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Article

Cut Off By The Tide: How Ocean Literacy Can Help Save Lives

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Abstract

The United Nations Agenda 2030 promotes safe access to green spaces, and the Ocean Decade aims to enhance humanity's preparedness for ocean hazards and relationship with the ocean. The tide is not considered an ocean hazard, yet half of the world's coastline is susceptible to tides rising more than two meters in a single tidal cycle and globally >300,000 people per annum lose their lives to drowning. We undertook the first nationally representative survey of public understanding of tide, revealing that over a quarter of the British and Irish public struggled to read a basic tide table. More than one in seven reported having been cut off by the tide, or nearly so. Common misconceptions leading to cut off included the tide coming in much faster and stronger than expected, and often from a different direction. This demonstrates a national failure to understand the variability in tidal movement – one of the most fundamental aspects of the ocean. As the "Ocean Literacy" agenda advocates for increased access and connection to the ocean, to enable responsible delivery of ocean literacy it is crucial to understand and increase the public knowledge of tidal variability. This will enable people to enjoy safe access and positive "emoceans" around the rapidly changing, and increasingly risky, marine environment of the future. We suggest considering the addition of a new Essential Principle of ocean science aiming to improve societal tidal literacy and risk recognition on the coast.

Keywords

beach safety; cut off by tide; drowning; ocean hazard; ocean literacy principles; tidal cut off; tidal inundation

1. Introduction

In 2021, an estimated 300,250 people around the world lost their lives to drowning, excluding those attributable to flood-related climatic events and water transport (World Health Organization [WHO], 2024). Although the majority of these were due to incidences such as unsupervised children near water or travelling on water, some people lose their lives due to being cut off by the tide along the coastline; exact numbers are not available as the reason of death often remains unknown, e.g., bodies found at sea may be victims of unreported cut off. We do know that between November 2017 and October 2022, the Royal National Lifeboat Institution (RNLI, 2023) in the UK recorded 1587 incidents of groups cut off by the incoming tide some of whom, without full intervention, could have drowned. Approx 63% of these were walkers or runners, not beach goers intentionally playing in, on or near the sea (RNLI, 2023). In addition, between 2018 and 2022 the RNLI lifeguards responded to at least 2,804 people cut off on beaches without need to launch a lifeboat (RNLI, 2023) and tidal cut off was the biggest reason for intervention by the National Coastwatch Institution in Wales, accounting for 20% of their recorded incidents to mobilise a rescue that did not always involve the RNLI (National Coastwatch Institution, 2023). To improve safety messaging on beaches around the world, practitioners, beach managers and safety educators such as the RNLI need to understand the levels of comprehension of tide and what the key issues are that people fail to realise about the tide, leading to the high instances of tidal cut-off.

The tide is a complex oceanographical phenomenon that, most simply put, describes the rising and falling (or flood and ebb) of the sea, due to the gravitational forces of the moon and sun. However, tides can vary extensively in their height, speed and direction of flow depending on many factors, including the phase of the moon, geographical location, local seabed and coastal features and pressure systems (weather). The difference between the highest and lowest tide in any tidal cycle is called the “tidal range”; with the biggest mean tidal range of 11.7m in Canada and the smallest in relatively closed waters of the Baltic, Caribbean and Mediterranean Seas. Davies (1980) notes that approximately half of the world's coastline experiences tidal ranges exceeding 2 meters. Macro-tidal (>4 m) and meso-tidal (2–4 m) regions are generally associated with partially enclosed seas and large embayments, such as the UK coastline and the Bay of Bengal. In contrast, micro-tidal regions (<2 m) are typically found along open coasts and fully enclosed seas, including those of southwest Africa and the Mediterranean.

Tidal cut off is the term used to describe when people are cut off from their exit points by the rising tide. There are three common types of tidal cut off recognised by the RNLI: 1) “Embayment” cut offs when people are trapped in a bay with no exit points; 2) “Sandflat” cut offs, when rapidly filling creeks and channels on undulating sand and mudflats block safe egress from a beach; and 3) “Causeway” cut offs, where people walk along a tidal causeway to a rock or islet, and the tide floods the channel back to the mainland (Figure 1). Given the significant tidal variations affecting many densely populated coastal areas, it is important that people understand these basic risks when spending time on the coast.

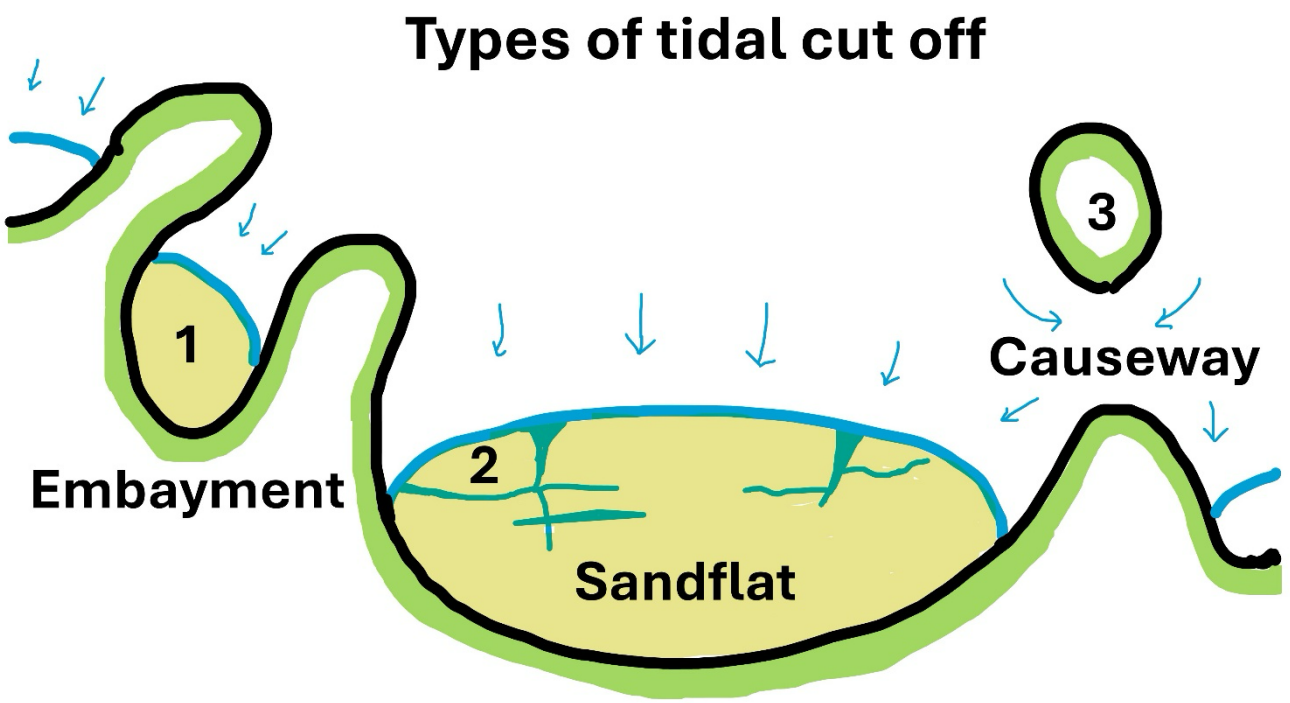

Figure 1. Types of tidal cut off: The three most common ways that people get cut off by the flooding tide.

Both the United Nations Agenda 2030 and the Ocean Decade recognise the need to provide safe access to green and public spaces (Agenda Goal 11.7; United Nations, 2015) and to increase community resilience to ocean hazards (Ocean Decade: Challenge 6; Pinardi et al., 2024). Although Challenge 6 of the Ocean Decade has so far focussed on preparedness for hazards, education related specifically to hazards and hazard warning systems, it has not yet recognised the need for public understanding of tides and the risks they pose, and it is not currently investing in nurturing basic skills in knowledge or awareness of the tide. In a time when the climate and ocean are changing, with increased risks from more frequent storms and sea level rise, local knowledge of tides is essential to ensuring a safe population (be they visitors to the coast, or local residents). The 2024 White Paper for Challenge 6 called for capacity building for community resilience, through stronger links between ocean literacy programmes and the ocean hazards community (Pinardi et al., 2024).

Ocean literacy has developed since 2004 from a campaign to provide a framework for informal and formal educators to deliver 7 Essential Principles of ocean science in the USA, into a global movement that aims to create ocean literate global citizens and societies that have “an understanding of your influence on the ocean, and it's influence on you” (National Marine Educators Association [NMEA], 2024). These Principles, designed originally for early education in ocean science, form the founding stepping stones for all subsequent guidance for ocean literacy practitioners (for example Santoro et al., 2017 and Kelly et al., 2022), many of whom are working to the broader, evolved concept of ocean literacy for wider society. Ocean literacy is no longer simply about knowledge of ocean science, it is also about people and their behaviour. It is currently accepted that peoples’ ocean literacy is affected by at least ten dimensions, which in turn will result in meaningful behavioural change and action for ocean sustainability (McKinley et al., 2023). Those delivering ocean literacy advocate for increased access, experience and emotional connection to the ocean, whilst decision makers and researchers call for monitoring the shifting levels of ocean literacy (Ocean Decade Challenge 10 White Paper: Glithero et al., 2024). However, with increased access comes increased risk: the ocean can be a dangerous place. As ocean literacy practitioners aim to restore people’s connection with the ocean through their activities, they may unintentionally increase the risk to life. In turn, any negative experiences may lead to fear of the ocean (“blue fear”) which will negatively affect some people’s relationship with and behaviour towards the ocean. Currently, the Principles of ocean science do not communicate localised variations in tide, whilst the ocean literacy dimensions do not acknowledge the need to build a safe relationship with the ocean. Meanwhile, there is a significant global knowledge gap on people’s understanding of how to access coastal space safely.

The 7 Principles of ocean science were developed by over 150 scientists and educators to be the most important ideas about the ocean that everyone should know. In 2010, this resulted in the publication of 45 Fundamental Concepts that

provided detail of each Principle, and a detailed Scope and Sequence guide for primary and secondary school educators, that include three specific fundamental concepts related to tide (NMEA, 2010, republished in 2021 and in The Ocean Literacy Framework in 2024). Many national curricula do teach the very basics of what causes tide in physics or natural sciences at school, but few (if any) teach the practicality of interpreting this knowledge into safe access to ocean spaces. In Turkey and South Korea, studies with preservice secondary school teachers found common misconceptions of lunar cycles and the moon's effect on tides, and the way teachers described their knowledge was found to be influenced by personal experience and causal observations of the world, rather than taught scientific models (Ogan-Bekiroglu, 2007; Oh, 2014). Finnish secondary school students (14-15yrs) and teacher trainees in their first and third years of study had difficulties in understanding the basic principles of tide and in describing the phenomenon of two tidal bulges (Viiri, 2000), which is perhaps less surprising than other countries as there are no significant tidal movements in Finland (Viiri & Saari, 2004). In Spain, the phenomenon of tides is taught from age 10, and researchers have revealed that preservice primary school teachers were not able to interpret the mental models of tide to make predictions in local situations, and have suggested methods to overcome learning difficulties (Armario et al., 2022). So, the evidence from education research suggests that when tidal knowledge is taught formally, its complexity means that it is not always conveyed well to students. Furthermore, few curricula nor the Fundamental Concepts associated to the 7 Essential Principles of ocean science, include teaching oceanographic variability in local contexts and there is little information on how this translates into risk recognition and coastal safety.

Research that has addressed beach safety often does so specifically in relation to rip currents, drowning, and in-water or on-open-water safety. In recent years there has been a rapid increase in interest in beach safety in the peer-reviewed literature. In the Netherlands researchers revealed that recognition of different coloured beach flag warnings was poor, with the exception of red flag recognition, indicative of the highest danger levels (Roefs et al., 2023). In Australia, between a quarter and a third of university students admitted that they never or only rarely read beach signage on unfamiliar beaches, and some students misinterpreted key terms when they did read them (Shibata et al., 2024). So what do the public understand and misinterpret about the tide? Although several papers have investigated the knowledge of beach safety, tide and currents in relation to open or in-water safety, no research could be identified that specifically focusses on being cut off by the tide (from here on referred to as "tidal cut off"). We could not identify one country that has undertaken surveys regarding the public understanding of the tide in relation to risks of tidal cut off.

To address this significant gap, we launched the first nationally representative survey of public understanding and misconceptions of tide and systematically assessed the public's experience of being cut off by the tide. Through a combination of closed (Likert scale, numerical or categorical) and open-response questions, with mixed methods analyses, we specifically asked the following research questions: RQ1) To what extent are people able to understand tides and apply that knowledge to everyday planning? RQ2) What are common understandings and misconceptions about the tide? and RQ3) What lessons can we learn from people who have experienced tidal cut off? Results will inform more effective safety messaging, as well as highlighting opportunities for improvements in the ocean literacy agenda and that could both save lives and improve people's relationship with the ocean.

2. Methods

As there is no published research, to our knowledge, on what the public needs to know to avoid tidal cut off, we developed a survey that assessed the public understanding of tide and common misconceptions. To gain a comprehensive multi-disciplinary view, the project brought together researchers and practitioners with expertise in the physics of tide (an oceanographer), marine survey logistics (a marine ecologist), rescue (the RNLI) and a specialist in the nuances of language, specifically misconceptions (a linguist).

Our questionnaire comprised 20 questions that used quantitative response categories (mainly numerical, scalar or categorical), six of which included opportunities to select 'other' to explain their answers. In addition, there were three open-response questions encouraging participants to freely articulate their knowledge and conceptions of the tide. Some questions were adapted from Natural England (2020), Department for Environment Food and Rural Affairs (2022), and Armario et al. (2022). The full questionnaire, detailing the origin of specific questions, is available in Supplementary Material 1.

2.1 Data collection

Data was collected via an online survey instrument that was programmed and disseminated by the Lucid Marketplace – Cint ™. The benefit of using a commercial online research panel provider is that it reduces self-selection bias associated

with advertising a survey that people may sign up to due to their pre-existing interests, and its dissemination methods support collecting data from a representative sample of the target population. Our survey achieved national representation by age, gender and region (county) across a sample of 1300 respondents from Britain and Northern Ireland, and 100 respondents from Éire (Republic of Ireland), reflecting its proportion of the population of the British Isles as a whole. These separate markets were joined for analysis of the data to represent the public understanding of tide for residents of the British Isles.

Ethical approval was obtained from the College of Environmental Sciences and Engineering Ethics Committee (Approval Number: COESE2023LMWCutoffbyTide01, 02/02/2023).

2.2 Quantifying tidal knowledge of the general public

To describe potential factors influencing tidal knowledge, standard questions elicited age, gender, education level and residency (coastal vs inland). All respondents were also asked about their personal, family or household coastal hobbies, frequency of and confidence in reading tide tables, where they access tidal information and if they have ever experienced tidal cut off. Some questions were also added for use by the RNLI, but not analysed in this paper. All questions are provided in Supplementary Material 1.

Six core questions were asked to answer RQ1) To what extent are people able to understand tides and apply that knowledge to everyday planning? Three questions were related to the respondents' basic knowledge of the tide (to confirm whether they understood that there are typically two tides per day, and that these tides vary both temporally and geographically), and three questions to test whether they could apply this knowledge to reading and interpreting a tide table in relation to a beach visit. Questions that probed people to interpret the tide table included one basic interpretation of a tide table (*"What time is low water?"),* one question that was considered of medium difficulty to interpret which day had the lowest tide for a beach visit*,* whilst the most difficult final question related to ensuring safe return from an island known to be cut off by the tide (presented in results, Table 1).

2.3 Exploring specific understanding and misconceptions of the tide from open survey responses

To address RQ2) What are common understandings and misconceptions about the tide? and RQ3) What lessons can we learn from people who have experienced tidal cut off?, respondents were asked three open questions to identify common knowledge and misconceptions regarding the tide. People who got specific tidal knowledge questions wrong were asked the reasons that they gave for answering the way they did. All respondents who answered that they had been cut off by the tide, or nearly so, were also asked four open questions about their experience including what they were doing at the time, how the experience has affected their behaviour and what they tell other people when describing their experience (research questions with associated survey questions are available in Supplementary Material 2).

To understand specifically what people fail to understand that leads to tidal cut off, responses to the questions about common understandings and misconceptions were analysed together with the responses describing experience of tidal cut off (Supplementary Material 2). Open survey data was imported into an Excel template following methodological principles elaborated by Cotton et al. (2024). Each row was a single participant's response to all the survey questions relevant to the overarching research question (Supplementary Material 2). Data retained participant unique identifiers, and conditions that may be relevant to tidal knowledge (gender Q22, residency Q2, and education level Q23).

To unpick the tidal knowledge and misconceptions of the tide and lessons learned from experiences of tidal cut off, we joined inductive thematic analysis of open responses with more deductive search term-analysis, following Cotton et al. (2024) who showed how this combined approach can add insights that may be missed when using only one qualitative analysis approach. Thematic analysis may lead to overlooking less prominent themes, whereas semi-automated search-term based analysis (e.g., Tenbrink, 2020) can lead to errors such as missing negatives or failing to recognise when comments are inferred or implied; especially nuanced, abstract or subtle suggestions that cannot be picked up by search term analysis alone. Cotton et al. (2024) suggest using thematic analysis to inform and iteratively develop the list of search terms, yielding a more robust representation of the data via the combined approach that offers increased rigour and transparency (Cotton et al., 2024; Seale et al., 2006). Search term analysis aimed to systematically reflect the respondents' concepts through the larger dataset, firstly across the whole data set for their answers to relevant questions (Supplementary Material 2), and secondly specifically for those who believe they have been cut off by the tide or nearly so. Those with experience of tidal cut off may have reflections of misconceptions from their experience, and may reveal useful advice for others in their responses.

Initial codes were generated during line-by-line reflexive thematic analysis of the answers to all relevant open survey questions. These codes were then categorised (into secondary codes, or conceptual categories) and themed into groups of codes that showed commonality related to the research questions (Braun & Clarke, 2006). Next, search term strings were identified from the initial codes, to represent each conceptual category within each theme (Tenbrink 2020; Cotton et al., 2024). For example: responses that included words related to the moon or gravity were categorised as "moon's gravitational pull" and grouped into the overarching theme "understanding of tides". Likewise, where respondents used the phrases "same time", "morning", "evening, "dusk", they were categorised as "consistent time of day" and grouped into the theme "misconceptions".

Each search term was placed into a single category and theme; i.e., a specific lexical item only counted as an indicator for one category. As the search was done semi-automatically (in Excel using a formula), search terms were reduced to their root form where appropriate, and care was taken that the automatically detected entries were consistent with the conceptual category the search term belonged to. For instance, the term "bank" was searched without spaces before and after the word, to ensure that both "sand banks" and "sandbanks" could be captured. However, the term " road" had to be coded with a deliberate space before the word, to avoid searching words that contain the letters "road", such as abroad. Also, some terms like "beach" were used in different contexts, necessitating manual double checking for each automatically detected instance. Search terms, categories and themes were reviewed, refined and adapted by the research team. Their prior in-depth conversations and experience interviewing people who had been rescued by the RNLI helped them understand more cryptic or nuanced terms used by the general public.

Search term analysis aimed to systematically reflect and automatically quantify the respondents' concepts for presentation per category or theme, addressing our research questions (full detail in Supplementary Material 2). The results are presented as the proportion (%) of participants who answered the contributing / relevant questions with a specific category and theme, e.g., % who expressed understanding (theme) related specifically to the moon's gravitational pull (category).

3. Results

In total, we collected responses from 1429 respondents (1322 from the UK and Northern Ireland; 107 from Éire). The data were subjected to validation checks, such as excluding nonsensical answers to open questions, which were sometimes combined with repetitive "same" or "don't know" answers to quantitative questions. Approximately 4.5% of the data was deemed invalid, and the remaining 1368 valid responses were pooled for analysis (1266 from the UK and Northern Ireland; 102 from Éire). After the validation process, data was confirmed to be nationally representative by age, gender and region for both the UK and Irish samples. The relative country sample sizes were proportionate to the population figures, allowing us to combine the two country samples for analysis.

Overall, of the 1368 respondents, 47.6% identified as male and 52.3% identified as female (no respondents identified as other). In total 35.6% of respondents were coastal residents (living within 5km of the coast), and 64.3% were inland residents (Figure 2). When asked '"*Do you have any of the following hobbies or interests related to the sea, or regularly undertake any of them for work?"*, nearly a quarter (23%) responded with no coastal hobbies or interests, whilst 53% had experience of at least one in or on water marine hobby (such as stand up paddleboarding or sailing), 48% included coastal walking as hobbies, and 44% selected spending leisure time at the beach as a personal, family or household hobby.

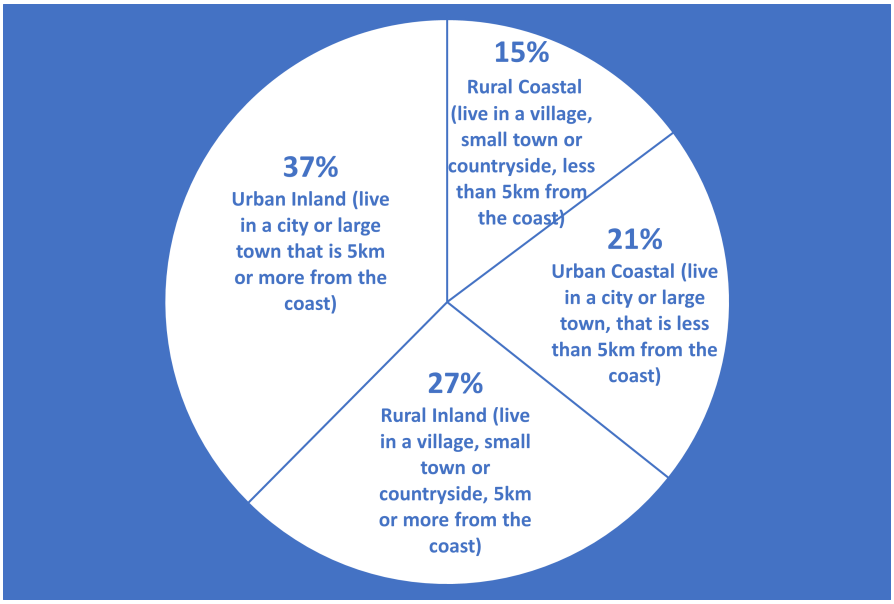

Figure 2. Residency of British and Irish respondents to the tidal literacy survey in relation to the coast (n=1368).

To preview our key insights, about two-thirds of respondents demonstrated basic understanding of the tide, and 15% reported some prior experience of being cut off by the tide. Open responses revealed what the public understand about the tide, but also several common misconceptions that could lead to tidal cut off.

3.1 Tidal knowledge: To what extent are people able to understand tides and apply that knowledge to everyday planning?

When asked *"Do you check the tide times before you visit the beach?",* 29% of respondents admitted that they never check a tide table before they visit a beach, whilst 22% rarely check a tide table, 31% sometimes check and only 18% always check a tide table before a beach visit. When asked to select where they access information about the tide, the most popular places to access tide information (n=968) were the BBC website (37% of respondents), beach signage (35%) and the Met Office (32%), whilst 20% of respondents are also informed by previous experience and 14% by word of mouth (Figure 3). Ten percent of these respondents rely solely on either previous experience or word of mouth for their tidal information (i.e., these respondents did not select any other sources of information). Of the 12% that access information elsewhere, most rely on apps, other websites and tide books, but some admit they rely on their partners, or they think they can assess the tide when on site, or that the tidal information does not apply to them unless they are going in the water *(e.g., "by looking at it when I get there. I'm generally at the beach to walk the dog, no other activities"*, or *"I don't check as I don't go in the sea"*).

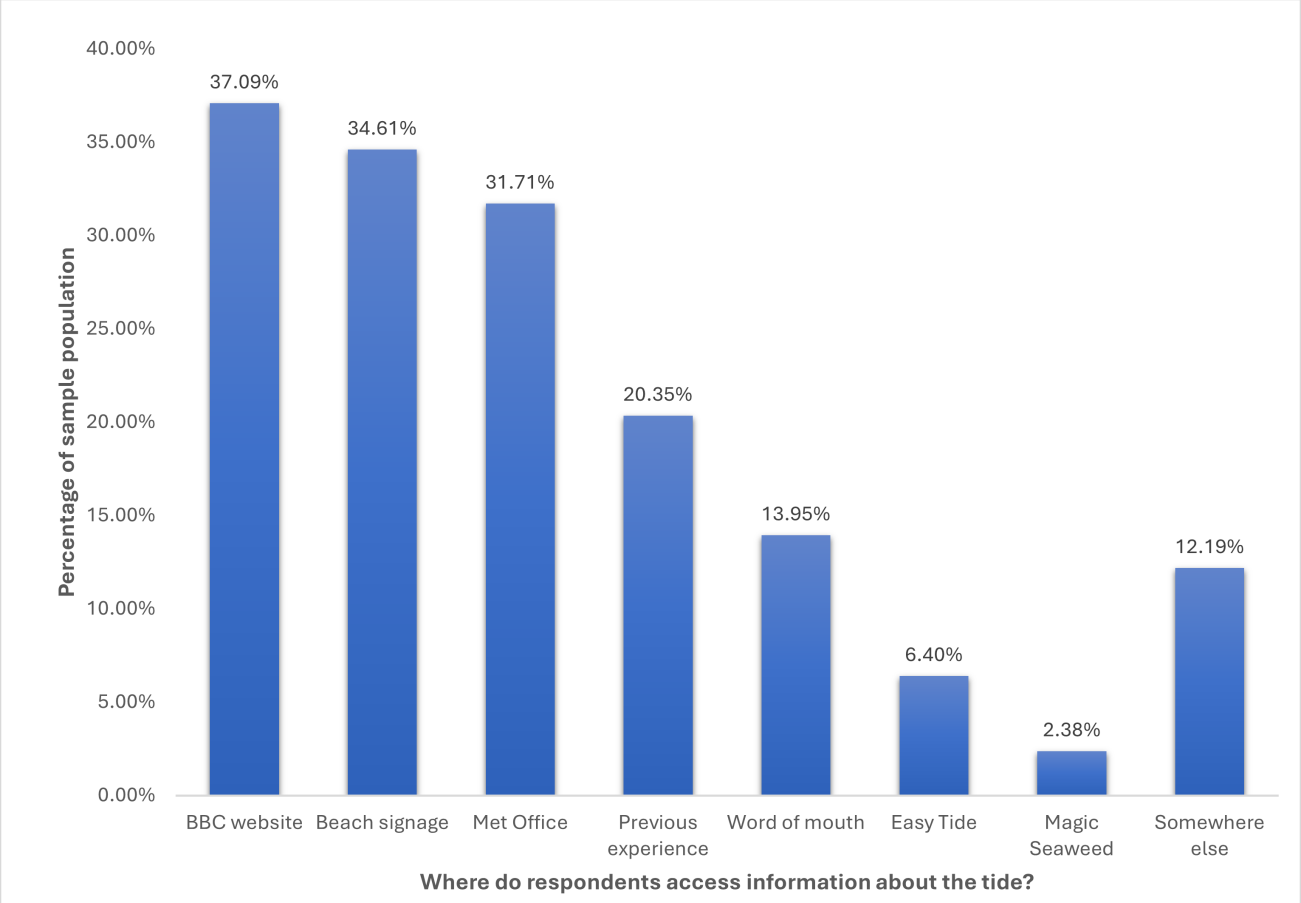

Figure 3. Where do the British and Irish public access tidal information (n=968).

When asked *"How confident do you feel finding information on tide times?",* 64% of respondents (71% of men and 57% of women) said that they were somewhat, fairly or completely confident to find information about tide times, leaving 36% of people either not at all confident or slightly confident to find information on tide times. This confidence in finding tidal information is consistent with our finding that 60-64% of people demonstrated basic knowledge about the tide (Table 1). A higher proportion of respondents identifying as female consistently selected that they did not know the answer when asked the specific tidal literacy questions (Table 1).

Table 1. The tidal knowledge of the British and Irish public (n=1368, 47.59% male, 52.26% female). Data shown as % of total sample; plus m= % who identified as male answering the question this way, and f= % of respondents who identified as female answering this way.

Q#	Question *(correct answer in brackets)*	Correct	Incorrect	Don't know
7	How many times does the tide typically come in over a 24hr period? *(2 times)*	**62.4%** m 67.8% f 57.5%	**23.10%** m 22.5% f 23.7%	**14.5%** m 9.8% f 18.7%
8	In the same location, are the rises and falls of the tide the same every day? *(no)*	**60.7%** m 63.3% f 58.4%	**15.3%** m 16.2% f 14.4%	**23.9%** m 20.4% f 27.2%
9	Are the rises and falls of the tides of equal size in all parts of the country? *(no)*	**64.2%** m 67.0%	**5.9%** m 6.3%	**29.9%** m 26.7%

		f 61.6%	f 5.5%	f 32.9%
15	Basic ability to read a tide table: Look at the BBC Tide Table for Chesil Cove on Christmas day displayed below. What time is low water? (Select all that apply) *(*Two low water times were available, and people were scored "correct" if they identified at least one low water time)*	**74.4%*** m 75.9% f 73.0%	**14.5%** m 15.8% f 13.3%	**11.1%** m 8.3% f 13.7%
16	Medium ability to read a tide table: You would like to spend an afternoon at the beach when the tide is at the lowest. Read the EasyTide tide table below and tell us which is the best afternoon to go.	**42.6%** m 42.8% f 42.5%	**46.8%** m 47.2% f 46.4%	**10.6%** m 9.9% f 11.2%
18	High ability to read a tide table: You are walking to an island that gets cut off mid tide on the incoming tide. Read the tide table below. What is the latest time you need to come off the island on each day to return in daylight?	**24.3%** m 26.7% f 22.1%	**55.8%** m 56.4% f 55.2%	**19.9%** m 16.9% f 22.8%

When asked "*What time is low water? (select all that apply)"* based on a BBC tide table, 74% of respondents identified at least one correct time for low water (Table 1), whilst less than 33% identified the correct times of both low waters offered to them. Respondents who identified at least one correct low water time were scored conservatively as "correct" in answering the question, as this discrepancy may be due to participants giving the first answer they saw rather than considering further options.

The questions presented in Table 1 above were scored as correct (1) or incorrect (0) for each participant. Tidal literacy was the sum of these scores, with a maximum score of 6. Nearly 30% of respondents, representing approximately 30% of the British and Irish public, scored less than average tidal literacy (Figure 4) indicating that they were able to correctly answer fewer than 3 of 6 questions about tidal variation or interpretation of a tide table.

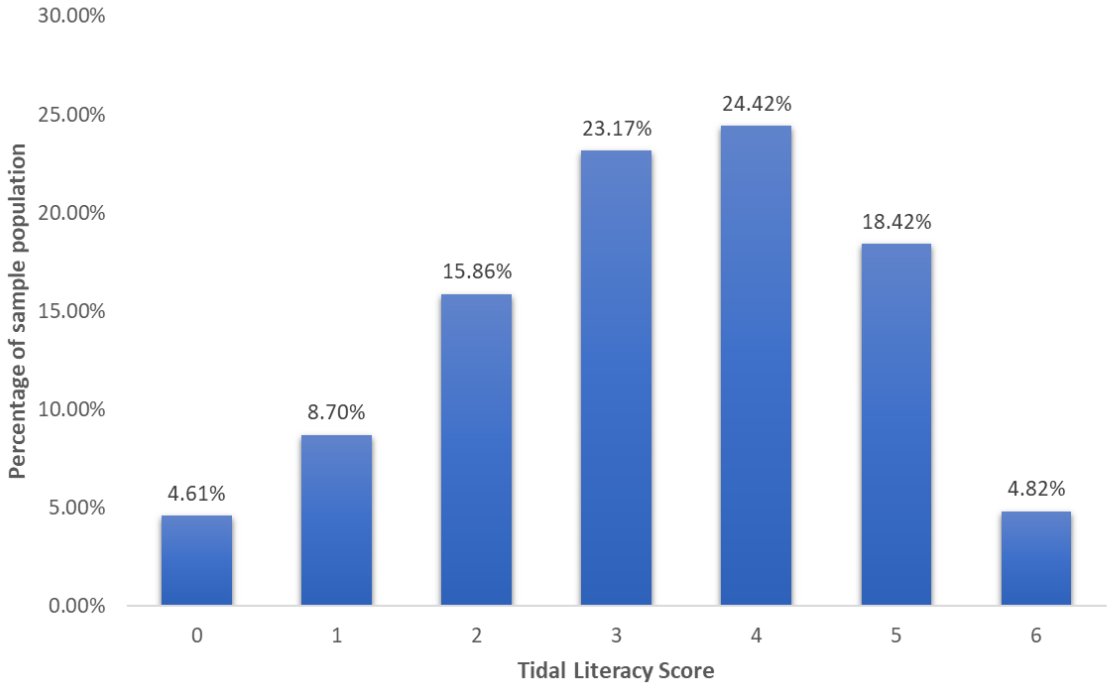

Figure 4. Tidal Literacy Scores for the residents of the British Isles, from no awareness of tidal definitions or how to access tidal information correctly (0) to high tidal literacy (6). To score 6, respondents were able to answer six questions

about the tide correctly. The average tidal literacy score was 3.29 for 1368 respondents of a nationally representative sample of the UK, Northern Ireland and Éire.

3.2 What are common understandings and misconceptions about the tide?

Hybrid thematic and search term analysis of open text answers found over 50% of respondents proved some basic understanding about the tide, when asked *"Are there any changes (on the coast) that could mean a risk to you as a visitor?"*, and "*What are tides, what do you know about them?"*. Specifically, 36% of respondents gave answers related to there being high and low tides, 11% mentioned that these tides changed through the day (evidence of the diurnal phenomenon of tides) and almost 20% gave some technical answers referring to the moon's gravitational pull causing the tide (Table 2). 41% of people recognised that the tide was a risk to them or specified that it was a danger. Overall, 8% of respondents wrote that that they had no or minimal understanding of the tide, with a slightly higher percentage of women stating they had minimal understanding.

Table 2. Common understanding and misconceptions surrounding the tide derived from thematic (TA) and search term analysis (STA) of open responses to a survey of the British and Irish public in 2022. Not all respondents answered questions relevant to each theme, as indicated in the table.

Theme (TA) / Category (STA)	No of respondents expressing category	% of possible respondents	% of males expressing category	% of females expressing category
No of respondents analysed for Themes 1-3	**1368**	**n/a**	**47.7**	**52.3**
TA1 Understanding	**812**	**59.4**	**63.3**	**55.7**
STA1.4 High and low	497	36.3	37.3	35.5
STA1.1 Moon's gravitational pull	270	19.7	24.5	15.4
STA1.5 Diurnal	161	11.7	14.3	9.5
STA1.2 Water movement	97	7.1	7.8	6.4
STA1.7 Speed	54	4.0	3.8	4.1
STA1.8 Strength	37	2.7	2.5	2.9
STA1.3 Sea level changes	36	2.6	3.4	2.0
STA1.6 Spring and neap cycle	19	1.4	1.4	1.4
STA1.9 Otherwise changeable	3	0.2	0.00	0.4
TA2 Misconceptions	**214**	**15.6**	**12.4**	**18.6**
STA2.3 Ripples and waves	109	8.0	6.4	9.4
STA2.2 Currents	50	3.7	2.6	4.6
STA2.4 Consistent time of day	34	2.5	1.8	3.1
STA2.1 Rip currents	19	1.4	0.9	1.8
STA2.6 Other	16	1.2	1.7	0.7
STA2.5 Consistent size / distance / area	4	0.3	0.2	0.4
TA3 Admit minimal understanding	**115**	**8.4**	**7.4**	**9.4**
No of respondents analysed for Themes 4 & 5	**785**	**n/a**	**47.5**	**52.5**
TA4 Interpretation of Q16a	**72**	**9.12**	**10.7**	**7.8**
STA4.2 Gave their preferred time	47	6.00	7.0	5.1
STA4.1 Judged best time to be the longest period of available beach, rather than lowest tide in daylight	26	3.3	4.0	2.7

T5 Technical problem with Q16a	**13**	**1.7**	**1.3**	**1.9**
No of respondents analysed for Theme 6 Danger	**1368**	**n/a**	**47.7**	**52.3**
TA6 The tide is dangerous	**560**	**40.9**	**39.7**	**42.0**
STA6.1 Tide as a risk	490	35.8	35.9	35.8
STA6.2 Specifically note danger	117	8.6	6.0	10.9

However, the above results may overestimate the public's understanding of tide. In answer to our question "*What are tides, what do you know about them?",* at least nine respondents provided very similar sentences defining the tide that were almost identical to the first few lines of the Wikipedia definition of "Tide" (2024):

> Tides are the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the Moon and are also caused by the Earth and Moon orbiting one another. Tide tables can be used for any given locale to find the predicted times and amplitude … (Tide, 2024)

Two respondents gave the exact same answers as Wikipedia. This raises the possibility that other answers may have been answered by internet searching, rather than reflecting the true participant understanding.

When exploring misconceptions, it is interesting to consider the explanations that the respondents did not give when defining tide or the risk it poses. Less than 10% of respondents mentioned water movement as something they knew about the tide, and less than 5% mentioned the tides' speed, strength, or the fact that the tidal cycle changes by way of spring and neap cycles (Table 2).

Our more detailed thematic and search term analysis across a range of open questions searching specifically for common misconceptions and their distribution among respondents found over 15% of respondents revealed some misconceptions about the tide (Table 2). Often these involved double checking the data to ensure whether the search term analysis had identified a real misconception. Common misconceptions included 8% believing that tides were ripples, waves, or tidal bores, 4% expressing that the tide were currents, specifically 1% thought tides were rip currents, and almost 2.5% who believed that the tides appeared at a consistent time of day. For example *"tide comes in in the morning and goes out late afternoon", "when I have been staying by the coast the tides have always the same time every day, once a day"* or *"I think they are around 12 noon and 12 midnight"*.

3.2 What lessons can we learn from people who have experienced tidal cut off?

More than 15% of respondents reported that they had been cut off by the tide, or nearly so, at some point in their lives. Through open responses that described their experience of cut off, half of the respondents revealed what type of cut off they had experienced: 35% were cut off on a sandbank or sand flat, that may have involved creeks back filling with the tide, almost 10% were cut off on via a causeway, such as a visit to an island, and almost 9% were cut off walking around a headland or cliff to a bay that became cut off (Table 3).

Of the respondents who gave information related to the activity they were undertaking at the time of their tidal cut off experience, 60% were partaking in activities that were intended to be by the side of water, not in or on the water, and 35% were walking or running along the coast. Of those cut off, 10% admitted that they were distracted by their activities, nearly 8% were somewhere unfamiliar, 7% were either cut off as a child or with children, and 5% acknowledged that they made an error on reading the tide table or got the tide times wrong (Table 3).

The descriptions given by those who had experienced some form of tidal cut off, revealed misconceptions about the tide that led to their cut off. Overwhelmingly, 57% of those cut off noted the speed of inundation, 15% noted that the direction of the incoming tide was different to what they had expected, and 13% noted that the tide was much stronger than they had expected (Table 3).

Three questions unpicked how tidal cut off experience changed perception of the tide, behaviour on the shore, and messages for other people regarding being cut off by the tide (Supplementary Material 2). 78% of respondents warned of the importance of staying alert and monitoring your surroundings on the beach, often specifically mentioning watching

for areas filling around you and blocking your exit route (Table 3). Some (6%) specifically mentioned to stay close to your exit point, and away from known danger points. 41% of respondents reiterated the importance of knowing the tide and / or site before visiting the beach, whilst 22% noted that they now respect the tide and advise others to not take risks (Table 3).

Some answers revealed that their experience of tidal cut off had instilled fear towards beach visits, with four people (2%) expressing that they no longer go to similar types of beaches, and three noting that they would prefer to use lifeguarded beaches. These included *"I no longer go to the bottom of the cliffs", "I would no longer go across to an island unless i knew the tide had only just gone out not really to be very wary … ",* and *"I try to be more alert and stay in areas patrolled by lifeguards".*

Table 3. Understanding and misconceptions surrounding the tide, and key messages to others from members of the British and Irish public who had been cut off by the tide or nearly so (N=207, 45.9% of whom identified as male, 54% as female). Themes and categories were derived from thematic and search term analysis of open responses to a nationally representative survey in 2022.

Theme (TA) / Category (STA)	No of respondents expressing category	% of possible respondents	% of males expressing category	% of females expressing category
TA7 Type of tidal cut off	**105**	**50.7**	**44.2**	**56.2**
STA7.3 Sandbank	73	35.3	27.4	42.0
STA7.2 Causeway	20	9.7	8.4	10.7
STA7.1 Embayment	18	8.7	9.5	8.0
STA7.4 River	1	0.5	1.1	0.0
TA8 Activity when cut off	**124**	**59.9**	**61.1**	**58.9**
STA8.1 Walking / running	72	34.8	31.6	37.5
STA8.2 Collecting / foraging / digging / rock pooling / fossil hunting	15	7.3	8.4	6.3
STA8.3 Relaxing / sunbathing	15	7.3	6.3	8.0
STA8.4 Playing	8	3.9	3.2	4.5
STA8.7 Swimming / paddling	6	2.9	0.00	5.4
STA8.11 Driving / parking	6	2.9	4.2	1.8
STA8.6 Climbing	5	2.4	3.2	1.8
STA8.8 Fishing	5	2.4	5.3	0.0
STA8.10 Work	3	1.5	2.1	0.9
STA8.5 Picnic	2	1.0	0.0	1.8
STA8.9 Photography	1	0.5	0.0	0.9
TA9 Links to reasons for cut off	**64**	**30.9**	**28.4**	**33.0**
STA9.1 Distracted	21	10.1	9.5	10.7
STA9.3 Somewhere unfamiliar	16	7.7	7.4	8.0
STA9.6 As child, or with children	14	6.8	6.3	7.1
STA9.4 Human error on tide times	11	5.3	4.2	6.3
STA9.2 Lost / cut off from access point	8	3.9	4.2	3.6
STA9.7 With dog	3	1.5	1.1	1.8
STA9.5 Returned to beach	1	0.5	0.0	0.9
TA10 Misconceptions leading to cut off	**171**	**82.6**	**82.1**	**83.0**
STA10.4 Speed leads to sudden inundation	118	57.0	59.0	55.4
STA10.12 Dangerous	73	35.3	34.7	35.7
STA10.9 Direction of incoming tide can be different to expected	31	15.0	17.9	12.5
STA10.5 Strength	27	13.0	11.6	14.3

STA10.2 Current	11	5.3	7.4	3.6
STA10.10 Tide times are unpredictable, or can be any time	10	4.8	4.2	5.4
STA10.11 Can change with weather	8	3.9	1.1	6.3
STA10.6 Can be higher than expected	4	1.9	1.1	2.7
STA10.8 Tide is different to expected	4	1.9	2.1	1.8
STA10.7 Difficult to tell if the tide is coming in out	3	1.5	0.0	2.7
STA10.3 Creek	2	1.0	1.1	0.9
STA10.1 Rip current	1	0.5	1.1	0.0
TA11 How has cut off influenced behaviour or messaging to others	**195**	**94.2**	**92.6**	**95.5**
STA11.5 Stay alert, monitor and take care, incl. watch your escape / exit route and areas filling around you.	163	78.7	77.9	79.5
STA11.14 It is seriously dangerous!	94	45.4	42.1	48.2
STA11.1 Know before you go (tide and site)	85	41.1	39.0	42.9
STA11.10 Respect the tide and be sensible / don't take risks	47	22.7	20.0	25.0
STA11.7 Know it comes in fast and strong	22	10.6	9.5	11.6
STA11.2 Know when the tide begins to come in, or go before low	12	5.8	5.3	6.3
STA11.4 Stay close to exit point and away from known danger points	12	5.8	4.2	7.1
STA11.3 Check signage	10	4.8	5.3	4.5
STA11.13 Don't go!	4	1.9	1.1	2.7
STA11.9 Don't fall asleep!	3	1.5	2.1	0.7
STA11.12 Use lifeguard beaches	3	1.5	1.1	1.8
STA11.6 Be aware of creeks filling	1	0.5	1.1	0.0
STA11.8 Don't be complacent	1	0.5	0.0	0.9
STA11.11 Take safety precautions	1	0.5	0.0	0.9

4. Discussion

We undertook the first nationally representative survey of public understanding of tide, reaching more than 1,300 people across the British Isles. Results reveal that over a quarter of the British and Irish public struggle to read and interpret a tide table, and 15% have had personal experience of tidal cut-off. Most cut off incidents described occurred when people were partaking in beach or coastal activities rather than in-water activities, consistent with RNLI's statistics (RNLI, 2023). While simply being distracted from what is happening with the tide is not uncommon, a widespread lack of tidal understanding is clearly identifiable from our data as a root cause of cut off incidents, and it stands to reason that both are related: that is, a better understanding of the varied and sometimes threatening nature of tides would lead to higher alertness, reducing the likelihood of incidents happening due to being distracted. The identified lack of awareness is particularly alarming considering that almost half of our respondents regard coastal walking or spending leisure time at the beach as a hobby. While this interest in coastal pleasures is good news for the ocean literacy agenda, these activities evidently put people at risk.

Basic knowledge of the tide was evident in the quantitative responses to our "tidal literacy" survey questions (three questions about basic tidal characteristics and three about interpreting a tide table). 70% of respondents answered more than three of the questions correctly, indicating that they had basic tidal knowledge and were able to apply it to a tide table and local context in some way. Hybrid thematic and search term analysis of open text responses further revealed aspects of respondents' basic knowledge of tide phenomena, including 36% referencing high and low tides and 20% referring to the moon and / or gravity. Interestingly, more women than men selected that they did not know the answers to the tidal literacy questions, and the same trend was evident in the analysis of open text responses to explore peoples'

understanding of tide. The fact that men appeared more confident to give answers to tidal questions could give some insight into whether men have unfounded higher confidence levels or whether women are more likely to admit that they don't know, and this could be an interesting area for further work. This knowledge is a novel contribution to the literature, as no other peer reviewed research could be identified on the publics ability to interpret a tide table or apply this knowledge to a beach visit.

Some work has been done to develop research-based teaching tools to improve the teacher and student understanding of tidal phenomena in Finland (Viiri & Saari, 2004), but gender was not considered in analysis. Inquiry based instruction on tides, which integrates archived online data, can also help teachers understand and teach the basic physics related to the tide (Ucar et al., 2011). Although this may increase an understanding of the science behind the tide, little has been done to ensure that this knowledge is taught in a way that can be applied to safe access to coastal spaces. There is evidence that the use of interactive learning tools, such as video simulation in addition to traditional textbook education, can improve learning, but these tools are also known to not overcome students' preconceptions or lived experience, unless their misconceptions are specifically addressed (Ruzhitskaya & Montfrooij, 2011).

The ocean literacy agenda has evolved to recognise that knowledge alone does not always result in logical appropriate behaviours (McKinley et al., 2023), and whilst some of our 1368 survey respondents do understand the basic physics of the tide, 30% said that they never check a tide table before visiting a beach, and over a quarter could not find low water on a tide table. Of the 968 individuals who told us where they get their tidal information, almost 10% rely solely on either personal information or word of mouth, and a few of these people noted that they do not need to check tidal information as they never plan to be in or on the water. This is important, proving that a significant proportion of the public do not understand how to interpret tide tables for safe access, and some cannot see the relevance of, or risk from, tide to them as coastal visitors.

So, what are the main misconceptions that lead to 15% of the general public experiencing tidal cut off? The most common misconceptions were seen in the responses from those who had some experience of being cut off, and were related to the speed and strength of the tide, and the direction the incoming tide approached them from. Their experiences led them to warn others to stay alert and monitor their surroundings, specifically to watch their escape routes off the beach and be aware of areas filling around them. 41% of respondents reiterated the importance of knowing the tide and the site, including mention of knowing about local hazards.

Where might people learn about the risk of being cut off by the tide? The Fundamental Concepts (FC) supporting the 7 Essential Principles guide educators on what students should comprehend about ocean science through primary and secondary school (Halverson et al., 2021). FC 1C, associated with "Principle 1 Earth has one big Ocean with many features", guides what different grade students should understand about the basics of tide: from "*Tides move water higher and lower, covering and uncovering the shoreline"* in the early years; to "*Tides change cyclically relative to the position of the moon, sun and Earth"* (Halverson et al., 2021). Countries around the world have started to use the FCs in their national curriculum, and although we cannot be sure if the UK has engaged with this agenda, our evidence shows that these two fundamental concepts are often understood by the British and Irish public. However, the FCs were not designed to include the safety implications of ocean science, and as such does not provide information for educators on basic variations where we found the public knowledge lacking: that tides do not occur at the same time every day, that there can be massive variations at holiday destinations, or even along small sections of coast with differing landscapes that change the way the water moves. This is important not just for the citizens of the UK, but also for anybody visiting beaches in different countries or areas where the tide may differ from their previous experience. Notably, on half of the global coastline the tide can rise over 2m over 12hours, which far exceeds standing depth (Davies, 1980).

As the ocean literacy agenda is constantly evolving and now has a strong emphasis of behavioural change to improve our positive relationship with the ocean, there is opportunity to guide learning of these variations using the FCs associated with either Principle 1, where the concept of tide is introduced, or "Principle 6 The Ocean and humans are inextricably interconnected". FCs 6B and 6C, that guide teaching of Principle 6, detail coastal living and specifically coastal hazards, but the tide is not mentioned as one of those hazards. There is specific opportunity in P6 C5 *"Hurricanes, typhoons and tsunamis may adversely affect humans living along or near the coastline"* to specify tide, their variations, speed and strength, as a coastal hazard, and P6 C6 that *"Learning about and preparing for natural hazards can increase survival and minimize the adverse effects of these events"* (Halverson et al., 2021). Additions to the FCs here would be beneficial to formal educators seeking detailed curricular guidance.

However most informal ocean literacy practitioners will guide their activities and content by their own interpretation of the 7 Essential Principles (NMEA, 2010) in combination with the currently accepted dimensions affecting ocean literacy (McKinley et al., 2023). As the ocean literacy movement continues to develop, there are new practitioner toolkits, forums and practitioner guidance, such as the Ocean Decade Ocean Literacy for All toolkit (Santoro et al., 2017) or the *"ten best practise principles for ocean learning communication"* (Kelly et al., 2022). However, the 7 Essential Principles form the foundation for all of these ocean literacy practitioner guides, which were initially designed for the purpose of teaching ocean related science more than 20yrs ago (NMEA, 2010, and in NMEA, 2024 in The Ocean Literacy Framework). Therefore, it is important that these essential principles can also evolve to fit the new concept of ocean literacy. As the Ocean Decade agenda seeks to "*restore humanity's relationship with the ocean*" (Glithero et al., 2024) and "*capacity build for community resilience, through stronger links with ocean literacy programs and the ocean hazards community*" (Pinardi et al., 2024), we propose that improving the understanding of tidal variation in differing local contexts, or simply types of tidal cut off, could be embedded as an 8th Essential Principle of Ocean Science – explicitly meeting the ocean literacy agenda's duty of care to ensure safe access for the people it encourages to connect with the ocean, and ensuring uptake from the classroom to the public forum.

Beyond classrooms, for the RNLI as well as for proponents of ocean literacy, our findings raise the question as to how to improve the accessibility and good interpretation of tide and site information, and improved uptake of information regarding local hazards. There has been very little peer-reviewed literature on the effectiveness of safety messages specifically aimed to reduce tidal cut off, public understanding of tidal cycles, or how people interpret and apply a tide table to their needs. Beach safety is commonly confused with (in) water safety. Future research needs to decide what safety messaging is most appropriate to improve awareness of cut off risks, including speed, strength and directions of tide, and what warning signs to look out for when spending time on the beach. Beach managers and safety practitioners then need to consider the best dissemination pathways and materials suited for recreational users of beaches, who are not in or on the water. Researchers can take some lessons from research into the efficacy of rip current safety messaging. In Australia, targeted education programmes have proved effective at improving international students' knowledge of beach risks, signage and rip currents (Clifford et al., 2018). In Sydney, interactive learning with teenagers, led by rip current experts that incorporate memorable science of current presentations, was found to increase knowledge and identification of rip currents, but that this also led to over-confidence in selecting swimming locations (Brander et al., 2022). Analysis of the reality television show "Bondi Rescue" found that programmes focussing on beach and water safety can influence international audience's understanding of risks, particularly rip currents, and perceptions of who is at risk, but that the messaging should be cautious to not misrepresent the demographics of those being rescued (Warton & Brander, 2017). In the case of Bondi Rescue for instance, there was a heavy focus on rescues of international beach goers, when they comprise only 10% of coastal drowning incidents (Warton & Brander, 2017). Similarly, place-based reality television programmes could overemphasise local risks that may not apply to the audience's local beaches. In the UK, a similar analysis for effective messaging regarding tidal cut off could be undertaken on the popular television programme "Saving Lives at Sea", produced by Blast! Productions and aired by the BBC, that follows RNLI rescues.

5. Conclusion

In this paper we introduce the term "tidal literacy" with the definition of *"an understanding of how the tide works* and *how to apply this knowledge to stay safe on the coast, on and in the water"*. We have demonstrated a deep-rooted national failure to understand the nature of tidal movement, one of the most fundamental aspects of the ocean, and importantly a lack of ability to interpret this information in a local context that involves reading a tide table. Improving societal tidal literacy would not only reduce risk to life but also reduce reliance on water safety and rescues often offered by volunteers in the UK, and a support that is not available at all in some countries. As the ocean literacy agenda seeks to "*restore humanity's relationship with the ocean"* and "*capacity build for community resilience, through stronger links with ocean literacy programs and the ocean hazards community"*, we propose that tidal literacy should be embedded as the 8th Essential Principle of Ocean Science. The ocean literacy community has a duty of care to ensure safe access for the people it encourages to connect with the ocean, something that has already been recognised in the Welsh Ocean Literacy Strategy "Y Môr a Ni" (Wales Coasts and Seas Partnership, 2025). Water safety training is currently commonplace as a cure to being cut off by the tide, or finding oneself in the water unprepared. Improving tidal literacy should be seen as a preventative approach, to ensure safe access to our coast for all, be that in, on or beside the water – through informal and formal teaching, improved messaging, research, and development of more effective beach signage.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The full survey data set is available on Zenodo: http:///doi.org/10.5281/zenodo.15047185

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

Supplementary Material 1: Tidal literacy questionnaire.

Supplementary Material 2: All themes, categories and search strings used in search term analysis of tidal understanding and misconceptions.

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