



OPEN ACCESS

EDITED BY

Yaisel Juan Borrell Pichs,
University of Oviedo, Spain

REVIEWED BY

Brent Steel,
Oregon State University, United States
Emma McKinley,
Cardiff University, United Kingdom
Marta Rodríguez-Rey,
University of Alcalá, Spain

*CORRESPONDENCE

Chris O'Halloran
chris@healthyoceanshealthypeople.org

SPECIALTY SECTION

This article was submitted to
Marine Ecosystem Ecology,
a section of the journal
Frontiers in Marine Science

RECEIVED 22 June 2022

ACCEPTED 22 August 2022

PUBLISHED 14 September 2022

CITATION

O'Halloran C and Silver M (2022)
Awareness of ocean literacy principles
and ocean conservation engagement
among American adults.
Front. Mar. Sci. 9:976006.
doi: 10.3389/fmars.2022.976006

COPYRIGHT

© 2022 O'Halloran and Silver. This is an
open-access article distributed under
the terms of the [Creative Commons
Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use,
distribution or reproduction in other
forums is permitted, provided the
original author(s) and the copyright
owner(s) are credited and that the
original publication in this journal is
cited, in accordance with accepted
academic practice. No use,
distribution or reproduction is
permitted which does not comply with
these terms.

Awareness of ocean literacy principles and ocean conservation engagement among American adults

Chris O'Halloran^{1*} and Mary Silver^{1,2}

¹Healthy Oceans, Healthy People, Santa Cruz, CA, United States, ²University of California, Santa Cruz, Santa Cruz, CA, United States

Ocean literacy influences ocean conservation and might have an impact on sustainable development practices. We investigated the knowledge American adults possess concerning ocean literacy principles and ocean conservation behaviors by asking participants (N=1226) to complete an online survey on ocean literacy principles, health and well-being benefits of time spent in or by the ocean, emotions that result in behavioral change for conservation, and conservation actions. We used a representative sample of the US population by age, gender, and location. The majority of participants were aware of the ocean literacy principle, that the ocean supports a great diversity of life and ecosystems (82%). Calmness, stress reduction, reduced depression, awe, connection with nature, greater life satisfaction, improved happiness, and a feeling of a spiritual connection or refuge were all associated with the ocean environment's emotional health benefits. Monthly beach trips were associated with the physical health benefits of spending time near the ocean. Engagement in ocean conservation action was associated with multiple factors, including awareness of ocean literacy principles (the ocean is largely unexplored, ocean health and human health are connected, and the ocean regulates our climate and weather), monthly visits to the ocean, emotions of sadness and awe, feeling a connection to nature, living 10 miles or less to the ocean, and viewing nature documentaries and Instagram. Findings from this study may provide ideas how to engage the American public in understanding, valuing, and caring for our shared life sustaining ocean.

KEYWORDS

ocean literacy (OL), sustainable development, conservation engagement, ocean conservation

Introduction

Ocean literacy is an understanding of the importance of the ocean, the principles of how the ocean functions, and the interconnections between the ocean and people (Cava et al., 2005). An ocean literate person can communicate effectively about the ocean, make informed decisions about ocean resources and management (Fauville et al., 2019). The definition of ocean literacy has expanded over the past twenty years to include 48 fundamental concepts that incorporate marine awareness, knowledge, communication, sustainable behavior change, and ocean stewardship (National Oceanic and Atmospheric Administration, 2022). Ocean literacy is considered key in influencing sustainable development to benefit the health of the global ocean and people (Dupont and Fauville, 2017). Additionally, Brennan et al. (2019) state ocean literacy includes six aspects (awareness, knowledge, attitudes, communication, behavior and activism) which influence how people and society interact with the ocean.

UNESCO's Intergovernmental Oceanographic Commission developed an ocean literacy toolkit, Ocean Literacy for All, to help address the global ocean crisis (UNESCO, 2018). The United Nations member states established seventeen sustainable development goals (SDGs) to be achieved by 2030 to benefit humanity and the planet (United Nations, 2015). Specifically, the SDG's goals are to protect the planet, promote peace, end poverty and hunger, mobilize international partnerships, and ensure prosperity. SDG 14, Life Below Water, aims to conserve and sustainably use the oceans and marine resources for sustainable development (UNESCO, 2018). Many other SDGs are linked to SDG 14, life below water, including climate action (SDG 13), zero hunger (SDG 2), good health and well-being (SDG 3), and clean water and sanitation (SDG 6) (United Nations, 2015; UNESCO, 2017). The Decade of Ocean Science for Sustainable Development (2021-2030) was established by the United Nations to encourage efforts to improve ocean health worldwide from global stakeholders to assure a vision for the Global Ocean and sustainable development. The global ocean is key to improving human health and well-being and providing global sustainability (UNESCO, 2017).

Ocean literate people take sustainable actions for healthy communities, healthy seas and oceans, and a healthy planet (Sea Change Project, 2022). Unfortunately, Steel et al. (2005) found knowledge of ocean literacy to be low among Americans. The low level of knowledge concerning ocean issues implies the public requires access to better information delivered in the most effective manner. The research results suggested people best-accessed ocean information *via* newspapers and the internet as well as visits to the coast or online oceanographic education (Steel et al., 2005). Additionally, research among American students (K-12 grades) suggests that ocean literacy programs might result in more environment-friendly behaviors that will benefit the ocean (Plankis & Marrero, 2010).

Understanding how people perceive the ocean is crucial in designing and implementing ocean conservation interventions (Jefferson et al., 2015; Bennett, 2019). Kollmuss and Agyeman (2002) theoretical framework describes both internal factors (knowledge, feelings, emotional involvement, values, attitudes) and external factors (political, social and cultural, economic) lead to pro-environmental behaviors. Ocean perceptions vary between individuals and groups within society due to numerous factors, including socio-demographics, personality traits, access, exposure, and experience of the ocean environment (Jefferson et al., 2015; Jefferson et al., 2021). Stoll-Kleemann (2019) state that ocean conservation knowledge on its own rarely results in behavioral changes. Public awareness and knowledge of ocean conservation are important factors but other factors may be needed for citizens to make informed decisions to influence ocean policy and resource management.

Ocean literacy levels were found to be low among the European public in a survey of 10,000 EU citizens from ten European countries undertaken as part of the EU Seventh Framework Programme project Climate Change and Marine Ecosystem Research - EU FP7 CLAMER (European Commission, 2013). They found citizens were most concerned about ocean issues not directly related to climate change, such as habitat destruction, plastic pollution, and overfishing (Buckley et al., 2011). The most significant public support was for making the coastal ocean environments more resilient. An informed public addresses oceans and human health challenges (Fleming et al., 2015).

Effective ocean literacy requires people to engage in sustainable ocean-friendly behaviors (Dupont & Fauville, 2017). Knowledge of marine ecosystems is crucial in identifying marine resource management and policy actions for sustainable development of our Global Ocean and human health (Fleming et al., 2019). The Blue Health Project, funded by the European Union's 2020 program, explored the health and well-being benefits associated with aquatic environments, "blue spaces," in Europe (Blue Health, 2020). One cohort of recreational ocean enthusiasts, surfers, have been found to possess high levels of ocean literacy with prosocial behaviors that could foster ocean sustainability strategies for a sustainable future (Britton et al., 2021; Fox et al., 2021). Additionally, previous research has found that time spent in safe, healthy blue spaces - aquatic spaces, is associated with benefits in physical health, mental health, and well-being (Depledge & Bird, 2009; White et al., 2013; Gascon et al., 2017; Britton et al., 2018). As stated by Fleming et al., 2021 "healthy oceans foster healthy people".

The European Commission has funded ocean literacy initiatives such as Sea Change, ResponSEable, and European Ocean Coalition (EU4Ocean) to spread awareness of the vital role the ocean plays in our lives (European Commission, 2022; ResponSEable, 2022; Sea Change Project, 2022). Additionally, UNESCO has an ocean literacy toolkit online (UNESCO, 2018). The Ocean Literacy With All initiative is a global collaboration

of organizations that aims to reshape people's relationship with seas and oceans to make everyone ocean stewards during the next decade (UNESCO, 2018). Numerous organizations and governments worldwide are embracing ocean literacy concepts for a sustainable future. For example, Land, Water, Ocean, Us is a Canadian Ocean Literacy initiative that was developed by Canadians with the participation of over 400 organizations and 3,000 Canadians. The extensive research for this project was conducted through the Canadian Ocean Literacy Coalition (Canadian Ocean Literacy Coalition, 2022).

The objective of this cross-sectional study was to investigate awareness of ocean literacy principles and the association with ocean conservation behaviors among American adults. A survey was conducted to determine whether people were aware of the seven essential ocean literacy principles and what ocean conservation activities they participated. We also examined what associations, if any, existed between emotions and pro-environmental behaviors and ocean environmental stewardship. The emotional and physical health benefits of spending time near or in the ocean were also investigated. Specifically, we were interested in determining the characteristics of Americans who are ocean minded and take sustainable actions to benefit the ocean ecosystems.

Materials and methods

This cross-sectional observational study was designed as an online survey to collect data from a representative sample of the American adult population. The survey tool Survey Monkey Audience was used to gather the participant data. Demographic information, ocean exposure, ocean experiences, health, wellness, and ocean conservation action information were collected (surveymonkey.com). Survey Monkey, also known as Momentive, is a management company that provides global market research. In the United States, Survey Monkey Audience has millions of survey respondents that voluntarily join who are representative of a diverse online population. They take surveys to donate money to charity, win a chance for a sweepstakes, or earn credit to redeem for gift cards. All panelists share demographic information including gender, age, region they live, education level, income level, ethnicity, and other attributes that researchers can use to target their desired population. The study was conducted on May 18th and 19th, 2022. This study was approved by the institution review board of Ethical and Independent Review Services, a company providing independent institutional review board services (Protocol #22097 - 01).

The recruitment of the participants for the study occurred *via* Survey Monkey Audience, with census standardization for age, gender, and United States location. We utilized data from the 2020 census bureau on the population of American adults to select an acceptable sample size that would correctly reflect American adults (258,300,000). A sample size of 1,067 American adults

was needed to obtain a 95% confidence level and a confidence interval of three. Participants in the research had to be 18 years old or older, have an internet connection, live in the United States, be able to read English and complete the survey online.

Consent to participate in the study was obtained electronically *via* Survey Monkey Audience. A total of 1302 people started the online survey and 62 people (4.8%) did not consent to participate in the research. The survey ended after someone did not consent. Additionally, 14 people consented to participate but did not take the survey. The response rate was 94%.

The online survey consisted of 15 questions about demographics (e.g., sex, age, race, location, education level, income), health, well-being, number of ocean visits, ocean literacy principle awareness, emotions that influenced environmental action, ocean/beach recreation time, and ocean conservation actions. All data were self-reported by the participants. Self-reported outcomes included agreement with seven ocean literacy principles, action taken for ocean conservation, physical health, and emotional health. A checklist of ocean conservation actions in the past 12 months included recycling, reducing carbon footprint, donating money to ocean conservation organizations, working/volunteering for an ocean conservation organization, participating in a beach cleanup, consumption of sustainable seafood, decreasing plastic use, and membership in an ocean conservation group or other self-reported activity. A checklist of subjective well-being outcomes of time spent in or near the ocean included improved mood, life satisfaction, decreased depression, reduced stress, awe, wonder, love, happiness, feeling relaxed, better sleep, pain relief, spiritual connection, and a connection with friends (the survey can be accessed in the supplementary materials).

Statistical analysis

Descriptive statistics, univariate and bivariate analysis and regression analysis were used to quantify the strength of the associations between explanatory variables and the outcomes, ocean literacy and ocean conservation action. Data analysis was conducted using Stata 15 statistical software package (StataCorp LP, College Station, TX, USA).

Awareness of the seven ocean literacy principles, ocean conservation acts, and increased emotional and physical health after spending time in or around the ocean were all analyzed as outcome measures. Race, sex, age, annual income level, college graduation, and frequency of yearly ocean exposure were all used as covariates in the analyses. Descriptive statistics, such as means and percentages, were used to report these variables.

Bivariate associations of potential predictors with ocean conservation action were evaluated (sex, age, ocean visits per year, income level, emotions (love, joy, sadness, awe), college graduate, distance lived from the ocean, connection with nature, race, ocean literacy principles they agreed with, and more than twelve ocean and beach activities per year). Variables with $p < 0.05$ in the

bivariate regression analysis were included in the multivariable regression model.

A multivariable logistic regression analysis was used to estimate the association between the dichotomous outcome of ocean conservation action and participant explanatory variables or confounders. The covariates included in the model were awareness of ocean literacy principles (climate regulation, mostly unexplored, ocean and humans are interconnected), living within ten miles from the coast, twelve or more ocean and beach activities per year, emotions concerning the ocean (sadness, awe), feeling a connection to nature, viewing nature documentaries or Instagram. The odds ratio (OR) of ocean conservation action was estimated and adjusted for the previously mentioned independent variables.

Results

Participant characteristics

A total of 1226 people participated in this ocean survey. The participant demographic characteristics are shown in [Table 1](#).

TABLE 1 Characteristics of the study population (N=1226).

| Characteristics | Number | Percentage % |
|-------------------------------|--------|--------------|
| Age (years) | | |
| 18-29 | 263 | 21.47 |
| 30-44 | 311 | 25.39 |
| 45-60 | 346 | 28.24 |
| >60 | 305 | 24.90 |
| Sex | | |
| Female | 634 | 51.76 |
| Male | 591 | 48.24 |
| Race | | |
| Asian | 153 | 12.48 |
| African American/Black | 114 | 9.30 |
| American Indian/Alaska Native | 32 | 2.61 |
| White | 849 | 69.25 |
| Latino | 149 | 12.15 |
| Education | | |
| Graduated 4 year college | 268 | 21.86 |
| Household Income (annual) | | |
| < \$50,000 | 421 | 34.37 |
| Between \$50,000-100,000 | 375 | 30.62 |
| > \$100,000/year | 305 | 24.89 |
| Prefer not to answer | 124 | 10.12 |
| Time at the ocean or beach | | |
| > 12 times in past year | 558 | 45.51 |
| Swimming ability | | |
| Can swim | 871 | 71.04 |
| Cannot swim | 192 | 15.66 |

Age, sex, and regions were standardized with United States census data for the American adult population. The majority of the participants in this study were white (69%), between the ages of 45-60 (28%), female (51.8%), earned less than \$50,000 a year (34%) and 22% graduated from a four year college.

Individual conservation actions have a positive impact was reported by 64% of participants. Fifty-eight percent of participants agreed with the statement the “ocean is being damaged by climate change”. Spending time near or in the ocean benefits my emotional well-being was acknowledged by 56% of the participants. Forty-six percent of participants reported being very concerned about ocean conservation issues and agreed with the statement “ocean & human health are connected”. Forty-two percent of participants reported engaging in ocean conservation action. A minority of participants (27%) reported they were overwhelmed by state of the ocean and what to do to help (eco-anxiety).

Awareness of ocean literacy principles

We asked participants which ocean literacy principles they agreed with to ascertain awareness of the seven ocean literacy principles. [Table 2](#) shows the ocean literacy principles that participants agreed with in descending order. The majority of participants agreed that the ocean supports a great diversity of life and ecosystems (82%). Approximately 67% of participants were aware that the ocean: regulates climate and weather, shapes features on Earth, and is largely unexplored. Fifty-six percent of the participants agreed with the statement that the ocean and human health are inextricably connected. Only 58% of participants were aware that the ocean makes the Earth habitable. Few participants (22%) had knowledge that the Earth is covered by one global ocean with many features.

Ocean conservation

Forty-six percent of participants said they were very concerned about ocean conservation and 42% reported taking specific ocean conservation action ([Table 1](#)). We asked the question “In what ways have you supported ocean conservation in the past 12 months, if at all” (N=1199). Recycling (48%) was the most reported action. Other pro-social behaviors included: reduced use of plastic products (39%), reduced carbon footprint (35%), talking with friends/family about ocean issues (29%), eating sustainable seafood (25%), voting in support of ocean conservation issues (16%), donating money to ocean non-profits (15%), participating in beach clean up (15%), and working or volunteering for an environmental non-profit organization (8%).

Emotions

Participants reported on the influence of emotions on taking action for ocean conservation. Participant responses to the survey question “What emotions, if any, influence your decision to support ocean conservation?” included interest/wonder (41%), awe (37%), love (37%), joy (33%), sadness (22%), fear (15%), anger (15%), none (15%) and contentment (14%) and other (2%).

Additional participant comments reported in the other category of the survey question on emotions that influence ocean conservation action included: “concern”, “guilt”, “disgust”, “worry”, “anxiety”, “helping our planet”, “a sense of responsibility”, “it’s the right thing to do”, “well-being of our children and their children”, “just genuine care for the world”, “respect”, “passion to save what man has ruined”, “frustration due to peoples lack of care for trash on the beach”, “worry about what will happen with that big plastic patch in the Pacific”, and “concern about global warming and how it affects our oceans”.

Forty-two percent of participants reported “I take actions to protect the ocean & marine environment”. Multivariable logistic regression analysis found an association with ocean conservations actions and ten variables: knowledge of three ocean literacy principles (climate regulation, mostly unexplored, ocean and humans are interconnected), sadness elicited by the state of the ocean, connection with nature, monthly beach visits, living less than ten miles from the coast, sense of awe/wonder about the ocean, viewing Instagram, and watching nature documentaries (Table 3).

Association of participant factors and ocean conservation

After controlling for risk factors and potential confounders using multivariable logistic regression analysis, participants who took ocean conservation action were 1.50 times more likely to report that the ocean and human health are connected relative to participants who didn’t take ocean conservation action (odds ratio [OR] 1.50; 95% confidence interval [CI] 1.09-2.04; P=0.01); 1.65 times (OR 1.65; CI= 1.22-2.23; P=0.01) more likely to report

that the ocean is largely unexplored; 1.37 times (OR 1.37; CI=1.00-1.89; P=0.05) more likely to report that the ocean regulates climate and weather; 1.75 times (OR 1.75; CI=1.34-2.29; P=0.04) more likely to report that the ocean evokes awe/wonder; 2.30 times more likely to report 12 or more visits a year to the ocean (OR 2.30 CI=1.71-3.10 P=0.00); 2.32 times more likely to report sadness about the ocean condition (OR 2.32 CI= 1.71- 3.15 P=0.00); 1.86 times more likely to feel a connection to nature (OR 1.86 CI=1.40-2.46 P=0.00); 1.66 times more likely to live less than 10 miles to the ocean (OR 1.66 CI=1.16-2.37 P=0.01); 1.47 times more likely to watch nature documentaries (OR 1.47 CI= 1.10-1.95 P=0.01); and 1.68 times more likely to use Instagram (OR 1.68 CI= 1.14-2.47 P=0.01).

Health and well-being

Responses to self-perceived benefits of the ocean on participants’ well-being and health is found on Table 4. The survey asked, “How does spending time in or near the ocean impact your health? Please check all that apply.” Participants (72%) reported that being in or near the ocean decreased their stress. Fifty-six percent of participants reported that spending time at the ocean increased happiness and improved their mood. Participants also reported feeling a connection with nature (53%). Forty-three percent that the ocean had a positive impact on their well-being. Participants reported better sleep and improved life satisfaction (33%). Twenty-eight percent reported spending time near the ocean improves their physical health.

After adjusting for covariates (age, sex, race, distance from the ocean, income, education) self reports of improved physical health by spending time near the ocean was associated with significantly higher odds of monthly beach visits a year (odds ratio (OR) = 3.17; 95% confidence interval (CI) = 2.38-4.21), and walking, jogging, running or hiking at least once a month (odds ratio (OR) = 2.14 95% confidence interval (CI) = 1.58-2.91). Approximately 10% of participants reported an increase of stress (due to being scared of the ocean) with ocean visits.

Participants self-reported spending time near or in the ocean benefits my emotional well-being (56%). Analysis by multivariable

TABLE 2 Knowledge of Ocean Literacy Principles among participants (N = 1226).

| Ocean Literacy Principle | Frequency (n) | % |
|--|---------------|--------|
| The ocean supports a great diversity of life and ecosystems. | 1003 | 81.81% |
| The ocean is a major influence on weather and climate. | 820 | 66.68% |
| The ocean and life in the ocean shape the features of the Earth. | 816 | 66.56% |
| The ocean is largely unexplored. | 813 | 66.31% |
| The ocean makes Earth habitable. | 707 | 57.67% |
| The ocean and humans are inextricably interconnected. | 687 | 56.04% |
| The Earth has one big ocean with many features. | 268 | 21.86% |

TABLE 3 Association of participant factors with ocean conservation action using multivariable analysis.

| Participant factors | Odds ratio | 95% confidence interval |
|--|------------|-------------------------|
| Feel sadness about the ocean condition | 2.32 | 1.71- 3.15 |
| Monthly ocean visits | 2.30 | 1.71-3.10 |
| Feel a connection with nature | 1.86 | 1.40-2.46 |
| Feel a sense of awe | 1.75 | 1.34-2.29 |
| View Instagram | 1.68 | 1.14-2.47 |
| Live within 10 miles of the ocean | 1.66 | 1.16-2.37 |
| Aware the ocean is largely unexplored | 1.65 | 1.22-2.22 |
| Knowledge that the ocean and human health are interconnected | 1.50 | 1.09-2.04 |
| Watch nature documentaries | 1.47 | 1.10-1.95 |
| Aware the ocean influences climate & weather | 1.37 | 1.00-1.89 |

logistic regression of improved emotional well-being of spending time near or in the ocean, after adjusting for covariates, was associated with relaxation (OR 2.77; CI=1.96-3.95; $P<0.001$), improved life satisfaction (OR 1.82; CI=1.27-2.62; $P=0.01$), happiness (OR 2.64; CI=1.92-3.64; $P<0.001$), awe (OR 1.75; CI=1.27-2.40; $P=0.01$), spiritual connection/refuge (OR 2.02; CI=1.32-3.08; $P=0.01$), decreased depression (OR 1.53; CI=1.03-2.27; $P=0.03$), monthly beach visits (OR 2.82; CI=1.93-4.14; $P<0.001$) and connection with nature (OR 1.65; CI=1.20-2.28; $P=0.02$).

Discussion

This cross-sectional study of 1226 Americans revealed that the majority of participants (82%) were aware of the ocean literacy principle, the ocean supports a great diversity of life and

ecosystems. The least acknowledged ocean literacy principle was that the Earth has one big ocean with many features (22%). Overall, awareness of ocean literacy principles by American adults was low. Approximately, half of the participants reported they were very concerned with ocean conservation. Knowledge of three ocean literacy principles was associated with taking ocean conservation action: the ocean is largely unexplored, ocean and human health are connected, and the ocean influences the weather and climate. Additionally, ocean conservation action was associated with several other factors, including the emotions of awe/wonder and sadness, monthly beach visits per year, living less than 10 miles from the ocean, watching nature documentaries, and viewing Instagram. These associations can be helpful in effectively designing strategic communication to engage the American public about critical ocean conservation issues to protect and restore the ocean. How the public relates and perceives the ocean are important factors to successful societal

TABLE 4 Self-perceived benefits of the ocean on participants' well-being and health (N = 1226).

| Benefit | Frequency (n) | % |
|--|---------------|-------|
| Calming/relaxing, decreases stress/anxiety | 888 | 72.43 |
| Increased happiness | 683 | 55.71 |
| Connection with nature | 644 | 52.53 |
| Emotional well-being | 521 | 42.50 |
| Improved life satisfaction | 409 | 33.36 |
| Sleep better | 407 | 33.20 |
| Connection with friends | 397 | 32.38 |
| Decreased depression | 367 | 29.93 |
| Improves physical health | 343 | 27.98 |
| Refuge/Spiritual connection | 311 | 25.37 |
| Eat healthy seafood | 311 | 25.37 |
| Time seems more plentiful | 286 | 23.33 |
| Pain relief | 178 | 14.52 |
| Increases stress/anxiety, I am scared of the ocean | 119 | 9.71 |
| No benefit | 78 | 6.36 |
| Other | 40 | 3.26 |

marine conservation engagement (Jefferson et al., 2021). Our findings suggest effective methods for increasing ocean literacy among the American public include the use of emotions of sadness and awe to connect people with the ocean environment. In addition, the use of Instagram and nature documentaries may help expose people to ocean literacy principles as well as spending time in the marine environment.

The ocean ecosystem sustains, nurtures, and supports humanity. Marine conservation and sustainable use of the ocean and marine resources will aid global sustainable development. To our knowledge, this is the first study to address the multiple factors influencing ocean conservation actions among American adults. Nearly a third of participants reported eco-anxiety, being overwhelmed by the dire state of the ocean, and what they can do to help. People who become anxious about anthropogenic climate crisis can become overwhelmed and immobilized to take sustainable action. Eco-anxiety is a form of anxiety relating to stress caused by environmental changes and can present as panic attacks, obsessive thinking, appetite changes, and insomnia caused by environmental concerns (Castelloe, 2018). However, 64% of participants believed that individual actions could positively impact ocean conservation. The most reported behavioral action taken was recycling. Sadness, interest, awe, and love were all reported to influence conservation action. Due to anthropogenic climate change, we need informed ocean citizens with an understanding of the critically important planetary role the ocean plays in our lives to make our planet habitable (oxygen production, weather and climate regulation, protein source). Additionally, it is of paramount importance that people understand ocean health and human health are intricately connected (Fleming et al., 2021).

Awareness of the seven ocean literacy principles is one dimension of several ocean literacy aspects that potentially impact ocean and human interactions towards sustainable action for healthy oceans and a healthy planet (Brennan et al., 2019). Ocean literacy is broadly defined as an understanding of the ocean's influence on us and our influence on the ocean to benefit humanity (Cava et al., 2005, Dupont and Fauville, 2017, Fauville et al., 2019). The connection between the ocean and human health is not intuitive to most people. Previous observational studies have found associations with high levels of ocean exposure of surfers and ocean stewardship action. Fox et al. (2021) found surfers to be ocean literate, with a strong awareness of ocean processes and interconnections between ocean and human health, leading to sustainable practices. Additionally, Monterey Bay California surfers demonstrated high levels of ocean stewardship and self-reported recycling, eating sustainable seafood, decreased plastic use, voting for conservation measures, and smaller carbon footprints (O'Halloran and Silver, 2021). Increased awareness of ocean literacy principles could help improve knowledge of the connection between the ocean and human health, hence, promoting ocean conservation, and sustainability policies.

In this study, time spent near or in the ocean was associated with the emotional health benefits of improved life satisfaction, calmness, improved mood, spiritual connection/refuge, connection with nature, decreased depression, and awe. As well as physical health benefits of spending time near the ocean. Blue spaces (aquatic) have previously been found to be restorative, relaxing, and calming (Depledge and Bird, 2009; Britton et al., 2018; White et al., 2020). The biophilia hypothesis describes this innate connection people have with other living organisms in nature and the well-being and psychological benefits of spending time in nature (Wilson, 1984). During this time of anthropogenic environmental change, it is important for people to feel connected to nature, hopeful, and take positive action on behalf of the ocean and humanity for the long-term sustainability of the planet.

Additionally, we found a positive association with the emotions of awe and sadness and participants' behavior to take action for ocean conservation. Focusing on emotions that influence behavior change may assist ocean and public health advocates in impacting ocean conservation actions. For example, a sad video of the removal of a straw lodged in the nostril of a sea turtle received over 100 million views on Youtube (Figgenger, 2015). This video helped catalyze a campaign to eliminate the use of plastic straws. Schnurr et al. (2018) reports the internet campaign, the Skip the Straw Save a Sea Turtle, to eliminate plastic straws to save sea turtles was effective in changing consumer behavior to reduce single-use plastic pollution in the ocean. Behavior change and technology can lead to appropriate ocean solutions to the current dire state of the global ocean. A minority of participants reported eco-anxiety which may be addressed by acknowledging feelings of being overwhelmed and engaging in tiny individual action steps for ocean conservation like not using a plastic straw.

This observational study has its strengths and limitations. A strength was a large cohort standardized for American adults' age, gender and location. This study also included several potential limitations. The cross-sectional design may be subject to unmeasured confounding. There was the potential for information bias since participants self-reported all the information provided (e.g., health, ocean conservation actions, emotions). Self-reports by participants may be subject to recall bias or a social desirability bias, participants wanting to provide socially desirable responses. People who chose to engage in the study and complete the survey may have exhibited different characteristics from those who chose not to participate, which raises the possibility of selection bias. Additionally, due to a limitation on the number of survey questions we examined awareness of ocean literacy principles rather than using a larger bank of questions from other available ocean literacy tools.

In this cross-sectional study, we found that ocean conservation action among American adults was influenced by

multiple factors, including knowledge of ocean literacy principles, ocean exposure, connection to nature, entertainment, and an emotional connection to the ocean environment. Additionally, we found an association between the time spent in the coastal environment and emotional and physical health. These study findings may be helpful in designing effective ocean literacy communication to the public on the crucial link between ocean and human health.

During this time of anthropogenic climate change, embracing ocean literacy principles could help promote ocean conservation action and sustainability strategies for the health of the planet and humanity. The UN Ocean Decade is an opportunity to embrace ocean literacy from the perspectives of multiple diverse stakeholders. Additionally, ongoing interdisciplinary research focused on the risks and benefits of ocean ecosystems and ocean literacy can foster integrated approaches to solving our global ocean dilemmas.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Ethics statement

The study was approved by the Institutional Review Board of the Ethical and Independent Review Services (#22097).

References

- Bennett, N. J. (2019) Marine social science for the peopled seas. *Coast. Manage.* 47 (2) pdoi: 10.1080/08920753.2019.1564958
- Blue Health (2020). Available at: <https://bluehealth2020.eu> (Accessed May 23, 2022).
- Brennan, C., Ashley, M., and Molloy, O. (2019). A system dynamics approach to increasing ocean literacy. *Front. Mar. Sci.* 6. doi: 10.3389/fmars.2019.00360
- Britton, E., Domegan, C., and McHugh, P. (2021). Accelerating sustainable ocean policy: The dynamics of multiple stakeholder priorities and actions for oceans and human health. *Mar. Policy* 124, 104333. doi: 10.1016/j.marpol.2020.104333
- Britton, E., Kindermann, G., Domegan, C., and Carlin, C. (2018). Blue care: a systematic review of blue space interventions for health and wellbeing. *Health Promot. Int.* 3550–(1), 50–69. doi: 10.1093/heapro/day103
- Buckley, P. J., Pinnegar, J. K., Terry, G., Chilvers, J., Lorenzoni, I., Gelcich, S., et al. (2011). *Sea Change: public views on marine climate change impacts in Europe* Climate Change and Marine Ecosystem Research (CLAMER).
- Canadian Ocean Literacy Coalition (2022). Available at: <https://colcoalition.ca> (Accessed July 14, 2022).
- Castelloe, M. (2018) Coming to terms with ecoanxiety; growing awareness of climate change. In: *Psychology today*. Available at: <https://www.psychologytoday.com/au/blog/the-me-in-we/201801/coming-terms-ecoanxiety> (Accessed July 14, 2022).
- Cava, F., Schoedinger, S., Strang, C., and Tuddenham, P. (2005). Science content and standards for ocean literacy: A report on ocean literacy. Retrieved March 25,

Author contributions

CO'H and MS contributed to the concept and design of the study. CO'H wrote the first draft of the manuscript and conducted the data analysis. Both authors contributed to the article and approved the submitted version.

Funding

The nonprofit organization, Healthy Oceans, Healthy People, funded the study through a grant from 1% for the Planet/The Surfers Journal and The AIP group which were not involved in any aspect of study design or research.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

2015, from http://www.coexploration.org/oceanliteracy/documents/OLit200405_Final_Report.pdf

Depledge, M. H., and Bird, W. J. (2009) The blue gym: health and wellbeing from our coasts. *Mar. Pollut. Bull.* 58, 947–948 doi: 10.1016/j.marpolbul.2009.04.019

Dupont, S., and Fauville, G. (2017). "Ocean literacy as a key toward sustainable development and ocean governance," in *Handbook on the economics and management of sustainable oceans*. Eds. P. A. L. D. Nunes, L. E. Svensson and A. Markandya (Cheltenham, UK: Edward Elgar Publishing).

European Commission (2013). Available at: <https://cordis.europa.eu/project/id/244132/reporting>.

European Commission (2022). Available at: https://oceans-and-fisheries.ec.europa.eu/news/european-commission-and-ioc-unesco-join-forces-stronger-ocean-literacy-europe-2022-01-31_en (Accessed May 22, 2022).

European Ocean Coalition (2022). Available at: <https://www.marineboard.eu/eu4ocean-coalition-ocean-literacy> (Accessed July 15, 2022).

Fauville, G., Strang, C., Cannady, M. A., and Chen, Y. F. (2019). Development of the international ocean literacy survey: measuring knowledge across the world. *Environ. Educ. Res.* 25 (2) 238–263 doi: 10.1080/13504622.2018.1440381

Figgenger, C. (2015) *Sea Turtle with straw up its nostril - "NO" to plastic straws*. Available at: https://video.search.yahoo.com/yhs/search?fr=yhs-ima-remarklist&ei=UTF-8&hsimp=yhs-remarklist&hspart=ima&p=Skip+the+Straw+Save+a+Sea+Turtle+video&type=q3020_D3PK5_gn_bsfq#id=3&vid=6adbe848b7dfefb69da940911953cef&action=view.

- Fleming, L. E., Depledge, M., Bouley, T., Britton, E., Dupont, S., Eatock, C., et al. (2021). The ocean decade—opportunities for oceans and human health programs to contribute to public health. *Am. J. Public Health*. 111, 808–811. doi: 10.2105/AJPH.2021.306229
- Fleming, L. E., Depledge, M. H., McDonough, N., White, M., Pahl, S., Austen, M., et al. (2015) *The oceans and human health. Oxford research encyclopedia of environmental science*. Available at: <https://doi.org/10.1093/acrefore/9780199389414.013.12> (Accessed May 22, 2022).
- Fleming, L. E., Maycock, B., White, M. P., and Depledge, M. H. (2019). Fostering human health through ocean sustainability in the 21st century. *People Nature* 1, 276–283. doi: 10.1002/pan3.10038
- Fox, N., Marshall, J., and Dankel, D. J. (2021) Ocean literacy and surfing: Understanding how interactions in coastal ecosystems inform blue space user's awareness of the ocean. *Int. J. Environ. Res. Public Health* 18 (11) 5819 doi: 10.3390/ijerph18115819
- Gascon, M., Zijlema, W., Vert, C., White, M. P., and Nieuwenhuijsen, M. J. (2017). Outdoor blue spaces, human health and well-being: a systematic review of quantitative studies. *Int. J. Hyg. Environ. Health* 220, 1207–1221. doi: 10.1016/j.ijheh.2017.08.004
- Jefferson, R., McKinley, E., Capstick, S., Fletcher, S., Griffin, H., and Milanese, M. (2015). Understanding audiences: making public perceptions research matter to marine conservation. *Ocean Coast. Manage.* 115, 61–70. doi: 10.1016/j.ocecoaman.2015.06.014
- Jefferson, R., McKinley, E., Griffin, H., Nimmo, A., and Fletcher, S. (2021). Public perceptions of the ocean: Lessons for marine conservation from a global research review. *Front. Mar. Sci.* 8. doi: 10.3389/fmars.2021.711245
- Kollmuss, A., and Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environ. Educ. Res.* 8, 239–260. doi: 10.1080/13504620220145401
- National Oceanic and Atmospheric Administration (2022). Available at: <http://www.noaa.gov/> (Accessed May 22, 2022).
- O'Halloran, C., and Silver, M. (2021). Health risks and benefits among surfers after exposure to seawater in Monterey bay, Santa Cruz county, California, united states. *Front. Mar. Sci.* 8. doi: 10.3389/fmars.2021.714831
- Plankis, B. J., and Marrero, M. E. (2010). Recent ocean literacy research in united states public schools: Results and implications. *Int. Electronic J. Environ. Educ.* Vol. 1, Issue 1, 21–51.
- ResponSEable (2022). Available at: <http://www.responseable.eu/> (Accessed January 9, 2020).
- Schnurr, R. E., Alboiu, V., Chaudhary, M., Corbett, R. A., Quanz, M. E., Sankar, K., et al. (2018). Reducing marine pollution from single-use plastics (SUPs): a review. *Mar. Pollut. Bull.* 137, 157–171. doi: 10.1016/j.marpolbul.2018.10.001
- Sea Change Project (2022). Available at: www.seachangeproject.eu (Accessed January 9, 2020).
- Steel, B. S., Smith, C. L., Opsommer, L., Curiel, S., and Warner-Steel, R. (2005). Public ocean literacy in the united states. *Ocean Coast. Manage.* 48, 97–114. doi: 10.1016/j.ocecoaman.2005.01.002
- Stoll-Kleemann, S. (2019). Feasible options for behavior change toward more effective ocean literacy: A systematic review. *Front. Mar. Sci.* 6. doi: 10.3389/fmars.2019.00273
- Survey Monkey (2022). Available at: <https://www.surveymonkey.com> (Accessed April, 2022).
- UNESCO (2017) *Education for sustainable development goals*. Available at: <http://unesdoc.unesco.org/images/0024/002474/247444e.pdf> (Accessed 5/14/22).
- UNESCO (2018) *Ocean literacy for all. a toolkit*. Available at: <https://unesdoc.unesco.org/ark:/48223/pf0000260721> (Accessed 5/14/22).
- United Nations (2015) *General assembly. resolution adopted by the general assembly on 25 September 2015*. Available at: https://www.unfpa.org/sites/default/files/resource-pdf/Resolution_A_RES_70_1_EN.pdf (Accessed 5/14/22).
- United Nations Decade of Ocean Science for Sustainable Development (2021). Available at: <https://en.unesco.org/ocean-decade> (Accessed 5/14/22).
- White, M. P., Alcock, I., Wheeler, B. W., and Depledge, M. H. (2013). Coastal proximity, health and well-being: results from a longitudinal panel survey. *Health Place* 23, 97–103. doi: 10.1016/j.healthplace.2013.05.006
- White, M. P., Elliott, L. R., Gascon, M., Roberts, B., and Fleming, L. E. (2020). Blue space, health and well-being: a narrative overview and synthesis of potential benefits. *Environ. Res.* 191, 110169. doi: 10.1016/j.envres.2020.110169
- Wilson, E. O. (1984). *Biophilia* (Cambridge: Harvard University Press).