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Contribution to the Special Issue: "Ocean Literacy across the Mediterranean Sea region"

Support for the research and monitoring of marine algae: a study of Italian coastal users

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Abstract

Marine algae offer numerous extrinsic and intrinsic ecosystem services. Human impacts and climate change, however, have contributed to disrupting or compromising their ecology and distribution. Continuing research and monitoring of marine algae are pivotal but require public support. This study investigated public knowledge of and attitude towards marine algae and support for their research and monitoring. The focus was coastal users, a diversified group of interest for research into the perceptions of marine algae. The study was carried out in the Conero Riviera (Adriatic Sea, Italy), a location where coastal users come into contact with several types of marine algae. Semi-structured interviews were conducted in 2020 with 202 randomly selected scuba divers, beach and promenade visitors in the Riviera. Data analysis was thematic and statistical. Participants possessed basic knowledge of marine algae, which was more sophisticated among scuba divers. Coastal users ascribed both extrinsic and intrinsic values to marine algae. Most participants recognised the importance of protecting and managing marine algae while supported research and monitoring, prioritising types of marine algae which provide specific extrinsic and intrinsic ecosystem services. Based on the results, strategies of outreach, communication and engagement are suggested for the study location and types of coastal users. This study contributed to the growing body of research on Ocean Literacy, confirming the importance of investigating perceptions of marine resources to steer research, management and outreach strategies.

Keywords: Conero Riviera; Ecosystem services; Scuba diving; Beach recreation; Environmental education; Ocean Literacy; Citizen science; Macroalgae / Seaweeds.

Introduction

Marine algae are organisms that, despite their simplicity, underpin many complex processes of life on earth. They offer supporting, regulating, provisioning and cultural ecosystem services such as primary production, nitrogen fixation, nutrient cycling, water filtration, food, biodiversity, scientific value, and tourism (Chapman, 2013; Duffy *et al.*, 2019). Throughout history, humanity has been exploiting these services for disparate purposes, from harvesting for food, animal feed and fertilisers, to aquaculture, extracting alginates for the medical or cosmetic industries, biofuel production, and ecological monitoring (Gallardo, 2015; Mac Monagail *et al.*, 2017). The commercial use of marine algae supports multi-billion-dollar industries worldwide, with increasing production and exploitation (Jacquin *et al.*, 2014).

Expanding global human impacts and climate change have contributed to disrupting the ecology and distribution of marine algae, with detrimental consequences on the algae themselves, other living marine resources, marine ecosystems, human health and human activities. Examples of disruptions and imbalances include: a) ocean warming and acidification affecting the ecophysiology, lifecycle, zonation and biogeographic distribution of marine algae (Mancuso *et al.*, 2018); b) pollution altering water pH and compromising settlement, photosynthesis, growth and other processes in marine algae (Contreras-Porcia *et al.*, 2017); c) overharvesting and overfishing removing marine algae or resulting in cascade effects including increased herbivory of marine algae (Mac Monagail *et al.*, 2017; Pinna *et al.*, 2020); d) introducing marine algae into new areas, for example by maritime traffic (Orlando-Bonaca *et al.*, 2019; Najdek *et al.*, 2020); and e) harmful algal blooms caused by pollution and eutrophication (Griffith & Gobler, 2020).

The major ecological, economic and societal role of marine algae, their complexity and the threats potentially altering their ecology and distribution call for continued research fitting within the scope of the UN Decade of Ocean Science for Sustainable Development, as well as the Agenda 2030 and Sustainable Development Goals

(SDG) (Chapman, 2013; Gallardo, 2015; Claudet *et al.*, 2020; Cornish *et al.*, 2020; Largo *et al.*, 2020). New research and monitoring focusing on marine algae, however, necessitate public support (e.g., to unlock funding), calling for studies of public perceptions of and relations with marine algae (Jacquin *et al.*, 2014; Grattan *et al.*, 2016). Researchers are also advocating for improved Ocean Literacy resulting in modified attitudes and behaviours, for example, support for the consumption and monitoring of marine algae (Koutsopoulos & Stel, 2021).

On the one hand, knowledge of, public opinion about and attitudes towards marine algae can be poor and negative. For example, coastal users (e.g., bathers, anglers) and authorities in Western countries, often spurred by negative media framing, may share misperceptions of and ascribe wrong negative connotations to marine algae, using expressions like "nuisance", "toxic", and "invasive" to describe them, and not considering their value and fundamental ecological role (Chapman, 2013; Mouritsen, 2013). Chapman (2013) argued that since most people will never learn about algae as part of their education, awareness of them would probably arise from bad direct or indirect experiences leading to everlasting negative perceptions towards them. For example, large accumulations of cast-up marine algae on beaches can impair surfers and swimmers by blocking access to the water, they can cause the presence of "nuisance" animals like crows and gulls harassing beachgoers, and can result in substantial economic losses for tourism and expensive clean-ups (Lapointe & Bedford, 2007; Williams *et al.*, 2008). Phenomena like algal blooms and beach-cast green tides may be covered by the local and international media exclusively for their problematic effects on people and wildlife while ignoring the human roots of these phenomena (Guyomarc'h & Le Foll, 2011). This could result in misguidedly negative attitudes towards marine algae, ignorance of their complexity and importance, and socio-political conflicts between stakeholder groups with opposing views (e.g., scientists and farmers) (Le Chêne, 2012).

On the other hand, new applications in phycology are highlighting the contribution of marine algae to sustainable production and economic development, stimulating public appreciation for the historically vital role of marine algae and their potential to sustain future challenges of human development, health and societal wellbeing (Jacquin *et al.*, 2014; Largo *et al.*, 2020). Such appreciation is particularly important considering that marine algae tend to be less popular than other plant and animal species (Jacquin *et al.*, 2014). For example, Al-Thawadi (2018) found that young people were willing to consume products based on marine algae, especially when they perceived the health benefits of these products and had some knowledge of and familiarity with marine algae. Similarly, Palmieri & Forleo (2020) demonstrated that a large proportion of Italian residents were open to consuming marine algae, probably due to the familiarity with some traditional dishes, the spread of Asian gastronomy in Italy, and the perception that marine algae are healthy and sustainable food. A European study by Varela Villarreal *et al.* (2020) showed that the public believed algal biofuels could provide strong benefits compared with other biofuels and would become consumers if there was clear evidence of the benefits and communication of potential risks. Research has pointed out that coastal users, such as swimmers, runners and beachcombers, can appreciate the ecological importance and aesthetic qualities of marine algae and accept their presence, for example as cast-up wrack, along the coasts (Schiro *et al.*, 2017). Merkel *et al.* (2021) explained how in several northern European countries an industry around marine algae has emerged, ranging from consumption at restaurants, spa treatments and seaweed tours including harvesting marine algae and preparing dishes based on them, to water-based recreational experiences such as kayaking and scuba diving in kelp forests to enjoy rich underwater sceneries. Various works have also highlighted the active, positive role the public can play in researching and monitoring marine algae, including participatory monitoring or citizen science. Examples include public participation in the monitoring of alien species of marine algae, kelp forests and coralline algae (Gerovasileiou *et al.*, 2016; Cerrano *et al.*, 2017; Freiwald *et al.*, 2018; Mannino *et al.*, 2021).

Perceptions of marine algae are variable and influenced by factors such as socio-demographic parameters, use of marine resources (e.g., recreation, fishing) and algae species. For example, Gregg & Wells (2019) showed that knowledge and perceptions of macroalgae-derived fuels varied according to stakeholder type (e.g., industry stakeholders, policy stakeholders, the general public) and produced conflicting opinions. Kirkpatrick *et al.* (2014) described long-term residents in Florida as more concerned about red tides caused by fertiliser use than short-term residents who also made greater use of fertilisers. Also in Florida, Kuhar *et al.* (2009) found women and older people to be most concerned about the risks associated with harmful algal blooms. Local coastal residents and people who had experienced blooms perceived them as more frequent, longer-lasting and riskier to health than beach visitors, who perceived them as naturally occurring. Varela Villarreal *et al.* (2020) described young people and people with high educational backgrounds in Europe as more inclined to believe that using algal biofuels would reduce environmental impact, although people with high educational backgrounds were also more sceptical about some environmental benefits (e.g., reduction in greenhouse gas emissions) and prioritised transparent communication on algal biofuel risks and benefits.

Aim of the study

Given their variability, public knowledge of and attitude towards marine algae require further enquiry, to steer strategies aimed at attaining or maintaining endorsement to research, monitor and manage marine algae. This study aimed to contribute to understanding public knowledge of and attitude towards marine algae and support for their research and monitoring. People using the coast are an interest group for research on the perceptions of marine al-

gae (Kuhar *et al.*, 2009; Schiro *et al.*, 2017; Merkel *et al.*, 2021). They include various stakeholders (e.g., beachgoers, scuba divers, regular visitors) with different views that could affect how support for research, monitoring and management of marine algae is shaped. For example, recreational scuba divers may value marine algae as a tourism offering, and be willing to contribute to their monitoring to assess ecological change in coastal environments (Cerrano *et al.*, 2017; Lucrezi, 2021; Merkel *et al.*, 2021). Consequently, this study specifically focused on answering the following research questions: What are coastal users' general knowledge of and attitudes towards marine algae, their research and monitoring? Do knowledge and attitude differ according to coastal use and other demographic parameters? What are the implications of coastal users' perceptions for the research, monitoring and management of marine algae?

Materials and Methods

Case study location

The selected location for this research was the Conero Riviera, in the north-western Adriatic Sea, central Italy (Fig. 1). It includes a stretch of rocky coast approximately 20 km long, starting at the city of Ancona and ending south of the town of Numana, covering the Conero promontory as well as several coastal villages. The Riviera is popular for coastal tourism and recreation such as swimming, diving, boating, and fishing (Rindi *et al.*, 2020).

A comprehensive study by Rindi *et al.* (2020) into the number of documented species of macroalgae in the Riviera found 133 current species of Chlorophyta, Ochrophyta and Rhodophyta. The authors described how anthropogenic stressors over the last 70 to 80 years, such as urbanisation, tourism, hard engineering and sediment runoff, have contributed to the impoverishment of macroalgal flora and the disappearance of various species from the Riviera. Meanwhile, new non-indigenous species have been recorded (probably transferred from the Lagoon of Venice which is subject to intense maritime traffic). There are some species of marine algae occurring in the Riviera (Fig. 1), which in this study were hypothesised to be known by the general coastal user. An example is the dinoflagellate *Ostreopsis ovata*. Its toxic blooms in August-September – the bathing season (Accoroni *et al.*, 2012) – have caused beaches to be closed to bathing (Tarabelli, 2017; Napolitano, 2018). Another example is the green alga *Ulva*, commonly called sea lettuce, which is often found floating in bathing areas and is a habitat to species of value for recreational diving and harvesting (Bulleri & Airoldi, 2005; Palmieri & Forleo, 2020). The canopy-forming brown algae of the genus *Cystoseira* are important ecosystem engineers along rocky shores. Highly vulnerable to anthropogenic stressors, they represent useful ecological indicators of water and ecosystem quality based on the Water Framework Directive (2000/60/EC) (Mancuso *et al.*, 2018). Recreational divers have been monitoring *Cystoseira* using protocols of citizen science in the Mediterranean Sea, such as Reef Check (Mannino *et al.*, 2021).

Research design, data collection and analysis

This study used a semi-structured interview to collect data, thus allowing members of the study community to freely voice their opinions (Yin, 2011). The interview targeted three different groups, namely scuba divers, beach visitors, and people walking along the promenade. Face validity of the interview questions (i.e., where experts analyse the questions and conclude that these will seemingly measure the concept that the researcher wants to measure) involved two marine biologists with knowledge of marine algae, two social scientists working on recreation segments, and one statistician with expertise in question construction. The interview comprised 11 open-ended questions. These were grouped into four sections covering demographic profile, knowledge of marine algae, attitude towards marine algae, and attitude towards

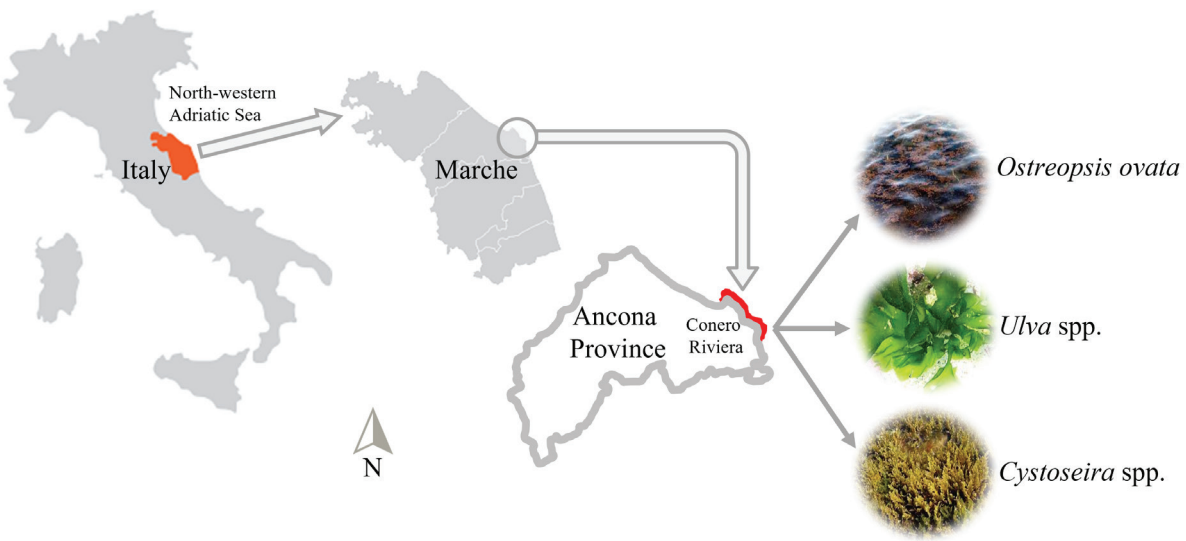

Fig. 1: Location of the study (Conero Riviera) on the north-western Adriatic coast, with examples of marine algae found locally.

research and monitoring of different types of marine algae (e.g., toxic ones, those used for food and aquaculture) (Table 1).

Fieldwork was carried out from August to October 2020 coinciding with the summer and autumn months, during both weekdays and weekends. This approach was used to avoid the potential effects of seasonality or day of the week on the final sample. Data were collected following COVID-19 safety protocols of social distancing. During a typical sampling day, between 09:00 and 18:00, two trained fieldworkers randomly approached people at local dive centres, beaches and promenades along the Conero Riviera, introducing themselves as part of a study on public perceptions of marine algae, and inviting them to participate in a 20-minute verbal interview. Agreeing people were provided with an informed consent letter and asked to be audio-recorded. Interviews took place in a comfortable environment, with participants sitting at the dive centre, beach or promenade benches. All interviews were conducted in Italian. At the end of the interview, participants who wished to obtain more information were provided with a QR code to a brochure on marine algae including local species.

The fieldworkers transcribed all interviews *verbatim* in Microsoft Word immediately after conducting them, with the author checking the quality of transcriptions, translating them into English, and analysing data to look for saturation (Sandelowski, 2010). Data saturation was achieved when approximately 50 participants per category (i.e., scuba divers, beach visitors, promenade visitors) were interviewed. As an additional confirmation of data saturation, sampling continued until approximately 70 participants per category were included.

Questions requiring participants to provide numerical or categorical responses were transferred to Microsoft Excel while those requiring participants to provide descriptions and opinions were subject to thematic analysis. Specifically, all answers to a given question (e.g., What is your general opinion of marine algae?) were pooled and analysed using *in vivo* open coding. Codes were extracted, kept in a master list, reapplied to similar segments of text, and grouped into broader themes which were transformed into dummy variables in Microsoft Excel (for each theme: 0 = not mentioned, 1 = mentioned by the respondent). All variables were transferred to the software TIBCO Statistica (Version 13.3, 2017) for further analysis. Basic statistics included frequency tables or averages. Statistical differences in the data between the three coastal user categories (i.e., scuba divers, beach visitors, promenade visitors) were calculated using cross-tabulations (Pearson's χ^2) and one-way ANOVA (ensuring variables met assumptions of normality and homogeneity of variance). Correspondence analysis was used to produce a simplified, two-dimensional representation of the main data frequencies, enabling visualisation of the correspondence between the main variables and between the three groups of coastal users. Finally, Spearman rank-order correlations (r_s) were computed to assess significant relationships between demographic parameters and the remaining variables (knowledge of marine algae, attitude towards marine algae, and attitude towards marine algae research and monitoring).

Table 1. Semi-structured interview questions.

Section A: Demographic profile
What is your: gender, age, highest level of education?
Do you live on the coast or inland?
Section B: Knowledge of marine algae
Where have you first heard of or come into contact with marine algae?
Do you know what are marine algae?
What are the types or categories of marine algae you can think of?
Do you know the difference between marine algae and higher plants like the *Posidonia* seagrass?
Section C: Attitude towards marine algae
What is your general opinion of marine algae?
Are there any threats to marine algae?
Do marine algae deserve protection and if so, what could be done to protect them?
Section D: Attitude towards research and monitoring of marine algae
Do marine algae need research and monitoring – e.g., collecting data about their distribution – and why?
Please select the order in which you think these marine algae types should be researched and monitored and explain why:
• Algae that are used for food and aquaculture (like the nori that you eat with your sushi)
• Algae that are used for medicinal purposes (e.g., *Sargassum*)
• Algae that are used for the cosmetic industry (e.g., skin care)
• Algae that are considered harmful or toxic to people and other marine species (e.g., harmful algal blooms)
• Algae that are defined "constructors" of reef-like ecosystems, or are symbiotic with species like coral (e.g., corallines)
• Algae that are popular in tourism (e.g., kelp forests)
• Other types of algae that are not in the categories above

Study limitations

The limitations of this study must be considered in the interpretation of the findings and planning future research. For example, the study only considered coastal users, offering a limited perspective on public perceptions of marine algae. Some groups including fishers were simply not accessible, limiting the general representation of coastal users. The study location was a circumscribed area on the coast of Italy, offering a limited geographic perspective internationally and nationally. Influential variables may have been excluded from this study, resulting in the generation of only partial information on the social support for marine algae research and monitoring. It is still believed that the study contributed to a better understanding of the *status quo* about public knowledge and opinion of marine algae and support for their research, monitoring and management.

Results

Demographic profile

A total of 202 people participated in this study: 67 scuba divers, 66 beach visitors and 69 promenade visitors. Their demographic profile is represented in Table 2. Participants comprised half males and half females except for the scuba divers who were mostly males (75%). Their age ranged from 18 to 86; promenade visitors, who were on average in their late thirties, were significantly younger than the remaining groups, who were in their mid-forties. Participants' highest level of education was the equivalent of high school for 60% and tertiary for 40% of the scuba divers and beach visitors, while roughly half of the promenade visitors had high school and the other half university education. Most participants resided along the coast at the case study location, while 22-36% resided inland and were visiting the coast at the time of the study.

Knowledge of marine algae

Participants had heard about or come into contact with marine algae in similar ways across the three groups (Fig. 2a), mentioning primarily experiences at sea or on the coast (45%) followed by biology education at school or university (31%). Other ways of contact were the media (e.g., books, documentaries), daily living (e.g., eating seaweed) and interactions with people (family, friends and fishers). Although most participants claimed to know what marine algae are (Fig. 2b), proportions differed significantly between the three groups (Pearson's $\chi^2 = 12.56$, $p = 0.002$), with 91% of scuba divers, 85% of beach visitors and 68% of promenade visitors claiming to know. More males than females claimed to know what marine algae are ($r_s = 0.17$, $p < 0.05$). Participants who made the claim described marine algae in similar ways across the three groups (Fig. 2b). Half of them simply stated that marine algae are a form of vegetation. About 20% described them in terms of their function in primary and secondary production, carbon sequestration, water filtration or indicating ecological imbalance (e.g., toxic algal blooms). Four per cent described them according to classification, mentioning that algae are protists, that they can be unicellular or multicellular, or that they include various phyla. The remaining participants described them as a plant (12%), an organism (11%), or provided an unclear definition (3%).

When asked to think of types of marine algae (Fig. 3a), most participants (78-88%) categorised them according to provisioning services, especially food and raw material for the health and cosmetic industry. A significantly greater proportion of scuba divers (50%) compared with beach and promenade visitors (Pearson's $\chi^2 = 9.27$, $p = 0.01$) listed types based on phyla (e.g., red, green, brown), complexity (i.e., unicellular microalgae versus multicellular macroalgae), or species found at the study location (*Ulva*, *Cystoseira*, *Sargassum*, *Padina*). Significantly more scuba divers (31%) than the other groups, more beach visitors than promenade visitors (Pearson's $\chi^2 = 7.83$, $p = 0.02$), and older than younger people ($r_s = 0.17$,

Table 2. Basic statistics of the participants' demographic profile (N = 202).

Variable	Category	Scuba divers (n = 67)	Beach visitors (n = 66)	Promenade visitors (n = 69)	*p*
Gender	Male	75%	50%	46%	0.001[a]
	Female	25%	50%	54%	
Age	Mean	43.5	45.4	38	0.02[b]
	Min-Max	20-70	18-86	18-77	
	SD	14	18	16	
	SE	1.7	2.3	1.9	
Education	High school	61%	59%	49%	0.33[a]
	Tertiary	39%	41%	51%	
Living on coast	Yes	72%	78%	64%	0.17[a]
	No	28%	22%	36%	

[a] Pearson's χ^2; [b] One-way ANOVA

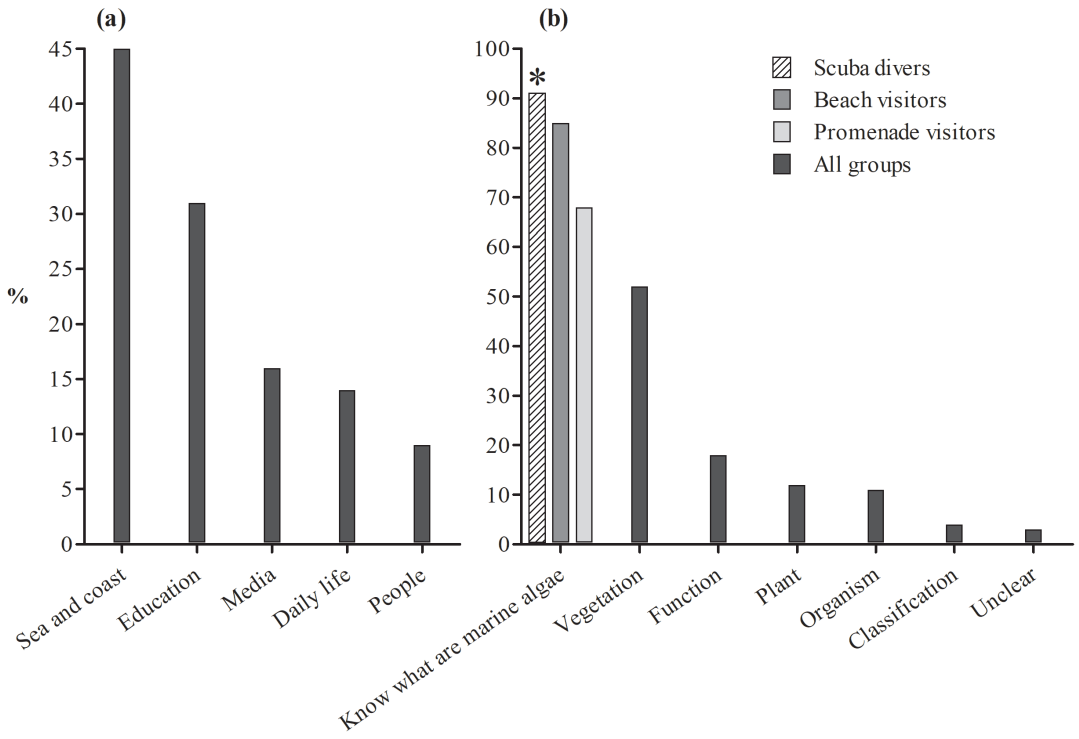

Fig. 2: Themes extracted from participants' descriptions of how they came in contact with marine algae (a), and self-reported knowledge and descriptions of marine algae (b). Asterisks denote significantly different percentages between scuba divers, beach visitors, and promenade visitors.

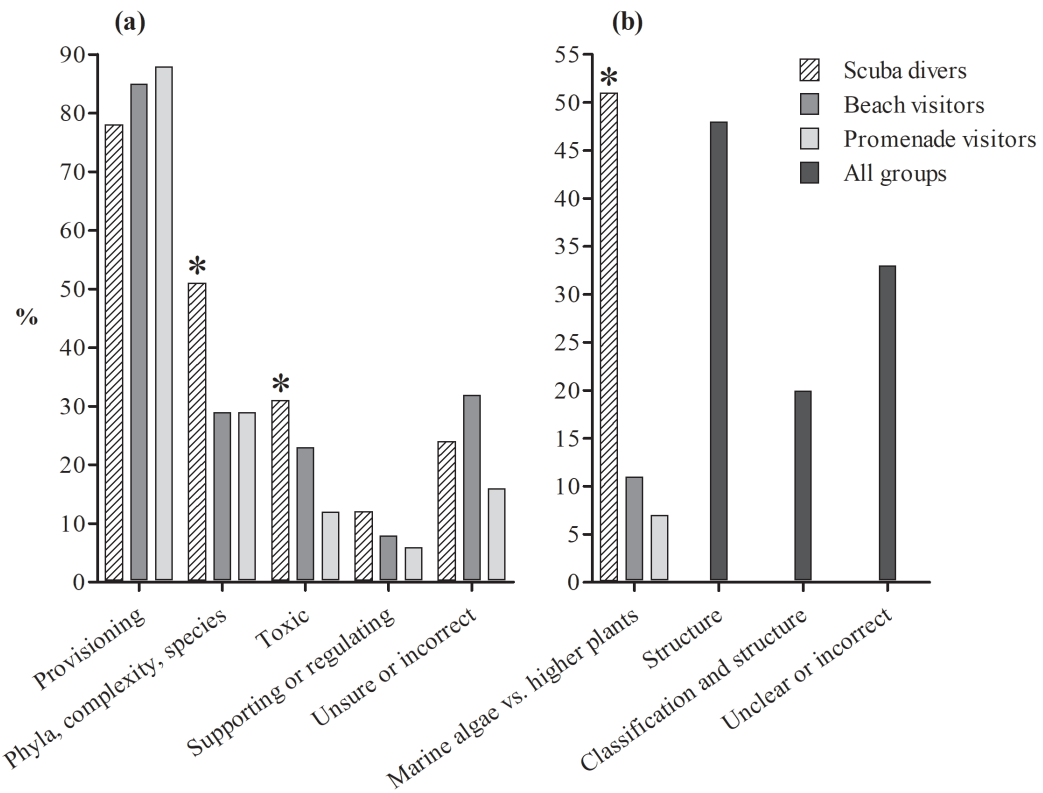

Fig. 3: Themes extracted from participants' categorisation of marine algae (a), and self-reported knowledge of the difference between marine algae and higher plants (b). Asterisks denote significantly different percentages between scuba divers, beach visitors, and promenade visitors.

$p < 0.05$) mentioned potentially harmful algae including *O. ovata* (which participants referred to as "the red toxic alga") and harmful algal blooms. A small percentage (6-12%) listed marine algae according to supporting and regulating services including primary production, habitat and water filtration. Several participants (16-32%) were unsure of different types of marine algae or provided incorrect types. Those who were unsure were mainly beach and promenade visitors. Those who provided incorrect answers included people from all three groups, who listed the seagrass *Posidonia oceanica* as a type of marine alga, as well as the anemone *Anemonia viridis*, and mucilage which is a polysaccharide produced by both algae and plants. Mucilage was perceived to be a type of potentially harmful algal bloom.

When asked specifically about the difference between marine algae and higher plants like *P. oceanica* (Fig. 3b), half of the scuba divers claimed to know the difference as opposed to only 11% of beach visitors and 7% of promenade visitors (Pearson's $\chi^2 = 44.83$, $p < 0.001$). More males than females claimed to know the difference ($r_s = 0.16$, $p < 0.05$). Of those who made the claim, half described the difference in terms of structure, mainly explaining how higher plants have roots, a stem or trunk and leaves, while algae lack these. An additional 20%, who were all scuba divers, added a differentiation by classification, explaining that algae are not in the plant kingdom. About a third provided unclear or incorrect differences, for example, the misconception that algae are exclusively unicellular, aquatic and not photosynthetic.

Attitude towards marine algae and their research and monitoring

Most participants (58-71%) held positive opinions of marine algae linked with extrinsic values, mainly the use of marine algae in the food, health and cosmetic industry, but also their importance as primary producers supporting life on earth (Fig. 4). According to 18-30% of participants, harvesting marine algae for various purposes had to be sustainable in order not to cause damage; older people were less concerned about this issue ($r_s = -0.20$, $p < 0.05$), while people with tertiary education were more concerned ($r_s = 0.17$, $p < 0.05$). Between 22% and 30% of participants expressed opinions linked to intrinsic values, supposing that marine algae would be important for marine life and ecosystems but not necessarily being able to explain how. Compared with the remaining groups (Pearson's $\chi^2 = 6.38$, $p = 0.04$), more scuba divers (22%), males and older people ($r_s = 0.16$, $p < 0.05$) expressed concern related to the potential harm of toxic algae, algal blooms and invasive algae to human health (e.g., skin irritation, breathing problems) and marine species (e.g., suffocation, displacement). Some participants, particularly among the promenade visitors (20%), did not have any opinion of marine algae.

When asked about potential threats to marine algae (Fig. 5a), the majority of participants from all three groups (72-75%) claimed that water pollution including wastewater discharge and eutrophication could make algae problematic by causing excessive growth, while

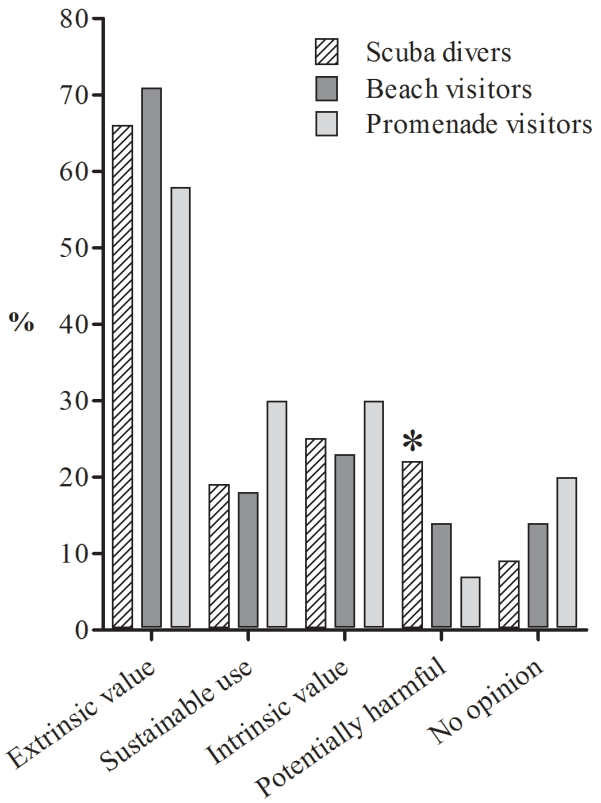

Fig. 4: Themes extracted from participants' opinion of marine algae. Asterisks denote significantly different percentages between scuba divers, beach visitors, and promenade visitors.

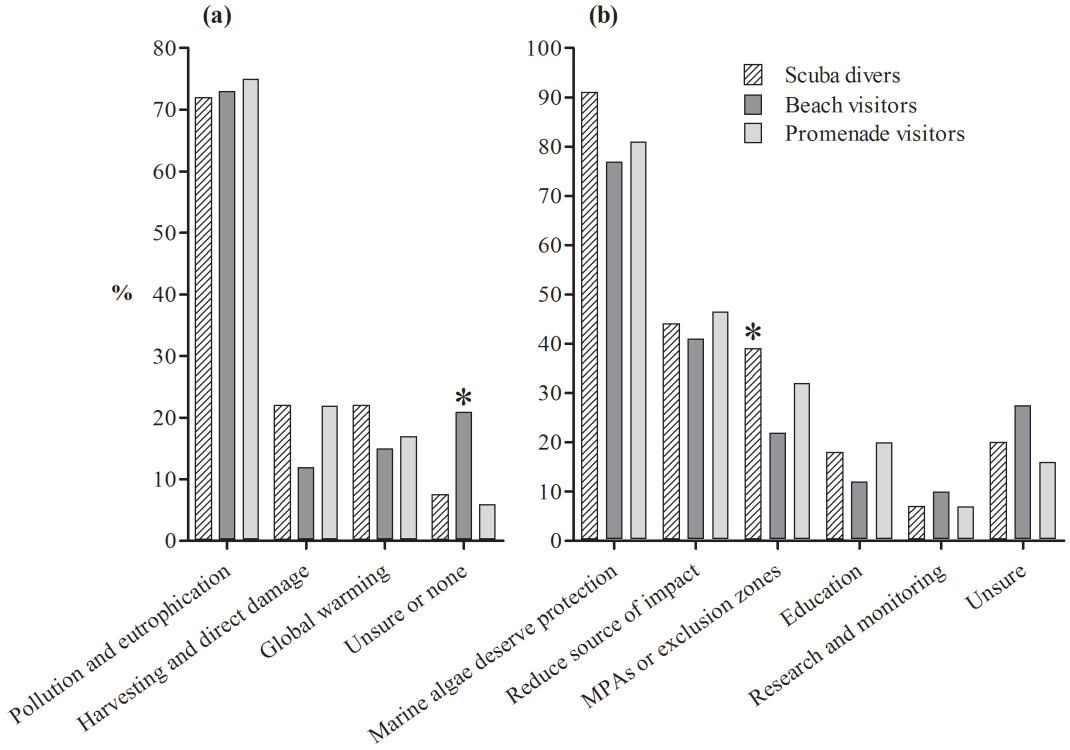

Fig. 5: Themes extracted from participants' perceptions of threats to marine algae (a), and perceptions of whether and how marine algae deserve protection (b). Asterisks denote significantly different percentages between scuba divers, beach visitors, and promenade visitors

chemical pollution including hydrocarbons could impair photosynthesis or kill algae. Harvesting and direct damage (e.g., by bottom trawling) were discussed as potential threats especially by scuba divers and promenade visitors (around 20%). Between 15% and 22% of participants, especially people with tertiary education ($r_s = 0.17$, $p < 0.05$), argued that global warming, and in particular rising sea temperatures, would cause uncontrolled algal growth, or stress, death and change in the distribution of marine algae. In comparison with the other groups, more beach visitors (21%) did not know what could threaten marine algae (Pearson's $\chi^2 = 9.47$, $p = 0.01$).

Most participants (77%-91%) agreed that marine algae generally deserve protection (Fig. 5b). Approximately half of these people across the three groups mentioned that it would be necessary to reduce pollution, eutrophication and greenhouse gas emissions potentially affecting sea temperatures. Significantly more scuba divers (39%) compared with the remaining groups (Pearson's $\chi^2 = 6.30$, $p = 0.04$) believed that marine protected areas or special zones excluding human use would help preserve marine algae. Between 12% and 20% of participants believed that public education would raise awareness of marine algae and ultimately generate support for their conservation. Around 10% mentioned that research and monitoring would improve understanding of marine algae and ways to protect them. Several participants, especially among beach visitors (27.5%) and older people ($r_s = 0.16$, $p < 0.05$), were unsure how marine algae could be protected.

The majority of participants (68% promenade visitors to 91% scuba divers) agreed that marine algae should be researched and monitored, providing reasons in similar percentages across the three groups (Fig. 6a). Around 40% argued that marine algae could indicate ecosystem health in response to stressors like pollution and rising temperatures. Some 30% believed that research and monitoring would allow further study of marine algae and their properties. About a quarter justified research and monitoring of marine algae to ensure the delivery of extrinsic ecosystem services including primary production and raw material. A similar proportion explained that marine algae need research and monitoring to guarantee intrinsic services such as biodiversity and to best plan for

Table 3. One-way ANOVA comparing the average ranking of various types of marine algae according to research and monitoring importance between the three groups of participants (scuba divers, beach visitors, promenade visitors).

Type of marine algae	$F_{(df, error)}$	*p*
Constructors	$5.67_{(2, 195)}$	0.004
Health and medicine	$2.58_{(2, 194)}$	0.08
Toxic	$0.21_{(2, 195)}$	0.81
Food and aquaculture	$0.66_{(2, 194)}$	0.52
Tourism	$0.43_{(2, 194)}$	0.65
Cosmetics	$0.22_{(2, 194)}$	0.80

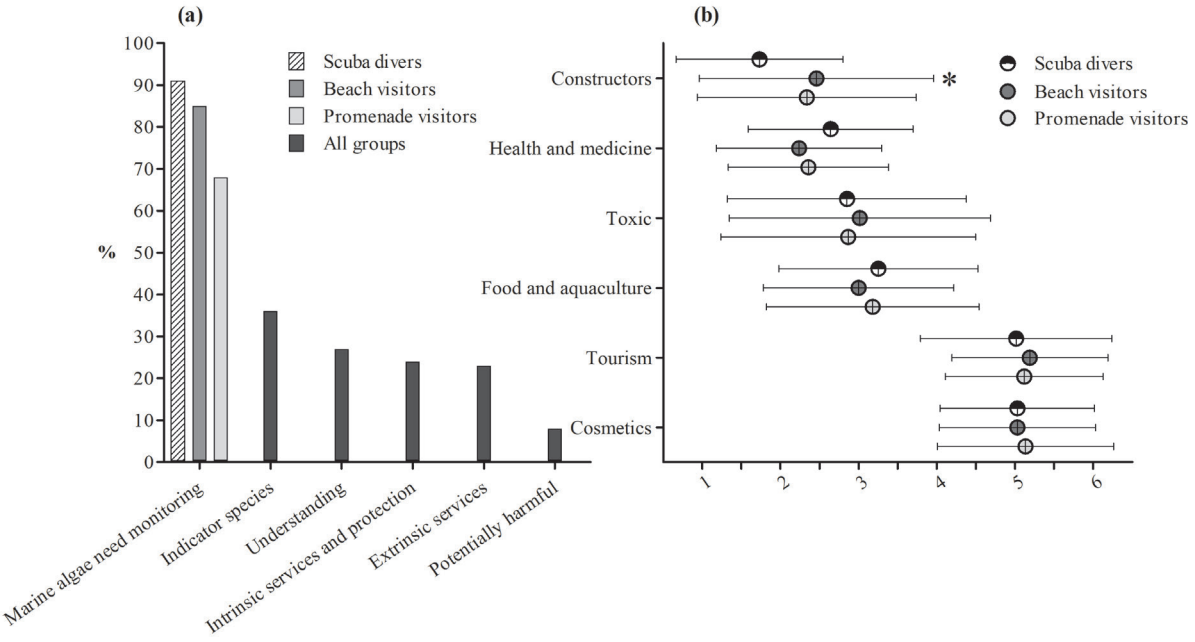

Fig. 6: Themes extracted from participants' perceptions of whether and why marine algae need to be researched and monitored (a), and average ranking of various types of marine algae according to research and monitoring importance (b). Asterisks denote significantly different averages between scuba divers, beach visitors, and promenade visitors.

their protection. Less than 10% argued that it is important to research and monitor potentially harmful algae to "keep them under control".

The ranking of different types of marine algae according to research and monitoring importance was similar across the three groups (Table 3; Fig. 6b). The only exception was that scuba divers and people living on the coast (r_s = 0.22, $p < 0.05$) prioritised research and monitoring of constructor and symbiotic algae over those used for health and medicine, while beach and promenade visitors gave similar importance to both types (Table 3). Constructor and symbiotic algae were on average ranked either first or second, because they were understood to be essential in creating or sustaining marine habitats and ecosystems. Marine algae used in the health and medical industry were prioritised for their perceived potential to improve human health. Toxic algae and algae used in the food and aquaculture industries were, on average, respectively placed third and fourth. Females gave more importance to the research and monitoring of toxic algae (r_s = 0.19, $p < 0.05$). They also gave less importance to algae used in the food and aquaculture industries (r_s = -0.18, $p < 0.05$), while older people and people living on the coast gave more importance to them (r_s = 0.33 and 0.23, $p < 0.05$). Marine algae considered of least research and monitoring importance included those supporting tourism and used in the cosmetic industry. Participants justified this choice by arguing that marine algae are unimportant in tourism and that the cosmetic industry is either negative or not as relevant as other industries like health and food. Four people (two promenade visitors, one beach visitor and one scuba diver) added that algae usable as biofuels would be worth studying and monitoring.

General distinction between coastal user groups

A visual representation of data frequencies for variables of knowledge and attitude, and the three groups of participants, based on correspondence analysis, is provided in Figure 7. The total variance explained by the two dimensions in the graph is 100%, with the horizontal dimension explaining most (65%) of the variance in the data.

Scuba divers, placed on the right of the graph's origin, represented a unique group compared with beach and promenade visitors, placed on the left of the graph's origin. They possessed better knowledge of marine algae and slightly more sophisticated opinions about specific threats to marine algae and mitigation solutions. While beach visitors were generally less knowledgeable about marine algae, focusing on their potential harm and their extrinsic value, they still supported their research and monitoring. Promenade visitors were a mixed group who did not necessarily have an opinion of marine algae, but those who did, ascribed intrinsic values and identified important threats to marine algae, as well as solutions to enhance protection, such as public education.

Discussion

Knowledge of marine algae

Overall, study participants possessed some basic knowledge of marine algae, with evident gaps, echoing literature outlining the general orientations and challenges in public knowledge and understanding of marine

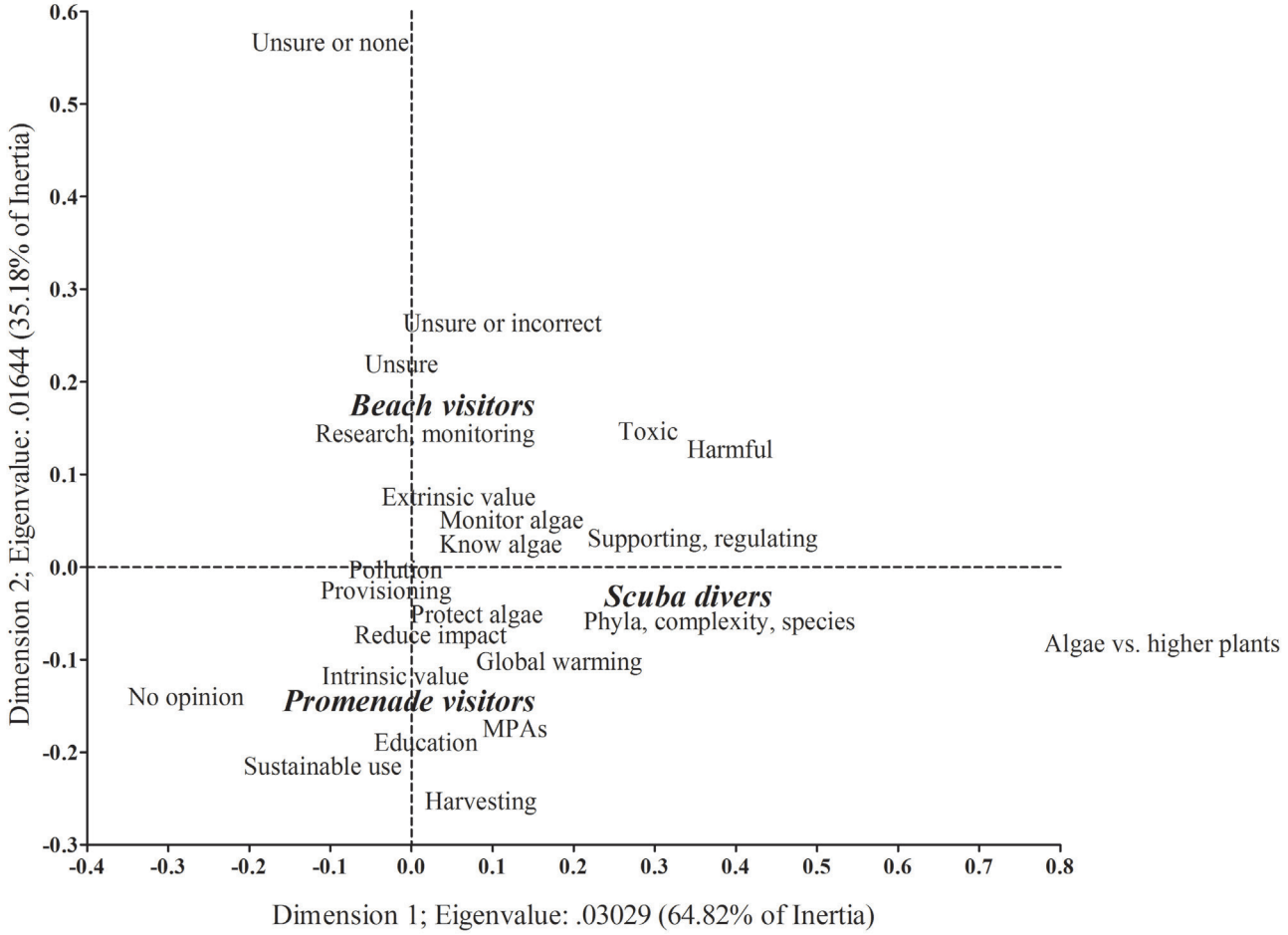

Fig. 7: Ordination biplot of the correspondence between scuba divers, beach visitors and promenade visitors, and between main variables of knowledge of and attitude towards marine algae and their research and monitoring.

algae (Guyomarc'h & Le Foll, 2011; Le Chêne, 2012; Chapman, 2013; Mouritsen, 2013). People may focus on extrinsic properties of marine algae because of their commodification in the food and health industry, or on negative properties because of extensive media coverage of phenomena like harmful algal blooms (which are recurrent in the study location). Meanwhile, they may not fully comprehend the value and fundamental ecological and societal role of marine algae.

The results of this study are also positive in that participants had come into contact with marine algae mainly by personal experience but also education; this could have contributed to enhancing knowledge among some beyond the basic understanding that marine algae are a form of vegetation and not the same as higher plants like seagrasses. Research has demonstrated the critical role of personal experience and education in shaping public understanding of marine algae (Redfern *et al.*, 2013; Skukan *et al.*, 2020). This understanding could lead to the support for research on marine algae, for example, those useful as biofuels or in the food industry (Al-Thawadi, 2018; Varela Villarreal *et al.*, 2020), and for sustainably managing marine algae, for example, those with ecological value as cast-up wrack (Schiro *et al.*, 2017).

In this study, knowledge and understanding depended on coastal user type. Scuba divers stood out as the group with the most sophisticated knowledge. Research has confirmed the positive relationship between the level of coastal use and marine environmental knowledge (Wiener *et al.*, 2016; Portman & Camporesi, 2020). Beach use may be associated with better awareness of specific types of algae, such as those that are cast up as wrack, those that are normally found in surf and intertidal zones, and those that are toxic to bathers (Alves *et al.*, 2014). Going underwater, scuba divers are likely to possess a greater awareness of other species of marine algae, such as constructors of coralligenous reefs, invasive algae (e.g., *Caulerpa*), ecological indicators like *Cystoseira*, and marine algae popular in tourism including kelps (Cerrano *et al.*, 2017; Lucrezi, 2021; Mannino *et al.*, 2021). It must be noted that, regardless of coastal use, age may play an important role in greater awareness of recurrent phenomena including harmful algal blooms (Kuhar *et al.*, 2009), and this may be a reason why older people in this study were more familiar with the toxic dinoflagellate *O. ovata*.

Attitude towards marine algae and their research and monitoring

Participants in this study mainly ascribed positive and direct and indirect extrinsic values to marine algae,

focusing on their potential exploitation in the food and health industries, a topic which is increasingly discussed in European scientific and policy reports as well as the literature in general (Enzing *et al.*, 2014; Palmieri & Forleo, 2020). This result is also confirmed in studies emphasising increasingly positive public opinions of marine algae especially as the source of alternative and sustainable food and health products (Jacquin *et al.*, 2014; Al-Thawadi, 2018; Palmieri & Forleo, 2020). The positive opinions of participants were supported by beliefs that marine algae deserve protection and management, and an understanding of and concern for anthropogenic stressors affecting marine algae, particularly pollution. These concerns match what are generally known to be critical stressors on marine algae (Grattan *et al.*, 2016; Mancuso *et al.*, 2018; Griffith & Gobler, 2020).

The perceptions that emerged in this study had been encountered before in research on the values ascribed to marine algae, which showed a growing public appreciation for the foundational role of marine algae in earth's history, as well as wider acknowledgement of the ecological role of marine algae beside supporting human life (Jacquin *et al.*, 2014; Schiro *et al.*, 2017). This outcome may be the result of a mixture of factors, such as more personal experiences of marine algae, pollution and algal blooms, better exposure to education on marine algae, the introduction of marine algae as consumable products in the food and health industry, and more positive framing of marine algae in mainstream media (e.g., as biofuels or negatively affected by human impact) (Redfern *et al.*, 2013; Palmieri & Forleo, 2020; Skukan *et al.*, 2020).

The participants ascribing to marine algae some intrinsic value is in line with research showing that coastal users' opinions of marine algae are not limited to extrinsic value but extend to ecological and biodiversity values (Schiro *et al.*, 2017; Merkel *et al.*, 2021). However, a proper appreciation of these and other values, such as cultural ones, calls for better communication and education. The dynamics by which marine algae contribute towards ecosystems and species would then be well understood, and people could create connections between marine algae and other intrinsic ecosystem services, for example, their role in the Italian culinary tradition, or tourism and recreation (Chapman, 2013; Palmieri & Forleo, 2020; Merkel *et al.*, 2021). Paradoxically, only a small percentage of participants in this study considered public education a useful tool in protecting marine algae. However, promenade visitors – the group least knowledgeable of marine algae – gave particular importance to education, probably recognising their lack of knowledge and consequently thinking of education as the best way for people to first understand and then appreciate and act with respect towards marine algae.

Among some participants, particularly youth, people with tertiary education and divers, opinions that marine algae possess extrinsic values were accompanied by concerns for their sustainable harvesting. Higher education also resulted in more sophisticated perceptions about the putative effects of global warming on marine algae. These are real concerns also among scientists (Mac Monagail *et al.*, 2017; Duffy *et al.*, 2019). Research has shown that the younger generations and people with a higher educational level are more likely to possess better awareness of certain marine environmental problems, possibly as a result of increased Ocean Literacy and exposure to more and detailed information about these problems (Varela Villarreal *et al.*, 2020; Forleo & Romagnoli, 2021).

Scuba divers also distinguished themselves from other coastal users for their concern regarding the potential harm of various types of marine algae (e.g., toxic, invasive) to human health and marine species, as well as beliefs that marine protected areas and exclusion zones would effectively contribute to the protection of some marine algae. Attachment to diving, as well as diving in locations like marine protected areas, may lead to a greater understanding of marine ecosystems and concern for their wellbeing, potentially leading to divers being suitable sentinels of environmental change (Wiener *et al.*, 2016; Cerrano *et al.*, 2017; Freiwald *et al.*, 2018).

Only one-tenth of participants stated that research and monitoring could serve a purpose in protecting marine algae. However, when asked further, most agreed that marine algae should be researched and monitored, and provided several other justifications aside from protection. These results indicate that coastal users not only correctly identify several key characteristics of marine algae (e.g., sentinels of change, poorly studied) (Gallardo, 2015; Grattan *et al.*, 2016; Ingrosso *et al.,* 2018; Rindi *et al.*, 2019), but also support their research and monitoring based on these characteristics. Given the similarity of these opinions across the three groups studied, the results show that support for research and monitoring of marine algae could be indiscriminate and independent of the level of coastal use.

Concerning the types of marine algae that should be researched and monitored, the rankings provided by participants reflected their attitudes. Species with both specific extrinsic and intrinsic values were prioritised, including those that can be used in medicine and constructor or symbiotic species supporting habitat creation and biodiversity (Mac Monagail *et al.*, 2017; Rindi *et al.*, 2019; Largo *et al.*, 2020). These results suggest that supporting research and monitoring of marine algae depends on their perceived essential extrinsic and intrinsic value. Scuba divers and people living on the coast tended to be slightly more supportive of research and monitoring of constructive species, possibly as a result of a better understanding of the role of these species and more personal experiences with these, such as scuba diving in habitats formed by coralligenous biocenoses which are very common in the Mediterranean Sea (Cerrano *et al.*, 2017).

Interestingly, participants were not particularly concerned with the research and monitoring of marine algae providing cultural ecosystem services including tourism. This outcome is at odds with research demonstrating growing public interest in seaweed tourism, at least among divers and also in countries where seaweed is abundant, like Sweden (Lucrezi, 2021; Merkel *et al.*, 2021). The perceptions of participants could have been due to a general lack of knowledge of the relevance and

versatility of marine algae in tourism, as well as the absence in Italy of charismatic species of seaweed such as giant kelp, which is highly attractive in diving tourism (Freiwald *et al.*, 2018; Lucrezi, 2021).

Implications for research and monitoring of marine algae, public involvement and Ocean Literacy

The main outcome of this study, namely the coastal users' support for marine algae research and monitoring, can be considered an indication of a social licence to operate in various spheres of marine algae research and monitoring. Kelly *et al.* (2017) described social licence in the marine sector as an act of society providing unwritten permission to other parties to use and manage a marine resource. It can influence policymaking and regulations involving marine resources (Boutilier, 2014). It can also identify gaps in society's knowledge of marine resources and opportunities for improved communication and education to achieve sustainable use and management (Kelly *et al.*, 2017). The parties requiring social license are responsible for establishing channels of engagement and communication with communities from which it must be obtained and ensuring that the outcomes of actions requiring social licence are made known to these communities after implementation (Kelly *et al.*, 2017). In this regard, two important considerations emerge from this research.

The first consideration is that social licence to research and monitor marine algae should lead to wider public involvement in research and monitoring actions, including education and citizen science. Public education of marine algae can take many shapes (e.g., learning material in books, experiential learning activities) and be coordinated by different role-players (e.g., school teachers, non-profit organisations) (Redfern *et al.*, 2013). The selected study location, the Conero Riviera, offers multiple opportunities to boost public education about marine algae, which could include dedicated campaigns launched and coordinated by stakeholders such as the local university (the Polytechnic University of Marche), local non-profit groups (e.g., "Il Pungitopo"), regional territorial authorities (e.g., Conero Regional Natural Park), and local dive centres. This study showed that, while coastal users are aware of various species and phenomena locally, their knowledge could be improved. For instance, a greater focus could be placed on the ecology of toxic *O. ovata*, invasive species and their characteristics, species of relevance as indicators of sea health, the ecology of the cast-up wrack, the difference between marine algae and higher plants including seagrasses or other seaweed "look-alikes", and important species of marine algae in the Italian cultural tradition. The managing authorities of the Conero Regional Natural Park have already shown themselves adept at securing significant funding for environmental education campaigns targeting residents, schools and tourists (Redazione Centro Pagina, 2021). An education and awareness campaign focusing on marine algae could form part of the curriculum offered by environmental education centres accessing this funding.

Scuba divers in this study had sharper perceptions of marine algae than other coastal user groups. They are knowledgeable, attached to the environment where they practise their sport, and both inclined and equipped to participate in activities of marine conservation and research, including monitoring (Cerrano *et al.*, 2017; Freiwald *et al.,* 2018; Lucrezi, 2021; Mannino *et al.*, 2021). Scuba divers are already effectively engaged in participatory monitoring or citizen science aimed at marine species including algae (Mannino *et al.*, 2021). In Europe and Italy, the pressing need to tackle important transboundary issues, from managing non-indigenous species to mitigating climate change and managing marine protected areas, has led to coastal users' involvement in monitoring, with a focus on scuba divers. Examples are the EU-funded interregional project MPA-Engage (https://mpa-engage.interreg-med.eu/), the *Caulerpa* Project in Sicily (Sinopoli *et al.*, 2020), and the citizen science organisation Reef Check Med (Turicchia *et al.*, 2021; https://www.reefcheckmed.org/).

The contributions of scuba divers should continue to be exploited and valued, not least because they can be informal environmental educators and advocates of coastal and marine conservation (Lucrezi *et al.*, 2018). A new challenge would be to persuade other coastal user groups, such as beach visitors, to be similarly passionate about engaging in marine algae research and monitoring. For example, beach visitors could be useful monitors of algal blooms, non-indigenous species and other cast-up seaweeds, as demonstrated by research in different areas of the world (Thiel *et al.*, 2014).

The second consideration is that social licence to research and monitor marine algae should be maintained through effective communication and dissemination to the wider public of efforts made and outcomes achieved. For example, EU-funded research and innovation projects require work packages that are entirely dedicated to communication about progress and the dissemination of outputs, in answer to the need to maintain social support and engage the public (European Commission, 2021). Communication of research and innovation plans and outputs should be accompanied by narratives, for example in mainstream media, centred on marine algae with a focus on large-scale efforts and policies that the public can become familiar with. An example is media campaigns on the European guidelines for sustainable seaweed aquaculture (as in this study there were perceptions that seaweed exploitation practices may not be sustainable) and the European Union legislation on macroalgae products (Barbier *et al.*, 2019; Lähteenmäki-Uutela *et al.*, 2021).

This study effectively contributes to the growing body of knowledge on Ocean Literacy, by providing information on public perceptions of marine resources and support for their research and monitoring, as well as the role of coastal use in shaping perceptions. This information and the recommendations that stemmed from this research confirm several assumptions. First, on the foundational role of education and Ocean Literacy in enhancing public understanding of the inextricable connection

between people, the sea and marine resources (Kelly *et al.*, 2021). Second, on the potential of different role players to actively involve different members of the public, starting with coastal users, in the study, conservation and management of marine resources (Ferreira *et al.*, 2021). Third, on the importance of values associated with marine resources and how these could influence attitudes and ultimately decision-making concerning the conservation and sustainable use of the ocean and its resources (Stoll-Kleemann, 2019). Last, on the need to expand research on perceptions of marine resources in the Mediterranean context, which deserves more attention with regards to strengthening the relationships between people and the sea through Ocean Literacy (Mokos *et al.*, 2020). The contributions of this study can help to achieve Ocean Literacy's objectives outlined by Fauville *et al.* (2019) including awareness and attitude – to help people acquire an awareness of and sensitivity to the global environment and its problems, as well as values and feelings of concern for the environment; and skills and participation – to help people acquire the skills for identifying and solving environmental problems, and to provide them with an opportunity to be actively involved at all levels in working towards resolution of these problems.

Conclusions

This study assessed basic knowledge of and attitude towards marine algae, with a focus on their research and monitoring, among coastal users in the Conero Riviera in Italy. While the study did not include the wider public on a national level, it offered insight into the variation of perceptions among some stakeholder groups, suggesting that public opinion of marine resources has different shades and can be steered in different directions depending on the knowledge of and value associated with these resources. The results, which highlighted general support for the research and monitoring of marine algae, confirmed the importance of considering the social dimension in decision-making about marine species and environments, which is increasingly advocated by scientists as it also represents one of the pillars of ecosystem-based management. Based on the findings of this study, it is argued that social support for the research and monitoring of marine algae can be maintained through strategic public engagement using communication, education and active involvement in participatory activities like citizen science. With new discussions emerging in mainstream media as well as European agendas and policies, for example about the exploitation of marine algae for biofuels, public perspectives may continue to change. Research studies such as this could be useful in monitoring this change so that public engagement strategies can be adapted and support for research into marine algae maintained.

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