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Community engagement approaches and influencing factors in *Aedes* mosquito management: a case study from North Queensland, Australia

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Abstract

Aim Community engagement plays a crucial role in preventing and managing *Aedes*-borne mosquito disease outbreaks, such as dengue. There is limited research on the engagement approaches used in high-income country contexts with existing research suggesting a preference for top-down vector control relying on one-way communication to engage and mobilize at-risk communities. The reasons behind why authorities use certain engagement approaches over others are underexplored. This study explores the community engagement approaches used in *Aedes* mosquito management in Townsville, Australia, and the factors influencing the choice of these approaches.

Methods The study used a case study design employing two qualitative methodologies: semi-structured key informant interviews ($N=15$) and a review of key documents ($N=13$). Both inductive and deductive approaches were used to thematically analyse the data.

Results A range of approaches were used to engage the community in *Aedes* mosquito management. From mass media campaigns and door-to-door inspections, to engaging the community in *Wolbachia* mosquito-releases, and helping authorities with indoor spraying during outbreak response. The factors influencing the choice of these approaches included legal obligations and regulatory compliance, vector control norms, leadership beliefs, human and financial resourcing.

Conclusions This study provides new insights into why authorities adopt specific community engagement approaches in *Aedes* mosquito management, within a high-income country context. It identifies barriers to enhancing community engagement and suggests strategies for addressing them in future planning. These findings are particularly relevant given the increasing *Aedes* mosquito risk in similar high-income country settings.

Keywords Dengue, Community engagement, Management

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Background

Australia has a longstanding history of *Aedes* mosquito-borne disease risk dating back to the late 1800s. In 1879, the regional city of Townsville in North Queensland was believed to be the first Australian city to encounter a dengue outbreak [1]. Since this time, Townsville experienced several large outbreaks including one in 1953, resulting in an estimated 15,000 dengue cases [2], and an outbreak in 1992 (Townsville, Charters Towers) with over 900 confirmed cases [1]. Multiple factors have contributed to dengue risk in Townsville, including the presence of *Aedes aegypti* (vector for transmitting dengue), international travel to dengue-endemic countries, as well as various social and environmental influences [3].

Over the last decade, dengue outbreak risk in Townsville has decreased due to the success of the Monash University, World Mosquito Program (WMP) [4]. In 2014, the WMP introduced *Wolbachia*-infected *Ae.aegypti* into the wild mosquito population in the Townsville region. *Wolbachia* acts as a viral blocker in mosquitoes, preventing the transmission of *Aedes*-borne diseases such as dengue [5]. While the WMP has so far shown success in its approach to reducing dengue outbreaks in Townsville, its long term-effectiveness remains unclear, with the potential for virus strain resistance, evolutionary changes, or climate influences [4, 6].

Aedes mosquito management

Aedes mosquito management in Queensland, Australia is typically a shared responsibility between the local government authority (council) and state government health authority (Queensland Health). Both authorities are responsible for '*protecting and promoting the health of the Queensland public*' to reduce public health risk [7, 8] The local government authority are responsible for controlling pests, including disease-carrying mosquitoes such as *Ae.aegypti*, whereas the state government health authority (Queensland Health) are responsible for preventing and responding to disease outbreaks, including mosquito-borne disease outbreaks [9].

A core part of *Aedes* mosquito management is engaging residents and businesses, particularly given *Ae. aegypti* is a domesticated mosquito that lives close to its food source - humans [10]. When engaging the community, approaches should foster a sense of ownership and responsibility at both the household and community level. Approaches should extend beyond merely educating the community, to actively involve them in developing and implementing locally accepted *Aedes* mosquito management strategies. By leveraging local knowledge, resources and leadership, these efforts can empower communities, build resilience against disease outbreaks, and sustain long-term mosquito control initiatives [11, 12].

A review of community engagement approaches in *Aedes* mosquito management in high-income countries found a focus on authority-led vector control, with informing and consulting strategies primarily used to promote community involvement in source reduction in and around homes. There were fewer examples of collaborative approaches involving the community in planning or implementing of vector control approaches, utilizing local resources or expertise to address disease risk. The reasons why authorities use certain community engagement approaches over others was unclear [13].

With *Aedes* mosquito-borne diseases such as dengue increasing across the globe, including in high-income countries [14], it is important to understand how the community is engaged in the management of these diseases, and what influences this engagement [14]. Examining the community engagement approaches historically used by authorities, and understanding the reasons behind these choices will provide a foundation for addressing barriers to engaging the community and identifying ways to strengthen these approaches in the future.

This qualitative study explored the community engagement approaches used in *Aedes* mosquito management in the regional city of Townsville, Queensland, Australia. The study had two objectives:

1. To understand the types of community engagement approaches historically used in *Aedes* mosquito management in Townsville, Australia.
2. To explore the factors that have influenced the choice of these community engagement approaches.

Methods

Study design & setting

A case study design was used, drawing on two qualitative methods - key informant interviews, and a document review. Case studies enable in-depth investigation of a particular phenomenon within its real-life context, providing a comprehensive understanding of complex issues [15]. The phenomenon (case) we were studying was the community engagement approaches used in *Aedes* mosquito management, between the years of 1990 to 2020. This time was chosen due to pivotal historical events, including the development of the first Dengue Fever Management Plan in Queensland (1994). The case study site for the study was Townsville - with the geographic boundary defined by the Townsville Local Government Area (LGA), which spans 3736 square kms. The Townsville LGA includes the regional city of Townsville which is the largest city in North Queensland (estimated LGA population 192,768) (Fig. 1) [16]. Townsville typically experiences a tropical dry climate, marked by warm, dry winters and hot, humid summers with occasional bursts of rainfall [17]. The city has a varied economy,

Fig. 1 Townsville Local Government Area in the State of Queensland (Reference - https://en.wikipedia.org/wiki/City_of_Townsville#/media/File:Townsville_LGA_Qld_2008.png)

characterized by government administration, a large Australian Defence Force base (army and airforce), construction, mining, retail, property and business [18]. The Townsville LGA case boundaries were extended as necessary to account for programs such as the World Mosquito Program that were funded and implemented beyond the geographic limits of the Townsville LGA.

Data collection & participants

Purposive and snowball sampling drawing on investigator expertise and publicly available information were used to find participants to be interviewed. Suitable participants were classified as those with current or past involvement in *Aedes* mosquito management, dating back to the early 1990s. For the purpose of this study, *Aedes* mosquito management is defined as 'the surveillance, prevention, and control of *Aedes* mosquitoes *(Ae. aegypti)* and mosquito-borne disease threats resulting from these mosquitoes' [9].

At the time of data collection, three main agencies/programs representing state government, local government, and a public-private research initiative were involved in *Aedes* mosquito management in Townsville:

Table 1 Organisation, role & number of interviewees - Townsville

Organisation/Program	Role	Number of interviews
Townsville Public Health Unit	Vector Control Officer (2x) Environmental Health Manager (former) Health Promotion Manager (former) Unit Director	5
Townsville City Council, Vector Control Unit	Pest Control Coordinator Environmental Health Manager (former)	2
World Mosquito Program	Community Engagement Officer Reference Group Members (6x) Program Manager (former)	8
Total number of interviews		15

1. Townsville Public Health Unit, Queensland Health, State Government.
2. Townsville City Council, Vector Control Unit, Local Government.
3. World Mosquito Program, Monash University.

Each agency was contacted, and an invitation extended to those fitting the inclusion criteria to participate in an interview. Fifteen participants agreed to be interviewed, two declined, eight did not respond. Two Townsville Public Health Unit staff were also interviewed in their role as reference group members for the World Mosquito Program. Interviews continued until data saturation was reached or until no additional participants were available for interviewing. (Supplementary Material – Interview Guide) (Table 1).

A targeted search of grey literature and peer-reviewed articles was carried out to identify any contextual factors, key decisions, and community engagement approaches of relevance to *Aedes* mosquito management in Townsville. This process, conducted before and after the interviews, helped in triangulating the data obtained from the interviews and strengthening the validity of the findings. Searches included government (local and state) websites, as well as requests for relevant materials from interview participants. Documents reviewed included state and local *Aedes* mosquito management plans, guidelines, policies, legislation, evaluation reports and selected peer-reviewed literature. In total, 13 documents were reviewed.(Supplementary One).

We used thematic analysis, drawing on both inductive and deductive approaches to code the data [19]. The interviews were recorded using a dictaphone, mobile device or zoom recording, and then transcribed verbatim into Microsoft Word. Each data source (interview transcript or document artefact) was then imported into NVivo12+. Attribute coding was used, which is a way of organizing data in a clear, consistent way – by labelling

each artefact (interview, document) and filing against the different cases in NVivo. Following careful reading of each data source, the principal investigator coded the data inductively to ensure closeness or "giving voice" to the data [20]. Examples of initial coding for Objective One (community engagement approaches) included codes such as 'door-to-door inspections' or 'awareness campaigns'. The codes were then discussed with three other investigators and agreed on by consensus. Two existing frameworks - IAP2 Public Participation Spectrum© [21] and Laverack's Organisational Aspects of Community Empowerment [22] were used to help categorize the different engagement approaches. For ease of reporting, the data were also sorted into a chronological timeline across the period studied. A similar process was used for Objective Two, (factors influencing community engagement approaches). Examples of initial coding included codes such as 'community perceptions' and 'lack of time'. Scott's Institutional Analysis Theory, which examines elements of governance that influence the behaviour of individuals and organisations [23], informed the categorizing of key factors influencing the selection of community engagement approaches (Research Objective Two). The factors were grouped into four domains adapted from Scott (2005) [23], *Regulatory* (laws and regulations pertaining to vector control that influence community engagement), *Normative* (the institutional norms and leadership practices that shape community engagement approaches of relevant organisations), *Cognitive* (the attitudes and beliefs of individuals within vector control units or organisations towards engaging the community), and *Resources* (the workforce and material resources factors that influence community engagement approaches). For ease of reporting, the factors were discussed collectively across all the programs. The credibility of our research findings was optimized through data triangulation (using multiple sources), peer debriefing, and member checking with participants [24].

Results

The study findings are organised into two sections. First, we describe separately, the community engagement approaches used by the three key agencies involved in *Aedes* mosquito management in Townsville (Objective One). Second, we examine the key factors influencing the choices of community engagement approaches (Objective Two), described under the four domains of regulatory, normative, cognitive, and resource factors. Quotes are attributed to individuals from either – Townsville City Council (TCC), Townsville Public Health Unit (TVPHU) or the World Mosquito Program (WMP), and a sequential ID.

Community engagement approaches used in Aedes mosquito management

Townsville City Council

The Townsville City Council (TCC) played an important role in fostering community engagement in *Aedes* mosquito management. During the early 1990 s, TCC environmental health staff (hereafter referred to as TCC staff) worked collaboratively with the Townsville Public Health Unit (TVPHU) environmental health/vector control staff (hereafter referred to as TVPHU staff) to implement vector control and community engagement activities in this region. A large outbreak in 1992/1993 in Townsville and Charters Towers (900 confirmed cases) [1], saw TCC engage the community as part of door-to-door inspections, with the purpose of gaining permission to enter resident's properties to inspect and treat potential larval habitats, and to warn of potential fines if found to be breeding mosquitoes. During this period, TCC staff were implementing a range of broader community education strategies to promote dengue prevention and protective behaviours in the community. In the interviews, one TCC staff (former) described how they worked with the TCC public relations team to promote key prevention messages through newspaper articles, and television and radio advertisements. TCC staff also collaborated with the local university, James Cook University, to develop a school-based education program which was implemented in 26 Townsville primary schools during the early 1990s.

> *The overall plan of that [school education] was, if we did year two and three for 10 years or so, we've got a generation of people that know what's going on with dengue, and they hand it off to their kids. And lo and behold, we should have a population that knows about dengue. (TCC2)*

TCC staff continued with these education strategies until the mid-to-late 1990 s, when Queensland Health, health promotion and public affairs staff at the public health unit in Cairns (300 km north of Townsville) began implementing dengue prevention media campaigns across the wider North Queensland region including Townsville. The screening of the media campaigns negated the need for TCC to continue with their local dengue prevention campaign advertisements. To support the Queensland Health strategies, TCC staff engaged the community through providing information and education displays at community events, promoting annual kerb side waste collections to encourage residents to get rid of potential larval habitats and educating residents during door-to-door inspections.

This engagement continued until the World Mosquito Program (described separately) began in Townsville

(2014). The early success of this program led to a shift away from TCC staff engaging with the community in dengue prevention. In the interviews, one TCC staff described how the vector control team (2 officers) were now focused on controlling other pests, and vectors that could carry diseases such as Ross River Virus, with dengue no longer a priority for the council.

> *Since Dengue's sort of dropped off the radar, so to speak we target the Aedes vigilax, so the salt marsh mozzie [mosquito], not so much the dengue mozzie, because Queensland Health predominately does dengue, and then developed the Wolbachia [World Mosquito] program, obviously working as good as it is. So basically, what we do is targeting that salt marsh mozzie, which is out in the salt marshes and tidal areas up and down the coastline. (TCC1)*

Townsville public health unit

The Townsville Public Health Unit (TVPHU) played an integral role in engaging the community in *Aedes* mosquito management. In the early 1990s, TVPHU staff worked in conjunction with the TCC to engage residents to gain permission to enter properties to inspect and treat mosquito larval habitats. TVPHU staff also provided health promotion support and advice to TCC staff who were leading community education initiatives during this early period. As previously mentioned, in the mid-1990s, state government (Queensland Health) introduced their own mass media education campaign strategies [25], which were screened across North Queensland, including Townsville. TVPHU staff supported these strategies but were not directly involved in their implementation. These strategies included a series of mass media (television, radio and print) campaigns, such as the *'Stop Dengue Now Aye'* television advertisements, screened during the 1990s, demonstrating to residents how to get rid of potential larval habitats in their backyards. A '*Flozzie the Mossie*' television, radio and print campaign was implemented in the early 2000s, dispelling myths on where *Ae. aegypti* breeds. This campaign included a range of materials which were designed for different settings including workplaces, schools and the general community. The campaign was implemented in North Queensland, including Townsville, until 2008.

A multi-city outbreak (2008-9) saw the development of a new campaign, *'Defend Against Dengue'* promoting protective behaviours such as wearing insect repellent, screening houses, and eliminating mosquito larval habitats. Political imperatives saw campaign management transfer from the public health unit (Cairns) to Queensland Health's marketing branch in Brisbane.

Aside from the mass media campaigns, at a local level, TVPHU communicable disease control staff were involved in media/press conferences to warn the community of dengue risk, and public health nurses engaged with confirmed cases providing one-on-one advice on how to stop the virus from spreading.

> *I would announce proactively in dengue season [and] do proactive media and then responsive media in cases of imports or outbreaks around ensuring people knew what to do and also advising cases on how to protect themselves from further mosquito bites. (TVPHU3)*

During the 2008-9 outbreak there was a shift in vector control and engagement strategies by TVPHU staff, in a bid to reduce the spread of the virus in the city. Existing vector control measures introduced in the early 2000 s, and led by authorities, included selective indoor residual spraying using residual pyrethroid insecticides, such as deltamethrin or lambda-cyhalothrin. Additionally, larval control and source reduction activities, such as removing containers or treating them with S-Methoprene pellets or surface spray, were also implemented. However, these measures were laborious and time-consuming during outbreak response. A former TVPHU staff member explained the vector control staff wanted to focus on empowering residents by showing them how to spray inside their homes, rather than vector control staff doing this for them.

> *In the large outbreak in 2009, we looked very closely at what people could do themselves and that included the whole idea of spraying their own houses so doing their own interior residual spray. (TVPHU3)*

This type of engagement continued during outbreak response until 2017, when vector control priorities and community engagement approaches changed significantly with evidence of the early success of the World Mosquito Program in Townsville (2014–2017) (described below). As the outbreak risk decreased, TVPHU staff explained that their focus shifted from door-to-door inspections and outbreak response to monitoring *Wolbachia* levels in the local mosquito population a responsibility assigned to TVPHU staff following the conclusion of the World Mosquito Program.

> *Now we do surveillance for mosquitoes…instead of just looking for dengue mosquitoes, now we are looking at how many are Wolbachia mosquitoes and how that is being sustained. So that's what our focus is in now. (TVPHU2)*

World mosquito program

Community engagement was key to the implementation of the World Mosquito Program (WMP) (formerly *Eliminate Dengue*), a discrete *Aedes* mosquito management initiative implemented in Townsville between 2014 and 2017 [26]. In 2014, Townsville was the first city in the world to implement the WMP on a city-wide scale, marking a significant milestone in the program's expansion from suburb-wide releases in Cairns.

> *They did small-scale pilots [in Cairns] between 2011 and 2013. And then in 2014 they decided okay, let's scale up. That's when they set up the office in Townsville. (WMP2)*

To facilitate city-wide releases, in collaboration with an external consultancy, the WMP developed a Public Acceptance Model (PAM) which served as a guiding framework for community engagement throughout the program. The primary aim of PAM was to gain city-wide support, rather than seeking individual household consent for the *Wolbachia* mosquitoes to be released, whilst abiding by the principles of respect, inclusiveness, transparency, responsiveness, and honesty [27].

The WMP implemented a range of different approaches to gain community support. Firstly, a baseline survey was distributed across Townsville to gauge the community's attitude towards the *Wolbachia* mosquito releases. The survey findings were used to tailor an information and communication campaign to address community concerns and raise awareness of the program, before the *Wolbachia* mosquitoes were released. This included community meetings, information booths, traditional media, and social media. A post-campaign survey was distributed to assess whether the identified community concerns had been addressed. The survey results were presented to a WMP community reference group, who ultimately determined the community's readiness for the program to commence.

The WMP community reference group consisted of a broad cross-section of the Townsville community including local government, state government, local business, non-government, defence force and local Indigenous community representatives. The group aimed to hold the WMP to account for their engagement approaches, including ensuring alignment with the PAM values (as outlined previously) and providing advice on community readiness for the mosquito releases.

Once the WMP commenced, the community were informed of the project's progress using letter box drops, a newsletter, traditional media, and social media. In addition, the local community were actively involved in the release of *Wolbachia* mosquitoes. Firstly, a citizen science initiative '*Wolbachia Warriors*' was piloted in five schools, to engage primary school-aged children and their parents in the mosquito releases. Students were provided with project booklets and bucket mosquito release containers to release the *Wolbachia* mosquitoes in their backyards [28]. The success of this pilot resulted in its adoption as a central mosquito release strategy throughout the WMP and was evidently integrated into the primary school science curriculum in public primary schools throughout Townsville. The wider community was encouraged to participate in mosquito releases through a 'grow and release' approach. This method involved community members and businesses (approximately 6,000 households) who were recruited through door-to-door outreach and voluntary self-nomination, deploying MRC 'mozzie boxes' in designated release areas. This extensive community involvement was essential to achieve a city-wide mosquito release approach [26].

> *Stage two, three, and four of Townsville were all done through community releases. The program didn't release any mosquitoes. We just gave them to the community. (WMP1)*

What factors influenced the choice of community engagement approaches used?

A range of factors influenced the community engagement approaches used by all three agencies in *Aedes* mosquito management in Townsville including regulatory factors (legislative responsibilities), normative factors (moral obligations), cognitive factors (attitudes and beliefs) and resourcing factors (funds, capacity, time).

Regulatory factors

The extent to which TCC and TVPHU staff engaged the community was influenced by Queensland public health legislative requirements.

Legislative responsibilities to engage community and conduct vector control

In Queensland, the responsibility for mosquito control, including the removal of mosquito breeding sites on residential and/or commercial properties falls on the resident or property occupier [8, 35]. If a property owner is found to be breeding mosquitoes, TCC and TVPHU can place a public health notice (a time-bound warning to follow specific instructions) and TCC can carry-out enforcement for non-compliance [8, 35]. In the interviews, a TCC staff (former) described how they were required to engage particularly with high-risk properties to check for compliance. For example, during a major outbreak in Townsville in 1992/93, TCC staff repeatedly observed mosquito breeding on residents' properties and therefore used enforcement measures to mobilize residents to clean up their backyards.

I had convinced the council to take all of those matters [residents found to be breeding mosquitoes]to court for prosecution. Some were withdrawn, but there was a lot of people that were fined. (TCC2)

Along with community responsibility, when there is a disease outbreak risk, local government (e.g. TCC) and Queensland Health (e.g. TVPHU) can conduct vector control activities on behalf of residents, under an approved Authorized Prevention and Control Program [8]. As part of this program, TCC and TVPHU are required to engage with residents if at home, to seek permission to enter private properties to inspect and treat the potential mosquito larval habitats [8, 9]. At times door-to-door engagement by TCC and TVPHU staff with residents was minimal, particularly as part of outbreak response during the 1990s. At other times, the study found door-to-door inspections provided an opportunity to educate and involve residents in vector control.

Normative factors

Professional expectations and moral obligations for engaging the community were key factors influencing the engagement approaches used in *Aedes* mosquito management in Townsville.

Professional expectations to conduct top-down approaches

As previously described, the 'top-down' vector control approaches used by TCC and TVPHU were driven by legislative requirements, which contributed to a growing professional expectation for conducting effective and efficient vector control during outbreak response. This regulatory framework also shaped the professionalization of the Queensland Health vector control workforce in North Queensland, which indirectly influenced community engagement by vector control staff at TVPHU. For example, a specialized 'Dengue Action Response Team' (DART) was established in Cairns (1997/1998) to respond to outbreaks in North Queensland, and to support staff at TVPHU when required. The primary focus of the DART was to conduct top-down *Ae. aegypti* control on behalf of residents in and around their homes [25]. Although the TVPHU did not have an official DART, the move by Queensland Health towards having specialized professionals, led to an increased focus on authority-led vector control. This approach was considered the professional and expected way to manage outbreaks and reinforced the norm that expert-led interventions were best practice for managing outbreaks. Engaging the community for permission to enter properties was important to allow this work to proceed, however it also reduced the time and need for deep engagement with residents.

I suppose what we were trying to do is, get rid of the big stuff as quickly as we possibly could, so you know, pot plant bases, and buckets, and birdbaths, and all that sort of stuff. It [talking to residents] wasn't something that we were encouraging people to do, it was just something that happened. (TCC2)

As outbreaks grew in the region, these top-down style approaches started to pose multiple challenges. In the interviews, TVPHU and TCC staff in leadership roles described how relying exclusively on government-led vector control efforts during outbreaks was demanding and expensive, resulting in considerable strain on staff and leading to the neglect of other (local government) responsibilities. These experiences contributed to TVPHU and TCC staff trialling different ways to engage the community, particularly during outbreak response.

We had a lot of [local government] people doing a lot of [vector control] work, that was expensive. That was really, really expensive. And the things that we were missing out on, the food stuffs, the flammable and combustible, and development applications, which are really enormous, the complaints around all of those things. A lot of that stuff was not being done, so there were some operational costs that this thing [dengue outbreak] had on the whole of the department. Based on that, we then started getting into the ears of our public relations people, and we started looking at dengue education. (TCC2)

I inherited a model of vector control which was largely based on vector control staff going and doing it [vector control] to people's houses or going and spraying their yards or cleaning up their yards or spraying their homes. In other words, the whole response was very much our staff go and do it for them or we work with the council to do it for the community member. (TVPHU3)

The moral obligation to engage the community

The focus of engaging the community was different for the WMP, compared to TVPHU and TCC. Firstly, there was no legislation or ethical imperative to engage the community, but there was a moral obligation to gain community support and acceptance of the program. This obligation led the WMP (in conjunction with a consultancy agency) to developing a Public Acceptance Model (PAM), acknowledging the need to gain community support and acceptance of the program, but through passive, rather than active, consent. The PAM emphasized the program's commitment to maintaining moral standards, including the establishment of a community reference group, which served as a mechanism to uphold the

WMP's obligation to engage the community as part of the program.

> *They had been using individual consent for trials around the Cairns area. And we knew that that was not a scalable method. We couldn't go to every person in Townsville and ask their permission and sign a piece of paper. So [name] developed a theory called the public acceptance model. And Townsville was the first trial of that method. (WMP1)*

Social-cognitive factors

Social-cognitive factors influenced the community engagement approaches used including authorities' beliefs toward the role of community in *Aedes* mosquito management, and perceived views on how the community felt about being engaged.

Authorities' beliefs towards engaging the community

Staff from all three agencies/programs had similar views around the importance of engaging the community in vector control, particularly during outbreak response. For example, the WMP staff described how community engagement was essential for scaling up *Wolbachia* mosquito releases from small suburb-wide releases to city-wide releases. These beliefs formed the foundation of their engagement approach, initially involving children in the release of *Wolbachia* mosquitoes and later expanding to the broader community. WMP staff also described the importance of community involvement for future *Aedes* mosquito management efforts, beyond the World Mosquito Program.

> *Most health authorities I know struggle to have enough staff to be able to conduct any method alone… communities are going to have to be involved in order to implement whatever method is the preferred one to that area. (WMP1)*

TVPHU and TCC staff both felt that community engagement was an important part of *Aedes* mosquito management, and that using education approaches was key to mobilising the community into action.

> *Its powerful if you can mobilise people – if you can mobilise a section of the community, that you essentially have almost on standby. (TVPHU2)*
> *I keep going back to the education side of it. I think that is a key part of any mozzie program these days. It's essential that we educate people, and that people are aware, because you tell someone and they soak it in, then they go and sit around at the barbecue on Friday night and have a beer and talk to their friends. (TCC2)*

However, perceived apathy by the community, towards being involved in vector control was also identified by authorities (TCC and TVPHU) as a key barrier to engaging the community. Ironically, this apathy was recognized by staff to be attributed to the top-down approaches they had used during outbreak response (1990s), which over time had led to increased public expectations of government intervention, complicating engagement efforts during this time.

> *I think with the Townsville model, it got to the stage where people were basically waiting for the council to come and inspect their yard. And maybe we were so efficient at it, that we were there, that we probably helped people to believe that. (TCC2)*

Some TCC staff believed it to be part of their role to engage the community in education approaches such as providing information through displays at community events, organising mass media campaigns, and a developing a school education program (early 1990 s). Others felt that perhaps this work should be done by a health promotion team in conjunction with vector control.

> *If we had a department more dedicated to hp/community engagement to get our general public health messages across it would fall under that domain a bit more - it would probably have to be advised by us and rolled out. We definitely have the ability to do it ourselves. It could be a situation where we work in conjunction or team up with another public health community or hospital. (TVPHU1)*

Resourcing

Human resourcing and funding influenced the community engagement approaches used across the three agencies involved in *Aedes* mosquito management.

Funding and resourcing priorities

Dedicated funding for community engagement was determined by institutional limitations and shifting priorities, which impacted the type of approaches used to engage the community over the period studied. In the interviews, a TCC environmental health manager (former) described how having access to funding in the early 1990 s enabled TCC to lead various education approaches, including a school-based education program and mass media campaign in Townsville. These approaches were supported by TVPHU, who encountered difficulties in securing funding for similar initiatives during this period.

In the initial stages, for them [Queensland Health] to get money to go and do media releases, or newspaper, or television commercials, was difficult. (TCC2)

During the mid to late 1990s, funding priorities shifted, affecting the extent to which each agency prioritized community engagement. Capital outbreak funding became more available, in response to increasing outbreaks in the North Queensland region. A portion of these funds was used to develop mass media campaigns (television and radio advertisements), and limited reach materials (posters, pamphlets) to educate affected communities across North Queensland, including Townsville. Recognizing the redundancy of duplicating approaches and facing funding pressures, TCC eventually ceased their mass media funding, in favour of Queensland Health's initiatives.

I think our stuff [media campaigns] was going concurrently with Queensland Health. But we were probably, and rightfully, we had spent a lot of dollars on this. And we could see that Queensland Health was starting to take the baton and run with it…And over time, that [mass media and school education] eventually stopped. (TCC2)

There were limited human resources dedicated to engaging the community in *Aedes* mosquito management outside of the mandatory door-to-door engagement during outbreak response. A health promotion manager at TVPHU supported TCC and TVPHU's vector control and community engagement efforts, but competing priorities limited their direct involvement in local initiatives. The amount of staff specifically dedicated to *Aedes* mosquito management at TCC and TVPHU (1–3 team members per organisation) was small, with both authorities needing to draw on extra resources (as previously described) for surge capacity during outbreak response. Interestingly, this lack of human resources drove the need to involve the community in *Aedes* mosquito management over the period studied.

Discussion

Community engagement plays an important role in *Aedes* mosquito management. The study outlines the key community engagement approaches used in Townsville, Queensland, and examines the reasons why these approaches were chosen over the period studied. In the following discussion, we reflect on these two objectives and discuss their implications for future *Aedes* mosquito management practices.

First, the study highlights the challenges faced by authorities (TCC and TVPHU) in balancing government mandates to protect and prevent public health risks [8], with the need to foster a sense of ownership among residents for controlling mosquito breeding in and around their homes. Queensland legislative frameworks and government strategic guidance recommend that authorities (TCC and/or TVPHU) lead vector control activities on behalf of residents during outbreak response [8, 9]. While top-down practices can be effective in controlling outbreaks, the study showed that authorities felt these approaches were labour-intensive, time-consuming, costly, and leading to community apathy during outbreak response. These findings were similar to other studies, where top-down approaches have demonstrated efficacy, especially in resource-rich environments, yet their sustainability particularly in terms of resourcing, can pose challenges [13, 29]. The study revealed efforts to blend the top-down approaches of the 1990s and early 2000s, which resulted in minimal resident engagement, with approaches aimed at empowering residents with tools and knowledge to actively participate in mosquito management during outbreak response. However, despite these attempts, a lack of ongoing funding and strategic priority for such approaches outside of outbreak response made them hard to sustain.

Second, the study reveals ambiguity surrounding responsibility for community engagement in *Aedes* mosquito management. Planning frameworks and strategic guidance, for example the Queensland Dengue Fever Management Plan (2015–2020), emphasize that community engagement should be a collaborative effort between local government (Townsville City Council, TCC) and state government (Townsville Public Health Unit, TVPHU) [9]. While the plan provides guidance on who should lead outbreak media communications and the coordination of mass media campaigns (Queensland Health), it is unclear who is responsible for engaging local community groups/leaders and key stakeholders (e.g., schools, workplaces) and addressing barriers to behaviour change. Our study demonstrated ad-hoc implementation of these approaches by both TCC and TVPHU vector control staff, with barriers such as lack of funding or strategic priority identified as reasons why many of these approaches were not sustained. Although one of Queensland Health's core public health functions is to 'mobilize community partnerships to identify and solve health problems,' we found no clear guidance on how this should be applied to mosquito-borne diseases or which department within Queensland Health (for example Environmental Health, Vector Control or Health Promotion) should be responsible for this work [30]. Interestingly, we observed that other local government entities outside North Queensland often lead engagement approaches for mosquito-borne disease prevention, including dengue. For instance, Rockhampton Regional Council has a specific Dengue Fever Management Plan

outlining public awareness and community engagement strategies [31]. Our study showed that local government (TCC) historically led engagement efforts until Queensland Health assumed some of these responsibilities in the 1990s. The shared regulatory nature of *Aedes* mosquito management has likely contributed to challenges, particularly regarding funding and resourcing. This ambiguity underscores the importance of prioritizing community engagement—especially approaches that empower and mobilize the community in the planning of *Aedes* mosquito management, as well as clearly defining the roles and responsibilities for implementing these strategies and ensuring the allocation of dedicated funding, time and resources to support this work.

Third, we note an emphasis on education approaches by TCC and TVPHU in mobilizing the community into taking preventative or protective action. This was particularly evident in the priority given to funding mass media campaigns as a key preventative and outbreak engagement strategy throughout the period studied. Mass media campaigns are important for communicating dengue risk and promoting preventive behaviours to a wide audience, particularly in the event of an outbreak [29, 32]. While these approaches can help inform the community on what they need to do, they may not be able to create or sustain behaviour change unless they are supported by other approaches that can address barriers to people acting on these messages, such as having access to mosquito repellent, screening for windows, or having an affordable mechanism to get rid of potential larval habitats [32, 33].

Although the study did not assess the effectiveness of engagement approaches, it is important to recognize the limitations of relying on education strategies when engaging the community in reducing outbreak risk. To strengthen community ownership and make it easy for people to adopt preventative approaches, ideally, the focus of engagement should be on involving the community in the planning and implementing of approaches that are accepted by the community, using local resources, knowledge and expertise [12, 33]. Indeed, the study revealed examples of empowering strategies such as showing residents how to spray in their homes and involving children and the general community in the release of *Wolbachia* mosquitoes in Townsville. However, most of these were one-off approaches implemented during outbreak response or as part of a discrete, time-bound initiative, and were not sustained. These learnings are important to consider when advocating for policy to strengthen community engagement in *Aedes* mosquito management.

Study limitations and future research priorities

The study focused uniquely on the perspectives of those working in *Aedes* mosquito management and hence did not capture the views of the community. Future research should explore the community's perspectives on *Aedes* mosquito risk and preventive measures, including barriers and enablers to being involved in this work.

The authors are cognizant of the success of the World Mosquito Program in Townsville, which has resulted in a period of reduced dengue transmission risk. However, this success may lead to community complacency, making it important to monitor community perceptions to mitigate future mosquito-borne disease risk. Understanding how the community would like to be engaged in future mosquito-borne disease outbreaks in Townsville should also be an important consideration for future outbreak planning and preparedness.

Conclusions

This study offers valuable insights into the community engagement approaches used in *Aedes* mosquito management in Townsville, Queensland, since the early 1990s. It highlights approaches such as door-to-door inspections, school education and mass media campaigns, with the choice of these approaches determined by a range of factors. Considering growing *Aedes* mosquito-borne disease risk across the globe, it is important to consider how authorities are engaging with communities, why they are doing this and investigate ways to strengthen these approaches, including opportunities to influence future policy and resourcing decisions, to prioritize meaningful community engagement in *Aedes* mosquito management.

Abbreviations

LGA	Local Government Area
PAM	Public Acceptance Model
TCC	Townsville City Council
TVPHU	Townsville Public Health Unit
WMP	World Mosquito Program

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

TA designed the study, conducted the research and data analysis, and wrote the manuscript text. AC and SMT contributed to the design of the study. AC, SMT and TLR supervised and contributed to reviewing and editing the manuscript text.

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Data availability
James Cook University has a managed access system for data sharing that respects legal and ethical obligations to study participants to collect, manage and protect their data. Summarized non-identified data supporting the conclusions of this article can be made available from the corresponding author (TA) upon reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Townsville Hospital and Health Service Human Research Ethics Committee, Australia (HREC/2019/QTHS/53,053). Informed consent was obtained from all participants. Participation in the study was voluntary and confidential. Interviews and subsequent analysis followed the relevant guidelines and regulations as stipulated in the ethics approval. Standards for Reporting Qualitative Research were used as a guide for reporting on this research [34].

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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