Sansón et al. 2013, Riera et al. 2015). Furthermore, *Cystoseira* are low-dispersal species whose propagules do not have a planktonic stage, and reproductive drifting thalli in floating rafts are the main mechanism of connectivity between populations (Susini et al. 2007). Therefore, if connectivity is limited, the subsequent smaller population gene pools and sizes render populations more vulnerable to threats (Buonomo et al. 2017).

The regime shift from marine forests to barren grounds devoid of erect macroalgae is generally linked to overexploitation of predatory fishes (Ling et al. 2015, Thibaut et al. 2015, 2016a). In the Canary Islands, the long-spined sea urchin *Diadema africana* controls the transition from rocky bottoms dominated by erect macroalgae to barren grounds (Tuya et al. 2004, Sangil et al. 2014). This sea urchin may consume thalli of *C. abies-marina* at rates of 1-2 mg of algae per day and individual (Tuya et al. 2001). In addition, it is plausible that the sea urchin *Paracentrotus lividus* and herbivorous fishes (*Sparisoma cretense*, *Sarpa salpa* and *Diplodus* spp.) can contribute to the consumption of *C. abies-marina*, as in the Mediterranean for other *Cystoseira* spp. (Verges et al. 2009).

This study highlights the urgent need to monitor remaining *Cystoseira abies-marina* populations of the Canary Islands, and compare this data with other Macaronesian islands. It is also necessary to promote urgent actions to conserve current populations, including restoration programmes. Currently, *C. abies-marina* is regionally protected within the framework of the Canary Islands Catalogue of Protected Species (Law 4/2010, of 4 June 2010). This highlights the uselessness of legislation if it is not enforced. Furthermore, in the last update of this catalogue, the species lost the category of "vulnerable": it now belongs to a recently created category called "species of interest for the Canarian ecosystems", which only protects the species within zones of the Natura 2000 network. Our results clearly do not support this legislative change.

Cystoseira abies-marina has not yet been assessed for the IUCN Red List, i.e. it is "Not Evaluated" (IUCN 2017), nor is species included in the Catalogue of Life (Roskov et al. 2016). We are aware that *C. abies-marina* is undergoing a very important decline throughout the Canaries (Rodríguez et al. 2008) and also on Madeira and the Azores (Ballesteros pers. com.), but more data are needed to verify the magnitude of this decline. Nevertheless, with current data and evidence of the regional decline, we propose that *C. abies-marina* should be classified as "Critically Endangered" under the IUCN criteria CR A2ac. There are only very few algal species in the world whose conservation status has been properly assessed (Blanfuné et al. 2016a), due to lack of historical data. Information provided here could be used as a basis for improving the evaluation of the conservation status of *C. abies-marina*, an ecologically important species.

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SUPPLEMENTARY MATERIAL

The following supplementary material is available through the online version of this article and at the following link: http://scimar.icm.csic.es/scimar/supplm/sm04655esm.pdf

Fig. S1. – *Cystoseira abies-marina* communities in the 1980s, including those from Wildpret et al. (1987) (A) and from oral scientific communications (B).
Table S1. – *Cystoseira abies-marina*: historical sources (1980s).
Table S2. – Types of human pressures, Corine Land Cover (CLC) codes, area and length percentages, and corresponding scores used in calculations of the HAPI index in coastal sectors and populations of Gran Canaria Island.
Table S3. – Percentages of the area and length of each sector according to human pressure. Pressure scores (PS) assigned to each pressure are indicated. Correlation coefficients (R^2) between pressures, turnover score (TS) and the HAPI index (HAPIj=Σ(PSi×ri)/TSj) were calculated according to Blanfuné et al. 2017.

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Massive decline of *Cystoseira abies-marina* forests in Gran Canaria Island (Canary Islands, eastern Atlantic)

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Supplementary material

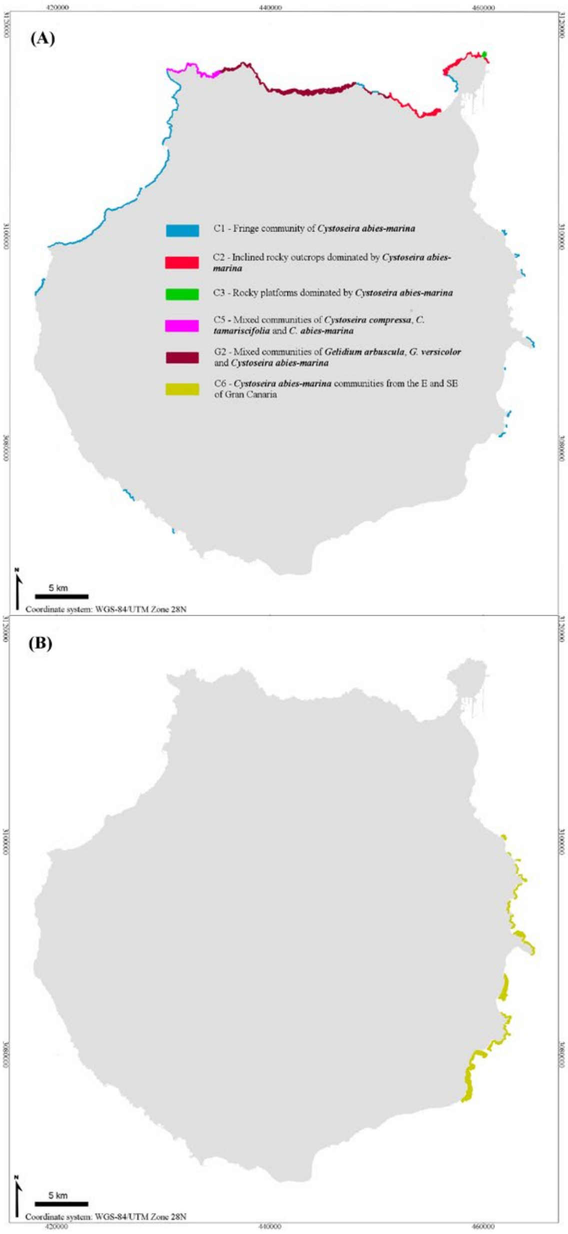

Fig. S1. – *Cystoseira abies-marina* communities in the 1980s, including those from Wildpret et al. (1987) (A) and from oral scientific communications (B).

Table S2. – Types of human pressures, Corine Land Cover (CLC) codes, area and length percentages, and corresponding scores used in calculations of the HAPI index in coastal sectors and populations of Gran Canaria Island.

Types of pressure	CLC code	Area percentage (%)	Score
Continental pressures			
Urban area	11, 14	0-10	1
		11-35	2
		36-75	3
		>75	4
Industrial area	12, 13	0-10	1
		11-25	2
		26-75	3
		>75	4
Agricultural area	21-24	0-5	01
		6-25	12
		16-30	23
		>30	34
Marine pressures		Length percentage (%)	
Coastal artificial-ization		0-5	1
		6-25	2
		26-75	3
		>75	4
Sewage outfall		0-5	1
		6-25	2
		26-75	3
		>75	4
Offshore fish farm		0-1	1
		2-15	2
		16-40	3
		>40	4

Table S1. – *Cystoseira abies-marina*: historical sources (1980s).

Name	Type	Substrate	Slope	Depth	Cover/Abundant	Source
Fringe community of *Cystoseira abies-marina*	C1	Rocky	80-100%	0-3 m	Continuous belt	Wildpret et al. 1987
Sloping rocky outcrops dominated by *Cystoseira abies-marina*	C2	Rocky	50-80%	0-9 m	Continuous belt	Wildpret et al. 1987
Rocky platforms dominated by *Cystoseira abies-marina*	C3	Rocky	0-50%	3-9 m	Continuous belt	Wildpret et al. 1987
Rocky platform mixed communities	C4	Rocky	0-50%	3-9 m	Continuous belt	Wildpret et al. 1987
Mixed communities of *Cystoseira compressa*, *C. tamariscifolia* and *C. abies-marina*	C5	Rocky	0-100%	0-9 m 3-9 m	Continuous belt	Wildpret et al. 1987
Mixed communities of *Gelidium arbuscula*, *G. versicolor* and *Cystoseira abies-marina*	G2	Rocky	70-100%	0-9 m 3-9 m	Continuous belt	Wildpret et al. 1987
Cystoseira abies-marina communities from the E and SE of Gran Canaria	C6	Rocky	0-50%	0-20 m	Continuous belt	Oral scientific communications

Table S3. – Percentages of the area and length of each sector according to human pressure. Pressure scores (PS) assigned to each pressure are indicated. Correlation coefficients (R^2) between pressures, turnover score (TS) and the HAPI index (HAPIj=Σ(PSi×ri)/TSj) were calculated according to Blanfuné et al. 2017.

Sector	Pressure	% Area	% Length	PS	R^2	TS	HAPI
1	Urban area	9.35		1	0.14	1.33	3.24
	Industrial area	27.91		3	0.31		
	Agricultural area	0		0	0.06		
	Coastal artificialization		44.74	3	0.68		
	Sewage outfall		43.46	3	0.4		
	Fish farm		0	0	0.15		
2	Urban area	72.15		3	0.14	1	5.48
	Industrial area	21.01		2	0.31		
	Agricultural area	0.04		2	0.06		
	Coastal artificialization		86.66	4	0.68		
	Sewage outfall		83.03	4	0.4		
	Fish farm		0	0	0.15		
3	Urban area	28.02		3	0.14	1	4.09
	Industrial area	24.93		1	0.31		
	Agricultural area	6.77		2	0.06		
	Coastal artificialization		19.07	3	0.68		
	Sewage outfall		49.29	3	0.4		
	Fish farm		0	0	0.15		
4	Urban area	25.03		2	0.14	1	3.58
	Industrial area	18.75		2	0.31		
	Agricultural area	34.54		2	0.06		
	Coastal artificialization		21.46	2	0.68		
	Sewage outfall		67.63	3	0.4		
	Fish farm		3.77	0	0.15		
5	Urban area	25.03		2	0.14	1	4
	Industrial area	18.75		2	0.31		
	Agricultural area	34.54		4	0.06		
	Coastal artificialization		21.46	2	0.68		
	Sewage outfall		67.63	3	0.4		
	Fish farm		6.77	2	0.15		
6	Urban area	2.1		1	0.14	1	2.81
	Industrial area	28.07		3	0.31		
	Agricultural area	41.16		4	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		34.56	3	0.4		
	Fish farm		7.09	2	0.15		
7	Urban area	10.31		2	0.14	1	0.83
	Industrial area	7.59		1	0.31		
	Agricultural area	40.97		4	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		0	0	0.4		
	Fish farm		0	0	0.15		
8	Urban area	6.71		1	0.14	1	4.55
	Industrial area	32.66		3	0.31		
	Agricultural area	31.55		4	0.06		
	Coastal artificialization		36.18	3	0.68		
	Sewage outfall		47.73	3	0.4		
	Fish farm		0	0	0.15		
9	Urban area	4.4		1	0.14	1	4.85
	Industrial area	28.19		3	0.31		
	Agricultural area	50.86		4	0.06		
	Coastal artificialization		34.83	3	0.68		
	Sewage outfall		32.88	3	0.4		
	Fish farm		13.57	2	0.15		
10	Urban area	2.02		1	0.14	1	3.13
	Industrial area	9.11		1	0.31		
	Agricultural area	12.61		2	0.06		
	Coastal artificialization		20.79	2	0.68		
	Sewage outfall		48.75	3	0.4		
	Fish farm		0	0	0.15		
11	Urban area	11.13		2	0.14	0.8	4.09
	Industrial area	0.84		1	0.31		
	Agricultural area	6.78		2	0.06		
	Coastal artificialization		20.171	2	0.68		
	Sewage outfall		68.83	3	0.4		
	Fish farm		0	0	0.15		
12	Urban area	59.95		3	0.14	0.8	4.19
	Industrial area	4.9		1	0.31		
	Agricultural area	0.93		1	0.06		
	Coastal artificialization		12.06	2	0.68		
	Sewage outfall		29.12	3	0.4		
	Fish farm		0	0	0.15		

Table S3 (Cont.). – Percentages of the area and length of each sector according to human pressure. Pressure scores (PS) assigned to each pressure are indicated. Correlation coefficients (R^2) between pressures, turnover score (TS) and the HAPI index (HAPIj=Σ(PSi×ri)/TSj) were calculated according to Blanfuné et al. 2017.

Sector	Pressure	% Area	% Length	PS	R^2	TS	HAPI
13	Urban area	8.28		1	0.14	0.8	3.83
	Industrial area	0.75		1	0.31		
	Agricultural area	58.21		3	0.06		
	Coastal artificialization		32.74	3	0.68		
	Sewage outfall		5.87	1	0.4		
	Fish farm		0	0	0.15		
14	Urban area	17.86		2	0.14	0.8	4.09
	Industrial area	7.29		1	0.31		
	Agricultural area	10.72		2	0.06		
	Coastal artificialization		14.05	2	0.68		
	Sewage outfall		71.96	3	0.4		
	Fish farm		0	0	0.15		
15	Urban area	12.97		2	0.14	0.8	4.44
	Industrial area	0.6		1	0.31		
	Agricultural area	0		0	0.06		
	Coastal artificialization		23	2	0.68		
	Sewage outfall		75.59	4	0.4		
	Fish farm		0	0	0.15		
16	Urban area	1.72		1	0.14	0.8	4.37
	Industrial area	0		0	0.31		
	Agricultural area	11.71		2	0.06		
	Coastal artificialization		29.74	3	0.68		
	Sewage outfall		33.16	3	0.4		
	Fish farm		0	0	0.15		
17	Urban area	0		0	0.14	0.8	0.075
	Industrial area	0		0	0.31		
	Agricultural area	5.67		1	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		0	0	0.4		
	Fish farm		0	0	0.15		
18	Urban area	0		0	0.14	1	0.06
	Industrial area	0		0	0.31		
	Agricultural area	4.3		1	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		0	0	0.4		
	Fish farm		0	0	0.15		
19	Urban area	0		0	0.14	1	0.06
	Industrial area	0		0	0.31		
	Agricultural area	4.37		1	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		0	0	0.4		
	Fish farm		0	0	0.15		
20	Urban area	2.34		1	0.14		1.8
	Industrial area	0		0	0.31		
	Agricultural area	22.39		3	0.06	1	
	Coastal artificialization		3.56	1	0.68		
	Sewage outfall		11.13	2	0.4		
	Fish farm		0	0	0.15		
21	Urban area	0		0	0.14	1.33	0.045
	Industrial area	0		0	0.31		
	Agricultural area	1.17		1	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		0	0	0.4		
	Fish farm		0	0	0.15		
22	Urban area	0		0	0.14	1.33	0.044
	Industrial area	0		0	0.31		
	Agricultural area	2.07		1	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		0	0	0.4		
	Fish farm		0	0	0.15		
23	Urban area	7.1		1	0.14	1.33	2.44
	Industrial area	3.16		1	0.31		
	Agricultural area	47.59		4	0.06		
	Coastal artificialization		0	2	0.68		
	Sewage outfall		0	3	0.4		
	Fish farm		0	0	0.15		
24	Urban area	10.44		1	0.14	1.33	1.93
	Industrial area	10.71		1	0.31		
	Agricultural area	41.45		4	0.06		
	Coastal artificialization		4.15	1	0.68		
	Sewage outfall		41.74	3	0.4		
	Fish farm		0	0	0.15		

Table S3 (Cont.). – Percentages of the area and length of each sector according to human pressure. Pressure scores (PS) assigned to each pressure are indicated. Correlation coefficients (R^2) between pressures, turnover score (TS) and the HAPI index (HAPIj=Σ(PSi×ri)/TSj) were calculated according to Blanfuné et al. 2017.

Sector	Pressure	% Area	% Length	PS	R^2	TS	HAPI
25	Urban area	14.98		2	0.14	1.33	1.53
	Industrial area	0.84		1	0.31		
	Agricultural area	59.7		4	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		45.91	3	0.4		
	Fish farm		0	0	0.15		
26	Urban area	5.33		1	0.14	1.33	1.42
	Industrial area	1.22		1	0.31		
	Agricultural area	39.31		4	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		62.18	3	0.4		
	Fish farm		0	0	0.15		
27	Urban area	14.55		2	0.14	1.33	2.55
	Industrial area	0.48		1	0.31		
	Agricultural area	45.37		4	0.06		
	Coastal artificialization		9.99	2	0.68		
	Sewage outfall		67.61	3	0.4		
	Fish farm		0	0	0.15		
28	Urban area	13.44		2	0.14	1.33	1.52
	Industrial area	5.98		1	0.31		
	Agricultural area	41.59		4	0.06		
	Coastal artificialization		0	0	0.68		
	Sewage outfall		42.19	3	0.4		
	Fish farm		0	0	0.15		