



PARLEE BEACH RESEARCH GROUP: BATHER DENSITY, PATHOGEN SHEDDING AND WATER QUALITY

An Annotated Bibliography Assembled by the New Brunswick Department of Environment and Local Government

Ref. No.	Author/Organization	Title	Overview	Date
1	Abreu, Roberto et al.	<u>Sediment characteristics and microbiological contamination of beach sand – A case-study in the archipelago of Madeira</u>	Beach sand can harbour pathogenic and opportunistic microorganisms, as well as faecal indicator bacteria that influence directly the bathing water quality. Pathogenic and opportunistic microorganisms often raise concern of exposure during beach related recreational activities. Statistical analysis showed higher contamination of sediment in artificial beaches compared to natural beaches and granulometry and chemical composition of sand did not influence in the microbial loads. Instead, bather density and the influence of coastal protection structures needed to maintain the volume of artificial beach sand regarding the removal potential of wave induced currents are obvious influencing factors.	2016.12
2	Ashbolt, N. J. et al.	<u>Predicting pathogen risks to aid beach management: The real value of quantitative microbial risk assessment (QMRA)</u>	Most epidemiologic studies to date have lacked statistical power, nor were they designed to specifically investigate health relationships to FIOs as well as bather density. Yet recent QMRA supports the potential concern of GI risk from bathers shedding pathogens. For virus risks, there is also greater likelihood of urine contribution to recreational waters being a concern. ...Experience with municipal swimming pools outbreaks shows that where there is high bather density and low rates of water exchange, ' bather shedding ' of pathogens can be a major source of contaminants. Bather shedding is an issue recognized in the WHO (2003) guidelines. Current routine monitoring and microbial source tracking (MST) may address the far-field but are poorer at identifying near-field risk due to shedding of pathogens and may be irrelevant or could conceivably make matters worse....High-risk situations due to bather shedding may be much more common and varied than currently appreciated. In many countries there are semi-natural marine tidal/coastal/ ocean pools along with lakes and increasingly 'natural pools' that have no clear capacity to disinfect viruses.	2010.06

Ref. No.	Author/Organization	Title	Overview	Date
3	Calderon, R.L. et al.	<u>Health effects of swimmers and nonpoint sources of contaminated water</u>	The health status and swimming activity of volunteer study participants was followed for 49 days during June, July and August. Multiple bacterial indicators of water quality were monitored daily during the course of the study. Swimming-associated symptomatic gastrointestinal illness was observed in individuals who swam in animal nonpoint source contaminated water. Swimmer illness was not associated with high densities of common faecal indicator bacteria or high volume rainy days. Swimmer illness was associated with high numbers of swimmers per day and high densities of staphylococci. The observed illnesses appeared to be caused by a swimmer to swimmer transmission via the water.	1991.03
4	Castor, M.L. and M. Beach	<u>Prevention of recreational water illnesses</u>	A high bather density that includes toddler and diaper-aged children engaging in activities of communal bathing and water sharing increases the likelihood of water contamination. Fecal accidents, improper cleansing after bowel movement and feces from swimmers' bodies may all add up to several pounds of feces a day in the average water park. Because waterborne pathogens such as Cryptosporidium and Giardia have such low infectious doses, consumption of only small volumes of water may be required for disease transmission to occur.	2004.05
5	Castor, M.L. and M. Beach	<u>Reducing illness transmission from disinfected recreational water venues: swimming, diarrhea and the emergence of a new public health concern</u>	Even in the absence of a fecal accident, the average bather sheds 0.14 grams of fecal material and children may shed up to 10 grams.	2004.09
6	Charoenca, N. and R, S. Fujioka	<u>Assessment of Staphylococcus Bacteria in Hawaii's Marine Recreational Waters</u>	Staphylococci were recovered from beach waters throughout the day, including evening hours, indicating the stability of these bacteria in marine waters. Moreover, the antibiotic sensitivity patterns and phage types of <i>S. aureus</i> isolates from marine waters and from clinical human skin cultures were similar. These results support the hypothesis that recreational waters can serve as vehicles for the transmission of staphylococcal skin infections .	1993.00

Ref. No.	Author/Organization	Title	Overview	Date
7	Cheung, W.H.S. et al.	<u>Variations in microbial indicator densities in beach waters and health-related assessment of bathing water quality</u>	Daily and hourly variations in microbial indicators densities in the beach-waters of Hong Kong have been described. The levels of Escherichia coli at a number of beaches was observed to be influenced by tide, and for staphylococci, by bather numbers . The tidal influence was most obvious during spring tides; and for the effect of bathers, during neap tides. Both organisms are present in high densities in external sources of faecal pollution of bathing beaches, with the average staphylococci to E. coli ratios being 0.04–3. Staphylococci may serve as an indicator of bather density and the risk of cross-infection amongst bathers (rather than as another indicator of faecal contamination) when the average staphylococci to E. coli ratio for a bathing beach is considerably higher than 3. The variability of microbial indicator densities means the routine sampling of bathing beaches should be carried out on weekend days with maximum numbers of swimmers exposed to the water, and spread throughout the bathing season.	1991.00
8	Craun, G.F. et al.	<u>Outbreaks associated with recreational water in the United States</u>	In this article, we review the causes of outbreaks associated with recreational water during 1971-2000. A bacterial or protozoan etiology was identified in three-quarters of the outbreaks; 23% of the outbreaks were of undetermined etiology. The most frequently identified agents were Cryptosporidium (15%), Pseudomonas (14%), Shigella (13%), Naegleria (11%), Giardia (6%), and toxigenic E. coli (6%). Outbreaks attributed to Shigella, E. coli O157:H7, and Naegleria were primarily associated with swimming in fresh waters such as lakes, ponds, and rivers. In contrast, outbreaks caused by Cryptosporidium and Giardia were primarily associated with treated water in swimming and wading pools. Important sources of contamination for both treated and untreated recreational waters were the bathers themselves .	2005.08

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9	Eisenburg, J.N. et al.	<u>Quantifying Water Pathogen Risk in an Epidemiological Framework</u>	Traditionally, microbial risk assessors have used point estimates to evaluate the probability that an individual will become infected. We developed a quantitative approach that shifts the risk characterization perspective from point estimate to distributional estimate, and from individual to population. To this end, we first designed and implemented a dynamic model that tracks traditional epidemiological variables such as the number of susceptible, infected, diseased, and immune, and environmental variables such as pathogen density. A case study is presented that explores the uncertainties in assessing the risk of giardiasis when swimming in a recreational impoundment using reclaimed water. Using literature-based information to assign parameters ranges, our analysis demonstrated that the parameter describing the shedding of pathogens by infected swimmers was the factor that contributed most to the uncertainty in risk. The importance of other parameters was dependent on reducing the a priori range of this shedding parameter.	1996.08
10	Elmir, S.M. et al.	<u>Quantitative evaluation of bacteria released by bathers in a marine water</u>	Results from the “large pool” study showed that bathers shed concentrations of enterococci and <i>S. aureus</i> on the order of 6×10^5 and 6×10^6 colony forming units (CFU) per person in the first 15 min exposure period, respectively. Significant reductions in the bacteria shed per bather (50% reductions for <i>S. aureus</i> and 40% for enterococci) were observed in the subsequent bathing cycles. The “small pool” study results indicated that the enterococci contribution from sand adhered to skin was small (about 2% of the total) in comparison with the amount shed directly from the bodies of the volunteers. Results indicated that bathers transport significant amounts of enterococci and <i>S. aureus</i> to the water column, and thus human microbial bathing load should be considered as a non-point source when designing recreational water quality models.	2007.01
11	Elmir, S.M.	<u>Bacteria Indicators Human Shedding Studies</u>	PowerPoint presentation summarizing the methods and results of <u>Quantitative evaluation of bacteria released by bathers in a marine water</u>	2008.10

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12	Elmir, S.M. et al.	<u>Quantitative evaluation of enterococci and Bacteroidales released by adults and toddlers in marine water.</u>	The current study expands upon prior research by evaluating shedding from both toddlers and adults , and by the expansion of measurements to include enterococci shedding via three different methods (membrane filter (MF), chromogenic substrate (CS), and quantitative polymerase chain reaction (qPCR)) and shedding of alternative fecal indicator bacteria (Bacteroidales human markers UCD and HF8 via qPCR). The estimated numbers of Bacteroidales human markers ranged from 1.8×10^4 to 1.3×10^6 for UCD, and ranged from the below detection limit to 1.6×10^5 for HF8. The estimated amount of sand transported per toddler (n=14) into the water column after sand exposure was 8+/-6g on average. When normalizing the numbers of enterococci shed from toddlers via sand by the 3.9 body surface area ratio, the differences between toddlers and adults were insignificant. Contributions of sands to the total enterococci (MF) shed per toddler was 3.7+/-4.4% on average. Although shedding via beach sand may contribute a small fraction of the microbial load during initial bathing, it may have a significant role if bathers go to water repetitively after sand exposure.	2009.10
13	Feng, Z. et al.	<u>Modeling Microbial Water Quality at a Beach Impacted by Multiple Non-Point Sources</u>	To evaluate the relative importance and impacts of various types of non-point microbial sources at a subtropical beach (Hobie Beach, Miami, USA), we utilized a coastal ocean circulation model (Delft3D) with a microbe transport-fate model. Those non-point sources include beach sediment, dog feces, bather shedding, and rainfall runoff. Bathers are the only Staphylococcus aureus source considered in the study and simulated levels are in the same order as prior field measurements.	2012.00

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14	Fewtrell, Lorna and David Kay	<u>Recreational Water and Infection: A Review of Recent Findings</u>	<p>Papastergiou [20, 21] did not find a relationship between gastrointestinal illness and indicator bacteria (Table 1) at three beaches with 'excellent' water, but they did find an association between bather density and both gastrointestinal [OR 2.13, 95 % confidence interval (CI) 1.95-3.79] and respiratory illness (OR 2.99, 95 % CI 1.64-5.46). Beach A (with a median bather density of 1.41 bathers/100 m³) was used as the baseline and compared to illnesses reported by bathers at beaches B & C (median densities of 2.91 and 21.65 bathers/100 m³, respectively). It was presumed that the increased illness was caused by bather to bather transmission via the water (gastrointestinal illness) and air (respiratory pathogens).</p> <p>Graczyk [29] found a significant relationship between bather numbers at a marine beach in the USA and turbidity. The detection of three selected pathogens was significantly correlated with both enterococci levels and bather density. It was thought that the bathers were causing re-suspension of bottom sediments, which resulted in the elevated levels of enterococci and pathogens seen when bather numbers were high.</p>	2015.01
15	Fewtrell, Lorna and J. Bartram	<u>Water Quality: Guidelines, Standards and Health: Assessment of risk and risk management for water-related infectious disease</u>	<p>Bathers have been shown to shed high densities of E. coli, enterococci and Pseudomonas aeruginosa in tank studies where total body immersion was examined under controlled conditions (Breitmayer and Gauthier 1978; Smith and Dufour 1993). Other studies have demonstrated the accumulation of faecal indicator bacteria over the course of a day at populated beaches (Cheng et al. 1991). Two elements, bather density and water bodies with very little water movement contribute to bather-to-bather transmission of illness. These two elements can be used to develop a risk potential matrix which lists low risk for high bather density and high dilution, and a very low risk in the case of low bather density and high dilution. Medium risk results from high bather density and low dilution, which becomes low risk if both the bather density and dilution are low. These risks may be higher if the beach is populated with high numbers of young children or if no sanitary facilities are available.</p>	2001

Ref. No.	Author/Organization	Title	Overview	Date
16	Gerba, C.P.	<u>Assessment of Enteric Pathogen Shedding by Bathers during Recreational Activity and its Impact on Water Quality</u>	An assessment was made to determine the potential loading of enteric pathogenic protozoa and viruses into drinking water supply reservoirs by body contact recreation. These and other organisms of fecal origin are shed from the body during bathing. A literature review was conducted on the concentration of selected enteric viruses and protozoa during infection, the incidence of these infections, and duration of excretion. In addition, from existing literature, the amount of fecal material released during bathing was estimated from the shedding of fecal coliforms by bathers. The mean amount of fecal material shed per bather was estimated at 0.14[emsp4]gram. The concentration of protozoan parasites (Giardia or Cryptosporidium) in feces of infected persons can range from 105 to 107 per gram and enteric viruses (enteroviruses, adenoviruses, rotavirus) from 105 to 1012 per gram. From this information, the concentration of enteric pathogens, shed into the water, could be calculated for a group of bathers. This information can be used to model the impact of body contact recreation on water quality in reservoirs used for drinking water supplies. Such information is useful in assessing the required treatment of the water to meet water quality regulations.	2000.03
17	Goodwin, K. D. et al.	<u>A multi-beach study of Staphylococcus aureus, MRSA, and enterococci in seawater and beach sand</u>	S. aureus concentrations have been correlated to bather density and attributed to human activity (Calderon et al. 1991, Charoencna and Fujioka 1995, Papadakis et al. 1997, World Health Organization 2003).	2012.00
18	Graczyk, Thaddeus K. et al.	<u>Quantitative Evaluation of the Impact of Bather Density on Levels of Human-Virulent Microsporidian Spores in Recreational Water</u>	During summer months, samples of recreational bathing waters were tested weekly for human-virulent microsporidian spores and water quality parameters in association with high and low bather numbers during weekends and weekdays, respectively. Enterocytozoon bienersi spores were detected in 59% of weekend (n = 27) and 30% of weekday (n = 33) samples, and Encephalitozoon intestinalis spores were concomitant in a single weekend sample; the overall prevalence was 43%. The numbers of bathers, water turbidity levels, prevalences of spore-positive samples, and concentrations of spores were significantly higher for weekend than for weekday samples. The study indicates that resuspension of bottom sediments by bathers resulted in elevated turbidity values and implies that the microbial load from both sediments and bathers can act as nonpoint sources for the contamination of recreational waters with Enterocytozoon bienersi spores. Both these mechanisms can be considered for implementation in predictive models for contamination with microsporidian spores.	2007.05

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19	Graczyk, Thaddeus K. et al.	<u>Bather density and levels of Cryptosporidium, Giardia, and pathogenic microsporidian spores in recreational bathing water</u>	The study demonstrated that the resuspension of bottom sediments caused by bathers and their direct microbial input resulted in elevated levels of <i>Cryptosporidium parvum</i> oocysts, <i>Giardia lamblia</i> cysts, and microsporidian spores, particularly <i>Enterocytozoon bienersi</i> , in recreational beach water on days deemed acceptable for bathing by fecal bacterial standards.	2007.11
20	Graczyk, Thaddeus K. et al.	<u>Relationships among bather density, levels of human waterborne pathogens, and fecal coliform counts in marine recreational beach water</u>	During summer months, samples of marine beach water were tested weekly for human waterborne pathogens in association with high and low bather numbers during weekends and weekdays, respectively. The numbers of bathers on weekends were significantly higher than on weekdays ($P < 0.001$), and this was associated with a significant ($P < 0.04$) increase in water turbidity. The proportion of water samples containing <i>Cryptosporidium parvum</i> , <i>Giardia duodenalis</i> , and <i>Enterocytozoon bienersi</i> was significantly higher ($P < 0.03$) on weekends than on weekdays, and significantly ($P < 0.01$) correlated with enterococci counts. The concentration of all three waterborne pathogens was significantly correlated with bather density ($P < 0.01$).	2010.00
21	Halley, J.W.	<u>Bacterial Indicators/health Hazards Associated with Water</u>	It is generally accepted that in artificial bathing places , particularly in instances of insufficient water exchange and disinfection, bather density is a major factor in determining the probability of swimming associated illnesses. However in natural bathing places, pathogenic microorganisms carried by bathers themselves probably contribute little to hazards associated with recreational use. Exceptions are small inland bodies of water (ponds, coves, etc.) which are subject to minimum water exchange and extremely high bather density.	1977.00

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22	Halliday, E. et al.	<u>Bacteria in beach sands: an emerging challenge in protecting coastal water quality and bather health</u>	This paper reviews the current state of knowledge regarding the abundance and distribution of fecal indicator bacteria and pathogens in beach sands of diverse climatological regions, and at beaches subjected to varied levels of anthropogenic impact. In all regions fecal indicator bacteria are nearly ubiquitous in beach sands, and similar relationships emerge between fecal indicator abundance in dry sand, submerged sands, and water. Taken together, these studies contextualize a potential public health issue and identify research questions that must be addressed in order to support future policy decisions...Staphylococcus aureus has been found to be enriched in beach sands relative to local waters and S. aureus counts were correlated to the presence of yeasts of human origin as well as the number of swimmers on the beach at the time of sampling, implicating bathers as the source of this bacteria	2010.12
23	Hanes N.B, and A.J. Fossa	<u>A qualitative analysis of the effects of bathers in recreational water quality.</u>	Abstract not available	1970.00
24	Jiang, S et al.	<u>Swimmer Shedding Study in Newport Dunes, California</u> <u>Final Report</u>	Although all measurements of total coliform bacteria were well below AB411 single sample standard, elevated levels of fecal and total coliform bacteria (2 to 5 fold increases) were detected in the afternoon at Dunes East outside swimming area and Dunes North. However, these increases do not appear to be caused by the bather shedding because the numbers of bathers at these two locations were less ¼ of those observed at the Dune East Inside the swimming area. The average bather count at peak-use period (noon) was less than 20 at the Dune East Inside (high-use area), therefore, bather shedding during swimming activity may go undetected during this study due to the limited number of bathers in the water. All sediment samples exceeded the current State of California water quality single sample standard for fecal coliform and enterococcus by one to two orders of magnitudes suggesting sediment is a sink for water column bacteria.	2002.00

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25	Kishimoto, R., and G. Baker	<u>Pathogenic and Potentially Pathogenic Fungi Isolated from Beach Sands and Selected Soils of Oahu, Hawaii</u>	Fungi capable of causing mycoses in man are known to occur in many types of soils and natural habitats, but their occurrence in Hawaii has not been studied comprehensively to date. Two known sources served as the basis for this initial Hawaiian survey: 1) sands taken from beaches of low and high swimmer-density and, 2) soils associated with avian droppings. A total of 361 sand samples representing Oahu's supratidal and intertidal zones was screened. More pathogenic or potentially pathogenic fungi were isolated from areas where the swimmer-density was very high and, conversely, few were isolated from low swimmer-density areas.	1969.06
26	Kress, M.M.	<u>Identification and Use of Indicator Data to Develop Models for Marine-Sourced Risks in Massachusetts Bay</u>	Bathers themselves may re-suspend bottom sediments and subsequently cause elevated levels of Enterococci and other microbes in bathing waters, however this is not likely to be a significant factor for Massachusetts marine beaches. As shown in Table 3-11 for 2014 the vast majority of water quality samples were taken when there were between 0 and 10 bathers present at a beach, yet this category included the greatest total number of exceedances (260 out of 329 total for the season). However, when samples were taken at beaches with 50 or more people present , they were more likely to result in an exceedance, almost 13% of these samples were associated with an exceedance. This suggests that sub-daily water sampling and bather counts might reveal bather-induced changes in Enterococcus levels at bathing beaches.	2016.05

Ref. No.	Author/Organization	Title	Overview	Date
27	Marion, J. et al.	<u>Changes in Microbial Water Quality Associated with an Extreme Recreational Water Event in Ohio, United States</u>	Extreme bather densities can have significant impacts on water quality in treated and untreated waters. In this case study, water quality was monitored throughout an annual event known as the "Mirror Lake Jump," in which thousands of 'jumpers' briefly entered a small lake fed by a municipal water supply, which provided an exceptional opportunity to track the water quality change due to extreme bather levels in a short period of time. Significant correlations ($p < 0.05$) were observed between the total number of jumpers and levels of turbidity, enterococci, E. coli, a human-associated marker (HuBac), and an antibiotic resistance marker (tetQ). Among bacteriological parameters, the tetQ marker presented the most significant time-associated trend ($p = 0.01$). Overall, the fecal indicator bacteria (FIB) densities observed during this extreme event ultimately exceeded water quality action values by an order of magnitude. Bather fecal shedding and resuspension of FIB and antibiotic-resistant bacteria likely occurred during the Mirror Lake Jump and future studies related to bather density impacts on microbial water quality are recommended for improving understanding related to potential public health impacts.	2015.03
28	Massachusetts Department of Public Health	<u>Marine and Freshwater Beach Testing in Massachusetts Annual Report: 2014 Season</u>	Bather density data were collected as part of routine sampling. Massachusetts regulations require samples to be taken within the area of greatest bather density (105 CMR 445.000). GPS surveys of marine beaches completed by MDPH/BEH in 2003 and subsequent observations by MDPH/BEH beach inspectors confirm that samples are being taken within the areas that typically receive the highest use (greatest bather density) such as areas near main entrances and/or areas closest to parking lots.	2015.05

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29	Massachusetts Department of Public Health	<u>Marine and Freshwater Beach Testing in Massachusetts Annual Report: 2013 Season</u>	<p>The bather load at a particular beach can affect water quality as well because humans are also sources of fecal pollution. The greater the bather density at a beach, the greater the likelihood that human sources are contributing to higher enterococcus levels. However, as in previous years, more than three-fourths of the marine beach samples (83%) and freshwater beach samples (78%) that reported bather density indicated low bather density (0-10 bathers on the beach) during sampling. This can be attributed largely to samples being taken during off-peak hours for swimming. Samples are primarily collected before 12:00 PM so that laboratories can begin the analysis before the close of business and before the six hour holding time expires.</p> <p>While the data relative to the impacts of bather density on exceedances are extremely limited, beaches staff did evaluate the data to determine if trends were apparent. For marine samples with a corresponding bather density, exceedance rates showed an increase when the bather density reached 50 bathers or greater. The overall rate of exceedances for all marine samples (4.4%) was higher than the rates of exceedance for the three lowest bather density groupings (0-10, 10-20, and 20-50 bathers) and lower than the rate of exceedance for samples that did not have a corresponding bather density. The rate of exceedance for samples with a corresponding bather density of >50 bathers was highest of all, at 12.9%.</p>	2014.00
30	McDonald, A.T. et al.	<u>The microbial status of natural waters in a protected wilderness area</u>	<p>Waters derived from remote 'wilderness' locations have been assumed to be largely free of bacterial contamination and thus such, near-pristine, protected catchments, unused for agriculture, have been first in the multiple line of protection (pristine catchment—long storage—treatment—disinfection) employed by the water industry. This assumption is challenged by a bacterial survey of the waters derived from the New Cairngorm National Park, Scotland. Over 480 spot samples were taken for 59 sites between March 2001 and October 2002 during nine field campaigns each of three to five days duration. Over 75% of samples tested positive for Escherichia coli (E. coli) and 85% for total coliforms. Concentrations displayed both temporal and spatial patterns. Largest values occurred over the summer months and particularly at weekends at sites frequented by visitors, either for 'wild' camping or day visits, or where water was drawn from the river for drinking. Overall the spatial and temporal variations in bacterial concentrations suggest a relationship with visitor numbers and in particular wild camping.</p>	2007.12

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31	Miller, M., and P. Denoble	<u>Microbial Hazards</u>	High swimmer density is a second factor shown to increase infection risk. Elevated numbers of minor ear and skin infections from human-shed bacteria are observed where swimmer density is high. Skin granulomas from <i>Mycobacterium marinum</i> have also been observed. <i>Staphylococcus aureus</i> levels have been proposed as indicators of exposure.	?
32	Natural Resources Defense Council	<u>Testing the Waters - 24th Edition</u>	All swimmers release fecal organisms when they enter the water in a process called bather shedding. Fecal accidents are also a source of pathogens, as are diaper-age children if care isn't taken to ensure that their wastes are kept from entering the water. The presence of <i>E. coli</i> and coliform bacteria has been shown to correlate with the number of visitors and periods of high recreational use (generally the summer and weekends).	2014.00
33	Office of Environment and Heritage, New South Wales, Australia	<u>Protocol For Assessment And Management of Microbial Risks in Recreational Waters</u>	A matrix is presented that can be used to determine the likelihood of contamination due to shedding of pathogens from bathers. It considers, bather density , water circulation and the presence or absence of available toilets at the beach. Bather density is considered high if there are more than 0.2 people per square metre.	2011.11
34	Ontario Ministry of the Environment	<u>Scientific Criteria for Microbiological Standards for Recreational Waters</u>	The levels of <i>P. aeruginosa</i> in a bathing area will be influenced by the bather density especially the presence of <i>P. aeruginosa</i> carriers or individuals with <i>P. aeruginosa</i> infections.	1984.02
35	Papadakis, J.A. et al.	<u>Bather-related microbial and yeast populations in sand and seawater</u>	A significant correlation appears between the number of swimmers present on the beach and <i>S. aureus</i> counts in water samples; the correlation is stronger at the more popular beach. In sand samples <i>S. aureus</i> counts correlate with the number of swimmers present on the beach only at the more popular beach. Yeasts of human origin correlate with the number of swimmers on the more popular beach, both in water and sand samples.	1997.04

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36	Papastergiou P., et al.	<u>Bather density as a predominant factor for health effects related to recreational bathing: results from the Greek bathers cohort study.</u>	Our aim was to examine the health effects on bathers from exposure to recreational seawater on three beaches with different microbiology quality and bather density through a cohort study. An initial questionnaire and a 10 day follow up were used. Univariate and backward logistic regression analyses were used to assess the risk of developing symptoms or diseases among the bathers. In total, 3805 bathers were included in the study and 149 samples were collected from the three beaches. Despite all the beaches being characterized of high quality the levels of bacterial indicators differed among them. Health effects among bathers were not associated with bacterial indicators. A statistically significant increased risk for symptoms related to respiratory illness, gastroenteritis, medical consultation and use of medication was observed among bathers at the higher bather density beaches. Beach bather numbers should always be taken into account when considering a risk assessment approach.	2011.03
37	Plano, L. et al.	<u>Shedding of Staphylococcus aureus and methicillin-resistant Staphylococcus aureus from adult and pediatric bathers in marine waters</u>	This is the first report of a comparison of human colonizing organisms with bacteria from human exposed marine water attempting to confirm that participants shed their own colonizing MSSA and MRSA into their bathing milieu. These findings clearly demonstrate that adults and toddlers shed their colonizing organisms into marine waters and therefore can be sources of potentially pathogenic S. aureus and MRSA in recreational marine waters. Additional research is needed to evaluate recreational beaches and marine waters as potential exposure and transmission pathways for MRSA.	2011.01
38	Reynolds, K.A. et al	<u>Incidence of enteroviruses in Mamala Bay, Hawaii using cell culture and direct polymerase chain reaction methodologies</u>	High bather density is suggested to account for high enterovirus numbers at a Hawaiian beach.	1998.06
39	Smith, B. and A. Dalfour	<u>Effects of Swimmers on the microbiological quality of recreational waters: a simulation study</u>	Abstract not available	1993.00
40	Stewart, J.R et al.	<u>The coastal environment and human health: microbial indicators, pathogens, sentinels and reservoirs</u>	As S. aureus is isolated from human sewage in relatively low numbers (103 CFU/100 ml) relative to enterococci (104 to 105 CFU/100 ml) [35], it can be used as an indicator to predict human bather impacts, which would include the combined effects of bather density , mixing, and dilution. The use of S. aureus as a potential supplemental indicator is especially significant as studies have shown an association between illness in swimmers and bather density.	2008.11

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41	Suffolk County, New York	<u>Suffolk County Beaches FAQs</u>	Tier 3 beaches, predominantly located on the open waters of the Atlantic Ocean and Long Island Sound, are sampled less frequently. Historical water quality monitoring has demonstrated that fecal bacteria contamination is not typically an issue at Level 3 beaches, despite generally high bather density, undoubtedly due to the greater degree of tidal circulation and flushing.	2016.00
42	Sunderland, D. et al.	<u>Impact of bathers on levels of Cryptosporidium parvum oocysts and Giardia lamblia cysts in recreational beach waters.</u>	Recreational beach water samples collected on weekends and weekdays during 11 consecutive summer weeks were tested for potentially viable Cryptosporidium parvum oocysts and Giardia lamblia cysts using the multiplexed fluorescence in situ hybridization (FISH) method. The levels of oocysts and cysts on weekends were significantly higher than on the weekdays (P<0.01). The values of water turbidity were significantly higher on weekends than on weekdays, and were correlated with the number of bathers and concentration of C. parvum oocysts and G. lamblia cysts (P<0.04). The study demonstrated positive relationships between number of bathers and levels of waterborne C. parvum oocysts and G. lamblia cysts in recreational beach water. It is essential to test recreational waters for Cryptosporidium and Giardia when numbers of bathers are greatest , or limit the number of bathers in a recreational beach area.	2007.08
43	Township of Tiny, Ontario	<u>An Investigation of Water Quality on the Coast of the Township of Tiny</u>	Bather density was not considered to be relevant in the context of the three beaches studied. Peak bather load on the beach and in the water was approximately 100 at Balm Beach and could not, by itself (i.e. body contact with the water in the beach area), have influenced quality appreciable. However, individual behaviour could influence quality through faecal matter from dogs or young children being deposited immediately prior to sampling.	2004.05
44	Wade, T.J. et al.	<u>The incidence and health burden of earaches attributable to recreational swimming in natural waters: a prospective cohort study</u>	Earaches were associated with swimming, but not water quality as measured by the fecal indicator bacteria Enterococcus or turbidity. Swimmer density was also not an important determinant of earaches in our data (results not shown). It is possible that earaches were associated with a water quality parameter we did not measure, although consistent associations between otitis externa and water quality have not been established.	2013.08

Ref. No.	Author/Organization	Title	Overview	Date
45	Wang, J.D. et al.	<u>Estimation of enterococci input from bathers and animals on a recreational beach using camera images</u>	Enterococci, are used nationwide as a water quality indicator of marine recreational beaches. Prior research has demonstrated that enterococci inputs to the study beach site (located in Miami, FL) are dominated by non-point sources (including humans and animals). We have estimated their respective source functions by developing a counting methodology for individuals to better understand their non-point source load impacts. The method utilizes camera images of the beach taken at regular time intervals to determine the number of people and animal visitors . The developed method translates raw image counts for week days and weekend days into daily and monthly visitation rates. Enterococci source functions were computed from the observed number of unique individuals for average days of each month of the year, and from average load contributions for humans and for animals. Results indicate that dogs represent the larger source of enterococci relative to humans and birds.	2010.00
46	Workman, M.	<u>Identification of Prophages in Hawaiian Coastal Water Isolates of Staphylococcus aureus</u>	Charoena and Fujioka (1993) observed that the concentration of <i>S. aureus</i> in marine water is significantly linked to swimmer density and similar findings were seen in this study. <i>S. aureus</i> concentrations were higher at the time of the June sampling than the May sampling as was the number of swimmers (85 in May vs. 125 in June). Although <i>S. aureus</i> concentrations correlate with swimmer density, it is possible that other variables such as wave height and flushing rate within the swimming area may have contributed to the higher counts in June.	2006.00
47	World Health Organization	<u>Guidelines for safe recreational water environments - Volume 1 Coastal and Fresh Waters</u>	The two principal factors of importance in relation to bathers are bather density and degree of dilution...The effect of bathers on water quality is most commonly seen as microbial buildup during the day, such that peak levels are reached by the afternoon. In circumstances of limited dispersion, bather-derived faecal pollution may present a significant health risk, as evidenced by epidemiological studies.Sheltered coastal areas and shallow lakes may also be subject to accumulation of sediments, which may be associated with high microbial loads that may be resuspended by water users and/or rainfall events. The health risks associated with resuspended sediments remain poorly understood, but should be noted as a potential risk during sanitary surveys.	2003.00

Ref. No.	Author/Organization	Title	Overview	Date
48	Wright, M. E. et al.	<u>Microbial Load from Animal Feces at a Recreational Beach</u>	The goal of this study was to quantify the microbial load (enterococci) contributed by the different animals that frequent a beach site. Comparing animal contributions to previously published numbers for human bather shedding indicates that one adult human swimmer contributes approximately the same microbial load as one bird fecal event. Given the abundance of animals observed on the beach, this study suggests that dogs are the largest contributing animal source of enterococci to the beach site.	2009.08
49	Wymer, L.J. et al.	<u>The EMPACT Beaches Project Results from a Study on Microbiological Monitoring in Recreational Waters</u>	Bather density at a beach was recorded in order to ascertain whether the presence of bathers itself influences microbial contamination. Both bathers on the beach and bathers in the water at the time of sample collection were categorized as fewer than 20, 20-100, 101-200, and more than 200. Bather effects were found to be significant at Wollaston and Imperial Beaches, where an increase in numbers of bathers was found to result in a corresponding increase in enterococci levels. At Wollaston Beach, few bathers were ever observed to be in the water at any given moment, but the presence of substantial numbers of bathers on the beach was adequate to trigger the increase in microbial levels in the water.	2005.08
50	Zhu, X. et al.	<u>A water quality modeling study of non-point sources at recreational marine beaches</u>	A model study was conducted to understand the influence of non-point sources including bather shedding , animal fecal sources, and near shore sand, as well as the impact of the environmental conditions, on the fate and transport of the indicator microbe, enterococci, at a subtropical recreational marine beach in South Florida. Bather shedding resulted in minimal impacts (less than 1 CFU/100 ml), even during crowded holiday weekends. In addition, weak current velocity near the beach shoreline was found to cause longer dwelling times for the elevated concentrations of enterococci, while solar deactivation was found to be a strong factor in reducing these microbial concentrations.	2011.04