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ORIGINAL RESEARCH

Applying systems leadership and participatory action research in developing a water contamination management tool

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Abstract

Objective: This research used systems leadership to explore stakeholder engagement regarding requirements, incentives and barriers to adopting a faecal source tracking method to identify contamination sources in surface waters.

Setting: The research comprised two branches, one quantitative, conducted in a food and water laboratory; the other qualitative, conducted within stakeholder organisations and meeting premises.

Participants: Ten stakeholder representatives participated in semi-structured interviews and ten in a focus group. Seven individuals participated in both activities while three who were interviewed were replaced by alternate representatives for the focus group.

Design: A multimethod participatory action research project was completed, with a quantitative trial of a microbial source tracking method conducted concurrently with two iterations of qualitative research into the needs of the stakeholder system through semi-structured interviews and a focus group.

Results: Thematic analysis of stakeholder interviews yielded key incentive and barrier themes, while the laboratory trial created a comparison library and tested the efficacy of the laboratory method. The focus group further explored key themes and identified requirements for collaborative effort across the system, and the need to address misinterpretation of statistical associations.

Conclusion: Systems leadership was effective in exploring stakeholder interest in the proposed faecal source tracking method. Two iterations of qualitative research helped to identify the needs of individual stakeholders, and then develop collective strategies for addressing the critical incentives and barriers.

KEYWORDS
decision-making, faecal source tracking, public health, service planning, stakeholder participation

1 | INTRODUCTION

Surface waters used for recreation and industry are increasingly affected by human development, and stakeholders responsible for these waters are seeking greater clarity on the origin of contamination when regulatory standards are not met.[1,2] Current regulatory testing only identifies non-compliance with regulatory guidelines, while identification of contamination sources through faecal source tracking (FST) could potentially contribute to more efficient remediation responses.

The Public Health Laboratory (PHL) is a food and water microbiology laboratory in Tasmania, which conducts regulatory testing across the island state to meet marine lease[3,4] and public health guidelines,[5] among others. The PHL is part of Public Health Services, which is responsible for protecting the population from public and environmental health hazards, and is located in Hobart, a linear city on the banks of the Derwent River. The beaches are monitored by the Derwent Estuary Program, which is a regional partnership between local governments, the Tasmanian Government, commercial and industrial enterprises, and community-based groups. In a preliminary cycle of research, a Derwent Estuary Program working group considered multiple chemical and microbiological FST methods and identified PhenePlate[6] as potentially suitable, affordable and within the scope of the PHL to develop.[7,8]

A range of systems thinking tools was used to analyse the regulatory compliance system from multiple perspectives, including rich picture, systems mapping, behaviour over time graphs, connection circles, causal loop diagrams, identification of leverage points, unintended consequences and specific actions.[9,10] These activities helped define the system, identifying elements, interactions and boundaries which contributed to the planning and initiation of a participatory action research (PAR) approach.

Stakeholders in the regulatory compliance system were grouped as regulatory authorities, intermediate authorities and end-users of surface waters. The regulatory authorities are State Government departments with legislated responsibility for regulation, while intermediate authorities included the Tasmanian water authority and industry bodies, which exercise both oversight and coordination. The end-users subject to regulation include Local Government councils and marine farmers. The overlapping needs of these stakeholders are based on differing motivations including public health, environmental health, regulatory and commercial interests in rural and urban areas. Additionally, laboratories provide relevant services to the stakeholders, and external groups such as the media, political representatives and the public, may influence the system.

What is already known on this subject:

- There is significant interest in being able to determine the source of faecal contamination in water to assist remediation. A variety of methods have been proposed with varying degrees of expense and success
- Stakeholder engagement and participation is increasingly valued in health care environments. Participatory action research is frequently reported as a mechanism for achieving these goals
- Systems leadership has been successfully applied to effect progress in complex systems and is promoted for complex situations where central authority is absent and cooperative relationships are required for progress

What this study adds:

- Describes a novel application of participatory action research and systems leadership to a laboratory and regulatory compliance environment
- Explores how potential barriers to stakeholder acceptance can be overcome by engagement, education and collaboration to identify compensating strategies
- Demonstrates an effective approach to gaining engagement, assessing a proposed intervention and achieving consensus for future action

Due to the complexity and non-hierarchical nature of the regulatory compliance system, no single stakeholder has direct authority over any other, and top-down decision-making is not appropriate. Instead, a combination of systems leadership and PAR offered a promising way of evaluating a novel laboratory method for meeting the needs of diverse stakeholders. Systems leadership involves leading across boundaries between organisations or structural groupings, where the leader does not have hierarchical authority to direct, but must lead through influence, relationships and empowering others to catalyse change.[11,12] Systems leadership has been applied to address major problems affecting complex systems of hundreds of organisations, but the principles can be applied on a smaller scale.[11–13] It is sparsely reported in health academic literature[14,15] and education,[16] and places service-users at its centre, focussing on improvement and progress rather than complete solutions.[17]

The PHL can provide services to stakeholders but has no direct authority, making a systems leadership approach appropriate.[11] Participatory action research approaches are particularly relevant in engaging systems which rely on cooperation rather than direct authority as this approach actively involves the people, who would be 'subjects' in conventional research, in generating outcomes that are specific to their needs.[18] Ultimately, PAR empowers participants to determine the merits of adopting a new approach through repeated cycles of observing, planning, acting and reflecting to incrementally adjust, or refine, interventions to maximise outcomes.[19] Qualitative research methods, including PAR, have been used extensively in change management[20] in many health contexts to identify implementation barriers.[21–24] An absence of published PAR research in laboratory or regulatory environments suggests an untapped area of application. The interaction of systems leadership and PAR within the regulatory compliance system is likely to facilitate cooperation through collaboration and more clearly identify stakeholder needs, especially given the diversity of stakeholders interested in using an FST method.

2 | MATERIALS AND METHODS

2.1 | Design, setting and participants

The study was conducted as a two-component multimethod PAR design, allowing triangulation by approaching the research question from two different perspectives.[18] The quantitative component trialled the PhenePlate FST method[6] to assess efficacy of FST at a stakeholder site (Pitt Water) over a 5-month period (28 September 2020–10 April 2021). Water and faecal samples were collected from potential faecal sources in the Pitt Water catchment and from marine farm sites in Pitt Water, the receiving water. PhenePlate was used to profile both Enterococcci and *Escherichia coli* (*E. coli*) isolates from each sample to evaluate the method for all stakeholders, due to differing regulatory indicators for marine farming[3,4] and recreational waters.[5] The populations of isolates derived from receiving water samples were compared to potential source samples using the proprietary PhPWIN (v.7.9) software.[6] In this article, only the quantitative findings pertinent to meeting stakeholder needs and conveyed in the focus group will be discussed.

The qualitative component examined stakeholder needs and assessed requirements for the applicability of the PhenePlate method. Ethics approval was granted by the Tasmania Social Sciences Human Research Ethics Committee (SSHREC) after assessment of a Minimal Risk application [S0021699 (H-75357)]. The human research described was undertaken with the appropriate informed consent of participants. Figure 1 illustrates the stakeholders and external actors in the compliance system. A PAR approach was utilised to determine participant views rather than be limited by preconceptions of the researcher.[18] Participant selection was purposive,[18] to obtain rich, relevant and diverse data from individuals identified by stakeholder organisations as willing and knowledgeable representatives. Fifteen stakeholder organisations covering all stakeholder categories were identified and approached informally to gauge interest. All responded positively and ten organisations were prioritised and formally requested to nominate suitable representatives who would agree to participate. The remaining five organisations comprised additional examples of stakeholder categories already represented and provided a reserve option should any of the ten selected organisations withdraw. No participants withdrew, before or after interview, and no further interviews were sought given perceived data saturation,[18] as assessed in the conduct of the interviews and confirmed on completing analysis of the ten interviews.

Semi-structured interviews were conducted over a 10-week period (09 October – 17 December 2020) and offered in-person or by teleconference to allow for possible COVID-19 concerns or prohibitive distance. All participants chose to be interviewed in-person at their workplace, except for one remote participant who was interviewed in-person at the PHL. Each interviewee received an information sheet explaining the study aims and provided written consent for the in-depth interview. Interviews were based on a general-to-specific funnel structure,[25] with scheduled questions to allow coverage of predicted topics of cost, timeliness, and participation; and flexibility to pursue other topics raised by the participant.

Interview and focus group recordings were made with a Philips DVT2810 Audio Recorder with iPhone X backup, with an average duration of 19 min (13–27 min). Stakeholder organisations and participants were given pseudonyms, with original data linked to deidentified transcripts by a code key. Transcripts were made from the recordings using coding adopted from DuBois[26] and were sent to participants for correction, comment or elaboration as required. Thematic analysis[18] of transcripts was then completed using both deductive and inductive approaches to identify and map all anticipated and emergent themes or sub-themes.

The interview outcomes, including the theme-map, informed the development (plan, act stages) of the briefing element of the focus group and thus formed the basis of a subsequent PAR iteration. A focus group was held in a central location, and all stakeholder organisations were invited, regardless of interview participation. Participants were provided with feedback on the qualitative interview

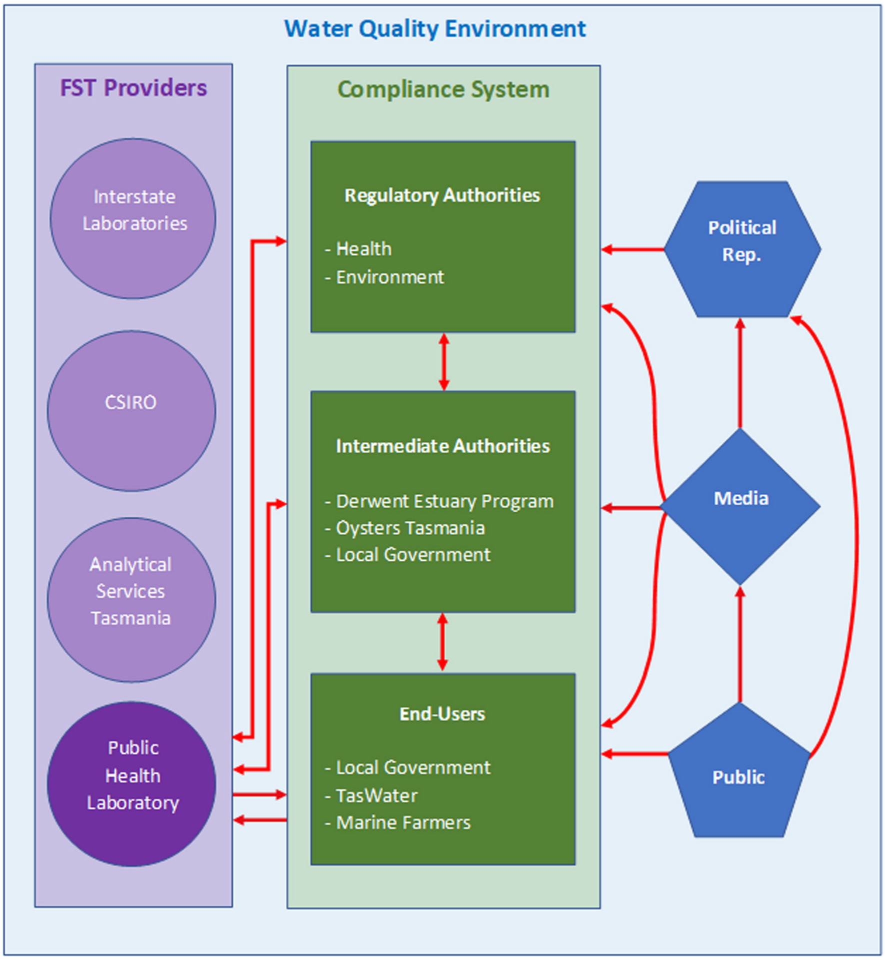

FIGURE 1 System diagram - regulatory compliance system and external actors

outcomes, details of the PhenePlate quantitative trial and a PHL implementation scenario outlining estimated cost, time-frame and participation requirements. This provided a context and discussion stimuli[27] for group discussion (reflect stage), which was also guided by questions presented visually, and verbally prompted as needed, regarding perceived and actual barriers and incentives, and a transcript was subsequently provided to participants for comment. The COREQ set of criteria were used in planning and conducting both interviews and focus group.[28]

3 | RESULTS

3.1 | Quantitative component – PhenePlate trial

A library of 3592 Enterococci and *E. coli* isolates was built over 5 months comprising populations of isolates derived from potential sources, and sites in the receiving water (Pitt Water). Then receiving water populations were compared to source populations to generate a Population Similarity Coefficient (Sp) using UPGMA (unweighted pair group method with arithmetic mean) clustering. During the focus group, participants were briefed on the method principles, the size and composition of the library established, and the statistical similarities indicated between receiving water populations and source populations. It was strongly emphasised to participants that the method is a statistical process and can only indicate an association, not provide a definitive judgement of contamination source. Participants varied in statistical knowledge, and some noted that their organisational management were likely to misinterpret statistical associations as being definitive. It was also advised that the statistical associations generated are neither provable nor falsifiable, although they can be discounted as insignificant. Accordingly, they can only be used to indicate probable sources among those sampled and should not be used to rule out other sources from being considered.

The trial was not conclusive as very few receiving water samples exceeded regulatory limits in the trial period, but the method was successfully applied and allowed the construction of a probable scenario for PhenePlate implementation through the PHL. The scenario required stakeholder customers to assess the catchment of interest, identify likely sources, obtain access and sample these sources over a specified time period, and provide samples for analysis. The customer would be responsible for the cost of establishing the library and on-going monitoring, predicted to be ~$4000 for a moderate (800 isolate) library and $90 per failing monitoring sample.

3.2 | Qualitative component – iteration one: semi-structured interviews

No participants elected to withdraw consent or information provided, and none responded with correction or elaboration when provided interview transcripts. All ten interview participants were willing to participate in the subsequent focus group, although three were not available on the nominated date.

Two key incentive themes were anticipated by the researcher: being able to *identify* contamination sources and meeting *regulatory* guidelines. These themes reflect the interest of stakeholders involved in the preliminary Derwent Estuary Program research and their need to determine the source to improve mitigation and demonstrate compliance. The four barrier themes predicted were: *cost* of testing, *timeliness* in obtaining results, level of stakeholder *participation* required, and *accuracy* of source identification. These barriers were identified as typical customer concerns around investment, both financial and personnel; and return on investment, in the form of timely and useable results. All predicted incentives and barriers were identified or endorsed by most participants. Additional themes and sub-themes emerged during the interviews, primarily identified by one or two stakeholders each. Table 1 summarises the predicted (P) and emergent themes and sub-themes identified from the interviews.

The emergent themes identified included *political pressure* and *reputation* which were viewed as both potential incentives and as potential barriers, depending on whether the results, or their implications, would be perceived as positive or negative by stakeholders. Results that identify the contaminant and facilitate mitigation would be seen in a positive light and act as incentives. Conversely, failure to identify contaminant sources, or identifying sources that cannot be mitigated could have a negative impact and create barriers. These themes largely concerned external groups that could influence the regulatory compliance system. Non-compliance can result in closed beaches and leases, which can cause public discontent and result in the media and political representatives interacting with the system. Variation in importance was noted across the compliance system, with source *identification* important to all stakeholder types, but *regulatory* responsibility only highlighted by those bearing such responsibility. Similarly, the predicted barriers of *timeliness* and *accuracy* were noted as important to all, while *cost* and *participation* requirements were more important to intermediate authorities and end-users, who are most likely to commission and fund work; and less important to regulatory stakeholders, who were primarily interested in the information generated. All themes and sub-themes identified were summarised in a theme-map as discussion stimuli for the focus group. Figure 2 shows the theme-map.

3.3 | Qualitative component – iteration two: focus group

The Pheneplate trial feedback and scenario presentation prompted participant questions on the method, and these were answered as they arose. A copy of the presentation and a transcript of the focus group discussion were provided to all invited participants for comment. Although several comments of appreciation, and expressions of interest in further work, were received, no amendments or further commentary were offered.

Focus group discussion did not contradict any of the themes raised during interviews, instead highlighting those of importance, and generating additional novel themes. It was quickly agreed there was sufficient incentive to use the method for all participants, despite the stated limitations. However, the value of a coordinated, collaborative approach was emphasised, as most catchment locations and contamination sources were relevant to multiple stakeholders, and the costs of building a library could thus be shared. Conversely, single stakeholder projects may raise barriers in ownership of data and restricting access, resulting in duplication of effort, and inefficient use of resources.

> Coordination… someone has to take some leadership and whether that means you have got to establish a group or whether one agency… leads it and everyone cooperates.

4 | END-USER PARTICIPANT

Discussion revealed that some anticipated barriers were perceived rather than actual as they were negated if specific conditions were negotiated. For example, *cost* and *timeliness* were considered critical barriers, but in the focus group the proposed costs and time-frames associated with the scenario were regarded by participants as reasonable and feasible. The consensus was that proposed costs would be entirely worthwhile if additional relevant information were achieved from current regulatory testing,

TABLE 1 Reported stakeholder incentives and barriers to adopting faecal source tracking

	Interview themes (P) = predicted theme	Regulatory	Intermediate	End-user
Incentives	Identification of source of faecal contamination (P)	X	X	X
	Application to recreational waters	X	X	X
	Application to marine leases	X	X	X
	Application to agriculture, irrigation water	X		
	Application to monitor catchment change		X	
	Application to groundwater seepage			X
	Regulatory responsibility (P)	X	X	X
	Accountability – Determining responsibility	X	X	X
	Reactivity – Test failed sample isolates		X	X
	Emergent			
	Political – Support if positive aspects from progress	X		
	Reputational – Avoid/mitigate negative messaging	X	X	
	State Policy – Protection of water quality for marine farmers		X	X
	Council part-ownership of TasWater			X
	Infrastructure planning			X
	Collaborative effort			X
Barriers	Timeliness – Timeframe too long (P)	X	X	X
	Time to build library		X	X
	Time to profile failing test		X	X
	Accuracy – Inability to discriminate source in sufficent detail (P)	X	X	X
	Clarity – Inability to obtain clear indication of source	X	X	X
	Discrimination – Identification of faecal source groups	X	X	X
	Access – Faecal source samples for building library		X	X
	Relevance – Identifying pathogenic vs. non-pathogenic			X
	Cost – Expense too great (P)		X	X
	Cost to build library		X	X
	Cost to profile failing test		X	X
	Participation – Sampling requires too great an investment (P)		X	X
	Staff		X	X
	Resources		X	X
	Commitment – Lack of perseverence in trialling FST methods		X	X
	Emergent			
	Political – Opposition if results are unpalatable	X		
	Availability – Limited availability of FST methods in Tasmania	X	X	
	Reputational – Avoid/mitigate negative messaging		X	
	Divided Responsibility – Multiple organisations		X	

however, stakeholder investment in library development was perceived as a greater barrier.

> If we consider the cost… for establishing a library, versus what we are currently spending on sampling, it's nothing, if we could… spend that much more and get more value out of it…

5 | INTERMEDIATE AUTHORITY PARTICIPANT

It was also confirmed that a significant barrier to implementation was the potential for stakeholder decision makers to misinterpret PhenePlate statistical associations as a definitive indicator of source. From this

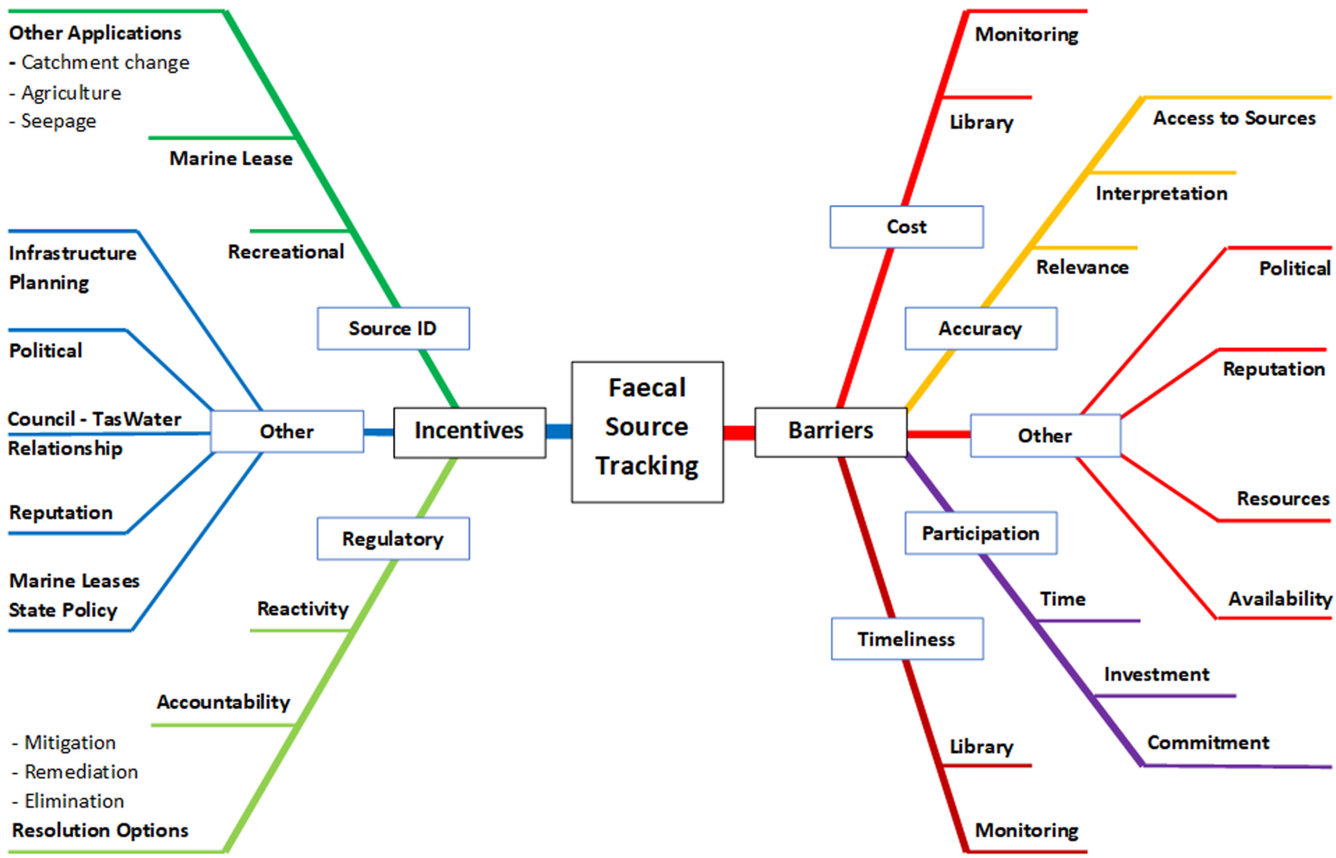

FIGURE 2 Theme-map – Interview themes mapped for presentation to focus group

TABLE 2 Focus group incentives and barriers to adopting faecal source tracking and identified strategies

	Focus group theme/strategies	Regulatory	Intermediate	End-user
Incentives	Source Indication – Any additional information		X	X
	Reactivity - Leveraging from regulatory test		X	X
	Cooperation – Funding/Access/Staff		X	X
	Coordination – Lead stakeholder		X	X
Barriers	Clarity – Inability to obtain clear indication of source	X	X	X
	Proprietary Development – Duplicated effort		X	X
	Misinterpretation – Statistical association only	X	X	X
	Laboratory capacity – Resourcing, Multiple projects	X	X	X
Strategies	Encourage collaborative development to share costs and data		X	X
	Encourage nomination of a coordinating lead stakeholder		X	X
	Seek management/political support and funding commitment		X	X
	Communication on nature of statistical association	X	X	X
	Flagship project to demonstrate application		X	

discussion, accuracy and clarity of results became the key barrier identified for effective use of the method, due to the inherent limitations of a library-based statistical method.

A particular benefit of the PAR approach was the opportunity for collaborative discussion to explore strategies to address incentives and barriers. There was general agreement that collaborative projects, to develop shared source libraries would be the most effective way of utilising the PhenePlate method, especially if these were coordinated by a stakeholder organisation with oversight responsibilities. The Derwent Estuary Program was nominated as an appropriate part of the system to take on such a role, as it monitors a single catchment area encompassing multiple Local Government councils and occupies a central position within the compliance system.

Further trials to demonstrate the utility of the method were also supported to increase confidence in the accuracy and utility, along with stakeholder canvassing of possible political support and funding for such trials. These initiatives are likely to generate further PAR cycles to explore the effectiveness of the PhenePlate method in meeting stakeholder needs. Table 2 summarises the incentives, barriers and proposed strategies that dominated the focus group.

There was continued interest in any information indicating probable source, despite the limitations discussed, especially as it could be derived from a non-compliant regulatory test, rather than having to take a subsequent sample which may not show the same contamination. The barriers identified included concern over duplicated effort if multiple stakeholders investigated the same catchment and limited laboratory capacity to support such efforts. These themes led to the proposal of strategies to strengthen incentives and mitigate barriers. There was general agreement that collaborative projects, coordinated by a lead stakeholder would most efficiently use laboratory capacity and reduce redundant stakeholder investment. A flagship project was recommended to demonstrate application of the method and strengthen efforts to obtain management support and funding.

6 | DISCUSSION

This article describes two PAR cycles aimed at evaluating PhenePlate, the only microbial source tracking method considered feasible to be implemented by the PHL. The quantitative component trialled the conduct of the method to evaluate the output produced from a local catchment, while the qualitative component explored the incentives and barriers influencing stakeholders in two iterations. Interviews with individual representatives examined the views of discrete parts of the compliance system, while the focus group brought the parts together to develop a system level perspective.

As the researcher was also part of the water quality system, but not in a leadership role, it was important to empower stakeholders in exploring the use of the PhenePlate method. The diverse stakeholder organisations had differing interests and responsibilities, and these were reflected in the incentives and barriers identified by their representatives. Responsibility for funding and resources in microbial source tracking is generally found at end-user extreme of the spectrum, with regulatory authorities primarily interested in testing outcomes. The engagement of stakeholder organisations, as well as level of cooperation by representatives during the interview and focus group stages suggested that system leadership and PAR were appropriate approaches for this context.

Despite these differences in perspective, all stakeholders participate in the regulatory system and have an interest in achieving compliance. The system leadership and PAR approach was effective in garnering input from this diverse group of stakeholders using both individual questioning and group discussion. The focus group demonstrated continued enthusiasm for the PhenePlate method despite some limitations with accuracy and clarity of results. In general, participants accepted that the method provided only a statistical indicator of probable source, but they concluded that this information was of sufficient value, particularly as the additional information could be obtained from the existing regulatory failing result, once a library had been developed. However, there was acceptance that an extension of the trial into winter months, when more samples tend to fail, could explore accuracy concerns, as well as addressing ways to reduce possible misinterpretation of results. Accuracy and interpretation aspects are likely to form the basis for another PAR cycle.

Reflections on the implementation scenario presented to the participants resulted in the conclusion that many perceived barriers were not actual barriers, as they were within acceptable limits, or could be mitigated through cooperative approaches and negotiation. The system leadership model was particularly relevant, with stakeholders agreeing that collaborative effort, preferably coordinated through an existing lead body or stakeholder, such as the Derwent Estuary Program, would be the best approach to efficiently develop the source library, and avoid wastage inherent in duplicated effort. It was recommended that the focus group outcomes be presented to Derwent Estuary Program to initiate a further PAR cycle in developing a Derwent Estuary source library, and to engage with necessary governing and political bodies to identify required time frames, funding and resources.

Thus, the use of a PAR and systems leadership approach was effective in four respects: identifying themes beyond those identified by the researcher, gaining an understanding of the priorities of different parts of the compliance system, identifying the benefits of a collaborative approach across the system, and the need for communicating and negotiating with the public and political bodies which influence the compliance system but are not directly part of it. A limitation of the study is that it did not attempt to engage with other, less defined groups that can influence the system, such as members of the public, the media, or political representatives. Also, the final investigation stage was a focus group, which may be dominated by the most motivated participants,[27] and lacked marine farmer input, as several planned to attend but accidentally missed the event.

7 | CONCLUSION

A systems leadership approach was utilised to facilitate engagement and collaboration in exploring possible service implementation to meet stakeholder needs, and this approach was effective in facilitating a high level of interest and participation in semi-structured interviews and a focus group. Despite diverse levels of responsibility, there was general agreement on perceived incentives and barriers. Some incentives were enhanced, and barriers mitigated, through proposal of a coordinated approach to resourcing to develop shared libraries and make efficient use of existing regulatory testing to obtain more information about contamination sources.

The combination of system leadership and PAR approaches was an effective avenue for exploring the appropriateness of the PhenePlate faecal source tracking method for meeting stakeholder needs. However, it is likely that further PAR cycles will be required to continue this process by developing collaborative partnerships between stakeholders which can effectively utilise the proposed service.

AUTHOR CONTRIBUTIONS

PG: conceptualisation; Data Curation; Formal Analysis; Investigation; Methodology; Project Administration; Resources; Visualisation; Writing – Original Draft Preparation, Writing – Review and Editing. SB: conceptualisation; Methodology; Supervision; Validation; Writing – Review and Editing. WQ: conceptualisation; Methodology; Supervision; Writing – Review and Editing.

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CONFLICT OF INTEREST

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. Part of the research was conducted in the Public Health Laboratory (Department of Health) using operational resources. The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support this study cannot be publicly shared due to ethical or privacy reasons, as no permission to share data was sought in the ethics approval.

ETHICAL APPROVAL

Ethics approval was granted by the Tasmania Social Sciences Human Research Ethics Committee (SSHREC) after assessment of a Minimal Risk application [S0021699 (H-75357)]. The human research described was undertaken with appropriate informed consent of participants.

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