

Supplementary material 1 (SM1)

This supplementary file accompanies the review article, *Framings in Indigenous futures thinking: barriers, opportunities, and innovations*, and contains the supplementary results text, figures, and tables that are referred to in the main text.

The Indigenous futures thinking database developed for this review article can be found in the following link: <https://data.csiro.au/collection/csiro:62010>.

S1. Search terms used in academic databases to identify relevant literature for review.

Database	Search timespan	Search terms
Web of Science	1864 - 2021	TS=(Indigenous OR aboriginal OR tribe* OR tribal OR peripatetic OR nomad* OR "Hill tribe" OR "scheduled tribe" OR "first peoples" OR "first nation*" OR "ethnic nationalit*" OR "ethnic minorit*" OR "indigenous minorit*" OR "Traditional Owner" OR "indigenous and local knowledge" OR "indigenous knowledge" OR "indigenous local knowledge" OR "indigenous research" OR "indigenous science" OR "local ecological knowledge" OR "traditional ecological knowledge" OR "traditional knowledge" OR "Two Eyed Seeing" OR "indigenous, traditional or local knowledge" OR "local knowledge" OR "farmer* knowledge" OR "folk knowledge" OR biocultural OR "cultural keystone") AND TS=(scenario OR forecast OR "adaptive capacity" OR "strategic foresight" OR "strategic plan*" OR backcast* OR "possible future*" OR "desirable future*" OR "prefer* future*" OR "foresight*" OR "futures research" OR "futures studies" OR futurist OR "horizon scanning" OR "alternative future*" OR "plausible future*" OR "visioning" OR "sustainable future*" OR "scenario analysis" OR "scenario plan*" OR "participat* scenario*" OR "qualitative scenario*" OR "multiscale scenario" OR "scenario develop*" OR "road map" OR "futures wheel" OR "three horizons" OR "weak signals" OR anticipat* OR "anticipatory governance") NOT TS=("indigenous species" OR "non-indigenous species" OR "nonindigenous species" OR "indigenous plant*" OR "indigenous organism" OR "indigenous biodiversity" OR "indigenous fauna" OR "indigenous flora" OR "indigenous factor" OR "non-indigenous marine species" OR "indigenous wildlife" OR "indigenous livestock" OR "indigenous forest*" OR "indigenous vegeta*" OR "indigenous bacteri*" OR "indigenous enzyme*" OR "indigenous microbe*" OR "indigenous sheep" OR "indigenous cattle" OR "indigenous pig*" OR "indigenous chicken*" OR "indigenous fish")
Scopus	No limit	TITLE-ABS-KEY (indigenous OR aboriginal OR tribe* OR tribal OR

	(earliest year is 1928)	peripatetic OR nomad* OR "Hill tribe" OR "scheduled tribe" OR "ethnic nationalit*" OR "indigenous minorit*" OR "first nation*" OR "first peoples" OR "ethnic minorit*" OR "Traditional Owner" OR "indigenous and local knowledge" OR "indigenous knowledge" OR "indigenous local knowledge" OR "indigenous research" OR "indigenous science" OR "local ecological knowledge" OR "traditional ecological knowledge" OR "traditional knowledge" OR "Two-Eyed Seeing" OR "indigenous, traditional or local knowledge" OR "local knowledge" OR "farmer* knowledge" OR "folk knowledge" OR biocultural) AND TITLE-ABS-KEY (scenario OR forecast OR "adaptive capacity" OR "strategic foresight" OR "strategic plan*" OR backcast* OR "possible future*" OR "desirable future*" OR "prefer* future*" OR "foresight*" OR "futures research" OR "futures studies" OR futurist OR "horizon scanning" OR "alternative future*" OR "plausible future*" OR "visioning" OR "sustainable future*" OR "scenario analysis" OR "scenario plan*" OR "participat* scenario*" OR "qualitative scenario*" OR "scenario develop*" OR "road map" OR "futures wheel" OR "three horizons" OR "weak signals" OR anticipat* OR "anticipatory governance") AND NOT TITLE-ABS-KEY ("indigenous species" OR "non-indigenous species" OR "nonindigenous species" OR "indigenous plant*" OR "indigenous organism" OR "indigenous biodiversity" OR "indigenous fauna" OR "indigenous flora" OR "indigenous factor" OR "non-indigenous marine species" OR "indigenous wildlife" OR "indigenous livestock" OR "indigenous forest*" OR "indigenous vegeta*" OR "indigenous bacteri*" OR "indigenous enzyme*" OR "indigenous microbe*" OR "indigenous sheep" OR "indigenous cattle" OR "indigenous pig*" OR "indigenous chicken*" OR "indigenous fish") Indigenous OR aborigin* OR "first nation*" OR "ethnic minorit*" OR "indigenous local farmer folk knowledge research" AND scenario OR forecast* OR "futures stud* research" OR "horizon scan*" OR "visioning" OR "alternative future*" OR "foresight"
Google Scholar	No limit	Indigenous OR aborigin* OR "first nation*" OR "ethnic minorit*" OR "indigenous local farmer folk knowledge research" AND scenario OR forecast* OR "futures stud* research" OR "horizon scan*" OR "visioning" OR "alternative future*" OR "foresight" OR "futures thinking" OR "foresight"

S2. Detailed methods outlining the searching, screening, and analyses of the literature review process undertaken in the review article.

From the 11,498 unique publications identified through the literature searching process, we used the artificial intelligence software, Rayyan, to screen all titles and abstracts by relevance, resulting in 2,956 publications. From this, we undertook two manual screening processes, which involved the manual review of 2,956 publications by at least one reviewer and three reviewers screened randomly selected publications to ensure consistency in literature screening decisions (of these, four conflicting reviewer decisions were made and subsequently resolved). We stopped manually reviewing search results in Rayyan once we were able to go through 200 records without finding new results to include in the review and more than 30% of the search results were manually screened. Following screening the initial literature search results with Rayyan, we conducted two further manual screening stages.

During the first manual screening stage, we excluded publications following three primary criteria. First, we excluded publications that were irrelevant to the topic of our review, based on a different interpretation of keywords. For example, studies that focussed on indigenous species of plants, animals, or bacteria were excluded. The term “scenario” is also used in a general way in many studies (e.g., “worst-case scenario”), without explicitly creating or analysing what the scenario would look like.

Second, we excluded publications that did not involve Indigenous peoples in some way. We followed the United Nations (UN) in recognising that no formal definition of Indigeneity is needed, as self-identification is the key requirement (UN General Assembly 2007, Hill et al. 2020). Thus if the publication identified its participants as Indigenous, or if other publications identified these participants as Indigenous, the paper was included (otherwise it was excluded). To be conservative, papers citing “local knowledge” were included until the full-text analysis stage. We also included studies relating to minorities (ethnic or otherwise), who were not necessarily self-identified as Indigenous in the publication, but had strong place-based attachments (e.g., farmers, peasants, rural workers), or came from regions where Indigeneity is contested (e.g., Africa, China, Laos).

Third, the publication had to involve planning for, thinking about, or creating alternative futures. There were a large number of publications that were related to thinking about the future but did not move beyond analysing or discussing responses to historical and current conditions, or focussed on predicting future climate conditions or spatial ecology (e.g., forestry or fisheries modelling for allocating sustainable yields). These were excluded if they did not involve explicit exploration of alternative futures. This includes case studies that strongly involved Indigenous peoples and modelling, but did not have a strong futures focus, e.g., Indigenous rangers in Australia using AI tools to monitor their

traditional lands and seas (Depczynski et al., 2019; Robinson et al., 2022). Where we found several publications about the same project, data for the respective case study was extracted from all publications.

This first manual screening process identified 113 publications for full-text analysis, following which a decision was made for inclusion or exclusion in the final review database. In this second stage of manual and full-text screening, we applied a final exclusion criteria that related to whether the work had an empirical component. Some of the publications at this screening stage were theory-based or providing a commentary without applying it in a real-world setting. In those cases we excluded the paper from the review but retained it as important theoretical or conceptual work to use to frame arguments in this paper, such as work by Indigenous scholars who have advanced the field (e.g., Whyte, 2017; 2018). In some cases, the futures thinking project or process had multiple publications (peer-reviewed articles, reports) associated with it. In these cases, relevant qualitative data would be extracted from all of the associated publications.

We used R to apply a Multiple Correspondence Analysis (MCA) to understand some of the factors that support innovation, representation of participant voice, and inclusion of Indigenous constructs in the futures thinking approaches used across the literature. An MCA is a form of multivariate analysis that can be used to identify similarities between a sample of individuals based on categorical variables, and associations between these variables (Husson et al. 2017). We applied an MCA on a subset of the data columns (i.e., variables) of the review database, where variables were selected based on being complete across all 64 publications (a necessary prerequisite for an MCA), and based on discussions between the review co-authors on potential supporting factors (e.g., the extent of Indigenous involvement in processes, inclusion of theoretical orientations that reflect Indigenous reality, whether cultural protocols were incorporated).

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S3. Final publications included in the literature review database (n = 64).

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S4. Categorical data columns in literature review database and their respective categories (see Glossary for category descriptions).

Column name	Data categories
Sector/Field	Health/medicine, Transport/infrastructure, Terrestrial environment (excluding climate change), Climate change, Governance, Agriculture, Water management, Fisheries/marine, Tourism, Community development, Economics, Indigenous focussed, Forestry, Other
Environmental sustainability as focus	Main focus, Side issue
Type of environment	Terrestrial, Marine, Freshwater, Multiple, Irrelevant
Biome	List of biomes from terrestrial and marine ecoregion classifications (Dinerstein et al. 2017, Spalding et al. 2007)
Scale	Global, Multiple countries, National, State/Province, Regional, Watershed, Indigenous nation area, Municipality, Local community, Protected area, Town/city
Countries	All countries listed
Indigenous participants grouping level	Individuals general public, Individuals community, Individual professional, Indigenous organisation, Government department
Non-Indigenous stakeholder types	General public, Local policy makers, Supra-local policy makers, Natural resource management group, Academics, Non-government organisation, Business sector, Government workers, Local community, Peasants and rural workers
Primary stakeholder categories	Indigenous only; Indigenous as primary stakeholder or rightsholder; Indigenous as one of two primary stakeholders; Indigenous as one of many stakeholders; Local actors/peasants, likely Indigenous, as primary stakeholder; Local actors/peasants, likely Indigenous, as one of two stakeholders; Local actors/peasants, likely Indigenous, as one of many stakeholders
Group leading research	Indigenous researchers, Indigenous group, Non-Indigenous group, Government, Non-Indigenous researchers/academic group, Co-led Indigenous initiated, Co-led science initiated, Co-led joint agreement, Unclear
Futures thinking as main aim	To a great extent, Somewhat, Very little, Not at all, Unknown
Why use futures thinking	Complementary research, Awareness raising, Social learning, Decision support, Individual ownership/Empowerment, Governance systems resilience, Generate shared vision, Indigenous nation building/revitalisation
Partnership type	Informal, Indigenous invitation; Formal, Indigenous invitation; Informal, other initiated; Formal, other initiated; Two or more Indigenous organisations; Two or more other organisations; Informal, initiation unknown; Formal, initiation unknown; Unclear; No partnership

Partnership history	Started with the project, Continuing from previous project work, Long-term from multiple projects, Unclear, N/A
Use of interpreters	One Indigenous language, > one Indigenous language, One other language, > one other language, One Indigenous & one other language, > one Indigenous and one other language, Unknown, Not needed, Not reported
Cultural protocols followed	Advisory group, Agreement/protocols, Ceremony, Complementary, Culturally grounded, Indigenous methodologies, Lore, Not reported
Relationship & trust in partnership	Yes, No, Inferred, Unreported
Futures thinking method (Western)	Scenario planning Participatory scenario planning 2 x 2 uncertainty axes Horizon scanning Roadmap Three horizons Multiscale scenario Strategic planning Emerging issue analysis Futures triangle Issue-centred scanning Simulation/modelling Visioning Causal layer analysis Backcasting Risk analysis Structured decision making Adaptive management Seven questions Storytelling/narration Fifth scenario Leading/lagging indicators Change management Trend impact analysis Reverse engineering Gaming/roleplay Critical futures Cross impact analysis Decision modelling Societal, Technological, Environmental, Economic, Political (STEEP) analysis Ethnographic futures research Dialogue Genius forecasts Positive scenarios Future generations Scenarios from seeds Integral futures Dynamic knowledge loop Six pillars approach 3D landscape visualisations Bayesian network analysis Q-methodology

	Fuzzy cognitive mapping Photovoice Rapid rural appraisal Bricolage Community diaries Social multi-criteria evaluation Other
Indigenous methodology	Yarning Readers theatre Listening sessions Dadirri Dialogue-based group concept mapping Talking circles Digital storytelling Rituals/ceremonies incorporating dreaming/visioning Walking workshops Elder-focussed sharing Culture camps Indigenous science fictions Storytelling general Visualisations other Pockets of the past Other
Tools	Interviews, Individual reflections, Small group discussions, Group discussions, Cards, Rankings, Collages/drawings, Maps, Stock flow diagrams, Mental models, Timelines, Quantitative models/data, Newspaper headlines, Gaming simulation, Songs, Art, Other
Process for identifying drivers	Focus groups, Workshops, Interviews, Surveys, Researcher-proposed, Literature review, Previous identified by community, Predefined by scope
Use of drivers	Morpho-matrix, 2x2 axes, Uncertainty scenarios, Hunt's archetypes, To elicit responses, Derive models for forecasts, Agent-based models (ABMs), Flesh out storylines, Basis and breadth of storylines
Criteria for driver prioritisation	Uncertainty, Relevance/Importance/Impact/Influence, No prioritisation, Structural analysis, Contrast, Likelihood, Vulnerability, Q-sort, Number of mentions, Context/Opportunity/Barrier, Unclear
Vantage point	Forecasting (exploratory), Backcasting (action pathways), Hybrid (involves forecasting and backcasting)
Scenario type	Exploratory, Policy-screening, Target-seeking, Integrated, Retrospective policy evaluation
Storyline type	Qualitative, Quantitative, Mixed
Validation method	No validation, Check in same workshop/process, Sent for comments to participants after workshop, Comments from external stakeholders, Comments from general public, Validation against other scenarios/futures process, Validation from external modelling, Validation from quantitative data

Outcome of validation	Scenarios/results updated, Taken on for future research, No change, Other
Innovation type	Creative methodology, Narrative methodology, Mixed methods, Online/e-research, Software/tools, Workshop/group methodologies, Cross-lingual methods, Validation, Products, Time/spatial scales, Co-design, Intellectual Property, Ceremony/rituals, Spiritual, Biosphere agency, Visualisation, Other
Indigenous constructs	Arts, Connections, Foods/medicines, Identity, Knowledge systems, Lore, Law, Renewal, Rights, Spirituality, Time, Worldviews, Absent
Type of outcome	Social learning, Implementation of plans, Policy changes, Community cohesion, Individual ownership/empowerment, Awareness raising, Creation of new programs, Indigenous nation building/revitalisation, Policy/management recommendations, Other
Product type	Collage, Drawings/artwork, Scientific publications, Report, Leaflets/factsheets, Illustrations, Videos, Co-produced spatial maps, 3D model/map (interactive), Project website, Social media/news reports, Model, Map (non-3D), Other
Trauma-informed approach	Promoting a sense of safety, Promoting calm/anxiety-managed environment, Promoting a sense of self-efficacy/collective efficacy, Critical reflection on colonial/historical/social context, Promoting connectedness (to community and country), Access to support for managing trauma, Promoting hope for future, Other
Strengths-based approach	Holistic approach, Revitalising language and culture as healing resource, Build on existing strengths, Empowerment, Wider range of metrics/adaptations based on Indigenous concepts, Other
Other theoretical orientation reflecting Indigenous realities	Adaptation, African futurism, Decolonising, Deliberative, Diversity, Futures, Indigenous futurism, Indigenous research, Rights-based, Social-ecological, Sustainable livelihoods, Transformations, Absent
Types of recommendations	Future monitoring, Methodology, Policy/planning/management, Process problem fix, Broader/extended participation, Knowledge weaving, Capacity building, Other

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S5. Types of innovation in futures thinking processes held with, for, or by Indigenous peoples, building on types identified in a review of innovation in qualitative research methods (Wiles et al. 2011).

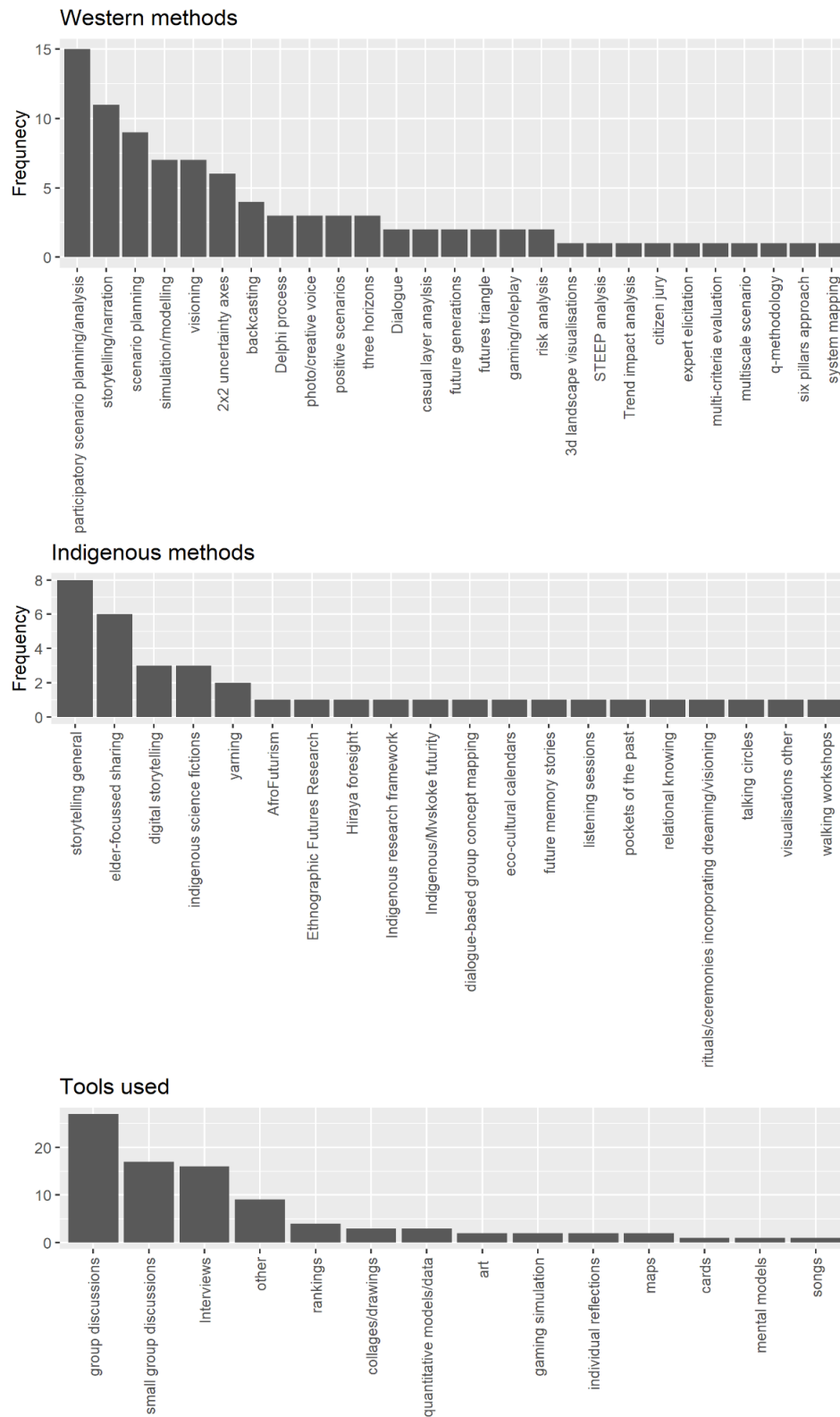
Innovation type	Description	Reference
Creative methodology	New or modified technique for employing a creative aspect (e.g., art, dance) to engage in a more holistic way	Wiles et al. (2011)
Narrative methodology	New or modified techniques for collecting, analysing, or presenting narratives	
Mixed methods	New or modified techniques for combining and analysing different types of qualitative/quantitative data	
Online/e-research	New or modified techniques for conducting research online	
Software/tools	New or modified software used to assist in, or enhance, analysis or sharing of data	
Workshop/group methodology	New or modified methods for collection/elicitation of data from groups	
Cross-lingual methods	New or innovative ways of incorporating language diversity in the process	
Validation	New methods of validating the outcomes of research with participants	Additional, this review
Products	New ways of producing, or types of products arising, from the research	
Time/spatial scales	New ways of incorporating other non-Western perceptions of time or space in the research process	
Co-design	New ways of supporting or doing a co-designed/Indigenous-led research process	
Intellectual Property (IP)	New or innovative ways of incorporating shared IP, including authorship and product ownership	
Ceremony/ rituals	New or modified techniques of incorporating ceremonies or rituals into methods	
Spiritual	New or modified techniques of incorporating spiritual	

	relationships into methods	
Biosphere agency	New or modified techniques of incorporating the agency parts of the environment (e.g., biosphere, river) is perceived to have (e.g., Australian Aboriginal Country as an author)	
Visualisation	New ways of visualising the research or process outputs and results (e.g., via art). This is different from Creative methodology innovations, which is about engaging participants	
Other		

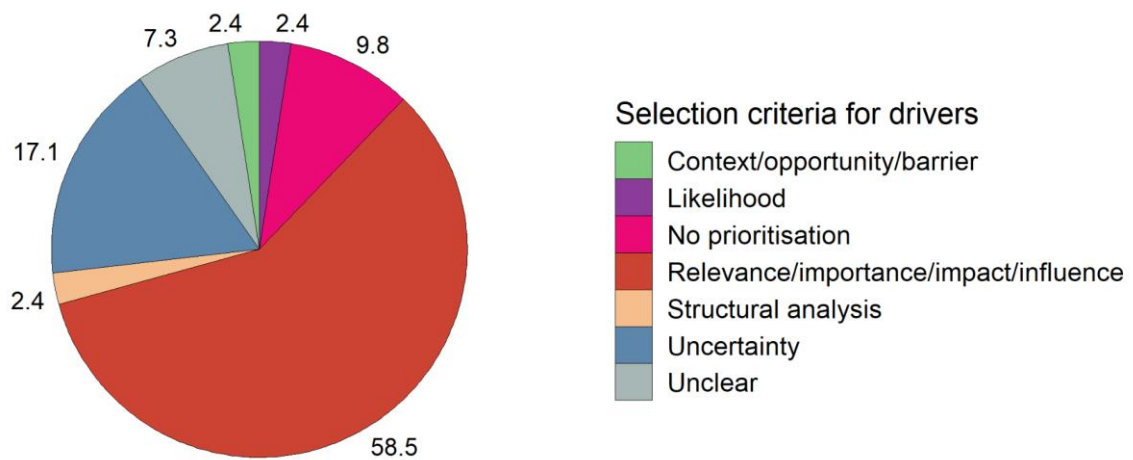
References

Wiles R, Crow G, Pain H (2011) Innovation in qualitative research methods: A narrative review. Qualitative research 11 (5):587-604

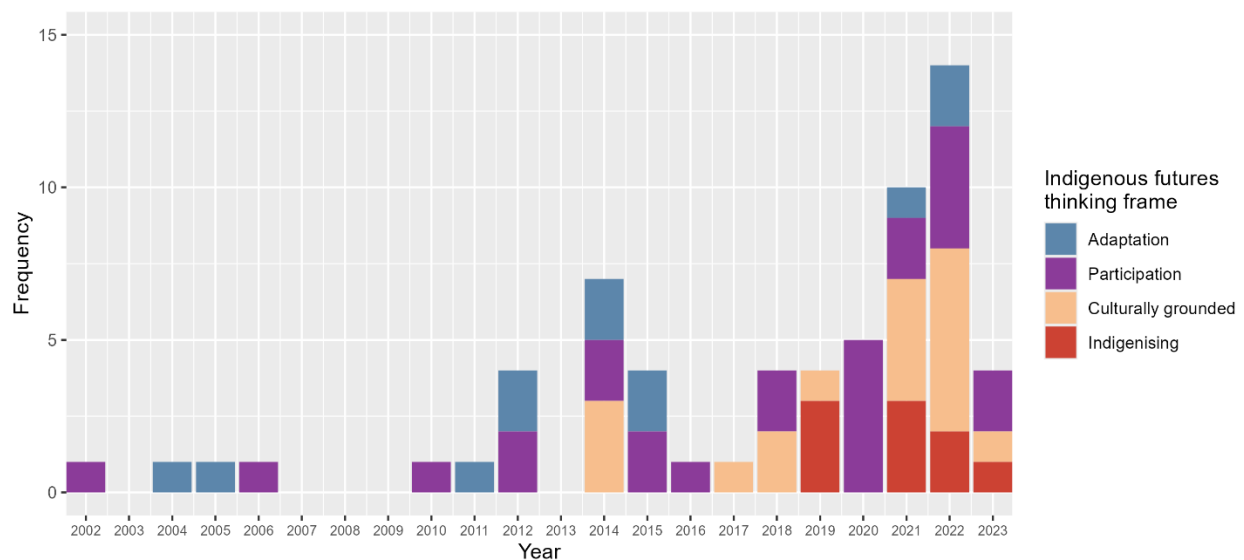
S6. Frequencies of Western and Indigenous methods used across all case studies and tools to support these methods.



S7. Selection criteria used to prioritise drivers of change to use in developing scenarios/stories in Indigenous futures thinking processes.

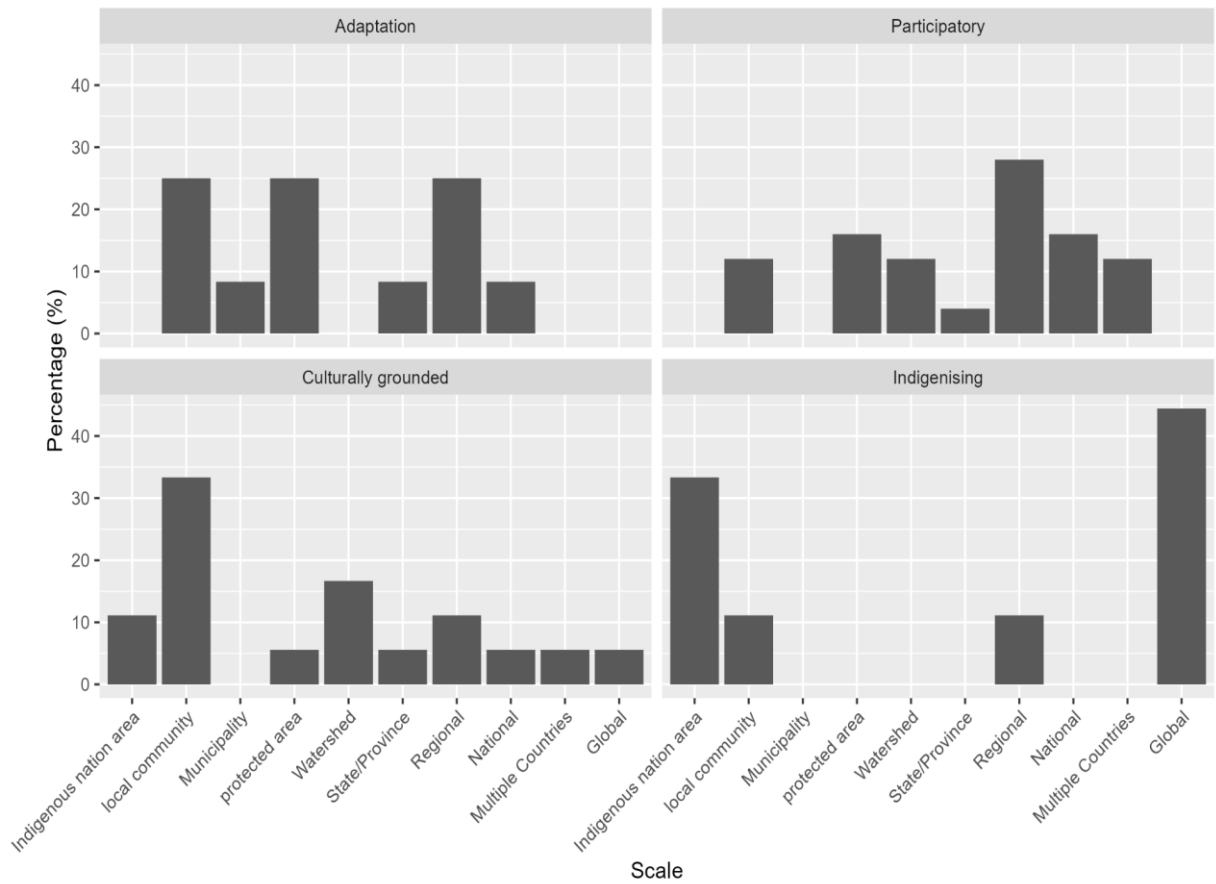


S8. Appearance and frequency of Indigenous futures thinking framings in the published literature across time.

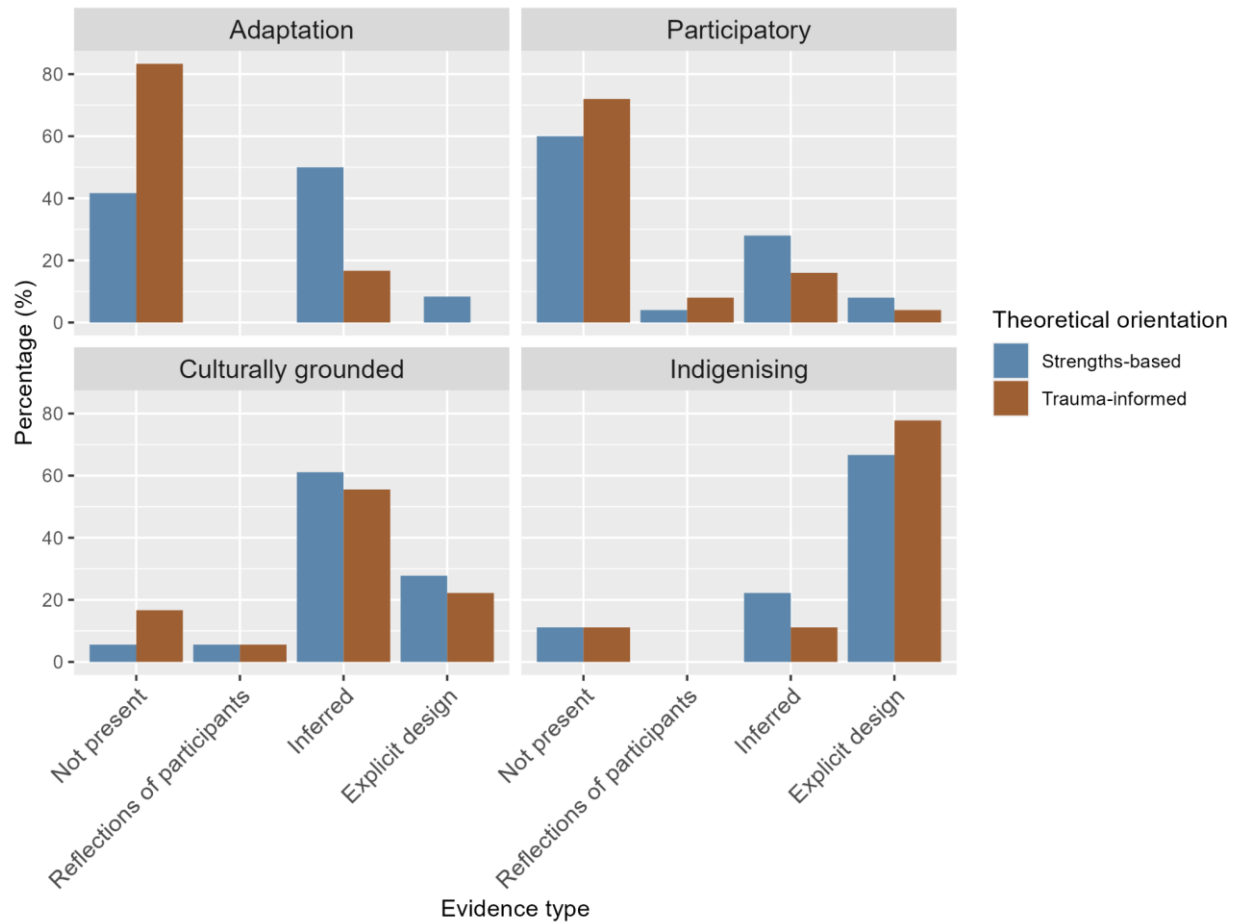


S10. Differences in groups leading the research across the four frames.

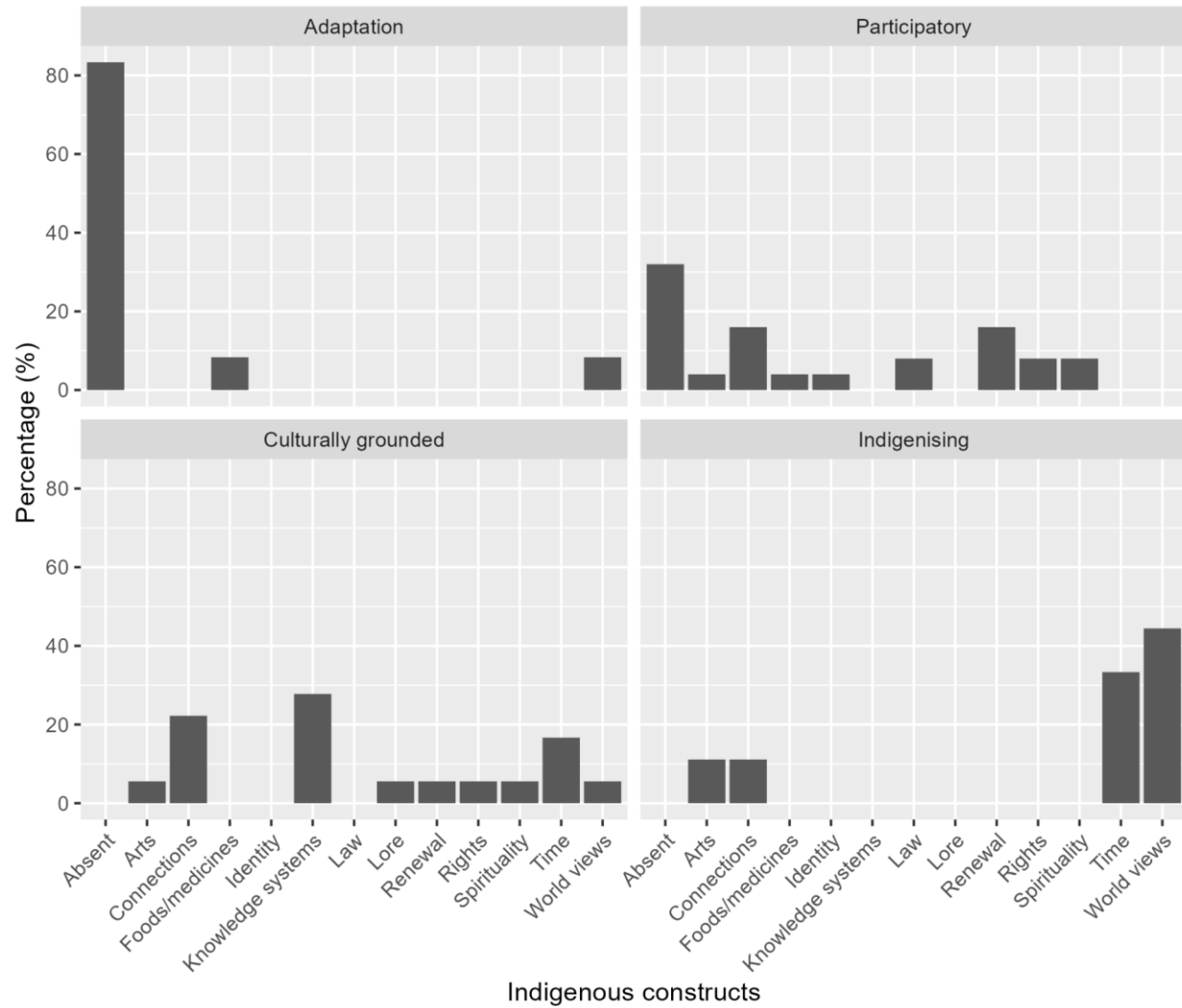
S11. Comparison of geographic scale of futures thinking projects across the four frames.



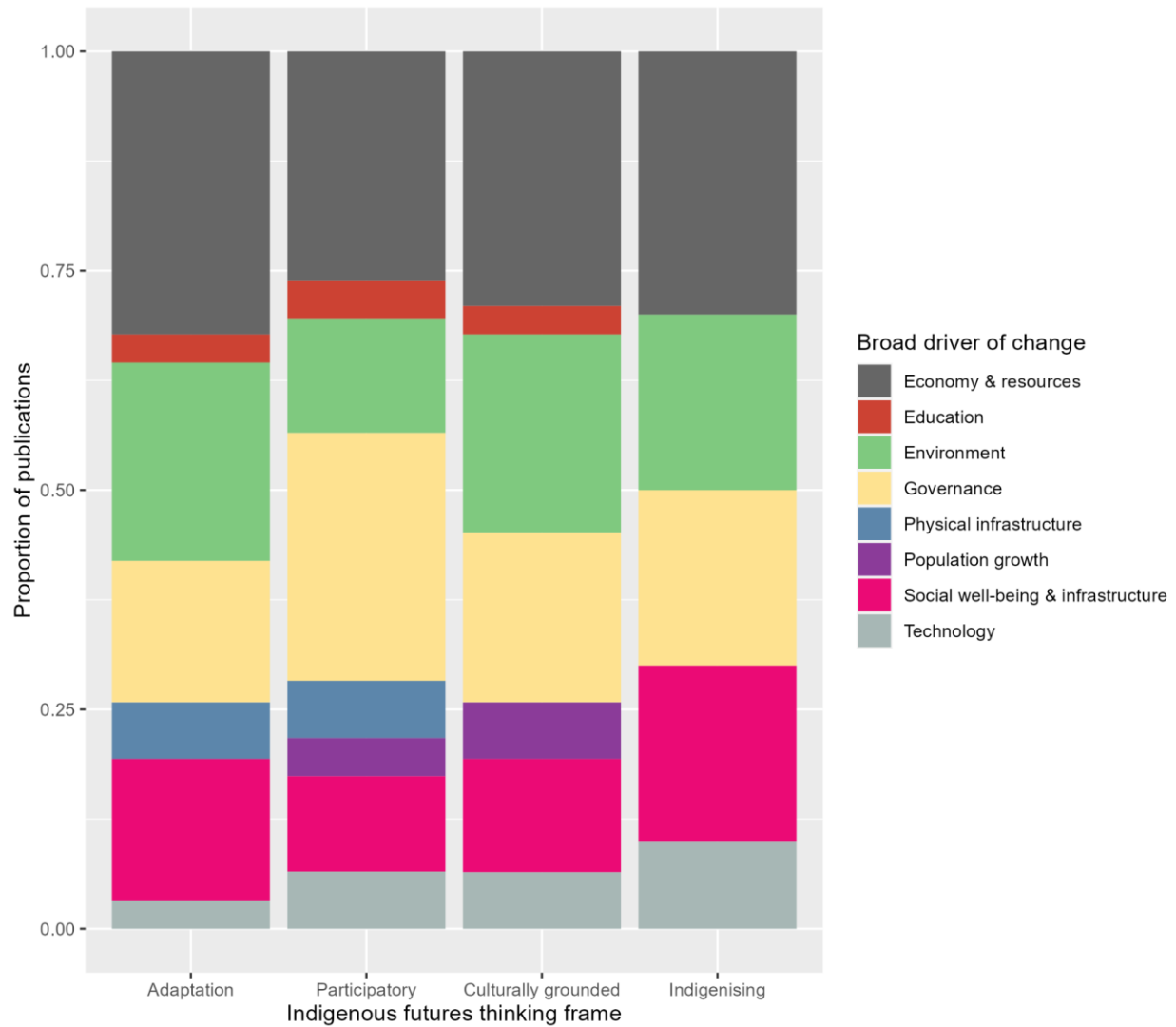
S12. Differences in use of strengths-based and trauma-informed theories across the four frames.



S13. Differences in the types of Indigenous constructs included across the four frames.



S14. Similarity of driver-identification across the four frames of Indigenous futures thinking.



S15. Detailed additional results describing an overview of Indigenous futures thinking as an emerging field, and the four framings identified in qualitative analysis of the literature: Adaptation oriented, Participation, Culturally grounded, and Indigenising.

Most of the publications involving scenario development (69%) identified and used drivers of change, which supported the following uses in story and scenario development: providing the basis and/or breadth of narratives e.g., in 2x2 uncertainty axes (Álvarez-Romero et al. 2021; Chitakira et al. 2012); fleshing out storylines (Enfors et al. 2008; Nikolakis 2020); informing models for forecasting e.g., future cumulative effects (Adams et al. 2023); using agent-based models (Steger et al. 2022); and to elicit participant responses to issues e.g., land zoning (Bourgoin and Castella 2011; Hazenbosch et al. 2022). Most processes identified many different drivers across these categories and prioritised a smaller number for exploring in scenarios, primarily through the driver's relevance, importance, impact, or influence (e.g., Drees et al. 2022; Koptseva 2014; Luft et al. 2022; S5).

Adaptation oriented frame

The Arctic Communities Synthesis Model (ACSM) is a good example of technological sophistication in an adaptation-oriented project. Innovations were predominantly incremental, with some interesting advances in participatory modelling:

Our inclusion of multiple, interacting shrub species is a novel aspect of the model ... due in large part to the co-design process, as workshop participants insisted on a certain level of realism ... in the model (Steger et al. 2022, p. 9).

Community cohesion and social learning were the dominant outcomes:

The participants felt confident with the results of the simulations because they had generated the parameters for their own village ... they learned that a plan has to be negotiated, and they somehow felt like better negotiators (Bourgoin and Castella 2011, p. 86).

Discussing future development was considered meaningful and constructive by the participants, assisting them in focusing on common interests and future possibilities rather than conflicting opinions (Carlsson et al. 2015, p. 131).

Nevertheless, technological sophistication was found to limit participation to some extent:

There is clearly a trade-off between using advanced methods and models for scenario development and the level of participation that can be achieved in the different steps of the process (Carlsson et al. 2015, p. 131).

Participation frame

One quarter of projects in this frame used some form of modelling, including conceptual, causal-loop, fisheries mass-balance, and participatory agent-based modelling. Models assisted the teams to bridge diverse perspectives, generate alternative futures, and pathways towards them:

In light of the expected hydrosocial dynamics, [the models] develop different alternative pathways. ... But what is the significance of the individual drivers, actions, and institutions from an expert and local perspective, and how can local communities interpret the scenarios for their own good? (Luft et al. 2022, p. 12).

We have contributed to transparently positioning a policy-based model as a boundary object to bridge a diverse group of stakeholders with individual and competing interests and perspectives (Rojas et al. 2022, p. 21).

Awareness raising and social learning were the most frequent outcomes in these projects:

Representatives and leaders from First Nations and non-First Nations community came together to develop rich mental images of the future, Clayoquot Sound's economy to 2050, and the policy measures to achieve these futures (Nikolakis 2020, p. 8).

Policy/planning changes towards increased participation and democratisation to legitimise decision-making were also frequently recommended, with this already underway in one project:

"The most important validation of the methods was the adoption of visioning and pathways as its participatory planning method by the local government in Bolivia (Evans et al. 2010, p. 617).

Culturally grounded frame

Storytelling and scenario creation were the dominant methods, supported by diverse tools including photovoice, creative voice, the three horizons approach, the futures wheel, causal layered analysis, and visioning. A few projects used modelling, including spatial optimisation (e.g., Marxan), land use (e.g., Landfire), a gaming simulation, and a conceptual model (cartooning). Diverse Indigenous methods included storytelling, elder-focussed sharing, ceremonies and rituals, paintings, embroidery, drawings, photos, mural newspapers, and mural artwork. Materials produced for community use included videos, artwork, photos, story-maps, workshop summaries, and a co-built 3D model.

Similar to the participatory frame, social learning and awareness raising were the most common outcomes:

Artwork is a powerful means to explore in depth perceptions, emotions, and histories related to native maize among farmers and community members (Lopez et al. 2018, p. 13).

Indigenising frame

Storytelling and scenario creation (exploratory, forecasting) were the dominant methods, using tools including causal layered analysis, the three horizons approach, visual techniques, conceptual modelling, and Bayesian modelling in one case. Indigenous nation building and awareness raising were the most common outcomes, with a wide array of outputs as well as scientific publications. Papers generally had some level of uptake by other Indigenous futures thinking papers.

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