Microbial risk classifications for recreational waters and applications to the Swan and Canning Rivers in Western Australia

B. Abbott, R. Lugg, B. Devine, A. Cook and P. Weinstein

ABSTRACT

Protecting recreational water quality where 'whole-of-body contact' activities occur is important from a public health and economic perspective. Numerous studies have demonstrated that infectious illnesses occur when swimming in faecally polluted waters. With the release of the 2008 Australian recreational water guidelines, the Western Australian (WA) Department of Health conducted a formal evaluation to highlight the advantages of applying the microbial risk management framework to 27 swimming beaches in the Swan and Canning Rivers in Perth, WA. This involved a two-phase approach: (i) calculation of 95th percentiles using historical enterococci data; and (ii) undertaking sanitary inspections. The outcomes were combined to assign provisional risk classifications for each site. The classifications are used to promote informed choices as a risk management strategy. The study indicates that the majority of swimming beaches in the Swan-Canning Rivers are classified as 'very good' to 'good' and are considered safe for swimming. The remaining sites were classified as 'poor', which is likely to be attributed to environmental influences. Information from the study was communicated to the public via a series of press releases and the Healthy Swimming website. The guidelines provide a sound approach to managing recreational water quality issues, but some limitations were identified.

Key words | microbiological assessment categories, recreational water, sanitary inspection, water quality, 95th percentiles

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INTRODUCTION

Numerous epidemiological studies have documented health risks associated with 'whole-of-body contact' activities such as swimming in faecally polluted waters, with gastrointestinal symptoms being the most commonly reported (Prüss 1998). The amount of time spent in the water and the quantity of water ingested have a direct influence on an individual's risk of experiencing a waterborne illness (Pond 2005). These factors are considered when classifying a recreational water body for 'whole-of-body contact' according to the World Health Organisation (WHO 2003) recreational water quality guidelines. A recent study conducted on two beaches in California, USA, estimated the health burden of recreational

water-related illnesses to exceed US$3.3 million per year (Given et al. 2006). Such an economic burden imposed on societies from polluting recreational waters highlights the need for improved management of recreational water quality issues, with a focus on better understanding and identifying faecal pollutant sources.

In 2008, the Australian National Health and Medical Research Council (NHMRC) released the *Guidelines for Managing Risks in Recreational Waters* (hereafter, Guidelines), based on the WHO (2003) model. The Guidelines seek the adoption of a nationally harmonised approach using risk management to reduce hazards and risks associated with

recreational waters. The proposed risk management framework assigns risk classifications (from very good to very poor) to popular swimming locations, depending on the perceived public health risk and uncertainty (NHMRC 2008). The classification is achieved by combining (1) the 95th percentiles of enterococci counts; and (2) information collected from sanitary inspections. These classifications are then used to promote informed choices to the public as a risk management strategy.

Informed public choice aims to decrease the gastrointestinal risk disease burden by deterring human exposure to poorer water quality. This does not remove the need or responsibility to decrease contamination at its source.

Enterococci are considered the single preferred faecal indicator bacteria (FIB) for marine recreational waters, exhibiting a clear dose–response relationship with disease outcomes (Kay *et al.* 1994; Turbow *et al.* 2003; Wade *et al.* 2006).

Since 1948, the Western Australian (WA) Department of Health has regularly monitored popular swimming locations along the Swan and Canning Rivers in the urban setting of Perth, WA, for FIB, typically *Escherichia coli* and thermotolerant coliforms (TC) (Iveson & Curtis 1986). Previously, FIB values were compared with water quality standards based on the traditional 'pass/fail' percentage compliance system (NHMRC 1990; ANZECC 2000). When an assigned FIB value was exceeded, it signified that water quality standards were not being met. This approach had a number of limitations. In particular, management responses to noncompliant results were retrospective, and a swimming site was classified dichotomously as safe or unsafe, with no gradient of health risk. As a result, only limited information was available to the public on the overall safety of swimming in popular waterways. Furthermore, in some instances, the traditional FIB were derived from non-faecal sources (NHMRC 2008).

With the release of the NHMRC Guidelines, the Department of Health in WA used the opportunity to apply the updated requirements to 27 popular recreational water sites that are regularly monitored within the Swan and Canning Rivers (WA was one of the first Australian states to implement the 2008 NHRMC approach). This analysis incorporated historical enterococci data collected by the Department of Health, which were summarised in an earlier report (Laidlaw *et al.* 2005). In the current paper, we review the procedures used to assess risk in these recreational waters; that is:

(1) the calculation of microbiological assessment categories; (2) undertaking sanitary inspections; and (3) assignment of risk classifications. The implications of these new guidelines for public safety are also described.

METHODS

Study region

The Swan and Canning River system (Figure 1) flows through the heart of metropolitan Perth, WA, a city of approximately 1.5 million people (ABS 2006). Within the metropolitan area it occupies 55 km^2, with the Swan and Canning Rivers traversing lengths of about 67 km and 13 km, respectively (Swan River Trust 2008). The rivers are listed as an official heritage icon and are considered to be a significant economic and recreational playground for WA residents and tourists alike, used extensively for activities such as swimming, water skiing, canoeing and boating.

The river system is located in a Mediterranean climatic zone, characterised by wet winters and dry hot summers. Rivers flow with fresh water during the winter, but these sources dry out during the summer (Swan River Trust 2008). The Swan River and part of the Canning River are estuarine waters and subject to marine inundation. Tides predominately cause the Swan and Canning Rivers to vary between being fresh-to-brackish in winter and salty in summer. It takes up to two months of rainfall in the subcatchments in late autumn/early winter before freshwater discharge is substantial enough to displace the summer salt water downstream to the middle-to-lower regions of the estuary. In spring, the catchment dries out and freshwater discharge decreases, causing salt water to move upstream (Swan River Trust 2008).

Up until 1936 the rivers experienced direct sewage discharge (Atkins & Klemm 1986). A large proportion of the river foreshores, which mostly consisted of natural low-lying wetlands, were used as landfill disposal sites and have subsequently been developed into recreational areas (Atkins & Klemm 1986). Through the interventions of the Swan River Trust, the river managing authority, and its predecessors, sewage or industrial wastes are no longer allowed to be discharged into the rivers, although stormwater drainage continues.

Microbiological water monitoring

Since 2001, the Department of Health in partnership with local government authorities has monitored 27 sites along the Swan (25) and Canning (2) Rivers (Figure 1) for FIB (enterococci most probably number (mpn)/100 ml and TC colony forming units (cfu)/100 ml) during the summer bathing season (November to April). Sites were established based on their popularity for whole-of-body contact activities (that is, involving a high degree of immersion, such as swimming). For the period 2001–2007, an extensive database of historical FIB data was collated based on samples collected during weekdays (Monday to Friday) from early morning to mid-afternoon on a weekly to fortnightly basis.

The Guidelines recommend a minimum of 100 entero-cocci samples over a five year period for assigning a recrea-tional classification to a site, which equates to collecting a minimum of 20 samples per site per bathing season. How-ever, because of limited resources, this has not been achieved to date. The number of samples collected from each of the 27 sites ranges from 51 to 76, with an average of 62. The year of commencement of sampling from each site has varied from 2002 to 2003 as a result of the reassessment of the usage of sites and new sites being added to the programme.

All samples were collected in 250 ml plastic sterile bot-tles, using standard aseptic techniques, 30 cm below the water surface with a water depth of 1 m. Samples were stored, below 4°C, in a car refrigerator and transported to an accredited government-funded laboratory for analysis within 6 hours of collection.

On each sampling occasion, field observations of the site were recorded on a log sheet to assess any visible sources of
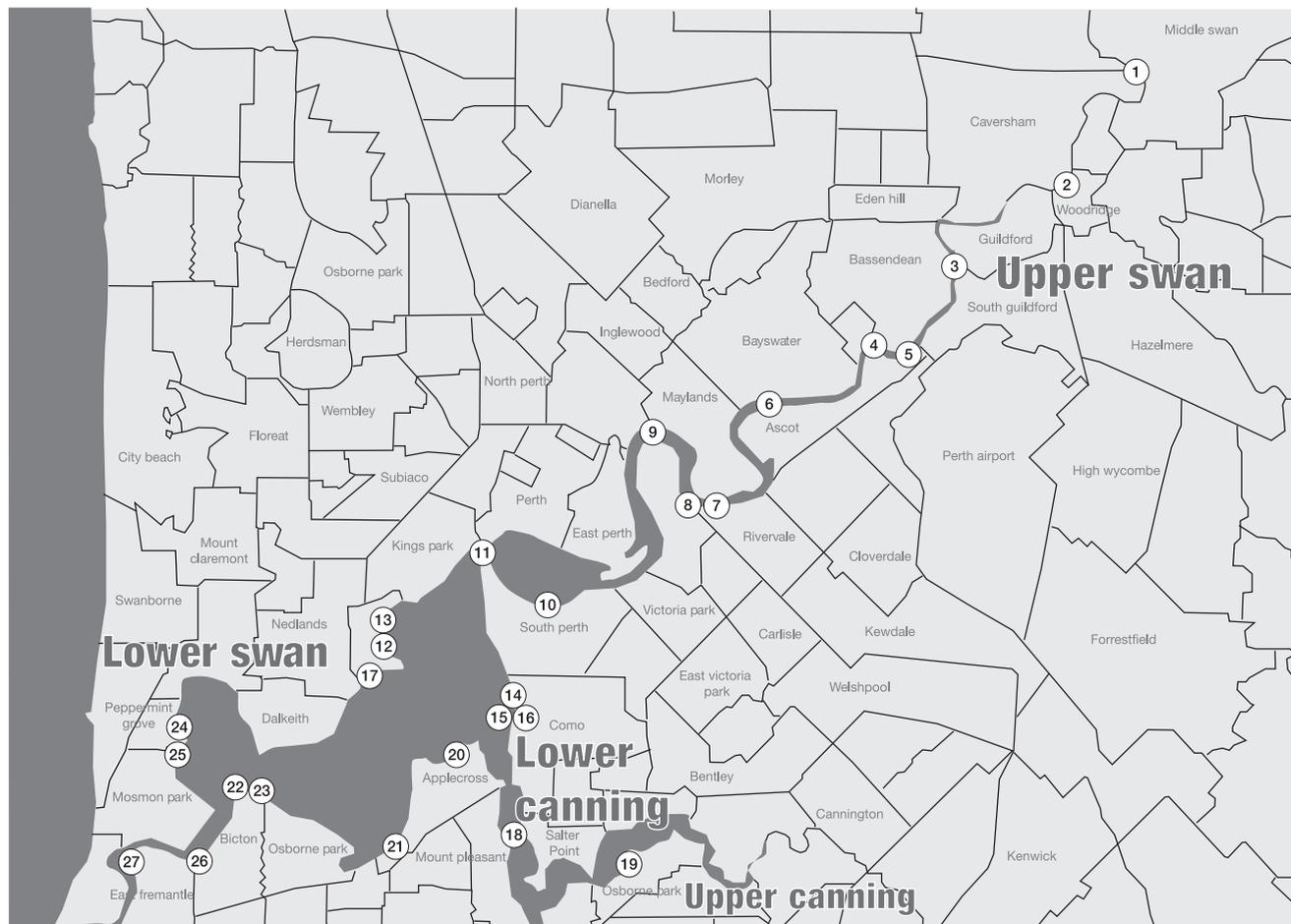

Figure 1 | Map of the Swan and Canning River sampling sites 1–27; refer to Table 2 for an overview of the provisional risk classification for each site and corresponding traffic light colour.

faecal pollution, the number of bathers in the water and other environmental effects, such as turbidity and the presence/absence of animals. Data were also obtained from the Bureau of Meteorology on rainfall.

Microbial assessment categories

Microbial water quality is assigned to one of four microbial assessment categories (MACs): from best to worst, A, B, C and D, respectively (Table 1). The categories represent different levels of infection risk to a water user based on the findings of a randomised control study conducted by Kay *et al.* (1994). The infection risks are derived from the concentration and distribution of enterococci in the water.

For the purpose of this study, an automated spreadsheet titled Enterotester Template^{TM} (DOH 2007) designed by Dr Richard Lugg, was used to calculate the MAC for each site (Available online at http://www.public.health.wa.gov.au/cproot/3394/4/EnteroTesterCorrected'09-700%20RL.XLT). The spreadsheet does this by assigning to a given set of enterococci results (the data set) a 95th percentile that reflects the risk of excess adult gastrointestinal infection as calculated from the equation of Wyer *et al.* (1999). This statistic (the *standardised* 95th percentile) is the 95th percentile of a lognormal distribution of enterococci with a log_{10} standard deviation of 0.81 and an infection risk equivalent to that of the data set. The figure of 0.81

is used because it is effectively equivalent to the reference value used by WHO (2003) and the NHMRC (2008).

The spreadsheet tests the lognormality of the data set, and if the lognormal assumption is statistically unsound (probability less than 0.05) calculates the infection risk from the empirical distribution. Otherwise, the infection risk is calculated using estimates of the geometric mean and log_{10} standard deviation of the data set (except where the log_{10} standard deviation is so close to 0.81 that the parametric 95th percentile of the data set can be used directly). The standardised 95th percentile is designed to be used in Table 1.

In addition to assigning the MAC, the spreadsheet has been designed to automatically calculate 'one off' and 'two in a row' trigger levels specific to a site. This is considered an important feature as it helps authorities respond to an unanticipated deterioration in water quality that is atypical for a site, rather then relying on generic trigger levels that may not be indicative of a potential health risk. Generic trigger levels may be triggered too frequently, leading to unnecessary, costly and time-consuming action being taken. The Guidelines do not explicitly discuss how to respond to elevated FIB results during routine monitoring.

In the current study, where an exceptional circumstance such as a sewage overflow occurred into a swimming location, the results were discounted from the MAC assessment. The Department of Health and the Water Corporation of WA

Table 1 | Classification matrix for faecal pollution of recreational water environments* (NHMRC 2008 Table 5.13 of the Guidelines)

		Microbiological assessment category (95th percentiles – intestinal enterococci /100 ml)				Exceptional circumstances[c]
		A ≤ 40	B 41–200	C 201–500	D > 500	Action
Sanitary inspection category (susceptibility to faecal influence)	Very low	Very good	Very good	Follow up[b]	Follow up[b]	
	Low	Very good	Good	Follow up	Follow up[b]	
	Moderate	Good[a]	Good	Poor	Poor	
	High	Good[a]	Fair[a]	Poor	Very poor	
	Very high	Follow up[a]	Fair[a]	Poor	Very poor	
	Exceptional circumstances[c]	Action				

[a] Possible discontinuous/sporadic contamination (often driven by results such as rainfall). This is most commonly associated with the presence of combined sewer overflows. These results should be investigated further, and initial follow-up should include verification of the sanitary inspection category and ensuring that samples recorded include 'event' periods. Confirm analytical results, review possible analytical errors.

[b] Non-sewage sources of faecal indicators (e.g. livestock) which need to be verified.

[c] Exceptional circumstances are known periods of higher risk, such as during an outbreak involving a pathogen that may be waterborne (e.g. avian botulism: where outbreaks of avian botulism occur, swimming or other aquatic recreational activities should not be permitted), rupture of a sewer in a recreational water catchment, etc. Under such circumstances, the classification matrix may not fairly represent risk/safety.

*In certain circumstances, there may be a risk of transmission of pathogens associated with more severe health effects through recreational water use. The human health risk depends greatly on specific (often local) circumstances. Public health authorities should be engaged in the identification and interpretation of such conditions.

have incident response procedures in place to minimise any risks to public health (DOH 2006*b*). This is the common practice outlined in the Guidelines when dealing with exceptional circumstances (NHMRC 2008).

Sanitary inspection

The sanitary inspection (SI) is designed to provide a detailed inventory and assessment of all pollution sources likely to cause faecal contamination of a water body. Recreational water environments are categorised by their estimated susceptibility to adverse faecal impacts. Sanitary inspections provide the foundation by which to design and implement an effective water quality sampling programme and to assist in the interpretation of water quality data (Bartram & Rees 2000). During this study, the SI focused on identifying dominant land- and water-based faecal pollution sources, including human and animal wastes, potentially impacting on the water quality of each site (Bartram & Rees 2000). The identification of human faecal pollution sources is particularly important as they represent a greater risk to health, and will tend to drive the overall sanitary inspection category (SIC) assigned to a site (EPA 2007; NHMRC 2008). Animal sources cannot be ignored and infectivity factors (WSAA 2003) are useful indicators in determining such significance.

The SI process produces five categories (SICs) ranging from very low to very high in terms of susceptibility to faecal influence. Each identified faecal source is assigned to one of these categories. The Guidelines do not provide a detailed template or an assessment format on how to rank individual faecal sources into one of the five categories. Rather, the Guidelines recommend adopting principles outlined in the *Best Practice Environmental Management Guidelines – Catchments for Recreational Water: Conducting and Assessing Sanitary Inspections* (WSAA 2003).

The WSAA (2003) approach is predicated on using worst-case scenarios (P. Nadebaum, personal communication 2006). Attempts to apply it to regional WA recreational waterways indicated that it was indeed conservative in its application, and tended to over-estimate the potential contamination of faecal sources identified (Shire of Murray 2006). The WSAA (2003) approach was more inclined to assign an overall classification of a site into a poorer or unsafe category, even though the microbiological results indicated that it may fall within the 'good' to 'very good' range.

In the absence of a practical methodology, a standardised SI report form (Appendix 1 available online at http://www. iwaponline.com/jwh/016.pdf) was drafted adopting principles from the WSAA (2003), New Zealand Ministry for the Environment (2002) and Bartram & Rees (2000). The SI report form provided consistency to the information recorded during the SI process, and incorporated details on site identification, physical characteristics of the water body, user history and identification of typical faecal pollution sources (such as stormwater and wastewater outlets).

Each local government in the study area was provided with a copy of the SI report form and requested to carry out on-site inspections and desk top studies for each site located within its jurisdiction. Aerial maps were requested detailing infrastructure proximity to the site. Information collated from the SI process was used to allocate a SIC to all 27 sites according to the NHMRC classification matrix (Table 1).

Information collected as part of the SI process was compared with the recommended risk potential classification tables (including wastewater outfalls, stormwater, bather density and riverine discharge) outlined in section 5.4 of the NHMRC Guidelines. The corresponding faecal pollutant source was assigned the most applicable category. The highest ranked category for each site was used as the overall SIC.

RESULTS

The outcomes of the MAC and SIC were combined using the desired 2008 NHMRC classification matrix (Table 1) to assign a provisional risk classification (because there were less than 100 samples per site) to each site (Table 2). Of the 27 sites, one was classified as 'very good', 21 classified as 'good' and five were classified as 'poor' or required follow up. These provisional classifications indicate that the majority of the sites within the Swan and Canning Rivers are acceptable for whole-of-body contact recreational activities.

Overall 26 sites were assigned a moderate SIC, with one low. The SI did not identify any direct human faecal sources discharging into the river systems. The highest ranked SIC was 'moderate'. Moderate sources generally related to stormwater drains or high densities of bird life.

Table 2 | Provisional risk classifications for Swan and Canning River sampling sites, Perth, Western Australia

No.	Site description	Years of sampling period	No. of samples	95th percentile	Microbiological assessment category	Sanitary inspection category	Risk classification	Website traffic light colour
1	Middle Swan Reserve	2002–07	52	3950	Category D	Moderate	Poor	Red
2	Ray Marshall Park	2002–07	52	480	Category C	Moderate	Poor	Red
3	Kings Meadow Reserve	2002–07	51	560	Category D	Moderate	Poor	Red
4	Sandy Beach Reserve	2002–07	53	250	Category C	Moderate	Poor	Red
5	Garvey Park	2002–07	69	170	Category B	Moderate	Good	Green
6	Hind Reserve	2002–07	56	195	Category B	Moderate	Good	Green
7	Cracknell Park	2003–07	69	115	Category B	Moderate	Good	Green
8	Belmont Park Beach	2003–07	68	100	Category B	Moderate	Good	Green
9	East Street Maylands Yacht Club	2003–07	55	460	Category C	Moderate	Poor	Red
10	Coode Street South Perth	2002–07	64	135	Category B	Moderate	Good	Green
11	Narrows Bridge	2002–07	64	10	Category A	Moderate	Good	Green
12	Hackett Drive Crawley (Kiosk)	2002–07	59	75	Category B	Moderate	Good	Green
13	Hackett Drive Crawley (Tree)	2003–07	60	32	Category A	Moderate	Good	Green
14	Como Beach North	2003–07	61	75	Category B	Moderate	Good	Green
15	Como Beach South	2003–07	62	100	Category B	Moderate	Good	Green
16	Como Beach Jetty	2002–07	62	14	Category A	Moderate	Good	Green
17	Abrahams Reserve Beach	2003–07	59	24	Category A	Moderate	Good	Green
18	Deep Water Point Beach	2003–07	72	2	Category A	Moderate	Good	Green
19	Shelly Beach (Near Drain)	2003–07	52	115	Category B	Moderate	Good	Green
20	Waylen Bay (Scout Hall)	2003–07	76	34	Category A	Low	Very Good	Green
21	Cunningham Street (Applecross)	2002–07	74	30	Category A	Moderate	Good	Green
22	Point Walter (Kiosk)	2003–07	73	70	Category B	Moderate	Good	Green
23	Point Walter (Boat Ramps)	2003–07	73	26	Category A	Moderate	Good	Green
24	Keane Street Beach (50 M S Irvine S)	2002–07	54	165	Category B	Moderate	Good	Green
25	Johnston Street–Hill Tce Beach	2003–07	52	32	Category A	Moderate	Good	Green
26	Bicton Baths	2002–07	74	28	Category A	Moderate	Good	Green
27	Preston Point–John Tonkin Park	2003–07	56	40	Category A	Moderate	Good	Green

The category D and category C sites are located in the Upper Swan River. The SI highlighted a number of differences in topographical features between the Upper and Lower Swan (described below) which may account for these variations in enterococci concentrations. A further review of the poorer grade sites indicates that they are not regularly used for whole-of-body contact activities, but rather for secondary contact activities such as canoeing. These sites are not considered to represent a significant risk to public health.

To communicate the results of the classification of the 27 sites more effectively to the WA public in accordance with the Guidelines, a traffic light system of green, amber and red was devised. Green represents the safer areas for swimming, and red represents areas of higher recreational risk. In the absence of definitions for each risk classification in the Guidelines, generic definitions were developed and assigned a colour corresponding to the perceived risk (Table 3).

Results of the study were successfully communicated on the Healthy Swimming website (www.healthyswimmin-

Table 3 │ Beach classification definitions and corresponding traffic light colour

Green	**Very good**:	Water is considered safe for swimming at all times. Consistently very good water quality tests and very few potential contamination sources indicate that water quality at this location should be of a high standard.
	Good:	Conditions are safe for swimming most of the time. Water quality tests are generally good on nearly all occasions and there are few potential faecal pollution sources identified. Standard advisories should be followed such as avoiding swimming for 3 days after heavy rainfall (>10 mm) in river and estuarine waters.
Amber	**Fair**:	Conditions are generally acceptable for swimming, although water quality tests may show times of elevated bacteria mostly due to animal pollutant sources (e.g. bird faeces) and rainfall. Swimming should be avoided for 3 days after heavy rainfall (>10 mm), and if the water is discoloured.
Red	**Poor**:	Conditions are generally not acceptable for swimming, as indicated by historical sampling results. There may be a higher risk of illness if water is ingested, particularly by the very young, the very old and those with compromised immunity. Swimming or putting your head under the water should be avoided. Activities such as wading, canoeing, boating and fishing are still suitable. High bird densities, narrow rivers, low dilution, low salinity and stormwater pollution may help pathogens survive longer in these waters, particularly after rainfall events.
	Very poor:	Avoid swimming at these locations, as there are direct discharges of faecal material. Permanent signage may be erected at the beach stating that swimming is not recommended.

g.health.wa.gov.au, accessed 17 November 2010) and through a series of press releases to community papers.

DISCUSSION

Table 4 summarises how the performance of the 2008 NHMRC Guidelines compares with previous recreational water models.

Beach classifications

This study indicated that the sanitary inspection played a crucial role in identifying potential causes of water contamination in the Swan and Canning River system. Over 306 stormwater drainage outfalls have been identified to discharge into the rivers, equating to an average of 4.7 outfalls per kilometre of foreshore (SRT 2006). The most common

Table 4 │ Performance of the 2008 NHMRC Guidelines compared with previous recreational water models

Previous recreational water model (1990 NHMRC Guidelines)	2008 NHMRC Guidelines
Limited and retrospective management response to non-compliant results	Management response based on the level of health risk identified
Basic calculation of risk using only five samples collected at intervals not exceeding one month	More robust calculation of risk using a maximum of 100 samples collected over a maximum of five years
Limited information available to the public which constrained their ability to make informed decisions about swimming in particular recreational water bodies	More information available to the public to assist with informed decision-making about swimming in particular recreational water bodies
Results not always based on faecally derived indicator organisms	Results are based on faecally derived indicator organisms
Water quality grade based on a pass/fail approach with no gradient level of health risk	Risk classifications are based on a gradient level of health risk, from very good to very poor
Limited opportunity to identify any patterns in contamination	Provides assessment in a form that more readily identifies patterns in contamination events and guides to implement management responses to mitigate health risks
Limited focus on identifying sources of faecal pollution	Provides a more robust methodology for identifying faecal pollution sources and implementing measures to reduce contamination at the source
	Provides more meaningful data to assist water managers to seek funding to decrease contamination at the source

drains discharge directly from the end of a pipe into the river while more complex systems include headwall structures, scour blankets, gross pollutant traps and settlement basins. Stormwater pollution is considered to be the greatest contributor to microbiological pollution in the rivers, predominantly following rainfall events (DOH 2006*a*). Stormwater runoff has frequently been identified as a significant determinant of faecal bacteria densities in recreational water (Wyer *et al.* 1994; Ackerman & Weisberg 2003; Hose *et al.* 2005; Shehane *et al.* 2005). The level of contamination is often greatest after rainfall as animal wastes and fertilisers may enter the stormwater system.

The SI clearly also revealed that more than 100 wastewater pumping stations are located along the river system. Wastewater systems rely mainly on gravity to transport the flow, but Perth's flat landscape makes it necessary to rely on pumping stations and pressure mains. Wastewater overflow incident response plans have been developed for the river systems and any overflow is dealt with as an exceptional circumstance (DOH 2006*b*).

Natural habitats which are mostly accessible in the Upper Swan and Canning attract a variety of birds including ducks, swans and geese. Although birds are sited throughout the rivers, they are considered a significant contributor to faecal pollution in areas where more habitats are readily accessible. Studies typically show an association between bird faeces and microbial water quality (Wither *et al.* 2005), yet faecal pollution derived from birds poses a significantly lower health risk to swimmers than faecal pollution derived from humans (WHO 1999; NHMRC 2008).

Environmental influences can also have an impact on recreational water quality (Ashbolt & Bruno 2003) and need to be properly assessed in the sanitary inspection process. Differences in topographical features between the Upper and Lower Swan and Canning Rivers were noted, and are considered to contribute to natural variations in enterococci concentrations throughout the river systems. The Upper Swan, compared with the Lower Swan, is characterised by narrow channels, is unaffected by saline intrusion from the Indian Ocean, and is more turbid, thereby reducing the degree of penetration of solar radiation into the water. It is also known that high dilution rates assist with dispersion and variability in concentrations of enterococci in water. Lower salinity can help prolong the survival of enterococci; the die-off rate of enterococci has been recorded to be much quicker in marine waters with a higher salt content compared with freshwater environments. Solar radiation is also known to contribute to the rapid die-off rate of most bacteria; turbid waters are likely to have a reduction in solar exposure, which will reduce enterococci inactivation (WHO 1999). These factors are typically associated with increased survival rates of enterococci in a water column (WHO 1999).

Public communication

The website and the traffic light system provide a resource for promoting safe swimming practices through the opportunity of exercising informed choice. Information from the website has been accessed by a number of key water users, including primary and secondary schools, to determine acceptable locations for swimming. Local governments also now have a readily interpretable tool to help promote safe places to recreate and to better manage water quality issues. Outcomes from the study may assist with redirecting resources to high priority areas, particularly where infrastructure such as stormwater drains have been identified as significant contributors of faecal pollution to poorer classified sites.

Limitations in the guidelines

Although the new NHMRC Guidelines have provided an evidenced-based method compared with previous models for communicating risks on recreational water quality, the study highlighted a number of areas within the guidelines where further investigation and refinement would be desirable. Firstly, specific guidance is required regarding the level of FIB counts that represents a trigger level for action. This creates uncertainty for water managers who must respond to unanticipated deterioration in water quality that is atypical for a specific site. Although the guidelines imply that a count of 41 enterococci/100 ml or greater is associated with a quantifiable health burden, triggers that are reflective of the water quality at a specific site may assist with a more meaningful public health management response. In addition, the measurement tool is limited by the lack of a user-friendly standardised method for calculating MAC (95th percentiles) or a basic template for the SI to enable consistency in assigning a SIC. Finally, use of five

risk classifications may be excessive when having to relay information to the public. The simple traffic light approach (green, amber and red) based on three risk classifications (e.g. good, fair and poor) has proven an acceptable alternative in Perth. The traffic light approach may be considered for adoption at a local level to assist with easier public interpretation of results.

Further analysis is recommended to reduce the requirement for 100 samples within a 5 year period to a more manageable number. Since the completion of this study, one of the authors (RL) had completed over 45,000 Monte Carlo (McBride 2005) simulations, using a variant of the Enterotester spreadsheet, to see how the 95% upper confidence limit for standardised 95th percentiles varies with samples of different sizes. Although this confidence limit increases as the sample size falls below the recommended number of 100 samples, the change is not marked until the number becomes quite small (see Table 5).

It can be seen that a minimum sample size of 65 samples provides only slightly less confidence ($>95\%$) than 100 samples. This (unpublished) analysis indicated that the requirement for 100 samples is too demanding where the standardisation of 95th percentiles is being employed. By comparison, 65 samples represents one sample a fortnight over a 26 week swimming season, accumulated over the five year maximum period recommended in the Guidelines. Adopting a sample size similar to 65 would be far more acceptable to regulators in the allocation of resources, with little deterioration in the level of confidence in making definitive classifications for each recreational water body. This will ensure more effective resource management and longevity of monitoring programmes as 100 samples were considerably demanding to achieve. The outcomes of these simulations will be published for further review during 2011.

CONCLUSION

The application of the 2008 NHMRC Guidelines has proven to be an effective tool in classifying and managing the microbial risks in recreational waters in the Swan and Canning Rivers. The practicability of the guidelines may be enhanced by the design of a uniform template for sanitary inspections to provide a complete and accurate assessment of the potential faecal pollution sources likely to impact on the recreational water. The adoption of the 95th percentile 'Enterotester' was found to be an effective computer tool to determine MACs and trigger levels for action when unexpected high results are recorded during routine sampling. Although the current classifications are provisional, the information is invaluable in helping the public understand the potential health risks. This will enable informed decisions to be made about where and when to engage in water-based activities. Local governments now have a greater ability to implement management strategies aimed at improving water quality and a stronger basis by which to promote areas for safe recreation. The development of the traffic light system to inform the public of the beach classification has proven successful and may be a model for other agencies to adopt.

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Table 5 | Highest standardised 95th percentiles for which there is 95% confidence that the underlying (true) value does not exceed 200 mpn/100 ml

Size (*n*)	10	20	30	40	50	65	80	100
95th %ile	90	107	117	123	129	135	140	145

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