Open Access Journal
JOURNAL OF COMMUNITY SERVICE

Climate Change Awareness and Community Resilience in Remote Atoll Villages of Tuvalu

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ARTICLE INFO

Received May 22, 2024
Revised June 15, 2024
Accepted July 13, 2024
Published July 30, 2024

Keywords:
climate change resilience, Tuvalu, atoll communities, community awareness, sea-level rise, Pacific Islands

ABSTRACT

Tuvalu, a low-lying Polynesian atoll nation in the central Pacific, faces an existential threat from anthropogenic climate change as accelerating sea-level rise, intensifying storm surges, saltwater intrusion, and coral bleaching events collectively undermine the ecological and social foundations of life on its nine atolls. This community service study evaluates a six-month participatory climate change awareness and resilience-building programme—Rising Tides, Resilient Communities—implemented across five remote atoll villages in Funafuti, Nanumea, Nui, Vaitupu, and Nukufetau atolls, engaging 184 adult community members. Employing a single-group longitudinal design with measurements at baseline, three months, and six months, the programme integrated climate science literacy, traditional ecological knowledge, adaptive food and water security strategies, ecosystem restoration practices, early warning system training, and community advocacy capacity building. Findings demonstrate statistically significant improvements across all ten resilience indicators measured, alongside strong cultural relevance ratings for all programme components. These results advance the evidence base for culturally grounded, community-led climate resilience frameworks in small island developing states facing existential climate risk.

INTRODUCTION

No inhabited territory on earth faces a more immediate and existential threat from anthropogenic climate change than the low-lying coral atoll nations of the

central Pacific, and among these nations, Tuvalu occupies a position of particular vulnerability that has made it both a symbol and a frontline in the global struggle over the pace and ambition of climate action. Comprising nine atolls and reef islands with a combined land area of approximately 26 square kilometres, a maximum natural elevation of barely five metres above current mean sea level, and a total population of approximately 11,000 people dispersed across islands separated by hundreds of kilometres of open ocean, Tuvalu possesses essentially none of the geographic, ecological, or infrastructural buffers that allow other nations to absorb the impacts of rising seas, intensifying cyclones, and changing precipitation patterns. The Intergovernmental Panel on Climate Change (IPCC, 2022) projects that under a high-emissions scenario, global mean sea level could rise by between 0.61 and 1.01 metres above 2000 levels by 2100, with low-probability high-impact scenarios reaching well above this range; for Tuvalu's atolls, which already experience regular king tide inundation of agricultural land and residential areas, even the lower end of this projection range would render large portions of the current inhabited land area functionally unusable within decades. Nurse et al. (2014) characterize small island developing states in the Pacific as exhibiting a distinctive risk profile that combines high exposure to multiple climate hazards, high sensitivity due to limited adaptive capacity, and constrained response options—a combination they term "compound vulnerability" that fundamentally differs in character from the risks faced by continental nations and demands analytical frameworks and policy responses specifically calibrated to island realities.

The scientific consensus on the physical dimensions of climate change in the Pacific, while itself contested in its precise projections, is substantially more robust than the evidence base regarding communities' awareness of, attitudes toward, and adaptive responses to these changes—particularly in the most remote and isolated island communities where research access is logistically and financially challenging for external institutions. Barnett and Campbell (2010), in their landmark analysis of climate change and small island states, identify a persistent gap between the aggregate vulnerability assessments that dominate international climate policy discourse and the granular, community-level knowledge of how specific Pacific communities understand their own risk, draw on indigenous ecological knowledge to interpret environmental change, and make practical adaptive decisions under conditions of deep uncertainty (Muhsyanur, 2020, 2023). This gap has direct policy consequences: development programs designed on the basis of externally generated vulnerability assessments without community-embedded knowledge frequently misidentify priorities, underutilize existing community adaptive capacity, and generate dependency rather than building the autonomous resilience required for long-term survival in the face of irreversible environmental change. Adger et al. (2013) further argue that the social dimensions of resilience—community cohesion, shared identity, collective institutions, and the cultural meanings that motivate collective action—are as determinative of communities' actual adaptive capacity as the physical and technical dimensions that receive more programmatic attention, yet

they remain undertheorized and underfunded in Pacific climate adaptation programming.

Indigenous and traditional ecological knowledge (TEK) constitutes a critically underutilized resource in Pacific climate adaptation, particularly in atoll communities like those of Tuvalu where centuries of accumulated observational knowledge about ocean behaviour, weather patterns, ecosystem dynamics, and island morphology represent an empirical archive of environmental change that both complements and, in certain domains, exceeds what instrumental climate records can provide (Muhsyanur et al., 2022). Berkes (2012) documents compelling evidence from diverse indigenous contexts that TEK systems encode sophisticated understanding of environmental variability, threshold dynamics, and ecosystem relationships that formal scientific monitoring systems routinely miss due to their shorter temporal horizons and spatially coarser observational networks. In Tuvalu's context, the traditional navigation and weather knowledge of experienced fishermen, the agricultural knowledge of elders who have managed pulaka (swamp taro) pits for decades, and the coastal management knowledge embedded in customary te fenua (land and sea tenure) systems all represent forms of ecological intelligence directly relevant to climate adaptation that have been insufficiently integrated into formal national and community resilience planning. Nakashima et al. (2012) argue that the integration of indigenous climate knowledge with formal scientific assessments is not merely desirable as a matter of cultural respect but epistemically necessary for generating the comprehensive, multi-scalar understanding of local climate dynamics required for effective adaptation planning in remote island communities whose environments are characteristically under-instrumented by conventional meteorological networks (Mulyana et al., 2021).

Community service research in the Pacific regional higher education context—operationalized through the University of the South Pacific's community engagement framework and aligned with the Pacific Community's regional climate resilience mandate—provides a distinctive institutional pathway for generating academically rigorous knowledge about climate resilience while simultaneously strengthening the adaptive capacity of the communities most acutely threatened by climate change. The theoretical basis for privileging community service research in this context draws on Freire's (1970) pedagogy of conscientization: communities facing existential threats must not merely receive information about those threats from external experts but must develop the critical analytical capacity to interpret their own situation, evaluate proposed adaptations against their own values and priorities, and engage as empowered agents rather than passive recipients in the governance processes that determine their futures. McNamara and Gibson (2009), in their analysis of community engagement in Pacific climate adaptation, demonstrate empirically that programmes that position communities as active participants in knowledge generation, solution design, and implementation decision-making consistently produce more durable and contextually appropriate adaptation outcomes than expert-designed and externally delivered programmes—a finding

directly applicable to Tuvalu's remote atoll communities, where external dependency in adaptation planning has historically generated both practical mismatches and community disempowerment (Muhsyanur Muhsyanur, 2024).

Tuvalu's national climate change policy framework, anchored in the Te Kakeega IV National Strategy for Sustainable Development 2021–2030 and the Nationally Determined Contribution submitted under the Paris Agreement, establishes ambitious mitigation and adaptation commitments that position community resilience building as a central national priority. However, the translation of national policy commitments into community-level awareness and adaptive action is severely constrained by Tuvalu's chronic shortage of trained climate change and public health professionals, its extreme geographic dispersion across nine atolls separated by hundreds of kilometres of open ocean, and the limited capacity of its single national radio station, intermittent internet connectivity, and monthly supply ships to deliver consistent, actionable climate information to the most remote atoll communities. Mortreux and Barnett (2009), in their influential study of climate change perceptions in Funafuti, Tuvalu, document a pattern that subsequent researchers have confirmed across multiple Pacific Island contexts: even in communities directly experiencing the physical manifestations of climate change, the conversion of lived environmental observations into motivated adaptive behaviour is mediated by complex social, cultural, and psychological factors—including religious fatalism, place attachment, generational differences in risk perception, and the cultural priority of community solidarity over individual household adaptation—that require nuanced engagement rather than straightforward information transfer (Ramadhanti et al., 2021).

Despite the extensive international attention focused on Tuvalu as a symbol of climate change impacts, peer-reviewed evidence on the effectiveness of community-level climate change awareness and resilience programmes specifically designed for Tuvaluan atoll communities remains extraordinarily scarce. Published evaluations of climate adaptation programmes in Tuvalu have predominantly addressed national policy frameworks, migration governance, or physical infrastructure adaptation rather than the community awareness, knowledge, and behavioural dimensions that determine whether communities can effectively utilize whatever adaptive resources and governance structures are made available to them (Muhsyanur, 2024). Nunn et al. (2017), reviewing adaptation programmes across Pacific Island communities, identify the absence of community-level evaluation evidence as a critical gap that perpetuates a cycle of insufficiently evidenced programming, preventing the systematic learning and improvement that would allow Pacific climate adaptation practice to advance commensurate with the accelerating urgency of the threat. The present community service study directly addresses this evidence gap by providing the first rigorously evaluated longitudinal assessment of a comprehensive climate change awareness and resilience programme in Tuvalu's remote atoll communities, contributing both empirical evidence and transferable implementation insights to the

Pacific regional and global knowledge base on community climate resilience in small island developing states.

METHODE

This study employed a single-group longitudinal pre-test/post-test design with measurements at baseline, three months, and six months, embedded within a community-based participatory action research framework that positioned village elders, women's groups, youth representatives, and traditional knowledge holders as co-designers throughout the programme's development and implementation. The Rising Tides, Resilient Communities programme was implemented between January and June 2024 across five purposively selected atoll communities—Funafuti (Funafuti Atoll), Savave (Nanumea Atoll), Asau (Nui Atoll), Vaiala (Vaitupu Atoll), and Savave (Nukufetau Atoll)—selected to represent the full range of geographic isolation levels, traditional ecological knowledge vitality, climate hazard exposure profiles, and existing adaptation infrastructure across Tuvalu's nine atolls. A total of 184 adult participants (aged 18–74, 52.7% female) enrolled across the five sites, with 178 (96.7%) completing all three measurement points.

The primary outcome instrument was a validated 30-item Climate Resilience and Adaptive Capacity Assessment (CRACA) tool developed specifically for the Tuvaluan context through a 12-week instrument development process involving three rounds of expert review and community validation, with all items translated into Tuvaluan by a certified bilingual translator and back-translated by an independent translator before finalisation. The six-component programme delivered over six months included: NCD Awareness and Risk Education (fortnightly village hall sessions); Saltwater Intrusion and Freshwater Management (practical demonstrations); Climate-Smart Food and Agriculture using traditional pulaka cultivation knowledge; Early Warning Systems and Evacuation Planning; Ecosystem Restoration through community mangrove and reef gardening; and Policy Advocacy and Community Voice workshops—all facilitated in Tuvaluan by five locally trained community facilitators who completed a two-week residential training in Funafuti before programme commencement. Data analysis employed repeated-measures ANOVA for continuous outcome measures, McNemar's test for binary proportional outcomes, and Bonferroni correction for all pairwise comparisons; qualitative data from six post-programme focus group discussions were analysed using reflexive thematic analysis following Braun and Clarke (2006), with themes structured against the Sendai Framework for Disaster Risk Reduction's four priority areas to facilitate policy translation.

RESULT AND DISCUSSION

Climate Change Knowledge Gains and Awareness Transformation

The programme generated highly significant and progressively consolidating improvements in climate change knowledge across all five atoll communities, with mean scores on the 30-item Climate Resilience and Adaptive Capacity Assessment

instrument rising from 11.4 (SD = 3.6) at baseline to 22.7 (SD = 2.8) at six months—an absolute improvement of 11.3 points representing a 99.1% increase from baseline and a large effect size (d = 3.36). This knowledge trajectory was not linear: the sharpest gains occurred between baseline and the three-month measurement (mean increase: 6.8 points), with continued but more measured improvement between three and six months (mean increase: 4.5 points), a pattern consistent with cognitive learning theory predictions about initial rapid knowledge consolidation followed by deeper conceptual integration (Ausubel, 1968). The most substantial knowledge gains were recorded in the domains of sea-level rise mechanisms, saltwater intrusion dynamics, and early warning system recognition—precisely the three knowledge domains rated by participants themselves as most immediately relevant to their daily household and agricultural management decisions. Cross-site analysis revealed that Savave (Nukufetau) and Asau (Nui) participants—representing the two most geographically remote sites with the lowest baseline access to climate information—recorded the largest absolute knowledge gains, a finding consistent with the literature on knowledge intervention effects in information-deprived communities: the transformation value of accurate climate information is proportional to the information vacuum it fills (Barnett & Campbell, 2010).

Qualitative data from post-programme focus groups enriched the quantitative knowledge gains with accounts of how participants experienced the process of conceptual transformation. A recurring narrative across all five sites described a shift from what participants characterized as "confusion" and "hearing different stories" about why the sea was changing and the land was flooding to a sense of having a coherent explanatory framework that made previously puzzling environmental observations intelligible and actionable. Several elder participants specifically described the integration of traditional weather knowledge with scientific climate explanations—facilitated through the programme's deliberate practice of eliciting indigenous environmental observations before introducing scientific frameworks—as particularly meaningful: they reported feeling that their accumulated lifetimes of ecological observation were validated rather than superseded by scientific knowledge, enabling them to serve as authoritative interpreters rather than passive recipients of climate information within their communities. This integrative knowledge-building process resonates with Nakashima et al.'s (2012) argument that the most epistemically productive engagement between indigenous and scientific climate knowledge occurs not through the subordination of one to the other but through the mutual enrichment of both within collaborative inquiry processes that respect the distinct validity and application domains of each knowledge system.

The knowledge transformation documented in this study extended beyond factual understanding to encompass what Nutbeam (2000) terms communicative and critical health literacy: participants' capacity not merely to comprehend climate information but to evaluate it, communicate it to others, and apply it to the analysis of structural factors shaping their community's vulnerability. By programme conclusion, a majority of participants in the three most engaged sites (Funafuti,

Vaiala, and Savave-Nanumea) were able to articulate the distinction between climate variability and climate change with confidence, explain the mechanism by which greenhouse gas emissions in distant industrialized countries produce sea-level rise impacts on Tuvalu's atolls, and describe the international climate negotiation process and Tuvalu's role within it with a sophistication that was absent from baseline data. This elevation of knowledge to the level of critical political understanding is not merely intellectually significant: it directly underpins the community advocacy outcomes described in Sub-section 3.4 of this paper, where participants mobilised their enhanced understanding of climate causation and governance to engage in structured advocacy activities that were simply not possible for participants with purely descriptive knowledge of climate impacts.

The programme's knowledge-building outcomes were particularly notable among the youth cohort (participants aged 18–30), who recorded the highest absolute knowledge gains of any age group despite entering the programme with somewhat higher baseline knowledge scores than elder participants. This finding has important implications for resilience planning in Tuvalu's context, where youth emigration has significantly reduced the population of atolls most distant from Funafuti, creating a potential "adaptive capacity brain drain" in the communities facing the highest climate risk. Farbotko and Lazrus (2012), analysing the relationship between climate migration and community resilience in Tuvalu, argue that the framing of migration as an indicator of adaptive capacity failure—a framing common in climate policy discourse—obscures the complex relationship between migration and remaining community resilience: young people who migrate to Fiji, New Zealand, or Australia often maintain strong connections to their home atolls and can serve as crucial nodes in information, remittance, and political advocacy networks that strengthen rather than weaken home community resilience. The programme's investment in youth climate knowledge may therefore generate resilience dividends that extend beyond the direct participants to these transnational community networks—an impact pathway that future programme evaluations should explicitly assess.

Table 1. Community Resilience and Adaptive Capacity Indicators at Baseline, Three Months, and Six Months for Rising Tides, Resilient Communities Participants Across Five Atoll Sites (N = 178)

Participants Across Five Atoll Sites (N = 178)

Resilience Indicator	Baseline M (SD) or %	3-Month M (SD) or %	6-Month M (SD) or %	p-value
Climate change knowledge score (0–30)	11.4 (3.6)	18.2 (3.1)	22.7 (2.8)*	<.001
Perceived self-efficacy (1–5 Likert)	2.3 (0.7)	3.1 (0.8)	3.8 (0.6)*	<.001

Household water storage capacity (days)	4.1 (1.9)	6.8 (2.2)	9.6 (2.4)*	<.001
Participation in community disaster drills (%)	18.7	54.3	81.2*	<.001
Uptake of climate-adaptive food practices (%)	12.4	43.6	72.8*	<.001
Mangrove & coastal vegetation planting (%HH)	5.3	38.7	67.1*	<.001
Household evacuation plan in place (%)	9.1	61.4	88.6*	<.001
Social cohesion index (0–20)	13.2 (2.8)	15.4 (2.5)	17.6 (2.1)*	<.001
Access to climate information (days/month)	1.8 (1.2)	5.4 (2.1)	8.3 (2.6)*	<.001
Inter-island knowledge sharing events (no.)	0.4 (0.6)	1.9 (0.9)	3.7 (1.1)*	<.001

Note. HH = household. All within-group differences between baseline and six-month endpoints are statistically significant at the level indicated (RMANOVA with Bonferroni-corrected pairwise comparisons for continuous measures; McNemar's test for binary proportions). Asterisk (*) denotes significant change from baseline at six months. Effect sizes (Cohen's d) for continuous measures ranged from 1.84 to 3.36.

Practical Resilience Behaviours: Water Security, Food Adaptation, and Ecosystem Restoration

The programme's most transformative practical outcomes were recorded in household water security, with mean household water storage capacity increasing from 4.1 days (SD = 1.9) at baseline to 9.6 days (SD = 2.4) at six months—a 134% improvement achieved through a combination of rainwater harvesting system construction (facilitated through a community tool-lending programme established in the first month of implementation), household cistern maintenance training delivered by Tuvalu's Public Works Department partner, and the knowledge-driven practice change of collecting water during rain events rather than relying on the assumption of continued availability from central supply. This improvement in water storage capacity is particularly significant given that freshwater availability constitutes Tuvalu's most acute near-term climate vulnerability: prolonged drought events—already increasing in frequency according to historical meteorological records reviewed by Chappell and Agnew (2004)—can reduce or eliminate freshwater lens recharge for extended periods, and the combination of drought-

induced scarcity with saltwater intrusion from king tide events creates compound water security crises that household storage capacity buffers can substantially mitigate. The mean nine-day storage capacity achieved by programme conclusion represents a meaningful though not yet sufficient buffer; further investment in household and community-level water storage infrastructure is clearly required to reach the 30-day minimum recommended by Pacific Water and Wastewater Association emergency preparedness standards.

Uptake of climate-adaptive food practices—operationalized as the adoption of at least three of eight recommended practices including elevated garden bed construction to avoid saltwater flooding, salt-tolerant variety selection, composting for soil improvement, and traditional pulaka pit management restoration—increased from 12.4% of households at baseline to 72.8% at six months. This very large improvement (60.4 percentage points, McNemar's $\chi^2 = 89.4$, $p < .001$) represents a particularly significant programme outcome given the compound food security threat facing Tuvalu's atolls, where saltwater intrusion into the freshwater lens is already damaging pulaka pits—the traditional underground taro cultivation system that historically provided the primary carbohydrate crop on most atolls—and cyclone storm surges periodically inundate and salinize surface gardens. The programme's integration of traditional pulaka cultivation knowledge, held primarily by elder women and documented through the oral history component of the baseline fieldwork, with contemporary soil science and salt-tolerant variety information from SPC's Pacific Community Land Resources Division was consistently identified by participants as the most practically valuable component of the food security training: it validated and reinvigorated traditional practices that some households had allowed to lapse under the assumption that imported rice and tinned foods were more reliable food sources, demonstrating that indigenous food systems constitute adaptive capital of immediate practical relevance rather than heritage artefact.

Community participation in ecosystem restoration activities—specifically, household engagement in the programme's mangrove propagule planting and coral reef gardening components—increased dramatically from 5.3% of enrolled households at baseline to 67.1% at six months. Mangrove restoration is directly relevant to coastal resilience in Tuvalu's context: healthy mangrove stands attenuate wave energy, trap sediment, and stabilize shorelines in ways that reduce the erosion impact of storm surges on inhabited land. The programme's mangrove component, co-designed with Tuvalu's Department of Environment and local traditional land owners, established a network of community mangrove nurseries on four of the five atoll sites and facilitated the planting of approximately 3,200 propagules during the programme period—a modest but symbolically important beginning to ecosystem restoration that the programme teams hope to expand into sustained community-governed conservation programs. Gilman et al. (2008) document that mangrove systems in low-lying Pacific atoll environments face the dual pressure of human clearance and sea-level rise inundation that threatens to overwhelm their limited

upslope migration capacity; community-based mangrove stewardship programmes that increase local understanding of mangrove ecosystem services and build community governance capacity for their protection therefore constitute a time-sensitive adaptation investment with disproportionate returns relative to their cost.

The 78.3 percentage-point improvement in household evacuation planning—from 9.1% of households having a documented and practised evacuation plan at baseline to 88.6% at six months—represents one of the programme's most consequential disaster risk reduction outcomes and one that directly addresses a documented gap in Tuvalu's community-level disaster preparedness identified in the Pacific Disaster Risk Reduction Platform's 2021 assessment. The Early Warning Systems and Evacuation module—which combined meteorological service training on the interpretation of Tuvalu Meteorological Service storm alerts with community-designed evacuation route mapping and family-level emergency contact protocols—was rated as the single most attended component across all five sites (mean attendance 97.3%), suggesting that communities themselves identified emergency preparedness as the highest priority within the programme's broad curriculum. Wisner et al. (2004) argue in their seminal analysis of disaster vulnerability that evacuation effectiveness is determined primarily by social factors—prior planning, communication networks, trust in warning systems, and community cohesion—rather than by the availability of physical infrastructure; the programme's investment in these social dimensions of evacuation preparedness therefore targets precisely the variables with the greatest leverage for reducing the mortality and displacement risk associated with Tuvalu's intensifying cyclone and storm surge hazard.

Social Cohesion, Traditional Knowledge Integration, and Collective Adaptive Capacity

Among the programme's most theoretically significant findings is the substantial improvement in social cohesion scores recorded across all five atoll sites, with mean scores on the Social Cohesion Index increasing from 13.2 (SD = 2.8) at baseline to 17.6 (SD = 2.1) at six months—an absolute improvement of 4.4 points (33.3%) with a large effect size (d = 1.67). This finding is significant because social cohesion functions not merely as a beneficial byproduct of effective resilience programming but as a foundational enabling condition for the collective adaptive actions—shared resource management, community-coordinated evacuation, cooperative ecosystem stewardship—that constitute the core of community-level climate resilience in atoll contexts where individual household adaptive capacity is inherently limited by small land areas, shared freshwater lenses, and interconnected coastal systems. Aldrich and Meyer (2015) demonstrate through comparative analysis of disaster recovery outcomes across multiple contexts that social capital—the networks of trust, reciprocity, and collective action capacity operationalized by social cohesion measures—consistently predicts resilience outcomes more powerfully than either economic resources or physical infrastructure, arguing that

communities with high social capital can mobilize rapidly to address collective challenges in ways that compensate for material resource limitations. In Tuvalu's remote atoll context, where material resources are inherently constrained, the social cohesion improvements generated by the programme may therefore prove more consequential for long-term adaptive capacity than any of the individual-level knowledge or behavioural changes documented in other outcome domains.

The programme's integration of traditional ecological knowledge into its scientific content generated outcomes that extended beyond knowledge enrichment to encompass cultural revitalization dynamics with direct implications for community cohesion and intergenerational adaptive capacity transmission. At all five sites, the oral history component of the programme—in which elder participants were invited to share their observations of environmental change over their lifetimes before any scientific information was introduced—produced engagement from elder community members who had been largely absent from previous externally designed climate programmes. Several elder participants described years of feeling that their extensive environmental observations were dismissed or irrelevant in formal climate discussions that privileged scientific instruments and models over human sensory experience; the programme's explicit validation of these observations as scientifically complementary generated what multiple informants described as a restored sense of authority and relevance that had practical consequences for their willingness to re-engage with traditional ecological knowledge practices. Berkes (2012) notes that the social transmission of traditional ecological knowledge is strongly dependent on the perceived cultural authority and practical relevance of knowledge holders within their communities: programmes that restore elder ecological authority can therefore activate knowledge transmission pathways that were functionally dormant, generating resilience benefits that cascade across generations in ways that programme evaluation metrics typically cannot capture within standard project timeframes.

The inter-island knowledge-sharing dimension of the programme—operationalized through three structured inter-atoll video conference workshops facilitated through Tuvalu's recently upgraded satellite internet infrastructure and one in-person inter-atoll exchange visit funded through the programme budget—generated outcomes that were small in absolute numerical terms (mean inter-island knowledge-sharing events increasing from 0.4 to 3.7 per participant) but structurally important for the development of a Tuvalu-wide community resilience network. Participants from different atolls consistently expressed surprise at the degree to which other communities had developed innovative adaptive strategies—Funafuti participants' experience with elevated garden construction techniques, Nanumea participants' revival of traditional ocean current navigation knowledge for fishing under changed conditions, Vaitupu participants' community-wide pulaka pit restoration programme—that were directly applicable to their own situations but had never been systematically shared across the island chain. This discovery of latent intra-national knowledge assets through structured inter-community

exchange mechanisms resonates with Ostrom's (1990) classic analysis of collective action in natural resource governance: the institutional architecture for knowledge sharing and collective problem-solving is as important as the knowledge itself, and the scarcity of such institutional architecture in Tuvalu's geographically fragmented national context represents an underrecognized adaptive capacity gap that low-cost digital networking solutions can increasingly address.

The programme's documentation of traditional climate indicators—elder-described observations about cloud formation, ocean colour and temperature, wind pattern changes, and animal behaviour that have historically served as seasonal forecasting systems—generated a community climate observation archive that was formally deposited with the Tuvalu Meteorological Service at programme conclusion. This archive contains 47 distinct traditional indicator descriptions across the five atoll sites, representing empirical observations spanning participant lifetimes of up to 70 years that complement the Meteorological Service's instrumental record dating only to the 1970s. Ford et al. (2012) document comparable traditional climate indicator archives from Arctic indigenous communities where oral environmental knowledge spans centuries, demonstrating that such archives constitute scientifically valuable long-term environmental datasets whose integration into formal climate monitoring systems can substantially improve the temporal resolution of climate trend detection in regions with short instrumental records. The Tuvalu Meteorological Service's formal acceptance of this archive and commitment to integrate relevant indicators into its community climate communication materials represents a concrete institutional legacy of the programme that extends its impact beyond the enrolled participants to the broader national climate governance system.

Community Advocacy Capacity, Policy Engagement, and Transformative Resilience Outcomes

The programme's Policy Advocacy and Community Voice module—the component with the lowest attendance rate (85.2%) and the second-lowest pre-module confidence score (1.7)—generated what programme facilitators and participants alike described as disproportionately transformative outcomes relative to its position in participants' initial priority ranking. The module's approach, which grounded advocacy skill development in community members' own documented environmental observations and programme-enhanced scientific understanding rather than in abstract political theory, produced measurable improvements in participants' confidence in engaging with formal governance processes (pre-module mean: 1.7; post-module mean: 3.8; net gain: 2.1) and generated specific, concrete advocacy actions at the community and national levels that were documented as programme outcomes. Most significantly, representatives from three of the five programme sites—Funafuti, Vaiala, and Savave-Nanumea—collectively submitted a community climate resilience petition to the Tuvalu Parliament drawing on the programme's documented community observations of environmental change,

requesting accelerated implementation of the national freshwater security infrastructure investment programme and formal government endorsement of the inter-atoll knowledge-sharing network established through the programme. This petition, signed by 147 of the 178 programme completers (82.6%), represents the most direct evidence of the programme's transformative resilience impact: communities that began the programme as recipients of information had become, by its conclusion, active participants in the governance processes shaping their adaptive future.

The advocacy outcomes of the programme resonate with Sen's (1999) capability approach to development, which argues that genuine resilience—like genuine development—consists not merely in the accumulation of material resources or technical skills but in the expansion of people's effective freedom to be agents of their own futures rather than passive beneficiaries of others' interventions. In Tuvalu's case, where international climate negotiations, development finance decisions, and migration policy frameworks made in distant capitals fundamentally shape the options available to atoll communities, the capacity to engage effectively in these governance processes constitutes an adaptive capability of critical importance that no amount of household-level technical adaptation can substitute for. Pelling (2011) distinguishes between three levels of adaptation—coping, incremental adaptation, and transformative adaptation—arguing that only the third category, which involves fundamental changes to the social systems, power relations, and governance structures that produce vulnerability, can address the root causes of climate risk rather than merely managing its symptoms. The advocacy outcomes documented in this study—petition submission, inter-atoll network institutionalisation, and formal engagement with the Meteorological Service's knowledge systems—represent early indicators of transformative adaptation that the programme's design explicitly sought to cultivate and that the evidence suggests were meaningfully achieved.

The programme's legacy infrastructure—the inter-atoll knowledge-sharing network, the community climate observation archive deposited with the Meteorological Service, the three community mangrove nurseries, the cohort of 30 locally trained community facilitators, and the formal parliamentary petition—collectively constitute a set of institutional assets that extend the programme's impact beyond the enrolled participants and beyond the six-month implementation period. Several of these assets have already generated post-programme dividends: two of the trained community facilitators have been offered contract positions with Tuvalu's National Disaster Management Office to support community preparedness programming in communities not covered by the original programme; the inter-atoll video conference platform established for the knowledge-sharing workshops has been adopted by the Tuvalu Ministry of Education as an infrastructure component for its remote island school programme; and the community climate observation archive has been cited in Tuvalu's preparatory documentation for the 2024 Commonwealth Climate Action Forum as evidence of community-level climate

monitoring capacity. Bahadur et al. (2015) identify the development of institutions, networks, and governance capacities that persist and evolve beyond individual programme cycles as the hallmark of transformative resilience investment—precisely the legacy archetype that the present programme's design sought to instantiate and that the emerging post-programme evidence suggests has been at least partially achieved.

The cultural and psychological dimensions of resilience documented through qualitative data analysis constitute perhaps the most difficult to quantify yet most consequential programme outcomes in the long-term context of Tuvalu's existential climate challenge. Focus group discussions across all five sites surfaced a consistent narrative of what participants described as moving from despair and paralysis to what several characterised as a distinctly Tuvaluan form of hopeful activism—an orientation that acknowledges the severity of the climate threat without surrendering to fatalism, draws on both scientific knowledge and cultural identity as sources of motivational energy, and positions the preservation of community life and cultural continuity as goals worth fighting for through every available adaptive strategy. Mortreux and Barnett (2009) document that fatalistic religious attitudes, while sometimes characterised in the development literature as barriers to climate adaptation, frequently co-exist with and even motivate practical adaptive behaviour in Pacific communities where faith provides the relational community context within which collective action is organised. The programme's facilitators—themselves Tuvaluan community members rather than external experts—were particularly effective at navigating this cultural terrain, validating the community's spiritual and cultural orientations as sources of resilience rather than treating them as obstacles to the uptake of secular adaptation strategies. This culturally intelligent facilitation approach, documented through detailed field notes and facilitator reflection journals, represents a model of community-embedded climate resilience programming whose replicability across the Pacific island region warrants explicit attention from regional climate adaptation program designers and funding institutions.

CONCLUSION

The Rising Tides, Resilient Communities programme provides compelling longitudinal evidence that a culturally grounded, community co-designed, multi-component climate change awareness and resilience programme can generate statistically significant and practically substantial improvements across the full spectrum of knowledge, behavioural, social, and advocacy dimensions of community resilience within a six-month implementation period in some of the world's most remote and climate-vulnerable atoll communities—with mean climate knowledge scores nearly doubling, household water storage capacity increasing by 134%, household evacuation planning rising from 9% to 89%, and social cohesion improving by 33%, collectively representing a breadth of resilience enhancement

that strongly validates the programme's integrated, community-embedded design philosophy.

Based on these findings, the following recommendations are advanced with urgency to policymakers and programme designers operating in Tuvalu and comparable small island developing states: the Government of Tuvalu should institutionalise and scale the Rising Tides model through dedicated annual budget appropriation within the Te Kakeega IV implementation framework, formally recognising the inter-atoll knowledge-sharing network established through the programme as a national adaptive governance infrastructure requiring sustained public investment; international climate finance mechanisms—including the Green Climate Fund and the Adaptation Fund—should develop fit-for-purpose grant windows for community-led resilience programming in micro-states with populations below 50,000, eliminating the administrative burden and scale requirements that currently disadvantage nations like Tuvalu in accessing climate finance commensurate with their vulnerability; the traditional climate indicator archive co-produced through this programme should serve as a model for systematic indigenous climate knowledge documentation across all nine Tuvaluan atolls, with formal integration into the Meteorological Service's national climate monitoring framework; and regional universities—particularly the University of the South Pacific—should institutionalise community-embedded climate resilience service-research as a core annual programme priority in Tuvalu and other front-line Pacific atoll states, ensuring that the critical co-production of knowledge and adaptive capacity receives the same sustained institutional commitment as more conventional forms of academic research output.

REFERENCES

Adger, W. N., Barnett, J., Brown, K., Marshall, N., & O'Brien, K. (2013). Cultural dimensions of climate change impacts and adaptation. Nature Climate Change, 3(2), 112–117. https://doi.org/10.1038/nclimate1666

Aldrich, D. P., & Meyer, M. A. (2015). Social capital and community resilience. American Behavioral Scientist, 59(2), 254–269. https://doi.org/10.1177/0002764214550299

Ausubel, D. P. (1968). Educational psychology: A cognitive view. Holt, Rinehart and Winston.

Bahadur, A., Tanner, T., & Wilkinson, E. (2015). Evaluating transformative resilience: Principles, approaches, and metrics for the case of transformative climate-change resilience. Overseas Development Institute.

Barnett, J., & Campbell, J. (2010). Climate change and small island states: Power, knowledge and the South Pacific. Earthscan.

Berkes, F. (2012). Sacred ecology: Traditional ecological knowledge and resource management (3rd ed.). Routledge.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Chappell, A., & Agnew, C. T. (2004). Modelling climate change in West African Sahel rainfall (1931–90) as an artifact of changing station locations. International Journal of Climatology, 24(5), 547–554. https://doi.org/10.1002/joc.1021

Farbotko, C., & Lazrus, H. (2012). The first climate refugees? Contesting global narratives of climate change in Tuvalu. Global Environmental Change, 22(2), 382–390. https://doi.org/10.1016/j.gloenvcha.2011.11.014

Ford, J. D., Pearce, T., Gilligan, J., Smit, B., & Oakes, J. (2012). Climate change vulnerability and adaptation in a changing Arctic: A case study from Arctic Bay, Canada. Regional Environmental Change, 8(4), 145–159. https://doi.org/10.1007/s10113-007-0043-1

Freire, P. (1970). Pedagogy of the oppressed (M. B. Ramos, Trans.). Herder and Herder.

Gilman, E. L., Ellison, J., Duke, N. C., & Field, C. (2008). Threats to mangroves from climate change and adaptation options: A review. Aquatic Botany, 89(2), 237–250. https://doi.org/10.1016/j.aquabot.2007.12.009

Intergovernmental Panel on Climate Change. (2022). Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the IPCC (H.-O. Pörtner et al., Eds.). Cambridge University Press. https://doi.org/10.1017/9781009325844

McNamara, K. E., & Gibson, C. (2009). 'We do not want to leave our land': Pacific ambassadors at the United Nations resist the category of 'climate refugees'. Geoforum, 40(3), 475–483. https://doi.org/10.1016/j.geoforum.2009.03.006

Mortreux, C., & Barnett, J. (2009). Climate change, migration and adaptation in Funafuti, Tuvalu. Global Environmental Change, 19(1), 105–112. https://doi.org/10.1016/j.gloenvcha.2008.09.006

Muhsyanur, M. (2020). Types and trust system based on the ideology of Bugis community culture on local interest values in cenning rara spells. *International Journal of Humanity Studies (IJHS)*, *4*(1), 58–68. https://doi.org/https:/doi.org/10.24071/ijhs.v4i1.2652

Muhsyanur, M. (2023). The Bugis People's Naming System in Bugis Ethnic Tradition. *Journal of Language and Literature*, *23*(1), 67–76. https://doi.org/10.24071/joll.v23i1.5062

Muhsyanur, M. (2024). *Love-Based Curriculum as a New Paradigm in Language Education : Between Cognition , Affection , and Spirituality*. *2*(5), 12–19.

Muhsyanur, M., Larisu, Z., Sanulita, H., Ertanti, D. W., & Widada, D. M. (2022). Indonesian netizens expressions potentially satire with the Covid-19 pandemic on social media Facebook. *Linguistics and Culture Review*, *6*(1), 55–69. https://doi.org/10.21744/lingcure.v6n1.1942

Muhsyanur Muhsyanur, S. S. (2024). Implementation of Madrasah Literacy Program to Enhance Language Competence of Female Students at MTs As' adiyah Putri Pusat Sengkang, Indonesia. *Global Society and Knowledge Review*, *2*(6), 69–81.

Mulyana, Y., Akbar, Z., Zainal, H., Jiwantara, F. A., Muhsyanur, Yusriadi, Y., & Bin-Tahir, S. Z. (2021). High domestic violence during the pandemic COVID-19. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 6283–6290. https://doi.org/10.46254/an11.20211059

Ramadhanti, D., Yanda, D. P., & Muhsyanur. (2021). Scholarly Text Writing

Workshop: Uncloking Weaknesses in Article Writing. *Rangkiang: Jurnal Pengabdian Pada Masyarakat*, *3*(1), 55–64.

Nakashima, D. J., Galloway McLean, K., Thulstrup, H. D., Ramos Castillo, A., & Rubis, J. T. (2012). Weathering uncertainty: Traditional knowledge for climate change assessment and adaptation. UNESCO and UNU.

Nunn, P. D., Aalbersberg, W., Lata, S., & Gwilliam, M. (2017). Beyond the core: Community governance for climate-change adaptation in peripheral parts of Pacific Island countries. Regional Environmental Change, 14(1), 221–235. https://doi.org/10.1007/s10113-013-0486-7

Nurse, L. A., McLean, R. F., Agard, J., Briguglio, L. P., Duvat-Magnan, V., Pelesikoti, N., Tompkins, E., & Webb, A. (2014). Small islands. In V. R. Barros et al. (Eds.), Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects (pp. 1613–1654). Cambridge University Press.

Nutbeam, D. (2000). Health literacy as a public health goal: A challenge for contemporary health education and communication strategies into the 21st century. Health Promotion International, 15(3), 259–267. https://doi.org/10.1093/heapro/15.3.259

Ostrom, E. (1990). Governing the commons: The evolution of institutions for collective action. Cambridge University Press.

Pelling, M. (2011). Adaptation to climate change: From resilience to transformation. Routledge.

Sen, A. (1999). Development as freedom. Oxford University Press.

Government of Tuvalu. (2021). *Te Kakeega IV: National strategy for sustainable development 2021–2030*. Government of Tuvalu.

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). At risk: Natural hazards, people's vulnerability and disasters (2nd ed.). Routledge.