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Youth and the sea: Ocean literacy in Nova Scotia, Canada

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ABSTRACT

Improving public awareness about the ocean can benefit the environment, economy, and society. However, low levels of 'ocean literacy' have been identified in many countries and can be a barrier for citizens to engage in environmentally responsible behavior or consider ocean-related careers. This study assessed the level of ocean valuation, knowledge, interaction and interest of public school students grade 7–12 (ages 12–18) in Nova Scotia, Canada, a region with strong connections with the sea. A survey was used in 11 public schools, with a total of 723 students participating in a quiz and survey. Many quiz questions were aligned with the 'Ocean Literacy Principles' established by the Ocean Literacy Campaign in the United States. Although the average quiz score was below 50%, students reported a high valuation of the marine environment and diverse interest in the oceans, including jobs and careers. There was a distinct difference in knowledge of biology-related questions and abiotic-related questions, with students having more knowledge of and interest in topics concerning ocean life. A significant positive correlation between knowledge and value indicated that ocean-literate students might value the marine environment more strongly. Students reporting greater interaction with the ocean also demonstrated higher knowledge levels, and students with higher knowledge levels were more likely to be interested in ocean-related jobs and careers. Participants' high valuation of the marine environment and interest in ocean jobs and careers suggests important links between ocean literacy and environmental and economic benefit, respectively. Enhancing interactions with the ocean through experiential learning could be the most effective way of improving ocean literacy as well as marine citizen- and stewardship.

1. Introduction

Although the social, ecological, and economic value of the ocean has been long and widely recognized [33,13], human activities continue to threaten the health and integrity of the marine environment [16,25,39]. To ensure sustainable use of ocean resources there is a need for both top–down and bottom–up approaches; that is, responsible policies, regulations and management strategies [29] as well as individual behavior changes [27]. However, it has become increasingly evident that citizens in many countries have a poor understanding of marine science and ocean issues [36,4,37,35,21,17], which may act as a barrier to individual behavior changes [20]. Furthermore, there is growing awareness that formal education curricula do not adequately communicate ocean science to young people, as low levels of ocean science understanding are evident among students in a number of countries [6,7,15,3,14,35].

Ocean literacy has been defined as "an understanding of the ocean's influence on you – and your influence on the ocean" by a cooperating group of scientists and educators in the United States [12]. Beyond understanding, an ocean-literate citizen uses ocean knowledge and awareness of ocean issues to communicate about the ocean in a meaningful way and make informed and responsible decisions [12]. This translation of knowledge into action has been recognized as 'marine citizenship', and is proposed as a method of 'bottom–up' ocean management to reduce negative human impacts on the ocean through collective behavior changes [27]. While not the principal goal of ocean literacy, it is believed that a greater understanding of the marine environment is likely to prompt citizens to feel a responsibility to act as stewards of the ocean [27]. Recognizing that many social, cultural, and economic factors are thought to influence marine citizenship, and that these may ultimately affect an individuals' likeliness to act as a marine citizen [28], ocean awareness is nonetheless deemed a crucial 'prerequisite' to behavioral change [20].

Ocean education therefore emerges as a logical step towards a more ocean-literate public and enhancing marine citizenship, as participation in environmental education has been identified as the most important predictor of environmental behavior [22]. Still,

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knowledge is not the sole cause for behavior change but rather one among many essential preconditions leading to action [24]; personal values and attitudes towards an environment are also an integral part of marine and environmental citizenship [5]. This is important to consider in approaching marine education, as students approach learning experiences with their previous knowledge, values, and memories of experiences [2]. On connecting society to the sea, Jefferson et al. [23] recognized the need to "involve multiple audiences, each considering different elements of the marine environment to be most interesting, valuable, or relevant." Hence, an investigation into students' knowledge of the ocean and attitudes towards the marine environment can aid in designing the most effective learning experiences.

In Canada, individual provinces and territories are responsible for designing and implementing educational curricula. It is important to know if current provincial education strategies encourage youth to value the ocean or develop a strong understanding of ocean science concepts, especially in provinces with strong cultural, social, and economic ties to the sea. Nova Scotia is one such province on the east coast of Canada; with a population of 920,000 and situated near one of the world's largest tides in the Bay of Fundy, its historic natural resources were primarily forestry and fishing [9]. Today, the ocean sector is responsible for over 15% of GDP and is expected to grow in the future [34], yet the province is facing a foreseen economic and population decline [31]. Understanding young people's knowledge of and interest in the ocean could play a critical role in overcoming these future challenges, as science education has been shown to influence career aspiration of students [38].

While ocean sciences are taught in the grade 8 (age 13–14) provincial curriculum and offered as an optional high school course since the late 1990s, it is unclear whether this is helping produce ocean-literate students. In 1987, a comparison of ocean knowledge between students in Maine, US and Atlantic Canada found that Canadian students demonstrated slightly higher scores on a quiz than their American counterparts, yet generally low scores were evident overall [6]. Still, Nova Scotia students score below the Canadian average on national science assessments [32], indicating a general knowledge gap in sciences.

Looking towards the future of ocean science in Canadian curricula, there is indication that the ocean is not viewed as a relevant topic for Canada's Education Ministers. In a 2014 report that identifies Canada's priorities to be addressed moving beyond the UN Decade of Education for Sustainable Development, oceans were not selected as an issue of importance [11]. The COSEE [12] Ocean Literacy 'Principles and Concepts' for grades K-12 (ages 4–18) have

Table 1
List of 11 short-answer questions asked on the ocean quiz and their corresponding ocean literacy principle [12].

Question	Ocean literacy principle
1. Multiple choice: A whale is a… a. fish b. mammal c. both	5
2. Fill in the blank: The surface of the earth is about ____% (percent) covered by oceans.	1
3. Multiple choice: What is plankton? a. Floating wood debris from land. b. Very small plants and animals that drift with ocean currents. c. A messy, slimy substance produced by whales. d. A type of small fishing vessel.	5
4. Multiple choice: Where does the salt in seawater come from? a. Ships dumping salty wastewater into the sea. b. Photosynthesis of coral reefs and ocean plants. c. Decomposition of dead fish and other ocean animals. d. Erosion of rocks on land and sea. e. I don't know.	1, 2
5. Multiple choice: An 'abyssal plain' is… a. A large flat area of the ocean floor. b. A special type of submarine used to explore the deep ocean. c. An underwater volcano. d. An aircraft wreck on the seafloor. e. I don't know.	1
6a. Multiple choice: How deep is the deepest part of the ocean? a. 500 m b. 1000 m c. 6000 m d. 11,000 m e. I don't know	1
6b. Open-answer: What is the name of the deepest part of the ocean?	1
7. Multiple choice: How much of the ocean, below the surface, have humans explored? a. Less than 5% b. 15% c. About half d. Humans have explored almost the entire ocean e. I don't know	7
8. True or False: Most rain that falls on land originally evaporated from the ocean.	3, 6
9. Open-answer: The largest animal in the world lives in the ocean. What is this animal?	5
10a. Multiple choice: How much oxygen in the atmosphere (that we breathe) comes from the ocean? a. None b. A little bit (10–25%) c. About half (50–60%) d. Almost all (90–100%) e. I don't know	3, 4
10b. Open-answer: What produces this oxygen?	3, 4
11. True or False: The first life on earth is thought to have evolved in the ocean.	4

already been used as a guiding framework for implementing ocean-focused curricula in the U.S.A., and more recently, in Portugal [10]. While the possibilities of using these 'Principles' in Canada are currently being explored, only a few investigations have been done on current public ocean knowledge in the country [6,15,18].

This study investigates the level of ocean science knowledge held by Nova Scotian public school students grade 7–12 (age 12–18), the value they place on the marine environment, and their interest in ocean activities and careers. The objectives were (1) to measure the level of ocean understanding of students (2) to assess how important the ocean is to youth, and how they interact with the marine environment, (3) to determine which ocean topics students are most interested in learning about, and whether they are interested in pursuing ocean-related careers, and (4) to define factors affecting ocean knowledge and valuation of the marine environment. The study is aimed at informing educators, policy makers, marine managers, conservationists, and industry and provides insight into the level of ocean knowledge, value and interest of Nova Scotian youth.

2. Methods

2.1. Survey design

A survey was used to address the research objectives. In the summer and fall of 2013, an ocean quiz and survey for grades 7–12 (ages 12–18) were designed and approved by Dalhousie University's Research Ethics Board (Project #2014-3104). The first half of the survey consisted of a demographics section, followed by 11 quiz questions that incorporated multiple choice, fill-in-the-blank, true or false, and open-ended (Table 1) as well as one open-ended multiple choice question (Table 2).

The second half of the survey contained questions on students' relationship with the ocean, marine activities they enjoyed, interest in ocean topics and ocean-related careers, and understanding of human benefit from the sea (Table 3). The quiz questions reflected several of the 'Ocean Principles and Concepts' created in the U.S. by marine education experts [12]. Thus, each question on the quiz was linked to one or more of the principles and concepts (Table 1). Efforts were made to equally portion easy, medium, and difficult questions on the quiz, and to ensure language of the questionnaire was appropriate for individuals aged 12 and older.

2.2. Survey distribution

While seven of the eight school districts in Nova Scotia were invited to participate, two of the invited districts (one of which included the largest urban area in the province) were not included due to either declining participation or time limitations. Hence, the majority of the schools involved were rural, however, the sample is considered to be representative as no difference in literacy levels have been observed between rural and urban students in the province [8]. Two of the five regions involved required written parental consent forms to be completed before a student could be invited to participate; schools within these regions were sent parental consent forms before the survey date.

Within each school board, 3–4 schools were invited to participate via email and a follow-up phone call. These schools were selected intentionally to ensure even geographic distribution within each board. When several candidate schools were suitable, a random selection method was employed. A total of 9 schools of grades 7–12 and 2 senior high schools (grades 10–12) agreed to take part, resulting in at least one involved institution per school board (Fig. 1). In order to source a population of 'average' students, mainly Academic English classes were selected to participate, as English is a mandatory subject for students at every grade level. All participating schools offered the optional Oceans course for students in grade 11.

Surveys were conducted in November and December 2013. During a visit to a school, surveys were presented to students in the classroom by the researcher, who explained the nature of the survey and invited students to participate should they choose. Within school boards that required parental consent only students who brought in signed permission forms were invited to participate. In that case, those students were called to a cafeteria or empty classroom to participate in the study. Students were asked not to speak to one another while completing the ocean quiz and survey. After completing the quiz and survey, students were given answers to the quiz and led in a brief discussion about ocean science.

2.3. Data analysis

The average quiz score was graded out of 11 questions, each worth 1 point. Two-part questions (questions 6 and 10) were worth 1 point in total. When marking the quiz answers, spelling errors ('mareanas trench' or 'photosytheses') did not affect the mark assigned. The open-ended questions (Table 2) were graded separately and scores were not included in the 'average quiz score' for each participant. Answers to the open-ended questions were judged by the three researchers involved in this study and marked as correct (1), partially correct (2), or incorrect (3). Each of the researchers graded the answers individually, after which the grades were pooled to determine a final grade for each answer.

All survey data were entered into a database in Microsoft Excel and analyzed using 'R' and 'StatPlus'. Analysis of variance (ANOVA) was used to measure effect of grade and gender on students' quiz score and ocean value, while a t-test was used to compare average quiz scores for males and females. The Bonferroni post-hoc test was used to test for differences in quiz scores between grades, as well as gender differences in quiz scores within grades. To assess relationships between quiz score and value, number of ocean activities engaged in, and number of ocean interests, Pearson's Linear Correlation was employed. Finally, a General Linear Model (GLM) was used to test for the effect of grade, gender, quiz score, and ocean value on students' interest in

Table 2
Open-ended question options presented to students in the ocean quiz. Students were asked to circle and answer ***one*** question of the 8 presented. Shown are the proportion of student choosing each question and the proportion of correct, somewhat correct and incorrect answers.

Open-ended questions	Chose to answer (%)	Correct (%)	Somewhat correct (%)	Incorrect (%)
a. How do ocean tides work?	11.8	48.24	29.41	22.35
b. What is 'bycatch'?	0.69	60.00	20.00	20.00
c. What could cause a tsunami?	37.34	75.93	11.11	12.96
d. What causes ocean acidification?	0.83	33.33	33.33	33.33
e. What is 'marine biodiversity'?	3.04	45.45	36.36	18.18
f. What causes ocean currents?	3.32	25.00	41.67	33.33
g. Describe an ocean food chain.	11.89	56.98	39.53	3.49
h. What can cause sea level to rise?	12.03	31.03	10.34	58.62
Chose not to answer any question or indicated 'I don't know any'	18.53			

Table 3
Questions asked in the ocean questionnaire and answer options provided.

Questions	Answer options
1a. What activities do you like that have to do with the ocean in Nova Scotia?	See Fig. 4a for a list of possible answers.
1b. What are you most interested in learning about the ocean?	See Fig. 4b for a list of possible answers.
2. How important is the ocean to you?	See Fig. 3 for possible answers.
3. Why is the ocean important to you?	a. Environmental reasons: the ocean is important for ocean life (plants and animals), weather and climate, etc. b. Economic reasons: the ocean provides jobs, seafood, shipping, fishing, etc. c. Recreational reasons: the ocean can be enjoyed by swimming, hiking the coast, photography, etc. d. Cultural reasons: the ocean is important to our history, tradition, inspiration for art and learning, etc.
4. Please circle the TOP 3 ways that you think humans benefit from the ocean.	a. Seafood (fish, plants) b. Medicines c. Moderation of the weather/global climate d. Transportation (shipping goods, traveling) e. Energy (oil, gas, tidal, hydropower) f. Recreation and enjoyment g. Minerals h. Oxygen source
5a. Would you be interested in learning more about ocean-related jobs and careers?	Yes No
5b. If so, what types of jobs or careers are you interested in learning about?	Open-ended

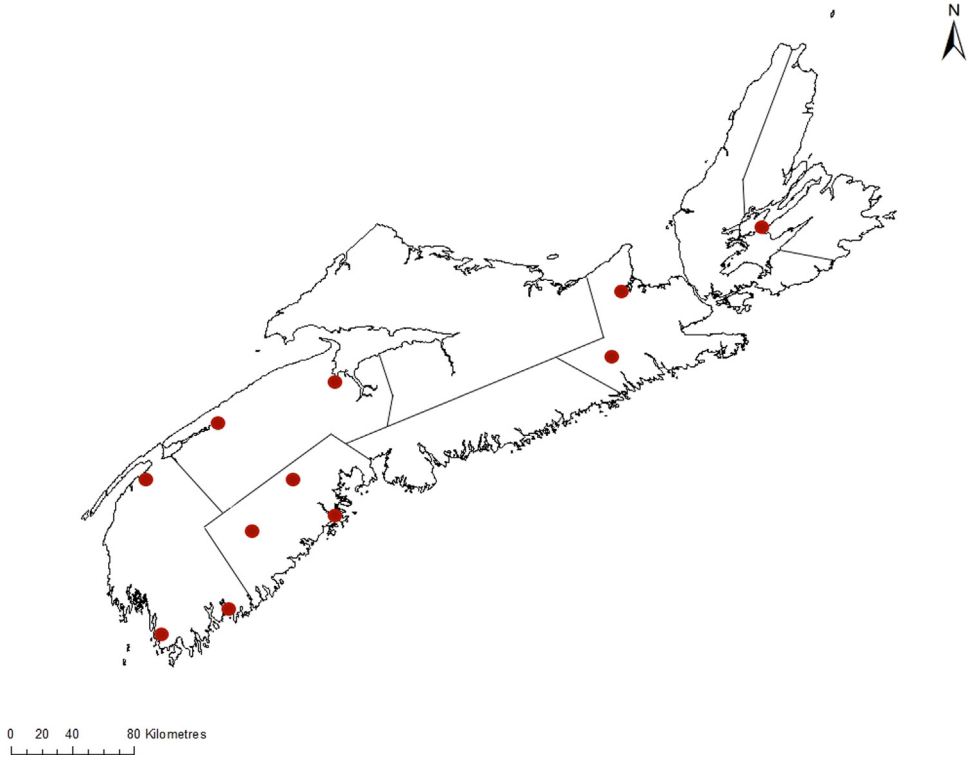

Fig. 1. Map of eleven schools (dots) involved in the study across five (of seven, delineated by lines) school boards in Nova Scotia. Edited ArcGIS Shapefile, 2014.

ocean-related jobs and careers. Prior to completing ANOVAs, homogeneity of variances and normality of data were checked. Quiz scores expressed in % were arcsin transformed before analysis in all cases.

3. Results

3.1. Demographics

A total of 723 students participated in the survey, with 48% of respondents identifying as 'Female', 44% as 'Male', and 8% as 'other' or choosing not to respond. The sample size as well as the ratio of males to females varied slightly between grades (Table 4). The maximum margin of error for the sample was $\pm 3.64\%$.

3.2. Quiz results

The average quiz score was only 5.23 (47.52%) out of a possible 11 points (Table 5). While some questions had a very high percentage of correct answers, others were surprisingly low. For instance, 84% of students knew that a whale is a mammal, yet only 33% knew why the ocean is salty. The knowledge gaps seem to be linked to physical

Table 4
Breakdown of Nova Scotian students that participated in the 2013 ocean survey and the proportion of male and female respondents by grade level.

	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11	Grade 12	Total
Number of respondents	110	143	111	145	95	119	723
% Male	53	39	51	36	48	41	44
% Female	39	48	39	55	46	55	48
% Other	8	13	10	8	5	4	8

Table 5
Results for 11 quiz questions from the 2013 ocean survey in Nova Scotian public schools, reported as the proportion (%) of correct and incorrect answers. All questions were worth 1 point towards a respondent's 'total quiz score', except for question 6a/b and 10a/b, which were each worth 0.5 points. Full question descriptions can be found in Table 1.

Question	Correct (%)	Incorrect (%)	'I don't know' (%)	No response (%)
1. Whale	83.54	15.08	0.97	0.41
2. % Earth covered by oceans	48.13	40.25	2.77	8.85
3. Plankton	71.09	16.04	12.59	0.28
4. Salt in seawater	32.92	31.81	34.85	0.41
5. Abyssal plain	49.38	7.19	43.15	0.28
6a. Depth at deepest point	40.94	23.24	34.44	1.38
6b. Name of deepest point	27.52	12.17	27.66	32.64
7. % Explored by humans	31.54	47.99	19.36	1.11
8. Evaporation	69.02	11.62	18.26	1.11
9. Largest animal	31.67	53.25*	4.29	10.79
10a. Amount oxygen from oceans	21.30	32.78	44.95	0.97
10b. Oxygen source in ocean	7.88	27.94	28.91	35.27
11. Evolution	56.85	18.53	23.10	1.52

* These data include 45% of students who wrote a whale species that was not the Blue Whale (humpback, gray whale, etc.).

and chemical ocean topics, as questions involving ocean life tended to have higher scores than those involving depth, saltiness, or ocean–atmosphere–land coupling.

Grade level and gender both had a significant effect on students' quiz score, but not their interaction (Table 6). Grade 11 students had the highest scores (Fig. 2), and significantly higher ocean knowledge levels than those in grade 7 (Bonferroni post-hoc test, $p=0.00001$), grade 8 ($p=0.00002$), and grade 10 ($p=0.026$). The lowest quiz scores were found in grades 7 and 8 (Fig. 2). The overall average score of male students (50%) was found to be significantly higher (*t*-test, $p<0.0001$) than that of females (44%), and the difference between genders was significant in grade 8 (Bonferroni post-hoc test, $p=0.004$), grade 11 ($p=0.031$), and grade 12 ($p=0.045$).

Of the 8 options presented to students in the multiple choice open-answer question (Table 2), the most frequently chosen (37%) was 'What could cause a tsunami?'. Second to this, more students chose not to respond to the question (15%) than chose another option. The least chosen questions were 'What causes ocean currents?' (3.32%), 'What is marine biodiversity?' (3.18%), 'What causes ocean acidification?' (0.83%), and 'What is bycatch?' (0.69%). Answers to questions were often brief and occasionally students confused two or more concepts in their answer, the most common example of this being 'tides' and 'sea level rise'. Students sometimes explained 'sea level rise' with a definition of 'tides', or vice versa, making 'What can cause sea level to rise?' the question with the largest proportion of incorrect responses (59%). The question with the highest proportion of correct answers was the 'tsunami' question (76%), followed by the 'bycatch' question (60%) and 'Describe an ocean food chain' (57%).

3.3. Ocean value

Responses to the question "How important is the ocean to you?" (Q2, Table 3) were ranked and coded from 1 (Not Important At All) to 5 (Extremely Important). The most commonly chosen responses were 'Medium' (37%) and 'Very Important' (36%) (Fig. 3), with an average score of 3.57. Neither gender, grade level, nor their interaction played a significant factor in explaining the value score (two-way ANOVA, all $p>0.05$).

When asked for the personal reason why the ocean is important to them (Q3, Table 3), the most commonly chosen responses from students were 'environmental reasons' (62%), and 'recreational reasons' (61%), followed by 'economic reasons' (50%) and 'cultural reasons' (31%). A portion of students (16%) selected all four categories of reasons.

Although economic reasons were not the most commonly selected option, students believed that humans receive the most benefit (Q4, Table 3) from the oceans from seafood (62%), transportation (57%) and energy (50%), indicating a clear understanding of the importance of the ocean as an economic resource. A large proportion of students also (42%) recognized humans benefit from the ocean as an 'oxygen source', while 'climate moderation' (23%),

Table 6
Results of a two-way ANOVA testing the effect of gender, grade, and their interaction on students' average quiz scores ($n=723$).

Factor	Df	*F*	*p*
Grade	5	7.875	0.0000003
Gender	2	9.627	0.00008
Grade × Gender	10	1.232	0.26668
Residual	704		

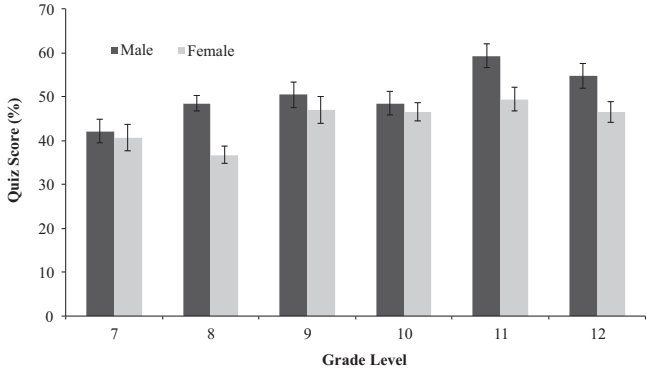

Fig. 2. Average quiz score (%, mean ± SE) by gender for each grade level surveyed. Quiz score is based on the average of 11 questions. For sample sizes by grade see Table 4.

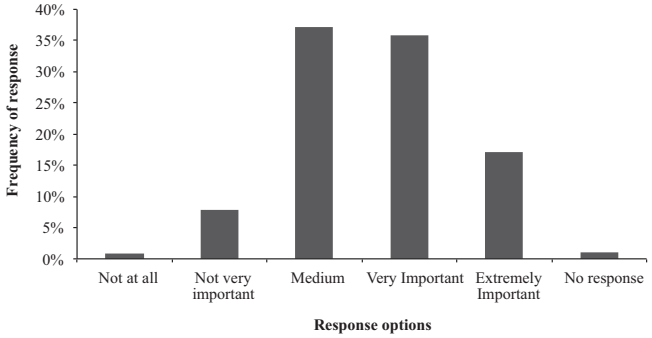

Fig. 3. Frequency of respondent answers to the question 'How important is the ocean to you?' in the 2013 ocean survey in Nova Scotia public schools ($n=722$).

'medicines' (20%), 'recreation' (18%), and 'minerals' (11%) were considered less important.

3.4. Interaction and interests

When asked 'What activities do you like that have to do with the ocean in Nova Scotia?' (Q1a, Table 3) almost all of the participants (96%) selected at least one activity, while 4% of the student sample chose zero activities, or chose not to respond. The most commonly selected activities include 'going to the beach/coast' (73%) and 'swimming in the ocean' (65%), followed by 'fishing' (53%) and 'eating fish/seafood' (52%), while others such as 'snorkeling' (19%), and 'surfing' (12%) were much less frequently chosen (Fig. 4a). Males were more likely to choose one or two activities while females were more likely to select 5 or more. Females were also more likely than males to select 'going to the beach or coast' and 'drawing/painting/photography' as activities they participated in.

About half of the students (54%) who took the survey were interested in learning more about ocean-related jobs and careers. There was no significant deviation in job interest between males and females or across grade levels (Table 7). Many of those who expressed interest in ocean careers indicated 'marine biology' (34%) as a field they were curious about, while 18% reported interest in 'fishing' or 'fisheries'. This affinity for learning about ocean life was echoed when students were asked 'What are you most interested in learning more about the ocean?' (Q1b, Table 3) and given 11 choices with the option to circle more than one answer. By far the most chosen response was 'animals that live in the ocean' (72%), while all others were chosen by around 20–35% of participants (Fig. 4b). Some students added interests in this section that were not listed, such as 'underwater welding' and 'shipwrecks around Nova Scotia'. The number of female respondents outnumbered males in almost all of the interest categories except for 'ships and boats', which was selected by 4% more males than females. As with ocean activities, more females selected 5 or more interests, while more males selected one or two.

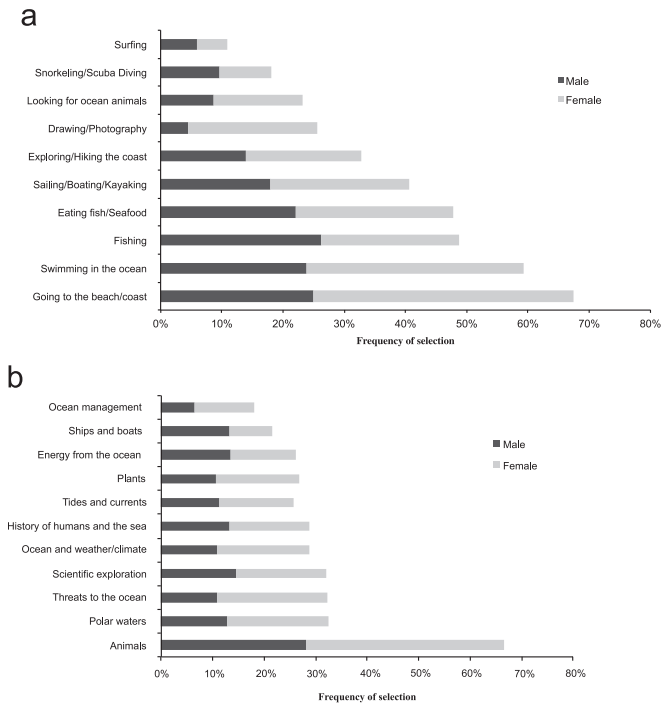

Fig. 4. Ocean activities (a) and interests (b) expressed by Nova Scotian youth in grades 7–12 separated by males and females ($n=716$).

3.5. Connecting ocean knowledge, value, interaction, and interest

Higher quiz scores were associated with higher ocean valuation by respondents (Fig. 5a), and this relationship was significant when linear regression was performed on the average value score ($R^2=0.957$, $p<0.0001$) as well as all individual value scores ($R^2=0.05478$, $p<0.0001$, $n=722$).

Individuals who reported enjoying a higher number of activities around the ocean also scored higher on the ocean quiz (Fig. 5b), as indicated in the results of a linear regression with the full dataset ($R^2=0.019$, $p=0.0001$, $n=723$) or with averaged quiz score ($R^2=0.708$, $p=0.001$). There was also a weak yet significant correlation between a student's average quiz score and the number of ocean topics a student would be interested in learning about (linear regression, $R^2=0.006$, $p=0.043$); students with higher quiz scores were more likely to select a larger number of ocean interests.

Both personal value for the oceans as well as average quiz score were significant indicators of students' interest in ocean-related jobs (Table 7). Students were more likely to be interested in learning about ocean-related jobs and careers if they had higher

Table 7
Results of a General Linear Model testing for the effect of grade, gender, quiz score, and value score on a student's interest in ocean-related jobs and careers ($n=702$). The overall model explained 52% of the deviance (pseudo $R=0.5247$).

Factor	Estimate	St. error	z Value	Pr($>\|z\|$)
Grade	−2.063	0.049	−1.832	0.0669
Gender	−0.091	0.164	−0.847	0.3972
Quiz score	−0.138	0.377	2.558	0.0105
Value score	0.769	0.101	7.609	2.76×10^{-14}

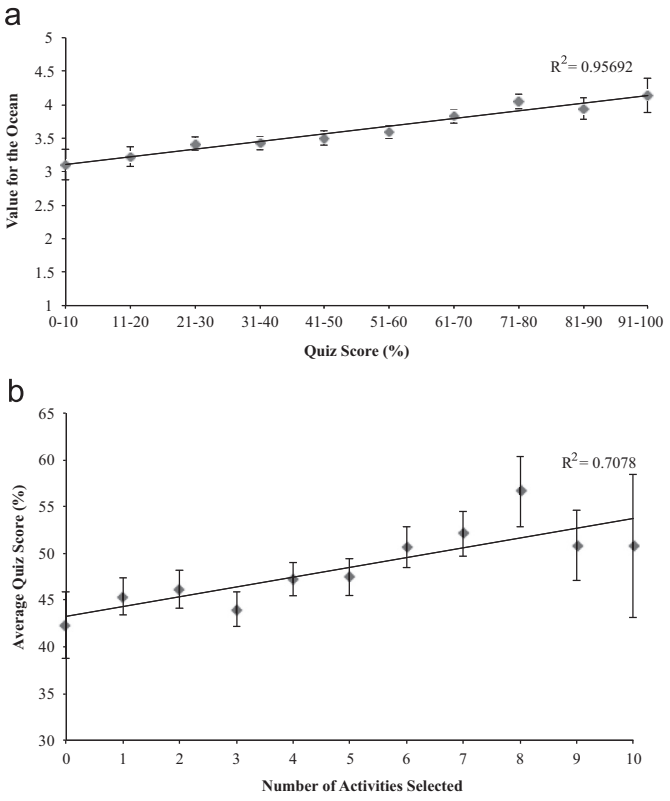

Fig. 5. Relationships between (a) average value score for the ocean (mean ± SE) and the student's ocean quiz score and (b) average quiz score (mean ± SE) and reported number of activities enjoyed around the sea. Solid lines indicate linear regression lines on average value and quiz scores, respectively with the associated R^2 value.

ocean knowledge levels (quiz score) or considered the ocean to be of higher importance in their lives. Grade was not a significant indicator of a student's interest in ocean jobs and the cohort of the oldest students (grade 12) reported the lowest interest (47%).

4. Discussion

This study suggests that grade 7–12 students in Nova Scotia value the ocean highly and are interested in learning more about the marine environment; yet possess generally low levels of ocean knowledge. Nevertheless, valuation was positively correlated with knowledge, while knowledge was positively correlated to the number of activities students pursue on or near the ocean, which illuminates the complex relationships between students' personal interests and their awareness of ocean science concepts. Finally, young people were more likely to be interested in ocean-related jobs and careers if they had higher knowledge levels or valued the ocean more. The results of this study contribute to creating a baseline of public ocean literacy and understanding of young peoples' relationship with the sea in Canada and around the world. Such a baseline assessment is essential to development of marine education programs and is a critical step towards increasing marine citizenship and promotion of sustainable use and interaction with the ocean.

4.1. Ocean knowledge

In this study, average 'ocean knowledge', as measured by a quiz score for over 700 students, was below 50%, suggesting that young Nova Scotians do not have a strong comprehension of many key ocean science concepts. This finding adds to a growing number of studies that have discovered generally low levels of ocean awareness among youth and adults in Canada, the United States, the UK, South Africa, New Zealand, and the Netherlands [6,36,7,15,3,37,14,35,21,17]. The questions related to Ocean Literacy Principle [12] 5, 'The ocean supports a great diversity of life and ecosystems' were among the highest-scoring, while questions relating to Principle 1, 'The Earth has one big ocean with many features', were among the lowest.

In Atlantic Canada, ocean science is currently taught in the grade 8 curriculum, with an optional 'Oceans' class in grade 11. Notably, grade 11 students had the highest quiz scores, which could indicate short-term retention of ocean concepts for students who may have been enrolled in the Oceans course at the time of taking the quiz. Although it is unknown how many of the students in this study may have been enrolled in the Oceans course at the time of participation, average quiz score for grade 11 did not exceed 60%. This may indicate that even with the Oceans course, current marine education efforts need to improve in order to increase students' understanding of the marine environment. Additionally, efforts should be undertaken to assess the course's impact and identify potential areas of weakness.

Though the average quiz score in this survey was low, there was considerable variation in average scores between questions (Table 5). Knowledge was generally lower for questions concerning salinity, bathymetry, and geography, in comparison to species-related or biological questions. Only 4 questions were answered correctly by over 50% of students, and 3 of these were biology-related, suggesting a knowledge gap in basic ocean science concepts. This gap was also identified when Ballantyne [3] found that young students (aged 10–11) in South Africa had a keen interest in marine animals, yet held many incorrect perceptions of the marine environment, particularly tides, waves and currents. In British Columbia, Canada, the average score of a 7-question physical oceanography test given to elementary students was 40%, with particularly low scores for currents and coastal geography [15]. Studies have found that learners often orient themselves towards topics they already hold an interest in [19] and within the ocean sciences young students hold a keen fascination for animal life [26]. This interest is again demonstrated here and is essential for approaching ocean literacy. Moving forward, and given the growing importance of the ocean for climate and resources related issues, marine education programs should be aware of this general interest while addressing the gap between physical/chemical and biological sciences to encourage a more complete understanding of the ocean.

On average, males scored significantly higher than females on the ocean quiz. However, this certainly does not imply that male students have a higher competence for ocean sciences. Gender-gaps in math and science achievement due to socio-cultural factors and stereotype reinforcement have been observed in many countries [30]. This is important to note when moving forward with ocean education initiatives; efforts to engage both males and females in ocean science will mean working to counter a pervasive cultural standard.

Respondents' selection and answers of the multiple choice open-ended questions (Table 2) are indicative of another knowledge gap. That most students (37%) chose to answer the 'tsunami' question suggests the majority of students felt most comfortable answering this over all other options. With 3 out of 4 students (76%) answering the question correctly, their familiarity with the term could be due to the media attention garnered by tsunamis and the human consequences of these natural disasters. Consistent with the first portion of the quiz, the questions with the next highest proportion of correct answers (bycatch, ocean food chain) were biology related, while questions of physical and chemical nature received a lower proportion of correct responses (sea level, currents, ocean acidification), with the exception of the tsunami question. However, very few students chose to describe terms like ocean acidification (0.83%) and bycatch (0.69%), and it is likely that most students did not know or understand these terms well enough to address them. There is a clear need to incorporate these important marine concepts and issues into ocean education curricula in the future so that students can make informed decisions as responsible citizens.

Conflation of ideas was evident from the answers to long-answer questions on tides, sea level rise, and currents, with students often using a combination of their knowledge of all three topics to answer one question. For example, students wrote; "What can cause sea level to rise is rain or a high tide" and "What causes a tsunami is when cold and warm tides mash together and causes a reaction (bad)". In both cases, students confused two or more ideas (tides, waves, currents) that they held previous knowledge about to explain something they did not know. In South Africa, students were observed making similar mistakes with tides and currents [3], while Brody and Koch [7] discovered this with students in the United States. Given Nova Scotian students' proximity to the Bay of Fundy's record tides, this is somewhat surprising and demands attention. These types of misconceptions are important for educators to identify in order to create effective marine education programs, especially when visits to local sites (e.g. Bay of Fundy) could allow for experiential learning in a marine setting.

4.2. Valuing the ocean

Nova Scotian students value the ocean highly. Only 9% of students reported the marine environment as being 'not very important' or 'not important at all' to them. This overall attitude towards the marine environment is a promising baseline for improving ocean literacy in the province – students believe the ocean is important to them, yet lack a developed understanding of its features and functions. This is comparable to a survey of undergraduates in the United States [14], where students had some misunderstanding of ocean concepts, yet expressed "a passionate, emotional response" when asked what interested them about the ocean. This clearly demonstrates the complex

relationship between values and knowledge; students may not need intricate knowledge in order to value the ocean.

Both 'recreational' and 'environmental' reasons were the leading explanations for students' value of the ocean, representing an interesting split between both anthropocentric (recreational) and ecocentric (environmental) values. However, students clearly understood the importance of the ocean in providing economic benefits (seafood, energy, transportation) to humans. In contrast, recreation was not considered a primary benefit humans receive from the sea (18%), even though 61% of students reported it as reason for their personal valuation of the sea, suggesting that young people are aware their personal values do not necessarily reflect those of broader society.

Students who scored higher on the ocean quiz were also likely to have higher 'value scores', suggesting that young people who better comprehend ocean science principles may also better appreciate its level of importance in their lives. The only other Canadian study to investigate this did not find a significant correlation between knowledge and value, yet the authors hypothesized this was due to the study's small size (26 students) [15]. The positive correlation here between knowledge and value corresponds well with theories on environmental stewardship [22], yet it does not imply a causal relationship between these two variables. There are a complex set of factors beyond knowledge and awareness that influence individuals' value for the environment and their likeliness to act on those values [24]. Our results support the idea that improved marine education could play a role in increasing marine citizenship [27], as individuals who value an environment are more likely to feel a responsibility to act as stewards of that environment [28]. Ultimately, there must be further investigation to determine how the role of marine education can affect society's relationship with the sea.

4.3. Interaction with the marine environment

Almost all students (96%) reported enjoying at least one ocean-related activity, and many indicated several activities. For both the 'activities' and 'interest' questions (Q1a, Q1b in Table 3) female respondents were more likely to select 5 or more options while males selected only one or two. Despite this apparently broader interest in the ocean, females scored slightly yet significantly lower in the knowledge quiz. These differences in higher quiz performance in male students compared to higher interaction and interest in the ocean in female students may provide some insight into how to engage students in ocean education through scientific facts versus experiential learning. These differences may also be a product of the survey method, with females considering all options and males selecting one or two and moving on. Notably, these gender differences did not lead to different levels of interest in ocean-related jobs and careers, highlighting the importance of rejecting gender-science stereotypes when designing science education [30].

Using the number of selected activities as a proxy for time spent near the sea, an association between ocean interaction, knowledge, and value was observed, as the number of activities selected was positively correlated with higher quiz scores, and higher quiz score were correlated with higher valuation of the ocean. This finding agrees with the proposal by Steel et al. [37] that "frequency of visits [to the coast] has a positive effect on both subjective and objective forms of knowledge holding". A study in the UK found that "respondents reporting limited interaction with the coast also showed lower knowledge, greater pessimism and disinterest in sea areas" [23]. By extension, it is likely that Nova Scotians and other coastal Canadians possess greater awareness and connection with the ocean than inland Canadians, yet this remains to be investigated.

The positive correlation of ocean-related activities and knowledge level also suggests that incorporation of visits to the sea could be essential to developing effective ocean science education programs for youth. Cummins and Snively [15] found that 91% of surveyed students in coastal British Columbia, Canada, reported learning about the ocean or seashore by 'doing things on or by the ocean'. For students without access to the coast, use of real-time data in schools has been proposed as a useful tool for bringing ocean science into the classroom [1]. Given the demonstrated interest in ocean life and marine biology, visits to an aquarium, a summer camp near the ocean, or other forms of experiential learning could be powerful education tools.

Although only 26% of students reporting 'looking for ocean animals' as an activity they enjoy, a large majority (70%) of respondents selected 'animals' as the marine topic they would be most interested in learning about. This may imply that young people don't believe there to be interesting ocean life along their own coasts. Citizens in the UK have reported being very interested in charismatic species, while at the same time not believing that those species live in their local marine environment [23]. Addressing this misconception in future marine education efforts is important, and field trips in coastal areas could help students realize what fascinating sea life is in their own backyard.

4.4. Interest in the ocean

Student's interest in the sea was piqued when it came to ocean animals (70%); a finding consistent with other surveys with youth in the United States and South Africa [3,14,26]. However, what people find 'interesting' about the ocean is not necessarily the most ecologically valuable. Jefferson et al. [23] found that the most ecologically valuable species on a list (in this case, marine plants) were viewed as the least interesting. This affirms that marine education programs could use marine animal life as 'hooks' to engage students and subsequently teach them about other ocean principles. Particularly, the use of aquaria and 'touch tanks' for improving ocean knowledge and value could be useful given this distinct interest.

Participants did not demonstrate this high level of interest in other ocean topics; however, the second most frequently selected interests were 'polar waters' (35%) and 'threats to the ocean' (35%). This indicates an opportunity to engage students with Canadian Arctic Ocean science and its importance in global relations and climate change. Also, the interest in threats to the ocean suggests that students are interested in environmental issues concerning the ocean, providing plenty of opportunities for educators as well as environmental organizations to engage students in learning and conservation activities, respectively.

Finally, ocean careers and jobs interested 54% of the participants in this survey, and students were more likely to be interested in an ocean related career if they had a higher quiz scores or high ocean value scores. The implication of this positive association is important for educators and industry alike. Increasing and improving marine education efforts could not only produce more ocean-literate individuals, marine citizens and stewards, but also increase the number of public school graduates seeking out careers in ocean science and technology. This could contribute to retention of Nova Scotia's youth population, which has been recognized as a major issue for the economic future of the province [31]. The lowest level of interest in marine jobs was from grade 12 students, as they may have a more concrete idea of their career aspirations by this age.

5. Conclusion

This study examined the ocean knowledge, value and interest of public school students in coastal Nova Scotia. The results suggest a generally low level of ocean science knowledge, particularly with physical and chemical ocean topics, despite a medium to high valuation of the marine environment. Students' higher

knowledge of and demonstrated interest in biological topics is an important finding for future development of ocean education, as it suggests introducing the oceans through a biological 'lens' could provide the initial interest to students who can then be taught important chemical and physical principles as well. The students' high valuation of the ocean is encouraging for improvement of marine citizenship, as value is a key indicator of likeliness to participate in environmental stewardship [28]. Participants who demonstrated higher knowledge levels were more likely to be interested in ocean-related jobs and careers, particularly marine biology, which alludes to the environmental and economic opportunities tied to improving ocean literacy. Although oceans are not currently viewed as an education goal in Canada [11], there is a need to prioritize this field of education.

Students' level of interaction with the ocean was positively linked with their knowledge level, corroborating previous research in the US and the UK [37,23]. This suggests that experiential learning methods could strengthen marine education, and be especially important for students who are interested in learning and engaging with the ocean, as were many female students in our study, yet currently possess lower ocean knowledge [30]. Subsequently, working with touch tanks and aquaria could be a particularly important tool to improve ocean literacy, as participants showed the greatest interest in the ocean when it came to marine animals. Ultimately, incorporating interactive ocean science lessons based around the Ocean Literacy Framework [12] into standard school curriculum would be an effective solution to creating a generation of ocean-literate young people in Canada and around the world.

Moving forward, it would be valuable to test if the disparities in knowledge between coastal and inland residents, as found in the US, are mirrored with Canadian citizens. Furthermore, this research did not specifically assess student interest or knowledge in ocean technology, which would be valuable information for effective integration of technology studies into ocean education. Lastly, measuring the effectiveness of existing marine education programs is necessary for refining and improving ocean literacy efforts. There are many organizations in Canada who operate marine education programs for both youth and adults; understanding their successes and challenges is critical for a coordination of approaches to advance ocean literacy.

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