The disparity between regulatory measurements of *E. coli* in public bathing waters and the public expectation of bathing water quality

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ABSTRACT

The main objectives of the European Union (EU) Bathing Water Directive (BWD) 2006/7/EC are to safeguard public health and protect designated aquatic environments from microbial pollution. The BWD is implemented through legislation by individual EU Member States and uses faecal indicator organisms (FIOs) as microbial pollution compliance parameters to determine season-end bathing water classifications (either ‘Excellent’, ‘Good’, ‘Sufficient’ or ‘Poor’). These classifications are based on epidemiological studies that have linked human exposure to FIOs with the risk of contracting a gastrointestinal illness (GI). However, understanding public attitudes towards bathing water quality, together with perceptions of relative exposure risks, is often overlooked and yet critically important for informing environmental management decisions at the beach and ensuring effective risk communication. Therefore, this study aimed to determine the effectiveness of current regulatory strategies for informing beach users about bathing water quality, and to assess public understanding of the BWD classifications in terms of exposure risk and public health. Two UK designated bathing waters were selected as case studies, and questionnaires were deployed to beach-users. The bathing waters had different classification histories and both had electronic signage in operation for communicating daily water quality predictions. The majority of respondents did not recognise the standardised EU bathing water quality classification signs, and were unaware of information boards or the electronic signs predicting the water quality on that particular day. In general, respondents perceived the bathing water at their respective beach to be either ‘good’ or ‘sufficient’, which were also the lowest classifications of water quality they would be willing to accept for bathing. However, the lowest level of risk of contracting a gastrointestinal illness that respondents would be willing to accept suggested a significant misunderstanding of the BWD classification system, with the majority (91 %) of respondents finding only a < 1 % risk level acceptable. The ‘Good’ classification is much less stringent in terms of likelihood of GI. This study has shown that the current public understanding of the BWD classifications in terms of exposure risk and public health is limited, and an investment in methods for disseminating information to the public is needed in order to allow beach-users to make more informed decisions about using bathing waters.

Introduction

Management of bathing waters in the European Union (EU) is currently legislated under the EU Bathing Water Directive (BWD) 2006/7/EC. The BWD has evolved since its introduction in 1976, helping to reduce faecal contamination of UK bathing waters primarily through the control and treatment of point-source sewage-related influx to surface waters (Kay et al., 2008). Microbial compliance parameters are fundamental for determining bathing water quality; the 2006 BWD uses two faecal indicator organisms (FIOs), *Escherichia coli* and intestinal enterococci (IE), as measures of microbial pollution in designated bathing waters (Kay et al., 2004). Sources of FIOs also include diffuse inputs, e.g. agricultural run-off, which are facilitated by precipitation and flooding events, and can lead to faecal contamination of both bathing waters and beaches through a variety of hydrological pathways (Kay et al., 2018; Bradford et al., 2013; Kay et al., 2007). Although FIOs are now considered poor surrogates for most pathogenic bacteria, viruses and protozoa (Wu et al., 2011), their presence is still widely accepted as an important indicator of faecal contamination. Furthermore, epidemiological studies have established that exposure to FIOs in recreational waters is significantly linked to a decrease in public health (Leonard et al., 2018; DeFlorio-Barker et al., 2018a), which has led to legislative pressures on EU member states to maintain and improve the microbial quality of designated bathing waters (Mansilha et al., 2009; Georgiou & Bateman, 2005).

The BWD requires that season-end classifications are produced for each bathing water, which are subsequently displayed at the start of the following bathing season. The classification (‘Excellent’, ‘Good’, ‘Sufficient’ or ‘Poor’) is calculated based on the previous four years of monitoring data, and uses either the 95th or 90th percentile, depending on the classification. There is also a requirement to produce a bathing water profile, which is a freely accessible update on potential catchment pollutant sources linked to each specific bathing beach (Quilliam et al., 2015). However, debates on whether the BWD continues to be ‘fit for purpose’ for protecting public health (Oliver et al., 2014), together with the impact of increased non-compliance following the introduction of more stringent microbial water quality standards in the most recent revision of the BWD (Quilliam et al., 2015; Lušić et al., 2013), jeopardises the confidence of beach-user stakeholders in the effectiveness of current bathing water management (Oliver et al., 2016; Hynes et al., 2013; Langford et al., 2000).

Static signs, or information boards, at every designated bathing beach are also required under the BWD, in order to communicate to the public the classification of the beach and recent water quality results. In addition, some Member States also choose to use electronic signage network systems (based on rainfall and/or river flow data) that provide the public with real-time daily predictions of bathing water quality (Bedri et al., 2016; McPhail & Stidson, 2009). Public perception of bathing water quality can be heavily influenced by the media (Pendleton et al., 2001), and any obvious contamination of bathing water with litter, debris or scum, will often define a beach-user’s perception of the water quality (Smith et al., 1991; House, 1996). The health risks from bathing in recreational waters contaminated with pollution, however, can also be underestimated by the public (Langford et al., 2000), although there is some evidence that beach-users can exaggerate the level of health risk from bathing water (Fleisher & Kay, 2006). Understanding public perception of bathing water quality can be useful to beach managers for developing future management strategies (Kelly et al., 2018; Pouso et al., 2018). For example, particular beach management options such as beach grooming and seaweed removal can increase public perception of the quality of a beach, although evidence suggests that the removal of seaweed can actually increase FIO levels in sand (Russell et al., 2014).

Beach classifications via the BWD also influence designations such as the Blue Flag award, the loss of which has the potential to impact tourism and local coastal economies (Saayman and Saayman, 2017). However, beach certification schemes are often used as an indicator of ‘beach cleanliness’ in an attempt to promote tourism rather than as a tool to promote environmental management (Klein & Dodds 2017). Their presence also has potential for misinterpretation by the public, for example beach awards may be perceived to signal zero risk of illness from sea-bathing. Understanding public attitudes towards bathing water, together with their perceptions of relative exposure risks, is critical for developing environmental management decisions and disseminating information to the public (Schernewski et al., 2018). Therefore, the aim of this study was to determine the effectiveness of current regulatory strategies for informing beach users about bathing water quality under the BWD, and to assess public understanding of the BWD classifications in terms of exposure risk and public health at two designated bathing waters in Scotland.

Methods

Site description

Two case-study bathing waters were used for this study: Largs (Pencil) Beach and Ayr (South) Beach, which are located on the West Coast of Scotland within 30 miles of each other. These two bathing waters were selected due to their different bathing water quality classifications, and the presence of electronic signage boards that provide daily water quality predictions for beach-users (McPhail and Stidson, 2009).

Largs (Pencil) Beach

Largs Beach is located in North Ayrshire (British National Grid Reference NS206580), close to the town of Largs, and was first designated as a bathing water in 2006. It is a sandy, relatively small bathing water of about 300 m in length, with a shallow bathing zone and two electronic signage boards. The beach is not groomed, and seaweed can accumulate at high tide marks. It has a small catchment area (1.2 km^2) with two streams that flow into the sea south of the bathing water, although there are no direct stream discharge points into the actual bathing water site. Parking access to the site is restricted, and there are no nearby food outlet areas; picnic benches for the public are set away from the bathing water and situated near public toilets. From 2012 to 2014 Largs was classed as ‘Guideline’ quality and from 2015 onwards it has been classed as ‘Excellent’, with these classifications representing the highest standards from the 1976 and 2006 Directives, respectively.

Ayr (South) Beach

Ayr Beach is located adjacent to the town centre of Ayr (British National Grid Reference NS330218), South Ayrshire. Designated as a bathing water in 1987, the beach is sandy and approximately 3.5 km in length. Ayr has a large catchment area: 930 km^2 of mainly agricultural land, which drains into the three rivers within the catchment. The beach is regularly groomed by tractors removing seaweed and litter. There are two electronic signage boards, both sited on the promenade. There are many nearby food outlets, as well as a children's playground and other entertainment facilities, and public toilets. Parking is available directly along the length of the beach and access includes mobility-friendly ramps from the promenade down to the beach. From 2012 to 2014 Ayr was classed as mandatory quality; in 2015, it was classed as ‘Sufficient’, while in 2016 it was downgraded to ‘Poor’.

Bathing water predictions

In Scotland, the EU BWD is implemented through The Bathing Water (Scotland) Regulations 2008, and the environmental management of bathing waters is regulated by the Scottish Environment Protection Agency (SEPA). Over the course of the bathing season, SEPA update their online “BeachLine” service with daily water quality predictions for 31 of the designated bathing waters in Scotland (http://apps.sepa.org.uk/bathingwaters/Predictions.aspx). These predictions are calculated through a computer-generated algorithm that considers, via telemetry, the antecedent 24 – 48 h precipitation volume and flows from river gauging stations against predefined trigger levels, which are used to remotely update the electronic signage boards located at the beaches. There were 107 days in the 2016 bathing season; daily water quality predictions were collected from the “BeachLine” website and recorded as either ‘No Predicted Issues’, ‘Poor’, or ‘No Forecast’ for both bathing waters.

Collation of regulatory water monitoring data

Monitoring of bathing water quality by SEPA occurs on predetermined days (per EU regulations, and a sampling calendar is released prior to the start of the bathing water season); results are entered onto their website a few days after the water sample has been processed. At the end of the bathing season, SEPA make all monitoring details along with any additional information publicly available. Water quality data for both Ayr Beach and Largs Beach were retrieved from the SEPA online database for the 2016 bathing season.

Beach-users questionnaire

Public perception of water quality, bathing water management, and associated risks at both Largs and Ayr were assessed using a face-to-face questionnaire (available upon request) at both beaches. Weekend days during the bathing season were chosen for questionnaire deployment due to expected higher numbers of beach users. Weather conditions were not used as a factor to determine days chosen, with a similar number of days experiencing ‘good’ or ‘bad’ weather at each location. The questionnaire was designed to assess the participant profile, their knowledge of beach attributes and bathing water monitoring, their views on bathing water quality and finally how the water quality would affect their use of the water for bathing. The questionnaire received ethical approval prior to conducting the study, and all participants were over 18 years of age.

Statistical analyses

All statistical analyses were carried out in Minitab 18.1 (Minitab Inc., PA, USA) and Differences at the $p < 0.05$ level (95% confidence interval) were considered statistically significant. The 95th and 90th percentile results were calculated from the SEPA water monitoring data for each FIO, using equations set out in the EU Bathing Water Directive. For the 95th percentile the equation antilog(μ + 1.65σ) was used, while for the 90th percentile the equation antilog(μ + 1.282σ) was used, where μ denotes the average concentration of each FIO, and σ denotes the standard deviation (CEC, 2006).

For the beach-user questionnaire, Chi-squared tests were used to determine whether there were significant associations between the location of the survey and participant responses to questions such as: distance beach-users travelled to the bathing water, perceived microbial water quality, and lowest classification of water beach-users considered acceptable for bathing. Mann-Whitney U tests were used to test for differences between beaches in terms of respondent age, average distance travelled to the beach, perceived water quality, how the quality of water would affect bathing decisions, and the level of risk considered acceptable for bathing. Finally, Spearman’s correlation analysis was used to determine relationships between perceived water quality and the lowest level of water quality found acceptable for bathing at each bathing water site.

Results

Bathing water predictions and regulatory water quality monitoring data

Over the course of the 2016 bathing season, 107 daily water quality predictions were collected from the “BeachLine” website. At Largs there were 17 days classified as ‘Poor’, 88 days with ‘No Predicted Issues’, and two ‘No Forecast’ days; in contrast, the predictions at Ayr Beach consisted of 54 ‘Poor’ days, 50 days classed as ‘No Predicted Issues’ and three days with ‘No Forecast’. Largs Beach had five times as many days with ‘No Predicted Issues’ compared to ‘Poor’ predicted water quality days, while over half of the bathing season at Ayr was predicted as ‘Poor’ bathing water quality.

As required by the EU BWD, microbial water quality was monitored at both Largs and Ayr Beaches 18 times during the 2016 bathing season. Over the course of the season, concentrations of *E. coli* were higher than IE at both bathing waters ($P < 0.05$), with generally higher concentrations of both FIOs at Ayr compared to Largs (Figures 1 and 2).

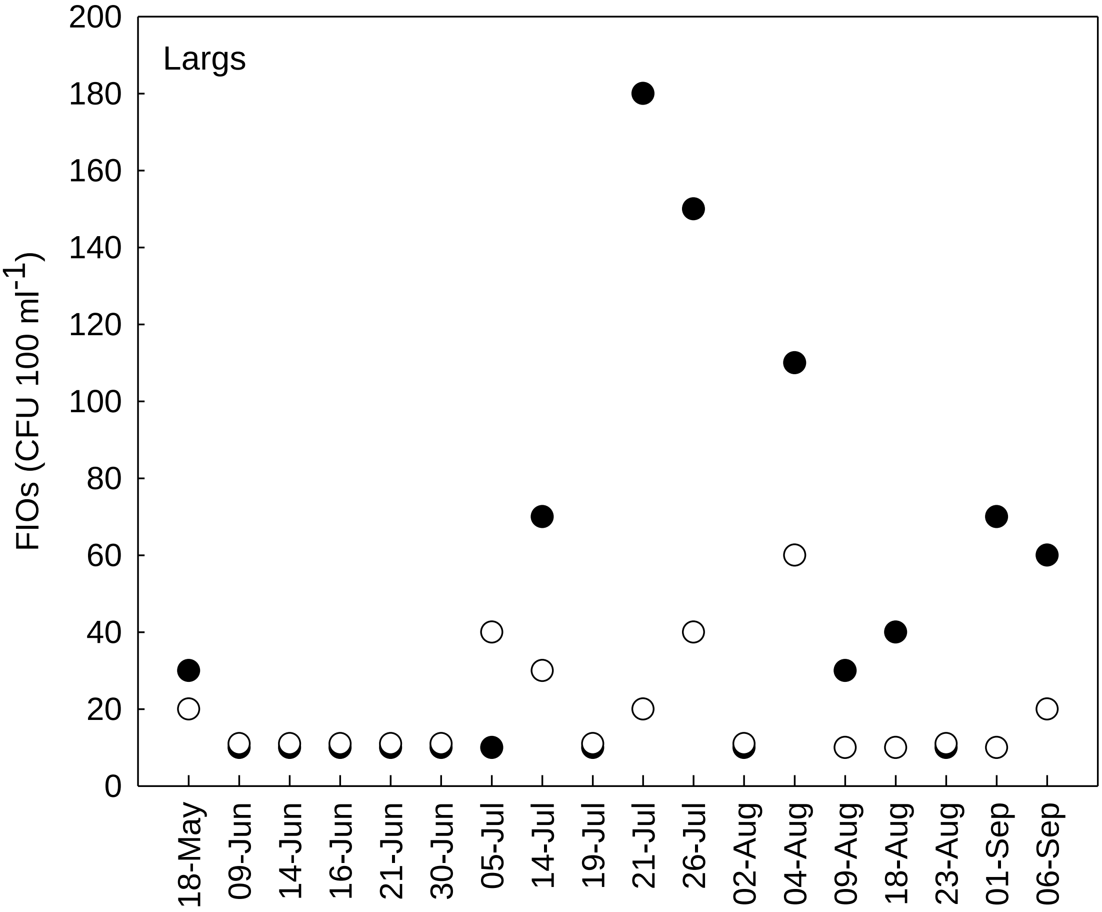

Figure 1: Regulatory microbial water quality monitoring results, *E. coli* (filled symbols) and enterococci (open symbols), at Largs Beach from the complete 2016 bathing water season.

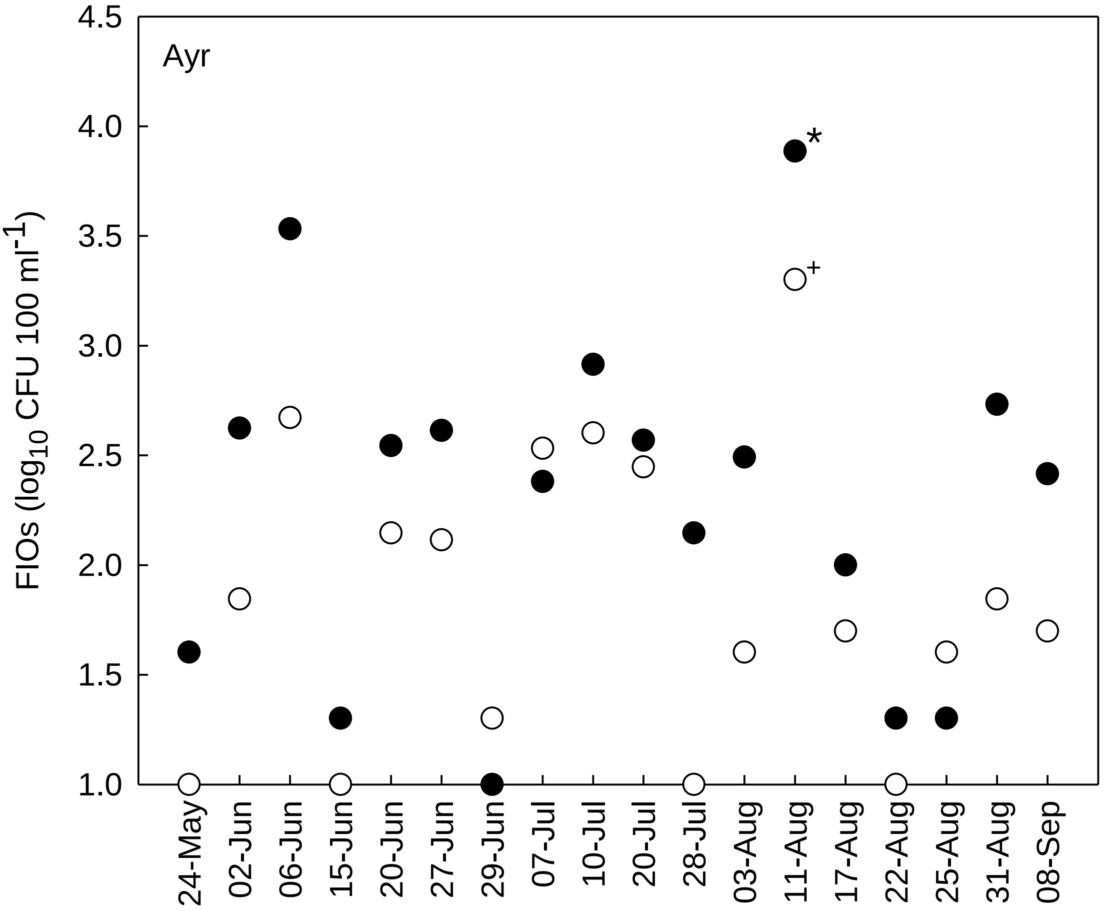

Figure 2: Regulatory microbial water quality monitoring results, *E. coli* (filled symbols) and enterococci (open symbols), at Ayr Beach from the complete 2016 bathing water season. Labelled data points for *E. coli* (*) and enterococci (+) were removed from the final compliance dataset.

At Largs, all 18 samples collected by the environmental regulator were included in the algorithm to determine the 2016 season classification; however, at Ayr Beach two samples were discounted by SEPA and therefore only 16 samples were used to calculate the 2016 classification. Largs Beach, based on the 2016 water monitoring results, was classified under the BWD as ‘Excellent’ from both its IE sampling results (42 CFU 100 ml^{-1} at the 95th percentile, with an allowable amount of 100 CFU 100 ml^{-1} for ‘Excellent’ ratings), and its *E. coli* results (156 CFU 100 ml^{-1} at the 95th percentile, with 250 CFU 100 ml^{-1} the limit for ‘Excellent’ ratings; Table 1).

Table 1: Regulatory 90th and 95th percentile results for FIO monitoring. Values in bold denote the final 2017 classification level.

	E. coli (CFU 100 ml^{-1})		Intestinal enterococci (CFU 100 m^{-1})	
	90th percentile	95th percentile	90th percentile	95th percentile
Largs	105	**156**	34	**42**
Ayr (full data set)*	1967	3800	631	1223
Ayr (compliance)	**1094**	1957	**346**	620

*The full dataset for Ayr was not used for the final classification due to the removal of two data points

Ayr beach, based on the 2016 compliance water monitoring results, was classified as a ‘Poor’ bathing water from its IE concentration (346 CFU 100 ml^{-1} at the 90th percentile, with an allowable amount of 185 CFU 100 ml^{-1} for a ‘Sufficient’ classification), and also its *E. coli* concentration (1094 CFU 100 ml^{-1} at the 90th percentile, with 500 CFU 100 ml^{-1} the limit for a ‘Sufficient’ classification; Table 1). These classifications were calculated with the compliance data set following the removal of the two discounted samples. However, the *E. coli* concentration was not significantly different between the compliance and full Ayr datasets.

Public perception, image recognition and perceived water quality assessments

In total, there were 303 respondents to the questionnaire, 117 at Largs Beach and 186 at Ayr Beach. Overall, 176 of these were women while 126 were men, with similar proportions of male and female respondents at each of the two bathing waters. There was a significant difference in respondent age profile between the two bathing waters ($P < 0.001$), with a modal age category for Largs > 60 years, and for Ayr 30 – 39 years. There was a significant association between the distance that respondents had travelled to the bathing water and the survey location with people having travelled greater distances to visit Ayr beach than Largs beach ($P < 0.001$).

At Largs, the most common reasons for visiting the beach were relaxation (42%), picnics (17%) and dog walking (16%), whilst at Ayr, the most common reasons were relaxation (40%), dog walking (18%) and other (for example, local attractions and children's play areas; 16%). Over a third of respondents at both beaches did not know if the bathing water was monitored (38% at Largs; 37% at Ayr), and of those respondents who did think it was monitored they either considered it to be the responsibility of the local council to monitor the water (32 % at Largs; 46 % Ayr) or the duty of the environmental regulator (24 % at Largs; 17 % Ayr). Respondents at both bathing waters were asked whether they recognised the four EU bathing water quality signs that are used to communicate classifications (Figure 3). A significantly higher proportion of respondents did not recognise the signs (60% at Largs and 61% at Ayr) compared to respondents who did recognise the signs ($P < 0.05$). Just under half (48%) of respondents at Largs knew that a water quality information board was present at the beach, while the majority of respondents at Ayr did not know if there was a board present (56%). At both locations, most respondents (60% at Largs and 72% at Ayr) did not know what the predicted water quality was on that particular day.

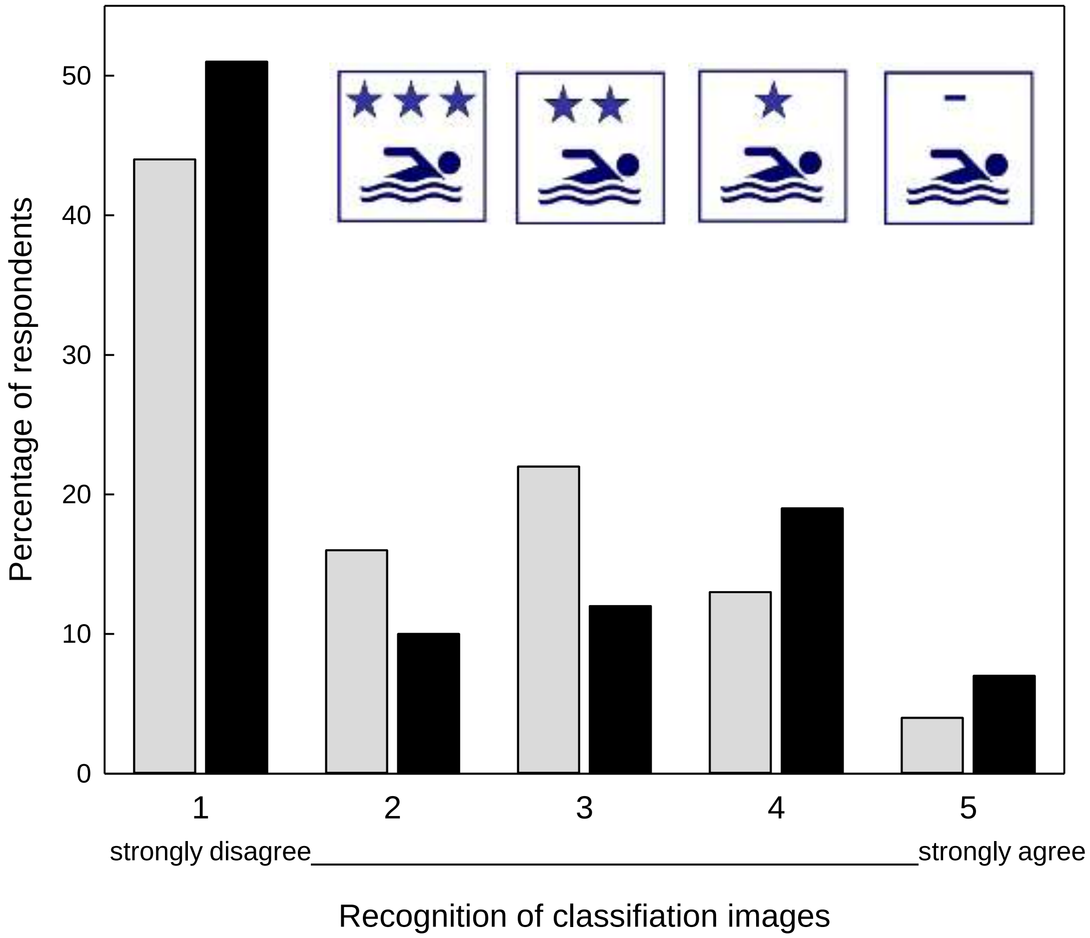

Figure 3: Responses to the question, "*Do you recognise these four EU bathing water signs?*" of respondents at Largs (grey bars) and Ayr (black bars) bathing beaches. Where 1 = strongly disagree and 5 = strongly agree. The insert shows the four EU bathing water quality signs that are used for informing the public about bathing water classifications

Information on perceived microbial water quality was obtained from respondents at both beaches on the day of each survey (i.e. their classification based on their perception of the water quality on that day, rather than being derived over the season), with significant differences between quality assessments at the two bathing waters ($P < 0.001$). At Largs, 10% of respondents classed the bathing water as ‘Excellent’, while only 2% of respondents at Ayr thought the water was ‘Excellent’ (Figure 4). The highest proportion of respondents at both bathing waters thought that the water was of ‘Good’ quality (64% at Largs, and 49% at Ayr). The majority of respondents at both beaches gave ‘clarity of the water’ as the reason for their choice. However, when asked whether the ‘quality’ of the seawater would affect their decision to go swimming in the sea, there was no significant difference between the two bathing waters in how the water quality would affect their decision ($P > 0.05$), with the majority ‘agreeing’ or ‘strongly agreeing’ with this statement (Figure 5). Respondents were also asked for the lowest level of microbial water quality they would find acceptable before entering the water (Figure 6). There was a significant difference between the two bathing waters ($P < 0.05$), with only one person at Largs willing to swim in poor quality water, compared to 14 people at Ayr. The majority of people would only accept a water quality classification of at least “Good” before swimming in the sea at both bathing waters. At Ayr, there were fewer respondents who perceived the water to be of ‘Excellent’ or ‘Good’ quality (52%) compared with the number of respondents who stated that only ‘Excellent’ or ‘Good’ water quality was acceptable for bathing (70%) (Figures 4 and 6).

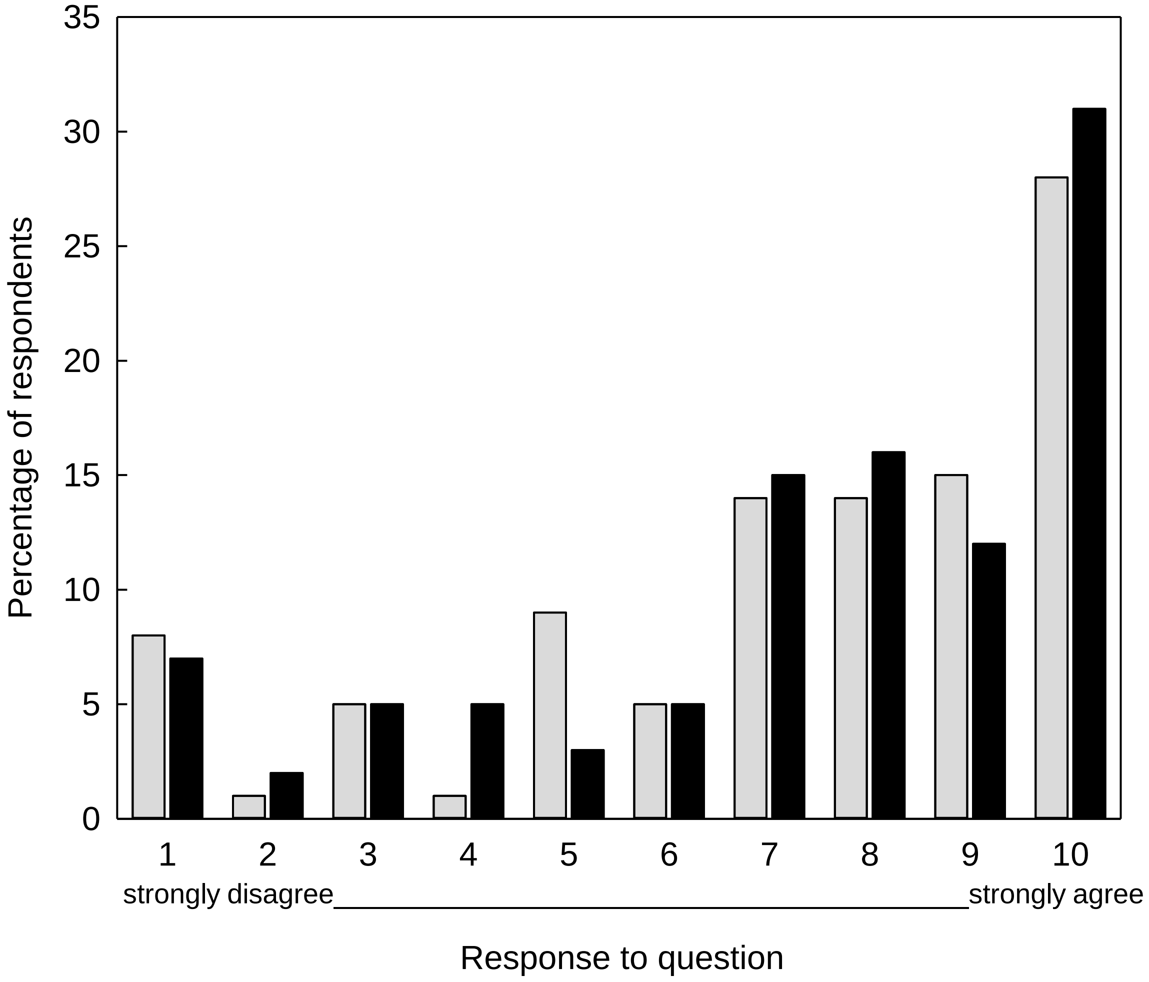

Figure 4: Responses to the question, "*Does the quality of the sea water affect your decision to go swimming in the sea?*" by respondents at Largs (grey bars) and Ayr (black bars) bathing beaches. Where 1 = strongly disagree and 10 = strongly agree.

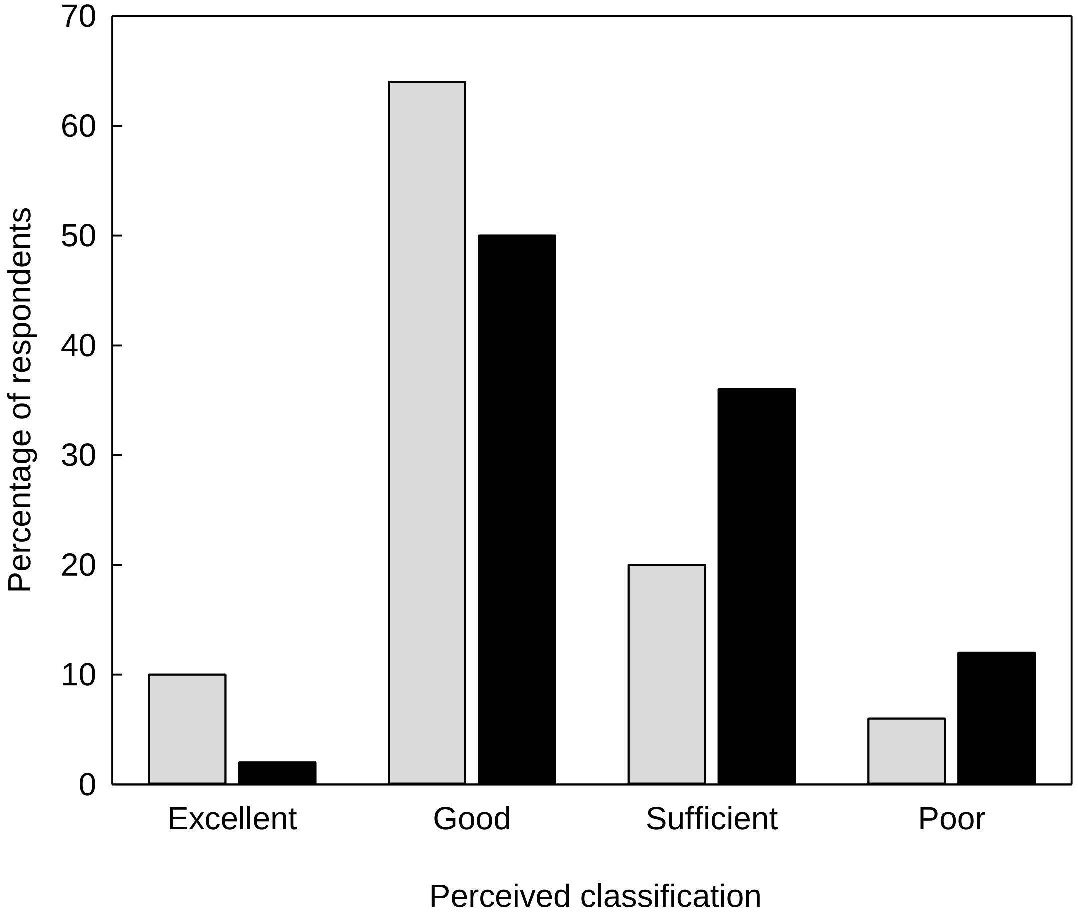

Figure 5: Perceived microbial water quality by respondents at Largs (grey bars) and Ayr (black bars) bathing beaches, answering the question, "*What do you think the bathing water quality at this beach is today?"*

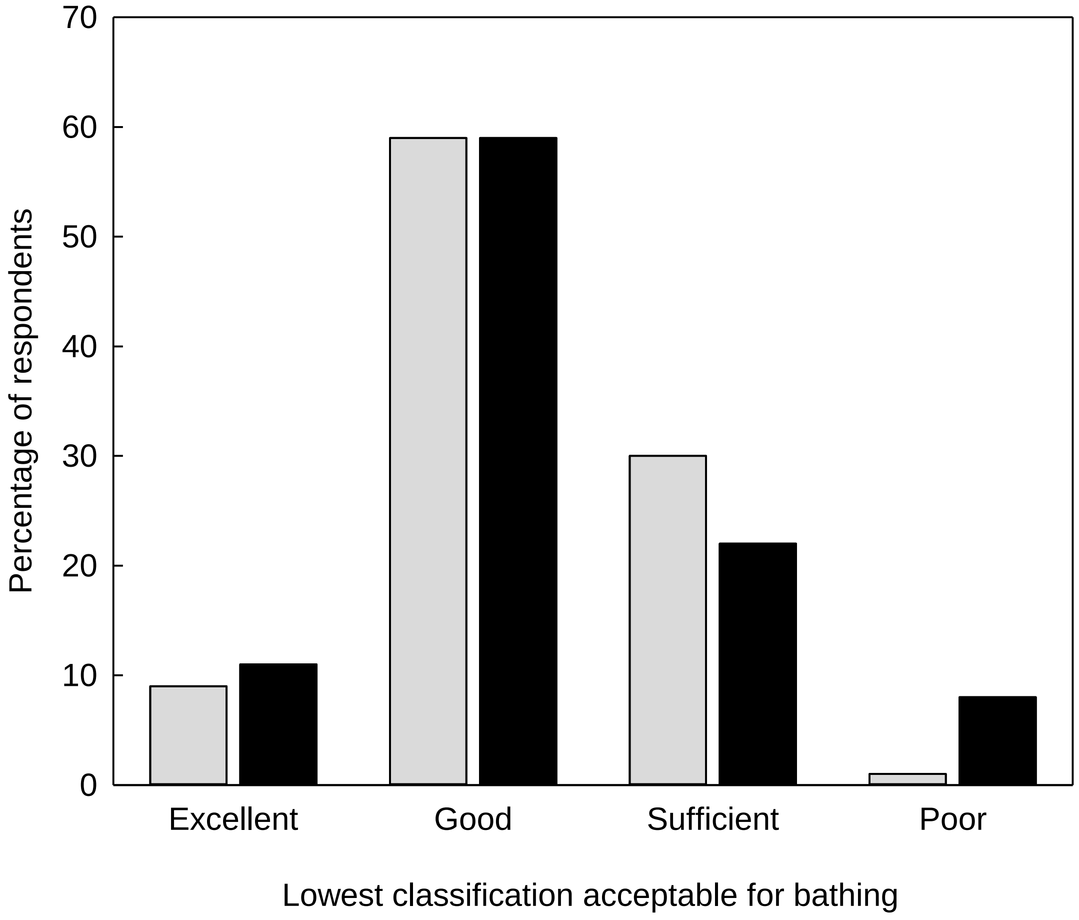

Figure 6: Lowest water quality respondents would find acceptable for bathing at Largs (grey bars) and Ayr (black bars) bathing beaches.

Finally, participants were asked what level of risk of becoming ill they would consider acceptable before entering the bathing water, ranging from a 10% risk (1:10) to a 0.0001% risk (1:1,000,000). There was no significant difference between the responses of people at the two bathing waters (Figure 7). At both bathing waters, the modal group was 1:1,000 (0.1% risk; 27% at both sites) with the next most frequently cited risk level being 1:10,000 (0.01% risk; 20% for Largs and 21% for Ayr).

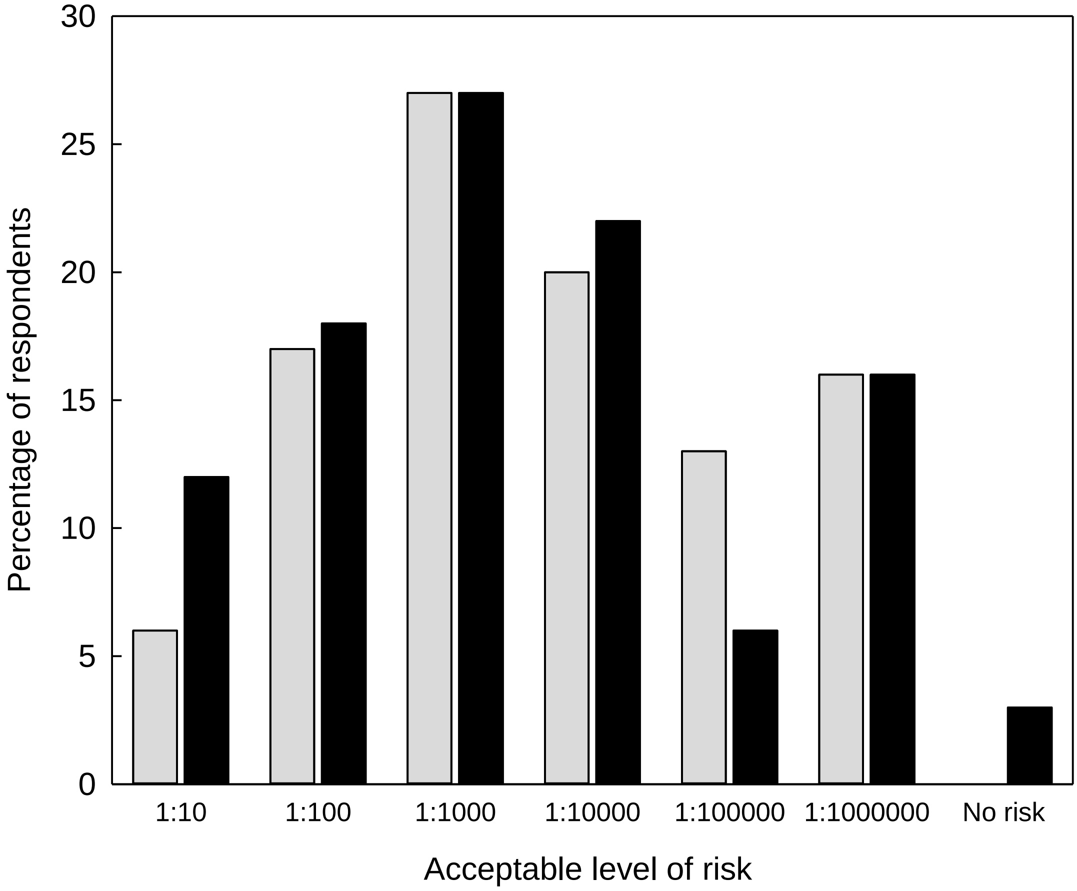

Figure 7: The level of risk of illness, e.g. stomach bug or ear infection, that respondents would accept before they considered entering the sea at Largs (grey bars) and Ayr (black bars) bathing beaches.

Discussion

The 2006 BWD requires environmental regulators to provide information to the public in the form of a bathing water profile, freely available updates on potential pollutant sources, and an information board at each designated bathing water that clearly displays recent microbial compliance results. In this study, in addition to information-rich notice boards, both beaches also have electronic signage boards installed that clearly state the predicted quality of the water for that particular day. Yet, over half of all respondent at both beaches were unaware of these information boards on bathing water quality, and over a third of respondents did not know that the beach was even monitored for water quality. The aim of the BWD is to reduce public exposure to contaminated bathing waters by providing an evidence-based classification system linked to an epidemiological risk of getting ill. However, there is currently a significant lack of data on beach user's knowledge of water quality classification under the BWD and the public perception of exposure risk at bathing waters. This study has shown that the current public understanding of the BWD classifications in terms of exposure risk and public health is limited, irrespective of the compliance record of a beach, and that there is a need to improve the delivery of information to beach stakeholders about the quality of bathing water.

During the bathing water season, water quality predictions from the "BeachLine" web service are created daily; however, the predictions are not updated during the course of the day, and are released each morning and remain accessible until the evening. Large rain events during the day can deliver FIOs to bathing waters from upstream in the catchment; yet bathing water advice remains the same until the following day's prediction is released. Consequently, although most of the time prediction tools are correct, or at least precautionary, (McPhail and Stidson, 2009), ‘Beachline’ predictions are unable to respond quickly enough to pollution events.

The sampling calendar for collecting compliance data is planned ahead of the bathing season, with the frequency and number of samples determined by individual EU member states, which means that pollution events occurring between samples could go unnoticed by the regulator even though the public continues to use the bathing water. Short term pollution events can considerably effect the final classification of a bathing water (Figueras et al., 2015), for example, if regulatory sampling occurs after a pollution event or heavy rain; therefore, the BWD allows a maximum of 15 % of samples to be discounted from the final classification calculation. Being able to remove “Poor” samples to potentially avoid a season’s-end “Poor” classification is arguably more representative of the normal classification conditions throughout the season, and gives the public more confidence in using the bathing water in the future.

Over 50% of the Beachline predictions at Ayr beach were for “Poor” quality bathing water, and an electronic sign predicting poor bathing water quality for over half of the bathing season is likely to have had a negative economic effect on the local community. With current climate change projections, there are increasing threats of summer storms driving elevated FIO transfer from land to water. Under these circumstances, reducing the likelihood of human exposure to contaminated bathing water through real-time information provision at bathing beaches offers an extra line of public health defence, if communicated effectively. Bathing waters that receive runoff from large agricultural catchments, such as Ayr, are particularly susceptible to high FIO loading after heavy rain, and although the algorithm for prediction models can be over cautious, they do provide more of a real-time indication of bathing water quality compared to regulatory microbial compliance data, which by the time it is ready to be communicated to the public is already 2-3 days out of date (Oliver et al., 2014; Searcy et al., 2018).

The majority of respondents in our study did not recognise the four EU bathing water quality signs that have been developed to give a quick visual guide to current bathing water quality (European Commission, 2016), which further demonstrates shortcomings in the public's awareness of the BWD. In the past decade, regulators in the EU have made bathing water information freely available on their websites, whilst social media and text-massage services are also used to disseminate current water quality information. However, despite the information boards and electronic signs, and several sources of online information, most beach-users in our study were unaware of the predicted quality of the bathing water on the day that they were at the beach. This issue seems to stem from more than just a lack of knowledge of who is responsible for monitoring water quality at beaches, but rather suggests that most beach users make the decision of entering a bathing water based upon their own perception of the water quality, e.g. by how 'clean' it looks or smells (Pratap et al., 2013; Jones et al., 2018). Constantly having a prediction of "Poor" water quality at a beach can also cause user fatigue (Kim and Grant, 2004), and may lead beach users to dismiss or ignore water quality predictions, leading to a public health risk as users wilfully ignore warnings that are considered out of date or overly cautious. This may explain the number of beach-users at Ayr beach who were willing to go swimming in water classified as 'poor' at the time of our study.

Bathing waters are heavily influenced by land use and management within the catchment, and as part of the EU Water Framework Directive, environmental regulators target water quality improvements at the catchment scale through their

River Basin Management Plan (RBMP). Indicators of faecal contamination in bathing water, such as *E. coli*, provide a measure of the level of faecal contamination rather than an indication of the presence of waterborne pathogens (Field and Samadpour, 2007). Nonetheless, the presence of waterborne FIOs have been linked to illness in bathers (Leonard et al., 2018), which is associated with a significant economic burden (DeFlorio-Barker et al., 2018b); therefore, exposure to poor quality bathing waters needs to be managed through evidence-based guidelines and targeted research leading to improvements in risk communication.

The two BWD microbial compliance parameters, *E. coli* and IE, are enumerated by culture-dependent methods, which is often criticised in terms of the speed of analysis. Processing FIOs in water samples can take between 18 - 96 h, by which time the bathing water quality information is out-of-date for the recreational beach-user. The transfer of existing molecular biological tools, such as qPCR, is therefore gaining momentum largely because these methods permit a much more rapid sample processing time (1 - 2 hours). Thus, molecular biological tools offer an opportunity to provide a more meaningful statement of microbial risk to water users by providing near-real-time information, and thus enable more informed decision-making for water-based activities (Dorevitch et al., 2017). However, our study has suggested that the majority of beach-users don’t engage with information on bathing water quality, and so the value of an increase in the speed of reporting microbial water quality to a typical beach-user is limited. Furthermore, FIO concentrations in seawater can vary during the day, e.g. due to fluctuations in UV irradiance, tides and wind direction; consequently, the time of day water samples are collected, together with the location they are taken from, can significantly affect concentrations of FIOs at a bathing water (Jennings et al., 2018; Quilliam et al., 2011), and so even with a more rapid processing time, the information given to the beach-user remains out of date. Whilst not perfect, culture-based methods, together with molecular approaches and modelling prediction tools allow beach managers to inform beach users about the risk of using a bathing water (Bedri et al., 2016; Oliver et al., 2014; Thoe et al., 2014).. However, our study has clearly demonstrated that resources should now be focussed on developing improved methods of disseminating information on water quality to the beach-user.

The public perception of bathing water can be influenced by the media or the historical reputation of a beach (Pendleton et al., 2001). Ayr beach has had a recent record of poorer water quality than at Largs beach, which may explain the lower perceived classification that respondents gave about the quality of the water at Ayr, i.e. beach-users have got accustomed to the water quality being described as poor at that beach. This also raises questions about how visitors and residents might respond differently to bathing water quality information (Dodds & Holmes, 2018). The lowest classification of water quality that respondents would find acceptable for bathing was very similar between the two beaches, with the majority stating that the water would need to be at least ‘Good’ or ‘Sufficient’ for them to be use it. However, this is not reflected in the responses to the risk of contracting a gastrointestinal illness (GI), with the majority of people (91 % of all respondents) only willing to accept a risk of 1% or less of getting ill (the ‘Good’ classification represents ~ 5% GI risk). Over the last decade, the risk of bathers contracting a GI has received increasing attention, and whilst it is generally accepted that using contaminated bathing water can increase the risk of GI (Leonard et al., 2018), there is concern that this correlation is inconsistent due to differences in data collection between epidemiological studies (King et al., 2014). Although, there remains little evidence for a significant dose response between FIOs and GI in marine water, guidelines suggest that bathing water with < 40 CFU IE 100 ml^{-1} presents < 1% risk of contracting a GI disease (this concentration of IE would equate to an 'Excellent' classification under the BWD) (Kay et al., 2004). This is not consistent with the lowest classification of water the respondents would be willing to use, with only 11 % of respondents saying that 'Excellent' was the lowest classification they would accept. The risk of contracting a GI in bathing water with 41 – 200 CFU IE 100 ml^{-1} (classification of 'Good') rises to 1 – < 4 %; whilst a concentration of > 500 CFU IE 100 ml^{-1} presents a risk of > 10% of GI disease (Kay et al., 2004). Our study has shown that 8 % of respondents were willing to accept a 10 % risk of contracting a GI, which would equate to a 'Sufficient' classification under the BWD. The perception of risk of illness from using bathing water suggests a lack of understanding of how the classification system of the BWD relates to risk. However, this is not exclusive to the BWD as there is a similar situation in the US, with a limited awareness of water quality regulatory guidelines among beach-users, and an unrealistic perception of the risk of contracting a GI (Pratap et al., 2013).

Conclusion

Recreational bathing waters are an integral part of the environment, and provide significant health and economic benefits. Improvements in bathing water quality in the EU, legislated under the BWD, have provided much safer environments for the public. However, there remains a disconnect between the regulator who is enforcing policy and the beach-user as a stakeholder. Environmental regulators channel significant time and resources into conforming to the BWD, but there now needs to be greater focus on the methods for disseminating bathing water quality information to beach users, with further development needed in order to attract greater public engagement. Social media may play a more significant future role for publicising information to beach-users, although it is well recognised that social media is not uniformly used across age groups, and tourists to the area may not speak the local language. There is a willingness to pay for improvements in bathing water quality among beach-users (Hynes et al., 2013); therefore, investing in innovative and novel methods for clearly disseminating the significance of compliance data under the BWD would increase public engagement, and allow beach-users to make more informed decisions about using bathing waters and deciding whether to allow their children to play in the water.

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